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THESIS

**SOCIAL NETWORK COLLABORATION FOR CRISIS
RESPONSE OPERATIONS: DEVELOPING A
SITUATIONAL AWARENESS (SA) TOOL TO IMPROVE
HAITI'S INTERAGENCY RELIEF EFFORTS**

by

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June 2011

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EFFORTS**

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ABSTRACT

The earthquake in Haiti represents an event of catastrophic scale. Relief efforts were thwarted by blocked roads and ruined runways. Relief organizations assisted in the effort using adhoc approaches but could have benefitted from improved Situational Awareness (SA). This thesis develops a new model and methodology, based on data collected following the Haiti earthquake that combines both text-mining methods with 3D graphics. This interpretive approach provides a qualitative improvement on the currently available graphic depictions of such data. Text mining is performed using Lexical Link Analysis (LLA), which tracks and links word pairs, and then visually depicts correlations between discovered words, themes, and entities, thus revealing how they are related to each other in terms of both relationship and content. Our findings reveal discovered patterns of self-organization within this crisis situation, and can demonstrate a dynamic, situational awareness tool that can be executed by a thin client to analyze and determine social-organization collaboration and self-organization for leaders to leverage. This effort can eventually help to create a real-time feedback loop to inform decision maker's organizational awareness, improve organization-to-organization collaboration, and perhaps better allocate resources to areas requiring relief operations.

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TABLE OF CONTENTS

I.	INTRODUCTION	1
A.	INTRODUCTION	1
B.	DISCUSSION AND BACKGROUND	2
C.	PURPOSE	5
D.	RESEARCH METHODOLOGY	7
	1. Literature Review	7
	2. Hands-On Experience	7
E.	ORGANIZATION	7
II.	CONCEPTS OF LEXICAL LINK ANALYSIS (LLA) AND SITUATIONAL AWARENESS (SA)	9
A.	INTRODUCTION	9
B.	COMMON TERMINOLOGY	10
	1. Lexical Link Analysis (LLA)	10
	2. Situation Awareness	12
	3. Self-Organization	13
	4. Collaboration	15
	5. Visualization	16
	6. Nonadversarial Crisis Response Operations (NCRO)	17
	7. All Partners Access Network (APAN)	19
C.	PRIOR WORK ON SITUATIONAL AWARENESS RELATING TO CRISIS RESPONSE OPERATIONS	20
D.	PROPOSED APPLICATION OF SITUATIONAL AWARENESS TO CRISIS RESPONSE ORGANIZATIONS INTERACTING IN SOCIAL NETWORK SETTINGS	23
E.	DESIGN	24
	1. Components	25
	2. Relationships	27
F.	PRIOR RESEARCH ON SOCIAL NETWORK COLLABORATION	29
G.	DEVELOPING TEAM SITUATIONAL AWARENESS AND PERFORMANCE REQUIREMENTS	30
H.	PROPOSED PARAMETER-CRITERIA SPACE FRAMEWORK FOR A DESIRABLE SYSTEM MODEL	34
I.	PROPOSED MULTI-CRITERIA MODEL FOR SOCIAL NETWORK COLLABORATION FOR CRISIS RESPONSE PERFORMANCE OPERATIONS	38
	1. Performance Criteria Definitions	38
	2. Design Variables	38
	3. Nodes	39
	a. Team Situational Awareness	39
	b. Heterophily	40
	c. Team Performance	41

d.	<i>Defined Mission and Defined Goals</i>	41
e.	<i>Required Collaboration and Commitment to Collaboration</i>	41
f.	<i>Team-Based Trust and Effective Use of Resources and Skills</i>	42
g.	<i>Mutual Accountability</i>	42
4.	Links	43
5.	Functional Constraints	43
6.	Time	44
J.	SCENARIO	44
K.	CHAPTER SUMMARY	47
III.	SOCIAL-NETWORK ANALYSIS (SNA) TOOLS	49
A.	INTRODUCTION	49
B.	QUALITIES OF THE "RIGHT TOOL"	50
1.	Accuracy and Precision	51
2.	Thorough Data Computation	52
3.	Data That Is Distinct	52
C.	COLLABORATIVE LEARNING AGENT AND LEXICAL LINK ANALYSIS	53
1.	Thorough in Data Capture	53
2.	Distinct Data Display	54
3.	Accuracy and Precision	55
D.	ORGANIZATIONAL RISK ANALYZER (ORA)	57
1.	Quantity of Data Capture	57
2.	Distinct Data Display	58
3.	Accuracy and Precision	60
E.	PAJEK	61
1.	Quantity of Data Capture	61
2.	Distinct Data Display	61
3.	Accuracy and Precision	63
F.	UCINET	64
1.	Quantity of Data Capture	64
2.	Distinct Data Display	65
3.	Accuracy and Precision	66
G.	EXTENSIBLE 3D GRAPHICS (X3D)	67
1.	Accuracy and Precision	68
H.	CHAPTER SUMMARY	69
IV.	APPLYING SNA TOOLS AND DEVELOPING AN X3D PROTOTYPE	71
A.	INTRODUCTION	71
B.	BRUTZMAN'S 10-STEP PROCESS	71
1.	Focused Brainstorming With Steps 1-3: Concept, Notional Examples, and Candidate Examples	71
2.	Step 4: Correspondences	78

a.	<i>Changes in Plans: Pajek Catches up to 3D (Creating a Simple X3D Model to Illustrate Sketches in X3D)</i>	78
b.	<i>15 January 2010 Basic Metrics to Consider</i>	81
C.	GENERATING X3D VISUALIZATION PROCESS (MODIFYING X3D MODEL TO INCLUDE ACTUAL SAMPLE DATA) THROUGH AN XML REPRESENTATION: CONVERTING CLA TO X3D	82
1.	Step 5 of 10-Step Process: Creating an XML Representation	82
a.	Step 5a. Importing CLA Datasets to ORA	82
b.	Step 5b. Visualizing Dataset Through ORA	82
c.	Step 5c. Applying Newman Color Attributes	83
d.	Step 5d. Exporting ORA Dataset to UCINET	85
e.	Step 5e. Visualizing Dataset Through NetDraw	87
f.	Step 5f. Applying Newman Attributes to NetDraw Dataset	88
g.	Step 5g. Exporting NetDraw Dataset to Pajek	91
h.	Step 5h. Importing Datasets Into Pajek	91
i.	Step 5i. Visualizing Datasets Through Pajek	92
j.	Step 5j. Exporting Pajek Dataset to X3D	95
D.	BUILDING A PROTOTYPE	96
1.	Step 6: Brute-Force Conversion to X3D and Comparison of Pajek X3D to "Brainstormed X3D"	96
E.	DEVELOPMENT OF AN X3D VISUALIZATION TOOL: DEFINING AND CREATING PROTOTYPE EXAMPLES	100
1.	Revising Embedded Script Using Updated Field Definitions With TracePrint Design Pattern	117
2.	Step 7: Prototype Declaration	119
3.	Step 8: Create Prototype Instance Examples	121
4.	Step 9: Stylesheet Conversion	123
a.	External Prototype Declarations	124
5.	Process of Conversion	125
6.	Visualizing the Final Product	127
7.	Step 10: Spiral Improvement	130
F.	CHAPTER SUMMARY	133
V.	ANALYSIS AND LIMITS OF OUR STUDY	137
A.	INTRODUCTION	137

B.	UTILIZATION OF X3D USER INTERFACE: CHALLENGES AND ISSUES	138
1.	Visualization Tool or Experience Tool?	138
2.	Navigating Through the "Fog" of 3D	140
3.	Why Choose 3D?	141
C.	ANALYSIS AND ASPECTS OF X3D USER INTERFACE: LIMITATIONS OF X3D VISUALIZATION	143
1.	Standardization	143
2.	Information Overload	144
D.	ANALYSIS OF CONCEPTS	147
1.	Situational Awareness	150
2.	Self-Organization	152
3.	Collaboration	153
E.	CONCLUSION	154
VI.	CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH ...	155
A.	RESEARCH CONCLUSIONS	155
1.	Recommendations for Future Work	157
2.	Further Development of Analytic Tools	158
3.	Additional Visualization Alternatives	160
4.	Future for Crisis Response Operations	160
5.	New Potential Purposes for Situational Awareness Tool	162
	APPENDIX A: DATASET MATRIX NOTATION	163
	APPENDIX B: 15 JANUARY 2010 XML AND DTD CODE	174
	APPENDIX C: PAJEK GENERATED X3D CODE FOR 15 JANUARY 2010 ...	183
	APPENDIX D: 15 JANUARY 2010 EXCERPT ARCS AND VERTICES	195
	APPENDIX E: X3D PROTOTYPE	199
	APPENDIX F: CONVERTED X3D CODE FROM XSLT	209
	APPENDIX G: XSLT PROTOTYPE FILE	213
	LIST OF REFERENCES	217
	INITIAL DISTRIBUTION LIST	221

LIST OF FIGURES

Figure 1.	Team SA can be determined by examining the goals and SA requirements of all team members (After Endsley, Boltè, & Jones, 2003).....	12
Figure 2.	Screen-shot of APAN's community webpage.....	20
Figure 3.	Model of situation awareness in dynamic decision making (From Endsley, Boltè, & Jones, 2003).....	21
Figure 4.	Example of LLA network of word associations produced by hand and superimposed.....	26
Figure 5.	Community assignments for a 2-community random network. (a) A standard undirected modularity maximization that ignores link direction. (b) The Garvin-Newman algorithm. The shaded regions represent the communities discovered by the algorithms with true community assignments are denoted by nodal shape (From Leicht & Newman, 2008).....	27
Figure 6.	Excerpt from January 13, 2010 network from ORA without attribute data incorporated into network.....	50
Figure 7.	Visualization of January 13 2010 Lexical Link Network with attribute data from UCINET.....	51
Figure 8.	14 January 2010 Lexical Link Network displayed in ORA with Newman grouping applied...	60
Figure 9.	Word network in 3D with Fruchterman and Gold distribution (14 January 2010), displayed with Newman attributes incorporated into the partition file.....	63
Figure 10.	Pajek screen capture showing multiple files uploaded revealing the difficulty in assuring the desired file is selected prior to visualizing the network data.....	64
Figure 11.	January 14, 2010 word network displayed on UCINET with integrated Newman attributes.....	66
Figure 12.	Front sketch of 15 January 2011 with desired geometric shapes for links and nodes.....	74
Figure 13.	Envisioned idea of embedded data.....	75
Figure 14.	Desired embedded data for link.....	75
Figure 15.	15 January 2010 Lexical Link Network from ORA...	76
Figure 16.	15 January 2010 Lexical Link Network with Fruchterman Reingold 3D Energy from Pajek.....	77
Figure 17.	15 January 2010 Lexical Link Network from UCINET.....	78

Figure 18.	Process of generating data from CLA to X3D.....	80
Figure 19.	Screen-shot of importing CLA datasets to ORA....	82
Figure 20.	Screen-shot of visualizing dataset through ORA..	83
Figure 21.	Screen-shot of applying Newman attributes to ORA.....	84
Figure 22.	Generated attributes viewed from Meta-Network manager with Newman attributes displayed.....	84
Figure 23.	Screenshot of saving Lexical Link Network with Applied Newman attributes.....	85
Figure 24.	Screen-shot of copying Newman attributes to paste in UCINET Matrix spreadsheet editor.....	86
Figure 25.	Screenshot of pasting Newman attributes into the UCINET Matrix spreadsheet editor.....	86
Figure 26.	Display of Opening file in NetDraw, selecting 2010-15-01.##h and pressing "OK".....	87
Figure 27.	NetDraw from UCINET displaying 15 January 2010 dataset.....	88
Figure 28.	Screen-shot of applying Newman attributes to NetDraw.....	89
Figure 29.	Screenshot of selecting attribute to apply to 15JAN2010 Network.....	90
Figure 30.	Once the 2010-01-15 attributes have been selected, we observed the following visualization.....	90
Figure 31.	Step 7 actions.....	91
Figure 32.	Screenshot of 15JAN2010 Network uploaded to Pajek and Newman attributes uploaded to <i>Partition</i> reader.....	92
Figure 33.	Display of initial Pajek visualization of 15JAN2010 Lexical Link Network.....	93
Figure 34.	15JAN2010 Lexical Link Network laid out in the 3D Fruchteman-Reingold format.....	94
Figure 35.	Screenshot of applying the following command: <i>[Pajek]Export>3D>X3D</i>	95
Figure 36.	Screen-shot of X3D data exported from Pajek into NetBeans.....	96
Figure 37.	Example of the Parent Name /Comment not placed together in a single group.....	98
Figure 38.	Example of what the Xj3D visualizer displays when overloaded.....	99
Figure 39.	Development of prototype interface field definitions.....	102
Figure 40.	Excerpt from the XML check for errors. Continual errors are demonstrated indicating that the degrees of rotation for the visualization are incorrectly defined.....	104

Figure 41.	Screen-shot of normalizing rotation and scaleOrientation values.....	104
Figure 42.	Sventon Subversion Database changes of x3d source scenes under version control. The red line indicates deletion of code, and the green line indicates the addition of code.....	105
Figure 43.	Embedded script connected to prototype interface.....	106
Figure 44.	Version control changes help expose details during software and model development. Here the <IS> attribute was deleted while <Appearance> was added.....	108
Figure 45.	Material properties are exposed in order to enable runtime visualization techniques, which might modify color or transparency.....	108
Figure 46.	Adding the definition of a Vertex to the ProtoBody.....	110
Figure 47.	Setting the accessType to initialize for Spheres and Cylinders.....	111
Figure 48.	Setting the Access Type to initialize for Spheres and Cylinders.....	113
Figure 49.	Default values for name, description that prompts updating when the prototype instances are created.....	115
Figure 50.	Updating the default Arc Proto Instance using updated field definitions.....	116
Figure 51.	Generated Prototype version of X3D for Visualization demonstrates how converts all information.....	122
Figure 52.	Initial three links and nodes extracted from 15 January 2010 dataset network produced by Pajek.	122
Figure 53.	Process of converting Pajek X3D to Prototype X3D through XSLT.....	124
Figure 54.	Screen-shot of using Altova XMLSpy's XSLT debugger to produce an X3D Output file from 15 January 2010 Dataset file.....	126
Figure 55.	Screen-shot of Altova XMLSpy's XSLT debugger showing the resulting X3D code (on right).....	126
Figure 56.	Visualization of the 15 January 2010 X3D file generated through XSLT conversion.....	127
Figure 57.	Newman Lexical Link Network, 15 January 2010, in Prototype Visualization format.....	129
Figure 58.	Example of 3D geometric shapes in Eculid's Geometry (published 1570) (Libraries University of Oklahoma, 2010).....	139

Figure 59.	2D Visual display of social network with multiple attributes produced by CLA program....	145
Figure 60.	Image of what may occur when the visualization is overloaded, demonstrating what happens when multiple-attributed network is loaded onto Bitmanagement software.....	146
Figure 61.	How operational planners and leaders can impact the Situational Awareness (SA) feedback loop (From Endsley 1995).....	152
Figure 62.	Example of Kinemage image generated by Mage (Biochemistry Dept at Duke University, 2011)...	159
Figure 63.	Example of Mage Processing image of crystal simulation. In addition to having 3D capability, it is capable of programming animation (Glutton, 2007).....	159

LIST OF TABLES

Table 1.	Description of Multi-Criteria for a desirable system model.....	35
Table 2.	Continued description of Multi-Criteria for a desirable system model.....	36
Table 3.	Additional description of Multi-Criteria for a desirable system model.....	37
Table 4.	Performance criteria, design variables, and functional constraint's measurement of range....	46
Table 5.	Node sets and names (Carley and Reminga 2004)...	59
Table 6.	Measurements of SNA tools.....	69
Table 7.	List of requirements from brainstorming.....	73
Table 8.	Constant and varying attributes in X3D visualization.....	117
Table 9.	Fields within X3D prototypes for Arc, Vertex, and Network Text.....	119
Table 10.	URLs implemented to generated prototype.....	123
Table 11.	Field comparison between the Pajek X3D and the X3D Prototype used to generate the XSLT.....	130

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LIST OF ACRONYMS AND ABBREVIATIONS

AIM	America Online Instant Messenger
APAN	All Partners Access Network
C2	Command and Control
CLA	Collaborative Learning Agent
DISE	Distributed Information Systems Experimentation
DoD	Department of Defense
HTML	HyperText Markup Language
IGO	International Government Organizations
LLA	Lexical Link Analysis
NCRO	Nonadversarial Crisis Response Operations
NGO	Nongovernmental Organizations
ORA	Organizational Risk Analyzer
SA	Situational Awareness
SMS	Short Message Service
SNA	Social-Network Analysis
TNT	Tactical Network Topology
UN	United Nations
UNICEF	United Nations Children's Fund
URL	Uniform Resource Locator
USAID	United States Agency for International Development
USSOCOM	United States Special Operations Command
X3D	Extensible Three-Dimensional Graphics

XML	Extensible Markup Language
XSLT	Extensible Stylesheet Language Transformations

EXECUTIVE SUMMARY

The earthquake in Haiti represents an event of catastrophic scale. Relief efforts were thwarted by blocked roads and ruined runways. Relief organizations assisted in the effort using adhoc approaches but could have benefitted from improved Situational Awareness (SA). This thesis develops a new model and methodology, based on a year's worth of data collected following the Haiti earthquake, which combines both text-mining methods with 3D graphics. This provides a qualitative improvement to the currently available graphic depictions of the data. Text mining is performed using Lexical Link Analysis (LLA) which tracks and links word pairs, and then visually depicts correlations between discovered words, themes, and entities, thus revealing how they are related to each other in terms of both relationship and content. Our findings reveal discovered patterns of self-organization within this crisis situation, and can demonstrate a dynamic, situational awareness tool—that can be executed by a thin client—to analyze and determine social-organization collaboration and self-organization for leaders to leverage. This effort can create and inform a real-time, feedback loop to inform decision maker's organizational system awareness and thus improve organization level collaboration, and perhaps better allocate resources to areas requiring relief effort operations and resources.

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I. INTRODUCTION

A. INTRODUCTION

This thesis investigates the incorporation of data flow analysis of social organization in crisis-relief operations, and the requirements for creating a collaborative tool that help supports the analysis of Haiti crisis operations. The specific crisis-relief operations being conducted in Haiti since the beginning of 2010 have been a growing concern for military, civil, and government leaders. The overarching objective is to support the end user and team they are operating in, and to improve situational awareness. Ideally, this can be accomplished with a team composed of multiple, diverse organizations that are typically involved in crisis-response operations.

Using a tool that visually displays the requisite abundance of nodes and links can potentially render the content necessary to display quantitative reasoning through generated visualizations. By providing multiple displays of information through abstract, nonrepresentational pictures, it is possible to show the relationships and behavior between organizations through social networks. We can produce useful methods of determining both how people are communicating in a social network setting within a stressful environment. We can also show how resources are being allocated within the confines of a given social setting with respect to the agents involved, each of whom necessarily retain a limited understanding of their distribution organization and the resources assigned to them.

B. DISCUSSION AND BACKGROUND

The way in which organizations interact with one another in a crisis situation is shaped by a number of factors. The factors themselves are often formed through social networks, available knowledge of personal connections, and organizational structures. Agents interacting in a crisis-response situation could benefit from a visualization of the influences manifested on the organizational structure, and by being aware of the various, essential resources available to them.

As crisis situations continue to pose unique global challenges, the capability of measuring how self-forming collaboration works is essential for individuals positioned in roles of responsibility, supervision, or command of these operations. While many had considered this to be a method of analysis conducted in a more retrospective historical aspect, it has only recently been considered a measure of behavior that can be examined in near-real time. We intend to do precisely that, and use recent historic data to further explain this methodology.

In January 2010, Haiti was struck by a catastrophic 7.0 magnitude earthquake, which occurred approximately 16 miles West of Port-au-Prince. After the tremors (lasting almost two weeks from the date of the primary event) had subsided, it was estimated that approximately three million people were affected by the earthquake and its associated aftershocks (Associated Press/CBS, 2010). This catastrophe claimed the lives of 230,000 individuals, with an additional 300,000 injured, along with 250,000 residences and 30,000 commercial buildings classified as damaged or

destroyed. The major infrastructure of Haiti's government had been demolished by the earthquake (Renois, 2010). Suddenly bereft of various governmental institutions, infrastructure, and leadership, multiple international organizations such as the United Nations (among others) declared a state of emergency on behalf of Haiti, and determined that major relief efforts were needed both for the rebuilding of the country, and to provide vital assistance to the survivors of this calamitous incident. These declarations of state emergency made by extra-national actors on behalf of a sovereign state in distress were demonstrably necessary. The earthquake and its associated aftershocks had effectively disabled Haiti, crippling its infrastructure and eliminating the possibility of timely, vital emergency response by national assets. With the notable exception of a few sporadic clinics associated with the program "Doctors Without Borders," the entirety of the hospital and medical care apparatus had been virtually eliminated. Compounding the problem of this catastrophic loss of vital services for its citizens, was the destruction of the control tower to the Toussaint L'Overture International Airport, along with that of the Port-au-Prince seaport command stations—a combination of which created a bottleneck, effectively choking the flow of relief aid that could enter the country. The only effectively operable seaport available for use by relief organizations was the northern Gonaives seaport. The disaster had made roads impassable via damage or debris, and telephone lines and communications had been demolished. With many Haitians left without the provisions necessary to sustain themselves, it became painfully

evident to many in the international community that Haiti was in need of immediate relief efforts on a large scale. There was also an immediate realization that tremendous difficulty existed as well in accessing those in dire needs due to lack of infrastructure support.

The response crafted by the United States to combat the crisis in Haiti involved many organizations, with diverse backgrounds and various strengths for vital contribution, to participate in the Haiti earthquake relief efforts. The International Committee of the Red Cross, Oxfam International (an international relief and development agency), World Vision International, Tèlècoms san Frontiers, SOS Children, Humanity First, and Doctors without Borders were just some of the nongovernmental and civil organizations that provided support to the Haiti relief effort. The United States focused its response through the Interim Haiti Recovery Commission, and through the U.S. Agency for International Development (USAID), which is headed by the State Department with the intent to provide "economic, development, and humanitarian assistance around the world in support of the foreign policy goals of the United States" (U.S. State Department, 2009). Along with the United States' providing traditional and civil foreign aid, the U.S. Department of Defense deployed to Haiti as part of the Operation "Unified Response". Over 16,000 U.S. military personnel under the control of USSOCOM were sent to bolster Haiti and restore order in support of the U.S. government's humanitarian response (Haven & Melia, 2010).

A supra-positional view of the earthquake in Haiti and the devastation it caused, and the subsequent monumental relief efforts undertaken by various organizational constituents, shows tremendous activity in the accumulation of data in a social-network setting. In an effort to locate and acquire essential resources by civil, government, and military organizations (i.e., the American Red Cross, USAID, and USSOCOM), the members of such organizations utilized social networking as a means to communicate, whether through chat, e-mail, Twitter, or commercial blogging programs to better understand their surroundings and the environmental elements that existed during the crisis environment and to communicate those findings to others. While some interactions bore fruit, and the whereabouts of required resources were effectively communicated leading to a better distribution of those resources, other communicative endeavors were insignificant and did not lead to any effective distribution of information. While there are combinations of outcomes that result from using social networks, the effort to develop a system that analyzes these interactions has become vital to the goal of achieving an expansive, detailed view of collaborative behavior in social networks that are attempting to tackle the core issues of the crisis response in Haiti. Progress on such a challenge can further help future efforts.

C. PURPOSE

With the vast complexity and volume of data produced during relief operations, the deconstruction of the information into more useful and easily understood

components can be arduous. Having command and use of a tool that can visually display the abundance of word nodes and hubs, or *lexical links*, can offer a superior display of quantitative reasoning through visual evidence. By displaying these *lexical links* in various formats, whether it be through abstract, nonrepresentational pictures, or displaying them on a geographical map of Haiti, this methodology has the potential to better show the relationships and behaviors between organizations through social networks and can become a useful tool in determining not only how people are communicating in a social setting; but can also reveal how resources are being distributed by improving the understanding of the distribution organizations.

The Lexical Link Analysis (LLA) program, used primarily through the Organizational Risk Analyzer (ORA) tool, is capable of tracking words to each other between various social network users and is a visual tool for depicting correlations between content topics and among certain entities related to each other, and can also display if relationships are effectively delivering the needed results for that organization. If we use visualization tools to analyze social network systems in which members of civil, government, and military organization members interact, then we can better understand the patterns of self-organization within crisis situations, and can thereby create a situational awareness tool for organizational leaders to use. This will, in turn, create a feedback loop for staff facilitating the

improvement of organizational collaboration, and can greatly improve allocation of resources to areas of a relief effort.

D. RESEARCH METHODOLOGY

Two principal research methods were used to develop this thesis. Together, they provided the basis of knowledge and expertise that laid the foundations of this paper.

1. Literature Review

We conducted a literature review of books, journals, internet articles, and previous research.

2. Hands-On Experience

We analyzed Lexical Link Data extracted from various social network websites and explored various social-network analysis tools. We took classes that familiarized us with social-network analysis and the technology required to extract and analysis Lexical Link Analysis. We developed a prototype by generating X3D prototypes through engineering X3D programming code. The work described in this thesis is computationally intensive; therefore, the dataset has been reduced in scope to the data occurring between January to February, 2010. Once a stable demonstration is achieved, the process can be scaled up to include data from increased data sets.

E. ORGANIZATION

This thesis is organized into the following chapters:

- Chapter I provides the introduction and overview of the thesis.

- Chapter II describes a conceptual analysis of Lexical Link Analysis, how it is associated with Situational Awareness and why it is important for the Command and Control (C2) process in crisis response operations.
- Chapter III describes how social-network analysis Tools can be used to display lexical link networks. There is also be a discussion on the various strengths and weaknesses associated with each social-network analysis tool used.
- Chapter IV describes the development of a situational awareness tool through X3D and a case study to generate an X3D situational awareness visualization prototype.
- Chapter V examines the strengths and weaknesses of the developed X3D situational awareness visualization prototype, the potential alternatives to visualizing the data, and how to best utilize this given situational awareness visualization tool.
- Chapter VI provides conclusions and recommendations for future research from this thesis.

II. CONCEPTS OF LEXICAL LINK ANALYSIS (LLA) AND SITUATIONAL AWARENESS (SA)

A. INTRODUCTION

Social-network analysis (SNA) is intended to detect and interpret patterns of social ties among actors, either multitudinous or relatively few (de Nooy, Mrvar, & Batagelj, 2005, p. 5). An aspect of analyzing these patterns that is unique to social-network analysis is uncovering the latent and fundamental social structure that brought about the formation of the network itself. By analyzing various social structures and their attributes, an analyst can discover useful aspects of social interaction in a host of various situations, from crisis management to project development, to peer-to-peer dynamics, and more.

However, these aspects are not always fully and immediately observable, and a network must be constructed from what is observed in order to visualize the pertinent aspects desired for analysis (Jackson, 2008, p. 443). It is here that social-network analysis tools can be useful. By looking at such networks and analyzing their attributes and configuration, the potential exists to detect present risks or vulnerabilities to the design structure of an organization, or in the case of Haiti, collaborative organizations. This design structure details the organizational relationship among its personnel, knowledge, resources, and task entities. These programs are used throughout the DoD and in the private sector to provide

empirical data for training facilities, operations research, defense analysis, social analysis, etc.

In this work, we examine one specific aspect of social interaction: language in terms of Lexical Link and linguistic semantics. The Lexical Link Analysis (LLA) approach is derived from social-network analysis (SNA) tools, and is explored in greater depth in the next chapter. To better understand these software models, it is necessary to develop an understanding of the terminology associated with such analysis, as well as integrate these terms into the theory of Situational Awareness, or SA. By addressing the importance and limitations of these powerful modeling tools, we can begin to see how SNA can contribute toward acquiring better SA and can contribute to a useful Command and Control (C2) tool.

B. COMMON TERMINOLOGY

The literature reviewed for this chapter defines *situational awareness* (SA), discusses *self-organization* within social networks, and the *collaboration* that exists when these forms of networks are utilized during nonadversarial crisis response operations (NCRO). By examining these self-organizing social networks we can determine the characteristics of self-organization in emergent conditions, and thereby can help determine if the resources of situational awareness in a crisis situation are adequate.

1. Lexical Link Analysis (LLA)

With the vast complexity and volume of data gathered in a given social network, the deconstruction of this

information can be arduous to quantify. By using a tool that visually displays the abundance of nodes and links, it is possible to display quantitative reasoning through visual evidence. By displaying abstract, nonrepresentational pictures to show the relationships and behaviors between organizations through social-networks, such an implementation can become a useful, powerful tool in determining how people are communicating in a crisis response setting. Furthermore, there exists the potential to see, in real time, how resources are being distributed in a given situation despite limited understanding of the distribution of organizations, and also discover whether resources are duplicatively assigned to the same respective areas of a crisis area.

The Lexical Link Analysis (LLA) program, which tracks words and links them to each other between particular social network users, has been a visual tool used for visually depicting correlations between what topics and given entities are related to each other. LLA can also be used to look at such relationships and determine if they are effectively delivering the needed end-results for that organization. If we use visualization tools to analyze social network systems that members of civil, government and military organization members interact in, then we can better understand the patterns of self-organization within crisis situations, and can thereby create a situational tool for organizational leaders to use. This approach can create a feedback loop for staff that can contribute to improving organizational collaboration, and better allocate resources to areas of a relief effort that need them.

2. Situation Awareness

Situational Awareness can be described as a perception of environmental elements within a volume of time and space. The concept originated from aviation tactics, where the understanding of how both friendly aircraft were formed with their tasking assigned to them in formation and the activities and capabilities of the *enemy's* aircraft in the air. When looking at collaborative traits that exist between several different organizations within a social network environment, mutual situational awareness is required in order to accomplish a common goal. This is often referred to as *team situational awareness* where each team member has a clear understanding of what his or her responsibilities are in order to effectively work together as members of that group.

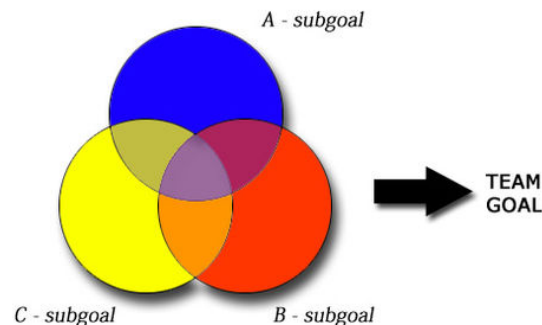


Figure 1. Team SA can be determined by examining the goals and SA requirements of all team members (After Endsley, Boltè, & Jones, 2003)

This concept also bases itself on the idea that the success or failure of any team is mutually dependent upon the success or failure of each of its team members (Endsley, 1995). When looking at crisis relief in Haiti, many of the limited resources that are available to all of

the organizations requires that there is a certain level of cooperation to produce a single end-result: the stated goal of relief for the people of Haiti. While each organization may possess several organizational missions, one goal is clear: they are all working toward promoting Haiti's relief.

3. Self-Organization

In systems theory, *self-organizing* is a term that is typically used to describe the ad-hoc integration of nodes to a network. How these nodes are linked together can be entirely subjective. While many people are linked to each other based upon previous relationships or knowledge, a design theorist can measure a self-forming organization based upon conversation or word-usage alone. When looking at the Tactical Network Topology (hereafter referred to as TNT) experiments hosted by the Naval Postgraduate School, we see that the plug-and-play interface systems allowed personnel to adapt and integrate processes through communicating between people, networks, sensors, and unmanned systems, creating a collaboration and synergy within the TNT cyberspace (Bordetsky, 2010).

When summarized, self-organization can be defined as the spontaneous emergence of new structures and new forms of behavior in open systems far before they reach equilibrium and are commonly characterized by internal feedback loops. When described mathematically, these are also seen as nonlinear equations (Capra, 1996, p. 85). With particular members of Haiti relief organizations interacting with each other through social media networks, we can see that this definition holds true. Depending upon

"who knows who," there is visible trending toward productive or destructive progression toward overall communication between these agencies. When looking at social networks, we can see that these groupings, on a basic level, exhibit certain "small world" features regardless of the size of a given network (Jackson 2008). This "small world" or scalable feature is a form of internal feedback loop that provides a connection between particular nodes across a given social-network application. In referencing a "small world," there is a given description of social network architecture as a network that is limited by its connection diameters and small average path length. This is measured by the members involved in the network specifically, to the number of members within a network, and these two characteristics of a "small world" remain constant throughout the social network architecture. This can be seen in many examples of crisis response management, including such examples as Hurricane Katrina and the 2004 Southeast Tsunami. Regardless of the characteristics of the network, frequently, these "small world" ties are considered weak ties or acquaintances (Jackson, 2008). However, these same associations are considered a bridge to the outside world where people that frequent different areas and organizations obtain their own information from different sources rather than their immediate friends, thereby proving the invaluable nature of these "small world" ties. Researchers concur that these weak ties play a critical role in a network's ability to communicate with the outside world (Barabási, 2002).

4. Collaboration

Organizations working together on relief efforts in nonadversarial crisis response operations have the potential, based upon its constituent members, to bring focus, competencies, personality traits, and organizational culture to a problem that, under extremis, requires a great deal of team coordination. Establishing meaningful collaboration so that resources are effectively allocated throughout the distressed area, is a central objective for these groups, but it is still met with a level of difficulty due to the limitation inherent in social networks. One example is the level of connectiveness a large network can possess. While there may be a connection between particular nodes or agents, they do not necessarily possess a level of importance or utility for the individual node. However, through the use of the “small worlds” social organization, we see an interesting effect: people who know each other, whether friends or casual acquaintances, come into contact with each other, resulting in a self-forming collaboration process. As time within the crisis response progresses, *homophily* – the tendency of others to bond with those similar to themselves—within a network decreases, resulting in *heterophily* – the tendency of individuals to bond with others outside themselves—thereby creating an expanded outlook of the member of multiple organizations interacting with other organizations in a network setting. This demonstrates the theory that growth and preferential attachment exists in collaborating self-forming organizations, in accordance with the “small world” theory, but that over time, the preference toward association with like individuals diminishes in favor of organic growth

potential represented by the opportunity to branch outwardly in search of additional assets, personnel or otherwise. From this, one can deduce that it is possible for these agencies to communicate effectively through social networks, to produce a level of shared situational awareness that enables these crisis response organizations to better work toward the common goal of relief with greater effectiveness (Barabási, 2002).

Through the theories of self-organization, situational awareness, and collaboration, we can see that there exists a theoretical basis for how networks approach organization and how complex social network systems interact in terms of connectedness, relationships, and context (Capra, 1996). By delving into a better understanding and measurement of how social networks self-organize and collaborate, we become better equipped to analyze and understand the large-scale networks within Haiti to prove or disprove these theories.

5. Visualization

Analyzing self-organizing collaboration requires the ability to organize empirical information of interagency collaboration in All Partners Access Network (APAN) into evidence that demonstrates dialogue and the way information is being disseminated over time. Displaying this information in a sociogram – a picture of nodes to links or diagram—or “picture format” is intended to help the user understand and reason about the materials at hand, and better appraise the quality, relevance, and integrity of the self-forming collaboration process (Tufte, 2006, p. 9). Like Galileo with his 38 drawings of the sun where, over

time, the construction of visual representations led to an understanding thereof (Tufte 2006, p. 10), the evidence extracted from APAN can, over time, help to demonstrate the effects of self-organizing collaboration in the Haiti crisis response operations.

6. Nonadversarial Crisis Response Operations (NCRO)

The United States has recognized that national security implications of operations that do not necessarily include either adversaries, nor combat. Peacekeeping, humanitarian relief operations, and support activities for civil authorities, both foreign and domestic, are operations that describe what is known by the DoD as Nonadversarial Crisis Response Operations (NCRO).

NCRO, through its interagency coordination, cooperation, and connectivity is a networking initiative that is focused on delivering humanitarian relief efforts throughout the world and in situations where infrastructure within the country or region, emergency response coordination between geographically distributed teams throughout different organizations seek to enhance the cognizance and SA. With this knowledge, high-level decision makers can coordinate relief efforts effectively.

For a NCRO mission to be successful, the members of the state, military, and civilian organizations must consider interagency coordination and cooperation, roles and responsibility, and principal organization. It is important to realize that several difficulties have arisen from the fact that many U.S. government agencies, civil, and military authorities, foreign government, the UN, NGOs, and IGOs share Foreign Humanitarian Aid responsibilities.

The U.S. military NCRO planners must remain cognizant that these various agencies usually fall outside the conventional military "command and control" system, and cooperation and coordination are essential in dealing with these various organizations. Interagency cooperation, coordination, and connectivity at all levels will ultimately enable key organizations to orchestrate the total NCRO effort (Department of Defense, 2001).

Through multiple disasters, such as Hurricane Katrina and the 2004 Southeast Asian Tsunami, NRCO Missions contributes greatly to the *prevention* of conflict by promoting interoperability and coalition-building with foreign military and civilian counterparts, while also improving basic living conditions of the civilian populace in a country or region that may become susceptible to terrorist or insurgent influence. In many instances, NCRO requires a level of flexibility by the certain organizations participating in the relief effort. By providing civil, government, and combatant relief efforts, not only does the United States promote a positive form of visibility, but it also improves the security and sustainable stability of a nation that would otherwise be vulnerable to negative influences, either domestically produced or in the form of interference from a foreign sovereign state, as well as exposed to major epidemics and greatly diminished standards of living.

The Haiti Earthquake NCRO offers a large-scale experiment test bed by its own nature, and can be used to observe the interagency coordination and communication that exists between organization members participating in social

network sessions. This social network setting can include chat, instant messaging, e-mail, Twitter, and accessing military and civilian relief websites (in particular APAN, or All Partners Access Network, a DoD-sponsored website). This test bed includes interaction by organizations belonging to the Department of State (DoS), Department of Defense (DoD), and Nongovernment Organizations (NGOs).

7. All Partners Access Network (APAN)

Interagency collaboration in Haiti required a virtual setting for various agents from various organizations to collaborate and share information. All Partners Access Network (APAN) provides this effective information setting to exchange information and collaborate on Haiti crisis response issues (Department of Defense 2010). Through APAN's sponsorship by the DOD, the site through the use of online networking and communication is intended to improve effective information exchange for crisis response, humanitarian assistance, and common NCRO operations. As stated by Lieutenant General Fraser, in a *Senior Leader Perspective* article, APAN benefited many organizations and allowed for greater coordination to be developed in a shorter amount of time:

By opening the air lines of communication, Airmen established a friendly center of gravity and, from Lieutenant General Keen's perspective, created a 'lifeline for Haiti—from civilian [nongovernmental organizations]. (Fraser & Hertzelle, 2010)

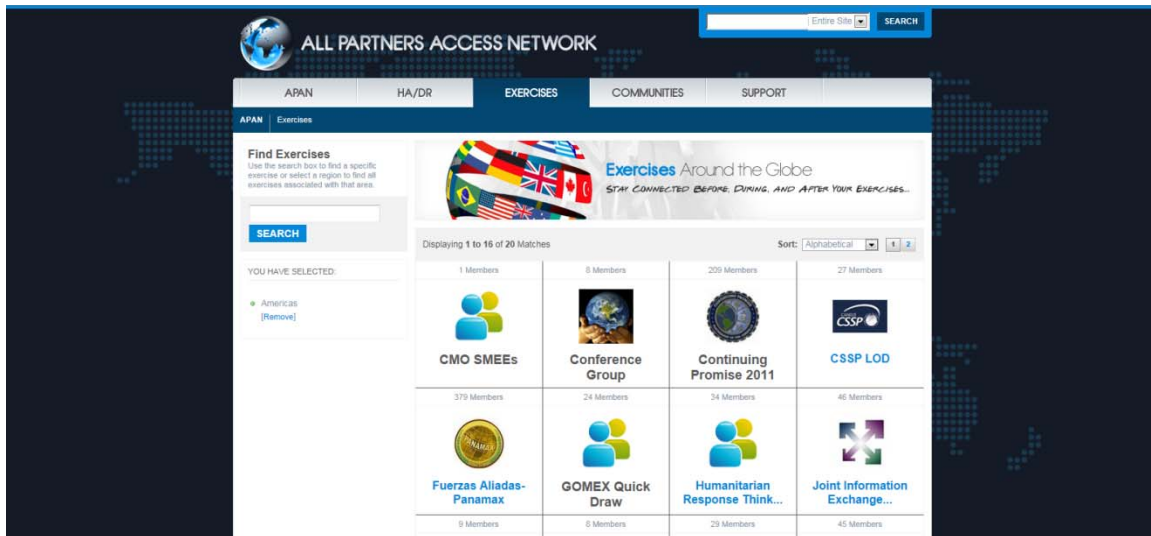


Figure 2. Screen-shot of APAN's community webpage

C. PRIOR WORK ON SITUATIONAL AWARENESS RELATING TO CRISIS RESPONSE OPERATIONS

This portion of the chapter focuses on providing support for a framework that measures the interaction of self-organizing, collaboration, and these effects in social networks when observed, and how it can produce a situational awareness tool for crisis-response operations. It is theorized that, to reduce the uncertainty of variables that are involved in the decision-making process during complex situations, a tool is needed to evaluate what is happening (Wickens, Gordon, Liu, & Lee, 2004). SA is a concept that harnesses this theory and is a perception of the elements in the environment with regard to a volume of time and space. The comprehension of time and space's meaning and the projection of their status in the near future is also critical toward achieving situational awareness (Endsley, Boltè, & Jones, 2003).

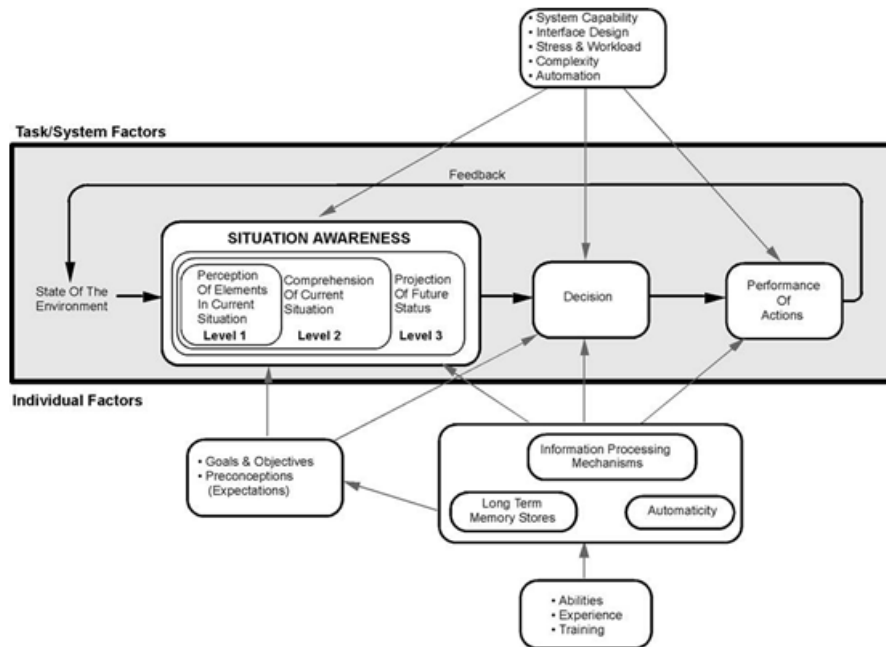


Figure 3. Model of situation awareness in dynamic decision making (From Endsley, Boltè, & Jones, 2003)

By considering SA, we can see that “elements” can vary between several organizations interacting in relief efforts. Through the Endsley model, we can also see that three levels exist that thoroughly describe SA. Level 1 describes the cues in the environment, with Level 2 describing how someone combines, interprets, stores, and retains information. This level also includes the integration of information and filtering what data is important for the situation; ultimately describing “what is happening.” Level 3, the highest and final level, relates to the ability to anticipate future events and their potential implications. Through this description, Endsley determines that the abilities, experience, and training are variables that affect the information-process synthesis. Although the data input remains constant, this process

varies for each organization member, since immanent abilities, experience, and training is not necessarily consistent among individuals. However, the disparities that can exist between both preconceptions and expectations can influence the interpretation of the environment and situational awareness.

Given the rise of complexity in the operational environment, recent trends in organizational design have placed a strong emphasis on "flattened" management structures and decentralized decision making which empowers lower-level operatives to make important management decisions. The use of work groups or teams has further increased efficiency and flexibility. With disaster response, it is apparent that cross-organizational teams commonly form using social networks in response to the complexity associated with the demands placed on the organizations (Wickens, Gordon, Liu, & Lee, 2004). While not necessarily formally grouped together as teams, the communication and coordination that is developed through social networks contributes to formal organizations that coordinate successful relief work. Such team coordination reduces the uncertainty of variables through communication and improves SA. With organization members interacting dynamically towards a common purpose, they in turn hold themselves mutually accountable, while also becoming more aware of what their various organizations' needs are, while contributing to the overall relief efforts. Often this type of interaction is called "groupthink," where groups emphasize the value of alternative perspectives and can

contribute their opinion and perspectives of a crisis situation freely, with the potential to help other organization members involved.

While organization members interacting within a social network setting may encounter reduced ability to communicate during periods of high stress or during an actual crisis response, organization members that are able to see the "down time" between these periods can become more effective. This time period can be used productively to share information regarding situations, plans, emergency strategies, member roles, among others (Oransau, 1990). Through such collaboration, certain affiliated individuals who are independent of any other organization, can develop better situational awareness about other separate organizations, and what their desired goals are. With this perception on what needs are required to be met, a larger goal can therefore be met through cooperation and interaction in social network settings that fits not just the needs of separate organizations, but also of the people that are being helped.

D. PROPOSED APPLICATION OF SITUATIONAL AWARENESS TO CRISIS RESPONSE ORGANIZATIONS INTERACTING IN SOCIAL NETWORK SETTINGS

With a focus on what has been determined by previous scholars (Self-Organization, Collaboration, and Team Situational Awareness), observation of how organizations' members conduct interagency communication through social network settings for crisis response coordination, yields information of the existence of certain traits and characteristics that ultimately shape the way collaboration

and self-organization are conducted. When observed, these traits have noticeable organizational behaviors, which if measured accurately, may be able to help organizational decision-makers in making better situational choices. The crisis-response operations used in the Haiti Earthquake Relief Effort has been a point of focus for determining how certain agencies with particular roles interact with each other. Through their communication and coordination, these agencies can create an emergent environment where collaborative network topologies dynamically shift to meet the demands of the earthquake victims. With this flexibility, these members acting in a flattened *groupthink* environment demonstrate characteristics of self-organizing and collaborate accordingly to their needs and cognizance.

This thesis analyzes metrics and structure of a social network environment in a crisis response situation. With the use of the Lexical Link Analysis tool, we will develop a visualization tool that can capture daily social network collaborative topologies. With the wording used by each organization member interacting in a social network environment, we can analyze network nodes and their links through their recorded dialogue. We will be able to measure the level of team collaboration that occurs in a particular event based upon the strength of word-dialogue associative links, and the frequency of conversation of certain topics with certain organizations.

E. DESIGN

The design of a study on a large-scale network of Haiti's Crisis Response Organizations includes a description of the design components, desired relationships

between those components, a review of prior research on possible prototypes or relevant parameter-criteria models, a proposed parameter-criteria space framework for a desirable system model, and a proposed multi-criteria model for social network collaboration using Extensible Three-Dimensional Graphics (X3D) lexical link network visualization.

1. Components

The selected networking environment may be described as a flattened, team-based, social network that is created to facilitate information sharing, knowledge sharing, and groupthink via written electronic communications as a set of links. As words form the basis of communication in social network environments, the nodes that exist within this network represent specific words, the organization that the words are generated from, and the location where that organization is stationed. Haiti's NCRO is a discovery experiment that is intended to analyze the developing configuration of a flat social network, and to determine how visualizing the collaboration and developing self-organization can produce an effective situational awareness tool (Alberts, 2005). By looking at Haiti's crisis response organizations from January to February 2010, these trends can provide a more representational and distinct depiction of the nodes, links, and their attributes considered in this study. An example is shown in Figure 4.

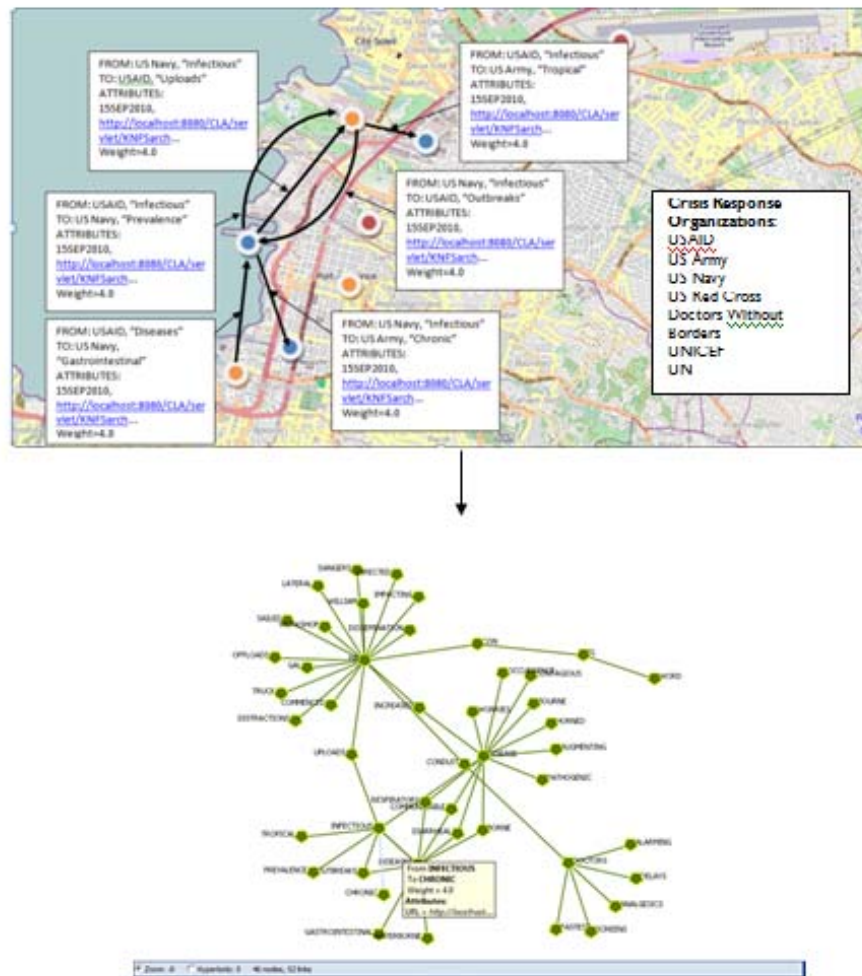


Figure 4. Example of LLA network of word associations produced by hand and superimposed

This data can then be taken and visualized through a lexical link analysis (LLA) tool. When looking at this information on a larger scale, there exists the possibility that it can be better utilized through a model that visualizes and organizes these links and nodes. Future work includes automatically displaying it on a map to display the location of the organization.

2. Relationships

For this study, the strength and links between words is what is used to determine if collaboration between particular organizations is desirable between nodes that are communicating and coordinating on a flattened social network. Several algorithmic tools over the years have been developed to analyze and identify communities in such complex systems.

Through the use of Girvan-Newman algorithm one can detect the relationships that exist within complex social networks (Leicht & Newman, 2008). These communities are defined as divisions of nodes, which have dense (or strong) connections between them. We can use this method of quantitative analysis toward detecting communities within social networks through the development of several algorithmic tools for discovering these communities.

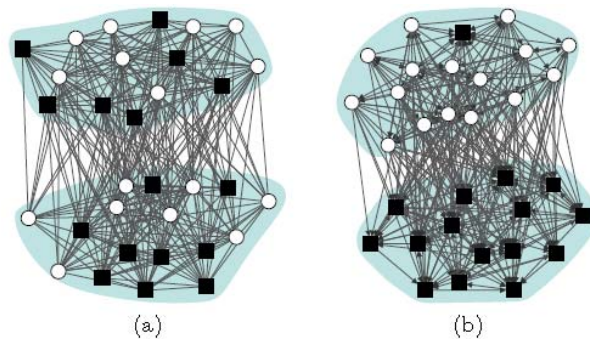


Figure 5. Community assignments for a 2-community random network. (a) A standard undirected modularity maximization that ignores link direction. (b) The Girvan-Newman algorithm. The shaded regions represent the communities discovered by the algorithms with true community assignments are denoted by nodal shape (From Leicht & Newman, 2008)

These communities have been proven through research to be building blocks within networks, and thus offer a level of insight into the dynamics or modes of network formation (Leicht & Newman, 2008). Other methods of network analysis involve assigning a weight for every link and then placing those nodes with the greatest weights within the community as the most important. The Girvan-Newman algorithm, alternatively, is based on a different approach. Instead of trying to construct a measure that indicates which links are most central to communities; it focuses on links that are the least central, and are most “between” communities (or nodes that link the communities together). The communities of a network are detected by progressively removing links from the original graph, rather than adding strongest links into an initially empty network. Along with this, the Garvin-Newman algorithm puts directions of the links into consideration, which previously in other network analysis tools had been discarded. These directions contain a good deal of information about the network’s structure, and in principle might enable many decision-makers to make more accurate determinations about social network behaviors.

When looking at the present lexical link network that we are attempting to analyze, we can see a diverse vocabulary that might typically be organized in some natural fashion such as a glossary or list. The datasets that are generated from these networks can be used by decision makers to determine key words and create a level of information about conversations occurring within networks. The nodes in this network represent terms and there is a link from one node to another, if the first term

was used to define the second. Because circular definitions are unhelpful and normally avoided, most links in the network are not reciprocated. The green lexical link network below shows the communities found in dialogue in Haiti's social network through the Garvin-Newman algorithm. This algorithm found six communities in this case that appear to correspond to the groupings of terms clustered around a few basic concepts. For instance, one group deals with words describing disease, such as "infectious" and "waterborne," while another deals with terms describing Haiti. A third group contains the terms "doctors" and "disease" and related concepts and the remaining groups associated with problems, concerns, and solutions mentioned among these terms. From this information regarding relationships, the Garvin-Newman algorithm appears to find meaningful structure in this social network, of the type that can be useful in understanding the broader shape of otherwise poorly understood crisis operations situations.

F. PRIOR RESEARCH ON SOCIAL NETWORK COLLABORATION

Prior research on how social network collaboration can affect situational awareness has been done by a few researchers in the previous years, looking at primarily the level of collaboration and communication done through online political blogging. By focusing on how two groups – specifically conservative and liberal bloggers – communicate through social network media, Adamic and Glance were able to determine how these two diverse online communities interact and collaborate (Adamic & Glance, 2005).

Within this network study, the network was composed of nodes that represented the blogs. A direct link between the nodes existed if blog linked (as in hyperlinked) to another. Political persuasion within each blog as conservative or liberal was based on textual content. When the Garvin-Newman algorithm was used to find communities, the blog network divided into two communities with, predictably, one being conservative and the other being liberal. The Garvin-Newman algorithm was able to place 97% of the blogs characterized by Adamic and Glance as conservative in the first community and 93% of those characterized as liberal in the second (Adamic & Glance, 2005). The Garvin-Newman algorithm was not able to find any subdivision of either community that would give an increase in modularity. This characteristic indicates that the networks ultimately consist of only two tightly knit communities corresponding to theories of homophily and "small world" networks (Jackson, 2008). This demonstrates the excellent level of capability provided by the Garvin-Newman algorithm to find meaningful structure in network data.

G. DEVELOPING TEAM SITUATIONAL AWARENESS AND PERFORMANCE REQUIREMENTS

While Adamic and Glance's study demonstrates the level of polarity that can be developed in a social network environment when collaboration is not necessarily required, and in some instances is discouraged, it is important to note that collaborative measures require a standard to be met by the decision makers who are in a supervisory position. This guides members interacting in a social

network to facilitate collaboration that is more effective. The standard instead required within crisis response operations should be word network communities, describing critical terms that are linked to particular "key-word" nodes and are used to describe these nodes explicitly. To contrast Adamic and Glance's study, we should also see an even distribution of nodes belonging to particular organizations, and a diverse mixture of nodes that are linked to each other respectively. By setting this standard of "heterophily" regarding organization, location, and URL's, we can determine if a dialogue is being established across the various organizations, and if collaboration is indeed occurring.

By observing if there is a "heterophily" of interagency collaboration, decision makers can thereby determine if the words that are being used to describe certain key words create a meaningful structure in depicting what is occurring within a crisis area. This can be examined with respect to the contribution each organization is making in regards to a particular keyword. This is helpful in that certain standards of performance have to be met to assure that that organization is a contributing team member to the overall crisis relief efforts. To gauge team performance, there needs to be individuals serving in a supervisory capacity. As seen through team dynamics, the leader should have a style that fits the project, while those participating in the social networks should have the necessary knowledge, skills (both technical, social, and operational) to interact effectively in the social network. As the problems encountered become increasingly complex within a crisis area, it is important

to assure the mobility of responders with regards to the capacity of teams to be divisible subteams, which can then attempt resolution of particular difficulties more accurately (Wickens, Gordon, Liu, & Lee, 2004). When constructing a team, it is important to keep the following qualities in mind:

- **Defined Mission:** The organization interacting in social networks must have a common, meaningful purpose regarding crisis relief operations. This should be intuitive when considering why a team should be working together.
- **Defined Goals:** There should be specific performance goals toward inter-organization communication and collaboration.
- **Required Collaboration:** Members must interact with other members within a social network that are mutually dependent on each others' experiences and abilities.
- **Commitment to Collaboration:** Commitment from every member toward team work.
- **Team-Based Trust** Those members in a position of leadership or supervision should delegate responsibility to the members interacting in the social network, keeping in mind the spirit of the social network environment.
- **Effective Use of Resources and Skills:** Coordination should be measured through effective use of resources, both material and personnel, and by the skill set present in individual participants.
- **Mutual Accountability:** Shared accountability should be based upon the feelings of the team that they are accountable as a unit within a larger crisis relief organization.

These requirements can be used to ultimately establish situational awareness within the group. Through the interaction of organization members within a social

network, and keeping the above requirements in mind, effective collaboration can be achieved while enhancing the level of situational awareness for their organization, thereby offering substantive improvement to the effectiveness of crisis response. It is, however, important to keep in mind that while teams are typically developed with a certain level of optimism, problems will occur that may interfere with collaboration and SA. Such issues as:

- Questioning power and authority within certain organizations
- Lack of shared norms or values
- Poor cohesion, trust, or morale
- Poor differentiation of problems of team structures
- Lack of shared and well-defined goals and task objectives
- Poor or inadequate communication within the social network
- Lack of necessary feedbacks from decision-makers (Wickens, Gordon, Liu, & Lee, 2004)

When structuring social network teams, it is important to be cognizant of these potential hazards, since when left unchecked, they represent distracters to effective and timely interagency collaboration. Furthermore, it is important to remain mindful of the "end game," or greater goal for which the collaborative efforts of agencies and individuals in a crisis response are engaged, because without effective communication and coordination between

all parties involved in crisis response management, the victims of the crisis are the ones who suffer from the end result of collaborative failure.

H. PROPOSED PARAMETER-CRITERIA SPACE FRAMEWORK FOR A DESIRABLE SYSTEM MODEL

By together considering the existing literature on Gavin-Newman algorithms, Team Performance, Team Situational Awareness (SA), and the literature on collaboration in lexical link networks, a parameter-criteria space framework was developed to propose a set of collaborative relationships between the given nodes and links that are found between crisis response operations.

Table 1. Description of Multi-Criteria for a desirable system model

Links	Team Situational Awareness	Social Network Collaboration -Heterophily	Team Performance- Defined Mission & Defined Goals	Team Performance-Required Collaboration & Commitment to Collaboration
Dense Lexical Link Clusters	Through the shaping of communities, meaningful structure of a social network is developed, leading to a better understanding of how a key term is described or defined by the social network in NCRO. A good criterion for Team SA is based on an evaluation taken of an individual team member asked a set of questions about the operational picture. Based on the scoring of 1-10 (1 poor, 10 errorless), determines the individual SA. When averaged together with all team members, end score determines Team SA. Strong Team SA should also indicate a large involvement in inputs to social network dialogue. A good community criterion is based on greater than 3 description nodes linked to a keyword node. A fair community criterion is based on 3 description nodes linked to a keyword node.	Where interagency collaboration is noticeable within a word network community and the contributions between organizations, location, and URL's are uniformly distributed in accordance with $P(x_1 < X < x_2) = (x_2 - x_1) \times \left(\frac{1}{b-a}\right) \text{ where } a \leq x \leq b$	Common mission and goals are defined by organizations and communications are reflected through the social network dialogue and word descriptions. Qualitatively determined by the organization's decision-maker.	Sharing of dialogue where the team members of one organization are mutually dependent of others' experiences and abilities. With this dependency in mind, each member must be committed to working as a team. Diversity in description nodes should be noticeable within communities as well as a uniform distribution of description nodes to keyword nodes by organization, location, and URL in accordance with $P(x_1 < X < x_2) = (x_2 - x_1) \times \left(\frac{1}{b-a}\right) \text{ where } a \leq x \leq b.$

Table 2. Continued description of Multi-Criteria for a desirable system model

Links	Team Situational Awareness	Social Network Collaboration -Heterophily	Team Performance-Defined Mission & Defined Goals	Team Performance-Required Collaboration & Commitment to Collaboration
Dense Lexical Link Clusters	When there are limited numbers of terms that are linked to create a community. A poor community criterion is based on less than 3 description nodes linking to a keyword node. Poor community criterion can also be an indication of poor Team SA, which is between 1 and 4.	Where agency coloration occurs within a limited organization(s) and the contribution between the organizations, locations, and URL's is not uniformly distributed.	Words linked do not make sense between the definition and description word. They are limited due to lack of sharing well-defined goals and task objectives amongst team members. Qualitatively determined by the organization's decision-maker.	Inter-organizational dialogue is limited and no mutual dependency exists between other teams. This may be an indication of teams having internal strengths or lack of communication and understanding of teamwork. Dialogue transmitted between teams is sparse, and homophily is apparent between description nodes in word network communities. Communities' description nodes are not uniformly distributed.

Table 3. Additional description of Multi-Criteria for a desirable system model

Links	Team Performance- Team-Based Trust & Effective Use of Resources and Skills		Team Performance-Mutual Accountability	
	Dense Lexical Link Clusters			
	Dialogue that is shared by team members of the organization is genuinely inputted by the team members. From this a level of trust exists between the supervisor and team. Team should also be willing to hear feedback regarding collaboration performance that will improve communication and dialogue between other teams. Skills and resources available to the team should be utilized during the collaboration process. Knowledge of other teams, as well as previous experience and social network media tools should be included to produce more dialogue and inter-organization collaboration. A good community criterion is based on greater than 3 description nodes linked to a keyword node. A fair community criterion is based on 3 description nodes linked to a keyword node.		A team when collaborating in a social network setting has a feeling of shared accountability between fellow team-members in and out of their given organization. This feeling is tangible and can be surveyed by organizations based on a scale of 1-10 (1 bad, 10 outstanding). By having a 10 in accountability, there are multiple links between description nodes and keywords nodes, creating large word network communities (greater than three description nodes to 1 keyword node). An acceptable criterion for shared accountability is rated between 5 and 10.	
	Sparse Lexical Link Clusters	Lack of required feedback from supervisors is not delivered to the team, which results in poor communication within the social network and poor distribution of communities. A poor community criterion is based on less than 3 description nodes linking to a keyword node.	With ill defined team structure and inadequate communication within the social network, lack of shared accountability exists. Based on the scale of 1-10 for feelings of shared accountability, a team member with subpar accountability is rated between 1 and 4. By having low feeling on shared accountability, communities share less than 3 description nodes to 1 keyword node.	

I. PROPOSED MULTI-CRITERIA MODEL FOR SOCIAL NETWORK COLLABORATION FOR CRISIS RESPONSE PERFORMANCE OPERATIONS

1. Performance Criteria Definitions

Performance in a social network that is collaborating during crisis response operations is measured in terms of dense and sparse community links in word networks. These links between keyword nodes and description nodes enable high levels of Team Performance, Team SA, Inter-Organization Collaboration and Diversity of Collaboration (also termed as "Heterophily"), and Improved Information and Resource Sharing among Organizations. This density of communities can also help to determine a common picture of what the demands of organizations are within that captured data time-set. With this information available on display through such tools as LLA, one can determine if such collaboration fits the needs of the organization and integral end-goal for disaster relief. Table 1 contains a set of proposed relationships between factors influencing the creation and termination of Dense Word Links and Sparse Word Links.

2. Design Variables

Design variables are defined as those that are under the immediate control of the systems architect. To study the design variables we will consider the attributes that define the nodes and links. Node design variables include: Word, Origin (both Geographic Location and Organization), Date Communicated, and URL. Link design variables include: Direction of Message (FROM-TO relationship between organization and/or location, and direction from

Description word to Keyword node), Weight (How repetitive the description word and keyword is used in the message transmitted). The following is a description of node design variables, Link design variables, and Opposing design variables that are considered. In addition to evaluating the Opposing design variables, we considered how these concepts affect the design of situational awareness visualization.

3. Nodes

Nodes in a social network may range from word, origin (organization or location), date communicated, and URL. From this study of social network collaboration, we are looking at the words that are generated through social network collaboration, which also means that nodes may range based upon keyword, vocabulary, and terms that have been set by an organization, team, or individual. The design variables used in this study: Team SA, Team Performance Requirements is determined by the measurement of word links between description nodes and keyword nodes, all of which are related to "heterophily," the definition of mission and goals, collaboration and commitment to collaboration, team-based trust, effective use of abilities and trust, and team members having a feeling of shared accountability.

The following Multi-Criteria design variables were selected to measure the node *capacity*:

a. Team Situational Awareness

The importance of SA is more easily realized after a major incident has occurred. A popular method of

measuring SA is by determining how well a particular system or operator preserves SA in the absence of an expected event. This is commonly done through the SA global assessment technique where the operator is briefly interrupted in the performance of a dynamic task and asked questions about it (e.g., identify the location of all the major and minor medical centers in Port-au-Prince). While this can sometimes be considered subjective (i.e., on a scale of 1 to 10), a concern about validity of such self-rating techniques is that people are not always aware of what they are not aware of (Wickens, Gordon, Liu, & Lee, 2004). When looking at team SA, we can base it on an average of questions asked to an entire team. Using a scale between 1-5 or 1-10, where 1 represents failure and a 5 or 10 represents success, a 5 or 10 rating is therefore considered an area where errorless choices are made and a team maintains a consistently high level of SA.

b. Heterophily

When looking at the origins of description words linked to key words within a network, we should see diverse organizations communicating and coordinating with other organizations with some level of regularity. In contrast to homophily, heterophily should display an interaction of different organizations interacting with other organizations and teams (Jackson, 2008). Through the use of uniform distribution,

$$P(x_1 \leq X \leq x_2) = (x_2 - x_1) \times \left(\frac{1}{b - a} \right) \text{ where } a \leq x \leq b$$

the number of nodes based on organizations within a community of perfectly diverse nodes are expected to be evenly distributed within communities.

c. Team Performance

This is measured by characteristics or preconditions that must exist for a team to be successful or effective in a social network environment. This effectiveness in turn leads to better communication in the social network, leading to greater communities in the word network that is used to extract dialogue from the social networks operating in a crisis situation. When viewed as a word network we will see densely linked communities, where multiple (greater than three) description words are linked to key words.

d. Defined Mission and Defined Goals

Common mission and goals are defined by participating organizations, and relevant communications which are reflected through the social-network dialogue and word descriptions. Word networks show a larger vocabulary and wider ranges of topics linking more description words to key words. Qualitative assessment by the organization's decision-makers can determine if the organization and team's missions are being met.

e. Required Collaboration and Commitment to Collaboration

Collaboration and commitment to collaboration is moderated by the sharing of dialogue between team members and the organizations involved in the social network. This revolves around interactions stemming from mutual

dependency of other organizations' experiences and abilities, and can be determined through description nodes generated from a uniformly distributed number of organizations, locations, and URLs. This Uniform distribution is measured as defined before as:

$$P(x_1 < X < x_2) = (x_2 - x_1) \times \left(\frac{1}{b-a}\right) \text{ where } a \leq x \leq b.$$

f. Team-Based Trust and Effective Use of Resources and Skills

Team-based trust in a social network environment is shown by the presence of dense links and is defined by individuals. A supervisor monitoring the progress of the team can typically trust dialogue shared between the team and supervisor toward improving the collaboration between other teams and organizations. Knowledge of other teams such as "small world" knowledge should be utilized to strengthen dialogue between organizations and collaboration. Communities within the word networks should have greater than three links between description words and key words.

g. Mutual Accountability

When dialogue is created between organizations in a social network, there must exist a sense of accountability between other team-members and organizations. While this is a subjective measure, it is nonetheless a vitally important measure for determining effective networking structure and team situational awareness (from a scale of 1 to 10, 1 being bad, 10 being outstanding). Through this idea of mutual accountability, there are multiple links between description nodes and

keyword nodes, creating a large word network communities (greater than three description nodes to 1 keyword node). An acceptable criterion for mutual accountability is between 5 and 10.

4. Links

From this study, links can be defined into two dimensions: the links between locations and organizations, and the links between words. When combined, this linked data can be extremely powerful for analysis in establishing a situational awareness tool. Dense communities in word networks can measure how clear a key word is understood (or perceived as being understood), and may also measure the level of interactions that exist between particular locations or organizations. Links are described also in terms of URL, date, and direction between nodes. This study, shows through Lexical Link Analysis that various topics, depending on the context, can determine if the knowledge within a particular topic is *weak* or *strong*. Additionally, we can also examine the utilization of knowledge resources within a particular social-network setting and determine if they are focused correctly. This study, we will be looking at Haiti's crisis response social network and how SOCOM, USAID, American Red Cross, UNICEF, the UN, and Doctors Without Borders interact through chat, e-mail, and social-network blogging and input applications.

5. Functional Constraints

A functional constraint is a variable that is assigned by the user of the system or environmental factors. When considering the use of data placed into a social-network

environment by crisis response operators in Haiti, these types and numbers of functional constraints are expected to vary. By exploring the Haiti APAN data for this work, we have a level of control in the selected scenario and are able to more directly define functional constraints.

6. Time

Using time as a functional constraint, provides an opportunity to better understand the relationship between the duration of the crisis response operations, and the amount of information being shared within a particular time interval via the number of newly created communities during a time period. From this, we can also determine how collaboration of words, definitions, and descriptions are shaping the mission of the crisis response from day-to-day. As seen in Adamic and Glance's study, by capturing a day's worth of blogging from two prominently opposing blogging sites, they were able to create a word analysis of politics and present a more static picture of the network's behavior. This also allowed a user to decipher patterns that existed between nodes and gain a better understanding of what the political attitudes and beliefs were of bloggers regularly contributing to these websites (Adamic & Glance, 2005).

J. SCENARIO

The creation of collaboration in a social-network crisis-response environment, and the use of densely formed Lexical Link Networks in a word network developed from the social network dialogue, is interlinked through the Lexical Link Analysis program, which takes social network inputs

and translates it into word networks. In particular, the Haiti earthquake social network inputs are analyzed to determine if there are strong operational descriptions, and definitions to improve contextual understanding of particular keywords of interest. As time progresses within the social network and more links are formed, we can see if certain key words have reached a level of common understanding through dense lexical links, or alternatively if less understood ideas or key words are separated into sparse word links.

By looking at the dates supplied by organizations as input dialogue into social networks and translated through LLA, we can then, through methods of discovery can provide an opportunity to evaluate the creation of newly formed links. This includes the use of dense word links across a series of time prior to determining new and significant theories on how social network collaboration in crisis response operations creates better team situational awareness of the response efforts themselves.

Table 4 provides a summary of the performance criteria definitions, design variables, opposing and complementary design objectives, and the functional constraints.

Table 4. Performance criteria, design variables, and functional constraint's measurement of range

Performance Criteria Definitions	Range
Collaboration of Scale	Low–High
Complexity of Task	Low–High
Time Urgency	Low–High
Organization Members Available	Low–High
Collaboration of Tools and Technology	Low–High
Latency Between Social Network and LLA	Time (sec-millisec)
Quality of Team-SA	Low-High
Average Bandwidth	Bps
Packet Loss	Percentage
Design Variable	
Nodes	
Defined Missions & Goals	Low–High
Required Collaboration & Commitment to Collaboration	Low–High
Team-Based Trust & Effective Use of Resources and Skills	Low–High
Mutual Accountability	
Links	
Direction	To-From Criteria Location Organization Description-Keyword
Dense Communities	>3 Description:1Keyword Links
Sparse Communities	<3 Description: 1 Keyword Links
Technology Platform	Type
Functional Constraints	
Time	Varied
Scenario	Varied

K. CHAPTER SUMMARY

Analyzing organizations in an informal setting poses a problem of focusing on complex network interactions. When considering NCRO, we can see that a considerable amount of “horizontal” communication and collaboration is conducted to better establish shared understandings of the common tactical picture that exists with the crisis response efforts. As we can see, social-network analysis tools are capable of detecting and interpreting patterns representing such interactions among various actors from different organizations. Despite some of the lesser limitations of the program, the importance of these tools are manifest and we see that social-network analysis is capable of acquiring a better Situational Awareness picture for decision makers. We can also see that SNA can potentially contribute to developing a C2 tool that strategic/operational leaders can use to determine how many crisis response members in their organizations are talking about and what is of greater importance for many organization members involved.

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III. SOCIAL-NETWORK ANALYSIS (SNA) TOOLS

A. INTRODUCTION

Picking the right tools is crucial in successful analysis of lexical data from Crisis Response Operations. Constructing these programs to contain the necessary features to display the correct, accurate information is a critical component in the development of analysis for this thesis. Additionally, developing a situational awareness tool capable of displaying the necessary data for the designated authorities to promote interagency collaboration requires a background in the accumulation of data that is generated for the analysis. This chapter is a description of those programs to be used in analyzing the Haiti Relief lexical data, and includes the strengths and weaknesses of each.

Through determining how these social-network analysis tools process network datasets and how they display these inputs into outputted data, it is possible to show how accurately these sociograms reflect the social organization applications they are extracted from, and potentially how much of an accurate operational picture they display. This is critically important in understanding the following chapter, which discusses and displays the information as a whole and the improvements that are made to build upon the data that is visualized through X3D. This foundation of information on current social network tools can help determine if the developed tool is viable for the current

decision makers and, and can potentially show the level of validity this thesis holds for interagency Crisis Response Operations.

B. QUALITIES OF THE “RIGHT TOOL”

In addressing what social-network analysis tool is right for a given job, it is first necessary to ask—and to understand—“What makes a good Social-network analysis tool?” One of the most important aspects of visualization is being able to see the data and having it making sense without further explanation. This is an intuitive characteristic of seeing data and content. With current calculations, most of the data generated through the Lexical Link Analysis tools can be seen numerically through Excel-like datasets, shown for example in Figure 6:

	aid	air	aircraft	airlift	alerted	ambassador	americans	amphibious
2010-01-13-ADFUSA.ORG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2010-01-13-ARMY.MIL	0.0	5.0	3.0	2.0	1.0	0.0	0.0	1.0
2010-01-13-DEFENSE.GOV-TRANSCRIPTS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2010-01-13-DIRECTRELIEF.ORG-EMERGENCYRESPONSE	2.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0
2010-01-13-FIELDNOTES.UNICEFUSA.ORG-2010	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2010-01-13-GOOGLE-LATLONG.BLOGSPOT.COM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2010-01-13-GOOGLE.COM-RELIEF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2010-01-13-NEWSROOM.REDCROSS.ORG-2010	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2010-01-13-SALVATIONARMYUSA.ORG-USN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2010-01-13-SOUTHCOM.MIL-APPSSC	2.0	2.0	8.0	0.0	0.0	0.0	0.0	2.0
2010-01-13-STATE.GOV-P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2010-01-13-STATE.GOV-R	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0
2010-01-13-STATE.GOV-T	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2010-01-13-TWITTER.COM-SOUTHCOMWATCH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2010-01-13-USAID.GOV-LOCATIONS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2010-01-13-USAID.GOV-OUR_WORK	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0
2010-01-13-WFPLOGISTICS.ORG-HAITI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Figure 6. Excerpt from January 13, 2010 network from ORA without attribute data incorporated into network

While this information is quantitatively accurate, it can be tedious to examine hundreds (and, in some instances, thousands, tens of thousands, hundreds of thousands, and

the right result, and can be similarly repeated. In the case of social-network analysis, accuracy and precision based upon the datasets is typically repeatable and consistent based upon the level of datasets that are accumulated, defining both the word-nodes and the connections between those word-nodes.

2. Thorough Data Computation

While looking at small-scale networks can be done on almost all of the SNA software tools created today, seeing a large level of nodes and large-scale networks is of key importance toward gaining greater situational awareness of a crisis situation. In this, the SNA tools used must be capable of processing a large amount of data, as well as being able to calculate the necessary attributes and statistical data of the lexical link networks. Some SNA software tools focus on just this; the ability to upload and calculate large quantities of network nodes. There are, however, many other fairly standard types of SNA tools that can be used for medium-sized to larger-sized lexical networks that contributes a wider variety of measurements provides potential benefits for visualization. The extent of analysis needed by the user typically determines the SNA tool that is most appropriate.

3. Data That Is Distinct

One of the largest prerequisites defined through the SNA is the ability to define the node and then define the link within that network to other node(s). Social network data consists of two basic elements: 1) the ties to the networks and 2) the knowledge, actors, or nodes that

connect these ties together and are required to have distinctions between each other to produce a network. This can be defined as two elements are represented through an $(n \times n)$ *adjacency matrix* (X) for which X_{ij} tie the variables from node i to node j (Huisman & van Duijn, 2004, p. 3). While these nodes can be dichotomous in their relationships (either connected or not) the self-loops (X_{ii}) are typically ignored. The remaining $n(n-1)$ links define the maximum required links for a network to be a complete network (Huisman & van Duijn, 2004, p. 4). Identifying these variables within a network is a fundamental component to social-network analysis, and without its distinction from other nodes, the information is without value. Having an SNA tool that is viable, and valuable, to the needs of analysis requires that this distinction be made for networks to be analyzed and displayed appropriately.

C. COLLABORATIVE LEARNING AGENT AND LEXICAL LINK ANALYSIS

1. Thorough in Data Capture

Being able to combine the thoughts, ideas, and knowledge of people from diverse organizations and backgrounds has been a continuing challenge in command and control (C2). When thoughts are integrated and discussed, there is a broader understanding of certain communicated concepts that exist. With regard to crisis response operations, like the one in Haiti, coordinating these thoughts together is a challenge that many have attempted to overcome without success. Along with the expansiveness of the information in its subject content, integrating

these thoughts into a single user interface is also phenomenally prolific. The sheer voluminous quantity of resources used by organizational members are so vast that with the limitation on time, the requirement to find effective solutions quickly is something that one or even several human beings cannot effectively do on their own.

2. Distinct Data Display

Despite these obstacles, the Collaborative Learning Agent (CLA) found within LLA, was intended to solve the issues that exist to mine and determine key issues inherent within online topics and reports. CLA is a data mining tool that searches for “abnormal” or unique words that have been used (Zhao, MacKinnon, Gallup, & Zhou, 2010, p. 5). By uploading a large quantity of data relating to the Haiti crisis, a user is able to generate a list of words that occur most (or least) frequently in these reports. Additionally, the Collaborative Learning Agent (CLA) is capable of producing datasets that are both .dynetml (an XML based interchange language for network data) and .xml file format compatible, making it compatible for the Organizational Risk Analyzer (ORA) tool. The Collaborative Learning Agent, in essence, creates a common interface, which can help to measure the level of connectedness that exists between several words. The accumulation of data within a given crisis situation can be prolific, since the typical quantities of data are almost incomprehensibly vast. When faced with sorting through various data to achieve better situational awareness in a crisis response, the data that must be analyzed usually takes far too long to examine manually, if there are to be timely and

effective results. In the case of Haiti, a great number of sources that were used to achieve situational awareness were accumulated and distributed through APAN—a designated collaborated website. Determining what is out of the ordinary and distinct from other terms is something that most administrative leaders attempt to recognize when going through the barrage of information given to them at any given time. This is where the Collaborative Learning Agent (CLA) serves a purpose in crisis response operations. These text files can be sorted and analyzed quickly and accurately.

3. Accuracy and Precision

Determining that the words selected from CLA and LLA are indeed significant to crisis-response operations, requires that we measure the degree of accuracy of a quantity to its actual or true value. While many words are seen as irregular or special compared to other common terms, CLA is more than capable of finding those types of words. A word misspelled, abbreviated, presented as an acronym, infrequently discussed, or presented out of context of crisis-response operations, can indiscriminately show up within a lexical link network, without CLA determining if such words were added by mistake or are considered significant. When accumulating a large amount of data over a long period of time, such typographical errors, acronyms, and/or abbreviations can add up to a lot of unnecessary clutter in the network process. If they are then connected to other key terms, there can be a misrepresentation of their importance with regard to the lexical link network. The user and the personnel who are

inputting information into the social-network applications may require the user, when analyzing these networks, to keep these inaccuracies in mind, and engage in further communication to allow disambiguation. As of 2010, it was found that CLA is 72% accurate in detecting word anomalies, making it an already powerful tool with room to improve (Zhao, MacKinnon, Gallup, & Zhou, 2010, p. 9). Adding supervisory controls such as spell-check options, and limitations on abbreviated terms, can potentially improve the input into CLA thus improving the level of data that is extracted by CLA and LLA. While it may also be tempting to use a control that 'ignores' particular words in the extraction of data, future words and context of words that are previously not determined can be potentially deleteriously affected by such a control, and may therefore serve to decrease the accuracy of the data extraction. Some human interaction is valuable at this point in the analysis so that not all of the analysis is conducted by the CLA algorithm.

Delivering information that is accurate and repeatable requires a consistent amount of data following over time. When measuring the crisis-response operations that occur over time, having consistent daily feedback is critical. With social-network applications, most input is strictly voluntary. As a result, some required daily updates can be missed due to user inactivity. This brings a large information gap that can be detrimental to the precision of the information. Without a constant flow of information, the measurement of links between words and their importance to lexical link networks are affected significantly. It is therefore up to the operational planners and leadership to

enforce the consistent and frequent feedback of information into the given social-network applications. Accountability for the knowledge is critical toward developing accurate reports and updates. Without this, the LLA and CLA's extraction of words is skewed toward words and information that is inputted into the social-network applications and websites.

D. ORGANIZATIONAL RISK ANALYZER (ORA)

1. Quantity of Data Capture

The choice of SNA tools is based upon the requirements of analysis and the preference of the user. The three primary—and most widely used—social-network analysis tools are Pajek (pronounced: pai'-ek), UCINET, and the Organizational Risk Analyzer (ORA). We will compare and contrast each of these one at a time, and will address ORA first in the section below.

ORA is seen as one of the most powerful social-network analysis tools, based upon user friendliness allowing for ease of navigation through the program, and also because it is able to generate accurately attributed sociograms with little manipulation from the user. Additionally, ORA is also exportable to XML and Dytemnl, both of which are extremely extensible and usable for other software applications and programs. By LLA generating particular data that can be converted to xml format, the Meta-Matrix generated visually, shows how these measures can be applied.

2. Distinct Data Display

ORA clearly defines its definitions for node identification and distinction in the ORA User's Manual. ORA can look at multiple aspects of a network and, depending on what quality of data that is provided to the software (whether it be knowledge, agents, resources, or tasks), can determine certain qualities about the relationships that exist within the network. This is done through mathematical computation. The following is a listing of measures that we will evaluate using ORA:

A network (N) consists of two sets of nodes, U and V, and a set of edges $E \subset U \times V$. An element $e = (i, j)$ in E indicates a relationship or ties between nodes $i \in U$ and $j \in V$. A network where $U = V$ and therefore $E \subset V \times V$ is called unimodal (also known as one mode); otherwise the network is bimodal (or two mode). Unimodal networks do not contain self loops in this situation, which means that $(i, i) \notin E$ for $i \in V$.

When defining or implementing measures a network can be represented as (1) a graph, or as (2) an adjacency matrix. To represent a unimodal network as a graph, let $G = (V, E)$, where V is the network nodes, and E are the ties; bimodal networks will not be represented as graphs. Both unimodal and bimodal networks are represented as adjacency matrices. (Carley & Reminga, 2004)

Defining the sets of nodes specifically is essential toward properly gauging the types of measurements to be used on the network in ORA. ORA is capable of looking at various sets of nodes such as Agents, Knowledge, Resources and Task. We will focus on be looking at knowledge nodes (keywords).

Table 5. Node sets and names (Carley and Reminga 2004)

Symbol	Node Sets		Name
	U	V	
K	Knowledge	Knowledge	Information Network

The knowledge $\times$ knowledge networks or Information Networks can indicate the relationships word nodes share between each other within multiple conversations in a given period of time. The following is an explanation of how ORA calculates these network measurements and defines:

Given a network $N = ((U, V), E)$, define a matrix M of dimension $|U| \times |V|$, and let $M(l, j) = 1$ if $(l, j) \in E$, else let $M(l, j) = 0$. Then M is called the adjacency matrix representation of network N . Unimodal networks are also called square networks because their adjacency matrix is square; the diagonal is zero diagonal because there are no self-loops. (Carley & Reminga, 2004)¹

The Visualizer that plays a major part in the development of the situational awareness tool is capable of taking these meta-matrix variables, and transforming them into relatively intuitive, integrated displays. Through this tool, the user can generate a graphical model that displays the meta-network in terms of links and nodes. Not only does this generate a more intuitive method of viewing the data, but also allows the user to better optimize a network's design structure (Carley, Reminga, Storrick, & Columbus, 2010, p. ii).

¹ For more information on ORA calculations, see Appendix A.

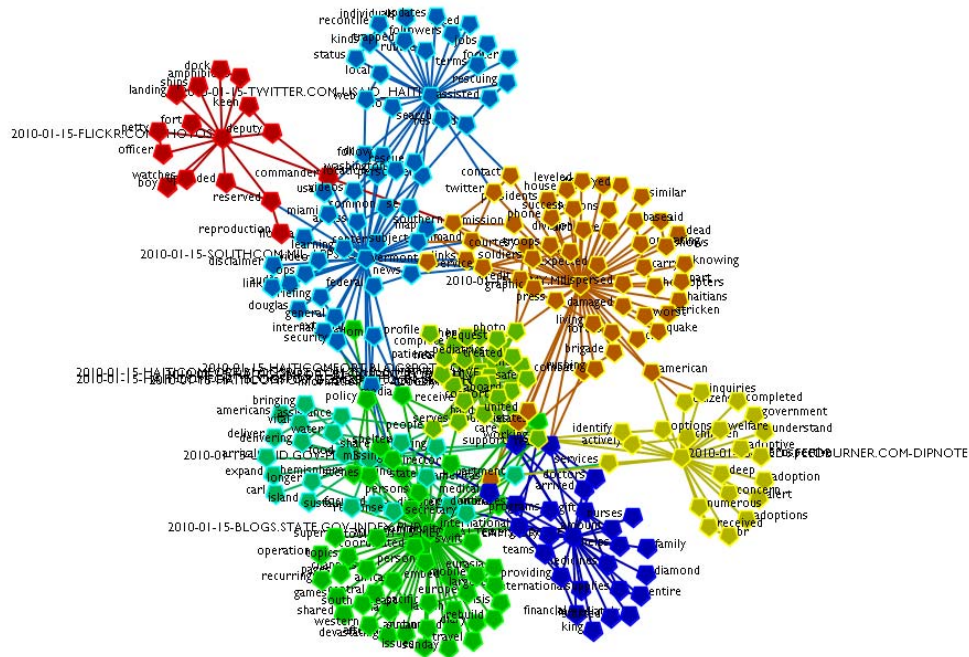


Figure 8. 14 January 2010 Lexical Link Network displayed in ORA with Newman grouping applied

3. Accuracy and Precision

The emphasis on selecting the proper categorization of node sets for analysis is critical for assuring the accuracy and precision of the lexical link network. Without proper representation of these variables (as referenced in Appendix A), the information displayed is only be inaccurate in their algorithmic calculations, but can also lack intuitive sense to the user. In some cases, the prompting of node sets can result in erroneous feedback. If information is to be generated that reflects the actual qualities of the information, complying with the requirements of the data measurements in the ORA tool is vital.

E. PAJEK

1. Quantity of Data Capture

Pajek (Slovene for Spider) is an extremely robust social-network analysis tool that can be used to look at networks through various modes. As written in the user's manual, "Pajek is a program, for Windows, for analysis and visualization of *large networks* having some thousands, or even millions of vertices [aka nodes] (Batagelj & Mrvar, 2003). With its ability to process large networks, it is considered an excellent social-network analysis tool. With its continued upgrades and free noncommercial distribution, it is frequently used by sociologists, defense analysts, and social-network analysts to calculate and analyze network data. Despite its ability to handle large networks and permit dynamic analysis of networks, it is simultaneously considered the most imperceptive programs (compared to ORA and UCINET). With Pajek, the user can find characteristics of a network, extract nodes that belong to that cluster, and show them in a new network with parts of the context. Compared to its counterparts with data collection, it contains less extensive statistical capabilities, which must be performed using separate files through partitions and vectors.

2. Distinct Data Display

When looking at the level of organization that exists in Pajek, its data is organized according to the types of data objects used as input. The two primary datasets for networks used in this analysis are networks and partitions that are capable of storing particular attributes of nodes in different scales. Network and partition files are

stored in ASCII format, and both ORA and UCINET can export their data files into these particular formatted files. The *network file*, which views the primary dataset, is capable of being displayed through the *Draw* function and with various layouts. When looking at a network with integrated attributes incorporated into the dataset (something utilized in this analysis), the *partition files* are used to display particular attributed details. Another incredible aspect of Pajek is its ability to give a wide variation in layout. Pajek, through *Layout>Energy* allows researchers to choose the starting positions of the network's nodes; allowing us to choose random and circular starting positions for analysis. This organization through the "energy" defined by the user is also exportable for the file, which gives a greater level of compatibility with X3D and many other visualization tools.

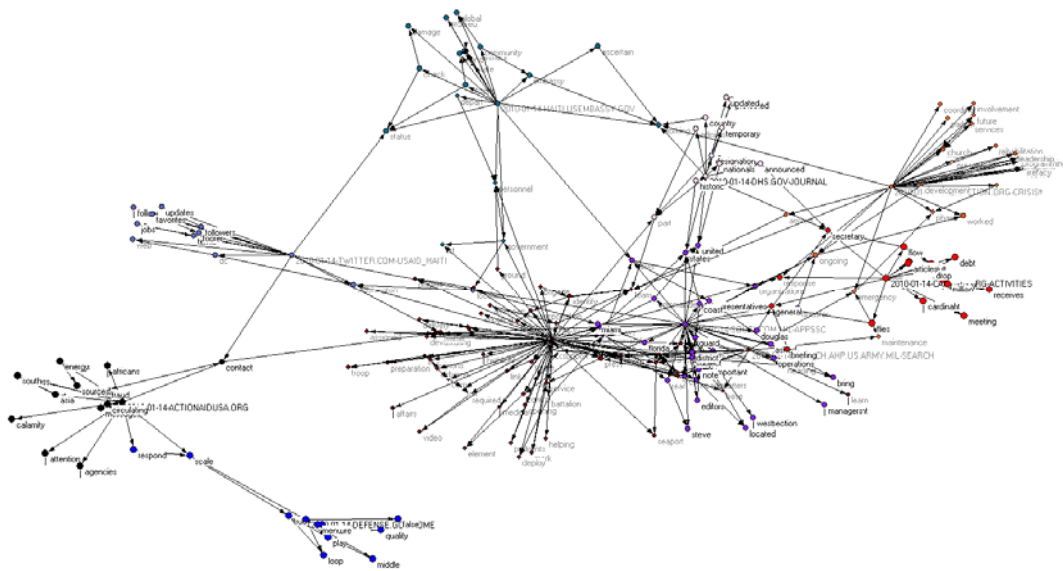


Figure 9. Word network in 3D with Fruchterman and Gold distribution (14 January 2010), displayed with Newman attributes incorporated into the partition file

3. Accuracy and Precision

Creating a level of consistency of information is dependent upon what type of ASCII file the user is applying to analyze and view the lexical link network. Having a tool that is capable of processing complexly coded data allows for the mapping of the code to be more realistically represented. As a SNA tool, Pajek proves to be capable of handling large quantities of data. With the level of attributes that can be coded into the data, this provides an increasingly accurate display. Nevertheless, even with the ability to upload several files and attributes, it is important that the user keep track of which network file they are displaying visually. As seen with the use of Pajek, the counter-intuitive display of data can at times confuse the user.

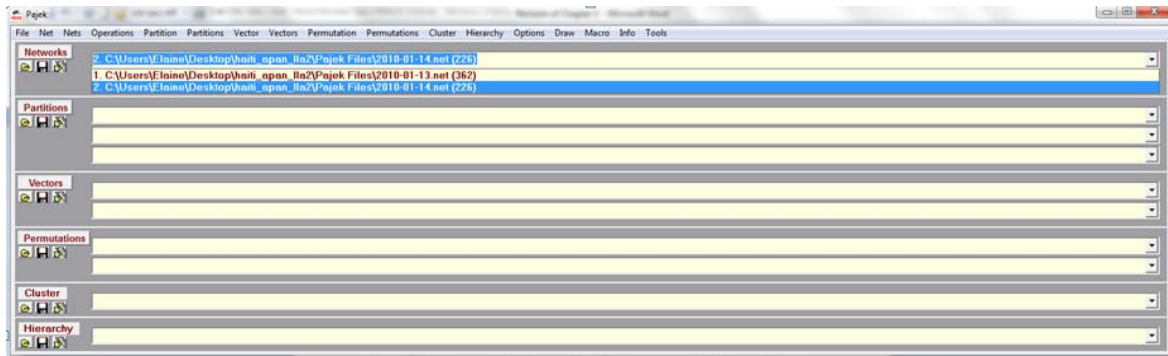


Figure 10. Pajek screen capture showing multiple files uploaded revealing the difficulty in assuring the desired file is selected prior to visualizing the network data

Selecting the correct type of file to display the data can also determine if the attributes of the lexical link network are displayed consistently as well. Partition files (.vec), when encoded with the correct attribute data, can show the required Newman groupings of the lexical link networks, while the use of the .net files (Network) will only display the lexical link dataset without attributes. The Vector file typically displays portions of the network selected. While helpful when trying to display sections of a large network, this feature can lower the level of accuracy and consistency of information by limiting the level of information displayed.

F. UCINET

1. Quantity of Data Capture

UCINET is a social-network analysis program that is extremely agile in its analysis, allowing the user to format their datasets into Excel (or matrix format) and then import it into Net Draw, the visualization software that is incorporated with UCINET. According to the

development website, UCINET can handle up to 32,767 nodes (with few exceptions) making it a medium-capable social-network analysis tool (ORA and Pajek being on the “high-end” of social-network analysis capacity) (Analytic Technologies, 2010). When comparing UCINET, ORA, and Pajek, many social network analysts consider UCINET to be one of the most intuitive programs with numerous amounts of metrics and algorithms available. This allows UCINET to be a diversely explorable option, giving the analyst the ability to choose from a wide variety of metrics and algorithms.

2. Distinct Data Display

The newest version of the program is UCINET 6, and was updated primarily to improve its processing speed. According to its User’s Guide, the programmers “had to choose between using a fast algorithm that used a lot of memory (and therefore reduced the maximum size of network it could handle), and a slow algorithm that saves memory and could handle much larger datasets ... in this version we usually chose speed” (Borgatti, Everett, & Freeman, 2002, p. 5). When analyzing and incorporating the lexical link networks into UCINET, there are a considerable number of nodes to be examined, as well as the incorporation of attribute datasets, reflect the Newman weights calculated for the networks. Being able to effectively use multiple metrics to determine the detailed characteristics of the networks, UCINET proves to be an effective tool in displaying various levels of information throughout the required networks.

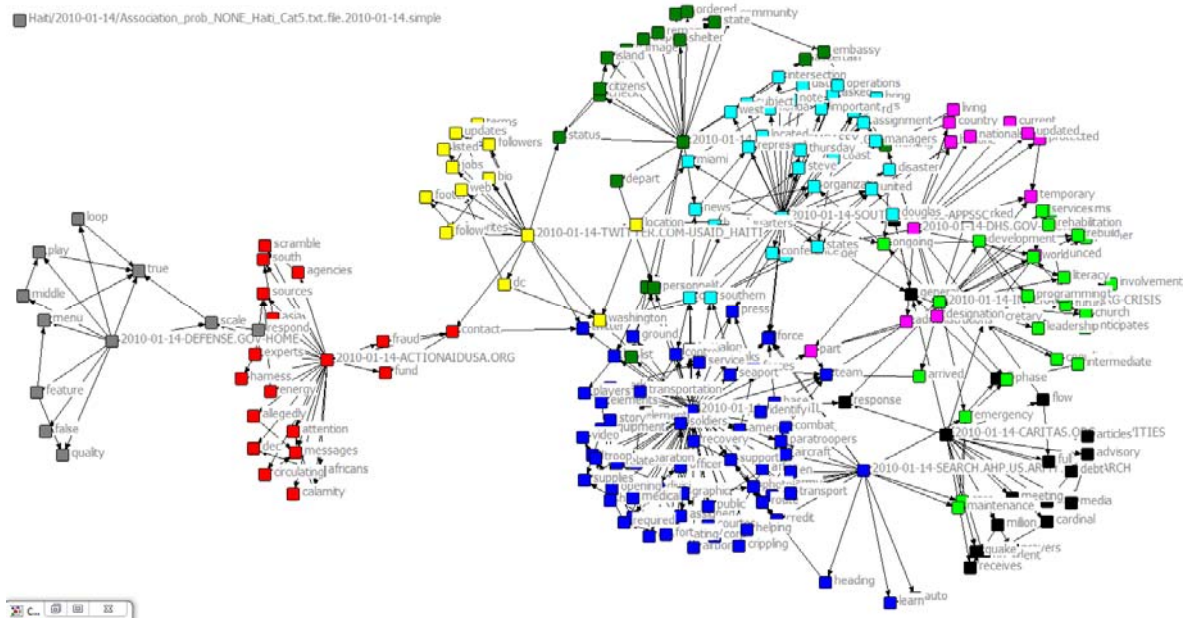


Figure 11. January 14, 2010 word network displayed on UCINET with integrated Newman attributes

3. Accuracy and Precision

UCINET's ability to manually input datasets through matrices, is a both good and bad in regard to increased accuracy. An analyst can account for and correct potential mistakes, typographical errors, or unnecessary terms through manual correction, but the potential for error increases with human involvement. While NetDraw recognizes the misalignment of datasets to attributes (the number of rows in an attribute set has to be equal to the number of rows in the datasets), the ability to override this error is available to the user through NetDraw. Producing information that is accurate and reflective of the data submitted within the social-network application is jeopardized by this capacity. When visually displaying information within NetDraw, the level of options within the program are comparatively limited. While shapes, size, and

color of the network attributes can be better defined, the ability to project in 3D, and with defined number of algorithmic distribution, is limited. To determine relationships between many different nodes, it is important that there exist multiple options available in depicting groups and potential relationships. While this may be easy with a few attributes, UCINET and NetDraw cannot handle a large quantity of attribute information, compared to ORA. If the information is intended to be displayed in a method that is reflective of the actual information, it is important that this be taken into consideration when using this tool.

G. EXTENSIBLE 3D GRAPHICS (X3D)

The Extensible 3D (X3D) Graphics is an intentional standard for saving and deploying interactive 3D models and the Web. X3D has many similarities to HTML standard for publishing hyperlinked documents on the Web. X3D is not a social-network analysis tool, yet it is nonetheless vital toward our social-network analysis and its programming. Pajek has recently developed a function to export data into X3D. Through the use of xml, X3D is able to format lexical link networks into 3D visualizations and provide a level of flexibility with the display of the information that can be updated and formatted to reflect the preference of the analyst. By utilizing X3D, there are numerous possibilities that exist regarding its integration into web services, distributed services, and integration through data transfer and applications.

When considering crisis relief operations in Haiti, it is essential that most of the applications used be mobile

and easily accessed through such interfaces as mobile phones. X3D provides the ability to be both broadcasted and/or embedded in various applications. With the high level of capabilities in the X3D coding itself, the speed of the information translated and then visualized is quickly realized.

1. Accuracy and Precision

Providing an application that is evolutionary in its ongoing development, and capable of easily adjusting itself to reflect real-life characteristics of words and networks, is something that X3D is, by virtue of design, capable of doing. Its ability to transfer data from an SNA tool into a displayed scene is important. However, by developing code that can also add on hyperlinks to the data that the node was extracted from makes this visualization tool interactive, and accurately reflective of the network itself. Chapter IV provides discussion into the development of such a tool (Web 3D Consortium, 2011). Along with its declarative nature, strict X3D validation allows for little error in its definition of information; creating a method of verification to assure that information is being properly demonstrated and/or displayed. However, this accuracy is only as good as the source of the information, and while the information is able to be restrictive in language error, it is difficult to determine if the information extracted from the SNA tool and the social-network application is accurate and consistent. This requires a level of verification of the original data

itself, as well as assuring that the information effectively reflects the data that exists in the social-network application.

H. CHAPTER SUMMARY

The capabilities of the social-network analysis tools of ORA, Pajek, and UCINET have been compared on the basis of displayability, computation capability, and accuracy and precision. The table provides a summary of our findings.

Table 6. Measurements of SNA tools

Metrics	Displayability	Computation Capability	Accuracy & Precision
ORA	High	Medium	High
UCINET	High	Medium	Medium
Pajek	Low	High	Medium

While these software tools have independent strengths and weaknesses, when combined together the user analyzing a lexical link network can utilize all of the strengths of each SNA software package. This hybrid approach compensates for their shortcomings Pajek opens up a completely new realm of possibilities with the introduction of X3D as an exportable option within any single tool. In Chapter IV these SNA tools are used toward a gradual development of an SNA visualization tool, which can help contribute toward improving the network visualization design, and potentially strengthen the level of interaction a user can have with these visualization tools. With the support of these

network analysis tools, and being cognizant their desirable features, our goal will be to create a useful SNA visualization tool that can improve the situational awareness in future crisis response operations.

IV. APPLYING SNA TOOLS AND DEVELOPING AN X3D PROTOTYPE

A. INTRODUCTION

As with the development of any program, particularly the development of a situational awareness tool capable of looking at the progression of crisis response operations, any development must start with small, measured steps. In this chapter, starting small requires that there be a development of a particular data set and expand this development into a process which can be replicated over time through X3D. To accomplish this task, a 10-step process has been constructed to develop an X3D social-network analysis tool that can help to contribute to the better understanding of a lexical link network. Through this 10-step process, we examine 15 January 2010's lexical link network to demonstrate a methodology of X3D model development.

B. BRUTZMAN'S 10-STEP PROCESS

Initially developed in Dr. Don Brutzman's X3D course, this process of general design for converting data into X3D visualization has become the basis for developing the X3D visualization coding for lexical link networks. We started with the following idea.

1. Focused Brainstorming With Steps 1-3: Concept, Notional Examples, and Candidate Examples

This step was intended for conceptualized ideation on how the data might look when visualized in three dimensions (3D). At the initiation of the development, it was clearly

evident that there were a great number of 2D visualizations for the lexical link data. By seeing these *sociograms*, the desired end product became evident. Additionally, there were many other features that were appealing in a 2D setting, such as being able to manipulate the *sociogram* so that all nodes that had merit for inclusion, could be visible for post-configuration calculations. Also, the ability to dynamically *rotate* the model is a useful capability. The display of data (such as color-coded connections to connected nodes according to Newman values) was determined to be appealing to the user and could be incorporating into the X3D programming. From this brainstorming process, a list of requirements shown in Table 7 was developed that are desirable goals for X3D visualization:

Table 7. List of requirements from brainstorming

Multiple Viewpoints	Being able to view the model from multiple viewpoints and making large datasets easier to examine and view from multiple visual perspectives.
Hyperlinks	Allowing the user to not just look at the key words for a given data with APAN data, but rather demonstrate the resources analyzed to generate the data.
Animation (Rotatable)	Enabling the user to see data according to preferred angles, and give a more "guided tour" of the data.
Embedded Descriptions	Allowing information to be disseminated to the user with added comments. This can potentially enhance the information provided by the operational planner to others analyzing the datasets.
Interactive	Providing the ability to interact with the information by moving and choosing several options allows for a more enriched understanding of the data, and gives the user multiple options to choose from according to his/her preferences and/or requirements
Archival	Saving the information onto a database and/or website allows for continued references for continued research and analysis.

With the use of the social-network analysis and other software tools, it was possible to create a clear design of a 3D social network visualization. From Pajek in particular, prior experimentation showed that the Fruchterman Reingold Distribution provided the best level of distribution for the lexical link networks (interestingly, the Fruchterman Reingold Distribution is also capable of being displayed in 3D). From Pajek's

displays, as well as from ORA and UCINET, the following visualization sketches were developed as shown in Figures 12-17.

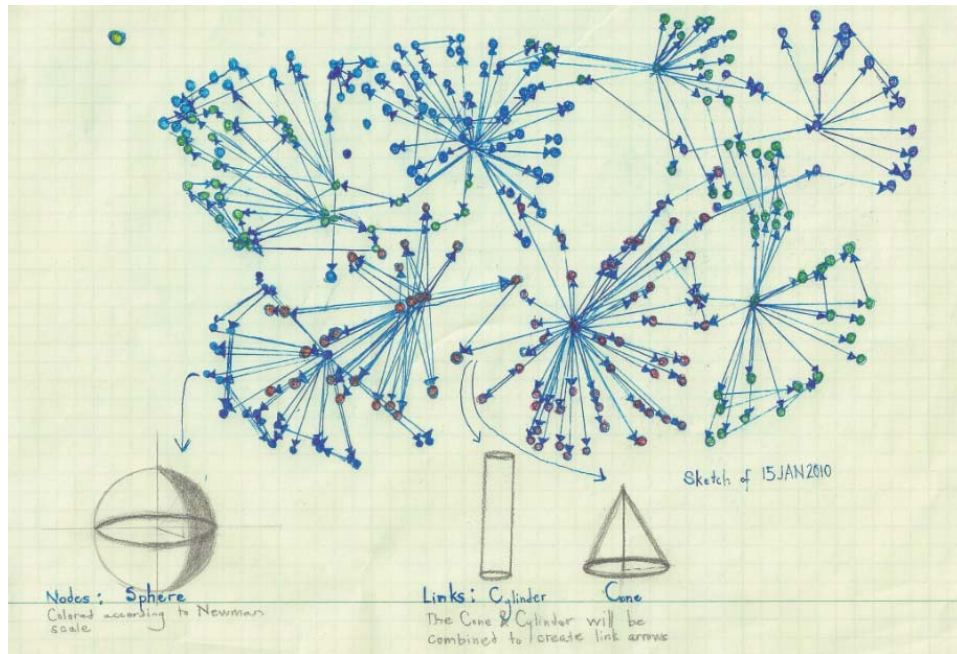


Figure 12. Front sketch of 15 January 2011 with desired geometric shapes for links and nodes

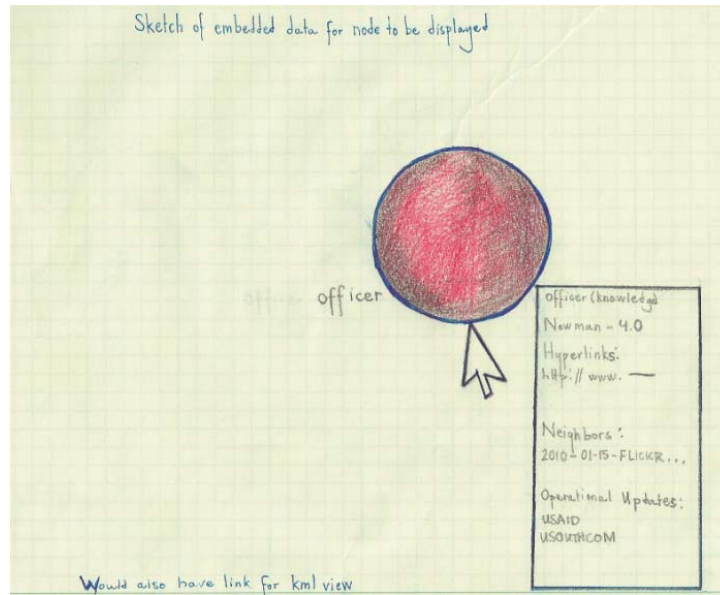


Figure 13. Envisioned idea of embedded data

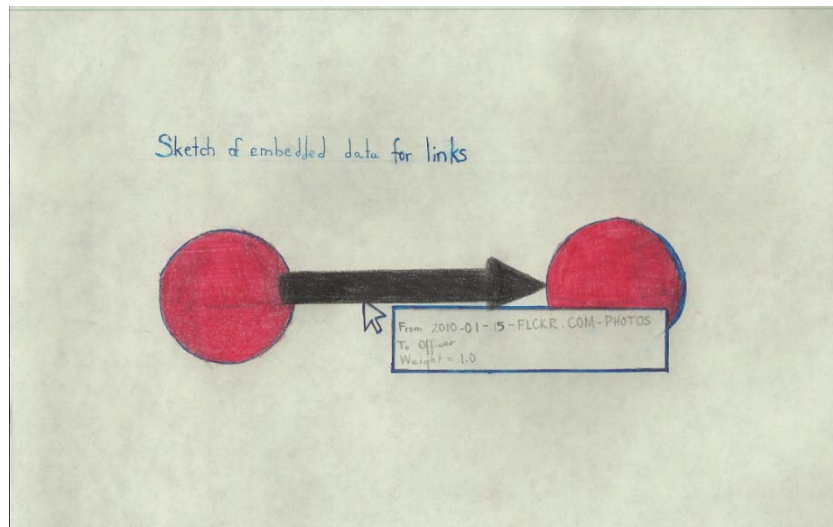


Figure 14. Desired embedded data for link

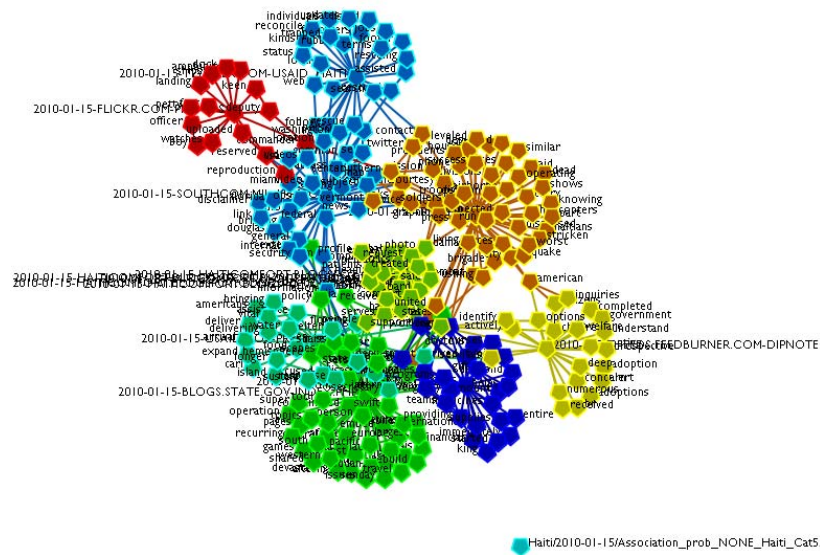


Figure 15. 15 January 2010 Lexical Link Network from ORA

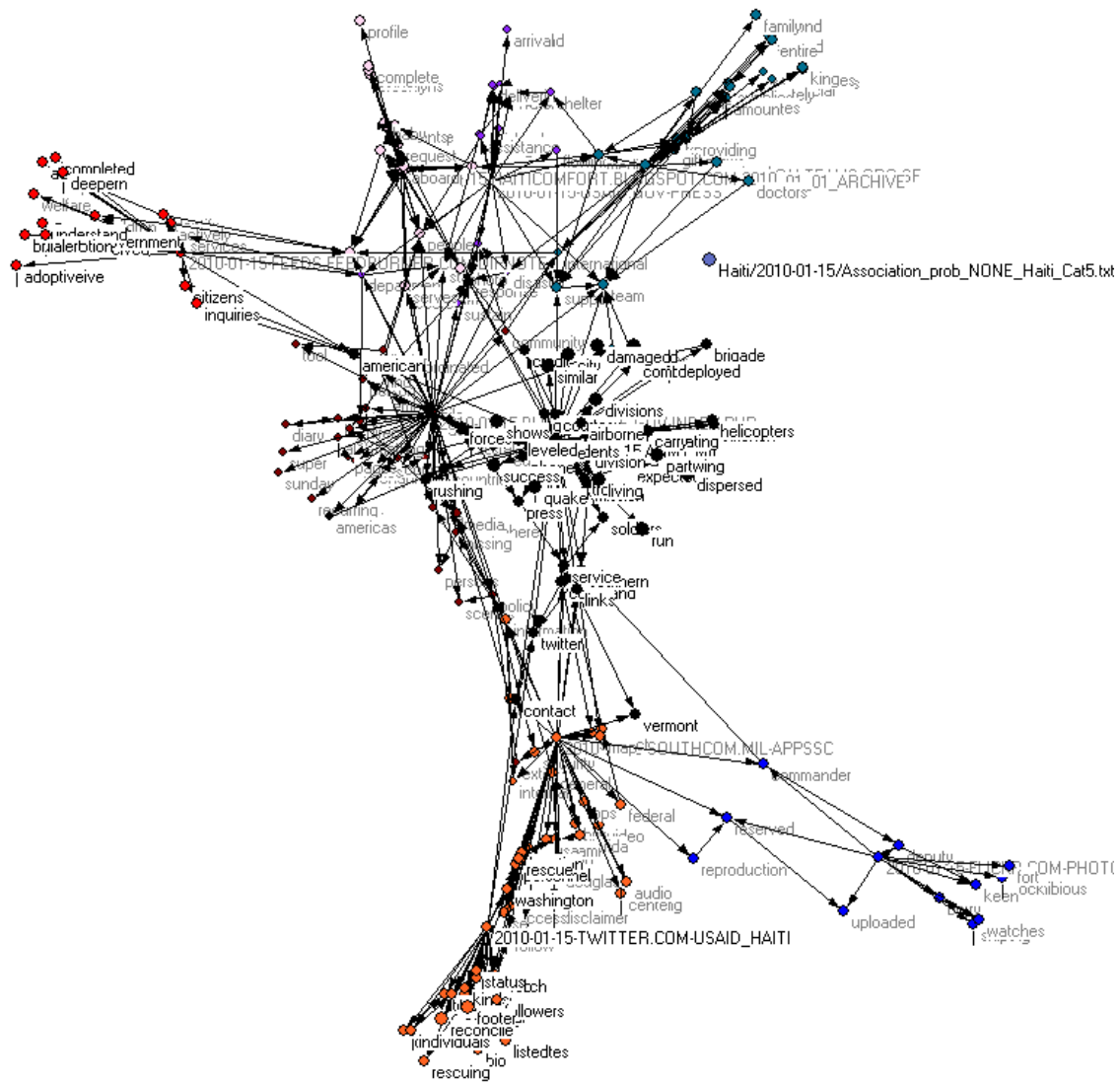


Figure 16. 15 January 2010 Lexical Link Network with Fruchterman Reingold 3D Energy from Pajek

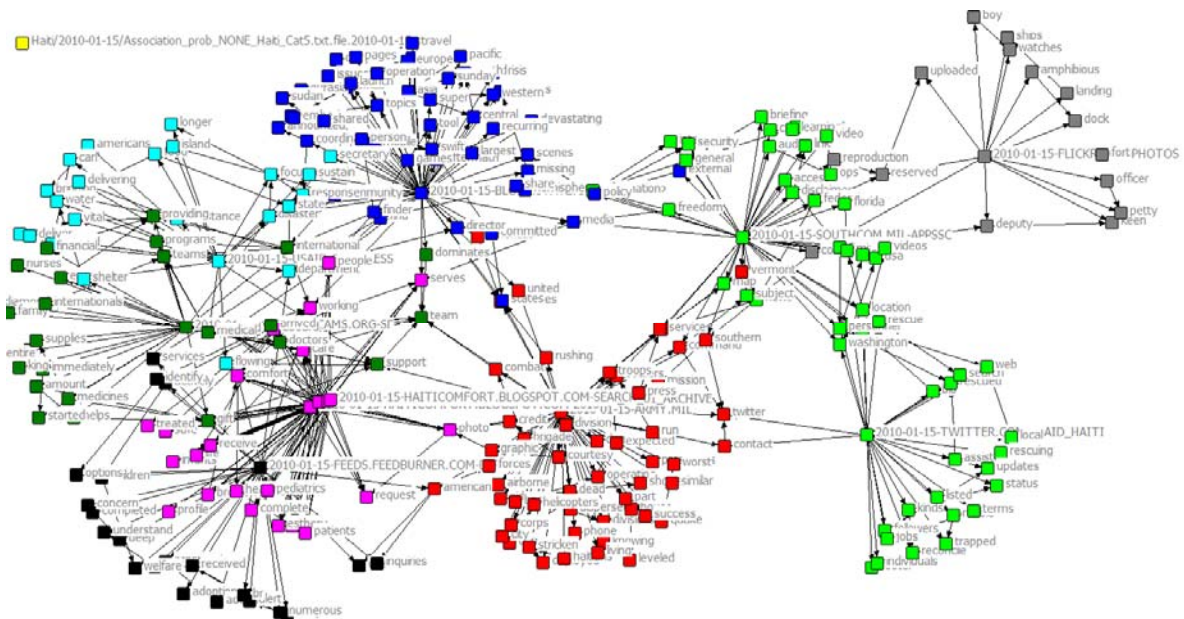


Figure 17. 15 January 2010 Lexical Link Network from UCINET

2. Step 4: Correspondences

a. *Changes in Plans: Pajek Catches up to 3D (Creating a Simple X3D Model to Illustrate Sketches in X3D)*

With these defined characteristics in mind, design work focused on the task of developing examples in X3D format that could potentially fit our requirements. Then Pajek delivered a breakthrough capability: a new export feature that could convert Pajek dataset files (.net, .clu, .vec) directly into X3D format, making it extremely easy to transfer data from Pajek form into X3D form. One challenge still remained—getting the level of detail required in analysis to be worth evaluating as an SNA visualization tool. Through several trial-and-error runs, the following process that could transfer the dataset from CLA all the way to X3D was determined. This required the datasets to be processed through several SNA software

systems, making the data more detailed and explicit. The diagram in Figure 18 describes the overall process of transferring data from CLA to X3D.

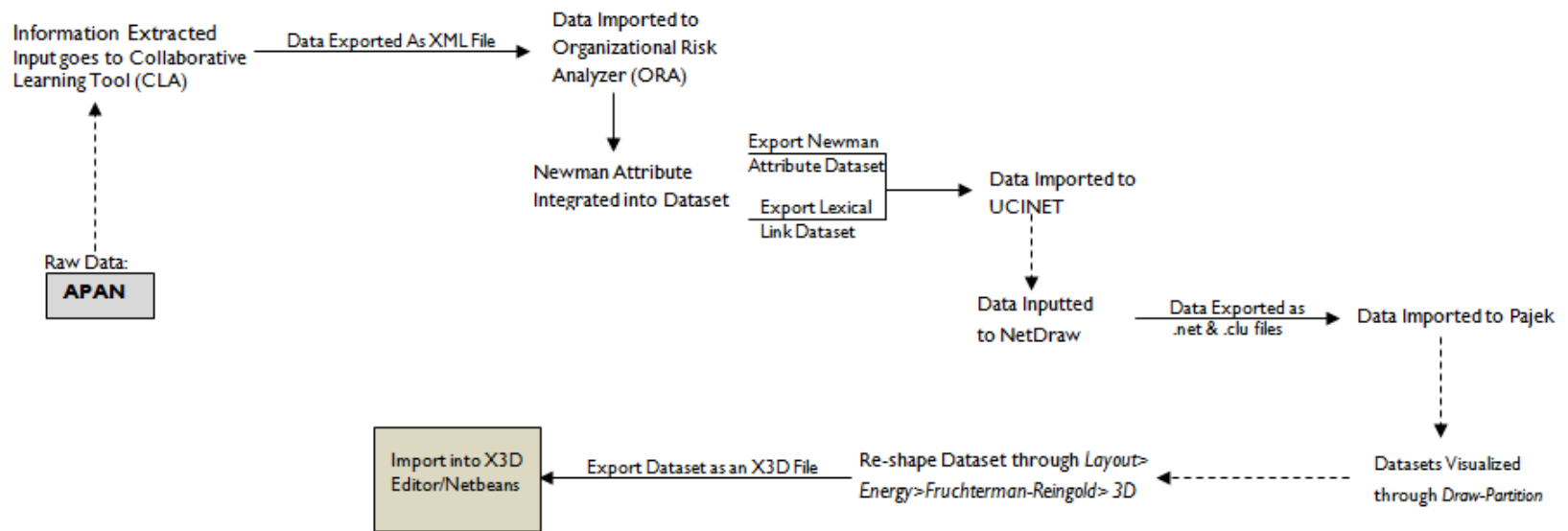


Figure 18. Process of generating data from CLA to X3D

While the graph in Figure 18 is rather self-explanatory, this process requires an ability to navigate through these various programs. To demonstrate this process, the 15 January 2010 dataset was used to illustrate the general process of how the lexical link datasets are converted into X3D visualizations. Due to the level of exportability that these programs offer, it is possible to bypass some of these steps. For instance, a user does not necessarily have to go through UCINET to generate the same visualizations. Based upon preference, a user can export data from ORA into Pajek, and then generate an X3D visualization.

b. 15 January 2010 Basic Metrics to Consider

The DyNetML file, which is an XML based syntax that the Collaborative Learning Agent (CLA) generates, is also a commonly used syntax for representing complex social network graphs or sociograms with the use of MetaMatrix. Metamatrix is another tool required in the translation from lexical link findings into usable social network diagrams (Zhao, Gallup and MacKinnon, Program-Awareness via Lexical Link 2010). When viewed in document form, the XML and DTD version of the 15 January 2010 dataset is over one hundred pages in length. To minimize the volume of data for this chapter, we minimized the number of datasets to three vertices and three arcs. To see the excerpted XML and DTD version of 15 January 2010, see Appendix B.

C. GENERATING X3D VISUALIZATION PROCESS (MODIFYING X3D MODEL TO INCLUDE ACTUAL SAMPLE DATA) THROUGH AN XML REPRESENTATION: CONVERTING CLA TO X3D

1. Step 5 of 10-Step Process: Creating an XML Representation

a. Step 5a. Importing CLA Datasets to ORA

This step begins with the information already converted from the CLA to XML. First we will go to ORA and import the already existing dataset. In this instance, we will be using 15 January 2010's Lexical Link Data extracted from APAN.

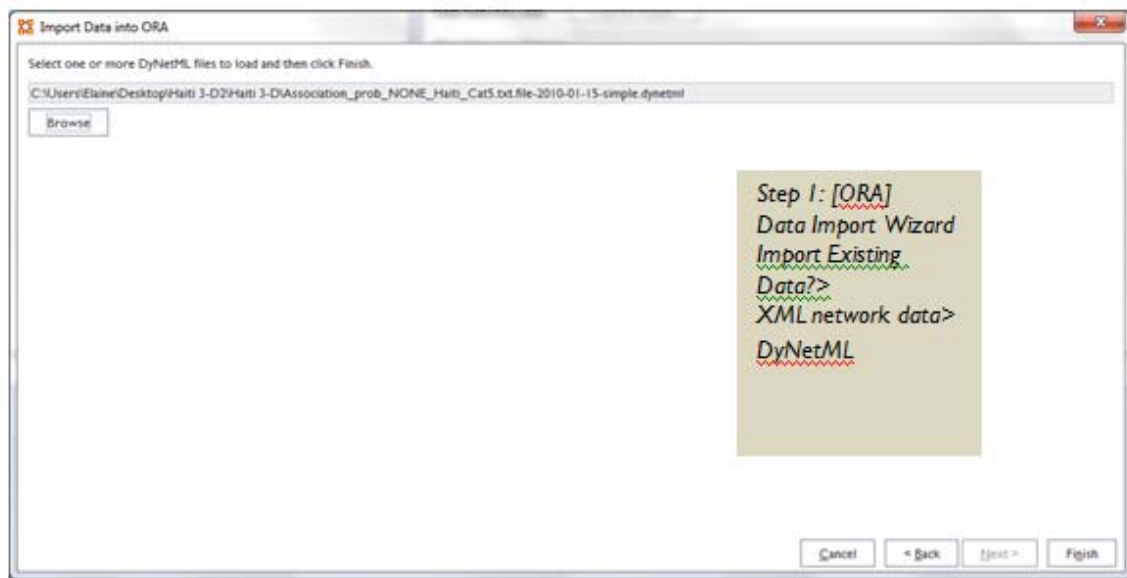


Figure 19. Screen-shot of importing CLA datasets to ORA

b. Step 5b. Visualizing Dataset Through ORA

The main screen now shows 15 January 2010 dataset. From here we generate the visualization. The ORA visualize window appears with the lexical link network mapped and a legend window on the right side of the screen. To make the nodes more visible, the *Legend window Control* >

Show All Nodes, can be selected. This repositions the nodes in a way that are more visible. 270 knowledge nodes should be visible in the network. The following depiction shown in Figure 20 reveals what is seen for the 15 January 2010 Network.

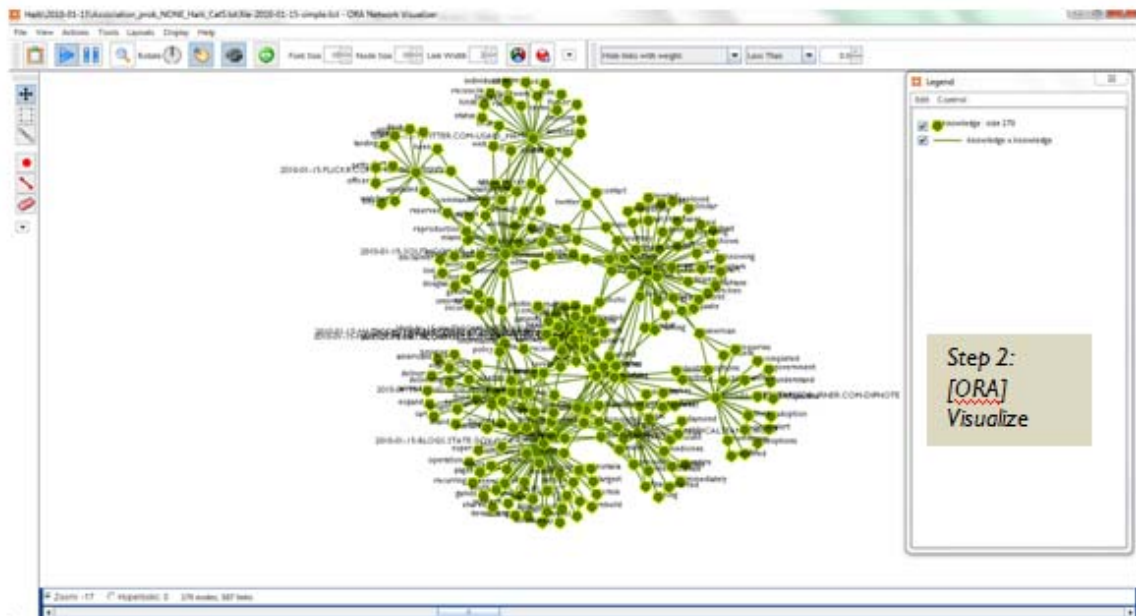


Figure 20. Screen-shot of visualizing dataset through ORA

c. Step 5c. Applying Newman Color Attributes

To define the Newman attributes within the lexical link network, we need to display it through the tool's visualization method. This will not only allow the clusters to be defined through the Newman attributes, but also establish a Newman attribute dataset in the main screen, which is required to generate the color scheme within the lexical link network visualizations. Figure 21 and 22 illustrates these intermediate results.

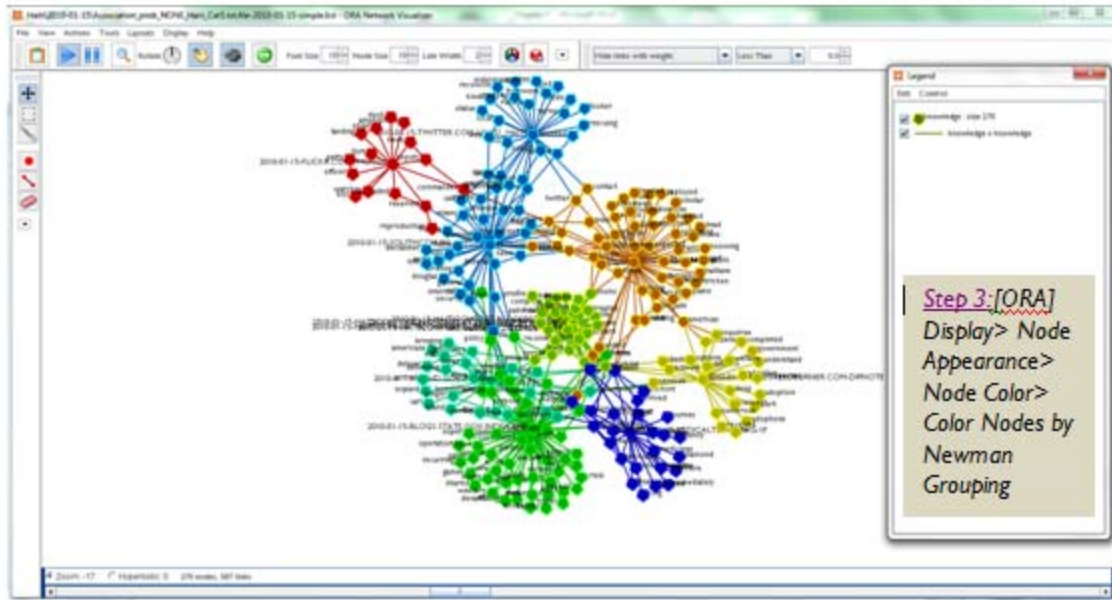


Figure 21. Screen-shot of applying Newman attributes to ORA

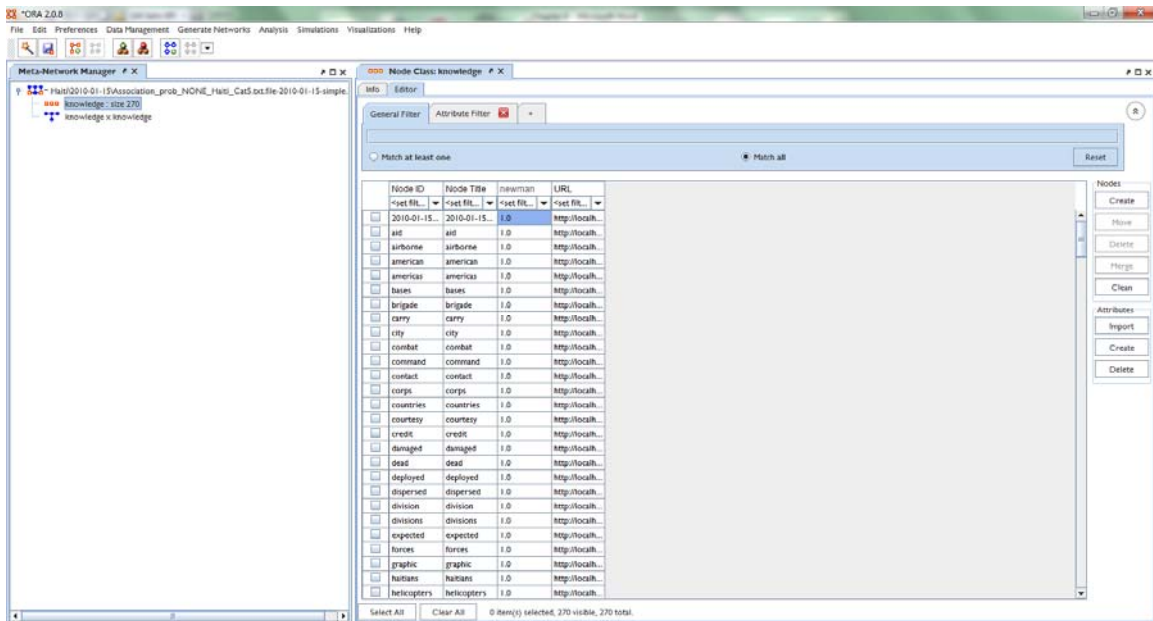


Figure 22. Generated attributes viewed from Meta-Network manager with Newman attributes displayed

d. Step 5d. Exporting ORA Dataset to UCInet

When the Newman attributes have been applied to the lexical link network we then exported the data into UCInet format. Along with saving the dataset, we can also save the Newman attributes by cutting and pasting the datasets into the UCInet attribute file. Figure 23 thorough 25 illustrates this process.

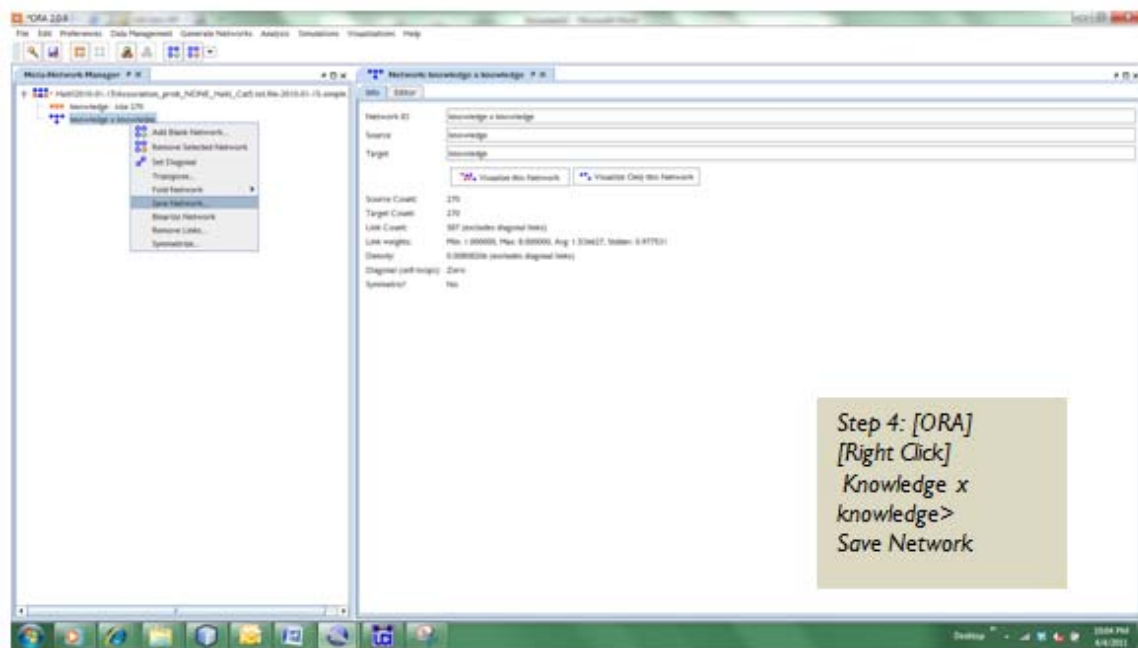


Figure 23. Screenshot of saving Lexical Link Network with Applied Newman attributes

After the attributes were provided to the spreadsheet editor, we saved the file as 2010-01-15Attributes.##h.

e. Step 5e. Visualizing Dataset Through NetDraw

The next step is to export the data to the UCINet Visualization tool, NetDraw. NetDraw is accessed by pressing the  [NETDraw] button on the UCINet toolbar. To make sure that the attributes are properly aligned with the network itself, we verified that the number of attribute columns are equal to the lexical link network columns (accomplished by opening each dataset and looking at the sidebar under "Dimensions"). We load the lexical link dataset first. By opening this dataset, we have a basic display of the data and the designated nodes and links within the 15 January 2010's network. Figure 26 and 27 illustrates this step.

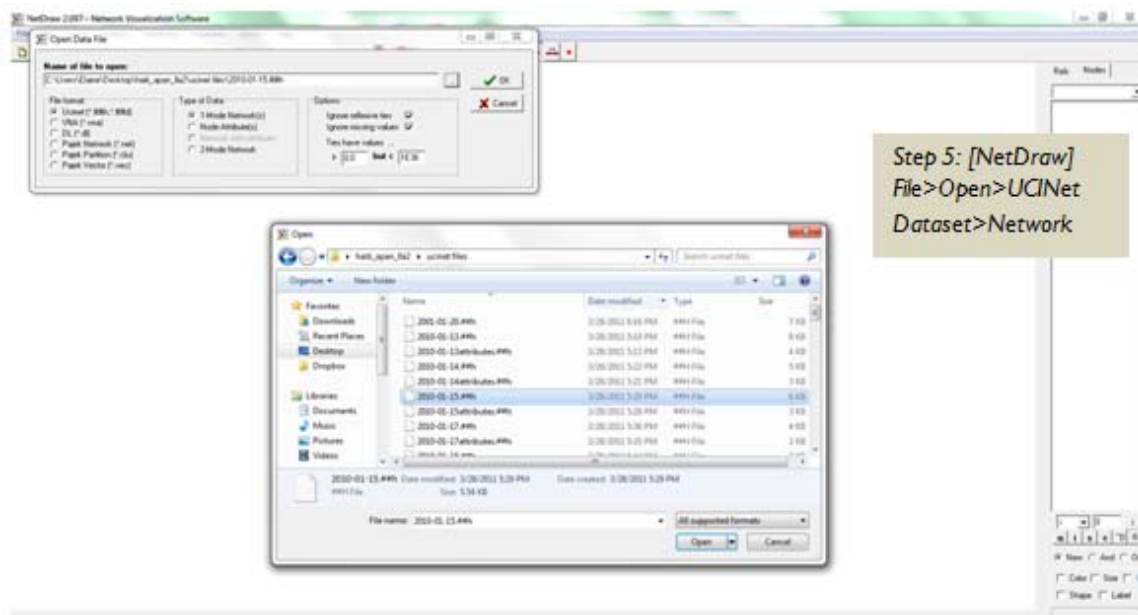


Figure 26. Display of Opening file in NetDraw, selecting 2010-15-01.##h and pressing "OK"

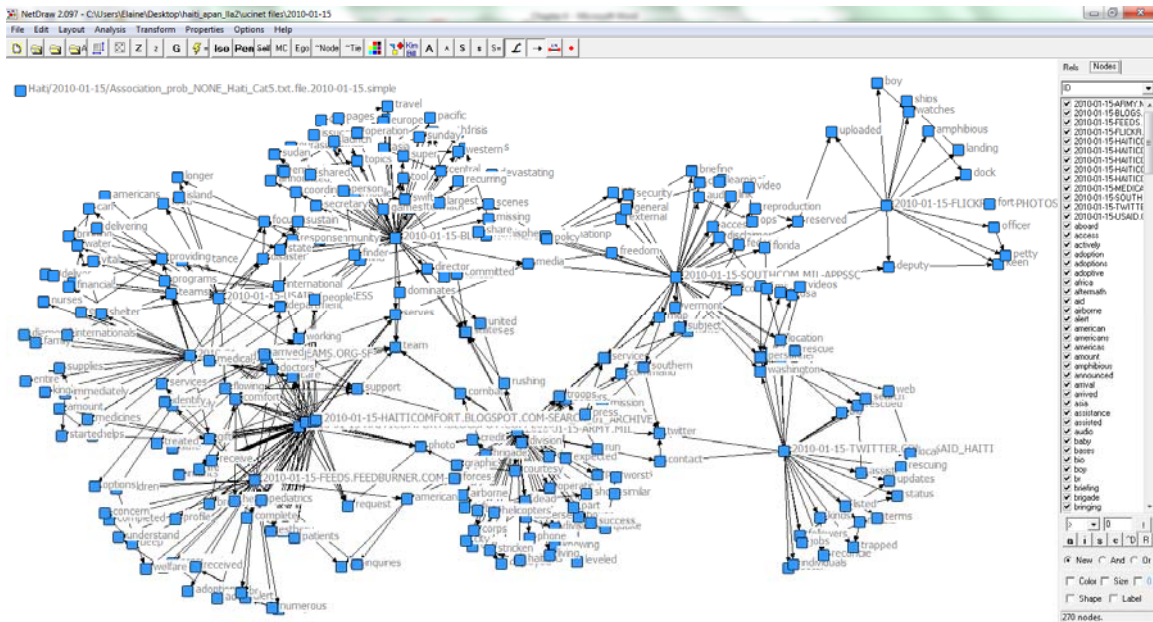


Figure 27. NetDraw from UCInet displaying 15 January 2010 dataset

As seen above, NetDraw not only displays the network, but also lists the nodes on the right side of the window, indicating what nodes are present in the lexical link network. The links, connecting these nodes, are also displayed as arrows.

f. Step 5f. Applying Newman Attributes to NetDraw Dataset

Here, we opened the attribute dataset and applied to the lexical link dataset. This step not only requires opening the attribute dataset, but also assigned colors to each of the various dataset attributes (ORA assigns a color set automatically, in NetDraw we do this manually). We selected 2010-01-15Attributes.##h and press "OK" to apply the attributes to the lexical link network, as shown in Figure 28.

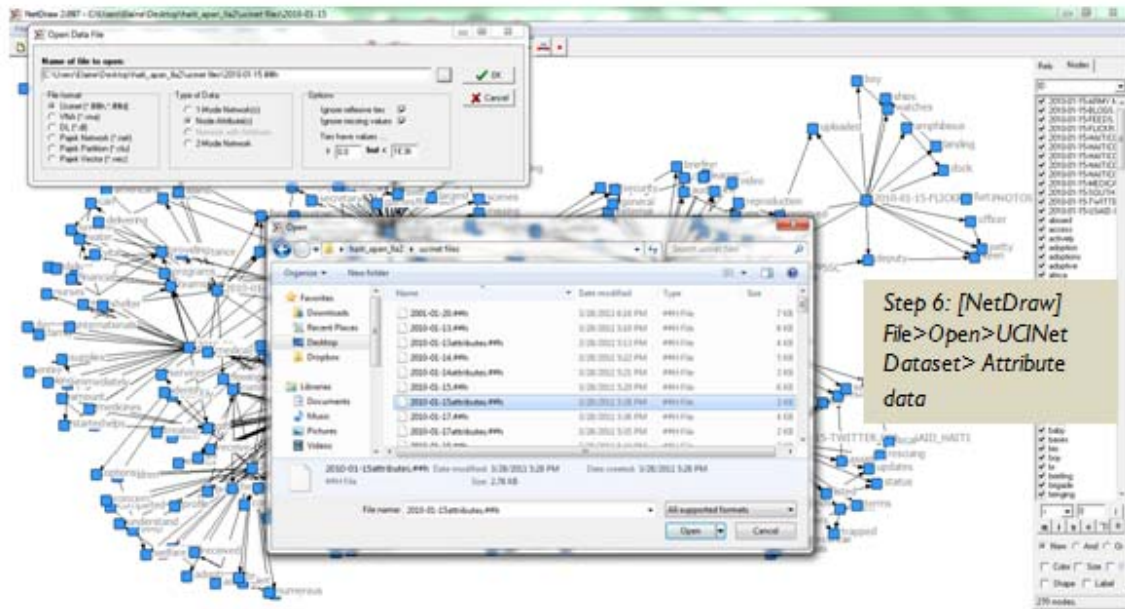


Figure 28. Screen-shot of applying Newman attributes to NetDraw

When the attribute file has been loaded, there is initially no sign that the attributes have been applied (at least visually). To make the attributes visually apparent, we assigned a specific color to each Newman value. By selecting **Color > Attribute-based** from the Properties selection, a “Color Nodes by Attribute” window will appear. By scrolling down the list of Select Attributes, we selected 2010-01-15Attributes (typically following the “ID” option). Figure 29 and 30 illustrates these steps.

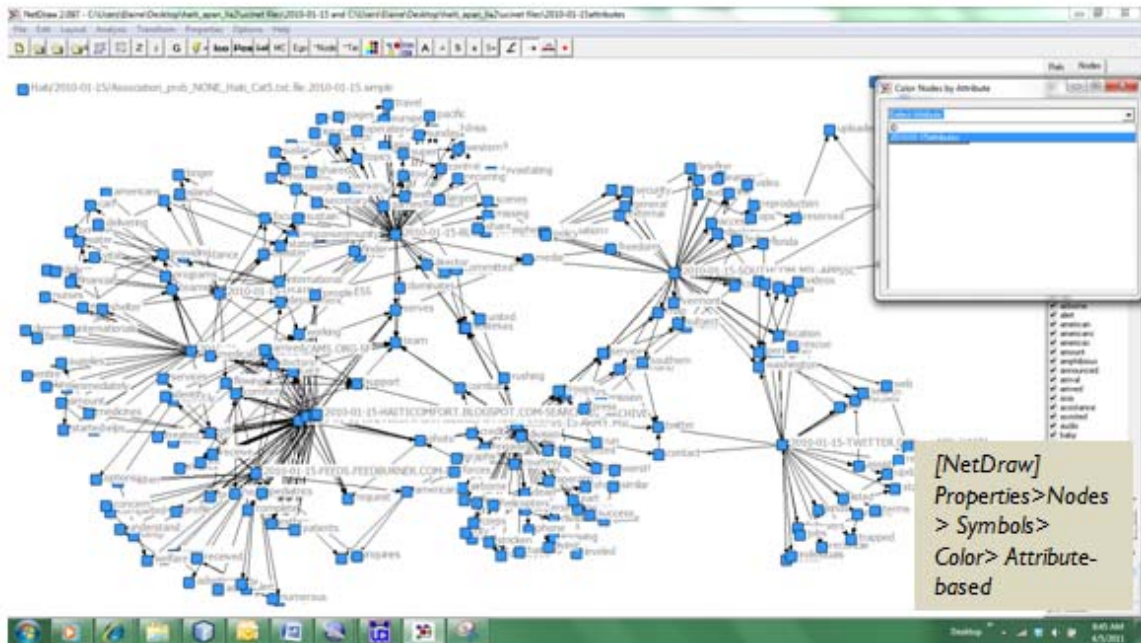


Figure 29. Screenshot of selecting attribute to apply to 15JAN2010 Network

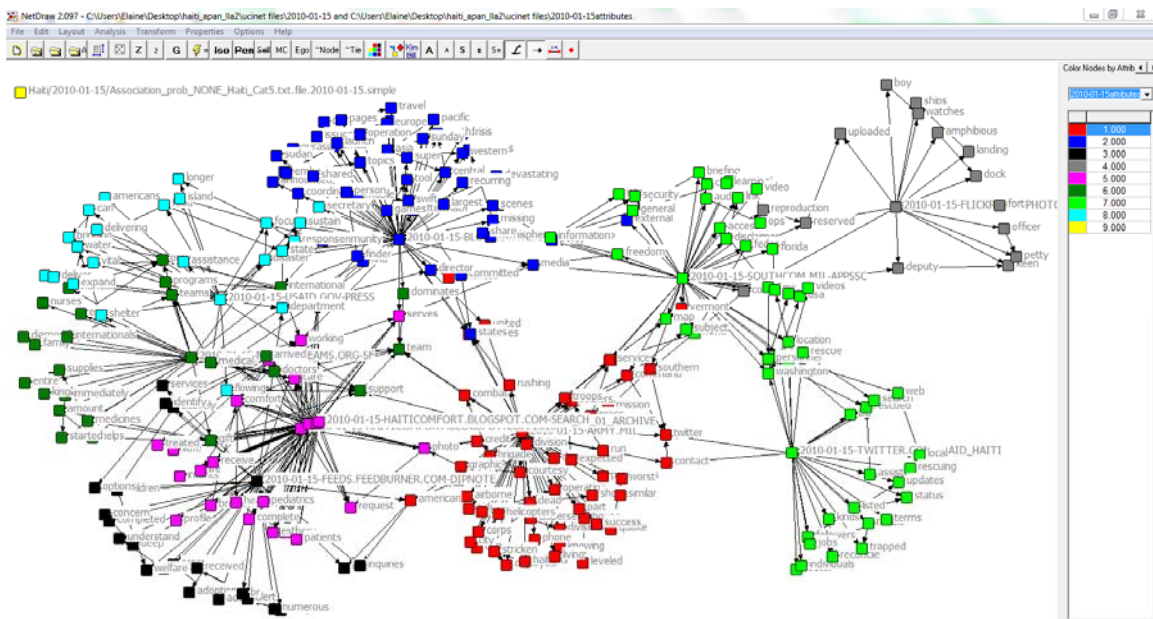
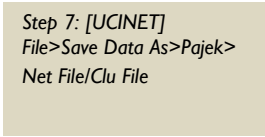


Figure 30. Once the 2010-01-15 attributes have been selected, we observed the following visualization

There is also an accompanying legend that is displayed explaining what each color represents for each Newman value. After comparing this visualization with the given ORA visualization, we noted that this representation of Newman clusters was accurate.

g. Step 5g. Exporting NetDraw Dataset to Pajek

The next step is to export this data in Pajek format. To have a file that is representative of the attribute datasets, there must be two files saved. The first one is the dataset as a network file, and the second is a partition file. This step allows allow the dataset information to be imposed on the lexical link network and displayed in the Pajek drawer. Figure 31 illustrates the export actions.



Step 7: [UCINET]
File>Save Data As>Pajek>
Net File/Clu File

Figure 31. Step 7 actions

h. Step 5h. Importing Datasets Into Pajek

We then launch Pajek and import both network and partition files. This can be done by either following the instructions on the left column or by pressing the  [Open Button] under both the “Networks” and “Partitions” categories. Figure 32 illustrates this process.

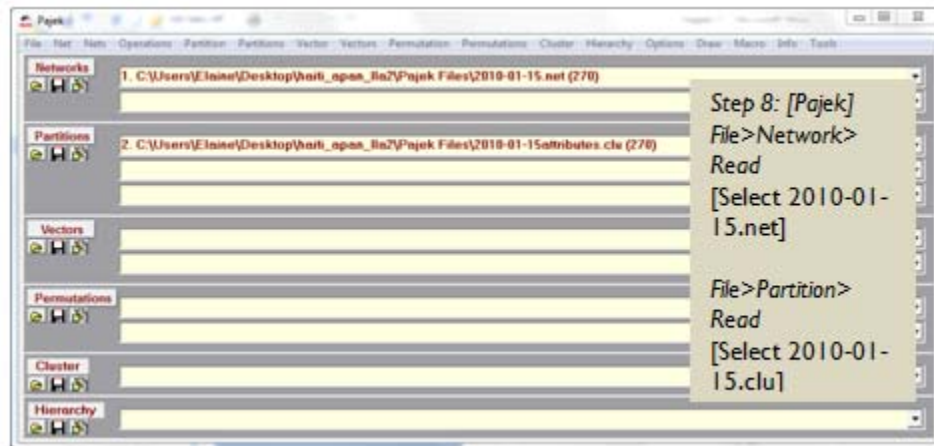


Figure 32. Screenshot of 15JAN2010 Network uploaded to Pajek and Newman attributes uploaded to *Partition* reader

As demonstrated in the figures above, both files have the matching quantity of nodes listed in parentheses. These numbers should be the same when they are imported. If a mismatched count occurs, an error message will appear when attempting to draw the data. In this case, the January 15 2010 datasets each have 270 nodes within the network.

i. Step 5i. Visualizing Datasets Through Pajek

Once the Network and Partition files have been uploaded, the lexical link network with attributes can be drawn. By drawing the Partitions, we were able to see not just the lexical link network but the attributes as well. If the network is drawn alone, then all that is displayed is the network without the Newman clusters being distinguished. Figure 33 illustrates the first option.



Figure 33. Display of initial Pajek visualization of 15JAN2010 Lexical Link Network

At this point, it became desirable to change the layout of the network to the Fruchterman-Reingold Energy Layout (in 3D) to better display the data in a way which the Newman cluster can be seen in a more distinguishable manner. Figure 34 illustrates this result.

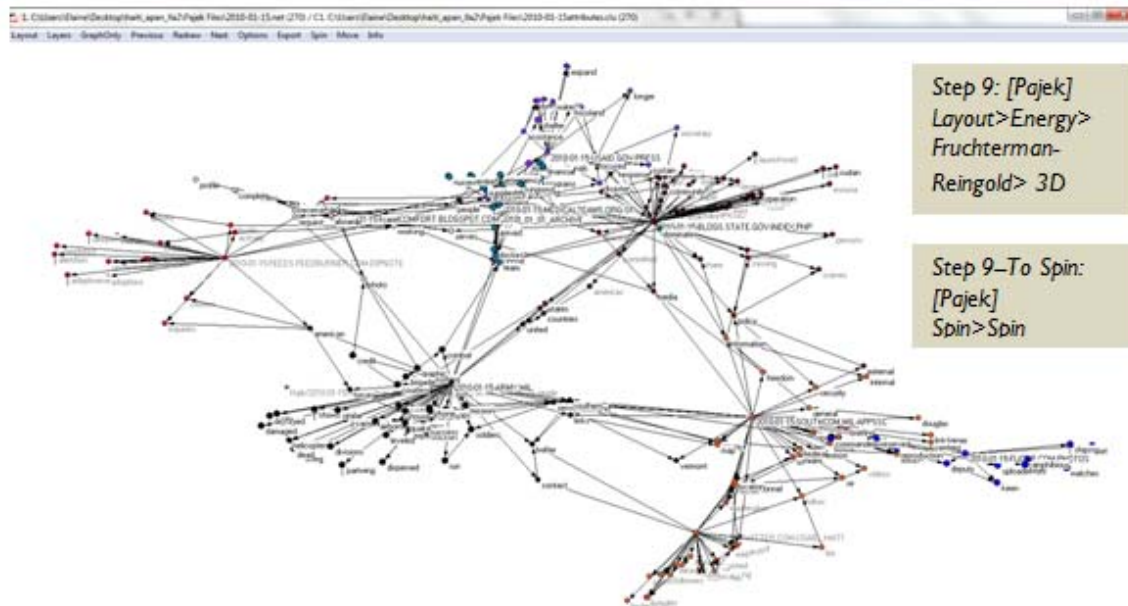


Figure 34. 15JAN2010 Lexical Link Network laid out in the 3D Fruchterman-Reingold format

Repeated comparison of the presented clusters with the Newman clusters that had been generated through ORA and UCInet determined that the visualizations were consistent with each other.

With this new 3D display, we can now rotate the data in a 3D environment and spin the data in multiple directions. This tool display rendering is also exportable to the X3D format as we exported the Pajek visualization to X3D. To export the data from the Pajek visualization to an X3D file, we used the Pajek drawing tool and the export options available through the toolbar. Figure 35 illustrates the result.

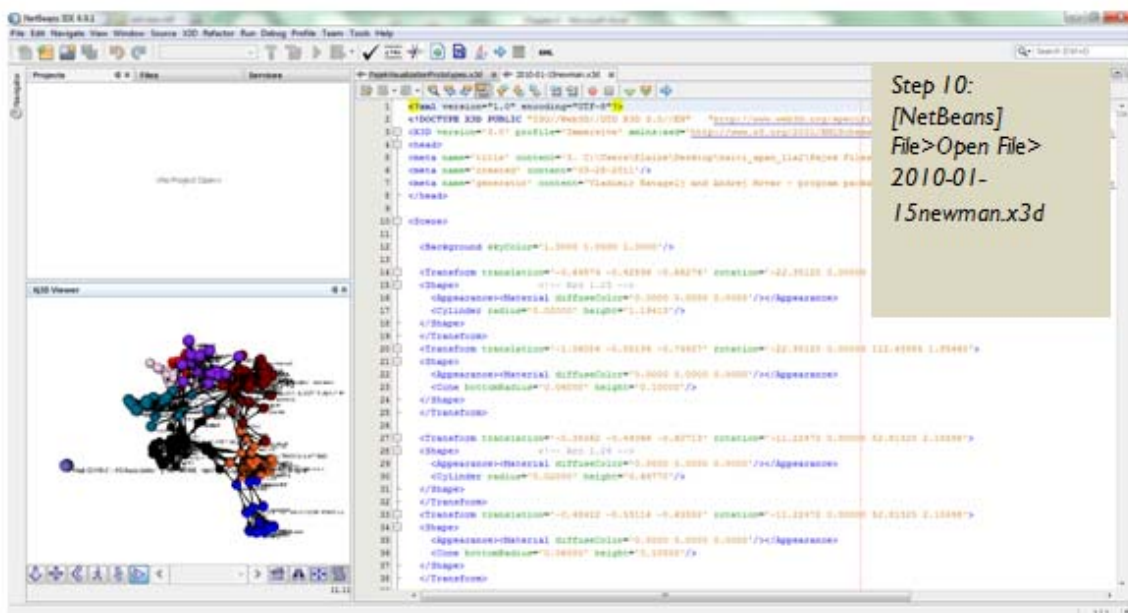


Figure 36. Screen-shot of X3D data exported from Pajek into NetBeans

As seen in Figure 36, not only is the visualization display active and movable cursor, but the X3D source is also presented, showing a detailed translation of the network information.

The next major task is to display the current X3D prototype used for improving the Pajek exports to X3D. See Appendix C for Pajek generated X3D code.

D. BUILDING A PROTOTYPE

1. Step 6: Brute-Force Conversion to X3D and Comparison of Pajek X3D to "Brainstormed X3D"

The ability to interact with 3D graphics is intended to enhance the understanding of the model generated (Brutzman & Daly, 2007). By generating an archival version of the 3D lexical link network using the X3D language, the model should be capable to expanding the understanding of

the model with some interaction and the ability to examine information with greater ease. This is not the same as the initial visualization evaluations performed by an analyst. Rather it is intended for longer review by end users without access to the sophisticated tool. When looking at the model that is generated through the previously described process, the end-result is that the user is now capable of moving the 3D lexical link network, can visually explore the Newman attributes, and is capable of moving the 3D model to further understand the links and connections that exist within the network. Yet, there are certain valuable characteristics that the initial X3D model does not provide. "Automatic viewpoints" is an example of a feature not included in the Pajek-produced X3D files. This is a useful feature in many 3D user interfaces that provides a consistent method for exploring a 3D scene. Viewpoints can be extremely useful and are typically used to give a "guided tours through a scene" (Brutzman & Daly, 2007, p. 102). While each lexical link network is different, such code can be added to the X3D prototype and leveraged by the user who wishes to give a presentation or better define orientation of specific fields. In addition, the code that is initially generated does not have the parent name and comment placed together in a given group. If the end-user (or X3D author) wanted to alter the Pajek-produced X3D coding to it can become extremely confusing and complicated to read, modify, and interpret the code. Figure 37 Illustrates how well-designed output X3d produced by Pajek can nevertheless be resistant to further modification by an X3D-capable analyst.

```

<Background skyColor='1.0000 1.0000 1.0000' />

<Transform translation='-0.64874 -0.42896 -0.66276' rotation='-22.35120 0.00000 112.43585 1.85460'>
<Shape>
    <!-- Arc 1.23 -->
    <Appearance><Material diffuseColor='0.0000 0.0000 0.0000' /></Appearance>
    <Cylinder radius='0.02000' height='1.19413' />
</Shape>
</Transform>
<Transform translation='-1.06026 -0.55134 -0.74457' rotation='-22.35120 0.00000 112.43585 1.85460'>
<Shape>
    <Appearance><Material diffuseColor='0.0000 0.0000 0.0000' /></Appearance>
    <Cone bottomRadius='0.06000' height='0.10000' />
</Shape>
</Transform>

```

Figure 37. Example of the Parent Name /Comment not placed together in a single group

One of the advantages of Pajek, as previously described in Chapter III, is its ability to read and properly analyze large quantities of network nodes. When the data is exported from Pajek to X3D, the code also reflects this immense level of data that Pajek (see Appendix C for initial code). When copied onto a document format, an output listing takes up to 108 pages! The reason for such a prolific quantity of data is that each node and link is defined individually. When looking at the limitations that certain portable computers and operating systems possess, adding on additional attributes (such as variation in the size of nodes to reflect additional network attributes) can cause an X3D visualizer to overload and potentially crash. Figure 38 shows such an example.

to be double quoted instead of single quoted (No <FontStyle family='Arial Unicode MS'>). When validating the code, a continual error is generated regarding the rotation axis values. These are typically standardized to avoid a schema validation warning. Yet, with the repeated errors on multiple datasets, this is a continually problematic issue that eventually needs to be repaired within the current pajek autogeneration code. A bug report suggesting these improvements has been submitted.

One of the most useful features that ORA provides through its visualizer, is the ability to observe *embedded* data for each node and link as the mouse is scrolled over a given node. Additionally, the ability to manipulate the network image itself so that certain nodes can be better displayed is also a desirable attribute in a network model. In the X3D output, such a capability has yet to be developed. Once the code has been revised and organized in a particular way that makes it easier to examine and input data, such desired attributes can be more easily added to the lexical link network X3D code, making the lexical link visualizations more easily dynamic. With the addition of embedded data, it is also possible to extend hyperlinks of the data accumulated from CLA to the particular resources. Together, these can, make the lexical link network methodology a truly dynamic situational awareness tool.

E. DEVELOPMENT OF AN X3D VISUALIZATION TOOL: DEFINING AND CREATING PROTOTYPE EXAMPLES

Now that the desired goals have been defined and compared to the current products, there can be a development of an improved X3D prototype. We first start

formatting canonicalization of code, to see the X3D code in a more organized fashion, then begins the process of redefining both the fields of vectors and arcs (nodes and links, respectively). We did this by defining a Prototype Interface, namely X3D fields that can be broken down into several detailed elements. We defined the access types (input-output for the links since they can be defined in the visualization tools as being bi-directional), the application information (which defined the arc and its position), the name (defined title of the link if given a name), the type (defined this as a String value), and the value of the Arc/Link (a designated position, with a name) with defined parameters which could be used to generate multiple and diverse sets of links and nodes. We also provided a *description* and *comments* section for future developers to describe where the initialization node resides. These are shown in Figure 39.

```

<ProtoInterface>
  <field accessType='inputOutput'
    appinfo='name to identify this Arc' name='name' type='SFString' value='TODO provide InitialValue'>
  <field accessType='inputOutput'
    appinfo='popup text describing this Arc' name='description' type='SFString' value='TODO customize this Arc description'>
  <field accessType='initializeOnly'
    appinfo='length of Arc between Vertex locations' name='cylinderHeight' type='SFFloat' value='1'>
  <field accessType='inputOutput'
    appinfo='link to some other resource' name='url' type='MFString'>
  <field accessType='inputOutput'
    appinfo='location of Arc' name='cylinderTranslation' type='SFVec3f' value='0 0 0'>
  <field accessType='inputOutput'
    appinfo='see TODO items in ArcScript' name='coneTranslation' type='SFVec3f' value='0 0 0'>
  <field accessType='inputOutput'
    appinfo='orientation of Arc' name='rotation' type='SFRotation' value='0 1 0 0'>
  <field accessType='inputOutput'
    appinfo='rendering choices: BallAndStick, Ball, Stick' name='displayMode' type='SFString' value='BallAndStick'>
  <field accessType='inputOutput'
    appinfo='diffuseColor of Arc' name='color' type='SFColor' value='0.0000 0.0000 0.0000'>
  <field accessType='inputOutput'
    appinfo='transparency of Arc' name='transparency' type='SFFloat' value='0.0'>
  <field accessType='inputOutput'
    appinfo='offset distance for Cone arrowhead; TODO this needs to match values in the Vertex prototype,
    which is initialized separately' name='ballRadius' type='SFFloat' value='1'>
  <field accessType='inputOutput'
    appinfo='debug trace to Browser output console' name='traceEnabled' type='SFBool' value='false'>
</ProtoInterface>

```

Figure 39. Development of prototype interface field definitions

In addition to providing a defined method of links that is flexible, this method of defining the elements through a ProtoInterface section helps to concisely map to the defined requirements of the lexical link network, namely, the *Arc* and *Cone* settings.

Once the Prototype Interface parameters are defined, we worked on making the Arc and Cone settings for the visualization more flexible. In some cases, the use of arrow for links is not necessary, and being able to adjust this as a setting in the X3D visualization could be used in this way. Previously the code generated through Pajek was more of a “brute force” method of conversion which would lead to each node and each link being defined separately. These links, composed of both a cone and cylinder were also separately defined, leading to a tediously redundant set of code, which repeated continuously throughout the output scene. Making a customizable prototype for the Arc, through defining the Cone and Cylinder were important, to minimize the amount of redundant code. In addition, defining the network Nodes (which are rendered as Spheres in this case study) is also intended to reduce the level of excessive code for the X3D visualization.

After we finished defining the various portions of the Proto Interface, we then considered the Proto *Body* of the code. We noted a repeated error in the coding was identified that incorrectly defined the rotation values of the network model. Figure 40 illustrates this problem.

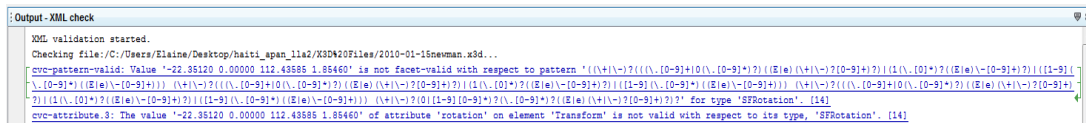


Figure 40. Excerpt from the XML check for errors. Continual errors are demonstrated indicating that the degrees of rotation for the visualization are incorrectly defined

To correct this error, we redefined rotation in radians, through by utilizing the X3D-Edit tool in Netbeans Transform Edit. Instead of recalculating the inputted degrees into radians manually, pressing “normalize rotation and *scaleOrientation* values” automatically converts these values into radian scales. Figure 41 illustrates this process.

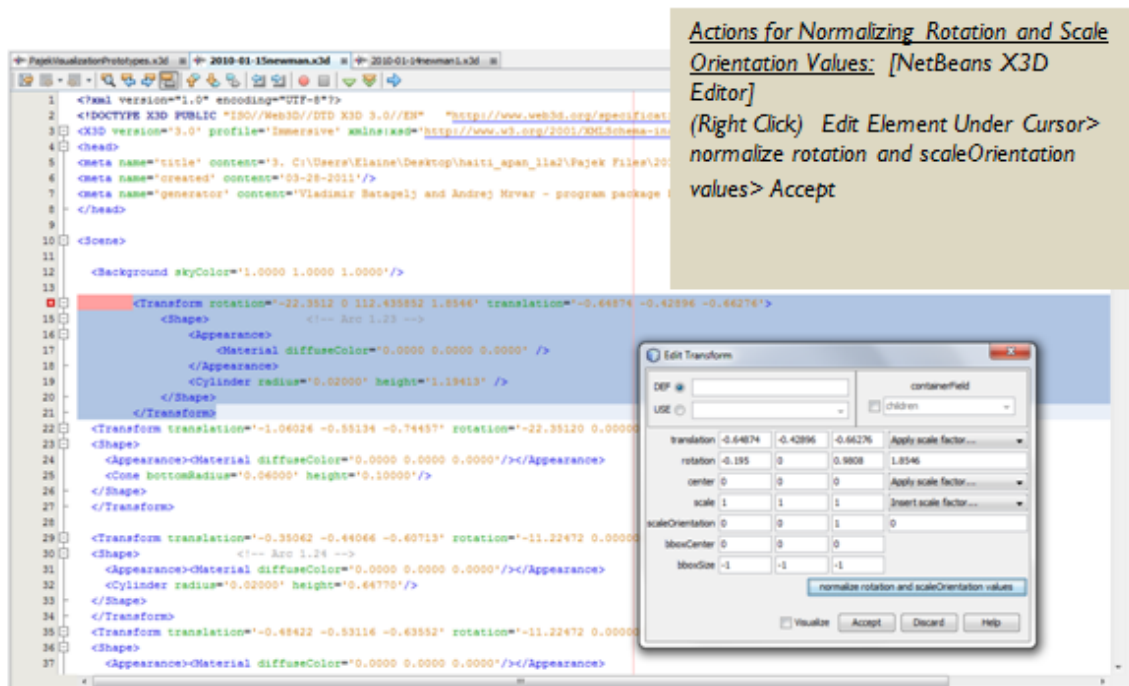


Figure 41. Screen-shot of normalizing rotation and scaleOrientation values

Through the use of subversion tools for the version-control database, the subversion changes archival X3D were saved under revision 2355. Figure 42 shows the difference between the previously generated version and the newly developed version of the X3D file. The Sventon subversion an online repository used to archive X3D files, and track and commit updates made to X3D files. This can be useful for programmers wishing to reference particular X3D examples online or extend work on previous projects for future projects.

```

30|30| <ProtoBody>
31|31| <!-- First node determines node type of this prototype -->
32|32| <Anchor>
33|33| <IS>
34|34| <connect nodeField=8apos:description8apos: protoField=8apos:description8apos:/>
35|35| </IS>
36|36| <!-- TODO add children nodes here -->
37|37| <Group 001=8apos:PrototypeScene0018apos:/>
38|38| <Transform rotation=8apos:-45.77820 0 94.31630 1.605638apos: translation=8apos:1.16600 0.60861 -2.322298apos:/>
39|39| <Shape>
40|40| <IS>
41|41| <connect nodeField=8apos:appearance8apos: protoField=8apos:appearance8apos:/>
42|42| </IS>
43|43| <!-- Arc 1.6 -->
44|44| <Cylinder radius=8apos:0.028apos:/>
45|45| <IS>
46|46| <connect nodeField=8apos:height8apos: protoField=8apos:cylinderHeight8apos:/>
47|47| </IS>
48|48| </Shape>
49|49| </Transform>
50|50| <Transform rotation=8apos:-45.77820 0.00 94.31630 1.605638apos: translation=8apos:1.49373 0.39592 -2.391368apos:/>
51|51| <Transform rotation=8apos:-0.4367 0 0.8996 1.605638apos: translation=8apos:-1.49373 0.39592 -2.391368apos:/>
52|52| <Shape>
53|53| <IS>
54|54| <connect nodeField=8apos:appearance8apos: protoField=8apos:appearance8apos:/>
55|55| </IS>
56|56| <Cone bottomRadius=8apos:0.068apos: height=8apos:0.18apos:/>
57|57| </Shape>
58|58| </Transform>
59|59| </Group>
60|60| </Anchor>
61|61| </ProtoBody>

```

Figure 42. Sventon Subversion Database changes of x3d source scenes under version control. The red line indicates deletion of code, and the green line indicates the addition of code

In addition to the defining the ProtoInstance's elements, an embedded script were inserted. When prepared within an X3D prototype, such a script allows for one or more new events to be executed and the field definitions to be updated within the defined auto generation pattern. When looking at the addition and subtraction of lexical networks, this script can help allow multiple incoming events (nodes and links), lowering the likelihood that the program becomes overloaded when it receives a large amount

of data. For each event that is generated within the network scene, this event is routed to the given Script method which matches the input of each event name as shown in Figure 43.

```

61 + <Script DEF=&apos;ArcScript&apos; directOutput=&apos;true&apos;>
62 + <field accessType=&apos;inputOutput&apos; appinfo=&apos;default value 1&apos; name=&apos;cylinderHeight&apos; type=&apos;SFFloat&apos;/>
63 + <field accessType=&apos;inputOutput&apos; appinfo=&apos;default value 0 0 0&apos; name=&apos;cylinderTranslation&apos; type=&apos;SFVec3f&apos;/>
64 + <field accessType=&apos;outputOnly&apos; appinfo=&apos;respond to changes in Cylinder&apos; name=&apos;coneTranslation&apos; type=&apos;SFVec3f&apos;/>
65 + <IS>
66 + <connect nodeField=&apos;cylinderHeight&apos; protoField=&apos;cylinderHeight&apos;/>
67 + <connect nodeField=&apos;cylinderTranslation&apos; protoField=&apos;cylinderTranslation&apos;/>
68 + </IS>
69 + <![CDATA[
70 + ecmaScript:
71 + function initialize ()
72 + {
73 + // TODO compute Cone translation (and perhaps cone size) based on Cylinder size
74 + // then send result to the Cone parent transform
75 +
76 + // conceivably this extended Cylinder length is a feature, not a bug...
77 + // if the Cylinder goes to the center of the ball, then you can turn off both
78 + // balls and Cone arrowheads to yield a simple stick-only model
79 + // so we need to consider this as an animation/visualization feature as well
80 + }
81 +
82 + function set_cylinderHeight (eventValue) // input event received for inputOutput field
83 + {
84 + cylinderHeight = eventValue;
85 + // TODO recompute, refresh Cone translation
86 + }
87 +
88 + function set_cylinderTranslation (eventValue) // input event received for inputOutput field
89 + {
90 + cylinderTranslation = eventValue;
91 + // TODO recompute, refresh Cone translation
92 + }
93 +
94 + ]>
95 + </Script>
96 + <!-- Add any ROUTEs here that connect Script to/from prior nodes within ProtoBody -->

```

Figure 43. Embedded script connected to prototype interface

In this case, the embedded Script includes the tracePrint design pattern to expose event changes during run time as a debugging tool. Next we added further fields, defining each sphere's radius and display mode. Close examination of the length of the links, the "stick" portion of the link was longer than the actual distance between two links when superimposed in X3D. From looking at the various options available for visualization from Pajek and other social-network analysis programs, we observe that the option to exclude nodes can be selected, thus only depicting links. From this, we left the defined height of the Cylinder to one that equals the distance,

plus the radius of a node which in this prototype remains at a consistent fixed length. Additionally, the node needs to also match the values of the Vertex prototype, which is designed separately (and in the same fashion).

Next, we the Arc definition was refined to use two animation-capable material properties rather than defining it in the Appearance attribute clause. This allows for modifying transparency and diffused Color to improve end-user visualization possibilities. The Vertex declaration and the Vertex's Proto Interface were also added. Figures 44 and 45 illustrate these changes.

```

26 - <field accessType=&apos;inputOutput&apos; appinfo=&apos;Reusable appearance for this Arc&apos; name=&apos;appearance&apos; type=&apos;SFNode&apos; />
27 - <!-- initialization node (if any) goes here -->
28 - </field>
29 -
29 + <field accessType=&apos;inputOutput&apos; appinfo=&apos;choices: BallAndStick, Ball, Stick&apos; name=&apos;displayMode&apos; type=&apos;SFString&apos; value=&apos;BallAndStick&apos; />
27 + <field accessType=&apos;inputOutput&apos; appinfo=&apos;diffuseColor of Arc&apos; name=&apos;color&apos; type=&apos;SFCOLOR&apos; value=&apos;0.8 0.8 0.8&apos; />
28 + <field accessType=&apos;inputOutput&apos; appinfo=&apos;transparency of Arc&apos; name=&apos;transparency&apos; type=&apos;SFFloat&apos; value=&apos;0.0&apos; />
30 - <field accessType=&apos;inputOutput&apos; appinfo=&apos;TODO this needs to match values in the Vertex prototype, which is initialized separately&apos; name=&apos;ballRadius&apos; type=&apos;SFFloat&apos; value=&apos;1&apos; />
31 - </ProtoInterface>
32 - <ProtoBody>
33 - <!-- First node determines node type of this prototype -->
34 - <Anchor>
35 - <IS>
36 - <connect nodeField=&apos;description&apos; protoField=&apos;description&apos; />
37 - </IS>
38 - <!-- TODO add children nodes here -->
39 - <Group DEF=&apos;PrototypeRootNode&apos; />
38 + <Group DEF=&apos;ArcPrototypeRootNode&apos; />
40 - <Transform rotation=&apos;-0.4367 0 0.8996 1.60563&apos; translation=&apos;-1.166 0.60861 -2.23229&apos; />
41 - <Shape>
42 - <IS>
43 - <connect nodeField=&apos;appearance&apos; protoField=&apos;appearance&apos; />
44 - </IS>
41 + <Appearance>
42 + <Material>
43 + <IS>
44 + <connect nodeField=&apos;diffuseColor&apos; protoField=&apos;color&apos; />
45 + <connect nodeField=&apos;transparency&apos; protoField=&apos;transparency&apos; />
46 + </IS>
47 + </Material>
48 + </Appearance>

```

Figure 44. Version control changes help expose details during software and model development. Here the <IS> attribute was deleted while <Appearance> was added

```

114 + <ProtoDeclare appinfo=&apos;Vertex is a node, typically connected by Arc segments, displayed using Sphere geometry with modifiable color and transparency&apos; name=&apos;Vertex&apos; />
115 + <ProtoInterface>
116 + <field accessType=&apos;inputOutput&apos; appinfo=&apos;name to document this arc&apos; name=&apos;name&apos; type=&apos;SFString&apos; value=&apos;someName&apos; />
117 + <field accessType=&apos;inputOutput&apos; appinfo=&apos;popup text describing this arc&apos; name=&apos;description&apos; type=&apos;SFString&apos; value=&apos;some description&apos; />
118 + <field accessType=&apos;inputOutput&apos; appinfo=&apos;TODO this needs to match values in the Vertex prototype, which is initialized separately&apos; name=&apos;radius&apos; type=&apos;SFFloat&apos; value=&apos;1&apos; />
119 + <field accessType=&apos;inputOutput&apos; appinfo=&apos;choices: BallAndStick, Ball, Stick&apos; name=&apos;displayMode&apos; type=&apos;SFString&apos; value=&apos;BallAndStick&apos; />
120 + <field accessType=&apos;inputOutput&apos; appinfo=&apos;diffuseColor of Arc&apos; name=&apos;color&apos; type=&apos;SFCOLOR&apos; value=&apos;0.8 0.8 0.8&apos; />
121 + <field accessType=&apos;inputOutput&apos; appinfo=&apos;transparency of Arc&apos; name=&apos;transparency&apos; type=&apos;SFFloat&apos; value=&apos;0.0&apos; />
122 + </ProtoInterface>
123 + <ProtoBody>
124 + <!-- First node determines node type of this prototype -->
125 + <Group DEF=&apos;VertexPrototypeRootNode&apos; />
126 + <!-- Subsequent nodes do not render, but still must be a valid X3D subgraph -->
127 + </ProtoBody>
128 + </ProtoDeclare>

```

Figure 45. Material properties are exposed in order to enable runtime visualization techniques, which might modify color or transparency

Further work added the definition of a Vertex to the ProtoBody and then set the accessType to initializeOnly for fields corresponding to the Spheres and Cylinders, since these primitive geometries cannot be resized directly once created by an X3D viewer. Finally, the appropriate application information prose descriptions were updated to document these changes Figures 46 and 47 pertain.

```

123 126 <ProtoBody>
124 127 <!-- First node determines node type of this prototype -->
125 - <Group DEF=&apos;VertexPrototypeRootNode&apos;/>
128 + <Group DEF=&apos;VertexPrototypeRootNode&apos;>
129 + <Anchor>
130 + <IS>
131 + <connect nodeField=&apos;description&apos; protoField=&apos;description&apos;/>
132 + </IS>
133 + <Group>
134 + <Transform>
135 + <IS>
136 + <connect nodeField=&apos;translation&apos; protoField=&apos;translation&apos;/>
137 + <connect nodeField=&apos;rotation&apos; protoField=&apos;rotation&apos;/>
138 + </IS>
139 + <Shape>
140 + <Appearance>
141 + <Material>
142 + <IS>
143 + <connect nodeField=&apos;diffuseColor&apos; protoField=&apos;color&apos;/>
144 + <connect nodeField=&apos;transparency&apos; protoField=&apos;transparency&apos;/>
145 + </IS>
146 + </Material>
147 + </Appearance>
148 + <Sphere>
149 + <IS>
150 + <connect nodeField=&apos;radius&apos; protoField=&apos;radius&apos;/>
151 + </IS>
152 + </Sphere>
153 + </Shape>
154 + </Transform>
155 + </Group>
156 + </Anchor>
157 + </Group>
126 158 <!-- Subsequent nodes do not render, but still must be a valid X3D subgraph -->
127 159 </ProtoBody>

```

Figure 46. Adding the definition of a Vertex to the ProtoBody

```

118 112 <ProtoInterface>
119 - <field accessType=&apos;inputOutput&apos; appinfo=&apos;name to document this arc&apos; name=&apos;name&apos; type=&apos;SFString&apos; value=&apos;someName&apos;/>
120 - <field accessType=&apos;inputOutput&apos; appinfo=&apos;popup text describing this arc&apos; name=&apos;description&apos; type=&apos;SFString&apos; value=&apos;some description&apos;/>
121 - <field accessType=&apos;inputOutput&apos; appinfo=&apos;TODO this needs to match values in the Vertex prototype, which is initialized separately&apos; name=&apos;radius&apos; type=&apos;SFFloat&apos; value=&apos;1&apos;/>
113 + <field accessType=&apos;inputOutput&apos; appinfo=&apos;name to document this Vertex&apos; name=&apos;name&apos; type=&apos;SFString&apos; value=&apos;someName&apos;/>
114 + <field accessType=&apos;inputOutput&apos; appinfo=&apos;popup text describing this Vertex&apos; name=&apos;description&apos; type=&apos;SFString&apos; value=&apos;some description&apos;/>
115 + <field accessType=&apos;initializeOnly&apos; appinfo=&apos;size of Vertex ball&apos; name=&apos;radius&apos; type=&apos;SFFloat&apos; value=&apos;1&apos;/>
122 116 <field accessType=&apos;inputOutput&apos; appinfo=&apos;choices: BallAndStick, Ball, Stick&apos; name=&apos;displayMode&apos; type=&apos;SFString&apos; value=&apos;BallAndStick&apos;/>
123 - <field accessType=&apos;inputOutput&apos; appinfo=&apos;diffuseColor of Arc&apos; name=&apos;color&apos; type=&apos;SFColor&apos; value=&apos;0.8 0.8 0.8&apos;/>
124 - <field accessType=&apos;inputOutput&apos; appinfo=&apos;transparency of Arc&apos; name=&apos;transparency&apos; type=&apos;SFFloat&apos; value=&apos;0.0&apos;/>
117 + <field accessType=&apos;inputOutput&apos; appinfo=&apos;diffuseColor of Vertex&apos; name=&apos;color&apos; type=&apos;SFColor&apos; value=&apos;0.8 0.8 0.8&apos;/>
118 + <field accessType=&apos;inputOutput&apos; appinfo=&apos;transparency of Vertex&apos; name=&apos;transparency&apos; type=&apos;SFFloat&apos; value=&apos;0.0&apos;/>
125 119 </ProtoInterface>

```

Figure 47. Setting the accessType to initialize for Spheres and Cylinders

After completing some application information refinements, the default values for name and description that require continual updating when prototype instances are created were set in addition to default updates for Arc Proto Instance. This information is based on the updated field definitions. Then we revised the embedded Script using updated field definitions and new X3D-Edit auto-generation patterns, and inserted additional embedded Script data to enhance the design pattern Figure 48 pertains.

```

19 19 <ProtoInterface>
20 - <field accessType=&apos;inputOutput&apos; appinfo=&apos;name to identify this Arc&apos; name=&apos;name&apos; type=&apos;SFString&apos; value=&apos;someName&apos;/>
21 - <field accessType=&apos;inputOutput&apos; appinfo=&apos;popup text describing this Arc&apos; name=&apos;description&apos; type=&apos;SFString&apos; value=&apos;some description&apos;/>
20 + <field accessType=&apos;inputOutput&apos; appinfo=&apos;name to identify this Arc&apos; name=&apos;name&apos; type=&apos;SFString&apos; value=&apos;TODO customize this ArcName&apos;/>
21 + <field accessType=&apos;inputOutput&apos; appinfo=&apos;popup text describing this Arc&apos; name=&apos;description&apos; type=&apos;SFString&apos; value=&apos;TODO customize this Arc description&apos;/>
22 <field accessType=&apos;initializeOnly&apos; appinfo=&apos;length of Arc between Vertex locations&apos; name=&apos;cylinderHeight&apos; type=&apos;SFFloat&apos; value=&apos;1&apos;/>
23 <field accessType=&apos;inputOutput&apos; appinfo=&apos;location of Arc&apos; name=&apos;cylinderTranslation&apos; type=&apos;SFVec3f&apos; value=&apos;0 0 0&apos;/>
24 <field accessType=&apos;inputOutput&apos; appinfo=&apos;see TODO items in ArcScript&apos; name=&apos;coneTranslation&apos; type=&apos;SFVec3f&apos; value=&apos;0 0 0&apos;/>
25 <field accessType=&apos;inputOutput&apos; appinfo=&apos;orientation of Arc&apos; name=&apos;rotation&apos; type=&apos;SFRotation&apos; value=&apos;0 1 0 0&apos;/>
26 <field accessType=&apos;inputOutput&apos; appinfo=&apos;rendering choices: BallAndStick, Ball, Stick&apos; name=&apos;displayMode&apos; type=&apos;SFString&apos; value=&apos;BallAndStick&apos;/>
27 <field accessType=&apos;inputOutput&apos; appinfo=&apos;diffuseColor of Arc&apos; name=&apos;color&apos; type=&apos;SFColor&apos; value=&apos;0.8 0.8 0.8&apos;/>
28 <field accessType=&apos;inputOutput&apos; appinfo=&apos;transparency of Arc&apos; name=&apos;transparency&apos; type=&apos;SFFloat&apos; value=&apos;0.0&apos;/>
29 <field accessType=&apos;inputOutput&apos; appinfo=&apos;offset distance for Cone arrowhead; TODO this needs to match values in the Vertex prototype, which is initialized separately&apos; name=&apos;ballRadius&apos; type=&apos;SFFloat&apos; value=&apos;1&apos;/>
30 </ProtoInterface>

```

Figure 48. Setting the Access Type to initialize for Spheres and Cylinders

After completing other application information Figures 49 and 50 illustrate how refinements, the default values for *name* and *description* (that require immediate updating when prototype instances are created) were set in addition to default updates for Arc Proto Instance. This information forms the basis of the updated field definitions. We revised the embedded Script using updated field definitions and new X3D-Edit auto-generation patterns, inserting additional embedded Script data to enhance the design pattern.

```

19 19 | <ProtoInterface>
20 - | <field accessType=&apos;inputOutput&apos; appinfo=&apos;name to identify this Arc&apos; name=&apos;name&apos; type=&apos;SFString&apos; value=&apos;someName&apos;/>
21 - | <field accessType=&apos;inputOutput&apos; appinfo=&apos;popup text describing this Arc&apos; name=&apos;name&apos; type=&apos;SFString&apos; value=&apos;some description&apos;/>
20 + | <field accessType=&apos;inputOutput&apos; appinfo=&apos;name to identify this Arc&apos; name=&apos;name&apos; type=&apos;SFString&apos; value=&apos;TODO customize this ArcName&apos;/>
21 + | <field accessType=&apos;inputOutput&apos; appinfo=&apos;popup text describing this Arc&apos; name=&apos;description&apos; type=&apos;SFString&apos; value=&apos;TODO customize this Arc description&apos;/>
22 22 | <field accessType=&apos;initializeOnly&apos; appinfo=&apos;length of Arc between Vertex locations&apos; name=&apos;cylinderHeight&apos; type=&apos;SFloat&apos; value=&apos;1&apos;/>
23 23 | <field accessType=&apos;inputOutput&apos; appinfo=&apos;location of Arc&apos; name=&apos;cylinderTranslation&apos; type=&apos;SFVec3f&apos; value=&apos;0 0 0&apos;/>
24 24 | <field accessType=&apos;inputOutput&apos; appinfo=&apos;see TODO items in ArcScript&apos; name=&apos;coneTranslation&apos; type=&apos;SFVec3f&apos; value=&apos;0 0 0&apos;/>
25 25 | <field accessType=&apos;inputOutput&apos; appinfo=&apos;orientation of Arc&apos; name=&apos;rotation&apos; type=&apos;SFRotation&apos; value=&apos;0 1 0 0&apos;/>
26 26 | <field accessType=&apos;inputOutput&apos; appinfo=&apos;rendering choices: BallAndStick, Ball, Stick&apos; name=&apos;displayMode&apos; type=&apos;SFString&apos; value=&apos;BallAndStick&apos;/>
27 27 | <field accessType=&apos;inputOutput&apos; appinfo=&apos;diffuseColor of Arc&apos; name=&apos;color&apos; type=&apos;SFCColor&apos; value=&apos;0.8 0.8 0.8&apos;/>
28 28 | <field accessType=&apos;inputOutput&apos; appinfo=&apos;transparency of Arc&apos; name=&apos;transparency&apos; type=&apos;SFloat&apos; value=&apos;0.0&apos;/>
29 29 | <field accessType=&apos;inputOutput&apos; appinfo=&apos;offset distance for Cone arrowhead; TODO this needs to match values in the Vertex prototype, which is initialized separately&apos; name=&apos;ballRadius&apos; type=&apos;SFloat&apos; value=&apos;1&apos;/>
30 30 | </ProtoInterface>

112 112 | <ProtoInterface>
113 - | <field accessType=&apos;inputOutput&apos; appinfo=&apos;name to identify this Vertex&apos; name=&apos;name&apos; type=&apos;SFString&apos; value=&apos;someName&apos;/>
114 - | <field accessType=&apos;inputOutput&apos; appinfo=&apos;popup text describing this Vertex&apos; name=&apos;description&apos; type=&apos;SFString&apos; value=&apos;some description&apos;/>
113 + | <field accessType=&apos;inputOutput&apos; appinfo=&apos;name to identify this Vertex&apos; name=&apos;name&apos; type=&apos;SFString&apos; value=&apos;TODO customize this VertexName&apos;/>
114 + | <field accessType=&apos;inputOutput&apos; appinfo=&apos;popup text describing this Vertex&apos; name=&apos;description&apos; type=&apos;SFString&apos; value=&apos;TODO customize this Vertex description&apos;/>
115 115 | <field accessType=&apos;initializeOnly&apos; appinfo=&apos;size of Vertex ball&apos; name=&apos;radius&apos; type=&apos;SFloat&apos; value=&apos;1&apos;/>
116 116 | <field accessType=&apos;inputOutput&apos; appinfo=&apos;rendering choices: BallAndStick, Ball, Stick&apos; name=&apos;displayMode&apos; type=&apos;SFString&apos; value=&apos;BallAndStick&apos;/>
117 117 | <field accessType=&apos;inputOutput&apos; appinfo=&apos;diffuseColor of Vertex&apos; name=&apos;color&apos; type=&apos;SFCColor&apos; value=&apos;0.8 0.8 0.8&apos;/>
118 118 | <field accessType=&apos;inputOutput&apos; appinfo=&apos;transparency of Vertex&apos; name=&apos;transparency&apos; type=&apos;SFloat&apos; value=&apos;0.0&apos;/>
119 119 | </ProtoInterface>

```

Figure 49. Default values for name, description that prompts updating when the prototype instances are created

155	155	<ProtoInstance name='Arc'>
↓	156	- <fieldValue name='name' value='test'/>
↓	157	- <fieldValue name='description' value='arc description value'/>
↓	156	+ <fieldValue name='name' value='TODOcustomizeThisArcName'/>
↓	157	+ <fieldValue name='description' value='TODO customize this Arc description'/>
↓	158	+ <fieldValue name='cylinderHeight' value='1'/>
	158	159 <fieldValue name='cylinderTranslation' value='0 0 0'/>
	159	160 <fieldValue name='coneTranslation' value='0 0 0'/>
	160	161 <fieldValue name='rotation' value='0 1 0 0'/>
↓	161	- <fieldValue name='cylinderHeight' value='1.04903'/>
↓	162	- <fieldValue name='appearance'>
↓	163	- <Appearance>
↓	164	- <Material diffuseColor='0.901961 0.992157 1'/>
↓	165	- </Appearance>
↓	166	- </fieldValue>
↓	162	+ <fieldValue name='displayMode' value='BallAndStick'/>
↓	163	+ <fieldValue name='color' value='0.8 0.8 0.8'/>
↓	164	+ <fieldValue name='transparency' value='0.0'/>
↓	165	+ <fieldValue name='ballRadius' value='1'/>
	167	166 </ProtoInstance>

Figure 50. Updating the default Arc Proto Instance using updated field definitions

1. Revising Embedded Script Using Updated Field Definitions With TracePrint Design Pattern

When looking at the volume of the Pajek produced X3D file, it is apparent that each node (vertex) and each link (arc) are defined independently of each other. While there are variations in color, size of arc length, and other various defining features, there are some features such as vertex/node radius, arrow-point dimensions that are constant. Table 8 shows the defined attributes of the arcs and vertices and how they are defined (constant or not) within the X3D visualization:

Table 8. Constant and varying attributes in X3D visualization

Attribute	Constant	Varying
Arc Prototype		
Name		X
Description		X
Cylinder height		X
Cone height	X	
URL		X
Cylinder translation		X
Cone translation		X
Cylinder Translation		X
Cone Translation		X
Display Mode (Ball and Stick)	X	

Color		X
Transparency	X	
Ball radius	X	

Vertex		
Name		X
Description		X
Sphere radius	X	
URL		X
Translation		X
Vertex Text		X
Text translation		X
Text Color		X
Transparency		X
Display Mode (Ball and Stick)	X	
Color		X
Sphere radius	X	

In addition to the link/arc translation varying for each instance, it is also important to note that these two translations are identical with regards to the three point coordinates. When combining hundreds of nodes and links together within X3D code, such redundancy can add up to

many more pages of text, and required memory. This design was iteratively refined in order to reduce such duplication.

2. Step 7: Prototype Declaration

To minimize the level of redundancy and improve the conciseness of the X3D code, our next step taken was to develop an exemplar X3D prototype instance capable of displaying the same visualization data but in a different and shorter format. We began by extracting three nodes and links provided by Pajek from 15 January 2010's datasets. We wrote an XSLT stylesheet converter to generate the desired data in the X3D visualization. Starting with the Scene, we included three ProtoDeclares, Arc, Vertex, and Network Text, which represent the fundamental characteristics of the X3D network model. We created particular fields or elements of these given attributes within the X3D model. The following generated fields are listed in Table 9.

Table 9. Fields within X3D prototypes for Arc, Vertex, and Network Text

Field	Applied Information (AppInfo)
Arc Prototype	
Name	Name to identify the Arc (Link)
Description	Popup text to describe the Arc (Link)
Cylinder Height	Length of the Arc between the Vertex (Node) location
URL	Link to some other resource

Cylinder translation	Defined Translation coordinates within the visualized network
Cone translation	Defined translation coordinates within the visualized network
Rotation	Orientation of the Arc
Display Mode	Rendering Choices: Ball and Stick, Ball, Stick
Color	The diffuse color of the Arc
Transparency	Transparency of the Arc
Ball Radius	Offset distance for the Cone arrowhead. This is also identify to the Vertex prototype which is initialized separately.
Trace Enabled	Function to debug the trace to Browser output consoles.
Appearance	Outward indication of appearance of the Arc.
Vertex Prototype	
Name	Name to identify the Vertex (Link)
Description	Popup text describing the Vertex
URL	Link to some other resource
Radius	Size of the Vertex ball
Display Mode	Rendering Choices: Ball and Stick, Ball, Stick
Color	Diffuse Color of Vertex
Transparency	Transparency of the Vertex
Translation	Location of the Vertex
Vertex Text	Labels to identify the Vertex
Text translation	Location of Vertex Text

Text color	Diffuse color the Vertex Text
Network Text Prototype	
Text	Information to identify the Integral Network

Additions of Network Text, URLs on the links and nodes, and descriptions of new attributes in the network, were then compared to the originally generated Pajek X3D network for completeness. Additionally, a viewpoint and background were added to the prototype to create a grounded orientation of the model, and make it easier for the user to reset the view of the network to its origin. When these two visualizations are compared, they display the same image of the network, with the addition of the background and the display of the Network Information.

3. Step 8: Create Prototype Instance Examples

The next step is to build some examples from the fields by creating *ProtoInstance* copies and applying the data generated from the original Pajek network visualization to our redeveloped prototype. Through the development of prototype instances, we saw that if the field elements are correctly defined in the X3D Prototype file, that those fields are similarly portrayed in the generated visualization. By reviewing, refining, and repeating this process, continuous testing helps to develop a more accurate *ProtoDeclare* template which in turn draws the *ProtoInstance* examples correctly, thereby producing useful visualizations. After validating these revisions, the visualization generated shown in Figures 51 and 52.

Close inspection reveals that the adaptation process was successful and no information was lost.

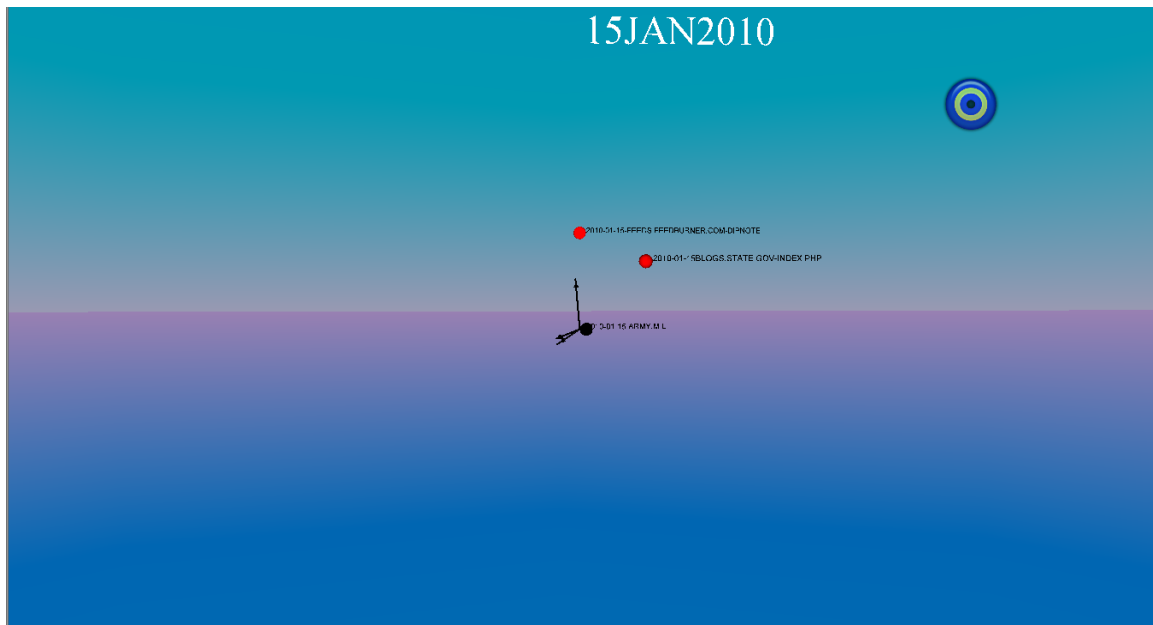


Figure 51. Generated Prototype version of X3D for Visualization demonstrates how converts all information

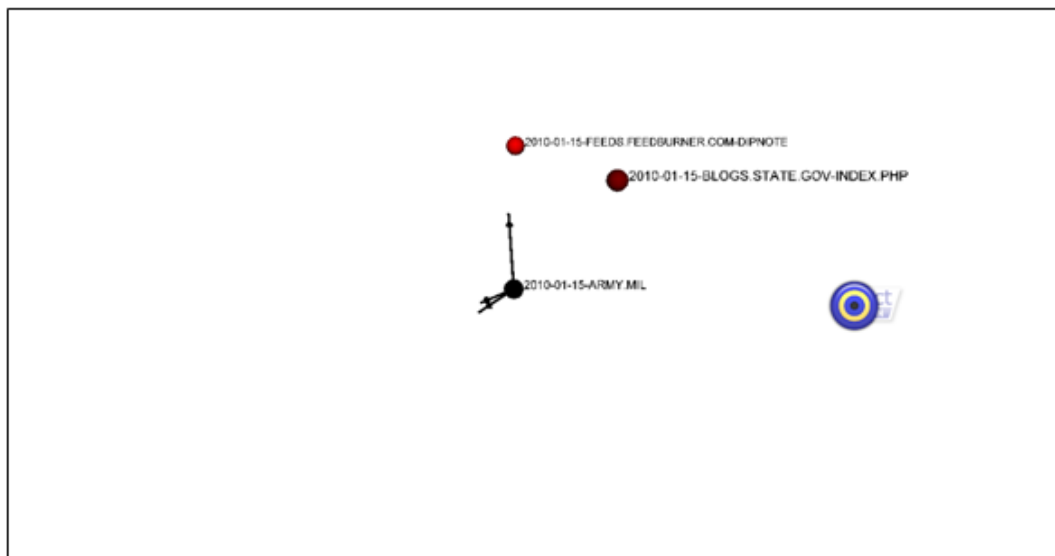


Figure 52. Initial three links and nodes extracted from 15 January 2010 dataset network produced by Pajek

When looking at the models from the user interface aspect, the redeveloped prototype contains hyperlinks for each link and node that open up a browser, and allow access to original data resources. This capability, when utilized for crisis response operations, can embed URLs to connect these links and nodes back to the originating Web documents generated from the CLA. This capability can potentially help an operational planner grasp the elements of the networks and how these particular key words are related to each other (for full .x3d Prototype File, see Appendix D).

Table 10. URLs implemented to generated prototype

Link /Node In 15JAN2010 Model	URL
Vertex 1 (2010-01-15-ARMY.MIL)	http://www.army.mil
Vertex 2 (2010-01-15BLOGS.STATE.GOV-INDEX.PHP)	http://www.state.gov
Vertex 3 (2010-01-15-FEEDS.FEEDBURNER.COM-DIPNOTE)	http://www.feedburner.com
Arc (1.24)	http://www.google.com (Notional website since URL not provided in dataset)
Arc (1.26)	http://www.google.com (Notional website since URL not provided in dataset)
Arc (1.39)	http://www.google.com (Notional website since URL not provided in dataset)

4. Step 9: Stylesheet Conversion

To fully and effectively develop this alternative format that is compatible with the data generated from Pajek's X3D exporter, we determined that there was a need to convert the automated X3D format into the new X3D Prototype visualization-oriented format. While doing this

by hand would take an immense amount of time to complete, the use of an XSLT stylesheet for X3D to X3d (i.e., XML to XML) conversion was determined to be the best method to convert this data into the desired model needed, and in turn, replicated the same results. We generated an XSLT stylesheet converter war then built that had the needed Prototype Declarations from the generated X3D file, and utilized them as the means of instantiating the given generated data into the needed format. This process is illustrated in Figure 53.

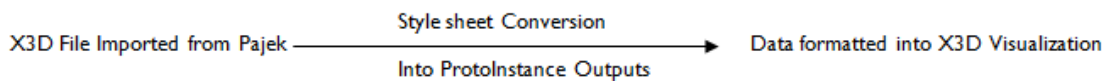


Figure 53. Process of converting Pajek X3D to Prototype X3D through XSLT

a. External Prototype Declarations

To minimize the level of revision and promote future development of this XSLT stylesheet, the use of External Prototype Declarations (or ExtProtoDeclares) were used. ExtProtoDeclares are references to a Prototype's ProtoDeclares which can be more easily interchanged. This allows for the reuse of a single prototype definition in other files, and allows for a URL field to be added to retrieve original prototype data (Brutzman and Daly, 2007). This allows for a level of repeatability and minimizes the complications that may result when an update to software or X3D modeling is altered. By referencing to an original Prototype Declaration—also known as ProtoDeclare(s) or ProtoDeclaration—from a particularly structured prototype,

this allows the developer to have a separately defined ProtoDeclaration, which can contribute to archival data maintenance, and better retrievability of extensive ProtoDeclare definitions. The development of our XSLT sheet required that the data generated from Pajek be processed into the manually created Prototype. With the use of External Prototype Declarations from a saved version from the X3D subversion file, we were able to create the following a stylesheet (seen in Appendix G as Stylesheet).

5. Process of Conversion

Through the use of the XMLSpyDebugger, we transformed the Pajek X3D into the X3D Prototype format. By opening the initial document (PajekVisualizationExamples.x3d) we used the XSL transformation option in Altova's XMLSpy program. This resulted in the generation of XSL Output and the data transformation from one format (the original Pajek X3D) to the new Prototype format. Figures 54 and 55 illustrate this step.

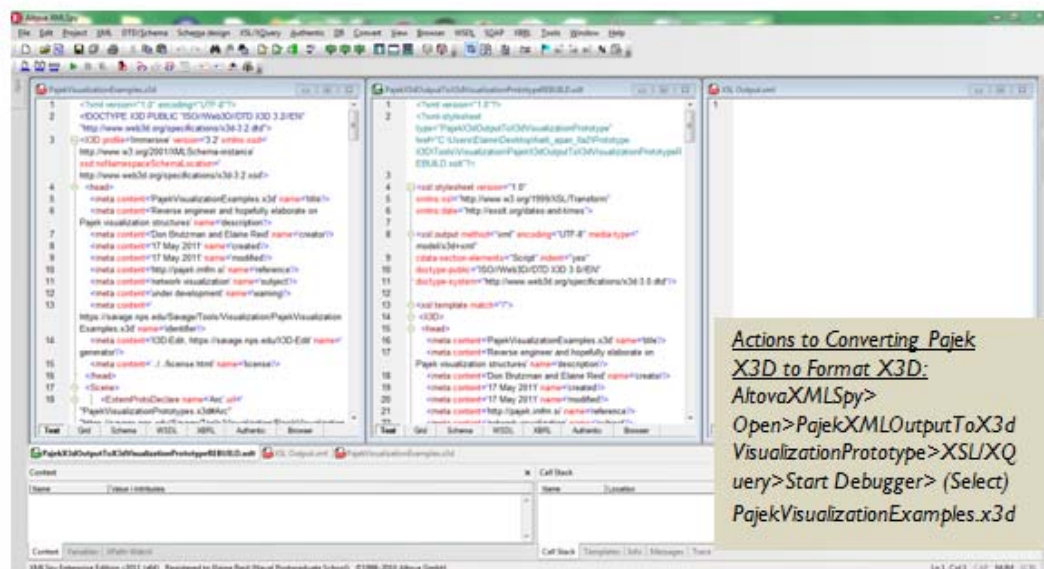


Figure 54. Screen-shot of using Altova XMLSpy's XSLT debugger to produce an X3D Output file from 15 January 2010 Dataset file

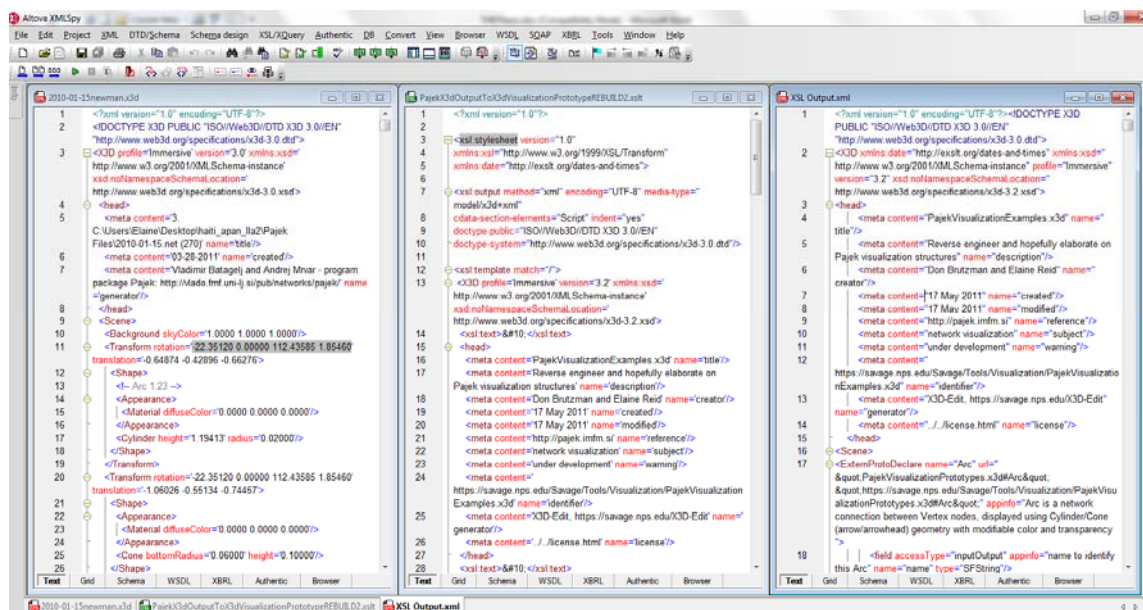


Figure 55. Screen-shot of Altova XMLSpy's XSLT debugger showing the resulting X3D code (on right)

6. Visualizing the Final Product

With the generation of this data into this new format, we began to view the end results. Initially, the XSLT transformation program from XML Altova Spy's software program created an .xml output. To test the model, we initially provided the three arcs/links and three vertices/nodes to the .xslt stylesheet. Figure 56 shows the generated visualization from processing the initial 15JAN2010newman.x3d file into the .xslt file:

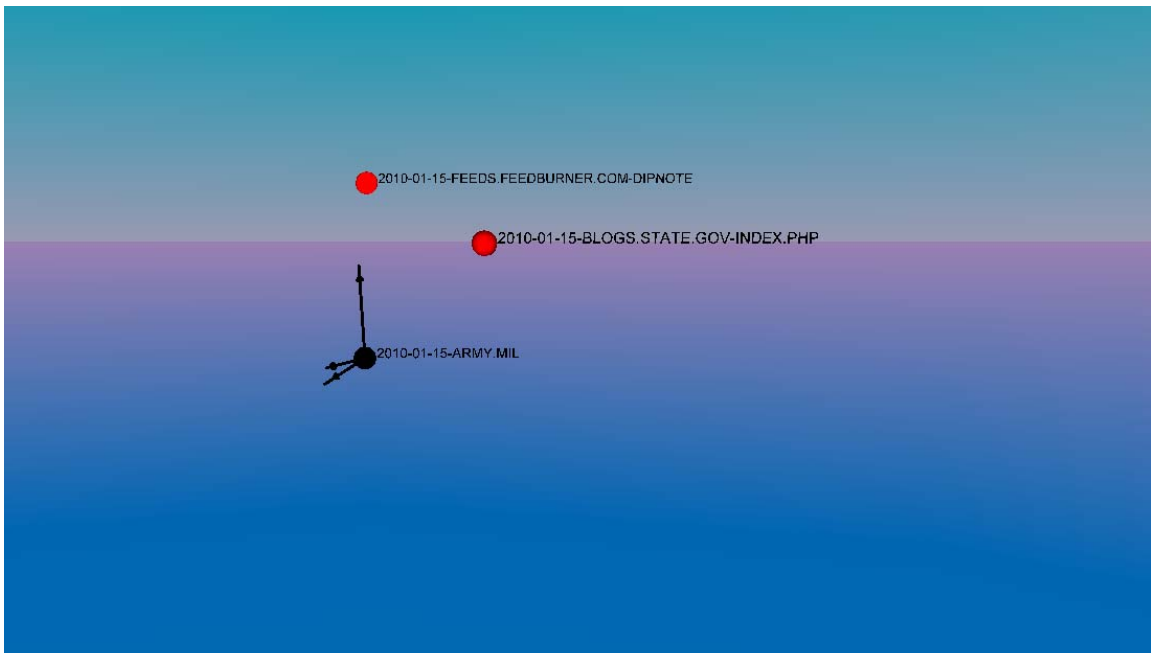


Figure 56. Visualization of the 15 January 2010 X3D file generated through XSLT conversion

When compared to the initial examples generated from Pajek, the node and link structure appeared visually identical. The differences however can be noted in the code, where the Pajek code is reorganized into the newly written prototype structure. The following excerpt is the code from Arc 1.24:

```

<Transform rotation='-11.22472 0.00000 52.81325 2.15598' translation='-0.35062 -0.44066 -
0.60713'>
  <Shape>
    <!-- Arc 1.24 -->
    <Appearance>
      <Material diffuseColor='0.0000 0.0000 0.0000'/>
    </Appearance>
    <Cylinder height='0.64770' radius='0.02000'/>
  </Shape>
</Transform>
<Transform rotation='-11.22472 0.00000 52.81325 2.15598' translation='-0.48422 -0.53116 -
0.63552'>
  <Shape>
    <Appearance>
      <Material diffuseColor='0.0000 0.0000 0.0000'/>
    </Appearance>
    <Cone bottomRadius='0.06000' height='0.10000'/>
  </Shape>

```

Through the use of the xslt stylesheet, the Arc and its other examples are transformed into the following format:

```

<ProtoInstance name="Arc">
  <fieldValue name="name" value=""/>
  <fieldValue name="description" value=""/>
  <fieldValue name="url" value=""/>
  <fieldValue name="cylinderHeight" value="0.64770"/>
  <fieldValue name="cylinderTranslation" value="-0.35062 -0.44066 -0.60713"/>
  <fieldValue name="coneTranslation" value="-0.48422 -0.53116 -0.63552"/>
  <fieldValue name="rotation" value="-11.22472 0.00000 52.81325 2.15598"/>
  <fieldValue name="displayMode" value=""/>
  <fieldValue name="color" value="0.0000 0.0000 0.0000"/>
  <fieldValue name="transparency" value="0.0"/>
  <fieldValue name="ballRadius" value="0.02000"/>
  <fieldValue name="traceEnabled" value="0"/>
  <fieldValue name="appearance" value="0 0 0"/>
</ProtoInstance>

```

As seen, name, description, url, and displayMode are not filled in. This is because the initial Pajek .x3d file does not have the initial elements defined. Yet, with the use of the new prototype format, it is possible to apply new attributes within the file that can result in a more extensive visualization, capable of expanding the presented

information and thereby expanding situational awareness (see Appendix E for the final .x3d file generated by the .xslt file).

With the ability to convert three arcs and three vertices, we then decided to test the .xslt conversion stylesheet was further by applying the entire 15 January 2010 network of 270 Nodes/Vertices and 587 Arc/Links to the .xslt stylesheet through the XML Altova Spy XSLT Transformation program. This last step was able to generate an entirely reformatted X3D Newman network in accordance with the visualization prototype code we developed. This extremely large conversion took 2 seconds on a laptop PC. Results are shown in Figure 57.

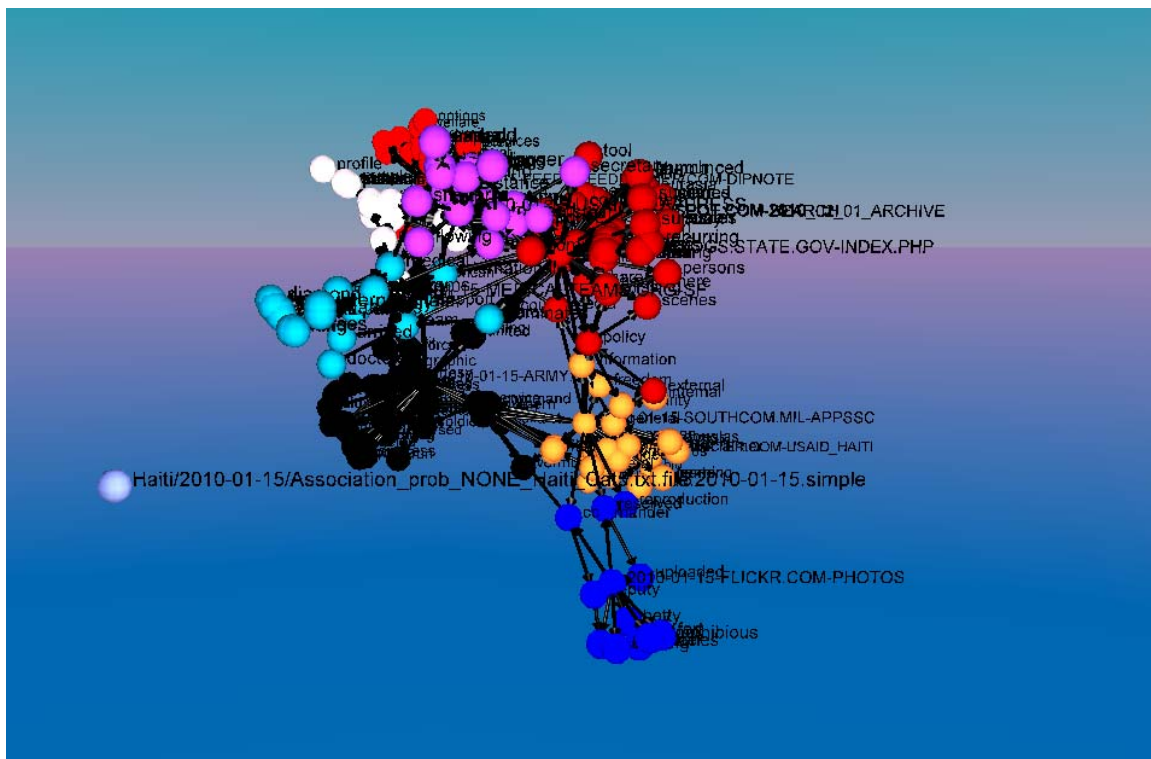


Figure 57. Newman Lexical Link Network, 15 January 2010, in Prototype Visualization format

7. Step 10: Spiral Improvement

This significant result, we inspected the output visualizations, with continued refinements of our visualization design patterns. As seen with visualization from 15 January 2010, there are both correspondences and differences between the Pajek-generated X3D file and the prototype-based visualization adaptation. Table 11 presents these mappings in detail.

Table 11. Field comparison between the Pajek X3D and the X3D Prototype used to generate the XSLT

Fields Used In Both Forms	Field Included in Pajek X3D	Field Included in Prototype
Arc Prototype		
Name	Not Included in X3D Format	Value from <ProtoInstance(Arc)/ fieldValue/@name
Description	Not Included in X3D Format	Value from <ProtoInstance(Arc)/ fieldValue/ @description>
URL	Not Included in X3D Format	Value from <ProtoInstance(Arc)/ fieldValue/@url>
Cylinder Height	Value from <Scene/Transform/Cy linder/@height>	Value from <ProtoInstance(Arc)/ fieldValue/ @cylinderHeight>
Cylinder Radius	Value from <Scene/Transform/Cy linder/ @radius>	Value from <ProtoInstance(Arc)/ fieldValue/ @ballRadius>
Cylinder Translation	Value from <Transform/@transla tion>	Value from <ProtoInstance(Arc)/ fieldValue/ @cylinderTranslation>
Cone Rotation	Value from <Transform/@rotatio n>	Value from <ProtoInstance(Arc)/ fieldValue/@rotation>
Cylinder Rotation	Value from <Transform/@rotatio	Value from <ProtoInstance(Arc)/

	<i>n></i>	<i>fieldValue/@rotation></i>
Display Mode	Not Included in X3D File	Value from <ProtoInstance(Arc)/ fieldValue/displayMode>
Color	Value from <Transform/Shape/Ap pearance/Material/@ diffuseColor>	Value from <ProtoInstance(Arc)/ fieldValue/@color>
Transparency	Not Included in X3D File	Value from <ProtoInstance(Arc)/ fieldValue/ @transparency>
Ball Radius	Not Included in X3D File	Value from <ProtoInstance(Arc)/ fieldValue/ @ballRadius>
Vertex Prototype		
Name	Not included in X3D Format	Value from <ProtoInstance(Vertex)/fieldV alue/@name>
Description	Value from <Anchor/@descriptio n>	Value from <ProtoInstance(Vertex)/fieldVa lue/ @description>
Vertex Text	Value from <Anchor/Transform/S hape/ Text/@string>	Value from <ProtoInstance(Vertex)/fieldVa lue/@vertexText>
Text Color	Value from <Anchor/Transform/S hape/ Appearance/Material / @diffuseColor>	Value from <ProtoInstance(Vertex)/fieldVa lue/@textColor>
Text Translation	Value from <Anchor/Transform/ @translation>	Value from <ProtoInstance(Vertex)/fieldVa lue/ @textTranslation>
URL	Not included in X3D format	Value from <ProtoInstance(Vertex)/fieldVa lue/@url>
Vertex Translation	Value from <Anchor/Transform/ @translation>	Value from <ProtoInstance(Vertex)/fieldVa lue/ @textTranslation>
Radius	Value from <Anchor/Transform/S hape/ Sphere/@radius>	Value from <ProtoInstance(Vertex)/fieldVa lue/@radius>

Display Mode	Not Included In X3D Format	Value from <ProtoInstance(Vertex)/fieldValue/ @displayMode>
Vertex Color	Value from <Anchor/Transform/Shape/ Material/@diffuseColor>	Value from <ProtoInstance(Vertex)/fieldValue/@color>
Transparency	Not Included In X3D Format	Value from <ProtoInstance(Vertex)/fieldValue/ @transparency>
Network Name Prototype		
Text Title	Not Included in X3D Format	Value from <ProtoInstance (NetworkText)/ fieldValue/ @networkText>

As seen in Table 11, there are many attributes which have been made available for author or tool input by the generated prototype. Such additional information values can be generated in either of two ways:

1. By manually inputting the information into the generated model, there are many benefits to the operational planner, who will see first-hand which notional website links and documentation links can be inputted to each node and link. This method however, is arduous, and with a large number of nodes and links within a given network, and can be time consuming to populate.
2. The second method is to generate these particular attributes by integrating these attributes with Social-network analysis tools, and have it be generated through Pajek. By creating a matrix matching each URL to for instance to each node, it can be integrated through any of the Social-network analysis tools used in this thesis (UCInet, Pajek, or ORA). This allows for the data to be converted from the Pajek X3D format into our X3D prototype format.

If Pajek software developers want to make these attributes available to their users, their work demonstrates that it is relatively straight forward to implement this prototype format using the generated data, in turn it might be easily converted into an arguably improved visualization of the given Lexical Link Network examples. Additionally the archival process of saving the data onto a given database allows for the user to accumulate information over a period of time; allowing for a tool that allows for powerful analysis and improved knowledge management.

All of this work produced by this thesis is published online under an open-source license for unencumbered reference and reuse.

F. CHAPTER SUMMARY

When Galileo wrote *Sidereus Nuncius* in 1610, he had intended to display not just written data about constellations, but also visual data that anyone might use to look at the stars in an informed and more scientific way. His term *oculata certitudine* or “visible certainty” promotes the idea of obtaining data through empirical observation, and has for centuries been credited with improving human reasoning of data and complex information (Tufte, p. 101, 2006). Networks, however, unlike the visible portion of the stars themselves from the perspective of earth-bound humans of ages past, are not static. Close examination of crisis response operations using lexical link data shows that they are constantly changing, making them as dynamic as (we now know) the stars themselves are. Lexical link nodes enter and leave

frequently, making it, at times, difficult for lexical link analysis to include every detail that is required to gain better situational awareness. Often, when the network is displayed through a visualization tool, analysts can only examine it at a particular point in time and determine what the aggregation of data means as far as the level of communication being conducted is concerned. With the utilization of X3D as a visualization deployment tool and with the improvements made to the current X3D code implemented, hopefully the difficult process of lexical link analysis becomes easier.

Additionally, the needs and requirements of looking at a network can become innumerable. By leaving a flexible extensive X3D code open to development, there can be modifications and improvements made to the current visualization to improve the exploration of lexical link networks, and help explain how organizations are communicating in a collaborative, self-organizing environment.

By creating a prototype through the code initially developed by Pajek, this work was able to generate a Web-based visualization tool that has viewpoints, animation, embedded data, and hyperlinks. Publishing such data during or following crisis operations, may become an important contribution to response planners and leaders. This approach encourages allowing for a consistent level of data to be fed into the lexical link network, and can help improve overall situational awareness. The goal of using CLA is to generate a method of organizing information in a way that can be useful to agents within crisis operations

as well as higher-level operational leaders and planners. With the multitude of information generated on a regular basis by such operations, organizing understanding (through unique and germane key words) is vital. With the use of X3D to distill data with generated hyperlinks and embedded information, this desire to organize the information is achieved. As we look at the need for improvements and potential issues with the developed prototype, it is important to see how certain alternatives to generating and organizing this information could also contribute to better improving this now developed visualization prototype.

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V. ANALYSIS AND LIMITS OF OUR STUDY

A. INTRODUCTION

Examining the final script generated through X3D and the modifications, we intended that our modifications be used to improve the visualization tool for Pajek, and to simultaneously improve the ability of a user to better understand lexical link networks. This tool might then help to answer questions of this tool's utility in improving situational awareness (SA). Answering this question, however, is not as simple as a "Yes" or "No" answer. While much of the X3D visualizations are, in fact, improved upon in an aesthetic aspect, at the same time, there are limitations in the formatting. This chapter is intended to address the extent of these limitations for X3D, the data accumulated, and potential alternatives to analyzing the data that could further the possibility of developing this tool. By looking at the case model, and incorporating the theories expounded on in Chapter II, we will gain a better understanding of what functions are needed in a visualization tool that can further improve the understanding SA in crisis response operations.

The embarkation upon this study of converting 2D network datasets into 3D datasets is, in essence, the effort of creating a hybrid 3D visualization apparatus. While Pajek has looked to export social networks into X3D code, the prototype that creates these images was addition-adaptable to produce a more flexible and detailed prototype that is capable of processing information and bigger lexical link networks. With the newly developed

visualization prototype, there are some limitations that still exist within it. This chapter examines these limits, and what potential issues exist when this model is utilized. In addition to looking at the technical portion of the case study, we also examine how the final X3D Prototype developed helps to improve situational awareness (SA), and how it can potentially impact Command and Control for crisis response operations.

B. UTILIZATION OF X3D USER INTERFACE: CHALLENGES AND ISSUES

1. Visualization Tool or Experience Tool?

Making a visualization tool that both interactive and capable of showing a large quantity of data is something that X3D strives to provide. The use of a third dimension (z) into the regular two-dimensional (x,y) plane extends not just to the thought of drawing an abstract plane of it, but rather having a certain level of interaction with the object projected. While many high school students believe that the extent of 3D geometry is to draw a 3D image, the initial modern publication of Euclid's geometry (published in 1570) included pop-out images, where the reader constructs 3D images from the components pasted from the page (Libraries University of Oklahoma, 2010). An example is shown in Figure 58.

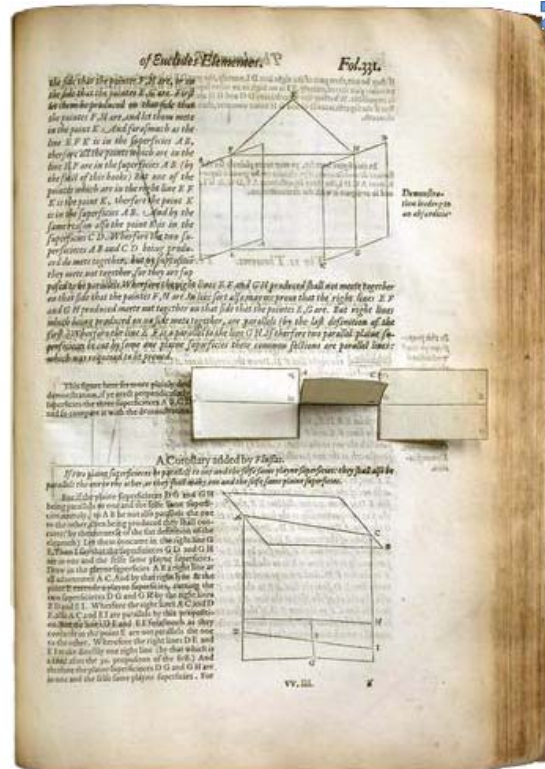


Figure 58. Example of 3D geometric shapes in
Euclid's Geometry (published 1570)
(Libraries University of Oklahoma, 2010)

This level of interaction, translated to the user interface of computers, has advantages and disadvantages. While such program prototypes as X3D are capable of displaying 3D images, they lose their appeal when the interaction with the objects or models becomes too complex. While the direct user is capable of seeing the interaction and "3D effects," the ability to translate this interaction into an image is limited. The issue of occlusion—where most-distant nodes are hidden by other nodes — makes it difficult to better define the composition of a lexical link network. As a user interface, the simplification of the visual representation available to the user is extremely important. It becomes apparent from this

limitation that despite the desire to expand into the realm of 3D, the advantages of this only now extends to the direct user, and to the observer utilizing the computer visualization tool. Instead of 3D being a visualization, it is more so an experience that is fully understood as a computer-based task.

2. Navigating Through the “Fog” of 3D

Additional implications exist when it comes to visualization in a 2D image. When we initially generated the 15 January 2010’s lexical link network into X3D, there were no viewpoints embedded in the 3D scene. When examining the various tools for interacting with 3D visualizations, it can become difficult to navigate around the tool. In essence, without a set of defined parameters for maneuvering around the image, there may result a lack of “coordination” in dynamically rotating the model, resulting in user frustration. To alleviate such frustration, it is necessary to place viewpoints within the X3D prototype, so that the user interface experience a self-controlled “guided tour” of the 3D image. Also utilizing more succinctly defined methods of movement (such as X3D “Examine” Navigation for focused inspection) can help to improve the user interaction. From this, a certain level of constrained programming for an X3D prototype is recommended when building onto or enhancing the developed X3D prototype.

When looking at the display design of the X3D visualization, typically the design elements can be considered using 6 criteria questions (Shneiderman & Plaisant, 2005, p. 491):

1. Elegance and Simplicity: Is there a level of unity, refinement, and fitness in the information displayed?
2. When looking at scale, contrast, and proportion of the lexical link network, does it display clarity, harmony, activity, and restraint?
3. Is the organization and visual structure adequate; displaying the grouping, hierarchy, relationship, and balance?
4. Does the model have focus, flexibility, and consistency in application?
5. Is the image and representation result in the immediacy, generality, cohesiveness, and characterization of the lexical link network datasets?
6. Does the style demonstrate distinctiveness, integrity, comprehensiveness, and appropriateness?

Evaluation of these features within the displayed lexical link network can be subjective based upon the user's preferences, familiarity to the program, and the motivation of viewing the image. While there may be differences of opinion on the displayed information, it is important to understand that if these X3D models do not meet the specific above-defined criteria, the information in this format might be rendered useless to the operational planner or leader.

3. Why Choose 3D?

Whilst caught up in the potential ability to display images into a 3D representation, there have been investigations into how users interact with 3D visualization versus 2D images. Some studies have found that the use of 3D representational images did not hold a significant advantage over two-dimensional displays. The use of direct manipulation as a strategy for investigating

information has provoked some doubt among user interface designers, and such visualization implementations can lead to disorienting navigation, complex user actions, and annoying occlusions, which in the long run can reduce user performance (Shneiderman & Plaisant, 2005). That is why utilization of X3D visualization should be approached with a level of caution in regards to the extent of its capabilities. The images themselves are seen as more user interface friendly when they are utilized as computer-based tasks. To assume that this visualization tool is an "all-in-one, one stop shop" for information understanding would be naïve, especially if the ultimate goal is to use this image is intended to be used by decision makers at leadership levels. The key element toward a 3D user interface being useful to an operational planner is whether or not it has design features that make the interface better than current reality. Since the lexical link networks are abstractions of words extracted from various sources and documentation, and presented in a "network" model, such a method could prove useful if hyperlinks are utilized, and information enhancing the understanding of the link is available. This organization of thoughts and ideas through words in a 3D pictorial representation can help to improve the way crisis response organizations collect their knowledge, enhance their understanding of the information, and disseminate the data to other agents and organizations. With this level of interactive capability, our model and methodology serve as a candidate tool to produce information organization that is unconventional, yet we argue, useful.

C. ANALYSIS AND ASPECTS OF X3D USER INTERFACE: LIMITATIONS OF X3D VISUALIZATION

1. Standardization

With the excellent design pattern produced by the Pajek models, and the visualization improvements made to update the X3D prototype, it was possible to rewrite the script in a more precise way, minimizing the quantity of construction code needed for X3D display. This improved the conciseness of the overall code and allows for larger networks to be created in X3D without overloading the computer or X3D editor programs. Scene designers again, however, faced with a difficulty when it comes to generating a prototype: while there is standardization of model syntax code, there is no standardization in the method of generating such code. The ability to produce concise has been a subject of great debate and varied practice when looking at XML-based languages. Pajek proved a perfect example of this issue by demonstrating the ability to use a "brute force" method of defining the networks' links and nodes; having each node and link defined within the code, and creating a large amount of data. Further compressing such information is something that many software programmers strive to achieve. However, the ability to actually come to a clearly defined concerns approach is more difficult. X3D, while a relatively new modeling language, has already demonstrated a high ability to generate varied 3D models that can be well utilized other by commercial software programs (Pajek is an example of this as well).

The standardization of coding practices is far more diverse, and requires some level of design direction. Don Brutzman, the co-author of *X3D: Extensible 3D Graphics for Web Authors* has made steps in this direction. By creating archival X3D files that can be open-sourced and accessed by anyone as points of reference, the number of programmers utilizing X3D have, through necessity, started establishing best practices, for X3D Modeling, the result of which has already started to emerge. While forcing scene authors to follow certain programming constraints (other than syntax and lexical constraints) seems limiting, educating models in effective X3D design patterns is also important to consistently create new prototypes. The utilization of prototype model development is another method of establishing more reliable best practices, where the needs of programmers can be realized, and modeling results can be repeatable and consistent. After developing the 15 January 2010 prototype, the Pajek developers were contacted about the prototype in the hopes that in the future revision of the Pajek program, they might use improvements in the prototype. This might potentially help generate more concise X3D models that can also hold more information due to the compressed structure of the design refinements.

2. Information Overload

When the dataset of 15 January 2010 was converted from its CLA format to X3D (as accomplished in Chapter IV), it had the Newman attributes applied to it so that when displayed in X3D, the various clusters of Newman values can be distinguished through the difference in colors. When using X3D for single-attribute networks, this method is

rather effective in creating a 3D visualization. Extending the attributes within a network is a more difficult task to produce and as tested, can sometimes produce either an overload of the visualization or an inaccurate 3D model. By taking a similar social network generated by CLA, we attempted to export it from Pajek to X3D. The size of the social network file is intended to distinguish Newman value by color and then size based upon its organization affiliation. Figures 59 and 60 describe results of this next test.

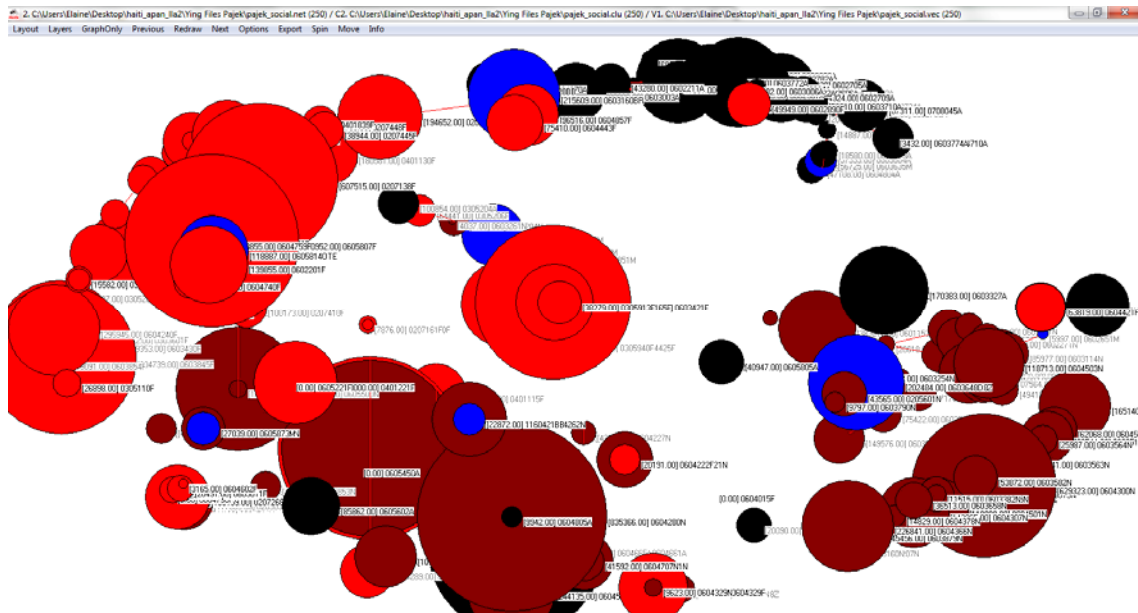


Figure 59. 2D Visual display of social network with multiple attributes produced by CLA program

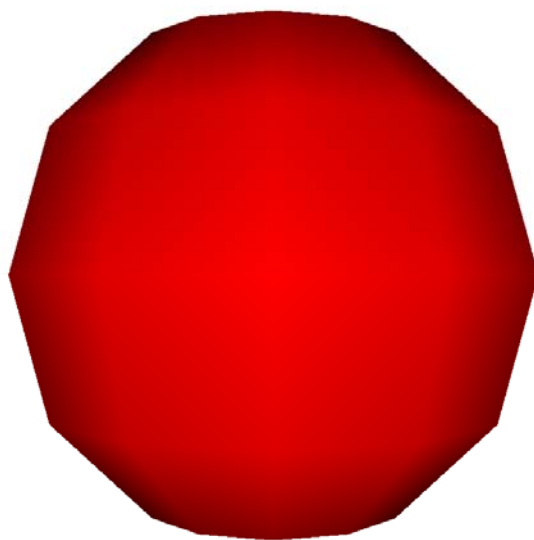


Figure 60. Image of what may occur when the visualization is overloaded, demonstrating what happens when multiple-attributed network is loaded onto Bitmanagement software

As shown in Figure 60, this method of transposing the network from Pajek to X3D resulted in the display of a large red ball when viewed using the Bitmanagement Software Visualizer X3D Player. When viewed from the Xj3D player in X3D-Edit that was seen was a black screen. Some other error might also have occurred, since error diagnosis is difficult in extremely large files. This continues to be a point of contention for the X3D visualization, and is deserving of future research and troubleshooting.

With this potential limitation on visualization dataset size, it makes sense to consider creating smaller interlinked models with X3D. This approach might require the user to download several integrated datasets of the same lexical link network to see the overall variation of the information displayed. The option of viewing smaller

models in isolation or in combination is a good practice to help deal with scaling problems.

Many other design possibilities exist. It may also be beneficial to map the data in a .kml format, instead of (or in addition to) a more abstract model. Additionally, the information that is provided has a limit with who in particular contributed the particular word to the lexical link network. While there is a URL address attached to the attributes of the node, it is still difficult to identify who exactly wrote each message. When regarding potential saboteurs in this data collection, identifying the source of malicious or misleading information can be further considered useful in the information assurance of the lexical link analysis and network processing.

D. ANALYSIS OF CONCEPTS

The intent of the thesis was to use a discovery method of experimentation to find a technology that might be useful for improving situational awareness among operational planners and leaders who are involved in crisis response operations. Examining the concepts that define situational awareness and through the desired criteria for interagency collaboration, this work was able to develop a hypothesis. We theorized that if the information was presented in a format that was easily accessible on a desktop computer, interactive, and extensive in its level of description (while possessing easy and extensive navigation capabilities) then the large amounts of information that are initially stored in documentation and shared in self-forming organizations can be better organized and disseminated with greater efficiency. Such

methods might in essence, provide an improved feedback loop between the self-forming organizational agents and the formalized operational leaders tasked in crisis response operations. The incentive of this interaction is that such leaders and planners have access to further information regarding their organizations' resources and capabilities, thereby fulfilling the requirements of agents from other organizations who potentially require these resources but who unaware of who possesses such necessities. In the context of an experimentation campaign, this thesis based its hypothesis on discovery-based experimental elements, where the innovation of lexical link analysis can be better utilized by the military, civil, and governmental agencies and potentially improves the command and control process for crisis response operations. With social-network analysis software, real-world collected data from the Haiti APAN website a method of mapping the datasets into a way that can be interactively visualized on a computer screen.

This work found that X3D was an excellent method for incorporating this data into a model since it demonstrates an extensible XML-based language that holds an extreme level of flexibility in directly converting information attributes and elements of interest. The data, when accumulated over time, can be archived through a database or online website, which provides an added benefit for analysts wishing to look at historical data on crisis response efforts over time to study and the trends that exist with interagency collaboration. From the data accumulated over time, it was our initial hypothesis that if such a visualization tool were utilized, it would improve situational awareness for operational leaders and

planners. Based upon the conditions that exist where the information was accumulated from one source (e.g., APAN) comes the following question: Will the data used in these tasks improve SA, or will it give only a slight operational picture of what is operationally valid in Haiti's crisis response operation? Instead of asking if the prototype generated from X3D improves SA, this question is in fact asking if the sources of the information influence operational planners and leaders into making decisions, and if APAN is accurate in its reflection of the crisis response operations in Haiti.

To answer these questions, information from people who were actively involved in Haiti's crisis response operations needed to be interviewed. Due to the limitation of time, this question remains to be fully explored in a future study leveraging the findings and trends of this effort which can further inform the efficacy of this model. This issue, which is addressed in this chapter, forms a more refined hypothesis: that if the information from APAN is an accurate reflection of Haiti's crisis response operations, then can the use of the given SA tool accurately reflect the operational picture of the needs of resources and capabilities in the area, and then that tool can potentially used to improve SA. While the development of this software model is effective in visualizing data, it is worth noting that further future research is required to produce a fully effective SA visualization, and that any model is only as accurate as the data accumulated. Conversely, the null hypothesis exists that if the information that is being utilized to generate the lexical link networks (from APAN) is inaccurate, then operational

planners who utilize this tool gain a *poor* understanding of SA for crisis response operations in Haiti.

1. Situational Awareness

Looking at the data that was accumulated from the case study (15 January 2010), we can see that collaborative traits exist between particular lexical nodes. While words connected through Newman's algorithmic equations show how these words cluster together, there is a limited level of information generated examining at the words alone. That is why further embedded information is incorporated into the X3D prototype script, including hyperlinks to relevant documents and information that can potentially expand the understanding of why certain words are in fact linked together. The ability to incorporate this information intrinsically displays collaborative traits based by the origins of the sources that generated the lexical node. By demonstrating the origin of sources and the content generated from these sources, we can depict the level of interagency collaboration, and also offer a better understanding of which organizations are cooperating with other organizations. This approach can also expose levels of expertise within a particular field when comparing to participating groups.

Based upon the feedback loop of organizational leaders observing the data accumulated through a lexical link network, such leaders and planners can essentially impact the level of content being distributed through such a tool by giving additional feedback to the lexical link network and thereby creating an additional feedback loop. If the intent is to improve the distribution of information across

different organizations, this goal can then be accomplished based upon the information displayed and the requirements applied to the network. This approach extends the *Endsley* model of Situational Awareness to include an additional Feedback Loop; it is not the Feedback process itself. This can help to refine the process of situational awareness and operational perception for agents attempting to accumulate data from other Interagency organizations.

Chapter II touched on the characteristics of what a lexical link network requires to support effective Situational Awareness. Having dense lexical link networks is an indication that particular topics addressed in a lexical link cluster are well linked and addressed through various other concepts. Contrastively, having a sparse lexical link cluster is an indication that there is a limit on information being addressed either due to relevance of information, ambiguity of information, or errors (typos) in terms that cannot be linked to anything else. When visualizing the lexical link networks through the X3D prototype model, it is possible to notice that there are differences in information that due to the level of participation in the input of information hinges upon if the information is also an accurate portrayal of the crisis response operations. By expanding these nodes to hyperlinks of data, the analyst can help to improve upon and provide a better understanding as to why such nodes are sparse or dense to get a better understanding of such mentioned concepts as Heterophily, Defined Missions and Goals, Team Performance-Required Collaboration, Commitment to Collaboration, and Team Based Performance in terms of

Trust, Use of Resources and Skills, and Mutual Accountability, as shown in Figure 61.

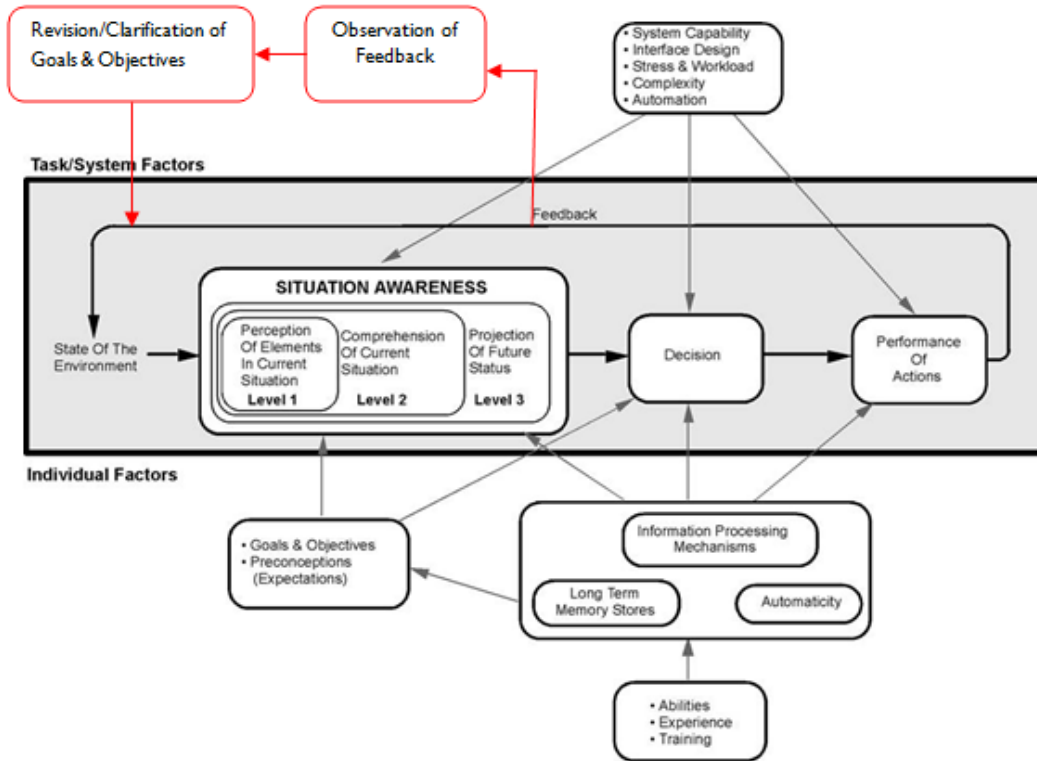


Figure 61. How operational planners and leaders can impact the Situational Awareness (SA) feedback loop (From Endsley 1995)

2. Self-Organization

Our study in this thesis helps to develop an X3D prototype that can be replicated across the various lexical link networks from January to February. As we different data was generated, we saw variations in the models themselves emerged over time. In some instances, the information generated was minimally populated. When looking at self-organization, this is a term that is used to describe ad-hoc integration of nodes to a network. The

nature of the information generated shows that there is no set number of nodes to links, and that the information can (at times) have gaps. When looking at APAN, we see that there is a spontaneous use of information. This might mean that the self-organization of information from APAN alone can be intentionally inconsistent and perhaps limits the level of information that it gives to operational planners. When it comes to creating an accurate picture of Situational Awareness, the sources for the Lexical Link extraction method may therefore need to be expanded to gain a better grasp on which organizations are talking to each other and what these organizations are talking about.

3. Collaboration

The level of complexity that exists within a social network system of individual interactions requires an evaluation of its connectedness, relationships, and context. Looking at lexical link networks, we note the ways how words and on a more integral scale. Finding a means of linking documents together are essential for producing achieving a more cognizant understanding of Haiti's crisis-response operations. The use of a visualization tool can help to develop a better understanding of these concepts are connected and, more importantly, how they interact with each other. By evaluating the theories of self-organization and situational awareness, we can measure how effectively these various organizations collaborate in an effort to reach a more effective result in crisis relief.

E. CONCLUSION

When Thomas Jefferson was designing the University of Virginia's campus, he initially intended to put in walking paths that could be utilized by the students. Yet, as the campus opened and as students started to walk from each building to class, he noticed that the students were forming their own paths by choosing directions and courses unintended by the original design of the architect himself. By observing the patterns of the students and their preferences to walking on campus, he redesigned the walking paths so that they would match the preferences of the students. To better understand the concept of collaboration and how it applies to Haiti's crisis response operations, it would be wise to emulate Thomas Jefferson's approach to modifying the paths travelled by students, to be willing to see the trends of those organizational agents, and then move the design of the lexical link analysis into that direction. This concept is somewhat advantageous to the notion that a system is governed by what is measured, because the feedback loops effecting chains are driven by the repaired information. The model designed is entirely capable of adjusting to the data integrated. For operational planners and leaders to have an improved situational awareness, instead of a perhaps-myopic perception of Haiti's crisis response operations, we must be willing to open up released resources to include other widely used websites. UN WebRelief is an example of such a website that could be better leveraged. It may also be of benefit to examine Skype conversations and data accumulated over time. These possibilities are discussed more thoroughly in Chapter VI.

VI. CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

A. RESEARCH CONCLUSIONS

Since the Earthquake in 2010, which killed 230,000 people and left more than 1.5 million homeless (USAID, 2011), the United States government has attempted to take stock of the situation and look at lessons learned from this crisis. While many news sources reported a delay in the level of response in Haiti, there was also an understanding that within this situation—where local infrastructure had utterly collapsed due to the vastness of the destruction in Haiti's capital Port au Prince—there was little that could be done to tackle the complexities of challenges faced by massive, diverse groups conducting relief operations (ODI—Humanitarian Practice Network, 2010). This thesis attempts to challenge this perception, basing itself on the premise that crisis response operational planners and leaders, when given a visualization tool that is dynamic and can be used to organize Interagency information in a visualization model, can help to improve situational awareness, thereby helping to improve how resources are distributed and how information is communicated. With the exploration of social-network analysis tools (ORA, UCINET, and Pajek) that visualize complex datasets of information into sociograms (visual pictures). This thesis was able to convert this data into a 3D model through the use of X3D, an XML-based modeling language. By adding hyperlinks and other features to this initial model, we were able to create a method of organizing information in a way that is both interactive and visually descriptive.

Development of this situational awareness visualization tool led to improve our observation of the data itself. Lexcial Link Analysis (LLA), a data-mining methodology that is used to generate the initial datasets, has been leveraged to capture data from the DoD-sponsored website, All Partners Access Network (APAN). We refined our initial research hypothesis to state that if organizational members were to use an improved data depiction tool, situational awareness could be improved and thus leveraged in the crisis response operational environment. By this information depiction being accurate and consistent, operational planners can use the developed tool to make sound operational decisions, positively affecting the feedback loop produced through the use of these applications that promote self-forming organizations.

To explore this theory, a questionnaire was intended to be released. The findings from these questionnaires were revealing. It was found that the utilization of APAN, while valuable, was not necessarily a primary source of data exchange, and that the limited interaction provided by APAN, did not fully address all needs during Haiti's crisis response operations. Therefore, if the information is to be accurate and effectively display crisis response operations for the sake of improved situational awareness, the Lexical Link Analysis tool needs to consider and derive data from more than just one website. Additionally, those extracting information need to look at which websites and methods of communication are being the most utilized in these areas of operation. Such websites as UN ReliefWeb have been mentioned as being a good depository of information, as well as Skype conversations. These areas need to be

explored for future research, and may help to enhance the understanding of how the developed situational awareness tool can be utilized more effectively.

1. Recommendations for Future Work

In addition to enriching the resources of lexical link analysis, providing more alternatives to viewing the data can greatly benefit operational planners and leaders in crisis response operations. As discussed in Chapter III, the use of cross-correlated (knowledge x knowledge) datasets allows software tools such as ORA, UCINET, and Pajek to generate lexical link networks. This is a very productive approach. There are, of course additional variables that are vital toward better understanding how the information is transmitted and whether the data is relevant as well. One variable in particular, location, can help to determine the relevancy of certain subjects such as disease, or hunger, are in particular areas or regions of a crisis area. By conducting exploration into the social-network analysis tools, ORA was found to be a tool capable of mapping particular lexical nodes to particular areas (in this instance with notional areas) through an export application producing kml placemark files. Such an option is available through ORA, and inputting particular coordinates to each network node within a dataset is possible to achieve.

To extend the research we accomplished in this work, we recommend the following topics for further analysis:

- Analysis of additional visualization components that takes advantage of rendering flexibility and the X3D prototype developed.

- Accumulating, extracting, processing, and publishing additional examples from various areas such as terrorist organizations, revolutions and other crisis response operations.
- Continued work with Pajek developers that enhance and extend the X3D software tool.
- Finding methods to connect LLA products more directly to the tools used during relief operations to provide real-time analytic feedback.
- Further develop the analytic tools to produce additional X3D models. This can include a comparison and contrast of other alternative visualization programs.
- Conduct interviews of members involved in Haiti's relief efforts to verify lexical link visualizations produced are reflective of events occurring in the area.

2. Further Development of Analytic Tools

While ORA, UCINet, and Pajek have been utilized to generate X3D files, the use of other software such as Mage, has not been explored. Mage is a 3D vector display program that shows data through a "kinemage" (combined term for "kinematic image") graphics interface. It has been used previously for natural sciences and medical research, and appears to contain some promising potential in displaying 3D images. Of particular interest is the success shown in rendering and exploring complete graph structures (such as organic molecules). When exploring this, it would be beneficial to determine the level of exportability between Mage into X3D, and if it offers any potential advantages over Pajek's export to X3D options. From reading some of its capabilities, Mage is written in Java, and can potentially be run on multiple operating systems (Chen & Davis, 2009). Figures 62 and 63 show examples of Mage applications.

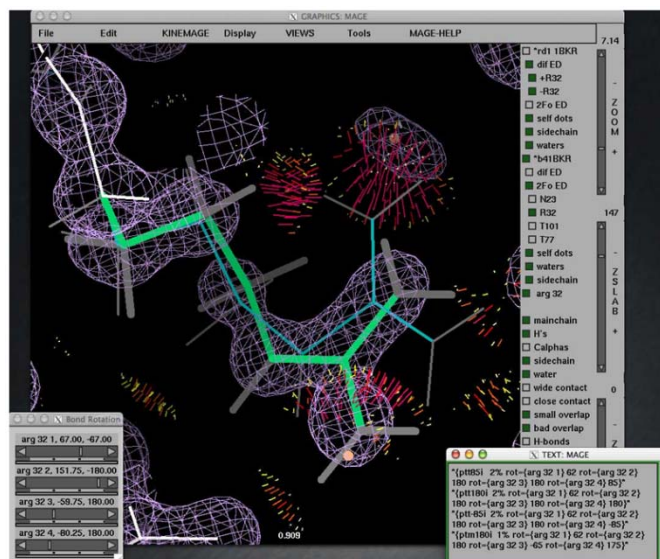


Figure 62. Example of Kinemage image generated by Mage (Biochemistry Dept at Duke University, 2011)

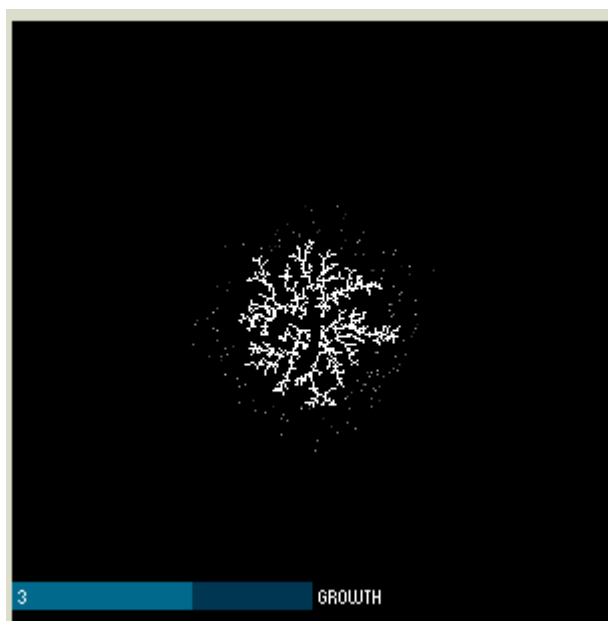


Figure 63. Example of Mage Processing image of crystal simulation. In addition to having 3D capability, it is capable of programming animation (Glutton, 2007)

3. Additional Visualization Alternatives

A newer 3D visualization programming language is also starting to make headway. *Processing* is a programming language that has been used for visual arts, but is slowly progressing into a program that can generate more quantitative information as well. As an open-source software tool, it is accessible to students and schools. With its continued online support through user participation, it shows a great deal of potential in generating a visualization tool that can extend what X3D has already produced so far (Fry & Reas, 2011). Certain visual attributes such as texture mapping have been reported as a potential advantage for *Processing* and can (as one user reported on processing.org) can be exported into X3D as an SFImage texture (Fry & Reas, Processing Discourse-Processing applet as texture in X3D world, 2007).

4. Future for Crisis Response Operations

The development of the situational awareness visualization tool was intended to be the discovery and development of a technology that could be used for crisis response operational planners and leaders, with the capability to be used for multiple purposes. We argue that our efforts help to create a methodology that can be used to further expand the crisis response and social-network analysis that can be applied to future crisis response operations. Whether the crisis requiring the assistance of government, civil, and military agencies are man-made or not, the depth of the crisis – if not handled appropriately and effectively – can range significantly, from small to cataclysmic events. Since Haiti's earthquake, we have seen

earthquakes in Chile and, most recently, Japan. The latter of which has had a detrimental effect on a population, in that while they were extremely prepared for earthquakes and seismic activity, were in no way capable of handling a 9.0 level earthquake. To better understand the capacity of the situational awareness visualization tool, using these given crisis response operations is a recommended future point of departure for future research for thesis students wishing to explore this software capability further.

The data that was extracted through questionnaires that were distributed to primarily IP Navy Officers and research employees at NPS who were involved in the Haiti crisis relief operations were taken with the intent of further expanding the understanding of if the information that was extracted through the Lexical Link Analysis data-mining tool was an accurate representation of the actual crisis response operations. The results reflected that there was a need to look at further websites to better grasp the level of activity and operational picture of the Haiti crisis response operations. Expanding the field of data extraction is a necessity to fully realize the potential this situational awareness visualization tool contains. Looking at some of the websites mentioned in the questionnaire would be a reasonable starting point for those interested in expanding the data-mining analysis. Also, depending on the crisis being evaluated, it might be beneficial for operational planners and leaders to survey their subordinates about which websites are being utilized, and target the data mining according to their feedback.

5. New Potential Purposes for Situational Awareness Tool

While crisis response operations prove to be a topic of interest for this situational awareness visualization tool, it is not just limited to these forms of operations alone. When exploring operations in general of the military and between other agencies, whether they be used for humanitarian-related or warfare based operations, the increased use and improvement of this methodology should be explored in the future – especially as strategic communications and interagency collaboration, in such areas as Afghanistan and Iraq, become more critical. This methodology could also be used to analyze “dark” self-forming networks, which pose a potential threat to U.S. national defense and security. Utilizing this tool as a method of organizing intelligence information could prove to be a vital tool in understanding the enemy, thereby gaining better situational awareness on potential and current, and real-time threats. Additionally, the use of this visualization could help to reinforce and potentially validate intelligence findings and theories addressed through other methods of analysis; enhancing the holistic understanding of other areas of research (Alberts, 2005, p. 29).

APPENDIX A: DATASET MATRIX NOTATION

The following matrix notation is used in this thesis

Notation	Definition
$ Matrix $	Dimension of a square Matrix (i.e., if Matrix has dimension $r \times r$ then $ Matrix = r$)
$Matrix(i, j)$	Entry in the i th row and j th column of Matrix
$Matrix(i, :)$	i th row vector of Matrix
$Matrix(:, j)$	j th column vector of Matrix

Notation	Definition
$sum(Matrix)$	Sum of the elements in Matrix (also Matrix can be a row or column vector or Matrix)
$Matrix^T$	The transpose of Matrix
$\sim Matrix, \sim Matrix(i, j)$	For Binary Matrix, $=1$ if $Matrix(i, j) = 0$
$Matrix @ Matrix$	Element-wise multiplication of two matrices (e.g., $C = A @ B \Rightarrow C(i, j) = A(i, j) \times B(i, j)$)
$card(Set) = Set $	The Cardinality of Set
$sgn(x) = 1$ if $x \geq 0$ and -1 otherwise	
$\mathbb{R}$	Real Numbers
$\mathbb{Z}$	Integer

Graph theoretical terms used in this thesis

Term	Definition
$d(i, j) \in \mathbb{Z}$	The length of the shortest directed path in G from node i to node j . Note that if there is a path from i to j in G the $d(i, j) \in \mathbb{Z}$. Therefore, let $d(i, j) = V $ if there is no path in G from i to j . Also, let $d(i, i) = 0$ for each $i \in V$.
Reachability Graph	For a square network $N = (V, E)$ is defined as follows: let $G = (V, E)$ be the graph representation for N . The Reachability Graph for N is the graph $G' = (V, E')$ where $E' = \{(i, j) \in V \times V \mid \text{directed path from } i \text{ to } j \text{ in } G\}$.
Underlying Network	For a network $N = (V, E)$ is defined as follows: $N' = (V, E')$ where $E' = \{(i, j) \in E \vee (j, i) \in E\}$. That is, a symmetric version of N .

Measure	Description	Reference	Formula
Average Distance	The average shortest path length between nodes, excluding infinite distances. Type Graph Level Input A: binary square Output $\bar{d} \in [0,1]$	NetStat	Let $G = (V, E)$ represent a square network. Define a set S of all pairs (i, j) of nodes such that i can reach j. Then average the shortest paths let $S = \{(i, j) i \text{ is reachable to } j \text{ from } i\}$ Then, Average Distance = $\frac{\sum_{(i,j) \in S} d_G(i, j)}{ S }$
Centrality, Betweenness	The Betweenness Centrality of node v in a network is defined as: across all node pairs that have a shortest path containing v, the percentage that pass through v. this is defined for directed networks. Type Node Level Input N: square Output $\bar{b}_v \in [0,1]$	Wasserman and Faust, 1994	Let $G = (V, E)$ be the graph representation for the network. Let $n = V $, and fix a node $v \in V$. For $(u, w) \in V \times V$, let $n_G(u, w)$ be the number of geodesics in G from u to w. If $(u, w) \in S$, then set $n_G(u, w) = 1$. Define the following: Let $S = \{(u, w) \in V \times V d_G(u, w) = d_G(u, v) + d_G(v, w)\}$ Let between = $\frac{\sum_{(u,w) \in S} \frac{n_G(u, v) \cdot n_G(v, w)}{n_G(u, w)}}{n_G(v, v)}$ Then Betweenness Centrality of node v = $\frac{\text{between}}{(n-1)(n-2)}$. Note: if G is not symmetric, then between is normalized by $(n-1)(n-2)$.
Centrality, Closeness	The average closeness of a node to the other nodes in a network. Loosely, Closeness is the inverse of the average distance in the network between the node and all other nodes. This is defined for directed networks. Type Node Level Input N: square Output $\bar{c}_v \in [0,1]$	Freeman, 1979	Let $G = (V, E)$ be the graph representation of the square network. Fix $v \in V$. Let $dist = \sum_{u \in V} d_G(v, u)$, if every node is reachable from v. Then Closeness Centrality of node v = $\frac{ V -1}{dist}$. If some node is not reachable from v then the Closeness Centrality of v is 0.

Measure	Description	Reference	Formula
Centrality, Eigenvector	Calculate the eigenvector of the largest positive eigenvalue of the adjacency matrix representation of a square network. Type Node Level Input N:square, symmetric Output $\mathbf{x} \in [0,1]$	Bonacich, P. 1972	Calculates the eigenvector of the largest positive eigenvalue of the adjacency matrix representation of a square network. A Jacobi method is used to compute the eigenvalue and vectors.
Centrality, In Degree	The In Degree Centrality of a node in a unimodal network is its normalized in-degree. Type Node Level Input N:square Output $\mathbf{x} \in [0,1]$	Wasserman and Faust, 1994 (Pp. 195)	Calculates the measure on page 195-6 of Wasserman and Faust. Nodes with 0 degree are first removed from the network, and the measure computed on the resulting sub graph. The removed nodes are given centrality value 0.
Centrality, Inverse Closeness	The average closeness of a node to the other nodes in a network. Inverse Closeness is the sum of the inverse distances between a node and all other nodes. This is defined for directed networks. Type Node Level Input N:Square Output $\mathbf{x} \in [0,1]$	Wasserman and Faust 1994 (Pp 195)	Let $G = (V, E)$ be the graph representation of the square network. Fix $v \in V$. Let $dist = \sum_{i \in V} \frac{1}{d_{vi}}$, where $\frac{1}{d_{vi}} = 0$ and $\frac{1}{d_{vi}} = 0$ if i is not reachable from v. Then Inverse Closeness Centrality of node $v = dist / (V - 1)$.
Centrality, Out Degree	The Out Degree Centrality of a node in a square network is its normalized out-degree. Type Node Level Input N:square Output $\mathbf{x} \in [0,1]$	Wasserman and Faust, 1994	Let $G = (V, E)$ be the graph representation of a square network and fix a node v. Let $deg = \text{card}\{u \in V (v, u) \in E\}$, this is the out-degree of node v. The Out Degree Centrality of node $v = deg / (V - 1)$.
Centrality, Total Degree	The Total Degree Centrality of a node in a square network is its normalized in plus out degree. Type Node Level Input N:square, undirected Output $\mathbf{x} \in [0,1]$	Wasserman and Faust 1994 (P. 199)	Let $G = (V, E)$ be the graph representation of a square network and fix a node v. let $deg = \text{card}\{u \in V (v, u) \in E \vee (u, v) \in E\}$, this is the out-degree of node v. The Total Degree Centrality of node $v = deg / 2 * (V - 1)$

Measure	Description	Reference	Formula
Clustering Coefficient, Watts, Strogatz	Measures the degree of clustering in a network by averaging the clustering coefficient of each node i , defined as the ratio of the number of triangles connected to i to the number of triples centers at i . Type Graph Level Input N:square Output $CC \in [0,1]$	Watts and Strogatz, 1998	Let $G = (V, E)$ be the graph representation of a square network. For each node $v \in V$ define the following: $let\ in_v = \{i \in V (i, v) \in E\}$ $let\ out_v = \{j \in V (v, j) \in E\}$ $let\ inconnect_v = \{(i, j) \in E i, j \in in_v\}$ $let\ outconnect_v = \{(i, j) \in E i \in in_v, j \in out_v\}$ Then compute for each node $v \in V$ its Clustering Coefficient cc_v using (1) in-degree, (2) out-degree, or (3) total degree. (1) $Let\ cc_v = \frac{ inconnect_v }{ in_v \cdot (in_v - 1)}, if\ in_v > 1, else\ cc_v = 0.$ (2) $let\ cc_v = \frac{ outconnect_v }{ out_v \cdot (out_v - 1)}, if\ out_v > 1, else\ cc_v = 0.$ (3) $let\ cc_v = \frac{1}{2} (case(1) + case(2))$ Then Clustering Coefficient for the graph = $(\sum_{v \in V} cc_v) / V $
Communicative Need	Measures the percentage of reciprocal edges in a network Type Graph Level Input N:square Output $CC \in [0,1]$	Carley, 2002	Let $G = (V, E)$ represent a square network: Then the Communicative Need = $(Reciprocal\ Edge\ Count\ of\ G) / E $
Component Count, Strong	The number of strongly connected components in a network. Type Graph Level Input N:square Output $Z \in [0, V]$	Wasserman and Faust 1994 (pg 109)	Given a square network represented by a graph $G = (V, E)$, the Strong Component Count is the number of strongly connected components in G . This is computed directly on G , whether or not G is directed.
Component Count, Weak	The number of weakly connected components in a network. Type Graph Level Input N:square, symmetric Output $Z \in [0, V]$	Wasserman and Faust 1994 (P. 109)	Given a square, symmetric network represented by a graph $G = (V, E)$, the Weak Component Count is the number of connected components in G . Such components are called "weak" because the graph G is undirected.

Measure	Description	Reference	Formula
Connectedness	Measures the degree to which a square network's underlying (undirected) network is connected. Type Graph Level Input N:square, symmetric Output $R \in [0,1]$	Krackhardt, 1994	The Connectedness of a square, symmetric network is the Density of its Reachability Network.
Constraint, Burt	The degree to which each node in a square network is constrained from acting because of its existing links to other nodes. Type Node Level Input N:square Output $R \in [0,1]$	Burt, 1992	This is the Constraint measure described by Equation 2.4 on pg. 55 of Burt, 1992. Note that the matrix Z is the adjacency matrix representation of the network N.
Density	The ratio of the number of edges versus the maximum possible edges for a network. Type Graph Level Input N Output $R \in [0,1]$	Wasserman and Faust 1994 (P. 101)	Let M be the adjacency matrix for the network of dimension $m \times n$. If the network is unimodal then $m = n$ and M has a zero diagonal and therefore $Density = \sum(M) / (n * (n - 1))$. If the network is symmetric, then Density is multiplied by two. For bimodal networks, $Density = \sum(M) / (m * n)$.

Measure	Description	Reference	Formula
Diameter	The maximum shortest path length between any two nodes in a unimodal network $G = (V, E)$. If there exist i, j in V such that j is not reachable from i , then $ V $ is returned Type Graph Level Input N:square Output $\mathbb{Z} \in [0, V]$	Wasserman and Faust 1994 (P. 111)	The diameter of $G = (V, E)$ is defined as: $\max\{d_i(j) i, j \in V\}$ That is, the maximum shortest directed path between any two vertices in G . If there exists i and j such that j is not reachable from i , then $ V $ is returned.
Effective Network Size	The effective size of a node's ego network based on redundancy of ties. Type Node Level Input N:square Output $\mathbb{R} \in [0, 1]$	Burt, 1992	This is the Effective Size of Network measure described by Equation 2.2 on page 52 of Burt, 1992. Note that the matrix Z is the adjacency matrix representation of the network N .
Exclusivity, Knowledge	Detects agents who have singular knowledge. Type Node level Input AK:binary Output $\mathbb{R} \in [0, 1]$	Ashworth, 2003	The Knowledge Exclusivity Index (KEI) for agent i is defined as follows: $\sum_{j=1}^{ K } AK(i, j) * \exp(1 - \text{sum}(AK(i, j)))$
Interlockers and Radials	Interlocker and radial nodes in a square network have a high and low Triad Count respectively. Type Node Level Input N:square Output Binary	Carley, 2002	Let $N = (V, E)$ be a square network. Let $t_i = \text{Triad Count from node } i, 1 \leq i \leq V $. Let $\mu = \text{the mean of } \{t_i\}$ Let $\sigma = \text{the variance of } \{t_i\}$ Then if $t_k \geq (\mu + \sigma)$, then agent k is an interlocker. If $t_k \leq (\mu - \sigma)$ then k is a radial.

Measure	Description	Reference	Formula
Network Centralization, Betweenness	Network centralization based on the betweenness score for each node in a square network. This measure is defined for directed and undirected networks. Type Graph Level Input N:square Output $\mathbb{R} \in [0,1]$	Freeman, 1979	Let $G = (V, E)$ represent the square network and let $n = V $ let $d_i = \text{Betweenness Centrality of node } i$ let $\bar{d} = \max\{d_i 1 \leq i \leq n\}$ Then Network Closeness Cent. $= (\sum_{i=1}^n \bar{d} - d_i) / (n-2)(n-1)/(2n-3)$
Network Centralization, Closeness	Network centralization based on the closeness centrality of each node in a square network. This is defined only for connected, undirected networks. Type Graph Level Input N:square Output $\mathbb{R} \in [0,1]$	Freeman, 1979	Let $G = (V, E)$ represent the square network, and let $n = V $ let $d_i = \text{Betweenness Centrality of node } i$ let $\bar{d} = \max\{d_i 1 \leq i \leq n\}$ Then Network Closeness Cent. $= (\sum_{i=1}^n \bar{d} - d_i) / (\frac{n(n-1)}{2} - \frac{n-1}{2})$

Measure	Description	Reference	Formula
Network Centralization, Column Degree	A centralization based on the degree of the column nodes of a network. Type Graph Level Input N Output $C \in [0,1]$	NetStat	Let N be a network with n column nodes. let d_j = degree of column node j, $1 \leq j \leq n$ let $d = \max\{d_j 1 \leq j \leq n\}$ Then Column Degree Network Centralization = $(\sum_{j=1}^n d_j - d) / (n^2)$.
Network Centralization, In Degree	A centralization of a square network based on the In-Degree Centrality of each node. Type Graph Level Input N:Square Output $C \in [0,1]$	Freeman, 1979	Let N be a unimodal network with n nodes. let d_i = In Degree Centrality of node i let $d = \max\{d_i 1 \leq i \leq n\}$ Then In Degree Network Centralization = $(\sum_{i=1}^n d_i - d) / D$, where $D = (n-1)$ if N is undirected, and $(n-1)$ otherwise.
Network Centralization, Out Degree	A centralization of a square network based on the Out-Degree Centrality of each node. Type Graph Level Input N:Square Output $C \in [0,1]$	NetStat	Let N be a unimodal network with n nodes. let d_i = Out Degree Centrality of node i let $d = \max\{d_i 1 \leq i \leq n\}$ The Out Degree Network Centralization = $(\sum_{i=1}^n d_i - d) / D$. Where $D = (n-1)$ if N is undirected, and $(n-1)$ otherwise.
Network Centralization, Row Degree	A centralization on based on the degree of the row nodes in a network. Type Graph Level Input N Output $C \in [0,1]$	NetStat	Let N be a network with n row nodes. let d_j = degree of row node j, $1 \leq j \leq n$ let $d = \max\{d_j 1 \leq j \leq n\}$ Then Row Degree Network Centralization = $(\sum_{j=1}^n d_j - d) / (n^2)$.

Measure	Description	Reference	Formula
Network Centralization, Total Degree	A centralization of a square network based on total degree centrality of each node. Type Graph Level Input N:square Output $R \in [0,1]$	Freeman, 1979	Let N be a unimodal network with n nodes. let d_i = Total Degree Centrality of node i let $\bar{d} = \max\{d_i 1 \leq i \leq n\}$ Then Total Degree Network Centralization $= (\sum_{i=1}^n \bar{d} - d_i) / (n - 2)$.
Network Levels	The Network Levels of a square network is the maximum Node Level of its nodes. Type Graph Level Input N:square Output $L \in [0, V - 1]$	NetStat	Let $G = (V, E)$ be the graph representation of a square network. Then the Levels of $G = \max\{d_G(i, j) i, j \in V, j \text{ reachable from } i \text{ in } G\}$
Node Level	The Node Level for a node v in a square network is the longest shortest path from v to every node v can reach. If v cannot reach any node, then its level is 0. Type Node Level Input N:square Output $L \in [0, V - 1]$	Carley, 2002	Let $G = (V, E)$ be the graph representation of a square network and fix a node v. Node Level for $v = \max\{d_G(v, j) j \in V, j \text{ reachable from } v \text{ in } G\}$; if v cannot reach any nodes, then its level is 0.

Measure	Description	Reference	Formula
Redundancy, Row	The mean number of row node edges in excess of one. Type Graph Level Input N of dimension m x n Output $R \in [0, n-1] \in \mathbb{R}$	Netstat	Let M be the matrix representation for a network N of dimension m x n. let $d_i = \max\{0, \text{sum}(M(i, :)) - 1\}$, for $1 \leq i \leq m$; this is the number of column entries in excess of one for row i. Then Row Redundancy = $\left(\sum_{i=1}^m d_i \right) / m$
Span of Control	The average number of out degree per node with nonzero out degrees. Type Graph Level Input N:square Output $R \in [0, V - 1]$	Carley, 2002	Let S = set of nodes in V that have positive out-degree Let $K = \sum_{i \in S} \text{outDegree}(i)$ Then Span of Control = $K/ S $
Speed, Average	The average shortest path length between node pairs (i,j) where there is a path in the network from i to j. If there are no such pairs, then Average Speed is zero. Type Graph level Input N:square Output $R \in [0, 1]$	Carley, 2002	Let $G = (V, E)$ be the graph representation of a square network. Let $D = \{(i, j) i, j \in V, j \text{ reachable from } i \text{ in } G\}$ Then Average Speed = $\left(\sum_{(i, j) \in D} d_G(i, j) \right) / D $
Transitivity	The percentage of edge pairs $\{(i, j), (j, k)\}$ in the network such that (i,k) is also an edge in the network.	NetStat	Let $G = (V, E)$ be the graph representation of the square network. Let $I = \{(i, j, k) \in V^3 i, j, k \text{ distinct}\}$ Let $Potential = \{(i, j, k) \in I (i, j) \in E, \text{ and } (j, k) \in E\}$ Let $Complete = \{(i, j, k) \in Potential (i, k) \in E\}$ Then Transitivity = $ Complete / Potential $

Measure	Description	Reference	Formula
Triad Count	The number of triads centered at each node in a square network. Type Node Level Input N:square of dimension V Output $T \in [0, (V - 1)(V - 2)]$	NetStat	Let $G = (V, E)$ represent a square network. And let Triad be matrix of dimension $V \times V$ Triad $(i, j) = 0$ Triad $(i, j) = \text{card}\{k k \in V, i \neq k \neq j, A(i, k) \wedge A(k, j) \wedge A(i, j)\}$ Then the Triad count for agent $i = \text{sum}(\text{Triad}(i, :))$
Upper Boundedness	The degree to which pairs of agents have a common ancestor. Type Graph Level Input N:square Output $R \in [0, 1]$	Krackhardt, 1994	

APPENDIX B: 15 JANUARY 2010 XML AND DTD CODE

This example scene is maintained under version control in the Scenario Authoring and Visualization for Advanced Graphical Environments (SAVAGE) archive of X3D models. All SAVAGE models are available under terms of an open-source license. Additional X3D Resources are available online.

- <https://savage.nps.edu/Savage>
- <https://savage.nps.edu/Savage/license.html>
- <http://www.web3D.org/x3d/content/examples/X3dResources.html>

Below is an excerpt of the XML source for the 15 January 2010 dataset as well as the grid-based layout provided by XMLSpy. This file was initially extracted by the Collaborative Learning Agent (CLA) into file *Association_prob_NONE_Haiti_Cat5.txt.file-2010-01-15-simple*.

<i>File Name</i>	<i>File Type</i>	<i>Total Nodes</i>	<i>File Size</i>	<i>XML File Size</i>
Association_prob_NONE_Haiti_Cat5.txt.file-2010-01-15-simple	DYNETML File	270 Nodes	86 KB	94 KB

XML File:

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  xsi:noNamespaceSchemaLocation="file:///C:/Users/Elaine/Desktop/haiti_apan_lla2/XML%20Version%20of%2015JAN2010/15JAN2010%20DTD.xsd">
-   <MetaNetwork id="Haiti\2010-01-15\Association_prob_NONE_Haiti_Cat5.txt.file-2010-01-15-simple.list">
- <nodes>
- <nodeclass type="Knowledge" id="knowledge">
- <propertyIdentities>
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<propertyIdentity id="URL" type="categoryText" singleValued="false" />
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        Keyword= % 222010-01-15-ARMY.MIL % 22" />
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</node>
- <node id="2010-01-15-BLOGS.STATE.GOV-INDEX.PHP">
    <property id="URL"
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        Keyword= % 222010-01-15-BLOGS.STATE.GOV-INDEX.PHP % 22" />
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</node>
- <node id="2010-01-15-FEEDS.FEEDBURNER.COM-DIPNOTE">
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        Keyword= % 222010-01-15-FEEDS.FEEDBURNER.COM-DIPNOTE % 22" />
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</node>
- <node id="2010-01-15-FLICKR.COM-PHOTOS">
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        Keyword= % 222010-01-15-FLICKR.COM-PHOTOS % 22" />
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</node>
- <node id="2010-01-15-HAITICOMFORT.BLOGSPOT.COM">
    <property id="URL"
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        Keyword= % 222010-01-15-HAITICOMFORT.BLOGSPOT.COM % 22" />
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</node>
- <node id="2010-01-15-HAITICOMFORT.BLOGSPOT.COM-2010">
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        Keyword= % 222010-01-15-HAITICOMFORT.BLOGSPOT.COM-2010 % 22" />
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</node>
- <node id="2010-01-15-HAITICOMFORT.BLOGSPOT.COM-2010_01_01_ARCHIVE">
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</node>
- <node id="2010-01-15-HAITICOMFORT.BLOGSPOT.COM-2010_02_01_ARCHIVE">

```

```

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- <node id="2010-01-15-HAITICOMFORT.BLOGSPOT.COM-SEARCH">
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/>
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- <node id="2010-01-15-MEDICALTEAMS.ORG-SF">
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- <node id="2010-01-15-SOUTHC.COM.MIL-APPSSC">
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- <node id="2010-01-15-TWITTER.COM-USAID_HAITI">
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</node>
- <node id="2010-01-15-USAID.GOV-PRESS">
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Keyword= % 222010-01-15-USAID.GOV-PRESS% 22" />
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- <node id="Haiti/2010-01-15/Association_prob_NONE_Haiti_Cat5.txt.file.2010-
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- <node id="actively">
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- <node id="adoption">
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- <node id="adoptions">
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- <node id="adoptive">
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- <node id="africa">
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- <node id="alert">
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- <node id="amphibious">
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- <node id="arrived">

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Additionally, here is the same information in "Grid Format"

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	encoding	UTF-8
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	xs:element	
	name	propertyIdentities
	xs:complexType	
	xs:sequence	
	xs:element	
	ref	propertyIdentity
	maxOccurs	unbounded
	xs:element	
	name	property
	xs:complexType	
	xs:attribute	
	name	value
	type	xs:string
	use	required
	xs:attribute	
	name	id
	use	required
	xs:simpleType	
	xs:restriction	
	base	xs:string
	xs:enumeration	
	value	URL
	xs:enumeration	
	value	newman
	xs:element	
	name	nodes
	xs:complexType	
	xs:sequence	
	xs:element	
	ref	nodeclass

↑ xs:element	name	nodeclass
	xs:complexType	
	xs:sequence	
	xs:element	ref propertyIdentities
	xs:element	ref node
	xs:element	maxOccurs unbounded
	xs:attribute	
	name	type
	use	required
	xs:simpleType	
	xs:restriction	
	base	xs:string
	xs:enumeration	
	value	Knowledge
	xs:attribute	name=id use=required
↑ xs:element	name	node
	xs:complexType	
	xs:sequence	
	xs:element	ref property
	xs:element	maxOccurs unbounded
	xs:attribute	
	name	id
	type	xs:string
	use	required
↑ xs:element	name	networks
	xs:complexType	
	xs:sequence	
	xs:element	ref network
↑ xs:element	name	network
	xs:complexType	
	xs:sequence	
	xs:element	ref link
	xs:element	maxOccurs unbounded
	xs:attribute	
	name	targetType
	use	required
	xs:simpleType	
	xs:restriction	
	base	xs:string
	xs:enumeration	
	value	Knowledge
	xs:attribute	
	name	target
	use	required
	xs:simpleType	
	xs:restriction	
	base	xs:string
	xs:enumeration	
	value	knowledge
	xs:attribute	
	name	sourceType
	use	required
	xs:simpleType	
	xs:restriction	
	base	xs:string
	xs:enumeration	
	value	Knowledge
	xs:attribute	
	name	source
	use	required
	xs:simpleType	
	xs:restriction	
	base	xs:string
	xs:enumeration	
	value	knowledge

		xs:attribute name id use required xs:simpleType xs:restriction base xs:string xs:enumeration value knowledge x knowledge
xs:element name link xs:complexType xs:attribute name value xs:simpleType xs:restriction base xs:decimal xs:enumeration value 2.0 xs:enumeration value 3.0 xs:enumeration value 4.0 xs:enumeration value 5.0 xs:enumeration value 6.0 xs:enumeration value 8.0 xs:attribute name=target use=required xs:attribute name=source type=xs:string use=required		
xs:element name MetaNetwork xs:complexType xs:sequence xs:element ref nodes xs:element ref networks xs:attribute name id type xs:string use required		
xs:element name DynamicMetaNetwork xs:complexType xs:sequence xs:element ref MetaNetwork xs:attribute name id type xs:string use required		

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APPENDIX C: PAJEK GENERATED X3D CODE FOR 15 JANUARY 2010

Below is an excerpt from the initial X3D code for the 15 January 2010 dataset that is generated by Pajek. The Collaborative Learning Agent (CLA) into file Association_prob_NONE_Haiti_Cat5.txt.file-2010-01-15-simple initially extracted the file.

<i>File Name</i>	<i>File Type</i>	<i>Total Nodes</i>	<i>File Size</i>	<i>XML File Size</i>
2010-01-15newman	X3D	270 Nodes	467 KB	94 KB

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE X3D PUBLIC "ISO//Web3D//DTD X3D 3.0//EN"
"http://www.web3d.org/specifications/x3d-3.0.dtd">
<X3D profile='Immersive' version='3.0' xmlns:xsd='http://www.w3.org/2001/XMLSchema-instance'
xsd:noNamespaceSchemaLocation='http://www.web3d.org/specifications/x3d-3.0.xsd'>
  <head>
    <meta content='3. C:\Users\Elaine\Desktop\haiti_apan_lla2\Pajek Files\2010-01-15.net (270)'
name='title'/>
    <meta content='03-28-2011' name='created'/>
    <meta content='Vladimir Batagelj and Andrej Mrvar—program package Pajek:
http://vlado.fmf.uni-lj.si/pub/networks/pajek/' name='generator'/>
  </head>
  <Scene>
    <Background skyColor='1.0000 1.0000 1.0000'/>
    <Transform rotation='-22.35120 0.00000 112.43585 1.85460' translation='-0.64874 -0.42896 -
0.66276'>
      <Shape>
        <!-- Arc 1.23 -->
        <Appearance>
          <Material diffuseColor='0.0000 0.0000 0.0000'/>
        </Appearance>
        <Cylinder height='1.19413' radius='0.02000'/>
      </Shape>
    </Transform>
    <Transform rotation='-22.35120 0.00000 112.43585 1.85460' translation='-1.06026 -0.55134 -
0.74457'>
      <Shape>
        <Appearance>
          <Material diffuseColor='0.0000 0.0000 0.0000'/>
        </Appearance>
```

```

        <Cone bottomRadius='0.06000' height='0.10000' />
    </Shape>
</Transform>
<Transform rotation='-11.22472 0.00000 52.81325 2.15598' translation='-0.35062 -0.44066 -
0.60713'>
    <Shape>
        <!-- Arc 1.24 -->
        <Appearance>
            <Material diffuseColor='0.0000 0.0000 0.0000' />
        </Appearance>
        <Cylinder height='0.64770' radius='0.02000' />
    </Shape>
</Transform>
<Transform rotation='-11.22472 0.00000 52.81325 2.15598' translation='-0.48422 -0.53116 -
0.63552'>
    <Shape>
        <Appearance>
            <Material diffuseColor='0.0000 0.0000 0.0000' />
        </Appearance>
        <Cone bottomRadius='0.06000' height='0.10000' />
    </Shape>
</Transform>
<Transform rotation='-53.23500 0.00000 8.51149 0.43344' translation='-0.12911 0.32068 -
0.81718'>
    <Shape>
        <!-- Arc 1.26 -->
        <Appearance>
            <Material diffuseColor='0.0000 0.0000 0.0000' />
        </Appearance>
        <Cylinder height='1.28361' radius='0.02000' />
    </Shape>
</Transform>
<Transform rotation='-53.23500 0.00000 8.51149 0.43344' translation='-0.16106 0.75793 -
1.01700'>
    <Shape>
        <Appearance>
            <Material diffuseColor='0.0000 0.0000 0.0000' />
        </Appearance>
        <Cone bottomRadius='0.06000' height='0.10000' />
    </Shape>
</Transform>
<Transform rotation='-95.76386 0.00000 53.68924 1.79233' translation='-0.35500 -0.38541 -
1.02982'>
    <Shape>
        <!-- Arc 1.39 -->
        <Appearance>
            <Material diffuseColor='0.0000 0.0000 0.0000' />
        </Appearance>
        <Cylinder height='1.12537' radius='0.02000' />
    </Shape>
</Transform>
<Transform rotation='-95.76386 0.00000 53.68924 1.79233' translation='-0.54712 -0.47389 -
1.37249'>
    <Shape>
        <Appearance>

```

```

    <Material diffuseColor='0.0000 0.0000 0.0000'>
    </Appearance>
    <Cone bottomRadius='0.06000' height='0.10000'>
    </Shape>
    </Transform>
    <Transform rotation='48.75144 -0.00000 90.05128 1.95648' translation='-0.53681 -0.46966 -
0.30725'>
    <Shape>
    <!-- Arc 1.44 -->
    <Appearance>
    <Material diffuseColor='0.0000 0.0000 0.0000'>
    </Appearance>
    <Cylinder height='1.10519' radius='0.02000'>
    </Shape>
    </Transform>
    <Transform rotation='48.75144 -0.00000 90.05128 1.95648' translation='-0.85670 -0.61735 -
0.13407'>
    <Shape>
    <Appearance>
    <Material diffuseColor='0.0000 0.0000 0.0000'>
    </Appearance>
    <Cone bottomRadius='0.06000' height='0.10000'>
    </Shape>
    </Transform>
    <Transform rotation='-55.36428 0.00000 34.38022 1.79172' translation='-0.25846 -0.33496 -
0.82783'>
    <Shape>
    <!-- Arc 1.49 -->
    <Appearance>
    <Material diffuseColor='0.0000 0.0000 0.0000'>
    </Appearance>
    <Cylinder height='0.66794' radius='0.02000'>
    </Shape>
    </Transform>
    <Transform rotation='-55.36428 0.00000 34.38022 1.79172' translation='-0.34800 -0.37309 -
0.97203'>
    <Shape>
    <Appearance>
    <Material diffuseColor='0.0000 0.0000 0.0000'>
    </Appearance>
    <Cone bottomRadius='0.06000' height='0.10000'>
    </Shape>
    </Transform>
    <Transform rotation='-46.30303 0.00000 108.25743 1.75207' translation='-0.62784 -0.36968 -
0.78252'>
    <Shape>
    <!-- Arc 1.55 -->
    <Appearance>
    <Material diffuseColor='0.0000 0.0000 0.0000'>
    </Appearance>
    <Cylinder height='1.19705' radius='0.02000'>
    </Shape>
    </Transform>
    <Transform rotation='-46.30303 0.00000 108.25743 1.75207' translation='-1.02443 -0.44875 -
0.95215'>

```

```

    <Shape>
      <Appearance>
        <Material diffuseColor='0.0000 0.0000 0.0000' />
      </Appearance>
      <Cone bottomRadius='0.06000' height='0.10000' />
    </Shape>
  </Transform>
  <Transform rotation='51.97689 -0.00000 44.63085 1.57991' translation='-0.30971 -0.26490 -
0.29112'>
    <Shape>
      <!-- Arc 1.56 -->
      <Appearance>
        <Material diffuseColor='0.0000 0.0000 0.0000' />
      </Appearance>
      <Cylinder height='0.68512' radius='0.02000' />
    </Shape>
  </Transform>
  <Transform rotation='51.97689 -0.00000 44.63085 1.57991' translation='-0.42864 -0.26656 -
0.15262'>
    <Shape>
      <Appearance>
        <Material diffuseColor='0.0000 0.0000 0.0000' />
      </Appearance>
      <Cone bottomRadius='0.06000' height='0.10000' />
    </Shape>
  </Transform>
  <Transform rotation='1.17675 0.00000 -71.83137 1.91260' translation='0.27260 -0.38957 -
0.54512'>
    <Shape>
      <!-- Arc 1.58 -->
      <Appearance>
        <Material diffuseColor='0.0000 0.0000 0.0000' />
      </Appearance>
      <Cylinder height='0.76252' radius='0.02000' />
    </Shape>
  </Transform>
  <Transform rotation='1.17675 0.00000 -71.83137 1.91260' translation='0.48103 -0.46374 -
0.54171'>
    <Shape>
      <Appearance>
        <Material diffuseColor='0.0000 0.0000 0.0000' />
      </Appearance>
      <Cone bottomRadius='0.06000' height='0.10000' />
    </Shape>
  </Transform>
  <Transform rotation='-91.31316 0.00000 -91.39963 2.01731' translation='0.37044 -0.57105 -
1.00757'>
    <Shape>
      <!-- Arc 1.66 -->
      <Appearance>
        <Material diffuseColor='0.0000 0.0000 0.0000' />
      </Appearance>
      <Cylinder height='1.43241' radius='0.02000' />
    </Shape>
  </Transform>

```

```

<Transform rotation='-91.31316 0.00000 -91.39963 2.01731' translation='0.72535 -0.81124 -
1.36214'>
  <Shape>
    <Appearance>
      <Material diffuseColor='0.0000 0.0000 0.0000'>
    </Appearance>
    <Cone bottomRadius='0.06000' height='0.10000'>
  </Shape>
</Transform>
<Transform rotation='-75.56031 0.00000 92.16901 1.67603' translation='-0.54740 -0.32472 -
0.92881'>
  <Shape>
    <!-- Arc 1.68 -->
    <Appearance>
      <Material diffuseColor='0.0000 0.0000 0.0000'>
    </Appearance>
    <Cylinder height='1.19846' radius='0.02000'>
  </Shape>
</Transform>
<Transform rotation='-75.56031 0.00000 92.16901 1.67603' translation='-0.88520 -0.37086 -
1.20573'>
  <Shape>
    <Appearance>
      <Material diffuseColor='0.0000 0.0000 0.0000'>
    </Appearance>
    <Cone bottomRadius='0.06000' height='0.10000'>
  </Shape>
</Transform>
<Transform rotation='36.53063 0.00000 -89.21894 0.86295' translation='0.35954 0.15075 -
0.36835'>
  <Shape>
    <!-- Arc 1.69 -->
    <Appearance>
      <Material diffuseColor='0.0000 0.0000 0.0000'>
    </Appearance>
    <Cylinder height='1.26892' radius='0.02000'>
  </Shape>
</Transform>
<Transform rotation='36.53063 0.00000 -89.21894 0.86295' translation='0.69314 0.45925 -
0.23176'>
  <Shape>
    <Appearance>
      <Material diffuseColor='0.0000 0.0000 0.0000'>
    </Appearance>
    <Cone bottomRadius='0.06000' height='0.10000'>
  </Shape>
</Transform>
<Transform rotation='-9.60126 0.00000 28.92563 1.46760' translation='-0.23118 -0.24600 -
0.59901'>
  <Shape>
    <!-- Arc 1.70 -->
    <Appearance>
      <Material diffuseColor='0.0000 0.0000 0.0000'>
    </Appearance>
    <Cylinder height='0.30640' radius='0.02000'>

```

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</Shape>
</Transform>
<Transform rotation='-9.60126 0.00000 28.92563 1.46760' translation='-0.22477 -0.24670 -
0.59688'>
  <Shape>
    <Appearance>
      <Material diffuseColor='0.0000 0.0000 0.0000'/>
    </Appearance>
    <Cone bottomRadius='0.06000' height='0.10000'/>
  </Shape>
</Transform>
<Transform rotation='-3.71922 0.00000 47.01569 0.89619' translation='-0.32163 -0.07318 -
0.56960'>
  <Shape>
    <!-- Arc 1.71 -->
    <Appearance>
      <Material diffuseColor='0.0000 0.0000 0.0000'/>
    </Appearance>
    <Cylinder height='0.60391' radius='0.02000'/>
  </Shape>
</Transform>
<Transform rotation='-3.71922 0.00000 47.01569 0.89619' translation='-0.43215 0.01549 -
0.57834'>
  <Shape>
    <Appearance>
      <Material diffuseColor='0.0000 0.0000 0.0000'/>
    </Appearance>
    <Cone bottomRadius='0.06000' height='0.10000'/>
  </Shape>
</Transform>
<Transform rotation='-103.13551 0.00000 54.29686 1.75787' translation='-0.35804 -0.37209 -
1.06668'>
  <Shape>
    <!-- Arc 1.73 -->
    <Appearance>
      <Material diffuseColor='0.0000 0.0000 0.0000'/>
    </Appearance>
    <Cylinder height='1.18625' radius='0.02000'/>
  </Shape>
</Transform>
<Transform rotation='-103.13551 0.00000 54.29686 1.75787' translation='-0.55629 -0.45265 -
1.44325'>
  <Shape>
    <Appearance>
      <Material diffuseColor='0.0000 0.0000 0.0000'/>
    </Appearance>
    <Cone bottomRadius='0.06000' height='0.10000'/>
  </Shape>
</Transform>
<Transform rotation='-54.10207 0.00000 105.08376 1.73073' translation='-0.61197 -0.35711 -
0.82152'>
  <Shape>
    <!-- Arc 1.75 -->
    <Appearance>
      <Material diffuseColor='0.0000 0.0000 0.0000'/>

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```

        </Appearance>
        <Cylinder height='1.19721' radius='0.02000' />
    </Shape>
</Transform>
<Transform rotation='-54.10207 0.00000 105.08376 1.73073' translation='-0.99696 -0.42696 -
1.01972'>
    <Shape>
        <Appearance>
            <Material diffuseColor='0.0000 0.0000 0.0000' />
        </Appearance>
        <Cone bottomRadius='0.06000' height='0.10000' />
    </Shape>
</Transform>
<Transform rotation='-75.56031 0.00000 92.16901 1.67603' translation='-0.54740 -0.32472 -
0.92881'>
    <Shape>
        <!-- Arc 1.80 -->
        <Appearance>
            <Material diffuseColor='0.0000 0.0000 0.0000' />
        </Appearance>
        <Cylinder height='1.19846' radius='0.02000' />
    </Shape>
</Transform>
<Transform rotation='-75.56031 0.00000 92.16901 1.67603' translation='-0.88520 -0.37086 -
1.20573'>
    <Shape>
        <Appearance>
            <Material diffuseColor='0.0000 0.0000 0.0000' />
        </Appearance>
        <Cone bottomRadius='0.06000' height='0.10000' />
    </Shape>
</Transform>
<Transform rotation='-61.22588 0.00000 49.07388 2.31042' translation='-0.33193 -0.61974 -
0.85714'>
    <Shape>
        <!-- Arc 1.88 -->
        <Appearance>
            <Material diffuseColor='0.0000 0.0000 0.0000' />
        </Appearance>
        <Cylinder height='1.06218' radius='0.02000' />
    </Shape>
</Transform>
<Transform rotation='-61.22588 0.00000 49.07388 2.31042' translation='-0.50337 -0.86986 -
1.07104'>
    <Shape>
        <Appearance>
            <Material diffuseColor='0.0000 0.0000 0.0000' />
        </Appearance>
        <Cone bottomRadius='0.06000' height='0.10000' />
    </Shape>
</Transform>
<Transform rotation='-16.72079 0.00000 37.32166 2.32792' translation='-0.27316 -0.45501 -
0.63461'>
    <Shape>
        <!-- Arc 1.89 -->

```

```

    <Appearance>
    <Material diffuseColor='0.0000 0.0000 0.0000'>
    </Appearance>
    <Cylinder height='0.56267' radius='0.02000'>
    </Shape>
  </Transform>
  <Transform rotation='-16.72079 0.00000 37.32166 2.32792' translation='-0.35365 -0.53835 -
0.67067'>
    <Shape>
    <Appearance>
    <Material diffuseColor='0.0000 0.0000 0.0000'>
    </Appearance>
    <Cone bottomRadius='0.06000' height='0.10000'>
    </Shape>
  </Transform>
  <Transform rotation='-15.64003 0.00000 91.66205 2.13858' translation='-0.54487 -0.55833 -
0.62921'>
    <Shape>
    <!-- Arc 1.90 -->
    <Appearance>
    <Material diffuseColor='0.0000 0.0000 0.0000'>
    </Appearance>
    <Cylinder height='1.10292' radius='0.02000'>
    </Shape>
  </Transform>
  <Transform rotation='-15.64003 0.00000 91.66205 2.13858' translation='-0.87020 -0.76884 -
0.68472'>
    <Shape>
    <Appearance>
    <Material diffuseColor='0.0000 0.0000 0.0000'>
    </Appearance>
    <Cone bottomRadius='0.06000' height='0.10000'>
    </Shape>
  </Transform>
  <Transform rotation='-34.49226 0.00000 28.69624 2.32062' translation='-0.23004 -0.47070 -
0.72347'>
    <Shape>
    <!-- Arc 1.103 -->
    <Appearance>
    <Material diffuseColor='0.0000 0.0000 0.0000'>
    </Appearance>
    <Cylinder height='0.61312' radius='0.02000'>
    </Shape>
  </Transform>
  <Transform rotation='-34.49226 0.00000 28.69624 2.32062' translation='-0.29863 -0.57058 -
0.80592'>
    <Shape>
    <Appearance>
    <Material diffuseColor='0.0000 0.0000 0.0000'>
    </Appearance>
    <Cone bottomRadius='0.06000' height='0.10000'>
    </Shape>
  </Transform>
  <Transform rotation='-53.78421 0.00000 18.25664 1.07163' translation='-0.17784 -0.10694 -
0.81993'>

```

```

    <Shape>
      <!-- Arc 1.117 -->
      <Appearance>
        <Material diffuseColor='0.0000 0.0000 0.0000' />
      </Appearance>
      <Cylinder height='0.64692' radius='0.02000' />
    </Shape>
  </Transform>
  <Transform rotation='-53.78421 0.00000 18.25664 1.07163' translation='-0.22397 -0.02869 -
0.95582'>
    <Shape>
      <Appearance>
        <Material diffuseColor='0.0000 0.0000 0.0000' />
      </Appearance>
      <Cone bottomRadius='0.06000' height='0.10000' />
    </Shape>
  </Transform>
  <Transform rotation='1.77559 -0.00000 16.35923 0.74567' translation='-0.16835 -0.17269 -
0.54213'>
    <Shape>
      <!-- Arc 1.124 -->
      <Appearance>
        <Material diffuseColor='0.0000 0.0000 0.0000' />
      </Appearance>
      <Cylinder height='0.24254' radius='0.02000' />
    </Shape>
  </Transform>
  <Transform rotation='1.77559 -0.00000 16.35923 0.74567' translation='-0.14223 -0.20114 -
0.54496'>
    <Shape>
      <Appearance>
        <Material diffuseColor='0.0000 0.0000 0.0000' />
      </Appearance>
      <Cone bottomRadius='0.06000' height='0.10000' />
    </Shape>
  </Transform>
  <Transform rotation='-53.22121 0.00000 39.57865 1.73205' translation='-0.28445 -0.31572 -
0.81711'>
    <Shape>
      <!-- Arc 1.125 -->
      <Appearance>
        <Material diffuseColor='0.0000 0.0000 0.0000' />
      </Appearance>
      <Cylinder height='0.67196' radius='0.02000' />
    </Shape>
  </Transform>
  <Transform rotation='-53.22121 0.00000 39.57865 1.73205' translation='-0.38810 -0.34398 -
0.95649'>
    <Shape>
      <Appearance>
        <Material diffuseColor='0.0000 0.0000 0.0000' />
      </Appearance>
      <Cone bottomRadius='0.06000' height='0.10000' />
    </Shape>
  </Transform>

```

```

    <Transform rotation='-95.76259 0.00000 53.80093 1.79083' translation='-0.35556 -0.38461 -
1.02982'>
      <Shape>
        <!-- Arc 1.128 -->
        <Appearance>
          <Material diffuseColor='0.0000 0.0000 0.0000'/>
        </Appearance>
        <Cylinder height='1.12555' radius='0.02000'/>
      </Shape>
    </Transform>
    <Transform rotation='-95.76259 0.00000 53.80093 1.79083' translation='-0.54809 -0.47252 -
1.37250'>
      <Shape>
        <Appearance>
          <Material diffuseColor='0.0000 0.0000 0.0000'/>
        </Appearance>
        <Cone bottomRadius='0.06000' height='0.10000'/>
      </Shape>
    </Transform>
    <Transform rotation='5.02016 -0.00000 49.31128 2.27982' translation='-0.33311 -0.47438 -
0.52590'>
      <Shape>
        <!-- Arc 1.131 -->
        <Appearance>
          <Material diffuseColor='0.0000 0.0000 0.0000'/>
        </Appearance>
        <Cylinder height='0.65305' radius='0.02000'/>
      </Shape>
    </Transform>
    <Transform rotation='5.02016 -0.00000 49.31128 2.27982' translation='-0.45885 -0.58280 -
0.51310'>
      <Shape>
        <Appearance>
          <Material diffuseColor='0.0000 0.0000 0.0000'/>
        </Appearance>
        <Cone bottomRadius='0.06000' height='0.10000'/>
      </Shape>
    </Transform>
    <Transform rotation='-47.41887 0.00000 69.71455 2.29882' translation='-0.43513 -0.63755 -
0.78810'>
      <Shape>
        <!-- Arc 1.147 -->
        <Appearance>
          <Material diffuseColor='0.0000 0.0000 0.0000'/>
        </Appearance>
        <Cylinder height='1.12946' radius='0.02000'/>
      </Shape>
    </Transform>
    <Transform rotation='-47.41887 0.00000 69.71455 2.29882' translation='-0.68494 -0.90686 -
0.95802'>
      <Shape>
        <Appearance>
          <Material diffuseColor='0.0000 0.0000 0.0000'/>
        </Appearance>
        <Cone bottomRadius='0.06000' height='0.10000'/>

```

```

</Shape>
</Transform>
<Transform rotation='11.68971 -0.00000 81.66135 2.29375' translation='-0.49486 -0.62570 -
0.49256'>
  <Shape>
    <!-- Arc 1.152 -->
    <Appearance>
      <Material diffuseColor='0.0000 0.0000 0.0000'>
    </Appearance>
    <Cylinder height='1.10013' radius='0.02000'>
  </Shape>
</Transform>
<Transform rotation='11.68971 -0.00000 81.66135 2.29375' translation='-0.78440 -0.88377 -
0.45111'>
  <Shape>
    <Appearance>
      <Material diffuseColor='0.0000 0.0000 0.0000'>
    </Appearance>
    <Cone bottomRadius='0.06000' height='0.10000'>
  </Shape>
</Transform>
<Transform rotation='-3.37791 0.00000 -65.23328 2.11032' translation='0.23961 -0.45734 -
0.56790'>
  <Shape>
    <!-- Arc 1.155 -->
    <Appearance>
      <Material diffuseColor='0.0000 0.0000 0.0000'>
    </Appearance>
    <Cylinder height='0.76135' radius='0.02000'>
  </Shape>
</Transform>
<Transform rotation='-3.37791 0.00000 -65.23328 2.11032' translation='0.42869 -0.57071 -
0.57769'>
  <Shape>
    <Appearance>
      <Material diffuseColor='0.0000 0.0000 0.0000'>
    </Appearance>
    <Cone bottomRadius='0.06000' height='0.10000'>
  </Shape>
</Transform>
<Transform rotation='-85.13596 0.00000 54.26538 2.06828' translation='-0.35788 -0.53591 -
0.97669'>
  <Shape>
    <!-- Arc 1.157 -->
    <Appearance>
      <Material diffuseColor='0.0000 0.0000 0.0000'>
    </Appearance>
    <Cylinder height='1.14886' radius='0.02000'>
  </Shape>
</Transform>
<Transform rotation='-85.13596 0.00000 54.26538 2.06828' translation='-0.55364 -0.73368 -
1.28380'>
  <Shape>
    <Appearance>
      <Material diffuseColor='0.0000 0.0000 0.0000'>

```

```

    </Appearance>
    <Cone bottomRadius='0.06000' height='0.10000' />
  </Shape>
</Transform>
<Transform rotation='-4.58522 0.00000 -0.93369 2.97423' translation='-0.08189 -0.40027 -
0.57393'>
  <Shape>
    <!-- Arc 1.167 -->
    <Appearance>
      <Material diffuseColor='0.0000 0.0000 0.0000' />
    </Appearance>
    <Cylinder height='0.28090' radius='0.02000' />
  </Shape>
</Transform>
<Transform rotation='-4.58522 0.00000 -0.93369 2.97423' translation='-0.08254 -0.38099 -
0.57074'>
  <Shape>
    <Appearance>
      <Material diffuseColor='0.0000 0.0000 0.0000' />
    </Appearance>
    <Cone bottomRadius='0.06000' height='0.10000' />
  </Shape>
</Transform>
<Transform rotation='-55.36728 0.00000 34.34280 1.79253' translation='-0.25827 -0.33522 -
0.82784'>
  <Shape>
    <!-- Arc 1.173 -->
    <Appearance>
      <Material diffuseColor='0.0000 0.0000 0.0000' />
    </Appearance>
    <Cylinder height='0.66788' radius='0.02000' />
  </Shape>
</Transform>
<Transform rotation='-55.36728 0.00000 34.34280 1.79253' translation='-0.34771 -0.37347 -
0.97204'>
  <Shape>
    <Appearance>
      <Material diffuseColor='0.0000 0.0000 0.0000' />
    </Appearance>
    <Cone bottomRadius='0.06000' height='0.10000' />
  </Shape>
</Transform>
<Transform rotation='-47.41887 0.00000 69.71455 2.29882' translation='-0.43513 -0.63755 -
0.78810'>
  <Shape>
    <!-- Arc 1.179 -->
    <Appearance>
      <Material diffuseColor='0.0000 0.0000 0.0000' />
    </Appearance>
    <Cylinder height='1.12946' radius='0.02000' />
  </Shape>
</Transform>

```

APPENDIX D: 15 JANUARY 2010 EXCERPT ARCS AND VERTICES

The following is the examples X3D scene that adapts and refactors the Appendix C output generated by Pajek from the 15 January 2010 dataset. This example is the design basis for the reusable X3D visualization prototypes in Appendix E.

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE X3D PUBLIC "ISO//Web3D//DTD X3D 3.2//EN"
"http://www.web3d.org/specifications/x3d-3.2.dtd">
<X3D profile='Immersive' version='3.2' xmlns:xsd='http://www.w3.org/2001/XMLSchema-instance'
xsd:noNamespaceSchemaLocation='http://www.web3d.org/specifications/x3d-3.2.xsd'>
  <head>
    <meta content='*enter FileNameWithNoAbbreviations.x3d here*' name='title'/>
    <meta content='*enter description here, short-sentence summaries preferred*'
name='description'/>
    <meta content='*enter name of original author here*' name='creator'/>
    <meta content='*if manually translating VRML-to-X3D, enter name of person translating here*'
name='translator'/>
    <meta content='*enter date of initial version here*' name='created'/>
    <meta content='*enter date of translation here*' name='translated'/>
    <meta content='*enter date of latest revision here*' name='modified'/>
    <meta content='*enter version here, if any*' name='version'/>
    <meta content='*enter reference citation or relative/online url here*' name='reference'/>
    <meta content='*enter additional url/bibliographic reference information here*'
name='reference'/>
    <meta content='*enter reference resource here if required to support function, delivery, or
coherence of content*' name='requires'/>
    <meta content='*enter copyright information here* Example: Copyright (c) Web3D Consortium
Inc. 2008' name='rights'/>
    <meta content='*enter drawing filename/url here*' name='drawing'/>
    <meta content='*enter image filename/url here*' name='image'/>
    <meta content='*enter movie filename/url here*' name='MovingImage'/>
    <meta content='*enter photo filename/url here*' name='photo'/>
    <meta content='*enter subject keywords here*' name='subject'/>
    <meta content='*enter permission statements or url here*' name='accessRights'/>
    <meta content='*insert any known warnings, bugs or errors here*' name='warning'/>
    <meta content='*enter online Uniform Resource Identifier (URI) or Uniform Resource Locator
(URL) address for this file here*' name='identifier'/>
    <meta content='X3D-Edit, https://savage.nps.edu/X3D-Edit' name='generator'/>
    <meta content='../license.html' name='license'/>
  </head>
  <Scene>
    <Background skyColor='1.0000 1.0000 1.0000'/>
    <Transform rotation='-11.22472 0.00000 52.81325 2.15598' translation='-0.35062 -0.44066 -
0.60713'>
      <Shape>
        <!-- Arc 1.24 -->
        <Appearance>
```

```

        <Material diffuseColor='0.0000 0.0000 0.0000'>
    </Appearance>
    <Cylinder height='0.64770' radius='0.02000'>
</Shape>
</Transform>
<Transform rotation='-11.22472 0.00000 52.81325 2.15598' translation='-0.48422 -0.53116 -
0.63552'>
    <Shape>
        <Appearance>
            <Material diffuseColor='0.0000 0.0000 0.0000'>
        </Appearance>
        <Cone bottomRadius='0.06000' height='0.10000'>
    </Shape>
    </Transform>
    <Transform rotation='-53.23500 0.00000 8.51149 0.43344' translation='-0.12911 0.32068 -
0.81718'>
        <Shape>
            <!-- Arc 1.26 -->
            <Appearance>
                <Material diffuseColor='0.0000 0.0000 0.0000'>
            </Appearance>
            <Cylinder height='1.28361' radius='0.02000'>
        </Shape>
        </Transform>
        <Transform rotation='-53.23500 0.00000 8.51149 0.43344' translation='-0.16106 0.75793 -
1.01700'>
            <Shape>
                <Appearance>
                    <Material diffuseColor='0.0000 0.0000 0.0000'>
                </Appearance>
                <Cone bottomRadius='0.06000' height='0.10000'>
            </Shape>
            </Transform>
            <Transform rotation='-95.76386 0.00000 53.68924 1.79233' translation='-0.35500 -0.38541 -
1.02982'>
                <Shape>
                    <!-- Arc 1.39 -->
                    <Appearance>
                        <Material diffuseColor='0.0000 0.0000 0.0000'>
                    </Appearance>
                    <Cylinder height='1.12537' radius='0.02000'>
                </Shape>
                </Transform>
                <Transform rotation='-95.76386 0.00000 53.68924 1.79233' translation='-0.54712 -0.47389 -
1.37249'>
                    <Shape>
                        <Appearance>
                            <Material diffuseColor='0.0000 0.0000 0.0000'>
                        </Appearance>
                        <Cone bottomRadius='0.06000' height='0.10000'>
                    </Shape>
                    </Transform>
                    <Anchor description='1: 2010-01-15-ARMY.MIL'>
                    <Transform translation='-0.08656 -0.26178 -0.55101'>
                        <Shape>

```

```

<!-- Vertex 1 -->
<Appearance>
  <Material diffuseColor='0.0000 0.0000 0.0000'/>
</Appearance>
<Sphere radius='0.1500'/>
</Shape>
</Transform>
<Transform translation='0.06344 -0.26178 -0.55101'>
  <Shape>
    <Appearance>
      <Material diffuseColor='0.0000 0.0000 0.0000'/>
    </Appearance>
    <Text string='2010-01-15-ARMY.MIL'>
      <FontStyle family='Arial Unicode MS' size='0.20000'/>
    </Text>
  </Shape>
</Transform>
</Anchor>
<Anchor description='2: 2010-01-15-BLOGS.STATE.GOV-INDEX.PHP'>
  <Transform translation='1.28526 1.19707 0.67279'>
    <Shape>
      <!-- Vertex 2 -->
      <Appearance>
        <Material diffuseColor='0.5020 0.0000 0.0000'/>
      </Appearance>
      <Sphere radius='0.1500'/>
    </Shape>
  </Transform>
  <Transform translation='1.43526 1.19707 0.67279'>
    <Shape>
      <Appearance>
        <Material diffuseColor='0.0000 0.0000 0.0000'/>
      </Appearance>
      <Text string='2010-01-15-BLOGS.STATE.GOV-INDEX.PHP'>
        <FontStyle family='Arial Unicode MS' size='0.20000'/>
      </Text>
    </Shape>
  </Transform>
</Anchor>
<Anchor description='3: 2010-01-15-FEEDS.FEEDBURNER.COM-DIPNOTE'>
  <Transform translation='-0.06623 1.98542 -1.19849'>
    <Shape>
      <!-- Vertex 3 -->
      <Appearance>
        <Material diffuseColor='1.0000 0.0000 0.0000'/>
      </Appearance>
      <Sphere radius='0.1500'/>
    </Shape>
  </Transform>
  <Transform translation='0.08377 1.98542 -1.19849'>
    <Shape>
      <Appearance>
        <Material diffuseColor='0.0000 0.0000 0.0000'/>
      </Appearance>
      <Text string='2010-01-15-FEEDS.FEEDBURNER.COM-DIPNOTE'>

```

```
<FontStyle family='Arial Unicode MS' size='0.20000' />
</Text>
</Shape>
</Transform>
</Anchor>
</Scene>
</X3D>
```

APPENDIX E: X3D PROTOTYPE

The following are the X3D Prototypes authored by Elaine Reid and Don Brutzman. Visualization techniques extending the Pajek output are captured as X3D Prototypes for simplification resues and repeatability. To minimize the amount of code and produce a prototype that can be tested, three nodes (vertices), and three links(arcs) are used. These prototype declarations make the adapted refactoring make the adapted refactorings of Appendix D into repeatable, reusable, simpler output design patterns.

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE X3D PUBLIC "ISO/Web3D//DTD X3D 3.2//EN"
"http://www.web3d.org/specifications/x3d-3.2.dtd">
<X3D profile='Immersive' version='3.2' xmlns:xsd='http://www.w3.org/2001/XMLSchema-instance'
xsd:noNamespaceSchemaLocation='http://www.web3d.org/specifications/x3d-3.2.xsd'>
  <head>
    <meta content='PajekVisualizationPrototypes.x3d' name='title'/>
    <meta content='Reverse engineer and hopefully elaborate on Pajek visualization structures'
name='description'/>
    <meta content='Don Brutzman and Elaine Reid' name='creator'/>
    <meta content='29 March 2011' name='created'/>
    <meta content='23 May 2011' name='modified'/>
    <meta content='http://pajek.imfm.si' name='reference'/>
    <meta content='network visualization' name='subject'/>
    <meta content='under development' name='warning'/>
    <meta
content='https://savage.nps.edu/Savage/Tools/Visualization/PajekVisualizationPrototypes.x3d'
name='identifier'/>
    <meta content='X3D-Edit, https://savage.nps.edu/X3D-Edit' name='generator'/>
    <meta content='../license.html' name='license'/>
  </head>
  <Scene>
    <ProtoDeclare appinfo='Arc is a network connection between Vertex nodes, displayed using
Cylinder/Cone (arrow/arrowhead) geometry with modifiable color and transparency' name='Arc'>
      <ProtoInterface>
        <field accessType='inputOutput' appinfo='name to identify this Arc' name='name'
type='SFString' value='TODOprovideInitialValue'/>
        <field accessType='inputOutput' appinfo='popup text describing this Arc' name='description'
type='SFString' value='TODO customize this Arc description'/>
        <field accessType='initializeOnly' appinfo='length of Arc between Vertex locations'
name='cylinderHeight' type='SFFloat' value='1'/>
        <field accessType='inputOutput' appinfo='link to some other resource' name='url'
type='MFString'/>
      </ProtoInterface>
    </ProtoDeclare>
  </Scene>
</X3D>
```

```

    <field accessType='inputOutput' appinfo='location of Arc' name='cylinderTranslation'
type='SFVec3f' value='0 0 0'/>
    <field accessType='inputOutput' appinfo='see TODO items in ArcScript'
name='coneTranslation' type='SFVec3f' value='0 0 0'/>
    <field accessType='inputOutput' appinfo='orientation of Arc' name='rotation'
type='SFRotation' value='0 1 0 0'/>
    <field accessType='inputOutput' appinfo='rendering choices: BallAndStick, Ball, Stick'
name='displayMode' type='SFString' value='BallAndStick'/>
    <field accessType='inputOutput' appinfo='diffuseColor of Arc' name='color' type='SFColor'
value='0.0000 0.0000 0.0000'/>
    <field accessType='inputOutput' appinfo='transparency of Arc' name='transparency'
type='SFFloat' value='0.0'/>
    <field accessType='inputOutput' appinfo='offset distance for Cone arrowhead; TODO this
needs to match values in the Vertex protopye, which is initialized separately' name='ballRadius'
type='SFFloat' value='1'/>
    <field accessType='inputOutput' appinfo='debug trace to Browser output console'
name='traceEnabled' type='SFBool' value='true'/>
    <field accessType='inputOutput' appinfo='outward indication of Arc' name='appearance'
type='SFImage' value='0.0'/>
</ProtoInterface>
<ProtoBody>
<!-- First node determines node type of this prototype -->
<Anchor DEF='ArcPrototypeRootNode'>
  <IS>
    <connect nodeField='description' protoField='description'/>
    <connect nodeField='url' protoField='url'/>
  </IS>
  <Group>
    <Transform DEF='CylinderTransform' rotation='-0.4367 0 0.8996 1.60563' translation='-
1.166 0.60861 -2.23229'>
      <IS>
        <connect nodeField='translation' protoField='cylinderTranslation'/>
        <connect nodeField='rotation' protoField='rotation'/>
      </IS>
      <Shape>
        <Appearance>
          <Material DEF='CylinderMaterial' diffuseColor='0 0 0' shininess='0.8'
specularColor='0.8 0.8 0.8'/>
        </Appearance>
        <!-- TODO these trial values are from Arc 1.6, radius is a candidate parameter -->
        <Cylinder radius='0.02'>
          <IS>
            <connect nodeField='height' protoField='cylinderHeight'/>
          </IS>
        </Cylinder>
      </Shape>
    </Transform>
    <Transform DEF='ConeTransform' rotation='-0.4367 0 0.8996 1.6056' translation='-
1.49373 0.59592 -2.39136'>
      <IS>
        <connect nodeField='translation' protoField='coneTranslation'/>
        <connect nodeField='rotation' protoField='rotation'/>
      </IS>
      <Shape>
        <IS>

```

```

        <connect nodeField='appearance' protoField='appearance'/>
    </IS>
    <Cone bottomRadius='0.06' height='0.1'/>
    <Appearance>
        <Material DEF='ConeMaterial' diffuseColor='0 0 0' shininess='.8' specularColor='.8 .8
.8'>
            <IS>
                <connect nodeField='transparency' protoField='transparency'/>
            </IS>
        </Material>
    </Appearance>
</Shape>
</Transform>
</Group>
</Anchor>
<!--This embedded script provides the X3D author with additional control and visibility over
Prototype inputs and outputs -->
    <Script DEF='ArcScript'>
        <field accessType='inputOutput' appinfo='name to identify this Arc' name='name'
type='SFString'/>
        <field accessType='inputOutput' appinfo='popup text describing this Arc' name='description'
type='SFString'/>
        <field accessType='initializeOnly' appinfo='length of Arc between Vertex locations'
name='cylinderHeight' type='SFFloat'/>
        <field accessType='inputOutput' appinfo='link to some other resource' name='url'
type='MFString'/>
        <field accessType='inputOutput' appinfo='location of Arc' name='cylinderTranslation'
type='SFVec3f'/>
        <field accessType='inputOutput' appinfo='see TODO items in ArcScript'
name='coneTranslation' type='SFVec3f'/>
        <field accessType='inputOutput' appinfo='orientation of Arc' name='rotation'
type='SFRotation'/>
        <field accessType='inputOutput' appinfo='rendering choices: BallAndStick, Ball, Stick'
name='displayMode' type='SFString'/>
        <field accessType='inputOutput' appinfo='diffuseColor of Arc' name='color'
type='SFColor'/>
        <field accessType='inputOutput' appinfo='transparency of Arc' name='transparency'
type='SFFloat'/>
        <field accessType='inputOutput' appinfo='offset distance for Cone arrowhead; TODO this
needs to match values in the Vertex protopye, which is initialized separately' name='ballRadius'
type='SFFloat'/>
        <field accessType='inputOutput' appinfo='debug trace to Browser output console'
name='traceEnabled' type='SFBool'/>
        <field accessType='inputOutput' appinfo='outward indication of Arc' name='appearance'
type='SFImage' value='0.0'/>
    <IS>
        <connect nodeField='name' protoField='name'/>
        <connect nodeField='description' protoField='description'/>
        <connect nodeField='cylinderHeight' protoField='cylinderHeight'/>
        <connect nodeField='url' protoField='url'/>
        <connect nodeField='cylinderTranslation' protoField='cylinderTranslation'/>
        <connect nodeField='coneTranslation' protoField='coneTranslation'/>
        <connect nodeField='rotation' protoField='rotation'/>
        <connect nodeField='displayMode' protoField='displayMode'/>
        <connect nodeField='color' protoField='color'/>

```

```

    <connect nodeField='transparency' protoField='transparency'/>
    <connect nodeField='ballRadius' protoField='ballRadius'/>
    <connect nodeField='traceEnabled' protoField='traceEnabled'/>
    <connect nodeField='appearance' protoField='appearance'/>
  </IS>
  <![CDATA[
ecmascript:
function initialize ()
{
  // TODO? potential visualization improvement (at possible cost of breaking simple 1:1 mapping)
  // compute Cone translation (and perhaps cone size) based on Cylinder size
  // then send result to the Cone parent transform

  // conceivably this extended Cylinder length is a feature, not a bug...
  // if the Cylinder goes to the center of the ball, then you can turn off both
  // balls and Cone arrowheads to yield a simple stick-only model
  // so we need to consider this as an animation/visualization feature as well

  tracePrint ('ArcScript ' + name + ': ' initialization() successful');
}
function set_name (eventValue)
{
  // input eventValue received for inputOutput field name
  name = eventValue;
  tracePrint ('name = ' + name);
}
function set_description (eventValue)
{
  // input eventValue received for inputOutput field description
  description = eventValue;
  tracePrint ('description = ' + description);
}
function set_cylinderTranslation (eventValue)
{
  // input eventValue received for inputOutput field cylinderTranslation
  cylinderTranslation = eventValue;
  tracePrint ('cylinderTranslation = ' + cylinderTranslation);

  // TODO author code (if any) goes here
}
function set_coneTranslation (eventValue)
{
  // input eventValue received for inputOutput field coneTranslation
  coneTranslation = eventValue;
  tracePrint ('coneTranslation = ' + coneTranslation);

  // TODO author code (if any) goes here
}
function set_rotation (eventValue)
{
  // input eventValue received for inputOutput field rotation
  rotation = eventValue;
  tracePrint ('rotation = ' + rotation);

  // TODO author code (if any) goes here

```

```

}
function set_displayMode (eventValue)
{
    // input eventValue received for inputOutput field displayMode
    displayMode = eventValue;
    tracePrint ('displayMode = ' + displayMode);

    // TODO author code (if any) goes here
}
function set_color (eventValue)
{
    // input eventValue received for inputOutput field color
    color = eventValue;
    tracePrint ('color = ' + color);

    // TODO author code (if any) goes here
}
function set_transparency (eventValue)
{
    // input eventValue received for inputOutput field transparency
    transparency = eventValue;
    tracePrint ('transparency = ' + transparency);

    // TODO author code (if any) goes here
}
function set_ballRadius (eventValue)
{
    // input eventValue received for inputOutput field ballRadius
    ballRadius = eventValue;
    tracePrint ('ballRadius = ' + ballRadius);

    // TODO author code (if any) goes here
}
// ===== Trace output functions =====

function tracePrint (outputString)
{
    // if traceEnabled is true, print outputString on X3D browser console
    if (traceEnabled)
        Browser.println ('[Arc ' + name + ': ' + outputString + ']');
}
function alwaysPrint (outputString)
{
    // always print outputString on X3D browser console
    Browser.println ('[Arc ' + name + ': ' + outputString + ']');
}
function set_traceEnabled (eventValue)
{
    // input eventValue received for inputOutput field
    traceEnabled = eventValue;
}
// =====

]]>
</Script>
<!-- Add any ROUTEs here that connect Script to/from prior nodes within ProtoBody -->

```

```

    </ProtoBody>
  </ProtoDeclare>
  <ProtoDeclare appinfo='Vertex is a node, typically connected by zero or more Arc segments,
and displayed using Sphere geometry with modifiable color and transparency' name='Vertex'>
    <ProtoInterface>
      <field accessType='inputOutput' appinfo='name to identify this Vertex' name='name'
type='SFString' value='TODOprovideVertexName'/>
      <field accessType='inputOutput' appinfo='popup text describing this Vertex'
name='description' type='SFString' value='TODO customize this Vertex description'/>
      <field accessType='inputOutput' appinfo='link to some other resource' name='url'
type='MFString'/>
      <field accessType='initializeOnly' appinfo='size of Vertex ball' name='radius' type='SFFloat'
value='1'/>
      <field accessType='inputOutput' appinfo='rendering choices: BallAndStick, Ball, Stick'
name='displayMode' type='SFString' value='BallAndStick'/>
      <field accessType='inputOutput' appinfo='diffuseColor of Vertex' name='color'
type='SFCOLOR' value='0.8 0.8 0.8'/>
      <field accessType='inputOutput' appinfo='transparency of Vertex' name='transparency'
type='SFFloat' value='0.0'/>
      <field accessType='inputOutput' appinfo='location of Vertex' name='translation'
type='SFVec3f'/>
      <field accessType='inputOutput' appinfo='labels to identify Vertex' name='vertexText'
type='MFString' value='TODOprovideVertexText'/>
      <field accessType='inputOutput' appinfo='location of Text' name='textTranslation'
type='SFVec3f'/>
      <field accessType='inputOutput' appinfo='diffuseColor of Text' name='textColor'
type='SFCOLOR' value='0 0 0'/>
    </ProtoInterface>
  <ProtoBody>
    <!-- First node determines node type of this prototype -->
    <Group DEF='VertexPrototypeRootNode'>
      <Anchor>
        <IS>
          <connect nodeField='name' protoField='name'/>
          <connect nodeField='description' protoField='description'/>
          <connect nodeField='url' protoField='url'/>
        </IS>
      </Group>
      <Transform>
        <IS>
          <connect nodeField='translation' protoField='translation'/>
        </IS>
      <Shape>
        <Appearance>
          <Material>
            <IS>
              <connect nodeField='diffuseColor' protoField='color'/>
              <connect nodeField='transparency' protoField='transparency'/>
            </IS>
          </Material>
        </Appearance>
        <Sphere>
          <IS>
            <connect nodeField='radius' protoField='radius'/>
          </IS>
        </Sphere>
      </Shape>
    </Group>
  </ProtoBody>
</ProtoDeclare>

```

```

    </Sphere>
  </Shape>
</Transform>
<!-- TODO for future work: Billboard for text visibility -->
<Transform>
  <IS>
    <connect nodeField='translation' protoField='textTranslation'/>
  </IS>
  <Shape>
    <Appearance>
      <Material>
        <IS>
          <connect nodeField='diffuseColor' protoField='textColor'/>
        </IS>
      </Material>
    </Appearance>
    <Text>
      <IS>
        <connect nodeField='string' protoField='vertexText'/>
      </IS>
      <!-- TODO do we really want to honor Pajek's default Text family? -->
      <FontStyle family='Arial Unicode MS' size='0.20000'/>
    </Text>
  </Shape>
</Transform>
</Group>
</Anchor>
</Group>
<!-- Subsequent nodes do not render, but still must be a valid X3D subgraph -->
</ProtoBody>
</ProtoDeclare>
<ProtoDeclare appinfo='Text describing what the Vertices and Arcs are about'
name='NetworkText'>
  <ProtoInterface>
    <field accessType='inputOutput' appinfo='information to identify the Integral Network'
name='text' type='MFString' value='TODOcustomizeThisNetworkText'/>
  </ProtoInterface>
  <ProtoBody>
    <Transform>
      <Group>
        <Transform>
          <Shape>
            <Appearance>
              <Material diffuseColor='0.9 0.9 0.9'/>
            </Appearance>
            <Text DEF='NetworkText' solid='false'>
              <IS>
                <connect nodeField='string' protoField='text'/>
              </IS>
              <FontStyle size='1'/>
            </Text>
          </Shape>
        </Transform>
      </Group>
    </Transform>
  </ProtoBody>

```

```

</ProtoBody>
</ProtoDeclare>
<Background groundAngle='1.309 1.571' groundColor='0 0.5 0.7 0 0.4 0.7 0.6 0.5 0.7'
skyAngle='1.309 1.571' skyColor='0 0.5 0.8 0 0.6 0.7 0.6 0.6 0.7'/>
<PointLight ambientIntensity='1' location='0 0 5' radius='30'/>
<NavigationInfo transitionType='ANIMATE' type=""EXAMINE""FLY""ANY""/>
<Viewpoint description='Inspect 15JAN2010Newman' fieldOfView='0.7854' orientation='1 0 0 -
0.0997' position='0 2 20'/>
<!-- type="3D" <date day="03" month="05" year="2011"/> -->
<Transform DEF='infogroup' translation='-8 2 -4">
  <Transform DEF='NetText' translation='0 6 0">
    <ProtoInstance name='NetworkText'>
      <fieldValue name='text' value='15JAN2010'/>
    </ProtoInstance>
  </Transform>
</Transform>
<Group>
  <!-- Simple examples follow -->
  <Transform>
    <ProtoInstance name='Vertex'>
      <fieldValue name='name' value='Vertex 1'/>
      <fieldValue name='description' value='2010-01-15-ARMY.MIL'/>
      <fieldValue name='vertexText' value='2010-01-15-ARMY.MIL'/>
      <fieldValue name='textTranslation' value='0.06344 -0.26178 -0.55101'/>
      <fieldValue name='textColor' value='0 0 0'/>
      <fieldValue name='url' value='http://www.army.mil'/>
      <fieldValue name='translation' value='0.06344 -0.26178 -0.55101'/>
      <fieldValue name='radius' value='.1500'/>
      <fieldValue name='displayMode' value='BallAndStick'/>
      <fieldValue name='color' value='0.0000 0.0000 0.0000'/>
      <fieldValue name='transparency' value='0.0'/>
    </ProtoInstance>
    <ProtoInstance name='Arc'>
      <fieldValue name='name' value='1.24'/>
      <fieldValue name='description' value='From blah to blah'/>
      <fieldValue name='url' value='http://www.google.com'/>
      <fieldValue name='cylinderHeight' value='0.64770'/>
      <fieldValue name='cylinderTranslation' value='-0.35062 -0.44066 -0.60713'/>
      <fieldValue name='coneTranslation' value='- .48422 -.53116 -.63552'/>
      <fieldValue name='rotation' value='-11.22472 0.00000 52.81325 2.15598'/>
      <fieldValue name='displayMode' value='BallAndStick'/>
      <fieldValue name='color' value='0.0000 0.0000 0.0000'/>
      <fieldValue name='transparency' value='0.0'/>
      <fieldValue name='ballRadius' value='1'/>
    </ProtoInstance>
    <ProtoInstance name='Vertex'>
      <fieldValue name='name' value='Vertex 2'/>
      <fieldValue name='description' value='2010-01-15BLOGS.STATE.GOV-INDEX.PHP'/>
      <fieldValue name='vertexText' value='2010-01-15BLOGS.STATE.GOV-INDEX.PHP'/>
      <fieldValue name='textTranslation' value='1.43526 1.19707 0.67279'/>
      <fieldValue name='textColor' value='0 0 0'/>
      <fieldValue name='url' value='http://www.state.gov'/>
      <fieldValue name='translation' value='1.28526 1.19707 0.67279'/>
      <fieldValue name='radius' value='0.1500'/>
      <fieldValue name='displayMode' value='BallAndStick'/>

```

```

    <fieldValue name='color' value='0.5020 0.0000 0.0000' />
    <fieldValue name='transparency' value='0.0' />
  </ProtoInstance>
  <ProtoInstance name='Arc'>
    <fieldValue name='name' value='1.26' />
    <fieldValue name='description' value='From blah1 to blah1' />
    <fieldValue name='url' value='http://www.google.com' />
    <fieldValue name='cylinderHeight' value='1.28361' />
    <fieldValue name='cylinderTranslation' value='-0.12911 0.32068 -0.81718' />
    <fieldValue name='coneTranslation' value='-0.16106 0.75793 -1.01700' />
    <fieldValue name='rotation' value='-53.23500 0.00000 8.51149 0.43344' />
    <fieldValue name='displayMode' value='BallAndStick' />
    <fieldValue name='color' value='0 0 0' />
    <fieldValue name='transparency' value='0.0' />
    <fieldValue name='ballRadius' value='1' />
  </ProtoInstance>
  <ProtoInstance name='Vertex'>
    <fieldValue name='name' value='Vertex 3' />
    <fieldValue name='description' value='2010-01-15-FEEDS.FEEDBURNER.COM-DIPNOTE' />
    <fieldValue name='vertexText' value='2010-01-15-FEEDS.FEEDBURNER.COM-DIPNOTE' />
    <fieldValue name='textColor' value='0 0 0' />
    <fieldValue name='textTranslation' value='0.08377 1.98542 -1.19849' />
    <fieldValue name='url' value='http://www.feedburner.com' />
    <fieldValue name='translation' value='-0.06623 1.98542 -1.19849' />
    <fieldValue name='radius' value='.1500' />
    <fieldValue name='displayMode' value='BallAndStick' />
    <fieldValue name='color' value='1.0000 0.0000 0.0000' />
    <fieldValue name='transparency' value='0.0' />
  </ProtoInstance>
  <ProtoInstance name='Arc'>
    <fieldValue name='name' value='1.39' />
    <fieldValue name='description' value='From blah2 to blah2' />
    <fieldValue name='url' value='http://www.google.com' />
    <fieldValue name='cylinderHeight' value='1.12537' />
    <fieldValue name='cylinderTranslation' value='-0.35500 -0.38541 -1.02982' />
    <fieldValue name='coneTranslation' value='-0.54712 -0.47389 -1.37249' />
    <fieldValue name='rotation' value='-95.76386 0.00000 53.68924 1.79233' />
    <fieldValue name='displayMode' value='BallAndStick' />
    <fieldValue name='color' value='0.0000 0.0000 0.0000' />
    <fieldValue name='transparency' value='0.0' />
    <fieldValue name='ballRadius' value='1' />
  </ProtoInstance>
</Transform>
</Group>
</Scene>
</X3D>

```

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APPENDIX F: CONVERTED X3D CODE FROM XSLT

This appendix contains the XSLT stylesheet that was based on the X3D Prototype example in Appendix D, then structured to transform the Pajek X3D File of Appendix D into the Prototype X3D File.

```
<?xml version="1.0"?>

<xsl:stylesheet version="1.0"
xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
xmlns:date="http://exslt.org/dates-and-times">

<xsl:output method="xml" encoding="UTF-8" media-type="model/x3d+xml"
cdata-section-elements="Script" indent="yes"
doctype-public="ISO//Web3D//DTD X3D 3.0//EN"
doctype-system="http://www.web3d.org/specifications/x3d-3.0.dtd"/>

<xsl:template match="/">
<X3D profile='Immersive' version='3.2' xmlns:xsd='http://www.w3.org/2001/XMLSchema-
instance' xsd:noNamespaceSchemaLocation='http://www.web3d.org/specifications/x3d-3.2.xsd'>
  <xsl:text>&#10;</xsl:text>
  <head>
    <meta content='PajekVisualizationExamples.x3d' name='title'/>
    <meta content='Reverse engineer and hopefully elaborate on Pajek visualization structures'
name='description'/>
    <meta content='Don Brutzman and Elaine Reid' name='creator'/>
    <meta content='17 May 2011' name='created'/>
    <meta content='17 May 2011' name='modified'/>
    <meta content='http://pajek.imfm.si' name='reference'/>
    <meta content='network visualization' name='subject'/>
    <meta content='under development' name='warning'/>
    <meta
content='https://savage.nps.edu/Savage/Tools/Visualization/PajekVisualizationExamples.x3d'
name='identifier'/>
    <meta content='X3D-Edit, https://savage.nps.edu/X3D-Edit' name='generator'/>
    <meta content='.././license.html' name='license'/>
  </head>
  <xsl:text>&#10;</xsl:text>
  <Scene>
    <xsl:text>&#10;</xsl:text>
    <ExternProtoDeclare name='Arc' url=""PajekVisualizationPrototypes.x3d#Arc"
"https://savage.nps.edu/Savage/Tools/Visualization/PajekVisualizationPrototypes.x3d#Arc"
appinfo='Arc is a network connection between Vertex nodes, displayed using Cylinder/Cone
(arrow/arrowhead) geometry with modifiable color and transparency'>
      <field accessType='inputOutput' appinfo='name to identify this Arc' name='name'
type='SFString'/>
      <field accessType='inputOutput' appinfo='popup text describing this Arc'
name='description' type='SFString'/>
    </ExternProtoDeclare>
  </Scene>
</X3D>
</template>
```

```

    <field accessType='initializeOnly' appinfo='length of Arc between Vertex locations'
name='cylinderHeight' type='SFFloat'>/>
    <field accessType='inputOutput' appinfo='link to some other resource' name='url'
type='MFString'>/>
    <field accessType='inputOutput' appinfo='location of Arc' name='cylinderTranslation'
type='SFVec3f'>/>
    <field accessType='inputOutput' appinfo='see TODO items in ArcScript'
name='coneTranslation' type='SFVec3f'>/>
    <field accessType='inputOutput' appinfo='orientation of Arc' name='rotation'
type='SFRotation'>/>
    <field accessType='inputOutput' appinfo='rendering choices: BallAndStick, Ball, Stick'
name='displayMode' type='SFString'>/>
    <field accessType='inputOutput' appinfo='diffuseColor of Arc' name='color'
type='SFColor'>/>
    <field accessType='inputOutput' appinfo='transparency of Arc' name='transparency'
type='SFFloat'>/>
    <field accessType='inputOutput' appinfo='offset distance for Cone arrowhead; TODO this
needs to match values in the Vertex protopye, which is iniialized separately' name='ballRadius'
type='SFFloat'>/>
    <field accessType='inputOutput' appinfo='debug trace to Browser output console'
name='traceEnabled' type='SFBool'>/>
  </ExternProtoDeclare>
  <xsl:text>&#10;</xsl:text>
  <ExternProtoDeclare name='Vertex' url=""PajekVisualizationPrototypes.x3d#Vertex"
"https://savage.nps.edu/Savage/Tools/Visualization/PajekVisualizationPrototypes.x3d#Vertex"
appinfo='Vertex is a node, typically connected by zero or more Arc segments, and displayed
using Sphere geometry with modifiable color and transparency'>
    <field accessType='inputOutput' appinfo='name to identify this Vertex' name='name'
type='SFString'>/>
    <field accessType='inputOutput' appinfo='popup text describing this Vertex'
name='description' type='SFString'>/>
    <field accessType='inputOutput' appinfo='link to some other resource' name='url'
type='MFString'>/>
    <field accessType='initializeOnly' appinfo='size of Vertex ball' name='radius'
type='SFFloat'>/>
    <field accessType='inputOutput' appinfo='rendering choices: BallAndStick, Ball, Stick'
name='displayMode' type='SFString'>/>
    <field accessType='inputOutput' appinfo='diffuseColor of Vertex' name='color'
type='SFColor'>/>
    <field accessType='inputOutput' appinfo='transparency of Vertex' name='transparency'
type='SFFloat'>/>
    <field accessType='inputOutput' appinfo='location of Vertex' name='translation'
type='SFVec3f'>/>
    <field accessType='inputOutput' appinfo='labels to identify Vertex' name='vertexText'
type='MFString'>/>
    <field accessType='inputOutput' appinfo='location of Text' name='textTranslation'
type='SFVec3f'>/>
    <field accessType='inputOutput' appinfo='diffuseColor of Text' name='textColor'
type='SFColor'>/>
  </ExternProtoDeclare>
  <xsl:text>&#10;</xsl:text>
  <ExternProtoDeclare name='NetworkText'
url=""PajekVisualizationPrototypes.x3d#NetworkText"
"https://savage.nps.edu/Savage/Tools/Visualization/PajekVisualizationPrototypes.x3d#NetworkTe
xt" appinfo='Text describing what the Vertices and Arcs are about'>

```

```

        <field accessType='inputOutput' appinfo='information to identify the Integral Network'
name='text' type='MFString'/>
    </ExternProtoDeclare>
    <Background groundAngle='1.309 1.571' groundColor='0 0.5 0.7 0 0.4 0.7 0.6 0.5 0.7'
skyAngle='1.309 1.571' skyColor='0 0.5 0.8 0 0.6 0.7 0.6 0.6 0.7'/>
    <xsl:text>#10;</xsl:text>
    <PointLight ambientIntensity='1' location='0 0 5' radius='30'/>
    <xsl:text>#10;</xsl:text>
    <NavigationInfo transitionType='ANIMATE' type=""EXAMINE""FLY""ANY""/>
    <xsl:text>#10;</xsl:text>
    <Viewpoint description='Inspect 15JAN2010Newman' fieldOfView='0.7854' orientation='1 0 0 -
0.0997' position='0 2 20'/>
    <xsl:text>#10;</xsl:text>
    <!-- type="3D" <date day="03" month="05" year="2011"/> -->
    <xsl:apply-templates/>
    <xsl:text>#10;</xsl:text>
</Scene>
<xsl:text>#10;</xsl:text>
</X3D>
</xsl:template>
<xsl:template match="Transform[Shape/Cylinder]" name="Arc">
<!--Next rule depends on the Arc Cone Transform of interest immediately succeeding the
Cylinder Transform-->
<!--This is why we specifically do not create a template for match="Transform[Shape/Cone]"-->
    <xsl:text>#10;</xsl:text>
    <ProtoInstance name='Arc'>
<!--in the Pajek produced X3D 'name', 'description', 'url', 'traceEnabled', are blank
        <fieldValue name='name' value=""/>
        <fieldValue name='description' value=""/>
        <fieldValue name='url' value=""-->
        <fieldValue name='cylinderHeight' value='{Shape/Cylinder/@height}'/>
        <fieldValue name='cylinderTranslation' value='{@translation}'/>
        <fieldValue name='coneTranslation' value='{following-sibling::node()/@translation}'/>
        <fieldValue name='rotation' value='{@rotation}'/>
        <!--Cone and Cylinder rotations are identical TODO? Write a rule to confirm that and
throw a warning at it for Quality Control-->
        <fieldValue name='color' value='{Shape/Appearance/Material/@diffuseColor}'/>
        <fieldValue name='ballRadius' value='{Shape/Cylinder/@radius}'/>
        <!--default values for traceEnabled, displayMode, and transparency-->
        <fieldValue name='traceEnabled' value='false'/>
        <fieldValue name='displayMode' value=""/>
        <fieldValue name='transparency' value='0.0'/>
    </ProtoInstance>
    <xsl:text>#10;</xsl:text>
</xsl:template>

<xsl:template match="Transform[Shape/Sphere]" name="Vertex">
<!--Next rule depends on the Vertex Text Transform of interest immediately succeeding the
Vertex Transform-->
    <ProtoInstance name='Vertex'>
        <fieldValue name='vertexText' value='{following-sibling::node()/Shape/Text/@string}'/>
        <!--... indicates Anchor Parent for description value-->
        <fieldValue name='description' value='{../@description}'/>
        <fieldValue name='url' value=""/>
        <fieldValue name='radius' value='{Shape/Sphere/@radius}'/>

```

```

    <fieldValue name='displayMode' value=''/>
    <fieldValue name='color' value='{Shape/Appearance/Material/@diffuseColor}'/>
    <fieldValue name='transparency' value='0.0'/>
    <fieldValue name='translation' value='{@translation}'/>
    <fieldValue name='textTranslation' value='{following-sibling::node()/@translation}'/>
    <fieldValue
        name='textColor'
        value='{following-
sibling::node()/Shape/Appearance/Material/@diffuseColor}'/>
    </ProtoInstance>
    <xsl:text>#10;</xsl:text>
</xsl:template>

<xsl:template match="NetworkText" name="NetworkText">
    <field accessType='inputOutput' appinfo='information to identify the Integral Network'
name='text' type='MFString' value='TODOcustomizeThisNetworkText'/>
    <Transform DEF="infogroup" translation="-8 2 -4">
        <Transform translation="0 6 0">
            <ProtoInstance name="NetworkText">
                <xsl:variable name="fullname" select="comment()"/>
            </ProtoInstance>
            <xsl:text>#10;</xsl:text>
        </Transform>
    <xsl:text>#10;</xsl:text>
    </Transform>
    <xsl:text>#10;</xsl:text>
</xsl:template>

</xsl:stylesheet>

```

APPENDIX G: XSLT PROTOTYPE FILE

The following is the generated X3D output created through the .xslt converter of Appendix F. This allows the .x3d file generated by Pajek in Appendix C to be transformed into the simpler, more powerful format of the X3D visualization prototype.

```
<?xml version="1.0" encoding="UTF-8"?><!DOCTYPE X3D PUBLIC "ISO//Web3D//DTD X3D
3.0//EN" "http://www.web3d.org/specifications/x3d-3.0.dtd">
<X3D xmlns:date="http://exslt.org/dates-and-times"
xmlns:xsd="http://www.w3.org/2001/XMLSchema-instance" profile="Immersive" version="3.2"
xsd:noNamespaceSchemaLocation="http://www.web3d.org/specifications/x3d-3.2.xsd">
<head>
  <meta content="PajekVisualizationExamples.x3d" name="title"/>
  <meta content="Reverse engineer and hopefully elaborate on Pajek visualization
structures" name="description"/>
  <meta content="Don Brutzman and Elaine Reid" name="creator"/>
  <meta content="17 May 2011" name="created"/>
  <meta content="17 May 2011" name="modified"/>
  <meta content="http://pajek.imfm.si" name="reference"/>
  <meta content="network visualization" name="subject"/>
  <meta content="under development" name="warning"/>
  <meta
content="https://savage.nps.edu/Savage/Tools/Visualization/PajekVisualizationExamples.x3d"
name="identifier"/>
  <meta content="X3D-Edit, https://savage.nps.edu/X3D-Edit" name="generator"/>
  <meta content="../..license.html" name="license"/>
</head>
<Scene>
<ExternProtoDeclare name="Arc" url="&quot;PajekVisualizationPrototypes.x3d#Arc&quot;
&quot;https://savage.nps.edu/Savage/Tools/Visualization/PajekVisualizationPrototypes.x3d#Arc&
quot;" appinfo="Arc is a network connection between Vertex nodes, displayed using
Cylinder/Cone (arrow/arrowhead) geometry with modifiable color and transparency">
  <field accessType="inputOutput" appinfo="name to identify this Arc" name="name"
type="SFString"/>
  <field accessType="inputOutput" appinfo="popup text describing this Arc"
name="description" type="SFString"/>
  <field accessType="initializeOnly" appinfo="length of Arc between Vertex locations"
name="cylinderHeight" type="SFFloat"/>
  <field accessType="inputOutput" appinfo="link to some other resource" name="url"
type="MFString"/>
  <field accessType="inputOutput" appinfo="location of Arc" name="cylinderTranslation"
type="SFVec3f"/>
  <field accessType="inputOutput" appinfo="see TODO items in ArcScript"
name="coneTranslation" type="SFVec3f"/>
  <field accessType="inputOutput" appinfo="orientation of Arc" name="rotation"
type="SFRotation"/>
```

```

    <field accessType="inputOutput" appinfo="rendering choices: BallAndStick, Ball, Stick"
    name="displayMode" type="SFString"/>
    <field accessType="inputOutput" appinfo="diffuseColor of Arc" name="color"
type="SFColor"/>
    <field accessType="inputOutput" appinfo="transparency of Arc" name="transparency"
type="SFFloat"/>
    <field accessType="inputOutput" appinfo="offset distance for Cone arrowhead; TODO
this needs to match values in the Vertex protopye, which is initialized separately"
name="ballRadius" type="SFFloat"/>
    <field accessType="inputOutput" appinfo="debug trace to Browser output console"
name="traceEnabled" type="SFBool"/>
    <field accessType="inputOutput" appinfo="outward indication of Arc"
name="appearance" type="SFImage"/>
</ExternProtoDeclare>
<ExternProtoDeclare name="Vertex" url="&quot;PajekVisualizationPrototypes.x3d#Vertex&quot;
&quot;https://savage.nps.edu/Savage/Tools/Visualization/PajekVisualizationPrototypes.x3d#Vert
ex&quot;" appinfo="Vertex is a node, typically connected by zero or more Arc segments, and
displayed using Sphere geometry with modifiable color and transparency">
    <field accessType="inputOutput" appinfo="name to identify this Vertex" name="name"
type="SFString"/>
    <field accessType="inputOutput" appinfo="popup text describing this Vertex"
name="description" type="SFString"/>
    <field accessType="inputOutput" appinfo="link to some other resource" name="url"
type="MFString"/>
    <field accessType="initializeOnly" appinfo="size of Vertex ball" name="radius"
type="SFFloat"/>
    <field accessType="inputOutput" appinfo="rendering choices: BallAndStick, Ball, Stick"
name="displayMode" type="SFString"/>
    <field accessType="inputOutput" appinfo="diffuseColor of Vertex" name="color"
type="SFColor"/>
    <field accessType="inputOutput" appinfo="transparency of Vertex" name="transparency"
type="SFFloat"/>
    <field accessType="inputOutput" appinfo="location of Vertex" name="translation"
type="SFVec3f"/>
    <field accessType="inputOutput" appinfo="labels to identify Vertex" name="vertexText"
type="MFString"/>
    <field accessType="inputOutput" appinfo="location of Text" name="textTranslation"
type="SFVec3f"/>
    <field accessType="inputOutput" appinfo="diffuseColor of Text" name="textColor"
type="SFColor"/>
</ExternProtoDeclare>
<ExternProtoDeclare name="NetworkText"
url="&quot;PajekVisualizationPrototypes.x3d#NetworkText&quot;
&quot;https://savage.nps.edu/Savage/Tools/Visualization/PajekVisualizationPrototypes.x3d#Netw
orkText&quot;" appinfo="Text describing what the Vertices and Arcs are about">
    <field accessType="inputOutput" appinfo="information to identify the Integral Network"
name="text" type="MFString"/>
</ExternProtoDeclare>
<Background groundAngle="1.309 1.571" groundColor="0 0.5 0.7 0 0.4 0.7 0.6 0.5 0.7"
skyAngle="1.309 1.571" skyColor="0 0.5 0.8 0 0.6 0.7 0.6 0.6 0.7"/>
<PointLight ambientIntensity="1" location="0 0 5" radius="30"/>
<NavigationInfo transitionType="ANIMATE"
type="&quot;EXAMINE&quot;&quot;FLY&quot;&quot;ANY&quot;"/>
<Viewpoint description="Inspect 15JAN2010Newman" fieldOfView="0.7854" orientation="1 0 0 -
0.0997" position="0 2 20"/>

```

```

<ProtoInstance name="Arc">
  <fieldValue name="name" value=""/>
  <fieldValue name="description" value=""/>
  <fieldValue name="url" value=""/>
  <fieldValue name="cylinderHeight" value="0.64770"/>
  <fieldValue name="cylinderTranslation" value="-0.35062 -0.44066 -0.60713"/>
  <fieldValue name="coneTranslation" value="-0.48422 -0.53116 -0.63552"/>
  <fieldValue name="rotation" value="-11.22472 0.00000 52.81325 2.15598"/>
  <fieldValue name="displayMode" value=""/>
  <fieldValue name="color" value="0.0000 0.0000 0.0000"/>
  <fieldValue name="transparency" value="0.0"/>
  <fieldValue name="ballRadius" value="0.02000"/>
  <fieldValue name="traceEnabled" value="0"/>
  <fieldValue name="appearance" value="0 0 0"/>
</ProtoInstance>

<ProtoInstance name="Arc">
  <fieldValue name="name" value=""/>
  <fieldValue name="description" value=""/>
  <fieldValue name="url" value=""/>
  <fieldValue name="cylinderHeight" value="1.28361"/>
  <fieldValue name="cylinderTranslation" value="-0.12911 0.32068 -0.81718"/>
  <fieldValue name="coneTranslation" value="-0.16106 0.75793 -1.01700"/>
  <fieldValue name="rotation" value="-53.23500 0.00000 8.51149 0.43344"/>
  <fieldValue name="displayMode" value=""/>
  <fieldValue name="color" value="0.0000 0.0000 0.0000"/>
  <fieldValue name="transparency" value="0.0"/>
  <fieldValue name="ballRadius" value="0.02000"/>
  <fieldValue name="traceEnabled" value="0"/>
  <fieldValue name="appearance" value="0 0 0"/>
</ProtoInstance>

<ProtoInstance name="Arc">
  <fieldValue name="name" value=""/>
  <fieldValue name="description" value=""/>
  <fieldValue name="url" value=""/>
  <fieldValue name="cylinderHeight" value="1.12537"/>
  <fieldValue name="cylinderTranslation" value="-0.35500 -0.38541 -1.02982"/>
  <fieldValue name="coneTranslation" value="-0.54712 -0.47389 -1.37249"/>
  <fieldValue name="rotation" value="-95.76386 0.00000 53.68924 1.79233"/>
  <fieldValue name="displayMode" value=""/>
  <fieldValue name="color" value="0.0000 0.0000 0.0000"/>
  <fieldValue name="transparency" value="0.0"/>
  <fieldValue name="ballRadius" value="0.02000"/>
  <fieldValue name="traceEnabled" value="0"/>
  <fieldValue name="appearance" value="0 0 0"/>
</ProtoInstance>

<ProtoInstance name="Vertex">
  <fieldValue name="vertexText" value="2010-01-15-ARMY.MIL"/>
  <fieldValue name="description" value="1: 2010-01-15-ARMY.MIL"/>
  <fieldValue name="url" value=""/>
  <fieldValue name="radius" value="0.1500"/>
  <fieldValue name="displayMode" value=""/>
  <fieldValue name="color" value="0.0000 0.0000 0.0000"/>

```

```

    <fieldValue name="transparency" value="0.0"/>
    <fieldValue name="translation" value="-0.08656 -0.26178 -0.55101"/>
    <fieldValue name="textTranslation" value="0.06344 -0.26178 -0.55101"/>
    <fieldValue name="textColor" value="0.0000 0.0000 0.0000"/>
</ProtoInstance>
<ProtoInstance name="Vertex">
    <fieldValue name="vertexText" value="2010-01-15-BLOGS.STATE.GOV-INDEX.PHP"/>
    <fieldValue name="description" value="2: 2010-01-15-BLOGS.STATE.GOV-
INDEX.PHP"/>
    <fieldValue name="url" value=""/>
    <fieldValue name="radius" value="0.1500"/>
    <fieldValue name="displayMode" value=""/>
    <fieldValue name="color" value="0.5020 0.0000 0.0000"/>
    <fieldValue name="transparency" value="0.0"/>
    <fieldValue name="translation" value="1.28526 1.19707 0.67279"/>
    <fieldValue name="textTranslation" value="1.43526 1.19707 0.67279"/>
    <fieldValue name="textColor" value="0.0000 0.0000 0.0000"/>
</ProtoInstance>
<ProtoInstance name="Vertex">
    <fieldValue name="vertexText" value="2010-01-15-FEEDS.FEEDBURNER.COM-
DIPNOTE"/>
    <fieldValue name="description" value="3: 2010-01-15-FEEDS.FEEDBURNER.COM-
DIPNOTE"/>
    <fieldValue name="url" value=""/>
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    <fieldValue name="textColor" value="0.0000 0.0000 0.0000"/>
</ProtoInstance>
</Scene>
</X3D>

```

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