Context-Awareness to Increase Inclusion of People with DS in Society

Dean Kramer, Juan Carlos Augusto, Tony Clark
Research Group on Development of Intelligent Environments
Dep. of Computer Science, Middlesex University, London, UK
email: {d.kramer, j.augusto, t.n.clark}@mdx.ac.uk

Abstract

Assistive technologies have the potential to enhance the quality of life of citizens. Most especially of interest are those cases where a person is affected by some physical or cognitive impairment. Whilst most work in this area have been focused on assisting people indoors to support their independence, the POSEIDON project is focused on empowering citizens with Down's Syndrome to support their independence outdoors. This paper explains the POSEIDON module which we are in the process of developing to make the system context-aware, reactive and adaptive.

Introduction

The POSEIDON[1] project, focuses on the task of bringing some of the latest technological advances to increase inclusion in our society of a specific group of citizens: people with Downs Syndrome (DS). The overall ethos of the project is to focus on the best abilities of people with DS and to help them to live their lives in a more fulfilling way by facilitating access to education, work and social events. The system is currently under development and it can be largely identified with what we call Intelligent Environments (Augusto et al. 2013) or more specifically Ambient Assisted Living (AAL) systems (Augusto et al. 2012). Although a substantial difference is that whilst AAL systems focus more on supporting life indoors, through the realisation of Smart Homes, for example, POSEIDON puts more emphasis on life outside the home. People with Down's syndrome often face the challenge of integration in our society and our project aims at supporting them to be more positively immersed in society. An essential step to facilitate their integration is to help them reach, as independently as possible, the places where they can learn, develop a profession, and socialise. Figure 1 shows an illustration of the type of scenarios we consider in our project. Imagine a person with Down's Syndrome leaving home in the morning to go to work, there are challenges on navigating through a busy city, there may be unexpected situations which further complicate the journey, at all times the person has to feel secure and also their family wants to feel reassured that everything went well.

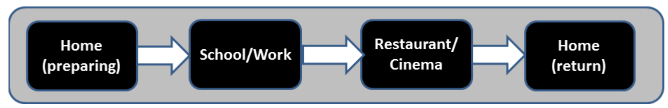

Figure 1: Main scenarios supported by POSEIDON.

All these systems rely heavily on a module providing context-awareness and this is the focus of this article. We explain the current plan to develop context-aware services for POSEIDON and how this relates to other elements of the system. Context-awareness has been described *to be intelligent applications that can monitor the users context and, in case of changes in this context, consequently adapt their behaviour in order to satisfy the users current needs or anticipate the users intentions* (Daniele 2006).

Related Work

The POSEIDON project crosscuts many aspects in context-awareness and AAL. We therefore present some of the more relevant related work, starting with context modelling.

Context Modelling Approaches

In order for a system to be context-aware it must deal with a number of important issues, some of them are internal (system own awareness of current internal status and capabilities) and some are external and relates to the real world (for example, place, time, user preferences and needs).

To achieve these, a context-aware system needs to model the context information. Context models and languages have predominantly been either *key-value models, markup scheme models, graphical models, object-oriented models, logic based models,* or *ontology based models* (Strang and Linnhoff-Popien 2004).

Key-value models are the simplest form of context models, involving a name and context value pairs, which have been used directly (without the use of AI techniques applied) in context-aware systems and frameworks (Kramer et al. 2011). Markup models are hierarchical data structures which consist of markup tags, attributes, and content, with an example being the Comprehensive Structured Context

[1]POSEIDON stands for PersOnalized Smart Environments to increase Inclusion of people with DOwn's syNdrome

Profiles (CSCP) (Held, Buchholz, and Schill 2002). CSCP is based in RDF, and expresses context information using service profiles, describing context information relevant to different sessions. Graphical models can use different graphical notations including UML, Object-Role Modelling (ORM), and other domain specific modelling languages. ORM based context models include the Context Modelling Language (CML) (Henricksen and Indulska 2006). Included in CML are constructs for describing information types, type classifications, metadata for quality, and type dependencies. UML based models include ContextUML (Sheng and Benatallah 2005), and the MUSIC context model (Reichle et al. 2008). These models can also be viewed as object-oriented models, as they use different object-orientation concepts including inheritance, and encapsulation. Other domain specific languages (DSL) for context modelling include PervML (Muñoz, Pelechano, and Fons 2004; Serral et al. 2008) and MLContext (Hoyos, García-Molina, and Botía 2013). These DSLs take a given context model and generate code for use in the final system, in the case of PervML a set of Java classes and OWL specifications, and MLContext, Java classes for the Java Context-Aware Framework (JCAF).

Many different logic based modelling languages also exist, including the Calculus of Context-Aware Ambients (CCA) (Siewe, Zedan, and Cau 2011), CONAWA (Kjæ rgaard and Bunde-pedersen 2006), SCAFOS (Katsiri, Seranno, and Serrat 2010), and an algebra of contextualised ontologies (Cafezeiro, Viterbo, and Rademaker, Alexandre Haeusler, Edward Hermann Endler 2008). The CCA proposes a logical language for expressing context properties using context expressions. Context expressions can be composed to form complex expressions and formulas using first order operators. The CONAWA calculus was inspired by the ambient calculus (Cardelli 1999), and extends it in a number of ways. First, it extends the syntax with constructs and capabilities allowing ambients navigation in complex context information. Second, it extends the semantics of different ambient capabilities to handle contexts, and context trees. The algebra of contextualised ontologies aims for a uniform representation of entities & context, and places an emphasis on the relationships between them. Different modular constructs are proposed to be applied to contextualised entities to combine entities and contexts coherently. These constructs are broken down into three classes including: Entity Integration, Context Integration, and Combined Integration.

Ontology models can be used for describing taxonomies of concepts, including relationships. Ontology based context models beneficial in a number of ways including knowledge sharing, logic inference, and knowledge reuse (Wang et al. 2004). User modelling ontologies include the General User Model Ontology (GUMO) (Heckmann et al. 2005), and User Navigation Ontology (UNO) (Kikiras, Tsetsos, and Hadjiefthymiades 2006). GUMO provides different dimensions of the user to be modelled, including characteristics, emotional state, personality, and physiological state. UNO on the other hand extends GUMO with concepts including mental ability, mobility ability, sensory ability, spatial ability, demographics, and preferences. Ontologies for ambient intelligence include GAIA (Ranganathan et al. 2003), BOnSAI (Stavropoulos et al. 2012), CoDAMoS (Preuveneers and Berbers 2005), and OntoAMI (Santofimia et al. 2009). GAIA includes concepts including physical (stock quotes, sport scores), personal (health, mood, schedule, activity), social (group activity, social relationships), application (email, websites visited), and system (network traffic, status of printers). The CoDAMoS ontology on the other hand considers the user, platform, service and environment. This ontology is also directly extended in BOnSAI to include context-related, service-related, hardware related, and functionality-related concepts.

Ontologies for ambient assisted living systems supporting elderly people have been proposed (Zografistou 2012). This collection of ontologies included a core ontology, a person profile ontology, health ontology, and time ontology. The core ontology is used for general purpose concepts including location, environment, simple events, person, activity etc. The person ontology added the ability to model the person's status, habits, impairments, contact profile, and preferences. The health ontology included the concepts disease, symptoms, treatments, and restrictions. Other health related ontologies includes OntoHealth, an ontology for pervasive hospitals (Librelotto et al. 2010). This ontology included concepts for patient, bed, tray, nurse, medical history, dosage, physician, exam, medicine, and treatment. Other general purpose context model ontologies have been proposed including SOUPA (Chen et al. 2004). SOUPA was built using a collection of reference ontology vocabularies including FOAF, DAML-Time and the Entry Sub-ontology of Time, OpenCyc, Regional Connection Calculus (RCC), COBRA-ONT, MoGATU BDI ontology, and the Rei policy ontology. This ontology is broken down into two distinct ontologies; SOUPA Core for generic pervasive applications, and SOUPA Extension for specific pervasive domains.

Reasoning & Learning

Artificial Intelligence (Russell and Norvig 2003) has been considered as a technological area which can make a substantial difference in the quality of services offered by AAL systems through *ambient intelligence* (Augusto 2007; Ramos, Augusto, and Shapiro 2008). In the last decade several approaches have been explored, mostly revisions of preexisting classical AI techniques: classical rule-based systems or variations of these to add uncertainty in various ways, probabilistic approaches like Bayesian networks or hidden Markov models, and Neural Networks (Sadri 2011).

As for any intelligent system, learning provides substantial support to reasoning and Ambient Intelligence is no exception (Aztiria, Izaguirre, and Augusto 2010). There has been some work in terms of specialising the systems have been proposed, for example LFPUBS extracts the frequent behaviours of a user in a smart home by analysing the sensors triggered and the context in which these are triggered (Aztiria et al. 2013).

One way of representing knowledge and reasoning with it have been through the use of Event-Condition-Actions (ECA) rules (Augusto 2007; Sadri 2011). The result of an LFPUBS analysis of a dataset is a list of ECA rules which reflect the frequent behaviours of a user. These two systems for reasoning and learning can be connected and this is part of our work in progress. An important advantage of using rule-based systems is that they are more amenable to forma verification of correctness (Augusto 2005; Augusto and Hornos 2013). This is an important feature in any system, especially in AAL systems, on which human beings may depend upon. This capability is missing in the options listed in the previous section and has been largely neglected so far.

General System Architecture

System Components

The system to handle the ambient intelligence and context-aware is split across multiple components

- **Mobile Devices**: These devices are used by the person with Down's syndrome to assist them when they are away from home. They will contain limit amounts of context-awareness and reasoning to ensure in conditions of no internet connection, they work in a limited way.
- **Centralised Services**: These services contain the majority of the learning and reasoning systems. They are connected to by each of the mobile devices to provide them make with context information to drive adaptation of the device applications. These services also act as agents to collects and pools weather, navigation, and personal data together to assist its reasoning, and learning.

Context Acquisition Self-Awareness

While the system can be adapted to suit a given context, so too can the context acquisition system itself. Context acquisition frameworks and systems historically have been static entities that only adapt the end application, not themselves (Fonteles et al. 2013). By making the context acquisition system self-aware and adaptive, the system can better optimise itself in a changing environment and condition. As an example, let us consider location-aware services. Depending on the current battery status, it can be beneficial to alter the frequency in which the device attempts to locate itself. This can allow the system to preserve power, when the battery is running low.

Other uses of self-adaptive context acquisition systems include switching between sensors in different settings. For example, while GPS sensors can provide location information outside, they are of little use inside. Instead, for indoor location tracking, we can use Wi-Fi positioning (di Flora and Hermersdorf 2008). Therefore mainly only one approach needs to be used at a given time, and should change automatically. Although in transition areas (very close to the home or work) more than one may be available and that is also useful context information.

In Figure 2, we illustrate the system architecture. It is only a partial view of the POSEIDON system and it is mainly focused on the modules which we are discussing in this paper: the interplay between Context-awareness, Reasoning and Learning.

Figure 3 provides a more general overview of the technologies which make up the POSEIDON system. For example, cloud services are used to retrieve different type of information (e.g. GIS) which inform the context awareness module. Although this is not the focus in this article we believe this contributes to the understanding of the topics of this article in the broader system.

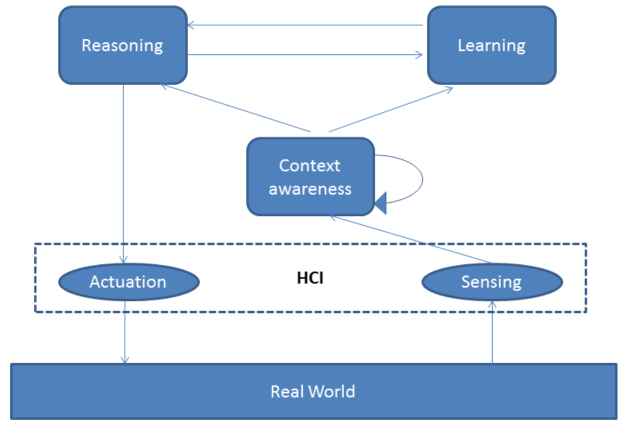

Figure 2: Context-aware focused sub-system architecture.

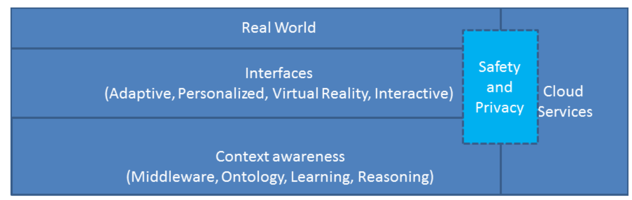

Figure 3: Overall system architecture.

Validation Scenarios

Our project has spent significant resources interviewing primary users (i.e., people with Down's Syndrome) and secondary users (i.e., those who regularly help support them, typically a relative or formal carer). This analysis included more than 300 online questionnaires answered in Europe, more than 20 interviews, workshops with families (including a person with Down's Syndrome in each). This gathering of data allowed us to shape the requirements of the project. This included to characterise our assistance which we classify in reactive and proactive. Below we offer examples of these and we provide a generic comment on how the different modules of the architecture presented in 2 are exercised.

Reactive Scenario

As a reactive scenario, we consider a user travelling to work.

1. **World**: Currently at a bus station within a city at noon.
2. **Sensor**: Coordinates the device and collects the current time.
3. **CA**: Associates coordinates with bus station, checks time with work hours, and deduces person is almost late for work.
4. **Reasoning box**:

(a) User lost the last bus to get to work on time.
(b) Therefore, user is going to be late.
(c) Calculates alternative
(d) Notifies user to agree one of the presented options e.g. to take a taxi.

5. **Learning**: Stores that Leaving home at a specific time led to miss bus
6. **Reasoning box**: If negative consequence exists, communicate to carer.
7. **Actuation**: Sends message to carer.
8. **Real world**: Message is delivered

Proactive Scenario

As a proactive scenario, we consider a user walking to meet a friend in the city.

1. **Sensor**: Finds the user has an appointment with a friend in his calendar.
2. **CA**: Checks the weather conditions for the area associated with the appointment.
3. **Reasoning box**:
   (a) Finds the weather at the listed location is bad e.g. raining.
   (b) Suggests that the user should wear appropriate clothing, and reminds the user to be careful with the device outside to avoid damaging it.
   (c) Prompts the user if they still wish to walk, or if they would rather take public transport, and awaits response.
4. **Learning**: Stores that when the weather is bad, the user prefers to either walk or take public transport.

We understand these scenarios provide only a small glimpse on how POSEIDON will interact and react with the different contexts. This is still work in progress and we are defining in increasing level of detail the system interaction with the primary and secondary users in collaboration with our Down's Syndrome Associations.

Discussion

AAL systems traditionally focused on in house support for independent living. Our project POSEIDON is focused mainly on the outdoors support for people with Down's Syndrome to be more integrated in their communities through work, education and socialisation.

We have described our project POSEIDON and gave some details on the different technical components and their inter-relation. We presented two scenarios which require proactive and reactive behaviours from the system and described how these scenarios will exercise different components.

The project has started recently and a series of iterative increments are planned to validate increasingly complex services. We expect the intelligence of the system to be of practical help to our users. At this stage we are considering rule-based notations as likely candidates given that they provide reasonably expressive means for knowledge representation, they can be tied to the options selected through the interface and can be also verified for correctness.

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