Rapid Information Integration for Emergency Response

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Abstract— **In this paper we advocate a new approach to building information integration systems that are particularly suited for applications in disaster and emergency response systems and situations. Our work is in the context of the "EBox" which is a data integration system we are building as part of a larger effort on situational awareness systems for fire fighter decision support. Our approach is aimed at providing several new capabilities over the current state of the art in the area, including facilitating rapid new application assembly without requiring much user expertise, the systematic incorporation of real-time data source such as sensor in data integration, and the rapid integration of information with geospatial aspects from different sources.**

Keywords-component; ***Emergency response systems, information integration, real-time information.***

I. Introduction

This paper presents a new approach to developing information integration systems, that facilitates very rapid new integration application assembly and in a manner particularly suited to situational awareness systems for disaster and emergency response. This approach is part of our work on developing the "Software EBox" - which is a software solution for information integration in the context of situational awareness systems for emergency response. Consider a particular disaster response domain which is that of fire response. Today, first-responders such as firefighters responding to an incident, typically arrive on the disaster scene with typically little useful information regarding the crisis site, buildings and other infrastructure, occupancy or the presence of victims, or even the exact nature of the call. Obtaining such information quickly and in a fashion in which it can be easily used in order to make decisions can be critical to the successful outcome of the emergency response activities, both from the view of neutralizing any hazards, as well as ensuring the safety of both the first responders and any other people in the vicinity. Instead, firefighters today depend heavily upon a variety of locally gathered information and expertise obtained at the time of the incident. For instance, they may ask for details from local people about building occupancy, hazards, exit routes etc. They may observe the locations of triggered alarms or detectors on a centralized alarm panel. Fire departments do frequently have map books which are usually printed books made on an annual or similar basis containing roads, building perimeters, water sources or fire hydrant locations etc. and these may be consulted.

Recognizing the deficiencies with regard to useful information available to decision makers at the time of an incident, a number of companies have begun to contract with individual organizations or with fire departments to conduct surveys of selected building sites [1]. This "pre-planning" data can be a valuable tool for firefighters during response to various potential types of incidents. However, there are many challenges: (a) pre-plan data is static and it is difficult to maintain or republish the data in an updated form, (b) such data is typically limited to infrastructure centric information such as building floor-plans. We believe that there are multiple other forms of information, which if captured and presented appropriately can provide vital situational information. Technology advances have enabled highly instrumented buildings and infrastructures equipped with sensors that can provide information on the structural integrity of the building, environmental conditions within the space (smoke, temperature, humidity) or multimodal situational awareness through video and audio sensors that can help dynamically determine occupancy levels within the building. Leveraging such infrastructure on the fly to provide better awareness poses multiple challenges such as addressing the diversity of the sensors, integration of sensor data with a-priori information and sensor hardware and software interoperability issues. Finally, other locally maintained data may be useful, for instance inventories of hazardous materials location, meeting and activity calendars for rooms in buildings etc., can provide additional situational awareness information.

To overcome the limitations we observe with custom built solutions namely the high cost and restriction to pre-assembled information, as well as provide the capability to exploit additional information such as local information and data from sensors, we propose a system called the software EBox. The EBox is being implemented as a web-service that enables organizations to provide their available data and information sources, which can then be accessed in an integrated fashion during a response situation. We envision that much of this data is provided in advance. First responders will connect to this service both prior to departing from the fire station and while at the crisis site, and download the necessary data into their own information systems in order to help them perform their duties. In addition, the service may offer mechanisms for responders to actively control elements of the building's infrastructure, e.g., sensors or surveillance cameras, through the EBox system.

The EBox can be viewed as a software and information analog to the traditional concept of a "knox-box" - a small safe located outside a building holding its master keys so that responders can quickly obtain and use them in a response situation.

II. EBOX DESIGN AND IMPLEMENTATION

The EBox architecture (Fig 1) is based upon the "Software-as-a-Service" (SaaS) paradigm where an EBox server can serve particular clients that require information. An EBox "user" i.e., a facility that will use the system first provides available data to the EBox server. This includes data relevant to that facility and the location such as maps of the location and facility, floor plans of buildings in the area, hazardous material location information, and other potentially useful information such as work schedules and shift timing information. All such data is loaded into the EBox server in advance. Further, at the time of an incident and response, we also have the capability of making real-time sensor data available to the EBox server. An example of such a sensor is surveillance cameras in a building at the incident site, which can be integrated in at real-time. The EBox server provides integrated "static" data which is uploaded in advance as well as real-time sensor data to clients i.e., situational awareness systems that will use such data for decision making.

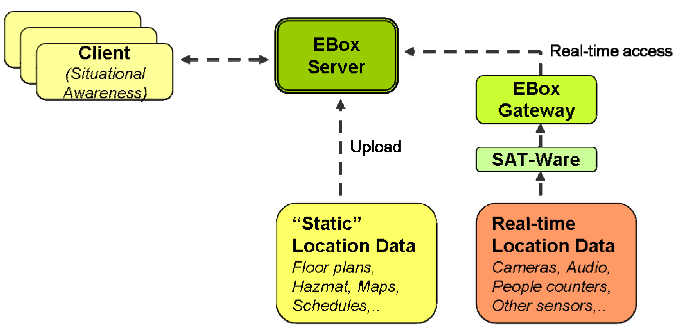

Fig 1. EBox System Architecture

The EBox architecture and implementation strives to achieve two key capabilities for different categories of EBox users, (i) We want to make it easy for a particular facility to provide their available data to the EBox server, (ii) To clients, the EBox must provide effective querying and information retrieval capabilities over the integrated information. Further, the EBox server must facilitate the integration and access of real-time sensor resources.

These capabilities are achieved with many detailed components or modules of the overall system (not illustrated) but which we will briefly describe. These are: **(i) An Ontology Manager:** This module manages the task of creating and maintaining ontologies in EBox applications. It includes some basic "upper" ontologies that are generic across applications. It further provides an interface and GUI tool to a user for creating and extending ontologies specific to applications. The ontology manager also provides interfaces to internal modules that use the ontologies in information organization and retrieval tasks, as we shall elaborate on shortly. **(ii) A Data Ingest Module:** This module handles the task of inserting data into the data repository. Through this module the user provides for storage various kinds of data ranging from maps and floor plans to information about hazardous materials or building occupancy. The user also provides key meta-data for each piece of information that is then used in data organization and for data retrieval. This data ingest module actually uses the domain ontologies to guide a user in providing their data and providing the appropriate meta-data. **(iii) A Data Repository:** This is the repository for all of the pre-assembled data in any EBox application. Storage is provided in a geospatially-enabled relational database as well as a file system. **(iv) The Core EBox Server:** Clients interface with the core EBox server which in turns communicates with other modules in the system to address the client information retrieval requests. **(v) An Ontology Store:** This is the store for all of the pre-assembled as well as newly created or extended ontologies in any application. **(vi) A Search Module:** Provides semantic as well as geospatially and temporally aware search capabilities over the information. We will elaborate on this later. **(vii) An Internet Data Access Module:** There are also many publicly available sources (over the Internet) that provide valuable information. For instance there are online databases of toxicology information or information about chemicals or explosives. The EBox has a module to be able to access and integrate data from such internet sources at real-time. In addition, EBox utilizes a system called **"SAT-Ware"** for interfacing to and integrating real-time sensor data. SAT-Ware [2] is a middleware system for high level access to multi-modal, distributed sensors. While SAT-Ware itself is a general framework developed prior to EBox, we have developed an "EBox-SAT-Ware Gateway" through which the EBox interfaces to SAT-Ware. The EBox creates a representation of each real-time sensor that is available at the incident location. A client request for real-time data from any such sensor (such as say a request to view the video stream from a particular camera) that arrives to the EBox server, is eventually handled through the gateway to SAT-Ware.

In creating any new EBox application or instantiation we go through the following preparation steps using the above modules: (i) *Create Ontologies* The first step is to create and assemble ontologies such as for information categories, key locations in the area of interest, and also (generic) spatial and temporal concepts and relationships. (ii) *Data Ingest* The next step is the ingestion of various available data which is the process of providing data and data source descriptions and meta-data for the information in the various sources. (iii) *Geospatial Anchoring and Integration* Another key step is the geospatial alignment of information from different sources for the purpose of integration. We must ensure that references to locations (such as "Bren Hall" or "Engineering Tower") are correctly anchored to relevant geography. Further, if multiple imagery datasets or other geographic data of the area are being used (for instance a campus map combined with floor plans for particular buildings) then such geographic data must be registered and projected correctly. (iv) *Integration of Sensor Data* Real-time sensors if available are integrated through the EBox-SAT-Ware gateway. (v) *Integration of Remote Data Sources* We provide real-time query access to any relevant remote (internet) sources through "wrappers" around these information sources.

We also provide some details on the implementation specifics. The Ontology Manager is implemented in Java and provides the Protégé tool to the user for the creation of ontologies. The ontologies are stored in the RDF format. The ontology manager further utilizes Jena as the ontology store and manager. Jena provides for the storage of ontologies in RDF format as well as providing an API for ontology manipulation and querying. The Data Repository is implemented using the MySQL relational database, which includes basic features for storing geographic information. Geographic data is prepared for the system separately, using external GIS tools to geo-register and re-project the data when necessary (such as ArcGIS [6], Manifold [7], GRASS, or GDAL). For the sake of compatibility, all GIS data is required to be in certain specific common projections. Raster imagery is expected to be provided in Universal Transverse Mercator WGS84, and vector data is expected to be in lat/long WGS84. The Data Ingest module is implemented in Java and it interacts with the Data Repository using JDBC. The Central Manager is implemented in Java. The Data Access module uses AJAX and Apache for offering the EBox as a Web service. Finally, the information search functionality is implemented using Lucene.

III. INFORMATION INTEGRATION CHALLENGES

Our work in progress on the EBox has served to propose and define an architecture for information integration systems that can be useful in emergency situations. As illustrated, we advocate the Software-as-Service architecture for such systems where a significant amount of useful information can be pre-loaded and pre-integrated into a central EBox server. Any client can than connect to this server during a situation and access this data in an integrated fashion. We have also provided for the incorporation of real-time data sources such as sensors into any application.

Our experience has also served to highlight certain key challenges for information integration technology in general. These are driven by a demand for new capabilities posed by such new integration applications and the fact that the current state of the art does not address these capabilities. The new capabilities and corresponding directions of further research can be summarized as:

1) *Being able to rapidly assemble new applications and without requiring much user expertise.*

Indeed for such systems to be practically feasible we cannot have a high overhead in time and effort in assembling such applications. Besides, it should be possible for the average providers of such data in an organization to be able to provide what is needed i.e., without requiring any additional expertise in assembling such applications. Some recent information integration research has indeed begun to address this issue, examples include the CopyCat system [8] and work on "building mash-ups by example" [9] where the approach is to automate many of the integration application building steps so as to make assembling new applications quick and easy. In this domain we observe that the domain and task of each new application is essentially similar across instances i.e., every application is about integrating information such as maps, floor plans etc., of the location in question and providing a similar integrated view to the user. We have initiated work on an approach where we can exploit the fact that applications are similar across instances. We are developing a systematic theory where integration artifacts, such as the integration model, mappings between data, data itself, and software components such as wrappers can be adapted and reused from application to application.

2) *New capabilities for geospatial data integration.*

Much of the data we integrate is either geospatial in nature (maps, floor plans etc.,) or has a geospatial aspect (for instance the locations of Hazardous materials have a location aspect to the data). In geospatial data integration, techniques such as conflation provide for the merging of multiple maps based on using "control points" across the maps [3]. While some techniques have been developed for the identification of control points for particular kinds of maps (such as road maps), we see a need for techniques generalized to other kinds of maps.

3) *New search and retrieval capabilities.*

Finally, the importance of intuitive yet powerful interfaces to browse, search and query the available integrated information cannot be underscored. For such applications our experience in that map oriented or geospatial interfaces are really the best suited to get a "birds eye" overview of a situation at any point. The current interface to the EBox supports such capabilities. We have further incorporated some of the system ontologies into the interface so that the user can search or browse information by particular categories (i.e., Hazmat information, vs Location of people etc.,) or by location category. The current EBox implementation also allows for a keyword based search capability. There is however need for semantic search [4] and also for situationally aware search capabilities [5].

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