GINA: System Interoperability for Enabling Smart Mobile System Services in Network Decision Support Systems

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Abstract

Smart mobile systems deployed in support of organizational decision-making objectives lead to a new, highly dynamic form of decision support systems (DSS) called network-DSS (NWDSS). We describe the salient properties of an NWDSS, emphasizing the central role of sensors and emergent knowledge processes (EKP) in such an environment. From a system design and development perspective, the defining property of sensor-driven EKP is that requirements cannot be identified in advance but rather emerge from the environment. This, in turn, demands an agile system development methodology which we argue must be built upon a flexible semantic system interoperability approach. We present the GINA (Global Information Network Architecture), a reflexive, executable, component-based, platform agnostic, model-driven architecture, which provides the necessary data, information and knowledge interoperability to enable services for smart mobile systems. We show how this approach works in a specific smart mobile system environment called Dragon Pulse.

1. Introduction

The evolution of mobile technology to the current state of smart handheld devices (e.g., iPhone™, Android™, iPad™) will have a profound impact upon organizational information system architecture and decision support systems (DSS). Smart mobile systems deployed in support of organizational decision-making objectives versus individual consumption lead to a new, highly dynamic form of DSS called network-DSS or NWDSS [9]. A NWDSS is characterized by fluid nodes of both human and machine agents, connected by mobile technology, which may enter and leave the network at unpredictable times. The ability of smart handheld devices to serve simultaneously as computer, sensor, and telecommunication device invests the nodes of a NWDSS with powerful and flexible capabilities heretofore unavailable in networks. NWDSS comprise a hybrid of technological and social networks which de facto, decentralize decision-making, pushing it to the “edge” [1] and in the process strongly emphasizing collaborative decision-making.

Current smart mobile services are largely consumer-centric rather than organizational in focus. Although the consumer-centric dimension of smart mobile devices will no doubt continue to adapt and evolve in innovative ways, smart mobile systems designed to satisfy organizational requirements promise to be the next big challenge in information architecture design and development. This aspect of mobile services has largely been ignored to date.

Our objective is to examine how to integrate data, information and knowledge in order to enable smart mobile services for the particular class of information systems we call NWDSS. In particular, we focus upon NWDSS for C4ISR (Command, Control, Computer, Communications, Information, Surveillance and Reconnaissance) tactical operations applications such as emergency response, search and rescue, border patrol / tunnel detection, and maritime interdiction. We describe the salient properties of such an NWDSS, contrasting it to other classes of existing information systems, and emphasizing the central role of emergent knowledge processes (EKP) [10; 6] in such an environment. From a system design and development perspective, the defining property of EKP is that requirements cannot be identified in advance but rather emerge from the environment. This, in turn, demands an agile system development methodology which we argue must be
built upon a flexible semantic system interoperability approach. We present the GINA (Global Information Network Architecture) for system interoperability, a reflexive, executable, component-based, platform agnostic, model-driven architecture, which provides data and information required by the requisite services for smart mobile systems. We show at a high level how this approach has been implemented in a GINA-enabled C4ISR operational environment called Dragon Pulse. Our contribution from this research is the elaboration of design principles based upon semantic interoperability for smart mobile sensor-based, NWDSS environments which extend the scope of mobile services from consumer-centric to organizational applications.

2. Organizational Information Systems and Mobile Services

The emergence of mobile platforms such as the iPad and Android herald in parallel the emergence of the mobile network as a major platform for organizational information systems as well. With the growing adoption of virtualization and cloud computing, “the network as the computer” is being brought to its fullest manifestation. Currently, mobile services are primarily consumer-centric rather than organization-oriented with mobile services characterized as either utilitarian (e.g., route finding, roadside assistance) or hedonistic (e.g., games, music) [14]. We will focus upon the former in this paper. Driving the utilitarian services and of imperative importance for the organizational applications we will be discussing are location-based services which allow the precise spatial identification of the mobile device and related points of interest (POIs). Another critical theme of mobile services is that of context-awareness which, in the large sense, refers to smart devices being able to monitor an individual’s current state, predict his/her short term desires and behavior from a personal profile, and then provide services which support those desires/behavior (e.g., noting that a user is visiting a city and providing hotel and restaurant proximate to his current location). Context-awareness expands upon the “hard” dimension of location-awareness and environmental parameters (weather, e.g.), coupling it with the “soft” dimension of an individual’s profile (e.g., personal calendar and social network). Significant research and development resources are currently being devoted to “context-aware computing” by major players such as Google, Intel and Apple1, although primarily with respect to consumer-centric applications.

However, as smartphone and netbook technology converge and mobile phones become simultaneously computer, communication device, and sensor, smart phones will become increasingly valuable organizational information assets as well. The full absorption of mobile technology into the organizational information infrastructure will present some interesting challenges along the way with respect to system design and development. Perhaps foremost among them is the inherent tension between the emergent nature of mobile networks as encapsulated, for example, in social networks versus the more traditional top down approach adopted for purposive organizational systems. Mobile services which enhance the utilitarian or hedonistic desires of individual consumers do not necessarily contribute to effective organizational systems. How to blend these two modalities to leverage their respective strengths should provide a fertile area of science of design research in the coming years.

Another critical dimension we consider in our discussion of mobile services is the relationship between decision-making and associated services. Consumer-oriented context-aware services provide decision options to the user but relatively less with respect to evaluation, or choice, amongst those options. In organizational contexts, particularly those that will arise around mobile networks, decision-making is paramount, and correspondingly more complex because there will typically be multiple participants rather than a single individual.

Our focus then is upon the design of interoperability, especially data interoperability, which can “feed” the mobile services required to support the confluence of “smart” mobile network technology, organizational information infrastructure, and collaborative decision-making. We address this issue by identifying a new class of information system, the NWDSS, which we characterize in the discussion below.

3. NWDSS and Emergent Knowledge Processes

The concept of a network-driven decision support environment has grown from the extensive field experiments in mobile networks conducted by the Naval Postgraduate School over the past decade as part of the Tactical Network Test bed (TNT). (For

Google/Apple patents http://www.fastcompany.com/blog/kit-eaton/technomix/google-apple-patents-vying-context-aware-smartphones-0

more detailed material on the TNT experiments, the reader is referred to [5]). These experiments began primarily as exercises to test and evaluate mobile networks but have steadily expanded to include a widely diverse set of users, sensors and decision technologies deployed to support tactical decision-making in operations such as search and rescue, target identification, and maritime interdiction. Emerging from this research has been the realization that none of the traditional types of DSS or modes of decision-making captures adequately the dynamics of these environments [4]. Rather, these environments seem to constitute a hybrid of the data-driven, model-driven, knowledge-driven and collaboration-driven DSS typology [11]. As a result, the concept of a network-driven DSS has evolved which we believe constitutes a distinct new type of information and decision support system. The major characteristics of a NWDSS are enumerated below.

- **Unstructured vs. semi-structured environments**: NWDSS environments such as emergency response operations often tend to be chaotic, unstructured, and often fraught with high risk and severe time pressures, in contrast to the semi-structured situations which have served as the focus of previous DSS research. Decision-making in these situations must frequently be done with highly imperfect information and without a clear delineation of the available alternatives, the possible outcomes, or the probabilities attached to each.

- **Fluid heterogeneous network**: This is perhaps the defining aspect of NWDSS, namely highly heterogeneous nodes (e.g., human, sensor, software agents representing different organizations such as military units, law enforcement agencies, firefighters, first responders, non-governmental organizations (NGOs), and various local, state and federal governmental agencies) within the network enter and leave in unanticipated fashion so that the structures of both the technological and social networks are dynamic and unpredictable.

- **Sensor-based**: The proliferation and miniaturization of sensors is a major driving force in the emergence of NWDSS. Sensors may be human or inanimate (e.g., unmanned aerial vehicles (UAVs), and passive (data collectors) or active, (e.g., intelligent agents). The rapid evolution of smart mobile technology accelerates the sensor-based nature of NWDSS since mobile users themselves can be seen as sensors with the means to transmit and receive rich information in many different modes in very near real time.

- **Collaborative, decentralized decision-making**: NWDSS do not always have a centralized node, or operations center. Decision-making in NWDSS is therefore pushed out to the “edge” [1] and much more reliant upon collaborative rather than individual decision-making.

- **Emergent knowledge-based process (EKP) environments**: NWDSS are characterized by EKPs [10] which emphasize knowledge flow and knowledge sharing as an integral part of the collaborative decision-making process, and in which system behavior is more apt to be emergent rather than driven from the top down.

- **Network science-based**: NWDSS are a combination of technological and social networks which can be studied theoretically using network science as a reference discipline [2].

Environments such as NWDSS characterized by emergent knowledge processes (EKPs) present a formidable challenge for designing mobile services because system requirements are no longer deterministic; rather they emerge dynamically in response to changing situations. Sensor-based information environments are prime examples of emergent knowledge processes where players and requirements are not known a priori. We will not in general know ahead of time the types, numbers, locations, and required integration of sensors which may be deployed in a particular tactical operation such as search and rescue, emergency response, or maritime interdiction. For example, we may decide spontaneously to launch a new unmanned aerial vehicle (UAV) which we want to coordinate with existing camera sensor so that when the UAV identifies a potential person or event of interest at a specific location, the cameras can be calibrated to the UAV-supplied coordinates in real time to provide a more detailed picture. Nor will we know a priori the players who will enter and leave the network as processes unfold. For example, the National Guard may or may not be called into a flood or earthquake situation depending on the severity of the natural disaster.

The highly dynamic and fluid nature of NWDSS environments requires a system design approach with capabilities that support extreme system agility in generating ad hoc, adaptable network configurations in near real time. We introduce the concept of a generative network architecture (gNA) to describe this configuration-based system design approach. gNA is a software- and data-oriented architectural design methodology for rapidly configuring and integrating data and information resources in NWDSS applications. In the context of designing
services for smart mobile organizational systems, the following high level requirements are paramount:

a. System of systems configurability via semantic interoperability. A gNA must be able to integrate existing sources of heterogeneous data (esp. sensor data), models, and systems dynamically. This is much more critical for organizational applications than for individual mobile services.

b. Simultaneous support and integration of context and situational awareness. A gNA must be able to leverage and blend the advances in context awareness evolving in the mobile handheld world at the individual level with the need for sense making, or situational awareness, at the organizational level.

c. Decision analytics in near real time. Decision analytics based upon data mining and visualization technology is becoming increasingly important in decision-making at all levels [7]. Replacing static data warehouse architectures with dynamic, multi-modal, interoperability-created knowledge bases will drive near real time decision support.

d. Valued information at the right time (VIRT). Pulling information and knowledge together is only part of the problem; pushing to each user only the subset of that information and knowledge which s/he requires when s/he requires it is even more critical [8]

e. Multiple platform operability. Platform interoperability is critical as well. Although NWDSS does not assume a central node, these inevitably emerge often in the form of control centers. Applications must work at the “conception of operations” (CONOPS) level as well as the individual handheld level.

What is needed first and foremost are highly flexible and agile interoperability capabilities for rapidly integrating heterogeneous data, model and system resources. In the succeeding sections, we describe the GINA (Global Information System Architecture) environment as an example of the gNA approach. We enumerate GINA’s properties and describe a mobile application which demonstrates GINA’s effectiveness in C4ISR-based NWDSS environments.

4. GINA: An Operational gNA Environment

GINA (Global Information Network Architecture) is a patented environment developed at the Naval Postgraduate School providing a coherent, universal configurable model that allows the consistent specification and use of all information resources within and across organizations. GINA provides complete facilities for managing information and services available on accessible networks. It can aggregate and objectify information from an unlimited set of heterogeneous information sources or service providers into a common information space which can be tailored to specific user views of information. These aggregated information objects and services can be referenced, transformed, combined, and/or presented in any way the user requires and on any platform, including handheld devices. GINA’s self-referential, multi-meta level foundation in combination with a new Vector Relational Data Model (VRDM), facilitates extremely rapid development of information, analytical/computational modeling, and decision support systems using model-driven architecture in concert with executable component-based structures that circumvents the need for code generation.

a. Model-based architecture for semantic interoperability

The model-based GINA approach functions on the premise that is better to build a model than it is to write code. Coding is unreliable and error-prone whereas a model is much more effective at capturing semantics while simultaneously and dramatically reducing the need for code. To illustrate why this is so, consider the “Paper-Rock-Scissors” configuration in Figure 1 intended to capture the simple rules of the childhood game where “paper covers rock”, “rock breaks scissors” and “scissors cut paper”. We’ve defined three objects: FORCE which is an expanded notion of a player in the game, FORCE_TYPE which identifies who the FORCE is affiliated with (“Red” or “Blue” in this case), and STRATEGY which describes the options a FORCE can select from in any particular move (ENGAGEMENT). Three relationships also have been specified: SELECTS which shows which STRATEGY a FORCE selected in any ENGAGEMENT, DEFEATS which defines the rules of the game determining the victor, if any, in any ENGAGEMENT between two FORCES. The ENGAGEMENT.outcome field is a derived field computed by comparing the two strategies against the appropriate row in the DEFEATS table. Thus in the 1st row of ENGAGEMENT, FORCE “F1” selected “Paper” and “F2” selected “Scissors” with the result that “F2” won since “Scissors” beats “Paper” as specified in the DEFEATS table.

There are several critical things to note about this representation. First, everything is data-driven, not coded. This means we can, for example, add more
players to the game by simply adding more rows to the FORCE table and similarly, we can add more force types to the environment by adding more rows to the FORCE_TYPE table. More to the point, we can enhance the game semantics by adding more strategies in the STRATEGY table along with their associated outcomes in the DEFEATS relationship table. Thus, we might add “Water” and “Fire” as STRATEGIES with the associated rules “Water douses Fire”, “Fire burns Paper”, and “Water shrivels Paper” in the DEFEATS table. In this way, we have added more semantics to the application without adding or changing a single line of code. This is what is meant when we say that “GINA is a semantically configurable, model-driven architecture”. In this approach then, the focus is upon getting the model right rather than multiple cycles of writing, debugging and testing code.

**OBJECTS**

FORCE( fName, fName_FK, ...)
- ‘F1’, ‘Blue’, ...
- ‘F2’, ‘Red’, ...

FORCE_TYPE ( ftName, ftDescr, ...)
- ‘Red’, ‘Foe’, ...
- ‘Blue’, ‘Friend’, ...

STRATEGY( sName, ...)
- ‘Paper’, ...
- ‘Rock’, ...
- ‘Scissors’, ...

**RELATIONSHIPS**

SELECTS( fName_FK, sName_FK, engId_FK)
- ‘F1’, ‘Paper’, ‘Game1’
- ‘F2’, ‘Scissors’, ‘Game1’
- ‘F1’, ‘Rock’, ‘Game2’
- ‘F2’, ‘Scissors’, ‘Game2’

DEFEATS( sName1_FK, sName2_FK )
- ‘Paper’, ‘Rock’
- ‘Rock’, ‘Scissors’
- ‘Scissors’, ‘Paper’

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A key related factor is that GINA can draw from any information source available on the network so it may very well be that the schema in Figure 1 was created “on the fly” from disparate operational data sources.

**Figure 1. A simple configuration model for the “Paper-Rock-Scissors” game.**

**b. Relationships as objects**

The separation of semantics from coding is a key element in the scalability and flexibility of GINA as the previous example indicates. However, GINA goes well beyond that in the way it represents relationships. Relationships are the critical concepts to model semantically in building any application because they define how and under what conditions various objects interact. Traditional data modeling approaches such as the entity-relationship model and the Unified Modeling Language (UML) address objects and relationships as primary drivers of models. Yet, when software is committed to code, the primacy of relationships disappears. This is more than just an issue of how models are implemented; the types of relationships that are typically envisioned in our models are limited to those that are easily conceptualized as their internal methods. GINA, however, makes a conceptual breakthrough by treating relationships as objects. Specifically, each relationship (DEFEATS, SELECTS, ENGAGEMENT in the example) in GINA is represented by an object called a Vector. The conventional way in which relationships are implemented in the relational database world is as foreign key fields which allow tables to be linked via the join operation in SQL. The Vector is a semantically richer representation which allows GINA to navigate more nimbly between objects and perform more complex set operations upon objects. In the “Paper-Rock-Scissors” game, for example, we may want to enable a FORCE to SELECT a STRATEGY based upon a historical trace of its adversary’s previous selections. This cannot be implemented with simple joins but requires a more sophisticated mechanism which the Vector is able to provide. The overall GINA environment is based upon the associated Vector Relational Data Model (VRDM) developed as the overarching object-oriented counterpart to the relational data model.

**c. Reflexive architecture**

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GINA achieves even more expressiveness than shown above in that it has been designed and implemented to be completely self-descriptive, or reflexive. This means that the GINA model is stored within the GINA model itself, or alternatively, GINA is itself a GINA application. Although this may seem unduly complex and abstract, this hierarchical “meta-level” structure accelerates the scalability, adaptability, and rapid implementation required of data interoperability applications.

Most database systems have a data repository, or data dictionary, which describes the data tables (objects) and fields (attributes) contained within the database. We show an object-based counterpart of the repository in Figure 2 below. Note that there are a couple of meta-levels at work here. The italics-faced entries represent a self-descriptive meta-level, for example, the OBJECT table has “OBJECT” as one its entries. Similarly, the ATTRIBUTE table has its field “attrName” as a row and the CONTAINS table has two “CONTAINS” rows.

```
OBJECT ( objId, objName, … )
001, ‘FORCE’, …  
002, ‘DEFEATS’, …  
003, ‘STRATEGY’, ..  
010, ‘OBJECT’, …  
011, ‘ATTRIBUTE’, …  
012, ‘CONTAINS’, …  
015, ‘VECTOR’, …

ATTRIBUTE ( attrName, dataType, ….)
‘fName’ , ‘String’, …
‘sName’ , ‘String’, …
‘eng_Id’ , Number, …
‘objId’ , ‘String’, …
‘objName’, ‘String’, …
‘attrName’, ‘String’, …
‘dataType’, ‘String’, …

CONTAINS ( objName, attrName )
‘FORCE’, ‘ FName’, …
‘OBJECT’, ‘objId’, …
‘OBJECT’, ‘objName’, …
‘CONTAINS’, ‘objName’, …
‘CONTAINS’, ‘attrName’, …

VECTOR ( vName, obj1, obj2, ….)
‘DEFEATS’, ‘STRATEGY’, ‘STRATEGY’, …
‘SELECT’, ‘FORCE’, ‘STRATEGY’, …
‘CONTAINS’, ‘OBJECT’, ‘ATTRIBUTE’, …
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Figure 2. Reflexive object-based repository.

At another level, these four tables capture the overall conceptual model consisting of objects, attributes, and vectors (relationships). The CONTAINS object is particularly interesting because this describes which attributes belong to which objects. As in Figure 6, one can now configure the model by specifying the appropriate objects and associated attributes in CONTAINS, and associated relationships in VECTOR without changing any code. There is one critical difference, however. Adding rows in the CONTAINS table about any of the four tables changes the structure of those tables. For example, if we add a row (“CONTAINS”, “keyField?”) in CONTAINS above, we have now changed the structure of that table to CONTAINS (objName, attrName, keyField?). This cannot be accommodated in conventional, relational database repositories which are passive, descriptive vehicles rather than proactive, table-creating mechanisms. GINA, however, uses object technology to capture these reflexive, cascading relationships. Thus, the meta-model itself can be altered dynamically in a similar (but much more powerful) way to how we altered the Paper-Rock-Scissors example. The ability to change these high level meta-descriptions and then have the resultant modifications propagate down through the various meta-levels without having to change code is an extremely powerful feature of GINA.

d. Component-based executable model

GINA is a hybrid methodology which leverages two major approaches to contemporary software development: model-based architecture and component-based development, both of which have the objective of reducing, if not eliminating, the amount of coding required to develop a system. We’ve shown above how GINA’s highly reflexive model-based architecture achieves this goal. Component-based development (CBD), or component-based software engineering (CBSE), also aspires to this end, although using a different strategy. In its most simplistic form, CBD is a primarily object-oriented software reuse approach drawing upon existing, pre-tested software components (e.g., objects, classes, modules, software packages) which it then composes in appropriate ways to meet system requirements [12]. One of the limitations of the conventional CBD approach is that the interfacing requirements for using any component must be precisely defined, and even then, uncertainty can prevail about the real underlying semantics of the component.

GINA uses component-based development but in a different way from the conventional approach. Specifically, GINA creates its own components as part of the design process by translating its
configurable models into a suite of corresponding component objects, which it then in turn composes in a semantically consistent way into an overall executable model. The resulting executable model runs without requiring any dynamic automatic code generation, thus saving considerable compiler / interpreter execution time. GINA thus avoids the semantic ambiguity problem because its objects have been assembled from components dynamically from a semantically consistent meta-model.

**e. Mobile platform-compatible**

The Consumer Device Information Management System (CDIMS) is the GINA user interface capability for smart mobile devices (iPhone and iPad currently). GINA tailors views of information to individual users via its “World-Space” environment that specifies which users can access which components through Vectors between the users and the model. As is true for all aspects of GINA, the CDIMS is itself a GINA application which is configurable and can capture and display information in GIS, map-based layers. GINA using CDIMS is adept at bringing in the required data sources for this layered approach based upon the principle of actionable intelligence. Passive information which earmarks most location-based mobile services, is “display-only”, for example Google maps with various points of interest identified. Actionable information on the other hand provides decision-makers with one or more course of actions (COAs) within the context of the display.

**5. Dragon Pulse: GINA Operational Environment**

Dragon Pulse is the current operational GINA environment for C4ISR applications. Figure 3 shows a high level conceptual display of the system as implemented for the XVIII Airborne Corps at Fort Bragg, NC. This version integrates multiple data sources and systems including a wide range of diverse sensors (e.g., unmanned and manned platforms and handheld devices), existing Department of Defense tactical and intelligence systems, commercial systems (e.g., ArcInfo™), and previously developed GINA applications such as the Asymmetric Threat Response Analysis Program (ATRAP) and iCOP (interactive Common Operational Picture).

ATRAP, developed by the Intelligence Battle Lab at Ft. Huachuca, provides a visualization environment for viewing data relationships semantically, temporally, and geospatially. CDIMS data is captured and loaded into ATRAP, either in bulk or in real-time to enhance situational awareness by providing early warning of potential threats. The analysis functionality that ATRAP provides includes: link analysis, ECA (enemy course of action) and DECA (derivative enemy course of action) templates which can be created and overlaid on the system dynamically, and the integration of heterogeneous data such as images, movies, audio files, and typed or tag-based selectable data. ATRAP is now enabled for real time data population and mobile interoperability via CDIMS, configurable data types and relationship types which can be identified and stored.

![Figure 3. Illustration of GINA interoperability across multiple systems, databases and platforms.](http://worldwind.arc.nasa.gov/java/)

The GINA iCOP (Figure 4) is a system fusion infrastructure that supports all distributable systems used for monitoring and action. The iCOP integrates an open ended set of resources, including recording devices, data stores, servers, radar, GPS/LPS, RFID, and Targeting Systems. Targets can be tracked using enhanced 3-D visualization interfaces, such as NASA’s open source WorldWind®. The GINA iCOP accommodates multiple modes of input from diverse communities of sensors working in parallel and interacting through extensible configuration via the ESRI Compliant C2 interface. iCOP is thus more adaptable and powerful than conventional monitoring systems with the salient feature of interoperability among systems not initially designed to work together. The GINA iCOP is currently deployed both at Fort Leavenworth Directorate of Plans, Training and Mobilization (DPTM) and Emergency Operation and NORTHCOM Department of Homeland Security for incorporating and testing new sensors in a system of systems on the US / Mexican Border.

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3. [http://worldwind.arc.nasa.gov/java/](http://worldwind.arc.nasa.gov/java/)
What Figures 3 and 4 do not adequately convey is the highly dynamic nature of these systems and the agility with which GINA can add and integrate data and systems as requirements evolve. GINA’s configurable model approach allows data sources and/or systems to be incorporated dynamically without having to retrofit existing system and data components. Thus, GINA system complexity only grows linearly as new elements are added whereas conventional approaches such as system reengineering, ad hoc integration, standards-based (star) interoperability, and data warehouses grow exponentially as more systems and databases are added.

Figure 4. iCOP display showing integration of eight existing systems.

6. Limitations and Future Research

GINA is designed under the premise that processing is nearly free, so its component assembly approach optimizes programming effectiveness at the expense of processing overhead, making it less efficient than hardcoded, and hence inflexible, applications. While GINA is by no means a slow system, in practice, that means it is not a good fit for implementing complex mathematical processes such as video object recognition, or very high speed tasks such as control of a fighter airplane. However GINA is suitable for integrating those capabilities into a larger systems model.

A related limitation is that GINA is not designed to generate algorithms, but rather to wrap algorithms. That is, the level of code complexity which GINA generates in its component objects is relatively low, corresponding roughly to SQL kinds of set operations. Thus, for example, one would not use GINA to create decision analytic procedures which are numerical in nature; rather these procedures would be wrapped for subsequent integration into the resulting product.

Because of GINA’s highly reflexive architecture, developers need to have a relatively advanced facility for meta-level reasoning and conceptualization. This turns out to be a relatively rare skill, the presence of which accelerates development substantially and the absence of which has the converse effect.

GINA currently provides limited decision analytics and VIRT services. NWDSS environments require the equivalent of near real time decision analytics (Figure 5) to implement collaborative decision-making. These capabilities can to some degree be supplied by human expertise available on the network, for example expert identification of nuclear devices in maritime interdiction operations, or biometrics analysis in border patrol monitoring. However, it would also be desirable to perform “on demand” data/text/image mining to augment limitations of available expertise. This could be facilitated by the ability to create dynamic, “on the fly” data warehouses from which such information mining can be creation of dynamic data warehouses as the underlying source for such information mining. GINA could serve as such an engine by integrating multiple modes of information (data tables, text, images, video, etc.) on demand and then applying existing pattern-matching or statistical inference models, for instance. This is an active area of our ongoing research as we seek to extend the utility of the architecture.

Figure 5. Real time decision analytics for C4ISR applications.

VIRT services also provide an intriguing area of research for enhancing the mobile service landscape. VIRT requirements blend context and situational awareness. Search and rescue missions, for example, require a CONOPS perspective to coordinate the
overall operation but also would benefit greatly from being able to push only that information necessary to a bandwidth-constrained individual helicopter pilot involved in that operation, for example. Having a context aware mobile device for the pilot working in conjunction with the situational awareness scenario of the control center could streamline the effectiveness of the overall NWDSS.

7. Conclusions

The emergence of smart mobile devices as components of purposeful decision-oriented organizational IS gives rise to “smart” sensor-based systems which we characterize as an NWDSS. NWDSS exhibit unique properties specific to an environment of emergent knowledge processes which make system design more difficult than in traditional organizational IS development. In such fluid and rapidly changing network-centric environments, it is not possible a priori to know either who the users will be or what their subsequent requirements will be. What this requires is an agile system of systems development methodology that allows design models to be configured and executed on demand as requirements emerge dynamically. Paramount in this scenario is the ability to integrate and display heterogeneous information sources rapidly, especially smart mobile sensor-based sources. System interoperability thus becomes the critical success factor in building NWDSS applications, a condition that typically is not the case in consumer-centric counterparts.

We have described the salient properties of the GINA which qualify it as an exemplar of semantic system interoperability, namely configurable and executable meta-models, the representation of relationships as objects, a high degree of reflexivity, and component-based services. Further, as demonstrated in the Dragon Pulse environment, GINA operates efficiently on cross-platforms blending mobile devices with conventional computing platforms.

The dimension of information and system interoperability is one that is critical to the successful implementation of C4ISR-oriented NWDSS applications, but one which has not received substantive attention in mobile services research. We believe the GINA artifact is a valuable system of systems approach to illuminating and understanding the issues of designing smart mobile systems and NWDSS.

8. References


