(U) The use of Analytic Decision Game (ADG) methods for test and evaluation of hard and soft data fusion systems and education of a new generation of data fusion analysts

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Abstract

The study and practice of human reasoning, has undergone significant change in recent years from both a theoretical and methodological perspective [1]. With the advent of ubiquitous communication, advances in computing and numerous available analytic support tools, the push for instantaneous reporting and analysis has become the expectation [2]. This is particularly prevalent in the intelligence community (IC) and in the military, where commanders (and their leadership) expect not only a bird's-eye view of operations as they happen, but a play-by-play analysis of operational effectiveness. While we have seen rapid technological advances to support collections analysis and dissemination; it is unclear if our human analysts made similar advances or whether they have even benefitted from the technological advances. Are human analysts capable of making instantaneous assessments or are they simply restating what the sensor/computing "black-box" is spitting out? This paper explores the use of the analytic decision game (ADG) as a method to train, not only the human analyst, but the data fusion systems that inform much of the black-box technology being touted as the next intelligence solution. The ADG is an adaptation of a proven training and planning methodology – the military war game. It presents students with a set of realistic problems and challenges them to work toward actionable intelligence, course of action or probable solution. Such training enhances the capability of the human-in-the-loop in a data fusion system (viz., the "human fuser") as well as providing a basis for training and testing on the same data sets. The ADG can also be used as a database for the test and evaluation of algorithms and the data fusion systems they support. The ADG is not the solution; but the pathway. This paper describes the concept of ADG and describes both research and training being conducted at Penn State using new multi-source synthetic data sets.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
OCT 2012	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
The use of Analytic Decision Game (ADG) methods for test and evaluation of hard and soft data fusion systems and education of a new generation of data fusion analysts	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **College of Information Sciences & Technology Pennsylvania State University University Park, PA, U.S.A.**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM202976. 2012 Joint Meeting of the Military Sensing Symposia (MSS) held in Washington, DC on October 22-25, 2012.

14. ABSTRACT

The study and practice of human reasoning, has undergone significant change in recent years from both a theoretical and methodological perspective [1]. With the advent of ubiquitous communication, advances in computing and numerous available analytic support tools, the push for instantaneous reporting and analysis has become the expectation [2]. This is particularly prevalent in the intelligence community (IC) and in the military, where commanders (and their leadership) expect not only a birds-eye view of operations as they happen, but a play-by-play analysis of operational effectiveness. While we have seen rapid technological advances to support collections analysis and dissemination; it is unclear if our human analysts made similar advances or whether they have even benefitted from the technological advances. Are human analysts capable of making instantaneous assessments or are they simply restating what the sensor/computing black-box is spitting out? This paper explores the use of the analytic decision game (ADG) as a method to train, not only the human analyst, but the data fusion systems that inform much of the black-box technology being touted as the next intelligence solution. The ADG is an adaptation of a proven training and planning methodology the military war game. It presents students with a set of realistic problems and challenges them to work toward actionable intelligence, course of action or probable solution. Such training enhances the capability of the human-in-the-loop in a data fusion system (viz., the human fuser) as well as providing a basis for training and testing on the same data sets. The ADG can also be used as a database for the test and evaluation of algorithms and the data fusion systems they support. The ADG is not the solution; but the pathway. This paper describes the concept of ADG and describes both research and training being conducted at Penn State using new multi-source synthetic data sets.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**SAR**	**9**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

The military community has made extensive use of simulations across the entire spectrum of warfare – strategic, operational and tactical. The U.S. Department of Defense (DOD) has led this effort since the 1950s; however the notion of the military war game can be traced back to the early 19th century. The modern war game is attributed to Prussian military tactician, Georg Leopold von Reisswitz's. Reisswitz's *Kriegspiel* [3] introduced the elements of force on force engagements, the use of tactical terrain, game umpires and the establishment of game rules. The Prussian military introduced war gaming in their officer training in the 1820's; the U.S. military adopted the practice in the post-Civil war era for use at the military academies in the 1880's.

The 2005 edition of Joint Publication 1-02, *DoD Dictionary of Military and Associated Terms* defines war game as a "simulation……of a military operation involving two or more opposing forces, using rules, data and procedures designed to depict an actual or assumed real life situation" [4]. The term *war game* is no longer part of official the DoD lexicon, with no listing in the most recent edition of Joint Pub 1-02 (2012). The term and concept has been modernized by the system, "modeling and simulation" [5]. Whereas DoD defines model as, "A physical, mathematical, or otherwise logical representation of a system, entity, phenomenon, or process;" and simulation as, "…a method for implementing a model over time" [6]. Even though the terminology has changed, the notion of the *war game* is actively used in planning, analysis and training. In particular it is being integrated into traditional education pedagogy at places like The Pennsylvania State University, where the *analytic decision game* (ADG) has become a staple for training future analysts of security and risk and for use in the test and evaluation of data fusion processes.

The ADG is an adaptation of the Tactical Decision Game (TDG); similar to military war-game simulations popularized by military planners and tacticians to increase the understanding of tactical awareness and decision-making [7]. The ADG was adapted by Graham [8] to promote exercise-based instruction for teaching and practicing structured analytic techniques, decision-making and critical thinking for the Security and Risk Analysis curriculum in the College of Information Sciences and Technology at The Pennsylvania State University. Several large scale decision games have been constructed for this purpose; each will be described briefly herein. Whereas the TDG focuses at the tactical level of decision-making, the ADG adopts an operational (or strategic) view of the engagement space. The ADG does not exercise military or law enforcement tactics. However, a purposefully constructed ADG could be used for such a purpose.

In the threat/risk management process, for military operations, law enforcement or emergency management, the testing and evaluation of plans, operational concepts, command and control procedures or incident management strategies is critical. Simulations can be invaluable for developing and evaluating such processes. Simulations can also expose biases emerging from group think; identify gaps and vulnerabilities; and highlighting areas for improving internal processes and inter-organizational cooperation. The value of using simulation and modeling to assess real problems should be a critical part of any security plan or evaluation of operational processes. While modeling and simulation benefits from the participation of subject matter expertise, innovations often emerge from novice participants who are not blinded by pre-conceived notions or embedded processes.

This notion is especially true in the examination of security and risk issues that are increasingly influenced by emerging technologies and social media. The current generation of students – the so-called digital natives [9] outfitted with a mobile suite of sensors and acting as both sensing and reporting platform, are developing novel ways to communicate, collaborate and analyze data. Participatory sensing has been described as "the citizen-powered approach to illuminating the patterns that shape the world…" [10]. Students acting as intelligence analysts are adapting analytic methods to fit their modes and methods of social communication with very positive results. To look at today's student participating in an analytic decision game is to get a glimpse at tomorrow's analyst; they are building their own set of digital tactics, techniques and procedures (digital TTPs) and applying them to real-life problems. Again, the ADG is not the solution, but the pathway.

The ADG is a scenario-based simulation involving synthetic data elements (reports, observations and intelligence products) that, when considered from end-to-end tell a story or suggest a probable course of action [11]. While the scenario may resemble actual events, by and large the dataset supporting the ADG is not real. It is, however, intended to be representative of the types of information that are observed and reported within the analytic environment represented. The ADG scenario is not intended to represent actual military, intelligence or law enforcement methods, intelligence collection efforts, intelligence systems or decision support mechanisms.

Figure 1: The Simulation Continuum [from 12]

Figure 1 depicts the simulation continuum indicating the utility of such tools that can be scaled and focused to suit a wide range of training participants and objectives. The simulation offers a simple, adaptable and effective method of providing realistic training in a time and resource-constrained environment. Taylor portrays the simulation continuum as one that extends from field exercises through computer simulations to analytic models, where the realism of forces on the ground (live maneuver) is countered by the economy of abstract simulations [12]. As Schmitt states, "…there is no substitute for experience of the real thing, it can be hard to come by and tragically unforgiving" [7]. Simulations offer a practical alternative that is reusable and tailored to the specific needs of the user. That need extends beyond the exercise environment and into the area of test and evaluation.

1.1 ADG for test and evaluation

There is a rising demand for new and improved data fusion techniques and algorithms that can address the evaluation and processing of hard and soft data types [13]. Much progress has been made in recent years in refining hard sensor processing, mostly in the area of one-dimensional signals [14]. More recently the research focus has shifted to include logical, non-signals based data with more emphasis placed on developing natural language processing techniques and software. Emerging research supporting the integration of hard and soft data types into a common analytic framework poses a myriad of problems, not the least of which is the supporting data.

One major limiting feature in the research of integrated hard and soft data fusion is the availability of realistic unclassified data sets. This is particularly true for data that deals with the challenges of complex operations, such as counterinsurgency, terrorism or other areas of security and risk. One means to address this shortfall is through the use of analogous scenarios and corresponding datasets. To fill the void researchers at The Pennsylvania State University developed a synthetic dataset called SYNCOIN [15]. SYNCOIN, which stands for the SYNthetic COunterINsurgency (SYNCOIN) data set was created to support the development and implementation of hard/soft fusion analysis processes. Developed at Penn State and partially funded under a grant by the U.S. Army Research Office (ARO), SYNCOIN filled the need for realistic representational data [16], [17].

The focus of the SYNCOIN counter-insurgency (COIN) dataset is to support the development and implementation of fusion and analysis processes, data stores design, and the development of process flows and interfaces required for both automated processing and user in-the-loop analysis to enhance Situation Awareness (SA) and Situation Understanding (SU) [18]. It was developed specifically for a multi-year Multidisciplinary University Research Initiative (MURI), sponsored by the Army Research Office. SYNCOIN focuses on the intricacies of improvised explosive device (IED) networks and operations. The scenario takes place in the waning months of Operation Iraqi Freedom (OIF) and is largely centered in Baghdad, Iraq [19].

The data models considered for the development of the SYNCOIN dataset are intended to mimic the analysis of various unstructured messages derived from the tactical intelligence effort within the counter-insurgency domain. The messages are intended to support the test and evaluation of entity extraction and semantic reasoning techniques to support entity capture for various fusion model elements emulated within the SYNCOIN dataset, including:

- *Agent*
  - *Person*: High Value Target (HVT), Person of Interest (POI), Group Leader, Interlocutor, Merchant, Informant, Victim, Witness, Terrorist, Detainee, Police, Military, Ethno-Religious, Political, Foreign agent, Insurgent
  - *Organization:* Militia, Military, Police, Terrorist, Ethno-Religious, Political, Commercial, Tribe, Clan, Family, Criminal
- *Location*: Geo-spatial Representation, Military Grid Reference System, Latitude/Longitude
- *Time*: Temporal Expression, Temporal Entity
- *Event/Transaction*: Organize, Plan, Meet, Execute, Communicate, Conflict, Transact
- *Equipment*: IED Components, Weapons Caches, Communications, Vehicles

Deception was not a specifically designed into the SYNCOIN dataset. However, misdirection, falsehoods, inaccuracies and bad information is resident in many of the reports, interviews, sightings and depictions that form the basis of the messages that make up the dataset. This was accomplished to provide background noise and to give a realistic feel to the messages.

SYNCOIN, while very useful, is admittedly imperfect. While it does some things fairly well, like represent unstructured observations and semi-structured reports; it falls short when addressing the underlying specifics of hard sensor modalities. This is largely a design issue. SYNCOIN was designed and constructed to represent a mix of reports, observations and records that might be received and recorded within a battalion level command post. Raw sensor data would not likely be part of this exchange, whereas an analysis of the raw data would more the norm. In fact it is reasonable that several levels of interpretation might occur.

For example, the signal intercept of a cell phone communication between a HVT and a named person of interest is captured and recorded at the signals battalion. The record is forwarded to a linguist for transcription and another record is made. This record is then sent onward to a HUMINT analyst for interpretation, and again a summary record is created. By this time, the original signals intercept is only reflected in the metadata (time, data, location, time of call, phone numbers, etc.) that is carried forward intact with expanding analysis; the raw signals are no longer of interest at this level. The HUMINT analytic summary is forwarded to an operations analyst who recognizes the operational significance of the transaction and parties involved and the report is further annotated. The annotated report is finally forwarded to the command post for information or action.

In essence, the hard-sensor related messages within SYNCOIN represent what might be referred to as hybrid reports. Hall, et al addresses the changing role of humans in the data fusion process; whereas traditional data fusion systems focused primarily on fusing data from physical sensors to address physical targets; the emerging trend focuses on human-centered data fusion processes [18]. The human-centered fusion approach has many advantages of over traditional methods which rely on highly calibrated systems collecting data within a specified domain. Humans acting as soft sensors, have the ability to detect intricacies of human behavior, mood and motivation.

Future attempts in building hard/soft datasets will need to address the handling and representation of underlying hard sensor information. Another approach might be to build up a separate but corresponding hard-data set to augment SYNCOIN or other existing datasets such as those that have been created for the Analytic Decision Game series of exercises.

While the topic of SYNCOIN was centered on the cause and effects of IED networks, other equally challenging operational environments can be addressed using scenarios like those that make up the analytic decision game. As a practical matter, any given ADG dataset is extensible beyond the exercise environment for use in test and evaluation of data fusion processes.

1.2 Role of the ADG in the classroom

The original motivation and focus of the ADG series exercises and data was to teach and promote the use of structured analytic techniques. Richards Heuer and Randolph Pherson in their outstanding primer, *Structured Analytic Techniques (SAT) for Intelligence Analysts* have set the standard for teaching structured analytics. The SAT primer is the perfect companion for the analytic decision game.

The adaptability of the ADG enables it to meet a broad range of teaching and training objectives; it can be tailored to specific course content, terminal or enabling learning objective or constructed to act as a stand-alone exercise. The ADG offers an intensive experience in critical analysis by broadening students' perspectives beyond their culture or educational discipline. It offers an opportunity for the introduction of new analytic techniques as well as the integration of knowledge, skills and abilities (KSAs) developed in previous courses of study. The ADG requires active engagement. Participants cannot just ride the exercise wave as passive observers; the ADG requires students to examine complex issues in substantial pieces of analysis, presentation and writing.

In the College of Information Sciences and Technology, the topics of the ADG address the key disciplines of the three (3) options that comprise the Security and Risk Analysis curriculum - Social Factors, Information & Cyber Security, and Intelligence Analysis & Modeling. The analysis derived from a given ADG scenario requires the application of analytic processes across all three disciplinary lines (SRA course options) to examine a significant problem of security and risk.

For example, the exercise written for ADG # 1, "*Show me the Money*," focuses on funding global terrorism [20]. Exercise participants working in teams must chart the flow of money and identify the individuals and groups that comprise the financial network funding a terrorist organization. ADG #1 was designed to illustrate the distributed nature of terrorist organizations and operations on a global scale. Student analysts, playing roles within a Joint Counter-Terrorism Task Force, are required to piece together the clues to thwart a terrorist plot while constructing visualizations to represent the terror group's organizational structure, area of operations, and the operational continuum of the terror plot. Data supporting this scenario takes the form of both finished and raw intelligence reports from the various agencies involved.

ADG #2 "*Diabolical Deeds in the District*" is similar from a team analytic perspective, but is constrained in the sense that analytic teams assume a single agency focus [21]. Student analysts are formed in agency teams to view information and perform sense-making from a particular mission focus to demonstrate and reinforce what Okerbloom calls "the influence of organizational culture on decision-making." [22]. In ADG # 2 four agency teams resolve to uncover the connections between a diamond heist, a terror organization and a crash on the Washington, D.C. Metro. Staying in their respective investigative lane is each team's challenge. Data for this scenario is represented by informal information exchanges between agency members in the form of e-mails, memorandums and text messages.

For ADG # 3, *Piracy on the High Seas*, the focus is on Somali Piracy [11]. This scenario was expressly built to support the very first Security and Risk Analysis (SRA) Capstone course. SRA is a relatively new major in Penn State's college of Information Sciences and Technology (IST). Because this is the capstone course, it requires students to dedicate a large portion of the course in research and writing. Preceding the exercise student teams develop a comprehensive study of the current state of Somali Piracy. The scenario written for the course seeks to exercise one probable future state. The *High Seas* scenario places students in the Intelligence Section (C-2) of a Combined Task Force (CTF). Data supporting this scenario has the look and feel of intelligence messages that could be received in a CTF command post. The scenario deals with more than just piracy however, causing students to sort through the ambiguities of media and

international political commentary to understand what groups pose the real danger; all while the threat of piracy moves from the Gulf of Aden to tourist areas closer to home.

ADG # 4, High Finance, which is under construction, will focus on persistent cyber threats to the financial sector. The analytic agency of record in this scenario is the Financial Services Information Sharing and Analysis Center (FS-ISAC), whose role is to support the U.S. Department of Treasury and the Financial Services Sector. Data for this scenario emulates that disseminated in the Department of Homeland Security Daily Report (DHS Daily). Exercise participants are required to make weekly cyber threat assessments and security recommendations to the financial sector to balance their control measures accordingly. This ADG is also being developed to support the SRA Capstone.

Finally, ADG # 5, *Cyber Futures,* which is also under construction and slated for a future SRA Capstone exercise, deal with cyber Armageddon. The research and writing assignment for this problem is to derive three probable cyber futures all in the year 2025: "*Life is Good*," where cyber-space is everything we ever imagined; "*Status Quo*," in which we have maintained our current cyber trends; and "*On the Brink*," in which we are facing cyber collapse. The exercise supporting this capstone involves a "post-cyber calamity." Exercise participants in this scenario take on a very different role in than their predecessors. Participants in ADG # 5 assume the various roles of community leaders who must work together to recover from cyber collapse.

The immersive nature of the exercise environment shifts the burden away from the instructor and onto the student participant. The goal is for student participants to analyze their way into and out of the scenario, perform analysis from disparate data and offer actionable recommendations based on sound analytic principles.

The use of simulations in the undergraduate classroom is not without its challenges. Exercise design, scenario and data creation, and exercise facilitation all provide significant barriers to the uninitiated. Exercise design and data creation to support an ADG simulation is an arduous task that must be thoroughly researched and artfully represented. First the data should sound and feel authentic. Second, it must be presented in a realistic, if not entertaining fashion in order to gain and hold the attention of the participants. Today's student who has been weaned on high fidelity gaming computers, software and game scenarios want realism and believability. Even though the simulation is built of synthetic data, it must have the look and feel of the real thing; lest the participant venture outside the scenario (bringing in external sources) in order to challenge its veracity.

Nothing will bring a scenario down harder or faster than Wikipedia [23]; therefore one word of caution is included in every exercise pre-brief; "All text-based evidence will be provided by the instructor. Knowledge exploration beyond the message traffic is encouraged to a degree. For example, the internet may be utilized to expand situational awareness (SA) of the named areas of interest and is a good source for maps, photos or other geo-reference material; however, do not introduce written evidence from outside the problem" [21].

Most undergraduate students have little experience outside the classroom and therefore may need substantial coaching and prompting to get them to think and act the part of the law enforcement, military or industry analyst whose role they represent within the scenario. To address this shortfall and to effectively facilitate the exercise in general requires a modicum of knowledge and/or experience in the problem space being represented in the simulation. This may be a reason why many traditional faculty members shy away from the construction and use of ADG-type exercises in the classroom.

Acknowledgements: Part of the research described in this paper was funded by a Multidisciplinary University Research Initiative (MURI) grant (Number W911NF-09-1-0392) for "Unified Research on Networked-based Hard/Soft Information Fusion", issued by the US Army Research Office (ARO) under the program management of Dr. John Lavery.

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