Interactive Multi-Level Situation Assessment in Ubicom Environments

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1 Abstract

The convergence of ubiquitous computing[1] with the semantic web[2] will lead to an increased importance of context in collaborative information systems. We propose a framework for a context aware system designed to augment the situation assessment proccess by domain experts in chaotic environments. Central to this framework is the ability to deal with heterogenous sensor data obtained from ad-hoc sensor networks to derive contextual information that describes the environment, and to use this context in multi-level situation descriptions relevant to it's user. A key to realizing this framework is the use of a set of common ontologies that model context and relations between contextual elements in the target domain.
Keywords: context modeling, situation assessment, sensor network, semantic web.

2 Introduction

Situation assessment is the first step in the desicion making process. A situation is defined as:

> ”The given circumstances occupying a certain volume of time and space.”

And can be described by context, where context is:

> ”Any information which can be used to characterize the situation of an entity and can be obtained by entity, where an entity can be a person, place, physical or computational objects. Context is typically the location, identity and state of entities [3].”

Context can generally be extracted from sensors that perceive the envrionment of the relevant entity. An increased availability of contextual information makes it possible to improve the completeness and quality of the situation assessment which in turn can lead to more effective decision making and collaboration.

Today, computing systems are becoming ever more pervasive in our society and one can find processors ranging from desktop processors in traditional PC's to Radio Frequency ID chips embedded in everyday objects such as smartcards. As a consequency of this development we can presently expect to find large numbers of informations systems within a chaotic environment such as the one described in the ICIS scenario [4]. Most of these devices will contain sensors of some sort. One can think of an image sensor in a digital camera or phone, or a GPS receiver in a car navigation system for example. The situation based ad-hoc networking of these devices into a grid network will enable these sensors and their data to be shared and aggregated. However, these sensor grids will contain highly heterogenous sensor data in different formats and notations and with quality aspects that might vary wildly. Assuming that these sensors will output their data according to the SensorML specification [5] it becomes possible to interpret the data and extract contextual information that can be used in the situation assessment process.

There already exist a number of contextual systems for chaotic environments [3] [8] [15]. However, for all of these frameworks, the interpretation and inferencing is done by the applications, which must themselves collate and assemble disparate pieces of data, and little seems to be done in developing a cohesive representation of a shared situation.

This workpackage proposes a framework that enables the transformation of sensor data into context information, as well as dynamic and realtime transformation of contextual elements into multi-level situation

[1] The trend towards increasingly ubiquitous connected computing devices in the environment, brought about by a convergence of advanced electronic - particularly, wireless - technologies and the Internet [1].

[2] The Semantic Web is an extension of the current web in which information is given well-defined meaning, better enabling computers and people to work in cooperation [2].

descriptions that augment the situation assessment process in expert domains. The main research question can now be formulated as:

> ”How can sensordata from distributed and heterogenous entities be used to extract contextual information that when combined accurately describes the situation of these entities, at a level of abstraction, timeliness and resolution that is meaningful to users in a certain domain?”

The main research question can be split up into five sub-questions:

1. How can context be derived from heterogenous sensordata?
2. How can context be classified within a situation assessment framework?
3. How can context be manipulated to increase its relevance in a specific domain?
4. How can context be made available to entites that require situational information can interact with it?
5. How can contextual elements be combined (context fusion) to accurately describe a situation at the required level of abstraction and resolution?

The proposal is organized as follows: First we will discuss the objective of the situation assessment framework and its key components. Secondly we will propose the approach to how the system will be designed including a number of methods and technologies that provide the needed functionality for this kind of system. Following is a summary of expected results in the course of this project. Also we will discuss its place in the ESA cluster and relations with other workpackes in the ICIS framework. Finally we present a nonexhaustive list of relevant work in this domain.

3 Project objective

The objective of this workpackage is to develop a framework for multi-level situation assessment in ubiquitous sensor networks. The academic challenge of this framework is to identify methods for context modeling, context fusion and context interaction, that when combined enable the delivery of semi-realtime interactive situation descriptions generated from distributed and heterogenous sensor data derived from adhoc sensor networks.

We will try to achieve this objective by partitioning the problem area in multiple segments or layers.

The first layer deals with the aggregation of sensordata in the form of a ContentRepository containing SensorML documents.
The second layer deals with extracting contextual information from the sensordata into ContextML documents and the aggregation of this information into a ContextRepository.
The third layer deals with operations that can be performed on context in order to enrich and enhance it to fit the requirements of it’s users.
The fourth and final layer deals with the dynamic retrieval of context by users and agents as well as the construction of multi level situation descriptions. Figure 1 displays the layers of the system including the associated services.

Although the system is in large part generic to allow for dynamic and fuzzy sensordata, the multi level aspect is provided by transforming the generic context in domain specific context using domain knowledge represented in an DomainOntology. The application of DomainOntologies on generic context will allow the system to be used by different types of domain experts that require different perspectives on a situation. The multi level aspect also refers to the ability of users to interact with the situational context by formulating queries. The functionality of the system will be demonstrated within the tunnel disaster scenario as specified by the ICIS framework.

Layer	Model	Service
Low-Level Context Aggregation Layer	Generic Context Model	Interpretation Classification Normalization
High-Level Context Transformation Layer	Domain Context Model	Inference Extraction Abstraction
Multi-Resolution Situation Assessment Layer	MR Situation Description Model	Acquisition Presentation

Figure 1: Layers in the MR-SA System

4 Methods and approach

The MR-SA framework will be designed using a webservice approach. Implementing the required services as XML based webservices will allow for a flexible framework that can be extended with new context namespaces as well as the addition new domain ontologies that define inferences and other operations that can be per-

Sensor Data	Context	Situation
Visual	Existential	Entity
Aural	Functional	Activity
Textual	Spatial	Location
	Temporal	Time
	Relational	Reason

Figure 2: Classification of stages in the MR-SA transformation process.

formed on elements in the contextRepository. Another benefit it the scalability of such a system: it can be deployed in small networks such as Personal and Local Area Networks up to a global level such as the Internet. Standardizing on a common context modeling language will allow context repositories on different networks to be fused if a situation requires so.

The framework will contain a number of components and associated technologies:

- **documents**: sensorML, contextML, situationML, preferenceProfile etc. based on XML, profiles can be based on P3P[]
- **models**: contextModel, domainModel, situationModel possible based on a combination of OWL [7], RuleML[], CoOL [6], and/or CoBRa[].
- **repositories** containing these documents: contentRepository, contextRepository.
- **services** that perform operations on content and context: interpretation, classification, normalization, aggregation, inference, fusion, extraction, abstraction, acquisition and presentation.
- **agents**: agents that are able to autonomously perform operations on (sets) of context.

The main contribution of this workpackage will the context and situation layers, and more specifically the ContextModel and SituationModel. Key services such as the classification, normalization and retrieval service will be implemented to demonstrate it's intended functionality in a demonstrator that will be deployed in the crisis management domain. This also involves the construction of a ontology specific to this domain that can be applied to the contextual information in order to demonstrate the multi level situation description capablities of the intended information system. Figure 3 shows the focus area within the MR-SA framework.

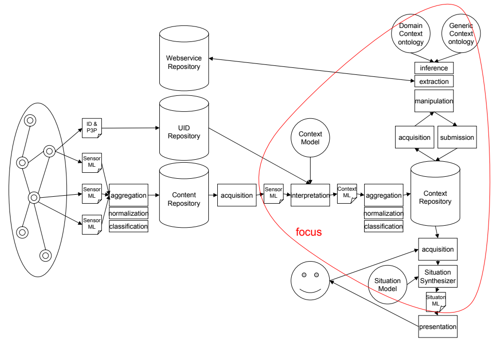

Figure 3: Draft architecture of the MR-SA system

The context model will be designed with the purpose of situation assesment in mind. We propose to create a model that uses 5 context dimensions that when combined will accurately describe a situation. The proposed dimensions are as follows:

1. existential. deals with the identification and description of entities. anwsers the question "who?"
2. functional. deals the the identification and description of actions and events. anwsers the question "what?"
3. spatial. deals with the identification and description of location and place. answers the question "where?"
4. temporal. deals with the identification and description of date and time. answers the question "when?"
5. relational. deals with the identification and description of relations, conditions and causes. answers the question "why?"

Each dimension will contain a number of classes, types and attributes. For example the temporal dimension migh contain the classes "time" and "date" that each contain different types. Figure **??** shows the basic context hierarchy.

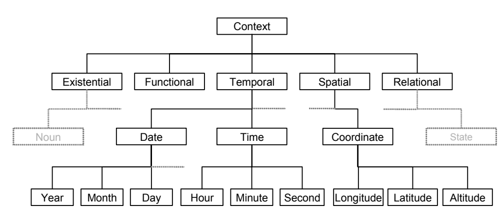

Figure 4: Simplified hierarchy of the proposed context model

A brief description of key services along with associated technolgies is given below:

- The interpretation service will parse a SensorML document into a ContextML document using the ContextModel.
- The classification service will identify where a contextual element will be placed in the ContextRepository
- The normalization service will convert the notation of an classified context element to conform to it's classification requirements.
- The aggregation service will encapsulate normalized contextual elements into a ContextRepository.
- The transformation service will transform contextual elements to enrich the context history and conform to domain requirements.
- The acquistion service will allow the contextRepository to be queried by users and agents
- The presentation service will combine contextual elements selected in the query with related context in other context dimensions to construct multi-level situation descriptions.

ContextML will be designed to accommodate contextual semantics and structure. Context and Domain ontologies will define inferences relevant to the contextual elements. Retrieval of contextual will be realized through the use of XQuery as a query language, presentation will use the SituationModel to dynamically assemble contextual elements relevant to the situation. Figure 5 illustrates the concept of context supertypes in a ContextML document.

```xml
<?xml version="1.0" encoding="UTF-8"?>
<!-- sample ContextML document -->
<Context xmlns="http://www.ubiq.org/ContextML" version="0.2">
   <existential>
      <EntityID value="0f:::44:12::0a:01"
      uom="http://myUnitDictionary#IPv6"/>
   </existential>
   <temporal>
      <TimeStamp value="2005:01:04:12:00:01"
      uom="http://myUnitDictionary#UTM"/>
   </temporal>
   <spatial>
      <LocationStamp value="25.5S:44.1W:40.1A"
      uom="http://myUnitDictionary#WGS84"/>
   </spatial>
   <values>
      ..
   </values>
</Context>
```

Figure 5: Simplified ContextML document

The Web Ontology Language (OWL)[7] can be used for modeling context in pervasive computing environments and for supporting logic-based context inference. The generic context ontology is used to model and manipulate low-level context, The domain specific ontology is an hierarchical extentsion that can be used to model and manipulate high-level context. Another possible candidate could be the Context Ontology Language (CoOL)[6].

5 Intended project results

In the first 18 month we expect to present the first results in a number of deliverables:

- At least one review paper to appear in a journal on context fusion and the state of the art in contextual computing systems designed for use in pervasive computing environments.
- An initial framework for the multi-level situation assessment system
- A demonstrator of underlying functionalities that highlights the role and function of key concepts such as the low-level context model, entity profiles, target domain ontology and the contextual query language.

6 Related work

within the ICIS framework there are relations with work being done in the clusters ESA and CHIM. One of the research packages deals with real-time grids. This package combined with the package 'Information Exploration in Distributed Systems' can provide a very solid foundation for the aggregation of sensor data in chaotic environments. The framework proposed here is designed to tie in with these projects and the ICIS framework in general. Figure 6 shows the focus area of this proposed work package within the ESA cluster framework.

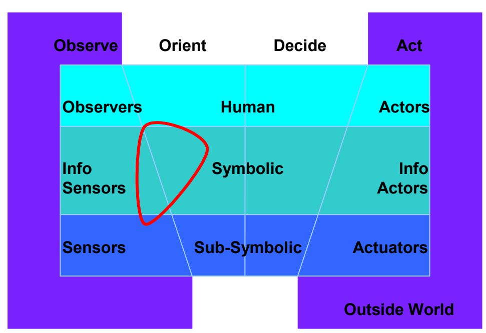

Figure 6: Workpackage scope within the ESA cluster

Outside the ICIS framework There is a large body of literature related to developing contextual systems for chaotic environments. Dey, Abowd, and Selber have created a Context Toolkit for detecting an entities state and using input events to trigger changes to the context-sensitive applications [3]. Lauffs API for ubiquitous computing takes device inputs and sends signals to components. Martin, Cheyer, and Morans Open Agent Architecture (OAA) [8] includes some facilities for triggering actions based on contextual information. Ajay Kulkarni has created a reactive behavior system called ReBa [15] which can trigger many different actions in response to device events. However, for all of these frameworks, the interpretation and inferencing is done by the applications, which must themselves collate and assemble disparate pieces of data, and little seems to be done in developing a cohesive representation of a shared situation.

7 Background

This proposal is part of the Intelligent Collaborative Information Systems (ICIS) initiative. Figure 7 gives an overview of this workpakage in the ICIS project. ICIS is a strategic impulse to position Dutch scientific and industrial efforts in collaborative, intelligent information systems technology. Its goal is to deliver a Framework for building intelligent network centric information systems , using an Integrated set of knowledge and technologies, validated with real world problems by using a Collaborative approach to bridge the gap between science and applications. Partners involved are THALES Nederland, Delft University of Technology, University of Amsterdam, TNO, University of Maastricht, University of Nijmegen, University of Twente and 4TEC. ICIS is made possible by a subsidy from the Department of Economic Affairs (EZ) in the Netherlands.

Work Package Overview	
Project	Intelligent Collaborative Information Systems (ICIS)
Type	PhD
Effort	1 fte + 0.2 fte (supervision)
Cluster	Enhanced Situation Awareness (ESA)
Title	Multi-Resolution Situation Assessment in Ubiquitous Sensor Environments
Problem Domain	Crisis Management
Scenario	Tunnel Incident
Timeframe	01/03/05 - 01/03/09
PhD student	Reinoud M. Vaandrager (reinoud@gmail.com)
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Supervisor	Leon J.H.M. Kester (kester@fel.tno.nl)
Partner	Thales

Figure 7: Overview of the workpackage in the ICIS project

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