Characterisation and Showcasing of Network Visualisation Approaches for Command and Control

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ABSTRACT

Network Visualisation technologies are becoming more relevant in Command and Control environments to help cope with the increased complexity of defence operations. A significant number of Network Visualisation technologies are currently available so the choice of a particular approach to support specific C2 tasks can be difficult. This paper describes an approach for characterising Network Visualisation tools in terms of domains of use, what they describe and how they present information using a reference model for visualisation. The paper also introduces a novel distributed system, named Imago, which supports the characterisation, discovery, showcasing, and evaluation of Information Visualisation approaches. We argue that the methods proposed in this paper could aid the process of selecting and deploying Network Visualisation tools for Command and Control activities.

1.0 INTRODUCTION

In the ever more complex world of networked and asymmetric military operations, command staff need to rapidly assimilate and understand a vast range of additional information including social and communication networks, resupply and logistics, belligerents profiling, etc. One would imagine that, given the vast array of visualisation approaches that have been developed and the critical and complex nature of defence operations, military decision-makers would be the early adopters of such technologies. Yet, relatively few command support applications make significant use of Information Visualisation approaches, in particular Network Visualisation approaches.

In recent years, surveys of Information and Network Visualisation technologies have been performed (e.g., Bouchard [1], Herman et al [7]), identifying over 70 different products to facilitate the discovery of Network Visualisation technologies. However, most of these surveys are functionality based. This makes it difficult to identify technologies to support specific contexts of use. Also, limited support can be offered from these surveys for evaluating and transitioning various approaches.

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Several taxonomies have been developed to help characterise and describe Information Visualisation technologies such as provided by Card et al [3]. However, these typically focus on the visualisation approach without reference to the context within which it is used. The Information Visualisation Action Group (AG3) of The Technical Cooperation Program (TTCP) developed a reference model (cf. [5, 6, 8]) for visualisation (RM-Vis) to characterise and showcase visualisation approaches within their usage contexts. The use of a reference model such as RM-Vis allows the rapid identification of relevant approaches for particular activities, as well as providing support for evaluation and transitioning of the approaches in operational environments.

This paper first introduces the TTCP RM-Vis reference model and describes how it has been used for characterising network visualisations technologies in terms of domains of use, the descriptive aspects (i.e. what they describe) and the approaches that they use for presenting the information. We discuss our experiences in using these approaches for the development and use of a system called C2NetVis which characterises and showcases network visualisation technologies. The contexts of use and descriptive aspects of network visualisation approaches used in Command and Control environments are provided.

Finally this paper discusses how we are extending on the work done by TTCP as part of Project Imago. This project is developing a web-based distributed environment that can be used to collaboratively define, prototype, evaluate, and transition visualisation approaches for C2.

2.0 REFERENCE MODEL FOR VISUALISATION

The TTCP Action Group on Information Visualisation developed a Reference Model framework (cf. [6]) for the application of Visualisation approaches (RM-Vis), which has been used to support the characterisation, identification and showcasing of visualisation approaches in several domains including C3I. This framework allows visualisation solutions to be defined in terms of their context of use, the representation and presentation techniques used, and key features of tool support provided such as types of user interactions and deployment support.

As shown in Figure 1, RM-Vis has three key dimensions:

- The **Domain Context** is a model that defines the focus for the application of visualisation approaches i.e. ***where*** visualisation approaches will be applied, ***who*** will be supported, and ***why*** the approaches are needed.

- **Descriptive Aspects** (DA) define what needs to be described for particular domain contexts. For example, DAs could be defined in terms of the various elements (or things) that are of importance, the relationships between those elements and particular attributes that describe the elements and relationships.

- The **Visualisation Approach** dimension defines how the required information can be provided through computer-based visualisation. Approaches are characterised in terms of the visual representations used (e.g. graphs, charts, maps), visual enhancements (e.g. use of overlays, distortion, animation), interaction (direct manipulation, drag and drop, haptic techniques etc), and deployment which includes the computing environment (display devices, COTS software) and advanced deployment techniques such as intelligent user support and enterprise integration.

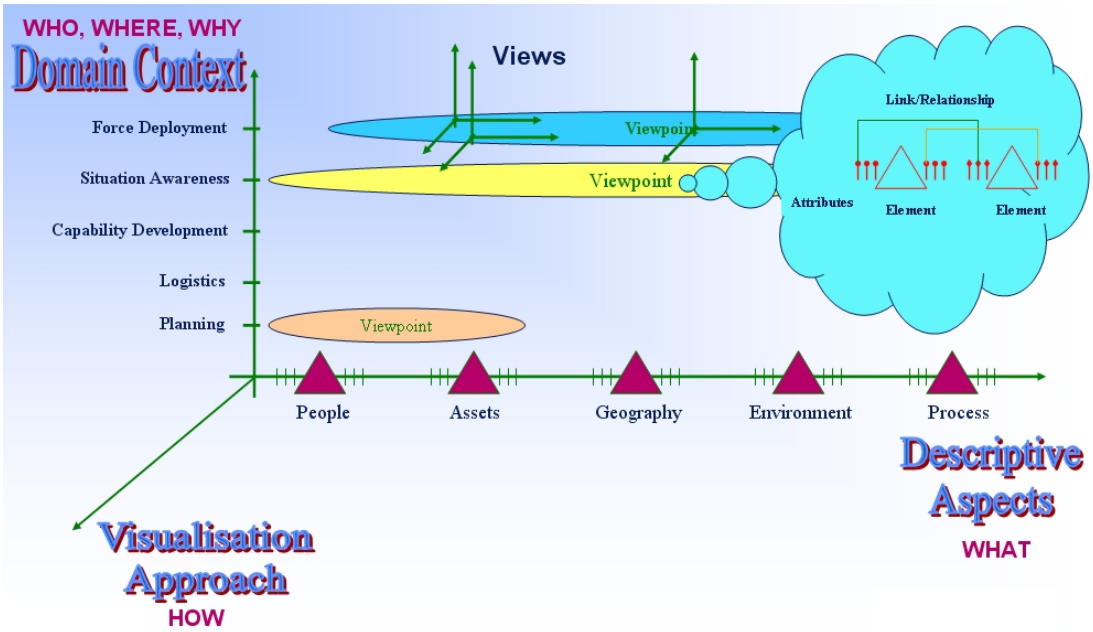

Figure 1. RM-Vis Framework

In parallel to the development of the reference model, the members of AG-3 created three instantiations of a database containing views referencing the model. C3I-Vis, MIL-Vis, and G-Vis were created to characterise and showcase visualisation approaches in the C3I, Military, and general domains. This paper discusses how these approaches have been used in the development and use of a system called C2NetVis which characterises and showcases network visualisation technologies.

3.0 USE OF NETWORK VISUALISATION FOR COMMAND AND CONTROL

Using Network Analysis techniques, especially Social Network Analysis, has become increasingly relevant approaches in recent years, particularly with the advent of Network Enabled Operations and the current focus on counter-terrorism. The battlespace is becoming more and more networked. Intel analysts are using these techniques to depict relationships among people and their behavioural activities (eg. travel, banking, phone calls, transfer of illicit material) to unearth suspicious behaviours and prevent unfortunate events. The same techniques are used to prosecute orchestrators of terrorist events, as described in Bouchard [2]. These graphs of relationships are often shared among staff officers and commanders for decision-making and situational awareness.

Social Network Analysis (SNA) is the most commonly used Network Analysis technique in Command and Control. SNA consists of representing people in graphs with their formal or informal relationships. For example Figure 2 depicts the al-Qaeda network information represented by an i2 Analyst's Notebook chart. Dekker [4] presents many applications of SNA in a C4ISR context, such as delays analysis and identifying best routes in logistics operations. Similarly, Network Analysis techniques are used in urban operations to identify shortest paths, safest paths, centre of gravities, vulnerabilities, and so on.

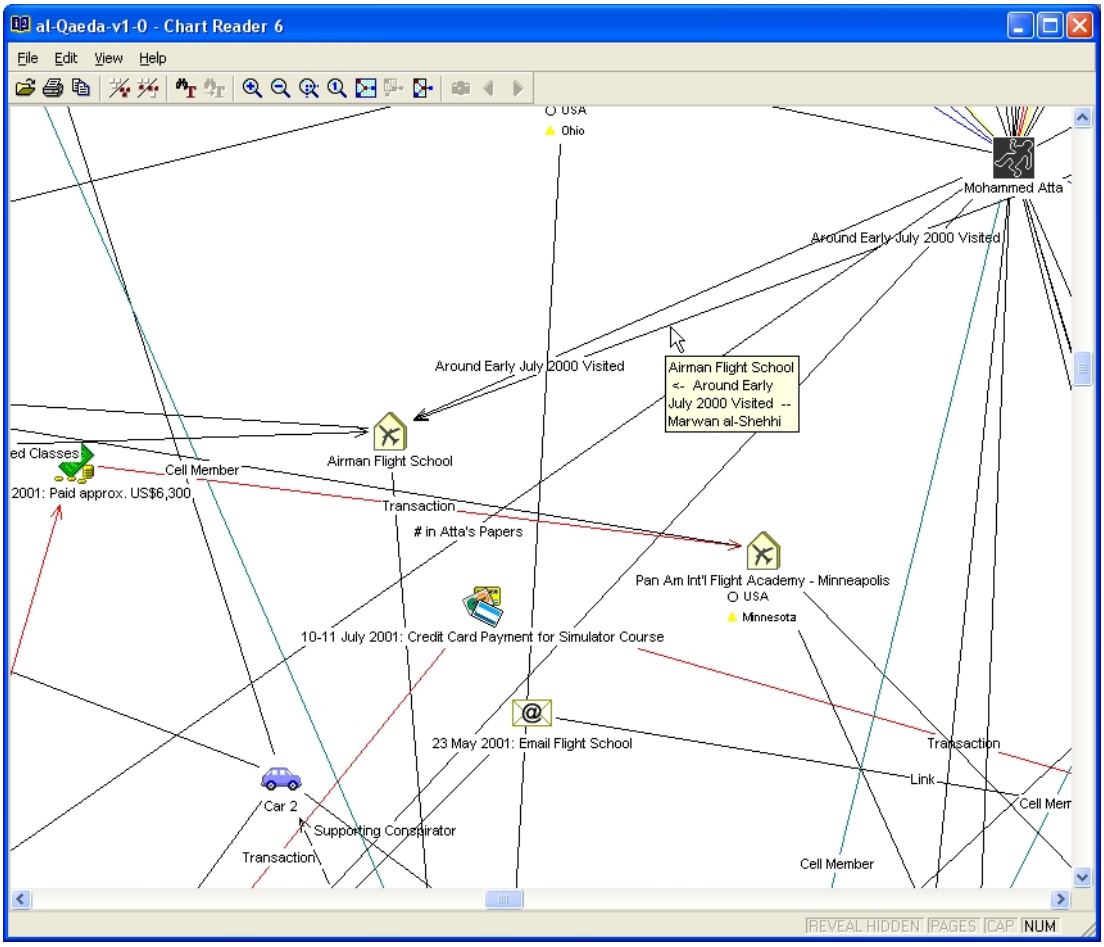

Figure 2. al-Qaeda chart created by i2 Analyst's Notebook

As with decision-makers in other enterprises, defence command staff require information to support activities related to planning, analysis, and synchronised action. This information includes aspects such as the disposition and status of force elements such as ships, planes, and people. In order to display such highly-dimensional information in a meaningful way, novel visualisation approaches using network analysis techniques, such as the one represented in Figure 3, are used in support to the traditional C2 applications.

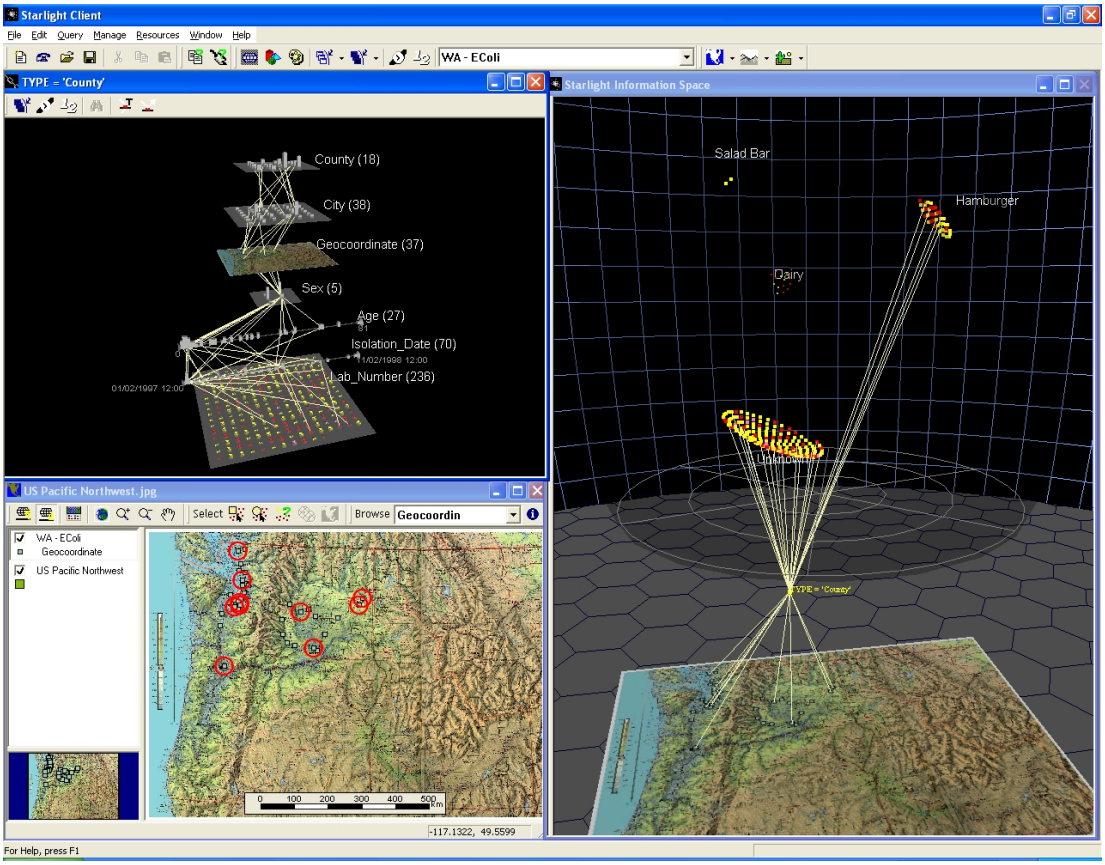

Figure 3. Starlight multi-dimensional representations (screen capture of e. coli dataset provided by Pacific Northwest National Laboratory)

Most of the tasks involved in creating these graphs of networked entities are manual but sometimes automated or semi-automated algorithms are used to extract information from unstructured documents.

The list of potential uses of network analysis and visualisation approaches in a C2 context is extensive. These techniques can be used to provide new insights into complex arrangements which are represented in graphs showing various entities, their attributes, and relationships. Since there are a large number of available network visualisation approaches available, it becomes time-consuming to identify an approach that is appropriate to a particular domain context, user, and representing the appropriate information. In order to address that problem, the following section presents a characterisation of network visualisation approaches to help the discovery and evaluation of network visualisation approaches

4.0 CHARACTERISATION OF NETWORK VISUALISATION APPROACHES

A fourth instantiation of the reference model database has been developed, called C2NetVis, to contain Network Visualisation approaches for the Command and Control domain context. The characterisation of the visualisation approaches required the instantiation of the three main dimensions of the reference model: domain context, descriptive aspect, and visualisation approach. From the two first dimensions have been

derived a list of viewpoints, which corresponds to the main tasks requiring network visualisations in C2. Finally 55 network visualisations have been characterised using the instantiation of the model. The following sections present these results.

4.1 Domain Context

The Domain Context (DC) is a model, which defines the focus for the application of visualisation approaches i.e. ***where*** visualisation approaches will be applied, ***who*** will be supported, and ***why*** it is needed. A domain context can be generated from existing enterprise models and tailored for the particular application of the reference model (cf. [6]). For example, various tasks require visualisation approaches in support to air operations, which tasks might be defined in term of roles and activities in the model.

This document focuses on the use of network visualisations in the Command and Control context. The same visualisations approaches could potentially be used in many other fields such as Health and Finance, but the pertinence and efficiency of these visualisations need to be assessed in these particular contexts. There are many reasons why a visualisation might be appropriate to achieve a task in one context but inappropriate for a similar tasks in a different context. Historical, technical, and even social aspects may influence the adoption or rejection of visualisations.

The Command and Control domain inherits its specificities from the more general military domain, which has a standardised way of categorising tasks based on pre-defined doctrines and procedures. The instantiation of the model follows this categorisation. Giving a particular task in the military domain, the where, who, and why aspects of the task are generally definite and have been used to define the model. The C2NetVis reference model adopted the domain context model from a previous instance of the RM-Vis database, C3I-Vis, with only minor changes. Table 1 outline the main aspects of the domain context model used to characterise the network visualisations:

Table 1. Domain Context model

	CATEGORY	ATTRIBUTE
Where	Level of Command	• Operational, Strategic, Tactical
	Environment	• Air, Land, Maritime, Joint, Littoral, Space, Urban
	Area	• Acquisition, Communications, Development, Engineering, Intelligence, Operations, Personnel, Plans, Requirements, Research, Training
	Scenario	• Humanitarian Assistance, Low/Medium/High Intensity Conflict, Peace Support, Special Ops
Who	Role	• COS, Commander, J2, J6, J7, J8, Intel Analyst, Logistics Officer, Ops Officer, Support Engineer
Why	Activity	• Analysis, Assess, Assign, Execute, Monitor, Plan, Report, Schedule, Track

In order to keep the model simple, a hierarchical definition has been adopted. However a more comprehensive model would have to be defined as a domain ontology, including relationships and constraints between categories. For example, certain roles and areas seem to have a close relationship (ex: intel analyst in intelligence area) while some others roles and areas are complete dichotomies (ex: Chief of Defence Staff in the Health or Finance domain).

4.2 Descriptive Aspects

Descriptive Aspects (DA) define ***what*** needs to be described for particular domain contexts. For example, DAs could be defined in terms of the various elements (or things) that are of importance, the relationships between those elements and particular attributes, which describe the elements, and relationships (cf. [6]). The DA dimension is a model by itself that is derived in the context of the DC model, identifying the entities that need to be represented in that context. The development of a DA model consists generally of using a more general model and adding domain specific aspects.

The DAs that are relevant to characterise network visualisation approaches in a C2 context is quite extensive mainly because, as mentioned earlier, the potential of use of network visualisations is extensive. As it was the case with the DC model, the C2NetVis reference model adopted the descriptive aspect model from the C3I-Vis reference model, with added network specific aspects. In fact, the core DAs in the C2 context is similar to the ones in many other contexts, many elements to be visualised are recurrent in many domains. For example the time, location, events, resource, and people aspects may be member of any DA model as these are common elements in visualisations. In the case of communication or computer networks, some more specific aspects such as computer, hardware devices, protocols, usage, and capacity need to be added to the model. In other physical networks, a road network for example, aspects as structure, speed, and weather need to be considered. Concerning social networks, other specific aspects such as identity, skills, influence, relationships, health, travel, and opinion are central elements displayed.

Again for the DA model a hierarchical approach has been selected to keep it as simple as possible and no particular relationships among the aspects has been established. In a more comprehensive model some relationships and constraints would be present. Some aspects may be meta-data of other aspects for example; a Currency descriptive aspect should always be attached to a Money aspect, a Time Zone to a Time aspect, and so on. Constraints should also be modelled. For example, two different aspects may represent opposite or sequential information and should be defined accordingly in the model. As an example a date of death is always greater or equal to a date of birth and reflects a change of state from alive to dead.

4.3 Viewpoints

A Viewpoint is a model of what needs to be described for particular domain contexts (cf. [6]). Specifically a viewpoint represents a task in a particular context, which requires the visualisation of different elements regardless of how this information is displayed. In other words the viewpoint lives in the two dimensional world of domain contexts and descriptive aspects. For example, an air traffic controller has the task, read viewpoint, to monitor the distribution of aircraft in space. The way by which the air controller achieves his task corresponds to the different approaches to visualise his viewpoint on screen.

As mentioned earlier, the number of tasks involving network analysis visualisations in C2 is extensive, as important is the number of viewpoints. The C2NetVis reference model characterises three viewpoints representing typical use of network analysis techniques. Table 2 presents the viewpoints and their definition.

Table 2. Example of viewpoints

VIEWPOINT	DOMAIN CONTEXT	DESCRIPTIVE ASPECT
Monitor belligerent activities	**Activity**: Analyse, Assess, Monitor, Track **Area**: Communications, Intelligence **Environment**: Joint, Land, Urban **Level of Command**: Strategic, Tactical **Role**: HQ J2, Intel Analyst **Scenario**: Special Ops, Low Intensity Conflict	**Communications**: Email, Phone **Events**: Sequence **Finance**: Currency, Money **Geography**: Area, City, Country, Origin, Destination, Location, Maps **Identity**: Name, Sex **Information**: Document, File, Opinion **Movement**: Flight, Travel **Occupation**: Activity, Engagement **Organisation**: Unit **People**: Belligerent, Group, Organisation, Warlord **Relationships**: Degree, Enemy, Friend, Non-friend **State**: Alive, Dead **Time**: Age, Critical, Current, Date, Duration, Interval **Transportation**: Vehicle, Car
Assess robustness of communication network	**Activity**: Analyse, Assess **Area**: Communications **Environment**: ALL **Level of Command**: Tactical **Role**: Support Engineer **Scenario**: ALL	**Computer**: Hardware, Network **Geography**: Location, Maps, Latitude, Longitude **Telecommunication**: IP, Network, Parabolic-dish, Satellite **Usage**: Frequency
Team building	**Activity**: Assign, Plan **Area**: Personnel, Training **Environment**: ALL **Level of Command**: ALL **Role**: Ops Officer **Scenario**: ALL	**Ability**: Skill **Assignment**: Mission, Order **Capacity**: Force **Events**: Scenario, Sequence **Identity**: Name, Sex **Occupation**: Activity, Engagement, Function, Jobs, Responsibility, Task, Work **Organisation**: Unit **People**: Group, Organisation, Person, Player, Soldier **Relationships**: Friend **State**: Ready, Standby, Not-Ready, Morale **Time**: Age, Deadline, Duration, Priority

4.4 Visualisation Approaches

The **Visualisation Approach** dimension defines ***how*** the required information can be provided through computer-based visualisation (cf. [6]). Approaches are characterised in terms of four independent sub-dimensions; the visual representation, visual enhancement, interaction, and deployment forming a visual abstraction in support to a viewpoint.

The C2NetVis database includes about two hundred different representations, enhancement, interaction, and deployment attributes. The representation sub-dimension refers to the techniques used in transforming data elements into visual forms. Card *et al* [3] taxonomy has been used to populate the representation dimension, which includes visual abstractions such as chart, colour, glyph, graph, icon, map, table, tree, etc. The

enhancement dimension contains items that allow an improved presentation of the visual elements on screen using groupings, overlays, stereoscopy, distortion, animation, and others. As for the interaction dimension, it includes the techniques which allow a user to tailor visual information to specific needs, including various ways that the user can interact with the visual elements such as drag & drop, cut & paste, pan, resize, undo & redo, zoom. Finally the deployment dimension, although not an intrinsic part of a visual representation, it refers to those features which allow for the provision of cost effective visualisation solutions including the computing environment (display devices, COTS software, operating system, hardware) and advanced deployment techniques such as intelligent user support and enterprise integration.

The visualisation approach dimension is agnostic of the viewpoints it represents, therefore independent of the domain context and descriptive aspects, as it is only a way of rendering elements on screen and providing interaction capabilities. In other words, a set of descriptive aspects in a particular domain context can be represented using any combination of representation, enhancement, interaction, and deployment characteristics. Therefore the definition of the visualisation approach dimension is fairly stable and can be reused in various contexts.

4.5 Characterising views

Characterising a view consists of positioning it into the three dimensional world of domain context, descriptive aspect, and visualisation approach as well as attaching a set of meta-data to the view, which might contain attributes such as a name, description, producer, and showcase examples. The first step in characterising a view consists of defining a viewpoint particular to that view, which contains the domain context and descriptive aspects information. Then the visualisation approach for that view may be characterised by selecting values from the four representation, enhancement, interaction, and deployment sub-dimensions. Finally, one can attach meta-data relevant to the view; attaching one or more showcase examples is particularly important so that the user can appreciate the effectiveness of the view in support to his viewpoints.

The C2NetVis database characterises 55 network analysis products. The characterisation of Analyst's Notebook geography view, as shown in Figure 5, is presented below as a thorough example. Figure 4 presents the meta-data for the view, as displayed in the general information tab of the database, and Figure 5 presents the view itself.

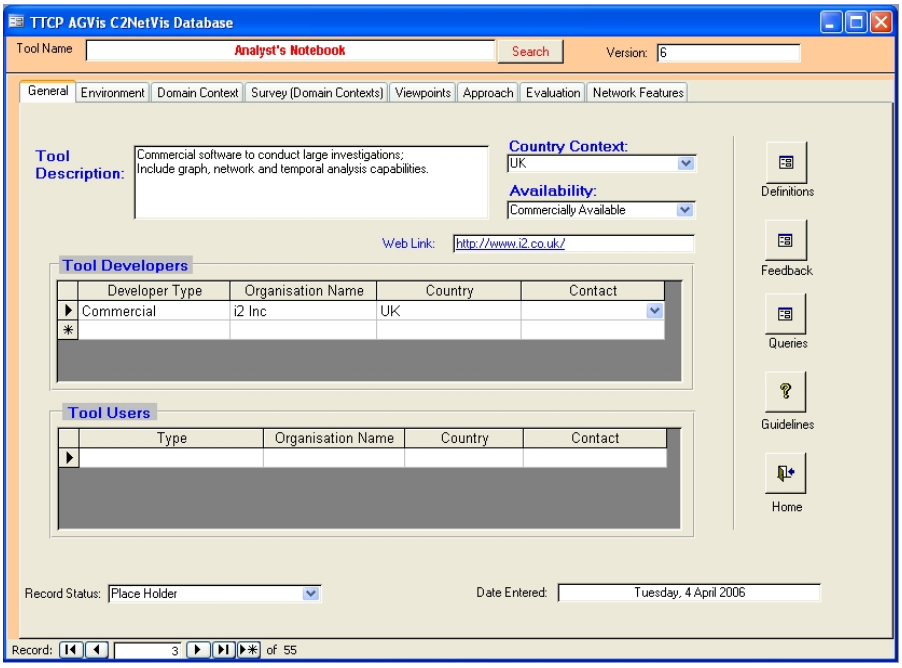

Figure 4. C2NetVis database showing Analyst's Notebook meta data

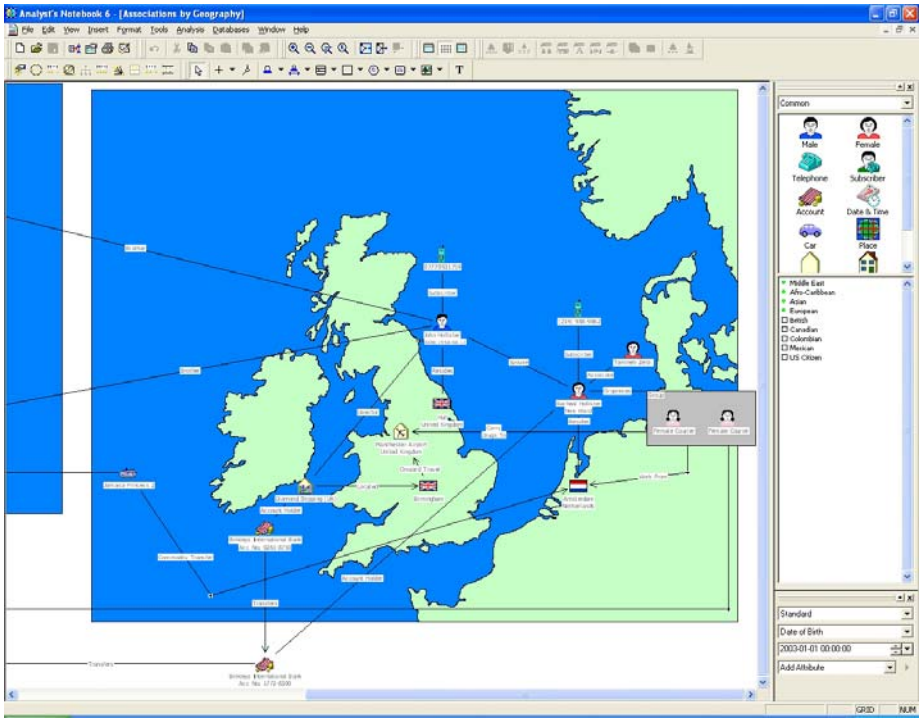

Figure 5. Analyst's Notebook geography view (dataset provided by i2 Inc.)

The definition of the viewpoint for that particular view is presented in Table 3, referencing the view in the domain context and descriptive aspect dimensions.

Table 3. Viewpoint for Analyst's Notebook geography view

DOMAIN CONTEXT	DESCRIPTIVE ASPECT
Activity: Analyse, Assess, Report, Schedule **Area**: Intelligence **Environment**: Joint, Land **Level of Command**: Strategic, Tactical **Role**: HQ J2, Intel Analyst **Scenario**: Special Ops, Low Intensity Conflict	**Communications**: Email, Phone **Family**: Brother, Sister **Finance**: Account, Money, Transfer **Geography**: Area, City, Country, Location, Maps **Identity**: Name, Sex, Flag, Nationality **Movement**: Flight, Travel **People**: Actor, Group **Possession**: Holder **Relationships**: Family **Time**: Age, Critical, Current, Date, Duration, Interval **Transportation**: Vehicle, Car, Ship

Looking at the Analyst's Notebook viewpoint, one can notice that many of its elements are also presents in the *Monitor belligerent activities* and *Team building* viewpoints, but fewer elements are shared with the *Assess robustness of communication network.* Therefore it can be assumed that this view might be appropriate to support these former tasks but might be less appropriate to support the latter. However it's not possible to assume the effectiveness of a view for a task unless a user actually evaluates the view in the context of the particular viewpoint. The subject of view evaluation is another complex subject by itself, although the closeness of a viewpoint to another one is a good indicator of effectiveness.

The viewpoint of the view being defined, the visualisation approaches supported by this view can be defined. Table 4 presents the characterisation of the visualisation approaches for the Analyst's Notebook geography view.

Table 4. Visualisation approaches of Analyst's Notebook geography view

REPRESENTATION	INTERACTION
Figure Graph.directed Graph.layout.symmetric Graph.link Graph.link.text Graph.node Graph.node.nested Graph.node.icon Graph.node.text Map.2D Table List	Cut & Paste Drag & Drop GUI.Point and Click Highlight Pan Resize Scroll Select Undo & Redo Zoom

ENHANCEMENT	DEPLOYMENT
Grouping Layering Overlay	Availability.Commercially available Extensibility.C# Extensibility.C++ Extensibility.COM Extensibility.COM+ Extensibility.NET OS.Windows.* Platform.PC.* Users.Multiple

4.6 Other network analysis features

RM-Vis being a generic visualisation reference model, it fails to include some domain specific features of tools that might be important to record and search against. Some non-visual features are sometimes essential in the production of a visualisation although they can't be referenced in the model, an algorithm for example. In the particular example of network visualisations features such as analysis functions (shortest path, pattern analysis), type of networks, transformational and mathematical properties, and constraints would be of interest to model.

For sake of comprehensiveness, the C2NetVis database includes a list of non-visual features that visualisation approaches can reference. These extra features are attached as meta-data to the views and can then be search as other meta-data entities in the database.

4.7 Using the database

The database has been populated with products surveyed from different studies and showcase examples of views from these products have been characterised using the framework. There are many ways of interrogating the database, listing all the views being the most straightforward. Predefined queries are also available for most common requests, such as listing views by domain context, and more complex interrogations, such as views that support intelligence in a peace keeping operation. Other queries can be defined by the user.

As an example of query, the database has been searched for views supporting the viewpoints defined in Table 2. The following table shows the result of the query:

Table 5. Query result of views by viewpoints

VIEWPOINT	VIEW	
Monitor belligerent activities	Analyst's Notebook Daisy InFlow NetMap	NetMiner Starlight VisuaLinks
Assess robustness of communication network	Analyst's Notebook Daisy FATCAT NetMap	NetMiner Starlight VisuaLinks
Team building	Agna Analyst's Notebook InFlow KrackPlot MultiNet Negopy Netdraw NetMap NetMiner	Netvis Pajek SocioMetrica Starlight StOCNET UCINET Visone VisuaLinks

These results clearly indicate that some more generic views, such as Analyst's Notebook, Starlight, VisuaLinks, might be applied for various purposes while others are more specialised and then less applicable for certain tasks. Also it can be noticed that all the views used in the context of monitoring belligerent activities can also be used in a team building process. This might be explained by the fact that, although the task of monitoring belligerent activities does not involve building a team as a sub-task, the viewpoint associated to the task of building a team is probably partially or totally included within the viewpoint of monitoring belligerent activities. In that case the inner viewpoint shares the same views of the including other.

Also, it has to be noted that software libraries might potentially be used in the context of all viewpoints, depending on the capabilities of the library but also on the host product using the library. Therefore no libraries have been included in the result of the query for clarity purposes.

Finally, even though scientists and analysts may populate and navigate the C2NetVis database itself, and similarly the other three database instantiations, the main interest in the database is the collaboration among many individuals to share approaches, evaluations, and for showcasing purposes. As the number of users and operations on the database increases it becomes difficult to synchronise remotely located instances. An ideal configuration would consist of a unique database instance shared by many users, distributed over an enterprise bus. The Imago project, discussed in Section 5, is addressing this issue.

5.0 FUTURE WORK

Imago is a project being lead by the Defence Science and Technology Organisation (DSTO) to support the development, evaluation and transitioning of Information Visualisation approaches for Command and Control (C2). Imago is a distributed environment that can be used to rapidly prototype, evaluate, and transition visualisation approaches for C2. The platform will provide a means of integrating and sharing the output of

visualisation tools, storing, accessing and managing showcase examples of visual representations via an underlying reference model, and providing access to underlying data sources provided through simulation, representative data, and/or operational data.

The work done in characterising network visualisations in terms of their usage contexts will be uploaded into Imago as one of its initial knowledge bases. Imago uses a semantic network modelling approach to support various queries and reasoning about the use of visualisation approaches within target domain contexts. The inference engine running in the back-end will allow querying and discovering complex relationships amongst data in the various model dimensions. The distributed aspect of Imago will allow multiple users to collaborate and share their knowledge of the effectiveness of views for their tasks. An evaluation framework is a core element of the Imago system. This facility will support the evaluation of visualisation approaches within actual usage contexts to provide information which will aid more effective transitioning into practice and for the development of enhanced visualisation techniques.

6.0 CONCLUSION

This paper introduced C2NetVis, the instantiation of a visualisation reference model and a database that characterises network visualisation approaches for the Command and Control domain. C2NetVis falls within a larger research program aiming to develop, evaluate, and transition visualisation approaches based on the RM-Vis reference model. Previous work involved the development of G-Vis, C3I-Vis, and MIL-Vis, three other instantiations of the RM-Vis model. C2NetVis serves as a knowledge base for the discovery, evaluation, and transition of network visualisation approaches. The database characterises these approaches using the three main dimensions of the reference model; domain context, descriptive aspect, and visualisation approach. C2NetVis also defines viewpoints, which are models of what needs to be described for particular domain contexts and usually correspond to user's tasks.

A typical use of the database consists of firstly creating viewpoints corresponding to the network visualisation tasks to be achieved in a C2 context. The relevant views can be discovered by searching the database against the predefined viewpoints. Finally the effectiveness of views can be evaluated in their context of use.

The main interest in C2NetVis is the collaboration between various users and scientists to share their experience on using network visualisations in Command and Control. The resulting database will serve as an initial knowledge base of the Imago system, which will extend the current system by providing a web-based distributed environment that can be used to collaboratively define, prototype, evaluate, and transition visualisation approaches for C2.

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Presentation Overview

- Context: Why are we doing this?
- C2 Network Visualisation Approaches
- The Reference Model for Visualisation (RM-Vis)
- Characterisation of visualisation approaches
- The C2NetVis database
- Future directions – The Imago Project
- Summary and Conclusions

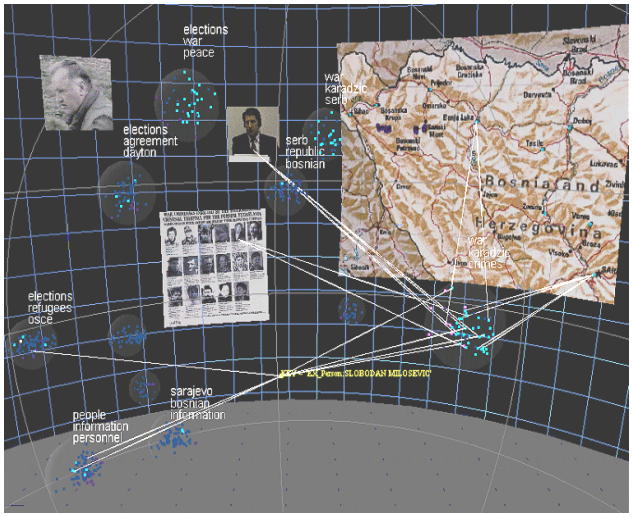
C2 Visualisation

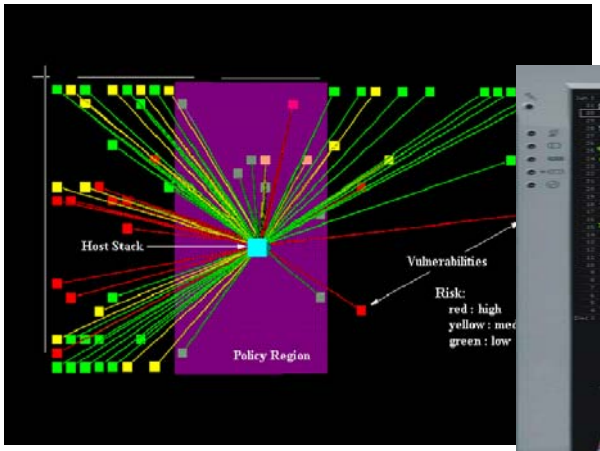
Operations Centres

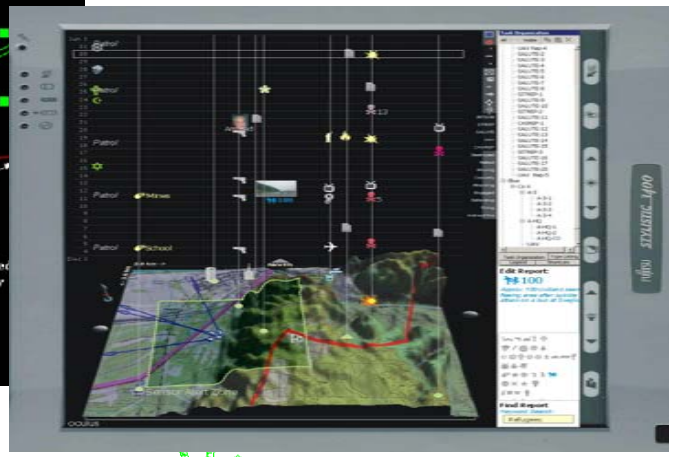
C2 Teams

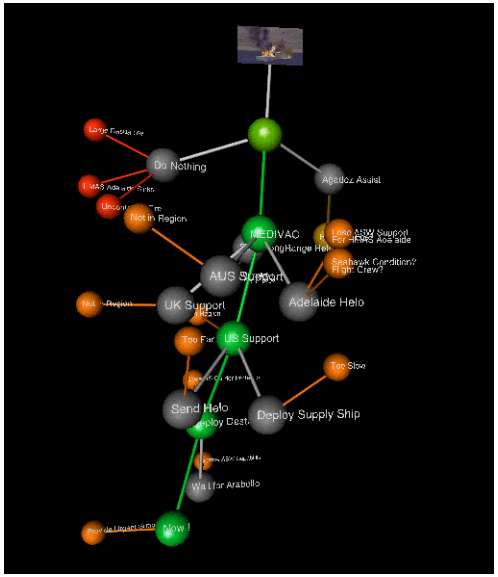
C2 on the Move

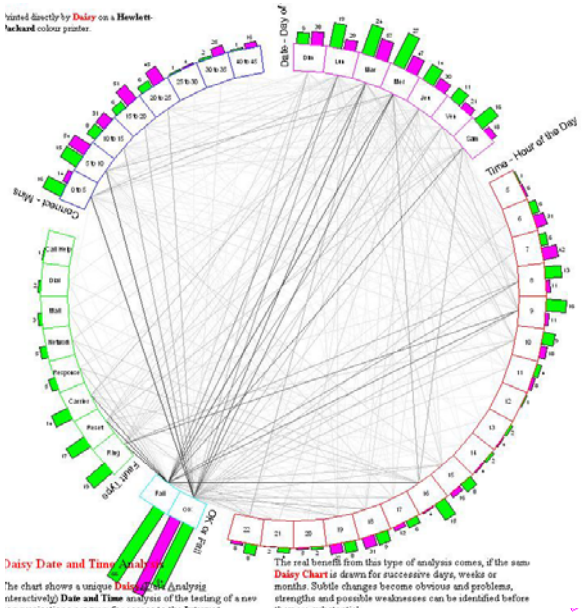
C2 Network Visualisation Approaches

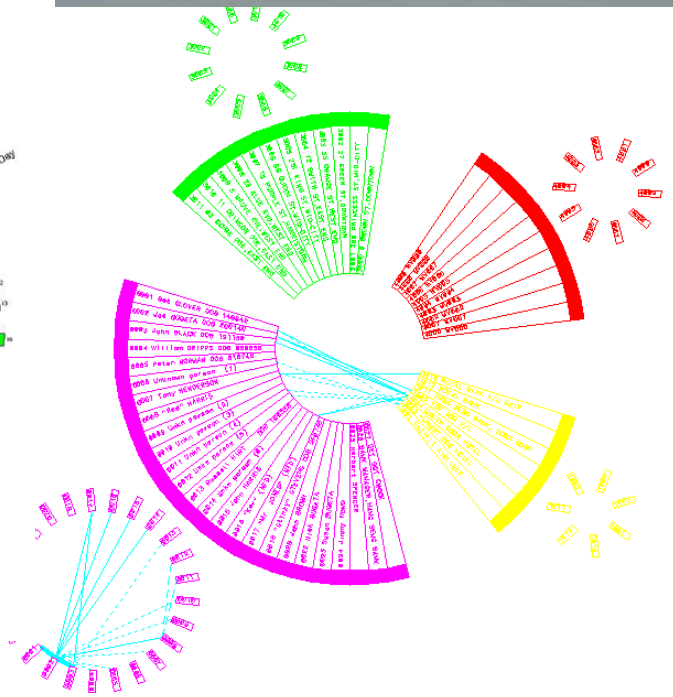




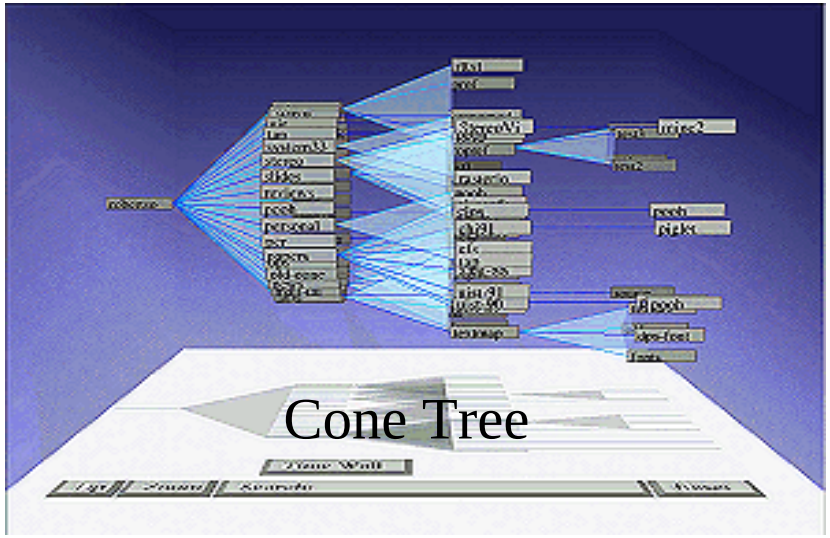






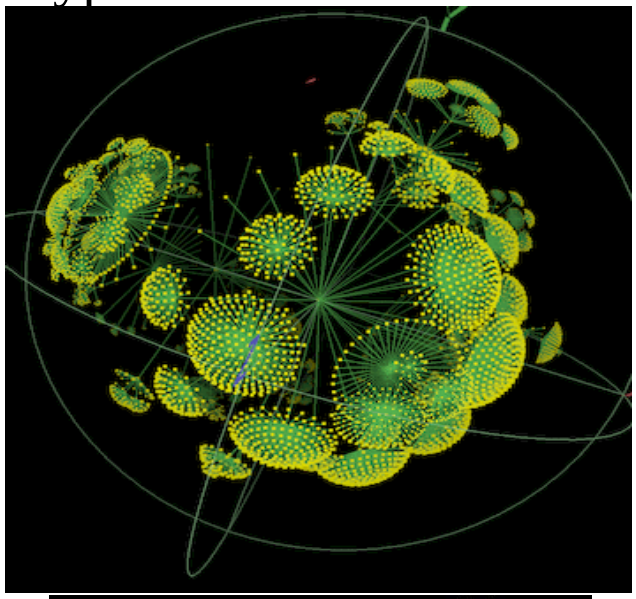


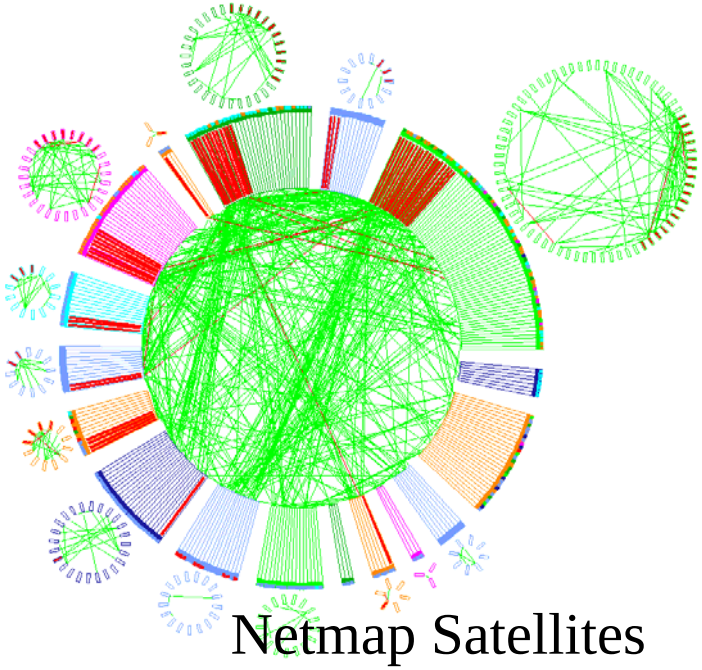
Network Visualisation R&D



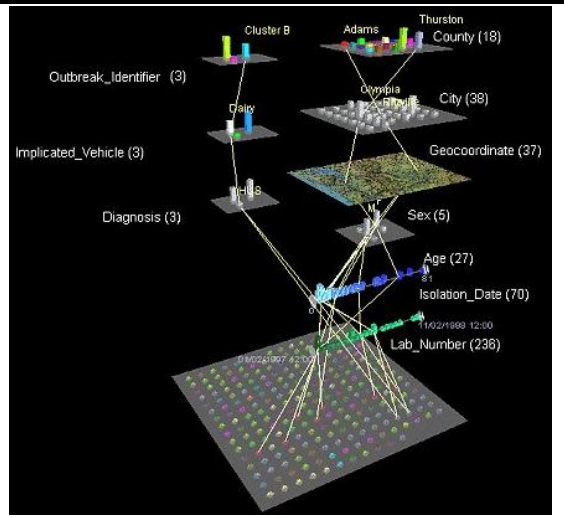
Cone Tree

Hyperbolic visualisation





Netmap Satellites



Parallel Coordinates

What's the problem?

- Considering the increasing complexity of military operations, we would think that the military personnel would be early adopters of network visualisation technologies
- No lack of novel approaches and prototype tools
- Wealth of novel approaches exist, but very few have found their way to operational use
- Limited evaluation of approaches
- No support for showcasing, applying and evaluating approaches within particular contexts of use

Product Surveys

- OLIVE (On-line Library of Information Visualization Environments), http://www.otal.umd.edu/Olive/
  - University of Maryland
  - ~50 visualisation tools surveyed and characterised based on Shneiderman taxonomy
  - Format: Web page
  - Last updated: 1998
  - Also survey visualisation projects and literature

Product Surveys (cont'd)

- TTCP C3I AG4 (now TP2) – Command Information Interfaces
  - ~350 visualisation tools surveyed and characterised based on RM-Vis model
  - C3I-Vis, Mil-Vis, G-Vis
  - Format: MS Access Database
  - Last updated: 2001
  - Also include showcase examples and evaluations

Product Surveys (cont'd)

- DRDC Valcartier (Alain Bouchard)
  - ~60 network visualisation tools surveyed but not characterised
  - Format: Report
  - Last updated: 2004
  - Also include some product evaluations

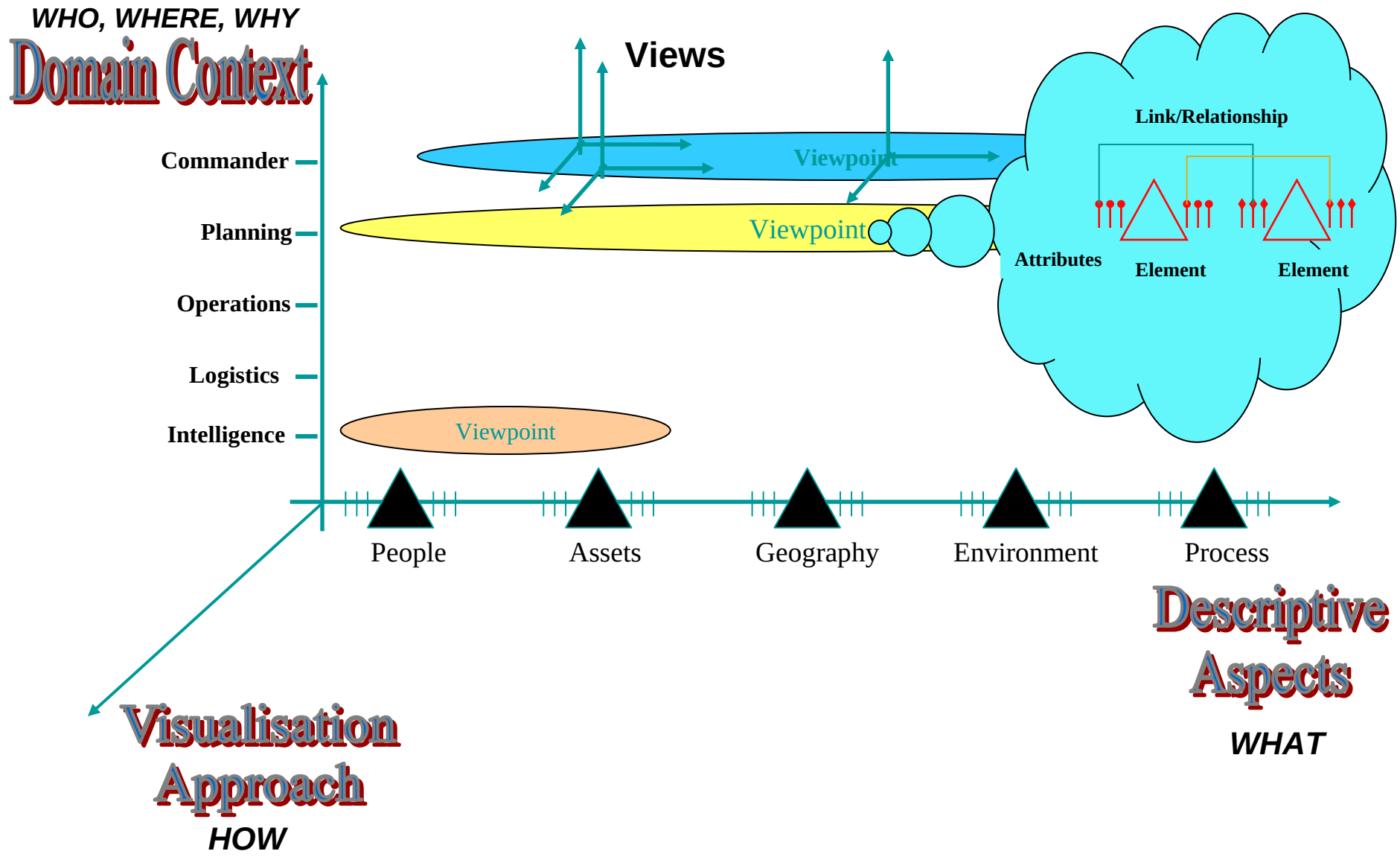
Product Surveys (cont'd)

- NATO IST-059/RTG-025 (Alain Bouchard, Annette Kaster, Joanne Treurniet, James and Adam Gort (NRNS Inc.))
  - ~67 network visualisation tools surveyed and characterised using an *ad hoc* taxonomy + ~15 tools not characterised
  - Format: Report + Database with web front-end
  - Last updated: 2006
  - Do not include evaluations *per se* beside text boxes to write comments

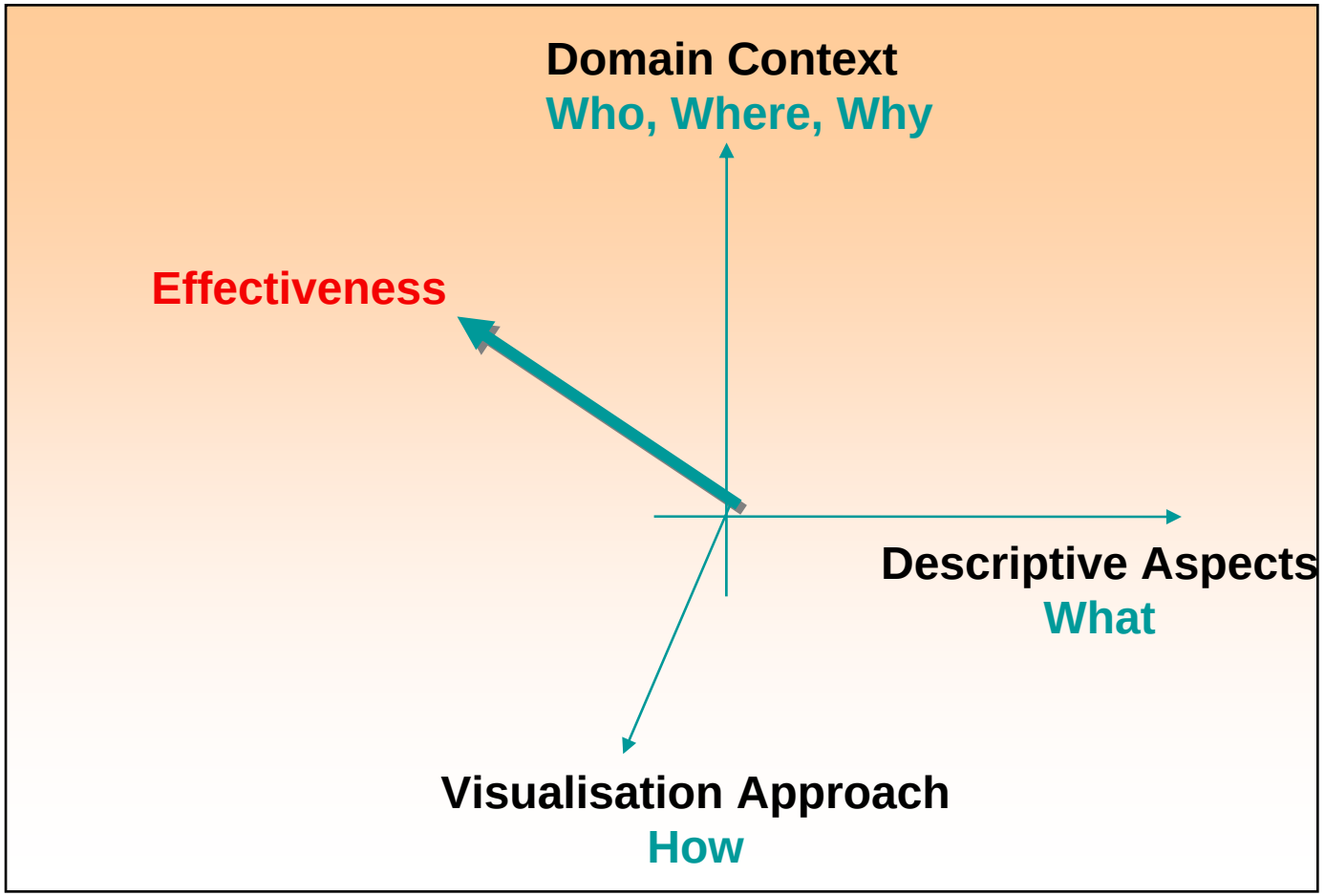
Reference Model for Visualisation (RM-Vis)

- Provides a framework for the development of Domain-specific models which capture knowledge about the application of visualisation approaches in the form of views that fulfill user information requirements.
- Has been used to characterise and showcase a broad range of visualisation approaches in domains such Command and Control, finance, and transport.

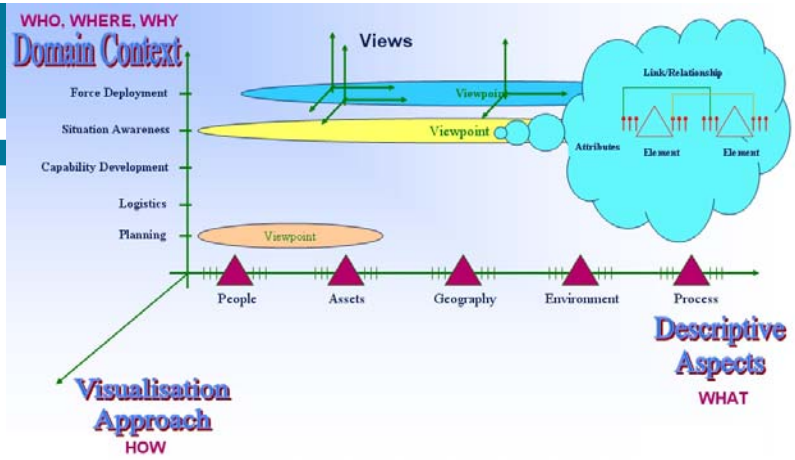
RM-Vis Framework (Overview)



- **Effectiveness** is considered in terms of the application of a specific **view** within a particular **domain context** and for a particular **viewpoint.**



Domain context



- The **Domain Context** is a model that defines the focus for the application of visualisation approaches i.e. ***where*** visualisation approaches will be applied, ***who*** will be supported, and ***why*** the approaches are needed
- We developed a taxonomy of domain context based on **Roles**, **Activities**, **Tasks**, and other elements

Examples of domain context

Table 1. Domain Context model		
	CATEGORY	**ELEMENT**
Who	**Role**	• COS, Commander, J2, J6, J7, J8, Intel Analyst, Logistics Officer, Ops Officer, Support Engineer
Why	**Activity**	• Analysis, Assess, Assign, Execute, Monitor, Plan, Report, Schedule, Track
	Task	• Manage air assets, Monitor suspicious activities
Where	Level of Command	• Operational, Strategic, Tactical
	Environment	• Air, Land, Maritime, Joint, Littoral, Space, Urban
	Area	• Acquisition, Communications, Development, Engineering, Intelligence, Operations, Personnel, Plans, Requirements, Research, Training
	Scenario	• Humanitarian Assistance, Low/Medium/High Intensity Conflict, Peace Support, Special Ops

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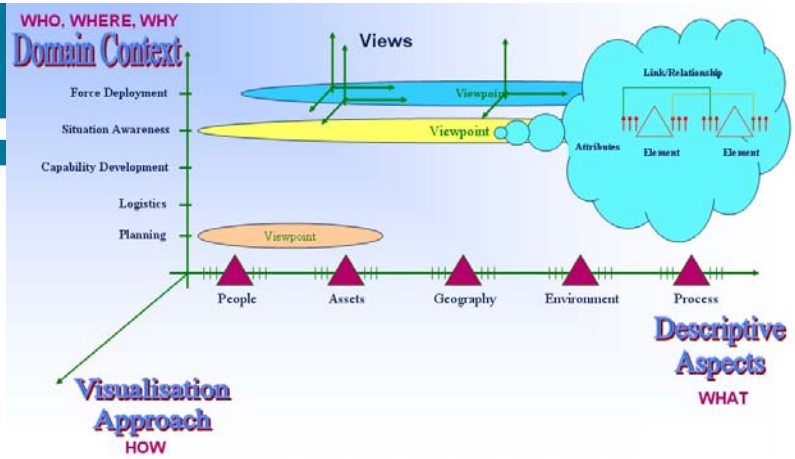
Descriptive aspects



- **Descriptive Aspects** (DA) define ***what*** needs to be described for particular domain contexts. For example, DAs could be defined in terms of the various elements (or things) that are of importance, the relationships between those elements and particular attributes that describe the elements and relationships .

Examples of descriptive aspects

DESCRIPTIVE ASPECT
Assignment: Mission, Order **Capacity:** Force, Quantity, Volume **Computer:** Hardware, Network, Software **Communications**: Email, Phone **Events**: Scenario, Sequence **Finance**: Currency, Money, Account, Transfer **Geography**: Area, City, Country, Origin, Destination, Location, Maps **Geometry**: Degree, Distance, Path **Identity**: Name, Sex, Nationality **Health**: Disease, Virus

DESCRIPTIVE ASPECT
Information: Document, File, Opinion, Fact, Gossip **Movement**: Flight, Travel, Speed **Occupation**: Activity, Engagement, Function, Task **Organisation**: Unit **People**: Belligerent, Group, Organisation, Warlord, Soldier, Leader **Politic**: Leader, Party **Relationships**: Degree, Enemy, Friend, Non-friend, Family **Resource**: Equipment, Fuel, Weapon, Sensor

DESCRIPTIVE ASPECT
State: Alive, Dead, Ready, Standby **Storage**: Database, Folder, File **Structure**: Module, Procedure, Process **Telecom:** IP, Mobile, Network, Satellite, Dish **Time**: Age, Critical, Current, Date, Duration, Interval, Deadline, Duration, Priority **Transportation**: Vehicle, Car, Ship, Vessel **Usage**: Frequency, Flow **Weather**: Condition, Snow, Rain

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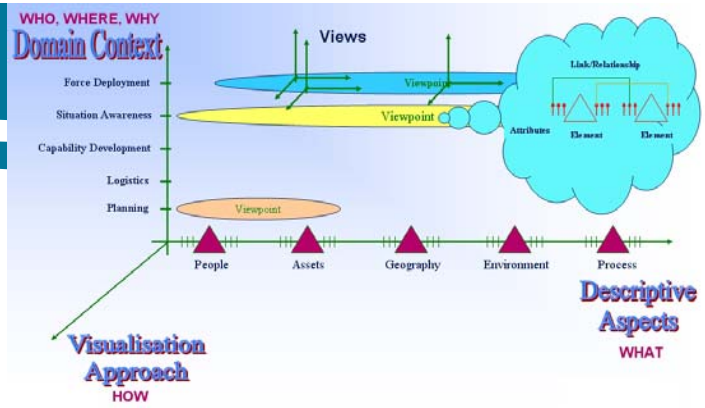
Viewpoint



A Viewpoint is a model of what needs to be described for particular domain contexts.

VIEWPOINT	DOMAIN CONTEXT	DESCRIPTIVE ASPECT
Monitor belligerent activities	**Role**: HQ J2, Intel Analyst **Activity**: Analyse, Assess, Monitor, Track **Area**: Communications, Intelligence **Environment**: Joint, Land, Urban **Level of Command**: Strategic, Tactical **Scenario**: Special Ops, Low Intensity Conflict	**Communications**: Email, Phone **Events**: Sequence **Finance**: Currency, Money **Geography**: Area, City, Country, Origin, Destination, Location, Maps **Identity**: Name, Sex **Information**: Document, File, Opinion **Movement**: Flight, Travel **Occupation**: Activity, Engagement **Organisation**: Unit **People**: Belligerent, Group, Organisation, Warlord **Relationships**: Degree, Enemy, Friend, Non-friend **State**: Alive, Dead **Time**: Age, Critical, Current, Date, Duration, Interval **Transportation**: Vehicle, Car

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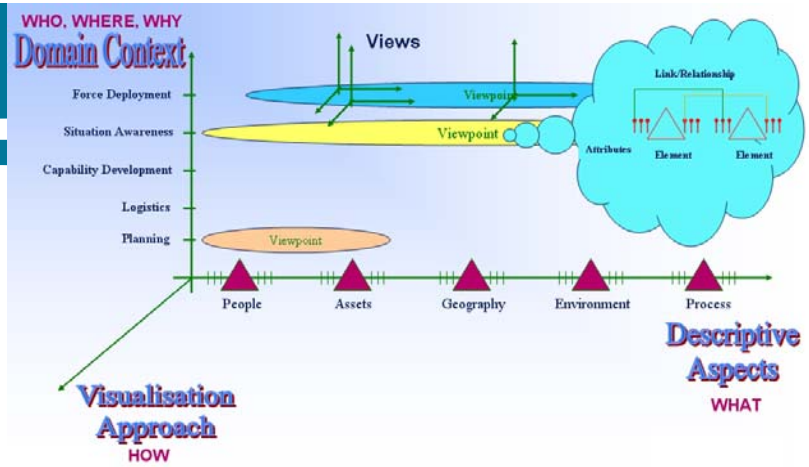


Visualisation Approach

- Defines "HOW" a viewpoint will be mapped into an visualisation solution.
- What are the characteristics for a Visualisation Approach?
  - **Representation**: refers to the techniques used in transforming data-sets into visual forms (Shneidermann taxonomy).
  - **Enhancement:** refers to the techniques used to enhance the effectiveness of visual information.
  - **Interaction:** refers to the techniques which allow a user or agent to customise/tailor visual information to specific needs.
  - **Deployment:** refers to those features which allow for the provision/application of cost effective visualisation solutions.

Visualisation Approach

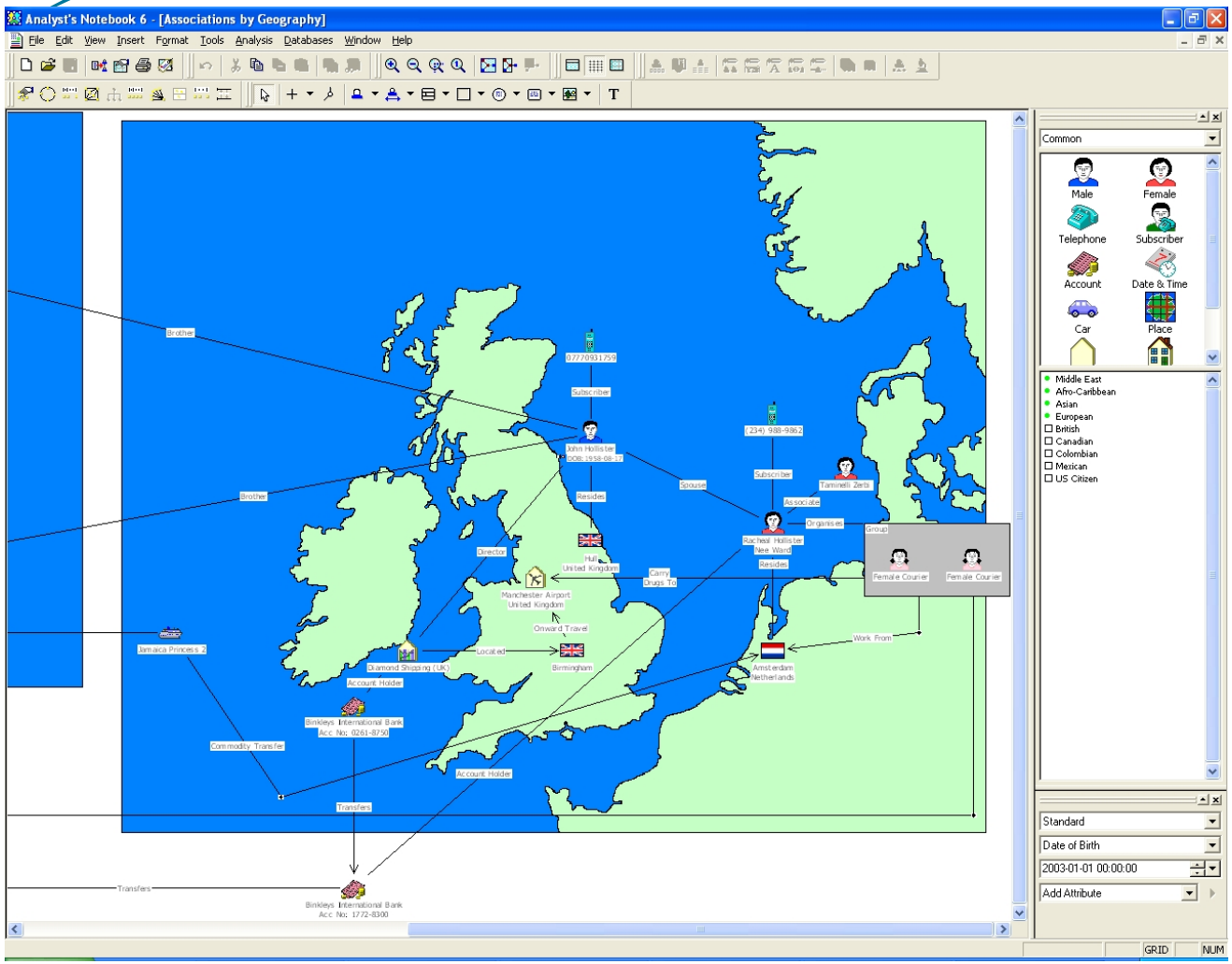
REPRESENTATION	
Chart	Shape
Colour	Symbol
Figure	Table
Form	Icon
Glyph	Image
Graph	Text
Layout	Tree
Link	Video
Map	Volume

ENHANCEMENT	
Animation	Integration
Array	Layering
Distortion	Level of Detail
Detail-In-Context	Overlay
Fade	Stereo
Fly Through	Transparency
Grouping	Video
Immersion	

INTERACTION	
Command Line	Reposition
Cut and Paste	Resize
Draw	Rotate
Drill Down	Scroll
Elide	Select
Filter	Sensory
Focus	Slide
GUI	Stretch
Highlight	Undo/Redo
Interogate	Zoom
Pan	

DEPLOYMENT	
Availability	Users
Extensibility	Virtual Machine
Scripts	Hardware
Platform	Operating System

Characterising a view (Analyst's Notebook)



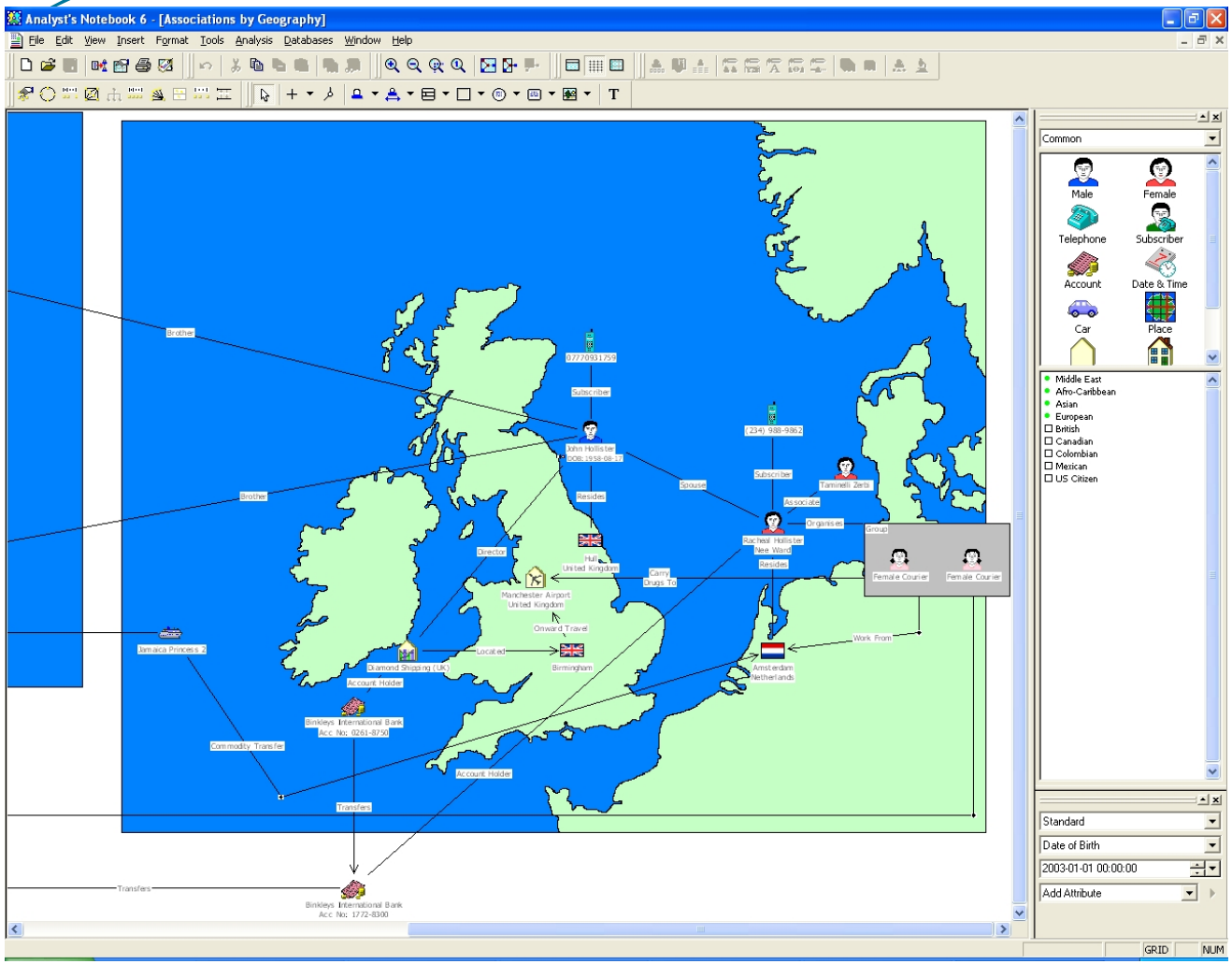
DOMAIN CONTEXT

Activity: Analyse, Assess, Report, Schedule
Area: Intelligence
Environment: Joint, Land
Level of Command: Strategic, Tactical
Role: HQ J2, Intel Analyst
Scenario: Special Ops, Low Intensity Conflict

DESCRIPTIVE ASPECT

Communications: Email, Phone
Family: Brother, Sister
Finance: Account, Money, Transfer
Geography: Area, City, Country, Location, Maps
Identity: Name, Sex, Flag, Nationality
Movement: Flight, Travel
People: Actor, Group
Possession: Holder
Relationships: Family
Time: Age, Critical, Current, Date, Duration, Interval
Transportation: Vehicle, Car, Ship

Characterising a view (Analyst's Notebook)



REPRESENTATION
Figure
Graph.directed
Graph.layout.symmetric
Graph.link
Graph.link.text
Graph.node
Graph.node.nested
Graph.node.icon
Graph.node.text
Map.2D
Table
List

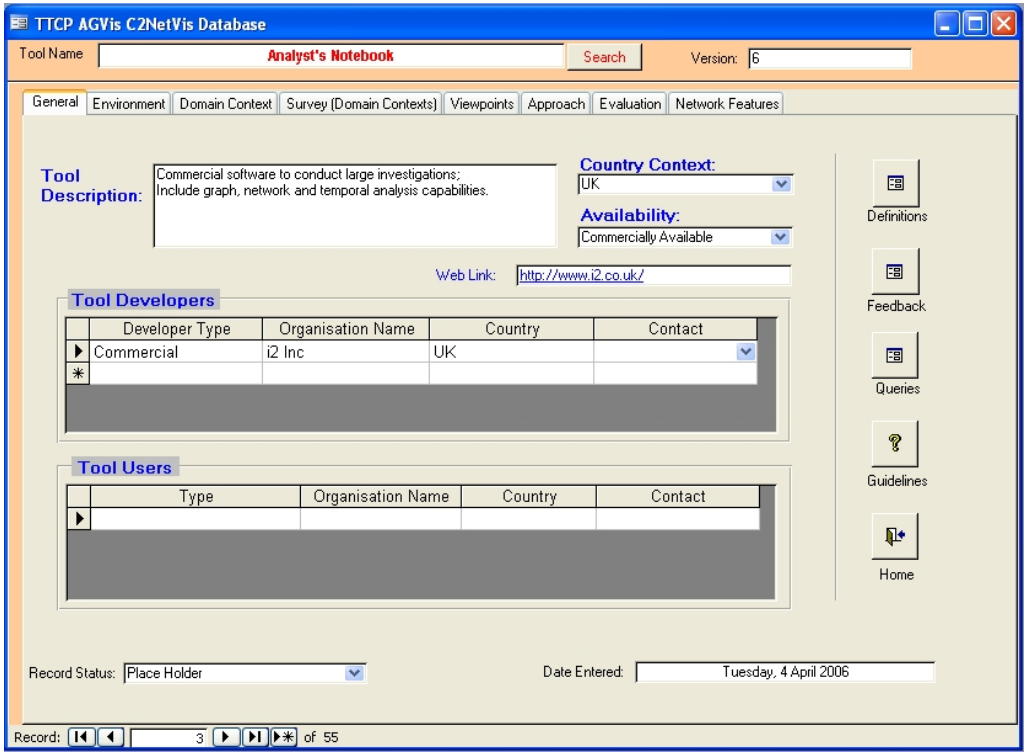
INTERACTION
Cut & Paste
Drag & Drop
GUI.Point and Click
Highlight
Pan
Resize
Scroll
Select
Undo & Redo
Zoom

ENHANCEMENT
Grouping
Layering
Overlay

DEPLOYMENT
Availability.Commercial
Extensibility.C#
Extensibility.C++
Extensibility.COM
Extensibility.COM+
Extensibility.NET
OS.Windows.*
Platform.PC.*
Users.Multiple

C2NetVis Knowledge Base

- ~55 network visualisation tools surveyed and characterised using RM-Vis
- Format: MS Access Database
- Last updated: 2006
- Includes showcase examples and evaluations



Searching the Knowledge Base

VIEWPOINT	VIEWS	
Monitor belligerent activities	Analyst's Notebook Daisy InFlow NetMap	NetMiner Starlight VisuaLinks
Assess robustness of communication network	Analyst's Notebook Daisy FATCAT NetMap	NetMiner Starlight VisuaLinks
Team building	Agna Analyst's Notebook InFlow KrackPlot MultiNet Negopy Netdraw NetMap NetMiner	Netvis Pajek SocioMetrica Starlight StOCNET UCINET Visone VisuaLinks

Future Directions: The Imago Project

A distributed environment that can be used to rapidly prototype, evaluate, and transitioning visualisation approaches for C2.

The platform provides a means of integrating and sharing the output of visualisation tools, storing, accessing and managing showcase examples of visual representations via an underlying reference model, and providing access to underlying data sources provided through simulation, representative data, and/or operational data.

Summary and Conclusions

- C2NetVis can be used to discover and evaluate Network Visualisation technologies in reference to a domain context
- It helps to identify the relevant approaches to achieve a task
- Facilitate the transition of approaches for operational use
- C2NetVis serves as a knowledge base for the Imago project