ONTOCARER: AN ONTOLOGICAL FRAMEWORK FOR ASSISTIVE AGENTS FOR THE DISABLED

Vassil Vassilev
London Metropolitan University
v.vassilev@londonmet.ac.uk

Michael Ulman
Soran University, Iraq and London Metropolitan University
m.ulman@londonmet.ac.uk

Karim Ouazzane
London Metropolitan University
k.ouazzane@londonmet.ac.uk

Hassan Kazemian
London Metropolitan University
h.kazemian@londonmet.ac.uk

Markson Aigbodi
London Metropolitan University
maigbodi@yahoo.com

Richard Boyd
Disability Essex, UK
info@disabilityessex.org

ABSTRACT

The **OntoCarer** Framework is a research programme of the Centre for Intelligent Systems Research of London Metropolitan University which aims at utilizing contemporary Web and Mobile Internet technologies for assisting disabled, elderly and impaired people. In this framework software agents will act on behalf of both the assisted and the assisting people. Its conceptual foundation is based on the World Health Organisation classification of Functioning, Disability and Health. The software agents will be located on their mobile telephones, and coordinated through service organisation agent. The representations used for the agent profiles will be Semantic Web ones built using RDF/OWL. The agent planning in the framework is organized on two-levels, combining an offline deductive planner, based on the BDI theory of rational behaviour and semantic pattern matching, and a continuous online planning, based on an action ontology and event-driven programming. This paper presents the pilot implementation of the framework which utilizes only standard communications infrastructure, public service hosting, open source software and inexpensive mobile devices.

Keywords: Disability Assistance, Ontological models, BDI Theory, Agent Frameworks, Two-level Planners, Mobile Applications

1. INTRODUCTION

The population of the UK, Europe and the rest of the world is aging. The disabled people who represent a small but important part of our society need integration. Several other categories of people in the contemporary society need assistance in their interactions with the organisations that they deal with on a daily basis - organisations such as schools, hospitals, colleges, universities, shopping centres, cultural venues, etc. A number of social service agencies try to assist them, allocating carers, supplying and servicing them.

At the same time, contemporary technologies, computing and communication technologies in particular, have entered our life and changed the way we work, interact, learn and entertain ourselves. The Web allows people to link to a vast repository of online information. The Mobile Web allows us to have access to this information wherever we are, and in this case we can also use it to communicate with and access services which can help in resolving some of the problems of assisting the disadvantaged groups in our society. The **OntoCarer** Framework is a research programme of the Centre for Intelligent Systems Research Center of London Metropolitan University which aims at utilizing contemporary Web and Mobile Internet technologies for assisting disabled, elderly and impaired people. OntoCarer is a Semantic Web [1] research project as it involves creating knowledge representations in the semantic web's ontology languages which are processable by software agents acting for the persons involved and incorporating knowledge-based planning and multi-agent systems. Since its initiation it has been progressing in close collaboration with one of the foremost centres of helping disabled people in the UK, Essex Disability (http://disabilityessex.org). This project is building upon the success of a previous collaborative project with Disability Essex to develop an intelligent keyboard for disabled people [2].

In the **OntoCarer** programme, to make the solution affordable it utilizes only standard communications infrastructure (Web and Mobile Internet), public service hosting (Web servers), open source software tools (databases, repositories and software libraries) and inexpensive mobile devices (e.g Android smartphones and PDAs). Currently the programme is in a pilot implementation stage with number of prototypes already developed and more are being explored.

In this project software agents will act on behalf of both the assisted and the assisting people. The software agents will be located on their mobile telephones, and coordinated through a service organisation agent. The representations used for the agent profiles are semantic web ones based upon RDF/OWL. The use of these languages for representations will provide a universal representation for the concepts describing the disabilities and abilities of the assisted and assisters, along with the descriptions of the organisations involved. The conceptual framework behind **OntoCarer** is based on the World Health Organisation classification of Functioning, Disability and Health (ICF) [3], adapted and extended according to the needs.

2. REVIEW OF RELATED PROJECTS

There have been a number of computer projects that have utilised mobile technologies to assist the disabled. One of the earliest projects in the UK, the Project **SARAH** for developing hand-held devices to assist disabled at home, was initiated by Barnsley Council in 2004. Over the years SARAH has matured and in 2012 it won a National Good Communications Award [4]. Typically for such projects the mobile devices are used to customize the service according to the personal profile. However, many of these projects rely on the use of specialized hardware, which does not allow the utilization of more intelligent software technologies for personalization, which are usually developed in research projects on standard equipment within universities.

One of the first projects which successfully utilized personalization of the communication services based on software profiling was **SCATEAgent** [5]. It uses a set of agents, components and utilities to provide personalized, dynamic and context-aware services to the mobile traveler in the form of plans tailored to their needs and preferences.The Semantic Web technologies added further opportunity for customization through semantic matching, like in **WebSenior** [6]. Developed in a joint project between Virginia Tech University and the Virginia Department for the Ageing in USA, it uses ontologies to automatically generate Web services, customized to retired persons'needs and government program laws and regulations concerning the disabled. **WebAgeing**, a flexible system for personalized accessing of services of different organisations for an ageing population based upon matching algorithms and semantic technology is another example of using a Semantic Web approach [7]. The Semantic Matching Framework (**SMF**) incorporated number of semantic matching techniques to allow a comfortable and highly tailored solution based on the needs of disabled people in their own homes [8].

A number of Projects are dedicated to assisting the disabled on the move, both for in-door and outdoor activities. The **Pedestrian Guiding Services** [9] uses RDF ontology for modeling contextual information about a user's indoor environment, which with interactive surfaces provides context aware pedestrian guiding services. The **Semantic Navigation System** [10] uses an OWL ontology to adapt the environment to people with disabilities based upon knowledge of a person's disability and the detection of the handicaped situations in their environment. The above projects incorporate elements of personalization and the use of semantic web technologies to provide services to the elderly and disabled. Some of them also make use of location-based services which are becoming a standard for smartphones.

The technical difference in the **OntoCarer** framework are in the use of dynamic autonomous agents for both the disabled person (Cared) and the person who cares for him (Carer). More fundamentally, the planning process in **OntoCarer** is implemented on two separate levels as a combination of active planning, based on a

social theoretical model (BDI theory) and reactive planning, based on the event-driven technology of programming. This allows us to avoid some of the difficulties, associated with the standard knowledge-based methods for planning in the case of highly structured plans and at the same time to utilize to a better extent the full potential of contemporary mobile devices in a highly efficient manner.

3. ONTOLOGICAL FOUNDATION OF ONTOCARER FRAMEWORK

The ontological foundation of the OntoCarer framework reflects on three different and largely independent developments during the last twenty-thirty years of the 20th century; the efforts of the World Health Organisation to identify, define and explain our understanding of human disability, the theoretical models of human behaviour in relation to the interaction with social organisations developed in social psychology and the models and algorithms for planning the actions of autonomous agents developed in Artificial Intelligence.

Disabled people have differing needs based upon their particular disabilities. The assistance provided to them needs to be tailored to their needs. The disabilities of the assisted needs to be matched with the abilities of the assisters, and the assistance coordinated in time and space to meet the needs of the assisted through a planning mechanism. Because of this, the ontology of the disability is the core of the **OntoCarer** framework.

3.1 World Health Organisation Classification of Functioning, Disability and Health (ICF)

3.1.1 Why ICF?

There are a number of reasons for considering using the ICF classification rather than creating a new ontology. The first reason is that as an existing standard created by the World Health Organisation it is already established as a standard in wide use for the purpose of classifying health states. As such it offers the prospect of being part of a universal standard that facilitates the adoption of this project's means of helping the disabled on a wider basis. The second reason is pragmatic; the ICF is a large and comprehensive classification of functioning and health related states, that is the result of much investment of time, money, and expertise related to medical knowledge and the understanding of disabilities, to attempt to reproduce this would be an expensive use of resources with possibly little gain if at all. The third reason relates to the development and use of ontologies within the Semantic Web. The ICF has already been translated into a Semantic Web representation, the Web Ontology Language OWL [15]. Currently it consists of approximately 1500 classes, which practically exhausts all possible cases of disability.

3.1.2 Structure of ICF

The ICF [7] is organised into two parts, each with two components. Part 1 is **Functioning and Disability** and its components are *Body functions and Structures,* and *Activities and Participation*. Part 2 is **Contextual Factors** and consists of *Environmental Factors* and *Personal Factors*. The components themselves consist of a number of domains which in turn contain categories. To each of these categories a qualifier which specifies the degree of functioning is added. The qualifier is either positive (+) or negative(-).

Each disabled person has body structures, body functions, and is able to do certain tasks through activities and participation. An example of the taxonomy of body parts is shown in Fig. 1.

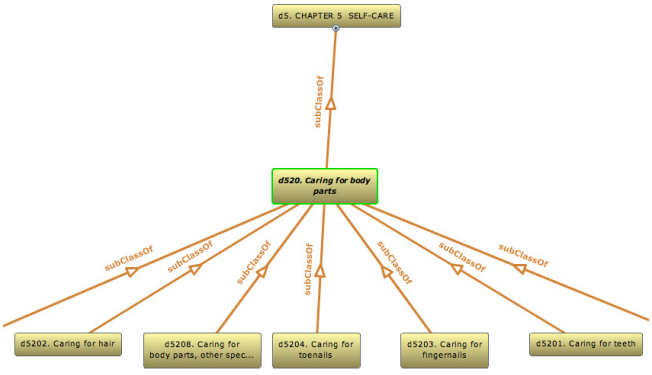

Fig. 1. ICF Body Functions (see [11])

ICF also organizes the body functions in taxonomies. Fig. 2, for example, shows the

classification of various activities under the generic term Washing oneself, which is useful to characterize the degree of ability to care for oneself, or the need for a carer for that matter.

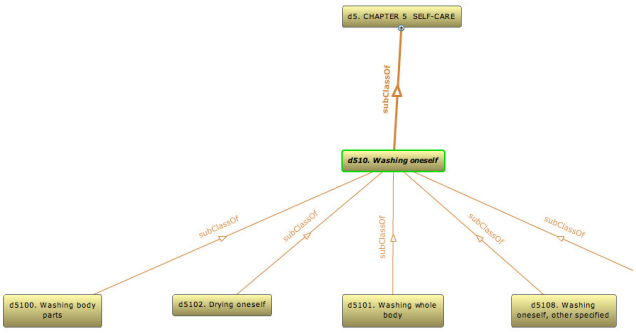

Fig. 2 Detailed Classification of Activities for Washing Oneself (see [11])

3.1.3 Using ICF ontology for modelling disabled, elderly and impaired individuals

These ICF OWL classes can be used to create instances for the particular disabled person who is being modelled, to relate the persons to different body parts and to associate various disabilities with each one of them.

3.1.4 Creating instances of the ICF OWL Body Functions classes

Each disabled person has body structures, body functions, and is able to do certain tasks (activities & participation). These ICF OWL classes can be used to create instances for the particular disabled person who is being modelled.

```
b21002instance1 rdf:type b21002
```

Where `b2002instance1` is an instance of the class `b21002` which is the ICF class **Binocular acuity of near vision**. This instance, which represents the particular body function of a person then needs to be related to the instance of the person it belongs to. In this case the person will be an instance of the Assisted class.

```
personInst1 rdf:type ocr:Assisted
```

3.1.5 Relating the Assisted agent instance to their body structures

Each of the ICF components will have its own predicate for relating a person to an instance of a body structure `ocr:BodyStructure`, a body function `ocr:BodyFunction` or ability to perform a task `ocr:Participation`. For example for the class `d410` (Sitting)

```
d410 rdfs:subClassOf
                ocr:Participation
```

the associated body structures and corresponding functions is;

```
ocr:hasBodyStructure
      rdf:subPropertyOf rdf:Property
ocr:hasBodyStructure
      rdf:domain ocr:Assisted
ocr:hasBodyStructure
      rdf:range ocr:BodyStructure
ocr:hasBodyFunction
      rdf:subPropertyOf rdf:Property
ocr:hasBodyFunction
      rdf:domain ocr:Assisted
ocr:hasBodyFunction
      rdf:range ocr:BodyFunction
ocr:hasParticipation
      rdf:subPropertyOf rdf:Property
ocr:hasParticipation
      rdf:domain ocr:Assisted
ocr:hasParticipation
      rdf:range ocr:Participation
```

3.1.6 Relating the Body Structures to their indicators of disability

In order to indicate the degree of functioning for each category in the ICF a qualifier is used. In the case of written documents the qualifier is one, two or more numbers after a point. The first qualifier for each component (b,s,d,e) describes the extent of the problems, where;

```
xxx.0 is No problems
xxx.1 is Mild
xxx.2 is Moderate
xxx.3 is Severe
xxx.4 is Complete
xxx.8 is Not specified
xxx.9 is Not applicable
```

In the case of this ontology an instance of the different categories is related to its qualifier, which is an integer and indicates the level of disability for that aspects of a person's body, functioning, or ability to perform a task.

```
ocr:hasBSQualifier
    rdf:subPropertyOf rdf:Property
ocr:hasBSQualifier
    rdf:domain ocr:BodyStructure
ocr:hasBSQualifier
    rdf:range xsd:nteger
ocr:hasBFQualifier
    rdf:subPropertyOf rdf:Property
ocr:hasBFQualifier
    rdf:domain ocr:BodyFunction
ocr:hasBFQualifier
    rdf:range xsd:integer
ocr:hasPQualifier
    rdf:subPropertyOf rdf:Property
ocr:hasPQualifier
    rdf:domain ocr:Participation
ocr:hasPQualifier
    rdf:range xsd:integer
```

The services to be provided relate to instances of the Participation classes as these are activities that the assisted person will want to do at a particular place and time.

3.1.7 Relationship of Body Structures to Body Functions

The relevance of the Body Structures is how they relate to Body Functions. An impairment in a Body Function such as the eyeball structure where there is damage to the eyeball implies an impairment in the functioning of the eyeball and so an impairment in seeing. The actual damage to the eyeball is not of interest to the application, only its impact on the functioning and so its implications for the ability to undertake desired tasks. But there may be cases where only the impairment to the body structure is known so the impact on the body function will have to be inferred. This will be represented by rules of the form;

```
If (BSinstance hasBSQualifier
        <value>) then
    BFinstance hasBFQualifier
        <value>
```

So that, for example, if a person has macular degeneration then one could infer that person could not read text or see faces. If information were only available about impairments to a person's body functions then it would be possible to infer the impact upon their ability to perform various tasks.

```
If (BFinstance hasBFQualifier)
then Pinstance hasPQualifier <value>
```

So for example if a person could not see then one could infer that person could not perform such tasks as reading.

In the case of body functions it is possible that knowing the state of the impairment would have a general use than just being able to infer for specific tasks whether the person was able to do them or not. For a body function such as impairments in sight there may be novel situations or environments for which one might infer a need for assistance without necessarily being able to specify the specific tasks involved in that situation or environment, and so for that reason it would be useful to have the state of the body function impairments recorded even where there is a complete record.

3.1.8 Extending ICF ontology with additional classes

ICF provides sufficient ground for modelling the individual disabilities. But although it is very extensive, it does not cover an important aspect of **OntoCarer**, namely the required model of the assistance service. It is a vital part of **OntoCarer**, that it needs to perform a match between the individual profile of the disabled and the assistance available from the servicing organisations.

3.1.8.1 Assister

The Assister is the assisting agent to the disabled person – the Assisted. It is the assister that will provide the services that the assisted. The assisted will have their own profile. An Assister will firstly be assigned to an Assister subclass. This will provide a profile principally of the assister's abilities but also of their core beliefs, desires and intentions to act.

```
ocr:Nurse rdf:subclassOf
      ocr:Assister
ocr:Driver rdf:subclassOf
      ocr:Assister
ocr:Driver rdf:subclassOf
      ocr:Assister
ocr:HomeHelp rdf:subclassOf
```

```
      ocr:Assister
ocr:Signer rdf:subclassOf
      ocr:Assister
ocr:Guide rdf:subclassOf
      ocr:Assister
ocr:CareAssistant rdf:subclassOf
      ocr:Assister
```

Each of these classes can be expected to have a different set of abilities according to their classification. A Nurse will be able to do such things as, wash, dress, feed, change dressings, and administer medicine to the assisted person. A HomeHelp will be able to tidy, clean rooms, wash pots, wash clothes, A signer will be able to translate speech to hand signs for the deaf, and so on. Most of these abilities will have a direct correspondence to the Participation activities on which the Assisted agent is assessed, so the ability to wash oneself will have a corresponding ability in the Assister to be able to wash someone else. Though there will be exceptions to this direct correspondence, an inability to hear speech in the Assisted will correspond to an ability to translate speech to signs in the assister. Just having the same ability in the Assister that the Assisted lacks does not always correspond to being able to assist the other person. For that reason there will be a set of separate classes from the Participation classes of the ICF. Though there will be a correspondence to the Assisted's Participation classes, as it is to those abilities or lack of them that the Assister will be making up for by providing assistance to the disabled person.

It should be noted that the Assister would only need as much knowledge about the assisted in order to perform the activities for them, as the decisions as to who does what and when will be decided by the Coordinating Agent. It is the Coordinating Agent that needs data in order to perform the matching and planning algorithms.

3.1.8.2 Integrating of the Assister into the ICF Ontology

The ICF is not primarily aimed at classifying disability but rather all health related states of persons, so it can be applied to the healthy person just as much as to the disabled. This means that the categories of the ICF could be applied to the Assister as well as the Assisted. There would be little value in knowing about the body structures and body functions of the Assisters. Whilst it is possible that an Assister would have their own disabilities it would be presumed that they would be sufficiently healthy in order to perform their functions as assisters in relation to the person they are assisting.

The aspect of the ICF that is relevant is that of the Activities & Participation categories because it is in those that the disabled person will register their difficulties in performing tasks and indicate what tasks they need assistance with. Because of these there should be a corresponding set of categories for each of the Participation classes, to indicate for a deficiency in an ability to perform a task then the assister can perform that task for the person. It will not be necessary to have a qualifier for the ability to do the task; if the assister is placed in relation to an instance of the assistive task then they are able to do the task.

```
ocr:canPerformTask
      rdf:subPropertyOf rdf:Property
ocr:canPerformTask
      rdf:domain ocr:Assister
ocr:canPerformTask
      rdf:range ocr:Tasks
```

An ontology of tasks is needed to provide a set of classes for the tasks that the Assisters can do for the assisted. It is part of the ontology of actions with the Service Organisation Agent a principle planning agent.

3.2 BDI Model of Rational Behaviour

A great number of projects in Artificial Intelligence during the last three decades of the 20th century have been dealing with different models of the rational behaviour, exemplified by the concept of a Rational Agent. In the **OntoCarer** framework the agents are the person with disability (Cared, or Assisted), the assisters who are acting to provide assistance to the disabled (Carers, or Assisters), and the coordinating persons who will aim to plan and schedule in order to connect the actions of the assisters with the desires of the assisted. Unlike the conventional agents the assisted cannot rely upon their own

actions in order to realise their desires in the world. Because of their disabilities they rely upon other agencies in order to meet their desires, and because of this there is a need for other agents to plan and act to carry this out. Due to this complication the theoretical model of rational behaviour adopted in **OntoCarer** is the so called Belief-Desire-Intention model (or BDI model), used in both computer science, cognitive and social psychology to model human behaviour and rich software agents [12].

The BDI model adopts an 'intentional stance' towards the computer agents involved [13]. They could be ascribed beliefs, desires and intentions to act, and act in a rational manner based upon these states in order to achieve these goals.

3.2.1 Agents

The agents in this case include both the human and software agents. Agents play a key role in the **OntoCarer** system both as human subjects and as software assistants to both the human carers and the disabled persons being helped.

Agents are the actors in the situation. These will principally be those that are disabled and so be Assisted, and those doing the caring and so Assister. Both Assisted and Assister can be further subclassed to describe the role they play. In the case of the Assisted the complex description of their abilities and disabilities will be given by their Body Structures, Body Functions, and the Participation component of Activities and Participation category of the ICF. These will provide a detailed classification of their disability and abilities. The ocr: prefix refers to the **OntoCarer** ontology;

```
ocr:Agent rdf:subclassOf owl:Thing
ocr:Person rdf:subclassOf ocr:Agent
ocr:Automata
      rdf:subclassOf ocr:Agent
ocr:Assisted
      rdf:subclassOf ocr:Person
ocr:Assister
    rdf:subclassOf ocr:Person
ocr:Assister
    rdf:subclassOf ocr:Automata
ocr:AssisterCoordinater
    rdf:subclassOf ocr:Automata
ocr:Person
    owl:disjointWith ocr:Automata
ocr:Assister
    owl:disjointWith ocr:Assisted
ocr:AssisterCoordinater
      owl:disjointWith ocr:Assister
```

Examples of Assister subclasses are:

```
  ocr:Nurse
      rdf:subclassOf ocr:Assister
  ocr:Driver
      rdf:subclassOf ocr:Assister
  ocr:Driver
      rdf:subclassOf ocr:Assister
  ocr:HomeHelp
      rdf:subclassOf ocr:Assister
  ocr:Signer
      rdf:subclassOf ocr:Assister
  ocr:Guide
      rdf:subclassOf ocr:Assister
  ocr:CareAssistant
      rdf:subclassOf ocr:Assister
```

3.2.2 Belief, Desire, Intention to act.

Beliefs are about states of affairs that the agent holds true. Desires are about states of affairs that the agent would want to become true, if not already true. In the case of Intention this means intention to act, or intends to bring about a desire.

```
ocr:IntentionalProperty
    rdfs:subPropertyOf rdf:Property
ocr:Believes rdfs:subPropertyOf
    ocr:IntentionalProperty
ocr:Desires rdfs:subPropertyOf
    ocr:IntentionalProperty
ocr:Intention rdfs:subPropertyOf
    ocr:IntentionalProperty
ocr:IntentionalProperty
    rdfs:domain ocr:Agent
ocr:IntentionalProperty
    rdfs:range rdf:Statement
ocr:Believes
    rdfs:domain ocr:Agent
ocr:Believes
    rdfs:range rdf:Statement
ocr:Desires
    rdfs:domain ocr:Agent
ocr:Desires
    rdfs:range rdf:Statement
ocr:Intention
    rdfs:domain   ocr:Agent
ocr:Intention
    rdfs:range rdf:Statement
```

An agent may believe, desire, and intend many statements. These may be asserted separately or it may be useful to collect them together using a collection such as a Bag. In which case one can use the predicates BelievesBag, DesiresBag, IntendsBag in order to do this.

```
ocr:IStatementBag
      rdf:subClassOf rdf:Bag
ocr:BelievesBag
      rdfs:domain ocr:Agent
ocr:BelievesBag
      rdfs:range rdf:IStatementBag
ocr:DesiresBag
      rdfs:domain ocr:Agent
ocr:DesiresBag
      rdfs:range rdf:IStatementBag
ocr:IntendsBag rdfs:domain ocr:Agent
ocr:IntendsBag rdfs:range
      rdf:IStatementBag
```

3.2.3 Choices

Choices will need to be made between desires and intentions, because of limited resources for actions. Not every desire can be realised, and certainly not all at once so choices need to be made between desires, and intentions to act.

```
ocr:isPreferedDesire
    rdf:subPropertyOf rdf:Property
ocr:isPreferedDesire
    rdf:domain rdf:Statement
ocr:isPreferedDesire
    rdf:range rdf:Statement
ocr:isPreferedDesire
    rdf:type owl:isTransitive
ocr:isPreferedIntention
    rdf:subPropertyOf rdf:Property
ocr:isPreferedIntention
    rdf:domain rdf:Statement
ocr:isPreferedIntention
    rdf:range rdf:Statement
ocr:isPreferedIntention
    rdf:type owl:isTransitive
```

The predicates `isPreferedDesire` and `isPreferedIntention`, will allow the expression of ordering of preferences between two statements of desire or intention. These predicates are transitive, so that a series of desires or intentions can be ordered. Beliefs are not ordered in terms of preferences as they are intended to represent beliefs about states of the world that exist regardless of the person's preferences.

```
ocr:hasUtility
    rdf:subPropertyOf rdf:Property
ocr:hasUtility
    rdf:domain rdf:Statement
ocr:hasUtility rdf:range Integer
```

The predicate hasUtility is used in order to give some statements of the value of a state of affairs. This may be used in order to choose between desires, or actions, but also to represent the utility of particular states of affairs in the world. The property `hasUtility` may be subclassed to create other particular measures of value. A single continuum scale of value may not always be appropriate in the area of health and disability, so there may be a need to create distinct categories of value measurement, such as `isLifeSaving`; for example where the state of affairs is crucial for saving the life of the person and so would override other such measures of utility.

The BDI model of rational behaviour is incorporated in the upper ontology for planning in **OntoCarer**, used "offline" to coordinate the procedures for finding service providers, allocating carers and assigning tasks for providing assistance.

3.3 Agent Planning Ontology

The planning process in **OntoCarer** is triggered by the deliberate intention of the agent, usually the assisted person choosing a goal, from the range of options (desires) available. Though they may also be triggered by events, which in conjunction with the agent's profile and the agent context will generate an intention and so a plan. In addition the planning process can also be triggered centrally by the organisation in scheduling the activities of its assisting agents. In turn these assisting agents may also trigger a planning process through their own status' updates, which may cause new plans to be initiated or current plans to be re-planned as a result of events causing changes in circumstances.

This process is part of a framework of organisational planning. The framework includes the Service Organisation Agent (Coordinator) and the Assisting Agents (Carers). Agents are not always tied to just one organisation. It is possible that agents are registered with different

organisations, not just as clients (assisted agents) but also as assisters as well. For some, assisters may work with other organisations and their personnel and client base. These include such organisations as the emergency services – firemen, police, and health professionals, but also other visiting services, such as plumbers, electricians, postmen, social workers, etc.

To facilitate the planning using the semantic web data about the organisations and the agents involved, one needs a planning ontology in RDF and OWL to work with this semantic data. In addition a common planning ontology is needed to allow the agents from different organisations to interact with each other, and also to link data from more than one source. Several ontologies for planning have been created in various Semantic Web projects, which address some of these issues – see, for example, [14] and [15]. Due to the fact that **OntoCarer** framework adopts two-level planning, where the upper ontology is used only for offline planning, this ontology is more abstract and serves the need for offline planning only. It allows modelling the few basic required classes like **Tasks**, **Plans**, **Actions**, **Events**, **Appointments** and **Locations** and it is sufficient to implement the offline planning using simple semantic match. Of course, this limits the planning capability to simple planning tasks, which can be solved using single action or sequence of actions without conditioning, looping etc. However, since this relatively weak planner is complemented by an event-driven reactive planner, capable of correcting the plans using additional heuristics, it is not a real limitation.

4. ONTOCARER AS AN AGENT-BASED FRAMEWORK FOR ASSISTING DISABLED

4.1 Working Scenarios

OntoCarer is an assistive agent framework that aims to aid the disabled person in their interactions with the organisations in society that they deal with on a daily basis. Three main scenarios have been considered:

- **Scenario 1 (Home Assistance).** The disabled person lives in his own home, the caring organisation is responsible for assisting him in his home environment in all his needs for food, dressing, etc. This is a typical case in caring for elderly people, people with dementia, Alzheimer, Korsakoff Syndrome, etc.

- **Scenario 2 (External Assistance).** The disabled person lives in his own home and is fully capable of taking care of himself, but needs to be assisted for visiting hospitals, local authorities, public organisations, etc. This is a typical situation in caring for partially sighted or immobile people

- **Scenario 3 (Autonomy).** This is the scenario where the person is capable of taking care of himself and transporting himself on his own, typically in a wheelchair, and the assistance is embedded directly in the environment.

The use-case diagram which covers the above three scenarios is shown in Fig. 3.

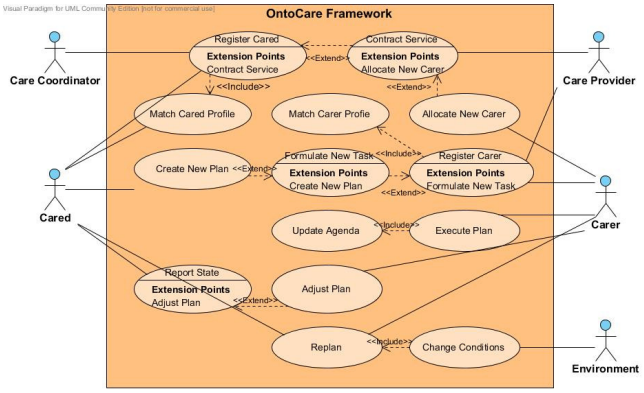

Fig. 3: Major Use-Cases of the OntoCarer Framework

4.2 The Framework in Operation

The OntoCarer framework consists of a number of different levels. The main physical constituents are:

Human Actors – these will be people interacting with the organisation as the assisted persons and the assisted persons (Cared, Carers, Coordinators).

Public Organisations – this will be the particular social organisation that the actors interact with. Organisations such as a hospital, university,

school, store, cinema, restaurant, police, fire service, etc.

Communication Infrastructure – it includes the necessary devices, communication infrastructure and servicing hosts needed for operating the framework (smartphones, PDAs, Internet servers, etc.)

Software Agents – these will include:

- *Organisation Agents* – this will act as the coordinator and main planner for the assisting and assisted agents.
- *Assisted Agents* – these are the software agents hosted on the mobile phones of the assisted persons, which will undertake planning and acting on their behalf.
- *Assisting Agents* – these are software agents hosted on the mobile phones of the assisting persons, which will undertake planning and acting on their behalf. The Assisting Agents will be mainly under the direction of the Organisation Agent they are acting for.

The technical infrastructure of OntoCarer is presented in Fig. 4.

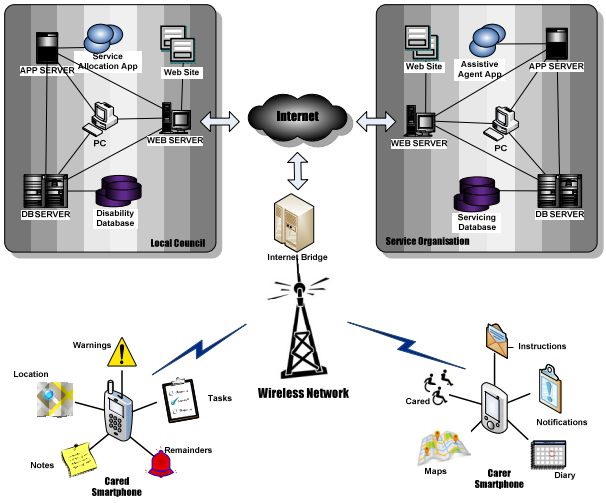

Fig. 4: Technical Infrastructure for Assisting Disabled using Mobile Devices

4.3 Types of Assistance provided

The type of assistance provided to the disabled depends on the individual profile (the Cared) and the type of assistance contracted by the servicing organisation (i.e. the Coordinator). It is limited by the capabilities of their Carers and the setup of their smartphones. The assistance assigned to the individual assistants (Carers) depends on the tasks allocated to them by their host organisations and the setup of their Personal Digital Assistants (PDA). There are several types of assistance potentially involved in the **OntoCarer** framework:

Alerts: Alerts are spontaneous matching and connecting between the Assisted and Assisters based upon matching their profiles in the current environment. For example, in situations where a deaf person goes into Student Services in a university building and they normally need a signer; if there is one in Student Services they will find a match and alert the Assister that there is a need for their signing abilities and arrange the assistance.

Timetabled Meetings: Timetabled meetings are those meetings such as regular classes at a school, college or university. They comprise regular participants meeting in particular rooms for particular time slots. Not all the participants are likely to be disabled. The needs of those disabled participants are matched with the abilities of the Assisters. This can mean informing the lecturer in advance that, for example if the student is deaf and can lip read that they must face the student when talking. It may mean that assistance is arranged in the form of a note taker for the lecture. It may mean technical aids are also arranged. All these will be performed through the **OntoCarer** system for the organisation once the disabled student has been timetabled for that class.

Meetings/Bookings: Meetings are where two or more individuals arrange a mutually satisfactory timeslot and meeting place, such as an arranged meeting between a student and lecturer. This may also, in the case of a disabled person, mean the arranging of additional support in the form of instructions, assisting personnel, technical equipment and support, and transport. Bookings mean ensuring a place is arranged at some public facilities where places are limited such as at a restaurant, cinema, theatre etc and then arranging the necessary support for the disabled individual well in advance.

Visits: This is where a product or service is delivered to a person's home, usually on a rota basis. For example those goods and services provided by social services, such as home helps or 'meals on wheels'.

Navigation: Plans for providing building navigation, such as providing a wheel chair friendly routes through a building, or audio guidance for routes for the blind.

Transport: In addition, personalised plans could be provided for the disabled when using transport. This could be in arranging transport, advising which services to get on, checking for disabled aids on the transport, informing transport staff of particular special needs in advance or as they occur.

5. IMPLEMENTATION

OntoCarer is a technically complex framework, which covers several different working scenarios and requires combining of a number of different models and algorithms for semantic matching, deductive planning and event-based re-planning. The software architecture of the pilot implementation of the framework under way is shown in Fig. 5.

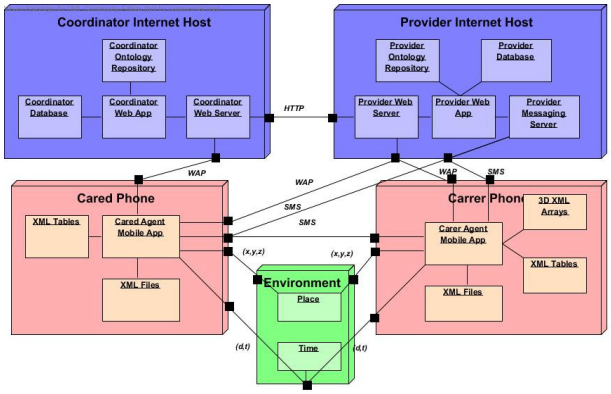

Fig. 5. Software Architecture of OntoCarer pilot

The software implementation integrates four separate applications; two Web applications (the Coordinator and the Service Provider applications) and two Mobile Internet applications (the Cared and the Carer applications). They integrate several different technologies - Internet server/side and client/side programming; synchronous and asynchronous messaging; XML data processing; Semantic Web data storage, querying and inference. All applications are built using Java as a programming language.

5.1 Ontology Repositories

Two semantic repositories are needed to host the ICF ontology of disability as extended for the purpose of the project. On the side of the Service Provider currently it is stored in Sesame RDF/OWL repository [16], while on the side of the Coordinator another identical Sesame repository is planned to be used at a later stage. The second ontology used by **OntoCarer**, the ontology of Agent Planning, is currently hosted in the same repository as the Disability Ontology on the site of Service Provider. Since the Coordinator is performing relatively simple tasks it is considered unnecessary to have another ontology on its side.

5.2 Offline Planner

The offline planner currently under development incorporates the Jena framework for Semantic Web applications [17]. It is based on the BDI model and uses pattern matching techniques to derive the tasks for assisting agents and the initial plans for implementing them. At a later stage it is planned to integrate it with the online planner to allow detailing of the plans through mapping the offline actions and online events as they occur.

5.3 Online Planner

Number of external events can cause changes in the planned activities and may require rescheduling. An essential part of the framework, the online planner is currently developed as an entirely event-driven, reacting to external events – asynchronous messages, synchronous calls and system timers. When completed, it will be fully integrated with the offline planner to provide the necessary support for refining of the plans and possible re-scheduling.

5.4 Event Notifier

As a prototype solution for event notification between the Service Provider, the Carer and the Cared a mechanism for asynchronous communication through asynchronous messaging has been prototyped. It is based on the PUSH technology for mobile devices and has been implemented in Java on Android platform. Fig. 6 provides a screenshot of the prototype implementation of this mechanism for cheap smartphones with minimal technical requirements.

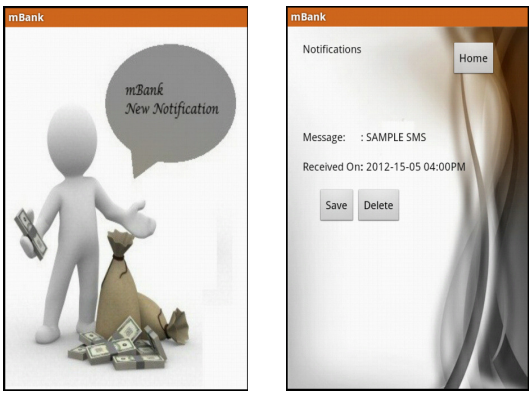

Fig. 6. PUSH Event notification

Unlike the ordinary SMS messages delivered to the mobile devises using standard asynchronous protocols, the messages delivered using PUSH technology are captured by dedicated applications and can be integrated into the framework, remaining under the control of the underlying logic of the framework. The same mechanism can be used for exchanging messages between each two of the participants – the Carer, the Cared and the Service Provider.

5.5 Diary Maintenance

The asynchronous messages delivered to the mobile devices can carry information which have an immediate external presentation.– The notifications can be shown on the screen as a warning text, the alerts can be played instantly using the build-in speakers and the video clips can be played online as broadcasted. However, some of the messages can carry information which does not need to be presented externally immediately. Instead, it can be stored internally in a suitable repository for a later use. For example the appointments can be entered directly into the calendar whereas the address information can be entered into the address book, etc. In **OntoCarer** number of XML formatted messages are processed programmatically and using suitable API are integrated with the smartphone repositories.

5.6 Location Control

One of the exceptionally useful features of the mobile devices nowadays is their ability to utilize location-based services for the purpose of 2D and 3D locating of the person caring them. Although initially this opportunity was available only through the satellite networks, now there are at least three alternative and complementary methods for locating; using GPS, using WiFi hotspots and based on standard 3G triangulation. In OntoCarer framework this is used for both locating and for navigation help in the case of Scenario 3 (Autonomy).

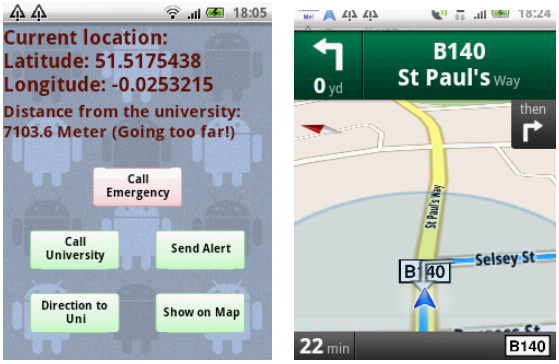

Fig. 7. Location Identification and Navigation

The Android platform is selected as a smartphone platform of choice for the **OntoCarer** framework and incorporates a number of useful APIs, which allow direct utilization of the rich location-based services and applications from Google, such as GoogleMap. Fig. 7 shows the prototype implementation of one such mobile application for the Android smartphones which has been integrated with two of these APIs – for map visualization and navigation direction. It can be used by both the carers (in Scenario 1 and 2) and by the cared (in Scenario 3). Of course, some of them may be unsuitable for particular types of disability (e.g colour blind people), but in any case they are useful for most of the carers.

6. CONCLUSION AND FUTURE DEVELOPMENT

The next generation Web, the Semantic Web, coupled with the rapid advancement in the Mobile Internet, creates an exciting opportunity for utilizing the Internet to assist disadvantaged groups and to integrate them in the society. **OntoCarer** framework, presented here, combines the standard Internet, Semantic Web and XML data processing technologies in a heterogeneous framework of stationed and mobile software agents. Currently in its pilot implementation, it separates the agent functionalities, making them largely autonomous, and integrates them using synchronous and asynchronous messaging. While the main modelling and client development has been already prototyped, the focus of the current work is in the implementation of the planning engines.

REFERENCES

1. The World Wide Web Consortium. Semantic Web (http://www.w3.org/standards/semanticweb/; last accessed on 28 Dec 2012)
2. Ouazzane, K., Li, J., and Kazemian, H. An Intelligent Keyboard Framework for Improving Disabled People Computer Accessibility, In: Engineering Applications of Neural Networks, Volume 363, 2011, pp 382-391; ISBN: 9783642239564
3. The World Health Organisation. International Classification of Functioning, Disability and Health (ICF), WHO Revised Edition October 2001. (http://www.who.int/classifications/icf/en/; last accessed on 28 Dec 2012)
4. Barnsley Community Council. SARAH Project: Mobile Technologies in Social Care. (http://www.barnsley.gov.uk/Mobile-technology-award-210711; last accessed on 28 Dec 2012)
5. Buthpitiya, S., Madamanchi, D., Kommaraju, S. and Griss, M. Mobile Context-Aware Personal Messaging Assistant, in: Klügl, F., Bazzan, A., Ossowski, S. (Eds.), Applications of Agent Technology in Traffic and Transportation, Birkhäuser (2005); ISBN: 3764372583
6. Medjahed, B. and Bouguettaya, A. Customized Delivery of E-Government Web Services, IEEE Intelligent Systems, Volume 20, Number 6, pp. 77-84, November/December 2005.
7. Moise, M., Popa, V., Zingale, M., Constantinescu, L., and Pirjan, A. WebAgeing - A Flexible System for Personalized Accessing of Services for Ageing Population, Int. J. of Computers, Communications & Control, Vol. III (2008), pp. 408-412.
8. Kadouche, R., Mokhtari, M., Giroux, S., and Abdulrazak, B. Personalization in Smart Homes for Disabled People, Proc. Second International Conference on Future Generation Communication and Networking (2008), vol. 2, pp.411-415; ISBN: 9780769534312
9. Bikakis, A., Patkos, T., Antoniou, G., Plexousakis, D., and Papadopouli, A. Semantics-based Framework for Context-Aware Services: Lessons Learned and Challenges, In: Proceedings of 4th International Conference on Ubiquitous Intelligence and Computing, Springer (2007), pp. 839-848; ISBN: 3540735488
10. Tsetsos, V., Anagnostopoulos, C., Kikiras, P., and Hasiotis, P. ; Hadjiefthymiades, S. A human-centered semantic navigation system for indoor environments. In: Proceedings of the International Conference on Pervasive Services, 2005. ICPS '05, pp. 188–197; ISBN: 0780390326
11. National Center for Biomedical Ontology. International Classification of Functioning, Disability and Health (http://bioportal.bioontology.org/ontologies/47404; last accessed on 28 Dec 2012)
12. Bratman, M. Intentions, Plans, and Practical Reason. Cambridge, MA: Harvard University Press (1987); ISBN: 0674458184
13. Dennett, D. The Intentional Stance, Cambridge, MA: The MIT Press (1996); ISBN: 026204093X
14. Gil, Y. and Blythe, J. PLANET: A Sharable and Reusable Ontology for Representing Plans. In: Y. Gil and K. L. Myers, editors, Proceedings of the AAAI Workshop on Representational Issues for Real-World Planning Systems (2000), pp. 28-33.
15. Rajpathak, D. and Motta, E. An Ontological Formalization of the Planning Task. In: Proc. 3-d Int. Conf. on Formal Ontology in Information Systems (2004).
16. SourceForge Open Software Repository. Sesame: Java RDF Framework and Database System (http://sourceforge.net/projects/sesame/; last accessed on 28 Dec 2012)
17. The Apache Software Foundation. Apache Jena (http://jena.apache.org/; last accessed on 28 Dec 2012)