

Development of a Diplomatic, Information, Military, Health, and Economic Effects Modeling System

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ABSTRACT

Having a clear picture of different facets of the current situation is key in the conduct of tactical operations within a theater. To this end, the ensemble application of sentic computing and intention awareness techniques is hereby examined to develop a novel analysis framework for estimating the effects of diplomatic, informational, military, health, and economic activities in the context of a theater of operations. A set of candidate models of the flow and evolution of population beliefs and intentions is evaluated and recommended as the starting point for developing an effects modeling system for tactical commanders. In particular, the following needs were identified: (1) understanding and representing the underlying causality within the population; (2) formulating models that are both sensitive and computable; (3) validating the predictions of population beliefs, intentions, and behaviors by model.

Keywords: Diplomacy-Information-Military-Health-Economics (DIMHE), Effects Modeling System, Intention Awareness, Military Information, Sentic Computing

1. INTRODUCTION

As conflicts become more systemically complex, leaders and military officials must use multidimensional analysis to assess the state and future of a conflict, rather than relying on more traditional metrics such as military progress and capabilities. This especially holds true of recent asymmetric conflicts, in which the effects

of each military operation must be carefully considered in order to avoid undermining the grand political strategy.

In response to this fundamental shift in the application of military power, the U.S. military coined the term effect-based operation (EBO). EBOs are “operations that are planned, executed, assessed, and adapted based on a holistic understanding of the operational environment

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in order to influence or change system behavior or capabilities using the integrated application of selected instruments of power to achieve directed policy aims (Smith, 2003).” This has led to the development of new doctrine models, such as diplomacy, information, military, health, and economics (DIMHE) and other conflict prediction systems (Howard, 2007). Such systems require that tactical commanders consider all of these factors in mission planning and execution.

The goal of DIMHE, which extends the diplomacy, information, military, and economics (DIME) paradigm by taking into account also health impacts, is “to avoid counter-productive and conflicting activities in the conduct of tactical operations within a theater (Applied Systems Intelligence Inc., 2007).” The importance of extending DIME with health effects is premised by the pursuit and the implementation of electronic health records for both peacetime and contingency/wartime operations by the U.S. military in the past two decades. Similarly, many other national militaries have embarked upon like efforts. During international conflicts and peacekeeping operations, the member countries of the North Atlantic Treaty Organization (NATO) routinely contribute personnel and resources to staff multinational operations for direct combat, combat service support, and health care delivery.

During these types of operations, it is common to have soldiers from a number of countries receiving care in a facility staffed by multinational medical personnel from across the NATO countries. The documentation of health care delivery often mirrors the capabilities within individual countries (e.g., paper-based, electronic, and hybrid) and can be dependent upon the lead country staffing the health care facility in support of the mission (Do, Lasome, & Parramore, 2011).

In an attempt to enable the U.S. Army to assess and manage the social aspects of stability operations in overseas conflicts, this paper identifies and characterized at least five classes of models that could be applicable to the DIMHE effects modeling (DEM) system. The identifi-

cation of possible models was supported by a broad, but necessarily limited, literature search that spanned political theory, demographics, group behavior research, biostatistics, genetic theory, health science, opinion mining, social networking, and group beliefs and motivations. From this search, a classification of models into five types was made. These model classes are broad, with considerable variation in breadth, depth of detail, and time span across the model instances found. Each of the model classes was intended to provide an approach to modeling the population, its beliefs and motives and its likely behaviors. Model classes were formulated based on the political, military, economic, social, infrastructure and information (PMESII) analytical tool, which forms a container for the effects of DIMHE phenomena (Hillson, 2009). The five classes hereby defined are:

- **System Dynamic Models:** This class of model generally consists of a system of differential equations that describe the relationships between attributes of the system state as the system evolves through time. Given an initial state $X(0)$, a future state $X(t)$ can be calculated. In practice, only the smallest systems of up to a few dozen equations can be solved unless the systems are assumed to be linear (all higher order derivatives = 0). Much larger systems can be represented and solved under the assumption of linearity, which often is acceptable for short time periods and small variations in the state attributes (Forrester, 1994);
- **State Transition Models:** A state transition model represents the state of the population beliefs and PMESII as a hierarchical state graph with nodes representing system state and links representing transition probabilities between the states (California Department of Forestry and Fire Protection, 2012). The hierarchical structure of the graph embeds subgraphs within nodes, so that substates can be defined within a state and so on. A node in a subgraph represents a total state for the population system be-

ing modeled, and a system can be in only one state at a time. A state transition model may also be composed of a number of disconnected state graphs, each representing state transitions for an independent part of the system;

- **Social Network Models:** These are graph-structured models of relationships between people or groups of people. Nodes represent the individuals or groups and vertices represent relationships such as communication or influence (Hanneman & Riddle, 2005; Niazi & Hussain, 2011). In particular, data processing at content-level is performed through the extraction of interaction semantics and sentics, that is, the conceptual and affective information associated with the interactive behavior of social network members (Grassi et al., 2011);
- **Group Ideology Models:** This type of model represents the beliefs and intentions of groups within a population and suggests what actions the groups are likely to take in the future (Marx & Holzner, 1977). The model is implemented using one or more symbolic reasoners to provide an “analyze-plan-act-coordinate” loop for each group. The groups are goal-driven with goals defined by their adopted ideology, and may be in conflict with the goals of other groups. The groups have beliefs that may be inaccurate, incomplete, and inconsistent. Groups take actions to fulfill their goals, and actions may be directly mediated by the state of the PMESII;
- **Group Dynamics Models:** This type of model represents the behaviors and intentions of groups within a population and suggests what actions the groups are likely to take in the future based on their internal and external dynamic relationships. Although similar to the Group Ideology model in mechanization, the knowledge within this class of model is focused on group dynamics rather than ideology, and is therefore more general and more re-usable (Lewin, 1945).

DEM is situated at the brigade-level because that is where the necessary operational and architectural resources exist today. The DEM model should be able to run its full analysis cycle in roughly one hour to accommodate the current status reporting procedure at the brigade-level. The analysis should include high fidelity predictions within a time frame of days, accompanied by lower fidelity predictions that span months. The system should facilitate situation assessment when one brigade relieves another on station, as well as sharing information between cooperating brigades. Finally, DEM should be granular enough to represent cultural differences in different theaters and adaptive as the theater evolves.

2. SYSTEM ARCHITECTURE

The DEM system is meant to be a state-of-the-art tool for analysts at the brigade-level to use for planning and evaluating the effectiveness of the effects-based operations, particularly focused on integration of diplomatic, informational, military, health, and economic effects. Because DEM is an integration of ideas from several disciplines, a component-based framework approach is the best investment for the DEM system. A component-oriented framework allows DEM to evolve as data visualization technologies evolve.

This research work confirmed that the initial framework necessary to setup DEM exists and is already integrated with major defense programs as commercialization opportunities for the DEM system.

Planning Timelines. Because of the dynamic nature of the domain, planning will be flexible and adaptive. The analyst expects to define goals for the short term, mid term, and long term focuses.

Maintenance of the Current State. The state of the PMESII will be very dynamic and some means of automation will need to be integrated. The system architecture accounts for automated scanning of news headlines and

translation of those headlines into a link analysis so the analyst can understand relationships between actors, groups, facilities, and resources in the PMESII. In addition, services are planned to handle spidering of open/closed databases such as the joint operations intelligence center (JOIC) database and services to recognize patterns in the data. The belief models of the PMESII elements will be maintained by the analyst. It is expected that the belief models will need to be edited as company-level soldiers relay intelligence back to the brigade. The architecture describes a service to maintain the belief models of these elements.

Definition of the Desired Goal State. In the U.S. Army, executable plans are communicated through operational orders (OP-ORD) (Lewin, 1945). Analysts will interpret the OP-ORDs as a set of desired goal states. Each of these goals will be further broken down into courses of action, which result in sequels in the OP-ORDs and planned contingencies. It is at this level that the analysts begin to plan the details and assign responsibilities by battalion. Progress metrics are tied to the goal states as a way to measure progress toward the goal.

Simulation of Operational Order to Current State. This functionality will enable the analyst to run a simulation of the interactions between the OP-ORD and the belief models of the PMESII elements to project a future state of the PMESII (Hillson, 2009). This projection can be generated for the short, mid, or long term. The analyst can then apply the progress metrics associated with the desired end state for that term and evaluate whether the current strategy is expected to be effective. If the analyst is not happy with the results, he can further modify the strategy and run the simulation again.

Each of these components forms a piece of the larger spatiotemporal picture of the environment offered by the DEM model. States, timelines, and goal states each provide information that contributes not only to greater battlefield situational awareness (SA), but in-

attention awareness (IA) as well. IA is a concept originally conceived by Howard et al. (2006) as a means to better understanding command, control, communication, and intelligence.

While the military applications are obvious, it has been extended to a number of other fields as well, particularly those involving a high ratio of information throughput to time available for analysis. While achieving the former has been the pursuit of military strategists and scientists throughout the history of organized warfare, the goal of DEM is to build on SA to achieve the latter. IA combines spatial and temporal information, as well as fundamental insight into the function of the human mind, to address the role of human actors in a given situation.

Instead of modeling the environment based on objects and apparent attributes such as speed, direction, and numbers, IA exploits circumstantial semantics and sentics, that is, the conceptual and affective information associated with objects and actors of the operating environment, and combines them with prior events to construct an event space from which human intentions can be inferred. The result is not entirely unlike enhanced SA, but due to its incorporation of human actor characteristics, it offers greater causal dimensionality.

SA can be enhanced by increasingly intuitive computer interfaces and greater data availability (Howard et al., 2005). For instance, a tank commander who, in addition to regular radio contact with the other members of his patrol, is provided with digital targeting information from circling aircraft, will have superior SA. However, what enhanced SA systems lack is the ability to prioritize information based on human needs and abilities. IA, and the goal of DEM, consists of extending SA to greater informational and intuitive depth. While this sometimes means a greater volume of information, the qualitative attributes of this information are what truly distinguish DEM systems from enhanced SA systems.

3. DEVELOPMENT METHODS

The adopted development methods follow the Xtreme programming methodology, working in short iterations to reach through all layers of the architecture to implement a small, well-defined use case. Feedback on each iteration’s prototype is elicited to further integrate the look and feel the analyst expects to work with (Howard et al., 2005).

In order to overcome the challenges of health information acquisition, in particular, AI and Semantic Web techniques are employed on publicly available health data. For patient tracking, disease surveillance, and medical situational awareness, in fact, doctrinal, organizational, policy, and operational barriers can heavily limit health information exchange and interoperability. Hence, sentic computing techniques (Cambria & Hussain, 2012) are adopted on both structured and unstructured available health record data free from privacy issues, e.g., health statistics and patient opinions.

Sentic computing is a multi-disciplinary approach to opinion mining and sentiment analysis that involves the use of: AI and Semantic Web techniques, for knowledge representation and

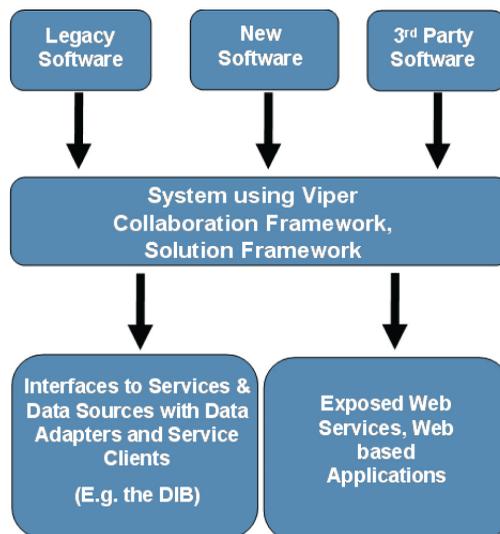
inference; mathematics, for carrying out tasks such as graph mining and multi-dimensionality reduction; linguistics, for discourse analysis and pragmatics; psychology, for cognitive and affective modelling; sociology, for understanding social network dynamics and social influence; finally ethics, for understanding related issues about the nature of mind and the creation of emotional machines.

Within DIMHE, in particular, a biologically inspired natural language processing approach (Cambria, Mazzocco, & Hussain, 2013) is employed, together with multi-dimensional scaling techniques (Cambria et al., 2013), for tasks such as health related quality of life measurement (Cambria, Benson, et al., 2012) and other patient centered applications (Cambria, Hussain, et al., 2012). (Figure 1).

4. SERVICE FRAMEWORKS

The envisioned architecture is a distributed infrastructure promoting application integration and collaboration across services and applications. It uses the service oriented architecture (SOA) to define, govern, and implement core

Figure 1. DIMHE development (courtesy Center for Advanced Defense Studies and Applied Systems Intelligence, Inc.)



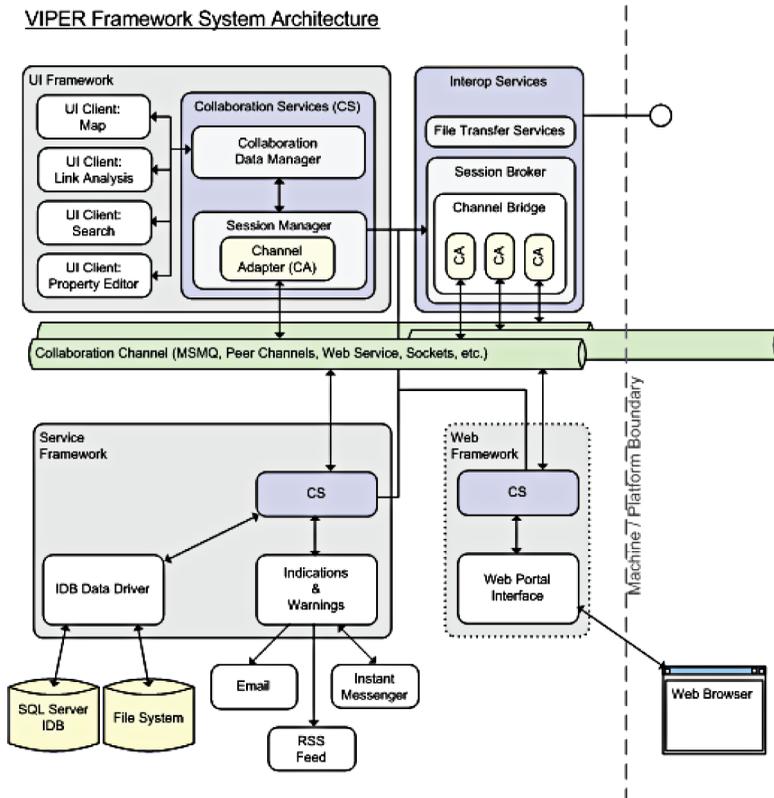
service interfaces, including discovery. It uses an event-driven architecture style for message routing and collaboration between users. It contains a suite of tools specifically designed to aid tying intelligence applications together. The value of this architecture lies specifically in its collaborative potential and in its open architecture (Spratt & Lawrence, 2012).

5. COLLABORATIVE FRAMEWORK

The collaboration framework is an event-based service integration framework, or more simply, a service bus. Systems are composed of compliant applications and services that interact via the collaboration framework. The framework

supports peer-to-peer and client-server configurations and runs on laptops or almost any Windows hardware. The value of the collaborative framework in the architecture is that it allows end-users to collaborate and share their data. More than just a screen-scraping technique, two collaborating users are actually sharing data, while maintaining separate presentation mechanisms. For example, suppose two analysts are collaborating on new intelligence data about a person of interest. The collaboration framework allows them to share their data about the person with each other, even though one analyst is using that data to evaluate the link analysis network for that person while the other analyst is using the data to simulate a belief model for that person. (Figure 2)

Figure 2. VIPER Framework (courtesy Center for Advanced Defense Studies and Applied Systems Intelligence, Inc.)



The following services make up the collaboration framework:

- **Collaboration Data Manager Service:** In-process object management and event notification service that handles activities such as creation and deletion of objects and client subscriptions;
- **Session Manager Service:** Windowed-ClientAdapter that provides the user an interface for connecting to local or remote SessionBrokers, managing their sessions, subscribing to sessions, and connecting the collaboration to the subscribed session;
- **Session Broker Service:** Service that manages available sessions on a single system. It handles activities such as keeping track of available sessions, session types, channel types, subscriptions, and session creation and deletion;
- **Interop Services:** Service responsible for providing information about available collaboration sessions on a system, bridging message traffic between heterogeneous collaboration channels;
- **Channel Adapter Service:** Service to enable collaboration messages to be sent and received across process (or system) boundaries. It is responsible for serializing and deserializing collaboration and session messages into a format appropriate for the current collaboration channel.

6. SOLUTION FRAMEWORK

Complementing the collaboration framework, the solution framework is an object-oriented execution environment for integrating components to form a Windows application, including service discovery. It provides basic components and mechanisms for connecting them together and defining their interaction. Ultimately, it is the framework that allows a user to work with related elements across multiple data sources. A PMESII element in the link analysis component window can be dragged and dropped into the

belief value model component window and analyzed immediately, even though the components are different applications. This ability allows the framework to integrate multiple vendors seamlessly to boost the analyst's view into the data. (Figure 3)

7. TESTING AND EVALUATION

The value of a suite of models such as DEM is directly related to the extent to which the models can be tested and evaluated against the real world they purport to model. But the testing and evaluation of models such as DEM is not an easy task. This section will provide a background for the complex issues facing evaluation of DEM systems, and provide a set of recommendations to guide further work.

When the output of a model is compared to the observations of the real world, discrepancies can arise in two ways: (1) the model has an error in its implementation, but may otherwise be properly founded, or (2) the model was implemented completely as desired, but the underlying foundations of the model were flawed. The first outcome is the area of test and evaluation known as verification testing, whereas the second is the problem of validation.

Verification testing is normally conducted with pre-defined and pre-certified test cases whose expected outputs are thought to be "correct" with respect to the real world. A second issue in verification testing is the extent to which the system under test is fully exercised. It may take a very large number of pre-certified test cases to provide coverage of all aspects of the system under test.

Validation testing of models requires head-to-head comparison with the real world. If the output of the models agrees reasonably with the observations of the real world, the model can claim at least local (for a particular case) validity. After many trials over a broad range of conditions, the outputs of the suite of models may continue to agree reasonably with the observations of the real world, thus

Lastly, one of the fundamental issues in testing is the ability to isolate and repair the sources of discrepancies between the outcome that was expected and the outcome that is observed. Even with a solid notion of correctness of model predictions, this can be a difficult problem. For DEM, evolution of a set of useful models will require a strong approach to separating the effects of initial conditions, model parameter settings, and model structure.

8. CONCLUSION

This study has investigated the requirements and technology base for a suite of models to support in-theater assessment and prediction of the effects of diplomatic, informational, military, health, and economic activities on the political, economic, and social infrastructure. Of particular interest is the ability to model the spread of ideas, motivations, and beliefs within the non-combatant population.

Moreover, the importance of health information exchange and interoperability in the context of a theater of operations was stressed, in which operational commanders and medical advisors have a real-time need for accurate status reporting for operations under their purview.

The challenges associated with this research area include understanding the causality between elements of the population, formulating models that are both sensitive and computable, and validating the predictions of a population's beliefs and intentions at some future time. This research focuses on providing insight on the specification of a DEM model. It proposes what the desired properties would be and describes the architecture in which DEM would be situated. Additionally, this report evaluated 24 sources regarding the most promising uses of social modeling in computer science, biology, sociology, health science, and political science to derive the most desirable characteristics of the DEM model and to anticipate where it

would present challenges. Finally, the research evaluated how such a system would be verified and validated.

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REFERENCES

- Applied Systems Intelligence, Inc. (2007). *Technical proposal for a DIME effects model for tactical commanders*.
- California Department of Forestry and Fire Protection. (2012). *Formulation of a state and transition model*. Retrieved June 11, 2012, from <http://frap.fire.ca.gov/projects/hardwood_expert/building_state/definitionofmodel.htm>
- Cambria, E., Benson, T., Eckl, C., & Hussain, A. (2012). Sentic PROMs: Application of sentic computing to the development of a novel unified framework for measuring health-care quality. *Expert Systems with Applications*, 39(12), 10533–10543. doi:10.1016/j.eswa.2012.02.120.
- Cambria, E., & Hussain, A. (2012). *Sentic computing: techniques, tools, and applications*. Dordrecht, Netherlands: Springer. doi:10.1007/978-94-007-5070-8.
- Cambria, E., Hussain, A., Durrani, T., Havasi, C., Eckl, C., & Munro, J. (2012). Sentic computing for patient centered applications. *IEEE ICSP*, 1279-1282.
- Cambria, E., Mazzocco, T., & Hussain, A. (2013). Application of multi-dimensional scaling and artificial neural networks for biologically inspired opinion mining. *Biologically Inspired Cognitive Architectures*. doi:10.1016/j.bica.2013.02.003.
- Cambria, E., Song, Y., Wang, H., & Howard, N. (2013). Semantic multi-dimensional scaling for open-domain sentiment analysis. *IEEE Intelligent Systems*. doi:10.1109/MIS.2012.118.

- Do, N., Lasome, C., & Parramore, D. (2011). Tutorial on health information exchange and interoperability requirements in multinational military operations: Issues and imperatives for success. *HL7 International Standards and Education Meeting*, Sydney, Australia.
- Forrester, J. (1994). *A guide to learning system dynamics*. Cambridge, MA: MIT.
- Grassi, M., Cambria, E., Hussain, A., & Piazza, F. (2011). Sentic web: A new paradigm for managing social media affective information. *Cognitive Computation*, 3(3), 480-489.
- Hanneman, R., & Riddle, M. (2005). *Introduction to social network methods*. Oakland, CA: University of California.
- Hillson, R. (2009). The DIME/PMESII model suite requirements project. *The Defense Technical Information Center (DTIC) NRL Review*, 235-239.
- Howard, N. (2007). *Intent-based automated conflict prediction and notification system (Pending)*. Washington, DC: U.S. Patent Office.
- Howard, N., Qusaibaty, A., & Kanareykin, S. (2006). Intention awareness in a nutshell. *Defense Concepts Journal*, 1(3), 48-57.
- Howard, N., & Singletary, B. A. (2005). Sensemaking in symbiotic joint-cognitive systems. In *Proceedings of the Computer-Human Interaction Conference, Association for Computer Machinery Special Interest Group on Computer-Human Interaction (ACM SIGCHI)* (pp. 1-4).
- Lewin, K. (1945). The research center for group dynamics at Massachusetts Institute of Technology. *Sociometry*, 8(2), 126-136. doi:10.2307/2785233.
- Marx, J. H., & Holzner, B. (1977). The social construction of strain and ideological models of grievance in contemporary movements. *Pacific Sociological Review*, 20(3), 411-438. doi:10.2307/1388916.
- Niazi, M., & Hussain, A. (2011). Social network analysis of trends in the consumer electronics domain. *IEEE ICCE*, 219-220.
- Smith, E. (2003). *Effects-based operations. Command & Control Research Publications*. CCRP.
- Sprott, D., & Lawrence, W. (2012). Understanding service-oriented architecture. Retrieved June 11, 2012, from <http://msdn.microsoft.com/en-us/library/aa480021.aspx>

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