Chapter 8

Conclusion

This thesis proposed Situation Awareness as important capability imparted to an individual or an organization in achieving desired goals in a system. Domain application scenario selected for this research work involved dealing with complex dynamical systems. The information management strategy is appropriately altered to meet the changing information needs of all the potential roles. The proposal is made in form of a process and required domain middleware services in meeting the information needs.

What has been achieved is a mechanism that facilitates the creation of information management applications for processing complex dynamic information. The designed templates allow information management services to be linked together to process dynamic and complex tasks. Dynamic instantiation and run-time configuration enable these templates to be adapted and tailored to suit specific analysis tasks and execution environments. This multi-level coordination mechanism supports both the design-time phase and run-time phase of a software lifecycle.

8.1 Research Issues Addressed

Chapter 1, discussed issues in meeting information needs of various users in complex dynamical system. In Section 1.3.1 specific research questions have been identified. This section revisits all the research questions and provides answers to them.

*How to characterize system and its boundary?* This research question is addressed by classifying the system as complex dynamical system. The nature of problem domain is discussed to reveal salient features. Hence, this characterization allowed selection of methodology for information management.

*How to identify the management strategy?* This research question is addressed by eval-
8.1 Research Issues Addressed

Evaluating various methodologies suitable for the given kind of the system. It was established that Soft Systems Methodology is suitable approach for complex dynamical systems.

**How situations can be defined and possible worlds can be determined?** The conventional definition of situation is updated with emphasis on information granularity. It is also stated that possible worlds are only restricted with known domains that are relevant for given goal statement. Hence, from very generalized definitions of situations and possible worlds, they are enhanced for utilization in complex dynamical systems. The utilization of domain knowledge is also identified as a basic requirement, towards modeling of situation.

**How situation awareness can be defined for complex dynamical systems?** This research question is solved by Situation Awareness Theory explained in Chapter 2. Based on the comprehensive definition of the situation, the situation awareness is defined for complex dynamical environment. First realization is that it should be separate for individuals and organizations. As individual and group behavior are separately governed by principles discussed in Chapter 2. Based on these principles, situation awareness is defined for actor, and organization point-of-view. These new definitions entrusted much information handling responsibility on system, and hence new definitions are required to characterize system, configuration and processes.

**What modeling strategy will be useful to capture required roles, properties and rules?** This research question is addressed by proposing a modeling strategy explained in Chapter 3. To capture all the required entities and their salient features important to establish complex interdependence and dynamism, the step-by-step conceptual modeling is introduced. Among the proposed sequence, first six conceptual models provide identification and characterization of various entities by providing templates and rules. The last model is information processing strategy, provided as a set of thirteen algorithms provided guidance for handling information in the runtime.

**How complex event processing can be achieved in complex dynamical environment?** This research question is addressed by Eventing model. By addressing the event processing need in complex dynamical system, new definition of event is proposed along with concept of Event Space. Templates for expressing various event profiles are also discussed. The evaluation of event profiles on the runtime is also a critical decision. The event detection strategy is provided as one of the information processing strategy that is recommended for the runtime.
8.1 Research Issues Addressed

*How coordinating agency can identify the setup and resource requirements?* This research question is solved by Situation Awareness Unified Process (SAUP) explained in Chapter 4. The delivery process provided estimates and project management details in order to meet the information need for stakeholders of the system in given UoD.

*How stakeholders can identify the work?* This research question is solved by Gap Analysis Matrices explained in Chapter 5. These products provide traceability to work products of activities in various stakeholder environments. Each element in work breakdown structure specifies resource and other requirements for successful completion of the task.

*How stakeholders can share the work products?* This research question is solved by Enterprise Continuum explained in Chapter 6. This enterprise continuum acts as a repository of work product outcomes. Also the traceability is established with various architecture products created for specific roles. Hence, after assuming these roles, the stakeholders can access the enterprise continuum to share the work and can explore the traceability matrices to identify the reuse of the shared products.

*How multiple systems and sources are integrated?* This research question is solved by Configuration Approach. It demonstrates that it is possible to connect to multiple situation awareness configurations. The identification of configurations is done by the types of artifacts that are planned to be accessed.

*How stakeholders can track the work and get feedback and still get separation of concern?* This research question is solved by Cross Environment Traceability explained in Chapter 4. Different architectural products allow traceability of their work product in individual stakeholder environments. Traceability matrix allows identification of gaps by providing coverage of current efforts.

*How information requirements of the stakeholders can be identified?* This research question is solved by Information Need Identification explained in Chapter 2. It is established that information need is determined not only by goal of individuals, but also by the complementary goal of the stockholders. Exhibited activities of stakeholders, dynamic behavior of other related entities and their impact of resources and the environment - all contribute to dynamic change in the information needs.

*Which new interaction patterns are required?* This research question is solved by Spatial Data Access Pattern explained in Chapter 6. Data is accessed according to
various interaction patterns. It is either accessed or provided to the seeking entity. The system in dynamic environment must quantify which part must be collected from the users, and how it should be managed to meet individual information needs.

**How dynamic set of stakeholders and their work products can be handled?** This research question is solved by strategy of corresponding *Transient Resources* explained in Chapter 6. Some examples of transient resources include: job specifications, representations and messaging patterns. These are the configuration environment artifacts and they are best managed with rule-based life cycle handling strategy of transient resources.

**How dynamic set of resources can be employed on the runtime?** This research question is solved by *Configured Pool of Resources* explained in Chapter 6. According to this strategy, configuration strategy is such designed that every time a resource noticed in UoD, a corresponding instance is created in the knowledge base. The monitoring and handling of this instance is then appropriately carried out in different functions. The corresponding transient resources are destroyed when resource disappear or cease to exist.

**How information specificity can determined for different stakeholder hierarchies?** This research question is solved by *Information Granularity* explained in Chapter 2. The concept of footprint is introduced in Chapter 3, allowing identification and handling of specific information granularity.

### 8.2 Conclusion

This research concentrated on information management methodology for complex dynamical systems like disaster management, environmental management and critical infrastructure protection that are now reaching global scales. A collection of entities and their behavior in retrospect with the available physical resources are visualized to form such a system. Extraneous forces, both positive and negative, act continuously and independently in either healing or harming this physical system. The instantaneous state of the system is controlled by the dominating force. Occurrence of sudden unpredictable events may further deviate the system from the desired state. A viable information management strategy was called for to involve multiple disconnected autonomous actors, their activities, resources and operating conditions in the real life decision making process for such systems.

It was observed that during the evolution and in response to the events, the system receives help from within and outside of its boundaries. Any attempt for management, thus must build
### Table 8.1: Summary of Research Issues Addressed as Requirements Vs. Design Matrix

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8.3 Directions for Future Work

This thesis addressed the information management issues of complex dynamical systems that are increasingly being handled in fields like disaster management, environmental management.
and critical infrastructure protection. It is recognized that these domains span geographical and political boundaries and any attempt towards management requires coordinated collaborative efforts. At international levels, commitment to build systems at such scale is evident in forms of intergovernmental agencies setting up policies followed by systems and processes that support.

By addressing possible issues, the thesis introduced a suitable information management strategy targeted for such collaboration. Duly recognizing the scale of effort required in realizing the information management, the limitation of the proposed work is accepted in the section on scope of work of this thesis. The proposed solution is designed for extensibility to facilitate contribution for the collaborators. Hence, the proposed methodology can be enriched by contribution of collaborators as they utilize the methodology in respective areas. While the components like method content can be enriched by individual contribution of collaborators, there are certain aspects that require contributions at research levels. Following issues requires special attention from research point of view:

**Extension of Situation Theory and Semantics to cover concrete domains:** Situation theory is identified as basis to handle basic unit of information during interaction patterns and its use in building complex situation prevailing in the given UoD. It is found that mere Boolean relations handled is not sufficient to meet as situation. Also situation in real world requires assignment of attributes. Hence, appropriate theoretical framework needs to be established with proper discussion of theorems and proofs as discussed by Barwise and Zalta. This will enable formal handling and representation of rich situations. Considerable level of effort from researchers is required in extending this aspect of the theory.

**Design Principles for Information Management Strategy:** Fifty seven design principles are introduced to guide the information management process. These principles are based on the theories establish specific ways that facilitate information generation, utilization and handling of information to meet the requirements in complex dynamical systems. The new theories will continue to establish more aspects that should be integrated as design principles in future version of strategy.

**Knowledge Representation Process:** Four types of concepts are handled by the proposed methodology namely: Domain independent, domain specific, location specific and application specific concepts. The knowledge engineering task involved in this creating and maintaining consistent and updated representation is identified with appropriate roles. Architectural product to identify the gaps in available knowledge representation and avail-
ability of guidance in creating the knowledge based is also discussed. Ontology mapping approach that allows management of the contribution of involved knowledge engineers introduces a difficult research challenge. Proper systematic approach is to be designed and tested to work in dynamic collaborative environment. Designing such system involves identification of knowledge representation gaps is not limited only to concepts, but also covers representation of rules regarding observations, measurements, type conversion, operating procedures, event detection, event notifications to suit the local and application specific needs.

**Upgrade SAUP method content:** In its current version, SAUP have single author content. As organizations adapt to SAUP, their lessons learned, some domain specific expertise and other guidance contributed by the SAUP users, need to be incorporated in SAUP. Hence future versions of the process method plug-in will have added guidance for existing roles. For instance, the seven models proposed for the conceptual modeling and information processing in complex dynamical systems can be further extended with additional models to cover other relevant aspects of such systems.

**Build and improve Visualization Capability:** Separation of concern is achieved by handling role-specific messages, matrices and architectural products. These are the information content derived as a part of situation awareness. These chunks of information exist in middleware domain that should be accessed by the end users. Based on the prevailing situation and the assumed roles; the information chunks containing the events, alerts, representations and guidance can be many. Users have cognitive capability that limits the comprehension and utilization of information at given time. As a unique feature of this strategy, user involvement is also expected for features like utterance, task allocation, task closure and establishment of traceability. All these features require design considerations from Human Computer Interaction domain.

**Introduction of new domain specific role sets and method content:** In its current version, SAUP consist content for domain independent roles. There are many domain specific roles, artifacts, delivery patterns required to meet the real-world complexities and therefore appropriate guidance is required for building domain specific SA Configurations.

**Establishment of Situation Awareness Maturity Model for individual Application Domains:** Planning phase has not been discussed in this work. In planning phase, coordinating agencies are expected to setup SA Configurations so that local, national and international level coverage is achieved. This is essential requirement for coordination
of collaboration at global scale, yet it can achieve only gradually. For example, realiz-
ing provisions of Hyogo Framework for Action in disaster management domain requires
global level coordination from involved organization, that can be achieved gradual devel-
opments in configuration. A Situation Awareness Maturity Model (SAMM) should be
established to identify and establish various stages in gradual advancement towards the
desired coverage of the configuration.

**Upgradation of SA System Architecture to incorporate new standards, services
and technology components:** Standardization processes are continuously resulting in
new standards and specifications. They are absorbed by related stakeholders in different
environments resulting in standard-based products. SA system architecture must appro-
priately be updated incorporating these components. For instance, various Web Services
related standards are continuously contributed by the community by bringing every rel-
evant aspect of business and practical needs. Governance of Web Services therefore is a
critical challenge that can be addressed in future research efforts related to architecture
frameworks.