Enhancing Data and Processes Integration and Interoperability in Emergency Situations: a SWS based Emergency Management System

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Abstract. In this paper we describe a powerful use case application in the area of emergency situations management in which to illustrate the benefits of a system based on Semantic Web Services (SWS), through the automation of the business processes involved. After creating Web services to provide spatial data to third parties through the Internet, semantics and domain ontologies were added to represent the business processes involved, allowing: ease of access and combination of heterogeneous data from different providers; and automatic discovery, access and composition to perform more complex tasks. In this way, our prototype contributes to better management of emergency situations by those responsible. The work described is supported by the DIP (Data, Information and Process Integration with Semantic Web Services) project. DIP (FP6 – 507483), an Integrated Project funded under the European Union's IST programme.

1. Introduction

In an emergency response situation there are predefined procedures which set out the duties of all agencies involved. A very wide range of agencies is often involved in the management of an emergency situation, potentially involving a huge data provision and communication requirement between them. Needs and concerns are escalated through a specified chain of command, but the organisations are independent of one another and decisions have to be made rapidly, based on knowledge of the situation (e.g. the type of problem, the site, and the population affected) and the data available. Gathering all the data in a manual or semi-automated way takes time and resources that those responsible for emergency planning and incident response may not have.

Having data and resources available through the internet, companies and public organizations can easily and inexpensively share information with customers and partners. Web Services (WS) would allow emergency planning agencies and rescue corps to interoperate and share vital information easily. The supplied services are autonomous and platform-independent computational elements. They can be described, published, discovered, orchestrated, and programmed using XML artifacts for the purpose of developing massively distributed interoperable application. Unfortunately, despite progress in the use of standards for Web Service description (WSDL [9]) and publishing (UDDI [10]), the syntactic definitions used in these specifications do not completely describe the capability of a service and cannot be understood by software programs. A human developer is required to interpret the meaning of inputs, outputs and applicable constraints as well as the context in which services can be used.

Semantic Web Services (SWS) technology aims to alleviate these problems. It combines the flexibility, reusability, and universal access that typically characterize a WS, with the expressivity of semantic mark-up, and reasoning in order to make feasible the invocation, composition, mediation, and automatic execution of complex services with multiple paths of execution, and levels of process nesting. As a result, computers can automatically interoperate and combine information, creating a comprehensive and most relevant possible response which is seamlessly delivered to end-users in real time.

The Emergency Management System (EMS) envisaged within the DIP use case will provide a decision support system which will assist the emergency planning officer to automatically gather and analyze relevant information in a particular emergency scenario, through the adoption of SWS technology. This should improve the quality of the information available to emergency managers in all the phases of emergency management: before (planning), during (response), and after (evaluation and analysis); thereby facilitating their work and improving the quality of their decisions in critical situations.

Our work contributes to raise the awareness of potential SWS benefits in real-world applications - ease the creation of infrastructure in which new services can be added, discovered and composed continually, and the organization processes automatically updated to reflect new forms of cooperation - and promote the availability of working SWS platforms.

2. Integrated Emergency Management (IEM) Requirements

In the definition of the use case scenario, an attempt has been made to bring together the needs of all the groups that would be involved in case of an emergency occurring in Essex - a large region in South East England (UK). We have conducted interviews with emergency planning personnel in Essex County Council (ECC) and several other agencies which are involved in various types of emergency scenario (e.g. Meteorological Office; police, fire, ambulance emergency services; traffic control service; British Airport Authority; and other County Councils surrounding Essex). As a result of this work, the following main requirements were delineated:

R1. *In an emergency event all the authorities involved have to cooperate and provide relevant data to each others upon request. This data comes from many sources in many different formats.* As required in the Civil Contingencies Act 2004 [1]: "local responder bodies have to co-operate in preparing for and responding to emergencies through a Local Resilience Forum (LRF)". ECC is aware of the importance of multi-agency working and consequently has belonged for many years to several emergency groups and networks. All of these groups collaborate now under the Essex Resilience Forum. There is also in Essex an "Essex Emergency Services Coordinating Group (EESCG)" which is formed by representatives from Essex Police, Essex Fire and Rescue Service, British Transport Police, Essex Ambulance Service, Maritime Coastguard Agency, Military and Local Authorities.

R2. *Interoperation and collaboration among many agencies in an emergency situation follow predefined procedures which set out agency's duties.* As stated in the COPE (Combined Operational Procedures for Essex) document [2]: "The purpose of the group is to develop, maintain and improve effective co-ordination between the Emergency Services and the principal emergency Support Organizations and to identify the means to ensure effective co-ordination and regular liaison between those services in the planned response to emergencies."

R3. *Geographical Information Systems (GIS) applied to an IEM scenario can ease the integration, storage, querying, analysis, modeling, reporting and mapping of geographically-referenced data relevant for the emergency situation.* As stated in by the UK Emergency Planning College in their "Guide to GIS Applications in Integrated Emergency Management (IEM)" [4]: "Geography matters to IEM: hazards are spatially distributed, and generally very uneven in that distribution, vulnerable facilities are distributed and clustered in space, and resources may be sub-optimally located to deal with anticipated and actual emergencies".

R4. *Cross-border relationships are highly important in an emergency situation*, especially in the context of the Stansted area. The Airport is considered to be in its own 'territory' governed by British Airports Authority (BAA) and does not form part of a local government District. In the event of an emergency situation around Stansted, ECC needs to work closely with the other affected adjacent local government authorities, namely: Hertfordshire County Council and Uttlesford District Council and with BAA itself.

3. The Emergency Management System

We are developing an Emergency Management System (EMS), which is an end-user Web application providing e-Emergency services to customers. The system is intended to be used during the planning and response phases of an emergency. Provided services can cover all kinds of information concerned with emergencies - including information about hazardous weather, personnel involved in an emergency situation, rescue corps involved in the prevention response and recovery phases of an emergency situation, evacuation procedures, provision of supplies and help to affected people, location of damaged facilities and the consequences, assistance needed by vulnerable people, location of 'hotspots' etc.

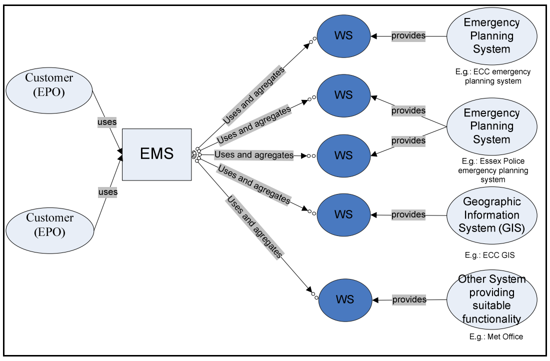

Figure 1 – Context Diagram

As depicted in Figure 1, there are three main actors in the general use case, which participate in this use case and with different roles. These are:

- *Customer (EPO):* The end user that requests the services provided by the EMS. They select and invoke services through a user-friendly emergency planning interface. We envisage this application will be used by the Emergency Planning Officers (EPO) in public organizations, and other emergency partners (Police, Fire & Rescue, Ambulance service, NHS, Rover Rescue, etc.). As a result we obtain a cross-border application (IEM requirement *R4*).
- *Emergency Planning and Geographical Information Service providers:* Governmental authorities, Ordnance Survey, Meteorological Office, emergency agencies, commercial companies, etc, which provide specific emergency planning services and spatially-related services through the Internet in the form of WS. They provide services to end users to improve collaboration in an emergency-based scenario (IEM requirements *R1, R3*).
- *EMS:* The intermediary between the customer and the providers. This management system holds all the functionalities for handling SWS - supporting automatic discovery, composition, mediation and execution. It exposes services to end-users, using existing emergency services and aggregating them into new high-level services in order to improve collaboration in an emergency-based scenario (IEM requirement *R2*). The EMS is considered to have a non-profit governmental basis and to serve public interests in case of an emergency. It interacts with customers (emergency planners and heads of rescue corps) via a user-friendly interface, allowing users to access and combine the different services provided by the service providers.

3.1 Use case

Several emergency-related scenarios were considered in order to pilot the prototype definition. With the collaboration of the ECC emergency planners, we finally decided to focus on a real past situation: "*Heavy snowstorm around the Stansted area and M11 corridor (Essex, UK)* on 31st January 2003", in which thousands of motorists were trapped overnight on some of Britain's busiest motorways [3]. By focusing on a past event we ensure the availability of real data. An additional advantage is the ability to compare the actions taken and the data available at that time, with the data and actions that would had been taken if a SWS-based emergency planning tool had been available.

3.2 Business process and data

The current version of the prototype focused on the planning phase. Figure 2 depicts the main goals to achieve (business processes) in a snowstorm hazardous situation before planning an adequate emergency response. The first step is to identify the affected area by analysing snow data. Then, the EPO has to locate suitable shelters for resting affected people and – not necessarily in this order - identify available relevant people (rescue corps) in the affected area. These goals are not merely retrieval operations, but involve sub-processes that select services and manipulate retrieved data according to situation-specific requirements. Semantics will be adopted to represent these decompositions. A detailed example is provided in Section 4.5.

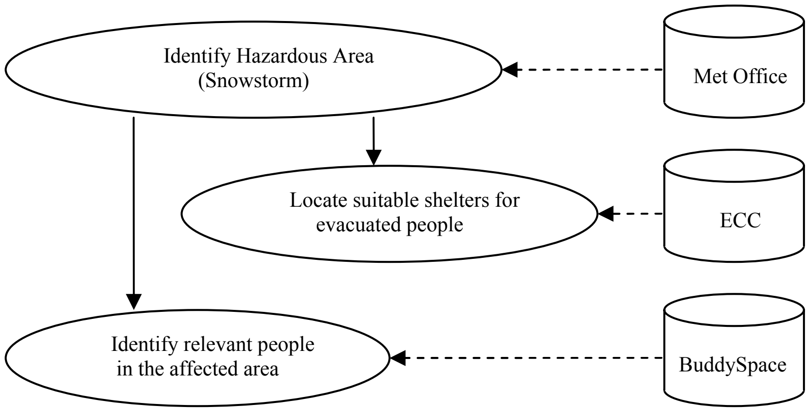

Figure 2 – Emergency procedure in a snowstorm hazardous situation.

The prototype will aggregate data and functionalities from the following three heterogeneous sources:

- *Meteorological Office*: a national UK organization which provides environmental resources and in particular weather forecast data. The prototype aggregates snow data related to the date of the snowstorm in question.
- *ECC geospatial and emergency data*: The prototype makes use of a wide range of geospatial data, such as administrative boundaries, buildings, Ordnance Survey maps, etc, as well as other data from the emergency department. Building related data is used to support searches for suitable rest centres.
- *BuddySpace* is an Instant Messaging client facilitating lightweight communication, collaboration, and presence management [5] built on top of the instant messaging protocol Jabber[1]. The BuddySpace client can be accessed on

[1] Jabber. http://www.jabber.org/

standard PCs, as well as on PDAs and on mobile phones (which in an emergency situation may be the only hardware devices available).

As many of the integrated real systems have security and access restriction policies, British Telecommunications (BT) has created a single corporate spatial data warehouse where all Meteorological Office and ECC data sources have been replicated in order to work with them in a safe environment, thereby providing suitable Web Services (WS) to work with. However, the prototype represents how this system would work in a distributed environment with heterogeneous and scattered data sources over Internet.

WS will provide a first level of interoperability by encapsulating functionality regardless of the specific technologies/protocols of the providers' legacy systems. Semantic descriptions will provide the final level of interoperability, allowing automation of all the stages of the WS use (mainly: discovery, composition and invocation). In Section 4, we will detail these aspects.

4. The Prototype

The main functional requirements of our SWS-enabled EMS are: (FR1) providing a graphic user interface (GUI) for customer interaction and displaying outputs: e.g. browser/visualization tool to display and select data layers on a map; (FR2) discovering, combining and invoking suitable Web Services for a user request; (FR3) providing a WS Execution Environment with control functions, error handling, and support for optional user interaction; (FR4) dealing effectively with heterogeneous resources, thus allowing for appropriate mediation facilities (Ontology-Ontology mediation has been identified in the earlier stages of the prototype, other kinds of mediation may be identified later); (FR5) providing interfaces for cooperation with GIS and emergency service providers.

In order to provide semantic and step toward the creation of added value services (FR2, FR3, FR4, FR5), we adopt WSMO [6] – a promising SWS framework – and IRS-III [7] – a tested implementation of this standard. The reference language for creating ontologies is OCML [8].

4.1 Semantic Web Services framework: WSMO and IRS-III

The Web Service Modeling Ontology (WSMO) [6] is a formal ontology for describing the various aspects of services in order to enable the automation of WS discovery, composition, mediation and invocation. The meta-model of WSMO defines four top level elements:

- *Ontologies*: provide the foundation for describing domains semantically. They are used by the three other WSMO components.
- *Goals:* define the tasks that a service requester expects a Web service to fulfil. In this sense they express the requester's intent.
- *Web Service* descriptions represent the functional behavior of an existing deployed Web service. The description also outlines how Web services communicate (*choreography*) and how they are composed (*orchestration*).

- *Mediators* handle data and process interoperability issues that arise when handling heterogeneous systems.

One of the main characterizing features of WSMO is that ontologies, goals and Web services are linked by mediators:

  - *OO-mediators* enable components to import heterogeneous ontologies;
  - *WW-mediators* link Web Services to Web Services;
  - *WG-mediators* connect Web Services with Goals;
  - *GG-mediators* link different Goals.

The incorporation of four classes of mediators in WSMO facilitates the clean separation of different mapping mechanisms. For example, an OO-mediator may specify an ontology mapping between two ontologies whereas a GG-mediator may specify a process or data transformation between two goals.

IRS-III, the *Internet Reasoning Service* [7], is a platform which allows the description, publication and execution of Semantic Web Services, according to the WSMO conceptual model.

Based on a distributed architecture communicating via XML/SOAP messages, it provides an execution environment for SWS; ontologies are stored by the server, and used in WSMO descriptions to support discovery, composition, invocation and orchestration of WS. It allows *one-click publishing* of "standard" program code to WS by automatically generating an appropriate wrapper. Standard WS or REST services can also be trivially integrated and described by using the platform.

Also, by extending WSMO goal and Web Service concepts, clients of IRS-III can invoke web services via goals. That is, IRS-III supports so called *capability*-, or *goal-driven* service invocation which allows the user to use only generic inputs, hiding the possible complexity of a chain of heterogeneous WS invocations.

4.2 Architecture

The general architecture of our semantically-enhanced prototype is depicted in Figure 3. As can be seen, it is a service oriented architecture (SOA) composed of the following four layers:

- *Legacy System layer:* consists of the existing data sources and IT systems available from each of the parties involved in the integrated application.
- *Service Abstraction layer:* exposes (micro-) functionality of the legacy systems as WS, abstracting from the hardware and software platforms. The adoption of existing Enterprise Application Integration (EAI) software facilitated the creation of required WS.
- *Semantic Web Service layer*: given a goal request, this layer, implemented in IRS-III will (i) discover a candidate set of Web services, (ii) select the most appropriate, (iii) mediate any mismatches at the data, ontological or business process level, and (iv) invoke the selected Web services whilst adhering to any data, control flow and Web service invocation requirements. To achieve this, IRS-III utilises the set of SWS descriptions, which are composed of goals, mediators, and Web services, supported by relevant ontologies.
- *Presentation layer:* is a Web application accessible through a standard Web browser. The goals defined within the SWS layer are reflected in the structure of

the interface and can be invoked either through the IRS-III API or as an HTTP GET request. The goal requests are filled with data provided by the user and sent to the Semantic Web Service layer. We should emphasise that the presentation layer may be comprised of a set of Web applications to support distinct user communities. In this case, each community would be represented by a set of goals supported by community related ontologies.

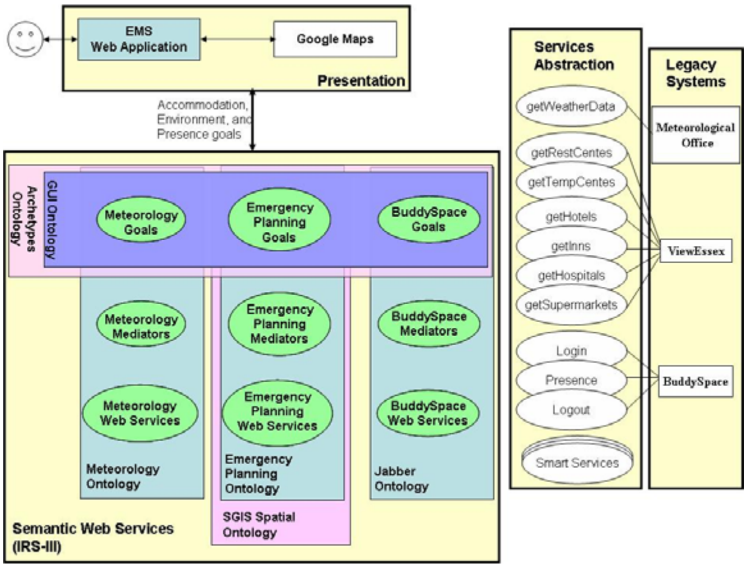

Figure 3. The EMS general architecture.

4.3 Services

We distinguish between two classes of services: *data* and *smart*. The former refers to the three data sources introduced in Section 3, and are exposed by means of WS:

- *Meteorological service:* this service provides weather information (e.g. snowfall) over a specific rectangular spatial area.
- *ECC Emergency Planning services*: using the ViewEssex data each service in this set returns detailed information on a specific type of rest centre within a given circular area. For example, the *'getHospitals'* Web service returns a list of relevant hospitals.
- *BuddySpace services*: these services allow presence information on online users to be accessed.

Smart services represent specific emergency planning reasoning and operations on the data provided by the data services. They are implemented in a mixture of Common Lisp and OCML and make use of the developed ontologies. In particular, we created a number of filter services that manipulate meteorological and GIS data according to emergency-specific requirements semantically described; e.g. rest centres with heating system, hotels with at least 40 beds, easier accessible hospital, etc. The criteria used were gained from our discussions with the EPO's.

4.4 Semantic Web Services: Ontologies

In this and next section, we focus on the semantic description defined in the Semantic Web Services Layer. The following ontologies reflecting the client and provider domains were developed to support WSMO descriptions:

- *Meteorology, Emergency Planning and Jabber Domain Ontology*: representing the concepts used to describe the services attached to the data sources, such as *snow* and *rain* for Met Office, *hospitals* and *supermarkets* for ECC Emergency Planning, *session* and *presences* for Jabber. If a new source and the Web services exposing its data and functionalities are integrated, a new domain ontology has to be introduced - also reusing existing ontologies. The services, composed of the data types involved as well as its interface, have to be described in such a ontology usually at a level low enough to remain close from the data.

To get the information provided by WS up to the semantic level, we introduce *lifting operations* that allows the passage of data types instances from a syntactic level (xml) to an ontological one (OCML) specified in the domain ontology definitions. These lisp functions automatically extract data from SOAP messages and create the counterpart class instances. The mapping information between data types and ontological classes is defined at design time by developers.

- *HCI Ontology*: part of the user layer, this ontology is composed of HCI and user-oriented concepts. It allows to lowering from the semantic level results for the particular interface which is used (e.g. stating that Google Maps API is used, defining "pretty names" for ontology elements, etc.). Note that although the choice of the resulting syntactic format depends of the chosen lowering process, concepts from the HCI ontology are used in order to achieve this transformation in a suitable way.
- *Archetypes Ontology*: part of the user layer, this is a minimal ontological commitment ontology aiming to provide a cognitively meaningful insight into the nature of a specialized object; for example, by conveying the cognitive ("naïve") feeling that for example an hospital, as a "container" of people and provider of "shelter" can be assimilated to the more universal concept of "house", which we consider to be as an *archetypal* concept, i.e. based on image schemata and therefore supposed to convey meaning immediately. It is moreover assumed that any client, whilst maybe lacking the specific representation for a specific basic level concept, knows its archetypal representation.
- *Spatial Ontology*: a part of the mediation layer, it describes GIS concepts of location, such as coordinates, points, polygonal areas, and fields. It also allows describing spatial objects as entities with a set of attributes, and a location.

The purpose of the HCI, Archetypes and Spatial ontologies is the aggregation of different data sources on, respectively, a representation, a cognitive and a spatial level. Therefore we can group them under the appellation *aggregation* ontologies. They allow the different data sources to be handled and presented in a similar way. Inversely to the lifting operations, *lowering operations* transform instances of aggregation ontologies into syntactic documents to be used by the server and client applications. This step is usually fully automated since aggregation ontologies are, by definition, quite stable and unique.

Context Ontology: the context ontology allows describing *context n-uples* which represent a particular situation. In the emergency planning application, context n-uples have up to four components, the use case, the user role, the location, and the type of object. Contexts are linked with goals, i.e. if this type of user accesses this type of object around this particular location, these particular goals will be presented. Contexts also help to inform goals, e.g. if a goal provides information about petrol stations in an area, the location part of the context is used to define this area, and input from the user is therefore not needed. Each time an object is displayed by a user at a particular location, a function of the context ontology provides the goals which need to be displayed and what inputs are implicit.

4.5 Semantic Web Services: WSMO descriptions

As depicted in Figure 3, the goals, mediators, and Web Services descriptions of our application currently link the UK Meteorological Office, ECC Emergency Planning, and BuddySpace Web services to the user interface. Correspondingly, the Web Service goal descriptions use SGIS spatial, meteorology, ECC Emergency Planning and Jabber domain ontologies whilst the goal encodings rely on the GUI and archetypes ontologies. Mismatches are resolved by the defined mediators. As introduced in the previous section, the inputs of the WS (XML in our particular scenario, but any other format could be provided) are lifted to the ontology, and, after invoking a Goal, the results are lowered back into XML so the results can be displayed back to the user. For illustration purposes, a small portion of the SWS descriptions are shown in Figure 4. The example details the main goal "*Locate suitable shelters for evacuated people*" introduced in Section 3.2.

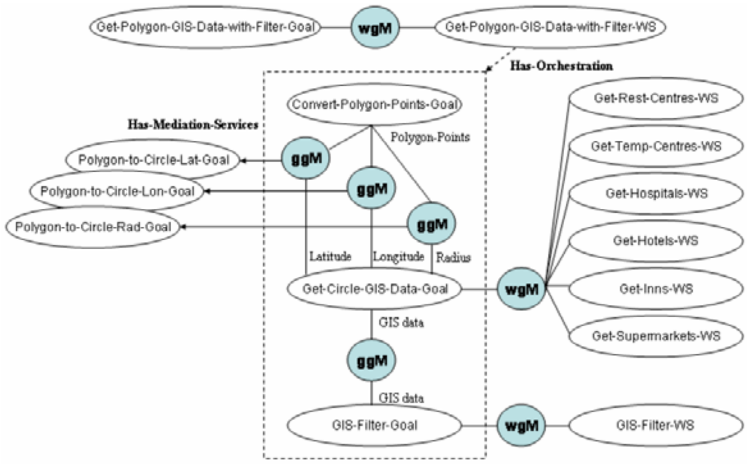

Figure 4. A portion of WSMO descriptions for the EMS prototype.

Get-Polygon-GIS-data-with-Filter-Goal represents a request for available shelters within a delimited area. The user specifies the requirements as a target area, a sequence of at least three points (a polygon), and a shelter type (e.g. hospitals, inns, hotels). As mentioned above the set of ECC Emergency Planning Web services each return potential shelters of a specific type with a circular query area. The obtained results need to be filtered in order to return only shelters correlated to emergency-specific requirements (for example a snowstorm). The process automated in our application is usually performed by EPO manually.

From a SWS point of view the problems to be solved by this particular portion of the SWS layer included: (i) *discovering* the appropriate ECC Emergency Planning Web service; (ii) *meditating* the difference in area representations (polygon vs. circular) between the goal and Web services; (iii) *composing* the retrieve and filter data operations. Below we outline how the WSMO representations in Figure 4 address these problems.

- *Web service discovery (FR2):* each SWS description of ECC Emergency Planning service defines, in its capability, the specific class of shelter that the service provides. Each definition is linked to the *Get-Circle-GIS-Data-Goal* by means of a unique WG-mediator (shown as wgM). The inputs of the goal specify the class of shelter, and the circular query area. At invocation IRS-III discovers through the WG-mediator all associated Web services, and selects one on the basis of the specific class of shelter described in the Web service capability.
- *Area mediation and orchestration (FR2, FR4, FR5)*: the *Get-Polygon-GIS-data-with-Filter-Goal* is associated with a unique Web service that orchestrates, by simply invoking three sub-goals in sequence. The first gets the list of polygon points from the input; the second is *Get-Circle-GIS-Data-Goal* described above; finally, the third invokes the smart service that filters the list of GIS data. The first two sub-goals are linked by means of three GG-mediators (depicted as ggM) that return the centre, as a latitude and longitude, and radius of the smallest circle which circumscribes the given polygon. To accomplish this, we created three mediation services invoked through: *Polygon-to-Circle-Lat-Goal*, *Polygon-to-Circle-Lon-Goal*, and *Polygon-to-Circle-Rad-Goal* (the related WG-mediator and Web service ovals were omitted to avoid cluttering the diagram). The results of the mediation services and the class of shelter required are provided as inputs to the second sub-goal. A unique GG-mediator connects the output of the second to the input of the third sub-goal. In this instance no mediation service is necessary.

It is important to note that if new WS – for instance providing data from further GIS are available, new Web Service descriptions will be simply introduced, and linked to the *Get-Circle-GIS-Goal* by the proper mediators (even reusing the existing ones, if semantic mismatches do not exist), without affecting the existing structure. In the same way, new GIS filter services (e.g. more efficient ones) may be introduced. The effective workflow – i.e. which services are invoked – is known at run-time only.

4.6 User Interface: usage example

The user interface has been developed using Web standards: XHTML and CSS are used for presentation, JavaScript (i.e. EcmaScript) is used to handle user interaction and AJAX provides IRS-III goal invocation (*FR1, FR3*). One of the main components of the interface is a map, which uses the Google Maps API to display polygons and objects (custom images) at specific coordinates and zoom levels. These objects are displayed in a pop-up window or in a hovering transparent region over the maps.

When the application is launched, a goal is invoked for the Essex region, and snow hazard or storm polygons are drawn according to data from the meteorological office. The value from which snow values can constitute a hazard or a storm are heuristic and as emergency knowledge is gathered it can easily improved, by modifying the smart services which are composed with weather information, while the goal visible to the user remains the same. As an example of practical usage, we describe how an EPO describes and emergency situation, before trying to contact relevant agents. The procedure is as follows:

1. The EPO clicks within the displayed hazard region to bring up a menu of available goals. In this case (Figure 5a) three goals are available: show available shelters, login to BuddySpace and get the presence information for related staff.
2. The EPO asks for the available Rest Centres inside the region, and then inspects the detailed attributes for the Rest Centre returned (Figure 5b).
3. The EPO requests to see the presence status for all staff within the region and then initiates an online discussion the closest online agency worker (Figure 5c).

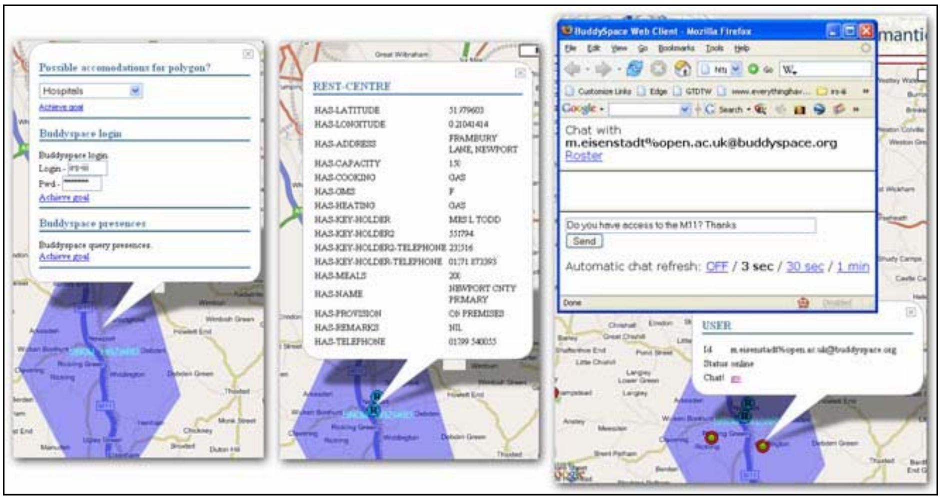

Figure 5 - Three views of the application in use: 5a) Goals available for the snow hazard, 5b) obtaining detailed information for a specific rest centre, 5c) initiating a discussion with an online emergency worker.

5. Related Work and Lesson Learned

Spatial-related data is traditionally managed with the help of GIS, which, by linking spatial algorithms and representation means to spatially extended databases, help supporting decision making by facilitating the integration, storage, querying, analysis, modeling, reporting, and mapping of this data to analyze possible models. However, each agency tends to collect only data relevant for itself and organizes it in the way that suits it best, managing it according to particular business processes and sharing only what is not judged confidential information. In an emergency situation, such access and semantic barriers are unacceptable and the wish for more complete interoperability through the network is often expressed[2].

Maps available on the web, for identifying an address or getting transportation information, are popular but allow only simple queries. However, recently, a new type of mapping systems has emerged; highly responsive mapping frameworks providing API (Google[4], Yahoo[5], Mapquest[6], etc.). They are also usually enhanced with "reality effects" – e.g. seamless transition between maps, satellite and hybrid views, 2.5-3D visualisations, street level photography, etc. – which make them even more appealing. API allow developers to populate online maps with custom information – location of "events" or "things" –, by collecting data from standard documents such as RDF files, or simply by ad hoc "web scraping" of HTML resources. These embryonic but very agile *Web GIS*, called *mashups*, can merge more than one data sources and add functionality such as filtering and search features. However, although extremely popular, relatively easy to build and to enhance, Web GIS do not avoid traditional issues attached to non semantic applications; indeed (i) handling data heterogeneity still requires considerable manual work, (ii) the lack of semantics limits the precision of queries, and (iii) limited expressiveness usually drastically limits functionality.

Any information system can gain advantage from the use of semantics [14]. In GIS-related application, the use of semantic layers, although not yet firmly established, is being investigated in a number of research studies [11][12][13]. Having ontologies describing a spatial-related data repository and its functionalities is believed to make cooperation with other systems easier and to better match user needs.

In our approach, we adopted WSMO and IRS-III to provide an infrastructure, in which new services can be added, discovered and composed continually, and allow the automatic invocation, composition, mediation, and execution of complex services. The integration of new data sources results relatively simple; the steps involved in the process of adding new data sources can be summarized as follow: (i) ontological description of the service; (ii) lifting operations definition; (iii) mapping to aggregation ontologies; (iv) goal description; (v) mediation description; (vi) lowering definition; and (vii) context linking. Although this procedure may seem tedious, and can actually only be performed by a knowledge expert, it presents many advantages compared to standard based approaches as the one demonstrated in the OWS-3 Initiative[3]:

- *Framework openness*: standards are helpful but not necessary. For example, if querying sensor data, the use of standards – e.g. SensorML[4] – helps the reuse of service ontologies and lifting procedures since they can be applied to any service using a similar schema. However any other schema can be integrated with the same results.

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[2] http://www.technewsworld.com/story/33927.html
[3] http://www.opengeospatial.org/initiatives/?iid=162
[4] http://vast.nsstc.uah.edu/SensorML/

- *High level services support*: since services are described as SWS, they inherit all benefits of the underlying SWS execution platform and are updated as more features are added to the platform (e.g. trust based invocation). In other solutions support for composition and discovery is imbedded in syntactic standards themselves, which implies specific parsing features and adding ad hoc reasoning capabilities to standard software applications, which is time consuming and error prone. Moreover, SWS introduce a minimalist approach in the description of a domain, by modeling the concepts used by Web Services only, and allowing on-the-fly creation of instances when Web Services are invoked (lifting).
- *Support of the Emergency Handling Process*: the conceptual distinction between goal and web services - introduced by WSMO – allows developers to easily design business processes known a priori (e.g. emergency procedure) in terms of composition of goals, and move the (automatic) identification of the most suitable service at run-time. Specifically, the constant use of context to link goals and situations greatly enhances the decision process. Indeed, actions are oriented depending on the use case, the object, user role and location. With the help of explanations of the utility of each goal in each context, the Emergency Officer's task is greatly simplified. A future development of the context ontology will include feedback from goal invocation history, and allow workflow definitions, i.e. this goal only appears after these two have been invoked. Note that all goals are also accessible independently of any context which allows non directed queries to occur, if needed.

6. Conclusions and Future Work

In the future, a new era of emergency management can be envisaged, in which EMS's 'collaborate' thorough the Internet to provide relevant information in emergency situations through SWS technology. In this way, involved agencies and emergency corps can extend their knowledge about a particular emergency situation making use of different functionalities based on data hold by other agencies which otherwise might not be accessible to them or slow to obtain.

The proposed EMS is a decision support system based on SWS technology, which assists the EPO in the tasks of retrieving, processing, displaying, and interacting with only emergency relevant information, more quickly and accurately.

In our approach, we aimed to obtain a development process that might be pragmatic - in order to quickly lead to a working outcome – as well as flexible - in order to easily respond to eventually changes/improvements and meet the multiple actors' viewpoints. We followed a prototyping approach that produced two main cycles; a third one is under way.

The first cycle rapidly defined the structure, processes and data sources of the EMS (Section 3) starting from the requirements of a real-world integrated emergency management (Section 2). The result has been valued by stakeholders (emergency planning department in ECC) before advancing with the application development.

The second cycle actualized the required EMS functional requirements (Section 4) by adopting semantic technologies. Specifically, WSMO and IRS-III have been used to implement the SWS infrastructure, which has been linked to the user interface (based on Google Maps) through AJAX approach. As a result, we obtained a working prototype that has been shown to the EPO's and other people dealing with emergency situations in the ECC area (i.e. potential end-users).

On the basis of their feedback, the third cycle has been planned. Future improvements involve integrating demographic, highways and transport data from ECC. Moreover, we are seeking to use real time data (e.g.: real time RADAR data instead of the weather forecast). Assuming the availability of this data, the system could also be used in the response phase of the designed EMS.

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