Imago: An integrated prototyping, evaluation and transitioning environment for information visualisation

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Abstract

This paper introduces Imago, an environment that supports the prototyping, evaluation and transitioning of information visualisation approaches into practice. The approach is based on the use of an underlying semantic model of contextual and visualisation knowledge and integrated evaluation capabilities to aid the transitioning process. We discuss the use of Imago in relation to our experiences in researching and providing information visualisation approaches for command and control activities.

Keywords: information visualisation, evaluation, transitioning, visualization.

1. Introduction

The research literature in the area of information visualisation provides a rich body of novel approaches including new types of visual representations, tools, and interfaces. So, why haven't more information visualisation approaches made it into mainstream use? In this paper, we argue that new approaches are needed to help capture and validate user needs, support more effective evaluation of potential solutions and allow more seamless transitioning into practice.

We use the context of military command and control to help develop and support our argument. As with decision-makers in other domains, defence command staff require information to support activities related to planning, analysis, and synchronized action. This has traditionally focused on aspects such as the disposition and status of force elements such as ships, planes, and people. However, in the ever more complex world of networked and asymmetric military operations, command staff needs to rapidly assimilate and understand a vast range of additional information including social and communication networks, agile resupply and logistics systems, and the relationships between multiple military and non-military contributions. One would imagine that, given the vast array of visualisation approaches that have been defined and the criticality and complexity of defence operations, military decision-makers would be the early adopters of such technologies. Yet, relatively few examples from wealth of information visualisation research reported in the literature have found their way into actual use.

This paper introduces Imago, an environment being developed at the Defence Science and Technology Organisation (DSTO) to support the prototyping, evaluation and transitioning of information visualisation approaches for military Command and Control (C2). The project draws from a substantial research base that has been developed by the DSTO and through relationships with other research bodies such as The Technical Cooperation Program [1] which draws together scientists engaged in Defence-related work from organisations in Australia, United States, Canada, New Zealand and the United Kingdom. The Imago environment discussed in this paper provides a means of integrating and sharing the output of visualisation tools; storing, accessing and managing showcase examples of visual representations via an underlying visualisation reference model; and providing access to underlying data sources provided through simulation, representative data, and operational data.

This paper is structured as follows: Section 2 provides an overview of command and control visualisation including background work that has been undertaken along the road to Imago. Section 3 provides an overview of the Reference Model for Visualisation which provides some of the key concepts for the Imago knowledge base. The Imago environment is then presented in Section 4. Section 5 discusses some of the initial experimentation and usage activities we have been undertaking with Imago. Section 6 outlines future directions followed by conclusions in Section 7.

2. Command and Control Visualisation

Decision-makers need information in an appropriate form to support their activities. The provision of information to support situation awareness is of key concern. Endsley [2] defines situational awareness in terms of a person's perception of the critical factors of importance in an environment, comprehending what these factors mean in relation to particular goals and projecting to identify particular courses of action based on the situation. Military decision-makers such as commanders, planners, logisticians, and intelligence analysts need ready access to a broad range of information to enhance their situational awareness including the status of their forces, the status of opposing forces, the possible impacts of environmental

factors such as weather. The most common visualisation approaches used to support situational awareness are based on the use of a geographical representation of an area of interest together with various overlays that provide needed information. Figure 1 provides an example of this type of visualisation where overlays are provided to show various entities of interest and to communicate awareness of intent.

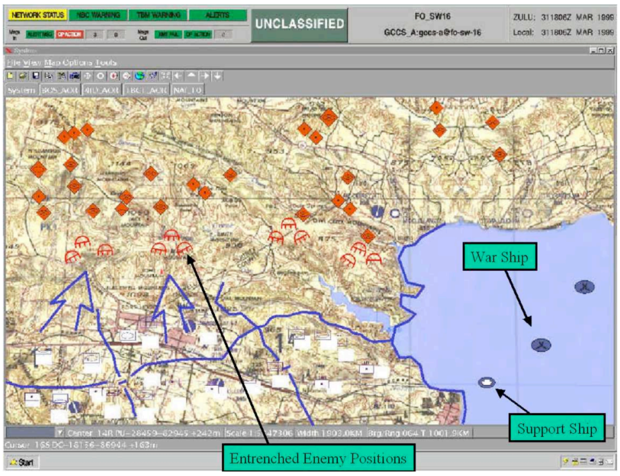

Figure 1. Traditional Command and Control Visualisation based on the use of geographical representations and overlays.

Advanced networking technologies have spawned new approaches for Defence and National Security. For example, new concepts such as Network Centric Warfare (NCW) [3] are based on the notion of information superiority. This approach, in part, focuses on the use of networks to rapidly access, fuse, and present data which can enhance the awareness and understanding of decision-makers thereby minimising the time from data acquisition to response. The advent of NCW and the ever increasing complexity of various types of military operations require command staff to gain rapid insights into very complex situations which could involve cultural and legal complexities, coalitions of multiple military and non-military contributors, asymmetric threats created through terrorist activities, and the operation of advanced capabilities such as Unmanned Aerial Vehicles and robotics. In addition to understanding the more traditional situational awareness aspects such as force disposition, command and control staff must quickly comprehend a range of complex indicators based on the data they receive on the status of their supplies, network intrusions, relationships between adversaries, the location of non-government organisations, and the impact that particular actions or effects might have on the results of an operation. For example, Figure 1 shows a more traditional command and control visualisation that provides situational awareness information of own and opposing forces Figure 2 shows the results of some of our research in providing enhanced situational awareness of NCW where we use our InVision [4]) composable visualisation system to rapidly generate visualisations tailored to other types of command information needs. In this case, InVision is showing social interactions and relationships between groups of people and organisational structures. Various integrated representations are used including directed graph, iconics, and our own Clovis views [5]

A major challenge for us has been to draw from and extend the wealth of information visualisation research to enhance the awareness, understanding and decision-making capabilities of command teams involved in these complex situations. A significant amount of work has been done in defining the types of visualisations that might be of benefit to decision-makers. Given, the wealth of work done in this area by the research community, various research laboratories and by industry, the TTCP community involving Australia, UK, USA, and Canada established an Action Group on Information Visualisation (AG-3) in 1999 to survey national activities and identify where future R&D should be directed. This work [6] provided the precursor and impetus for the current Imago work.

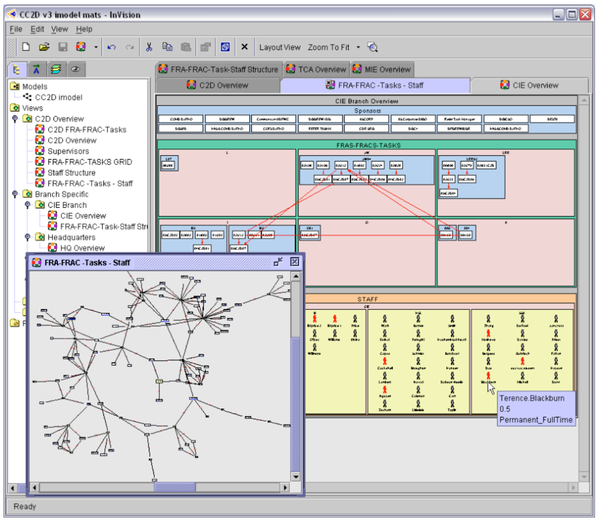

Figure 2. Visualisation showing complex socio- cultural effects

One of the foundational activities conducted by the group was the development of a Reference Model for visualisation (RM-Vis) [6]. This model, discussed in Section 3, provided the basis for the various surveys, analysis activities and user inputs. RM-Vis defines the user context for the application of visualisation approaches and provides a means of characterising various approaches in terms of the techniques they use in representing data, enhancement techniques which support the more effective presentation through approaches such as distortion and animation, and the various ways in which users interact with the visualisations. An important contribution of this work was the development of a modelling approach which supported the capture and analysis of user needs and allowed a mapping and evaluation of these needs to a substantial body of knowledge on applicable visualisation approaches. This background work plays a large part in the concepts and approaches being developed as part of Imago.

The group undertook comprehensive surveys of visualisation approaches that had been developed by the research community and commercially across a wide variety of domains including finance, transport, telecommunications, defence and national security. Other related sources such as the Olive On-line Library of Information Visualisation Environments developed by the University of Maryland [7] were used to support this activity. This work characterised and showcased some 350 key visualisation approaches [6]. A toolkit implementing the main elements the RM-Vis model was developed to support the characterization, showcasing and querying of visualisation approaches within domain usage contexts. Flexible querying mechanisms were implemented to support analysis activities. Three RM-Vis databases were developed using the toolkit: C3I-Vis which characterizes and showcases visualisation approaches in Command and Control and Intelligence domains based on a survey of national programs; Mil-Vis that provided more general visualisations of military importance; and G-Vis which characterizes and showcases some of the key information visualisation contribution in a range of domains such as transport, finance, medicine, entertainment, and engineering. The group also conducted workshops involving command teams and researchers to help understand visualisation needs, particularly in relation to coalition operations [8].

3. Visualisation Reference Model

Various taxonomies and models have been proposed for the characterization of visualisation approaches [9-11]. However, most attention has focused on defining visualisation tools in terms of the types of data that can be visualized and visual representation techniques supported. Other taxonomies focus on the particular domain of interest of the authors, such as software visualisation [12]. The contexts within which visualisations are used are often neglected. For example, it is rare to find taxonomies which characterize visualisation approaches in terms of specific tasks that need to be performed by users or the types of things that need to be described.

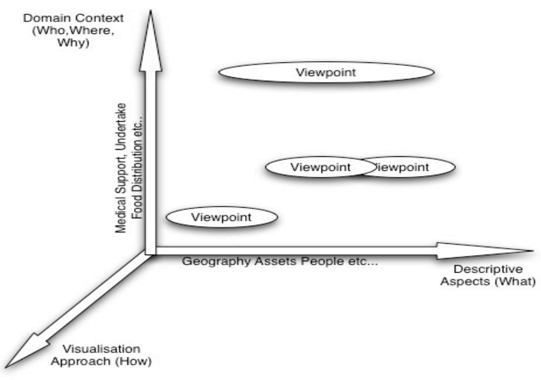

Figure 3. Visualisation Reference Model

A Reference Model for the application of Visualisation approaches (RM-Vis) was defined to support the characterization, identification and showcasing of visualisation approaches within particular domain contexts. This model has been used to characterize visualisation solutions 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. RM-Vis provides the basis for the central knowledge repository in Imago (Section 4).

As shown in Figure 3, RM-Vis has three key dimensions:

The **Domain Context** is a model that defines the focus for the application of visualisation approaches. It defines where visualisation approaches will be applied, who will be supported, and why it is needed. Typically a domain context is modelled in terms of the roles being undertaken, the activities being performed and the tasks or goals that need to be addressed.

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. These might include aspects of geography such the relationship between rivers and roads, people, various assets such as planes and ships, environmental factors such as weather, and process descriptions.

The **Visualisation Approach** dimension defines how the required information can be provided through computer-based visualisation. Approaches are characterized 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.

Other features of the model are defined on this dimensional substrate. In RM-Vis, a **Viewpoint** is defined in terms of what needs to be described for particular domain contexts. A **viewpoint** defines what needs to be described rather than how it is described from how it will be described. For example, an Operations Officer in an Air Defence domain may require information on the status of fighter and tanker aircraft to support decisions relating to a task such as “assign air assets”. Various visualisation approaches could be used to provide the information required for this **Viewpoint**. A **View** is the definition of the visualisation approach used to support the requirements of one or more **Viewpoints**. A **Viewpoint** might be supported by one or more integrated **Views**. In the Air Defence example, the **Viewpoint** might be met by two integrated views: one showing the location of air assets on a map and the other showing a dynamic Gantt chart of flight times and fuel loadings.

Effectiveness is considered as a fourth dimension of the model. We argue that effectiveness of particular

approaches can only be considered in terms of their domain context of use and deployed configuration. Imago has been designed to support this approach where evaluations are done within the context of the various dimensions of the reference model.

4. Imago Environment

As show in Figure 4, the Imago environment comprises several key features which combine to support the characterisation, prototyping, evaluation and transitioning of information visualisation approaches for particular contexts of use. The main features of the environment are: the semantic model; the evaluation framework; integrated instrumentation capabilities; and a mechanism called the collaboration bus which supports tool integration, efficient connectivity to underlying data sources, and distributed user interaction. The system supports the integrated use of various forms of instrumentation to aid in both the analysis of visualisations and the collection of evaluative information. This could include the capture of data on how and when various views are used by users through data provided by biological and neuro-psychological sensors.

The Imago environment draws from, extends and implements RM-Vis concepts. The core element of the environment is a **Semantic Model** which provides the central knowledge base of **domain contexts**, **descriptive aspects**, **viewpoints**, and **visualisation approaches**, as described in Section 3. For example, the environment supports the modelling and capture of domain contexts based on the roles and activities undertaken by users. Support is also provided for capturing user **viewpoints** which define what needs to be described in relation to particular tasks being undertaken within a **domain context**. Given this knowledge of user requirements, the system is able to suggest various **views** that support their specified **viewpoints**. **User** and **team** characteristics can also captured in the model. These characteristics include be physical, cultural, interpersonal and cognitive attributes. The **semantic model** also supports the integration of evaluation and instrumentation data in relation to user contexts and associated visualisation approaches.

The **semantic model** stores the various semantic relationships between the RM-Vis concepts, **evaluations** results, and **instrumentation** data. This provides the basis for the intelligence of the system. The central concept in Imago is the **viewpoint** which relates the **views** to a particular tasks being performed within a domain context and the aspects that need to be described. **Views** are the actual visualisations provided by the environment. In the initial version of Imago, **views** are provided as showcase examples from existing tools (images, video clips etc.) as well as concept sketches. In later versions, dynamic views will be provided by the actual tools using real or synthetic data. In particular, adaptive and composable visualisation systems such as DSTO's InVision [4] and PNNL's Starlight [13] will be integrated into the Imago environment. **Tasks** are defined according to **activities** and **roles** that they support. The rest of the imago concepts (**roles**, **activities**, **descriptive aspects**, **enhancements**, **interactions**, **representations**, **users**, **teams**, **evaluation**, and **domain contexts**) serve to establish relationships between **viewpoints** and actual **views** in order to allow the user to effectively decide on appropriate visualisations based on their particular situation.

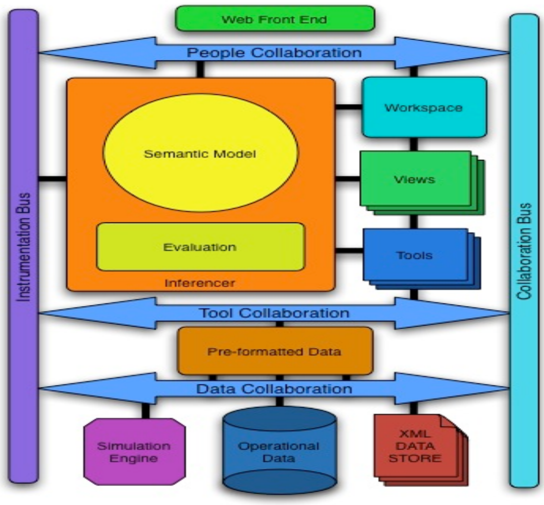

Figure 4. Imago Environment

Imago provides an integrated **evaluation** capability where evaluation results are stored in relation to the semantic model. In Imago, evaluations form meta-links between particular concepts within the **semantic model** or annotations on individual concepts. For example, an evaluation of the fitness of a **view** to a particular user's **viewpoint** is presented as a node connecting the two concepts together. This close integration means that evaluation is part of the model rather than additional data that is separate from the representation. An added bonus of using an integrated evaluation capability is that future **inferencing** support will be able to use the evaluative information in order to make more accurate predictions on user requirements.

Workspaces provide the main interaction mechanism for users of the system. A Workspace presents the relationship between usage contexts, user viewpoints and views. **Workspaces** support various classes of users including analysts, researchers, and end users. For example, analysts capture and model **domain contexts** and **viewpoints** within a user **workspace**. They can then draw from the knowledge base of visualisation approaches to identify the possible candidate **views** to support a user needs. Interactive evaluations with the user can then refine these to the set of **views** that the user believes would be most appropriate in meeting viewpoint requirements. In the end-user mode, provide the user with rapid access to their particular **views** and **viewpoints** in relation to their activities. In addition to having access to their own **viewpoints** and **views**, users can access other **workspaces**. This supports aspects such as shared awareness with other Imago users. This is

important in that many tasks require a common understanding across a team of individuals, often geographically distributed. **Workspaces** also provide the means of extending the knowledge base through the addition and characterisation of additional visualisation approaches, and contributing additional knowledge related to domain contexts and **descriptive aspects.** An Imago Workspace that was used for the fieldwork described in Section 5 is show in Figure 5. The workspace shows a screenshot of an airforce director of operations user with a task of managing assigned air assets. You can see in the diagram that the system based on the descriptive aspects (location A in diagram) and previously chosen views has list five different potential views to the user (B). The user has selected "3D Stealth Viewer" which has three showcase examples (C), one of which is a video of the visualisation. This video is running in the example pane(D).

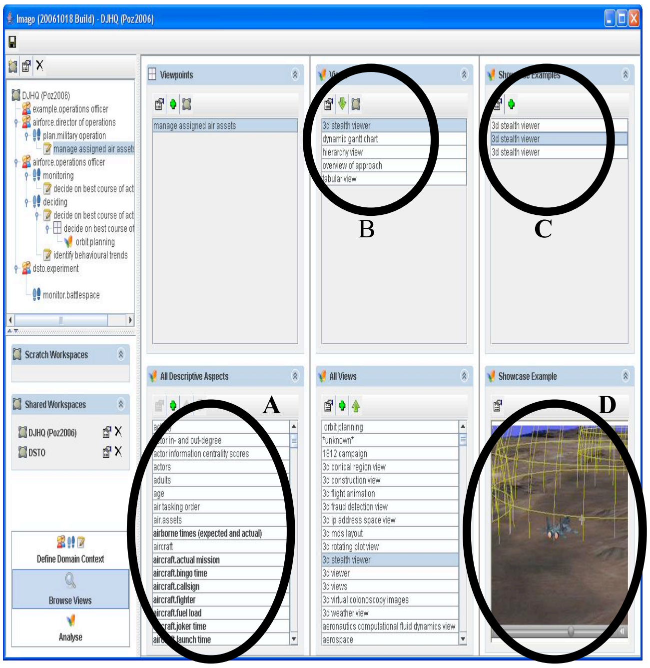

Figure 5. Imago Screenshot

The **Imago Collaboration Bus** is implemented using LiveSpaces technologies [8]. LiveSpaces implements a distributed infrastructure based on a publish/subscribe system that uses content-based routing [14]. This infrastructure provides a common platform for supporting data integration, tool collaboration, and distributed operation. At the people collaboration level, the **collaboration bus** supports shared awareness where users share the same pool of knowledge, such as **workspaces** and **views**, and where the modification by one user can be reflected in all users presences immediately. The **collaboration bus** also facilitates the other collaboration layers within the system. The **data collaboration** layer allows various data sources such as synthetic data provided through simulation, and operational data, to be accessed and structured in a way that will allow effective uploading into target tools for presentation to user. **Tool integration and collaboration** can be a formidable challenge. Imago supports the concept of allowing the generation of different views, derived from various tools, but based on the same data set. The collaboration bus provides a standard mechanism for controlling tools and so together with standardized datasets being created by way of the data collaboration layer, this challenge is significantly simplified.

5. Using and Experimenting with Imago

Table 1 provides an overview of the current Imago knowledge base. Much of current knowledge base was generated through previous TTCP surveys and activities.

Initial laboratory experimentation with the semantic model has been undertaken to validate the concept of rapidly identifying candidate visualisations based on particular **domain contexts** and **descriptive aspects** being entered into the system. Various scenarios have been entered into the systems to ascertain how efficiently the environment can identify candidate visualisations for particular domain contexts. For example, the request "*find **viewpoints** with the following **descriptive aspects** order, location, shipment*" returns the **viewpoints** such as "*Monitor performance of transportation and distribution systems*". A **view** returned for this viewpoint was the "*army-logistics-view*" produced by the Visage tool [15]. Further queries provided a description of the **view** and the characteristics that describe the approaches used to represent and interact with the information provided by the view. For example, this view allows a logistics analyst to explore the supply needs of a particular group within the context of an overall operation. In terms of RM-Vis the visualisation approach uses map, tabular, and chart representations. In terms of enhancement, view integration and overlay is provided so that selections on the tabular representation can be represented on the map. Interaction is characterised as supporting drag and drop, and the use of sliders for dynamic queries.

Table Contents	No. of Items
Views	500
Viewpoints	132
Descriptive Aspects	218
Tools	360
Domain Contexts	345

Table 1 Current Imago Knowledge Base

The laboratory experimentation has been a necessary precursor to field trails to ensure that the knowledge base and querying mechanisms are satisfactory to support experimentation in real domains. The current Imago system has been deployed as part of a field experimentation activity which was aimed at validating the concepts of use. The system was deployed within a Joint Task Force Headquarters to help develop and validate requirements for the use of information visualisation to support situational awareness in future command support systems. Figure 5 provides a screenshot of the system used for the field study. The initial field study indicates that the current Imago approach is effective for capturing user contexts and visualisation needs. The use of the knowledge base for

rapidly providing candidate visualisation approaches was investigated. Further studies will be needed to test the effectiveness of the integrated evaluation framework in relation to validating user needs and proposed visualisation solutions. We are also be conducting field experimentation to help identify the set of key attributes that need to be evaluated in these types of scenarios.

6. Future Work

As outlined in Section 5, further field studies will be undertaken to further validate the concepts and to capture quantitative data based on actual usage scenarios. There are a range of enhancements that we wish to experiment with. For example, the current version of Imago supports querying of the semantic model. However, we would like to explore how we might use and inferencing mechanism to support more intelligent considerations on what views may be appropriate for a particular user context and need. The use of a semantic model with automated analysis support also shows significant potential for the prototyping of new visualisation systems. It could support the designer by allowing the input of domain context and descriptive aspect information for particular users and returning potential solutions to be explored. In the future, one might envisage Imago extending from being a prototyping and evaluative tool into providing direct visualisation support for users. These types of adaptive visualisations systems would allow the users to craft visualisations on demand. Advanced features of this type require a significant supporting infrastructure and knowledge base, much of which has been developed and investigated as part of the Imago project

Although Imago is initially being trailed in military command and control domains, it has been designed to have much wider applicability. The Imago knowledge base contains examples of visualisation approaches from a wide variety of domains such as health, finance, transport, and telecommunications. The aim is to draw experiences from other domain and transition relevant approaches into the target domain. Similarly, researchers and analysts who focus on particular domain contexts of interest can draw from the broader knowledge base, including the substantial knowledge being derived from the command and control domain, to understand and develop solutions for their focus area.

7. Conclusion

In this paper we argue that new methods are needed to support more effective and efficient transitioning of visualisation solutions to users. We have discussed a new a distributed environment that we are developing to support the prototyping, evaluation, and transitioning of visualisation approaches. The Imago environment uses a semantic model of contextual and visualisation knowledge and integrated evaluation capabilities to aid the transitioning process. We have discussed the use of Imago in relation to our experiences in researching and providing information visualisation approaches for command and control activities.

8. Acknowledgements

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