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Towards Situation Driven Mobile Tutoring System for Learning Languages and Communication Skills: Application to Users with Specific Needs

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ABSTRACT

Current advances in portable devices and wireless technologies had drastically impacted mobile and pervasive computing development and use. Nowadays, mobile and or pervasive applications, are increasingly being used to support users' everyday activities. These apps either distributed or standalone are characterized by the variability of the surrounding environment, the constrained devices' characteristics and specifically the context they are used in. Building mobile apps that support the user while spanning different contexts and experiencing different situations, needs therefore to use relevant mechanisms dealing with mobility, context awareness, and adaptability. In this paper, we propose a new adaptable and re-configurable mobile Intelligent Tutoring System (ITS) architecture for acquiring relevant communication skills in different situations taking into account persons with specific needs. Adaptability and context awareness are addressed by combining and porting OSGi features and Semantic Web technologies on top of an Android platform.

Keywords

People with specific needs, Mobile ITSs, Semantic Web Technology, OSGi middleware, Dynamic adaptability

Introduction

Advances in mobile devices and related technologies are increasingly allowing the emergence of new applications. However, the very changing characteristics of mobile devices and their surrounding environment may lead to undesired and unpredictable situations preventing the user to use required services at a given time. Moreover, even though those characteristics may still unchanged, the user's mobility or her disabilities implies new or different situations and activities requiring new supporting services or adaptation of existing ones (Conde et al., 2009). For instance, during a common day life, the user may experience activities within which she is required to communicate and use domain specific expressions. She may be required to speak in a different language than her native or also experience strong communication problems and can't be aware of her surrounding environment (Massaro, 2004).

Acquiring new communication skills in formal or informal way by making use of technology have been addressed by researches since a long time (Shute & Zapata-Rivera, 2012). Indeed many researches in e-learning had established pedagogical methods, standards, tools and platforms in order to support learners and to provide them with learning as well as assessment activities for learning languages or social skills (Grawemeyer, Johnson, Brosnan, Ashwin, & Benton, 2012).

Some have addressed communication aspects intended to people with disabilities such as autism or impaired hearing (Jaballah & Jemni, 2013; El-Sattar, 2008; Venkatesh, Greenhill, Phung, Adams, & Duong, 2012). While others have focused on reviews to establish the effectiveness of the use of computer to educating people with disabilities (Askari et al., 2015; Sansosti, Doolan, Remaklus, Krupko, & Sansosti, 2014; Sanchez, Bartel, Brown, & DeRosier, 2014).

New challenging learning scenarios taking into account the learner's context has been also provided in e-learning settings and many attempts are being taken in the context of mobile learning (Boticario & Santos, 2007; Fragale, 2014; Judy & Krishnakumar, 2012).

Moreover, intelligent adaptability aspects have been already successfully integrated in ITSs which are considered as a particular category of one-on-one e-learning systems. For instance, ITSs main purposes are to simulate the real teacher's behavior and adapt learning processes and content to one's learners specific needs (Murray, 1999). Unfortunately, this kind of adaptation is always defined at design time. Additionally, even though there are some works that have tackled mobility issues for ITSs (Badaracco, Liu, & Martinez, 2013), those ITSs' architectures have not addressed modularity or dynamic adaptability to take account new user's mobile devices, physical contexts and new emerging needs especially those related to the appropriate use of a language within a specific context (Mahmoud, Belal & Helmy, 2014).

In order to overcome those drawbacks, relevant mechanisms dealing with context awareness, mobility, adaptability as well as adaptation of mobile apps are strongly required.

This paper, aims to provide an adaptable and re-configurable mobile ITS for supporting learning approaches addressed specifically to learning languages and communication skills for people with disabilities. In this ITS, mobility, context awareness and adaptability are addressed by combining and porting OSGi features and Semantic Web technologies on top of an Android platform.

The main contributions of the present paper are (1) the learning approach adopted to take advantages of the user's context (mobility and specific needs) and the ITS provided (2) the flexible ITS's architecture and its modular, lightweight and fine grained components (3) the mechanism provided for handling the user's context and the model on which it is based and (4) the semantic and ontological descriptions of the user's mobile context, the learning approach as well as the components and services provided by the ITS. These descriptions make it possible to run reasoning and inference rules on them. They enable, therefore, more efficient mobility and context awareness issues.

The rest of the paper is structured as follows:

In the "Research methodology" section, the research methodology adopted is presented.

In the "Learning/ supporting approach and the ITS's specific behavior" section, the provided learning approach and the ITS's functionalities are described.

The section "Underlying technologies for building the ITS app" focuses on the set of technologies on which the ITS will be based. Context awareness features for the Android mobile platform are described. This section ends by explaining the mechanism provided to tackle adaptability and context awareness.

In the "Semantic descriptions needed by the ITS app" section, semantics, ontological descriptions and reasoning applied to the OSGi middleware and the android platform are presented.

In the "Implementation and validation" section, a concrete architecture of the mobile ITS app and its components is presented and the manner it is used to allow adaptability and mobile context awareness is explained. As a proof of concept, in "The mobile ITS app context aware architecture" section, an implementation and a validation based on scenarios that illustrate the provided solution is presented.

Finally, in the "Conclusion and future work" section, some conclusions are drawn and future works are outlined.

Research methodology

Firstly, the main research question addressed by the present paper deals with the kind of ITS and adaptation approach to provide in order to support relevantly users and their changing needs as well as a large diversity of users with different disabilities.

To answer this question a list of criteria, characteristics and requirements have to be established. Different sources have been used to establish that list namely literature review about users' specific needs and existing ITSs provided to support those users for acquiring skills as well as scenarios' elaboration and analysis to highlight users' requirements.

A proposed solution and a corresponding prototype have been provided.

Evaluation of the proposal have been realized by simulating presented scenarios and comparing the required system's behavior to the effective behavior of the system. The results are analyzed and conclusions are drawn.

Literature review

Learning systems for learning/supporting persons with disabilities

During these last decades, several Intelligent Learning Systems (i.e., ITS or iLMS) have been realized to help in acquiring foreign languages and/or communication skills as VocaTest (Kazi, 2005), TenseITS (Cui & Bull, 2005), CAMLES (Nguyen, Pham, & Ho, 2010), LingoSnacks (Erradi, Nahia, Almerekhi & Al-kailani, 2012).

Most of these learning systems focus on modeling tutor activities via artificial intelligence techniques to adapt content delivery to the student, according to his/her particular characteristics (learning style, behavior, performance, and whether the student has a disability or not) (Cuesta, Ramos & Pavlich-Mariscal, 2012). Adaptation could also be based on the user's location, concentration, time and interruption/distraction (Cui & Bull, 2005), or more generally on the user's context (Nguyen et al., 2010; Uosaki, Ogata, Sugimoto, Hou, & Li, 2012).

More specific ITSs have addressed users presenting the autism spectrum disorders (ASD) and tackled specifically the teaching learning strategy (Coleman-Martin, Heller, Cihak & Irvine, 2005; Sarma & Ravindran, 2007; Drigas, Kouremenos, & Vrettaros, 2008; Judy & Krishnakumar, 2012; Vullamparthi, Khargharia, Bindhumadhava, & Babu, 2011). Others have provided authoring tools to help and advice non-experts as parents and caregivers to create instructional modules and interactive social scenarios (Boujarwah, Riedl, Abowd, & Arriaga, 2011; Conde et al., 2009).

Following works have however, addressed new communication features with the system.

For instance, Baldi offered a computer-animated tutor for teaching vocabulary and grammar to children with autism and those with hearing problems (Massaro, 2004).The TUTOR project (García et al., 2006) have proposed an ITS that integrates multimodal tools and human emotional feeling analysis to improve its usefulness. Study in (Sitdhisanguan, Chotikakamthorn, Dechaboon & Out, 2008) had suggested a Tangible User Interface (TUI) based tutoring system. ActiveMath a mathematic ITS have provided a man's eye tracker to trace child's attention and reading time (Melis & Siekmann, 2004). Authors in (Ritchings, Khadragi & Saeb, 2012) have developed a computer-based system for Sign Language tutoring using a data glove and a software application. El Ghoul and Jemni (2009) have proposed a Web based environment to help deaf people learning sign language where written texts are automatically interpreted in visual-gestured-spatial language using avatars which was later enhanced with a new animation approach that ensures real-time generation of the virtual character postures (Yahia, & Jemni, 2013). McCrickard, Abel, Scarpa, Wang and Niu (2015) have proposed a methodology to help future designers to propose relevant interface to people with ASD.

Finally, authors in (Conde et al., 2009; Irigoyen et al., 2010) have proposed the LAGUNTXO system which provides an assisting tool based on an intelligent structure for tutoring system's configuration and allowing any stakeholder (tutors, caregivers and relatives) to configure the ITS in two dimensions considering the characteristics of the operational task and the diversity of the disabilities. For that aim, an automaton-based mechanism has been developed to technologically adapt the large amount of possibilities related to the interaction between people with disabilities, the task that is going to be made autonomously by these people, and the system elements.

Context awareness and mobility in ITSs

Recently a few research works have addressed mobility and its challenges when it is applied to ITS or iLMS (Badaracco et al., 2013). The main focus of these works are how to deal with content, data storage and Human Communication Interfaces (HCI) within devices with constrained characteristics and features (Badaracco et al., 2013; Brown, Lee, Salvucci & Aleven, 2008; Boticario & Santos, 2007).

Two categories of works have tackled differently those problems. The first one makes content authoring (Stankov, Rosić, Žitko, & Grubišić, 2008) and HCI customization outside the mobile device in a static manner (Brown et al., 2008), (Zatarain, Barrón-Estrada, Sandoval-Sánchez, & Reyes-García, 2008).

The second category uses client/server architectures mainly Web oriented and so data processing, storage, reasoning, HCI adaptation or customization is done server side (Kazi, 2005). Synchronization techniques are also used for updating the client and its constrained data base. We notice therefore that adaptability implemented in these works concern only learning content, pedagogical learning paths and HCI (Ghadirli & Rastgarpour, 2013).

However, it is worth to stress that a software architecture and its flexibility for (re)-configuration, is a strong condition for context awareness and mobility. A survey and comparison between ITSs architectures have been done in (Mastour & Khemaja, 2013). The survey have considered Desktop or standalone ITSs, Web Oriented Architectures (WOA) (De Bra & Calvi, 1998), Services Oriented Architectures (SOA) (Dolog & Nejdl, 2007), multi-agents based architectures, (Lavendelis & Grundspenkins, 2008), Semantic Web based architectures (Vesin, Klašnja-Mili ćević, Ivanović & Budimac, 2011), (Merino & Kloos, 2008) and finally hybrid solutions combining more than one architecture. The comparison have considered flexibility adaptability and auto reconfiguration, as well as elements concerned with adaptability as content, interface and granularity or weight of services and components.

As a conclusion at the best of our knowledge, none of the existent research works have addressed functionalities or re-configuration of Mobile Intelligent Learning Systems at runtime, specifically by making use of ontologies and semantic reasoning in the client side to provide context aware services. Moreover, described ITSs address specific learning strategies and content which are predefined at design time and may not change at runtime. Except the LAGUNTXO system (Conde et al., 2009) that applies some kind of re-configuration, these systems are not able to respond rapidly to change and do not offer the possibility of applying sound and intelligent re-configuration based on human expertise and heuristics.

Scenario description and analysis

This section provides a motivating scenario where mobility constraints and aspects are changing and so do the learner's needs and context. The scenario analysis will highlights some challenging issues and guides the manner to address them.

Scenario description

Sabine is a teen girl presenting several communication disabilities. Her parents always try to engage her within activities allowing her to acquire communication skills. They also offered her a lightweight version of an ITS which is embedded and deployed on her mobile device. This ITS addresses specifically a subset of English language for specific use at home. After several weeks of experience, Sabine had successfully worked on all the provided activities. However, she still requires additional activities to enhance her communicative skills. Her school teacher proposes her a new ITS version with much more activities and vocabulary including location based ones. Unfortunately, due to hardware constraints, this new version could not run on the Sabine's mobile device. Moreover, although that Sabine were progressing successfully to learn, she is still facing several communication difficulties due to her ASD disability especially when she needs to deal with specific domains.

Scenario analysis

Even though, the initial version of the ITS have at the first time satisfied Sabine's needs, these latter have changed. The idea is therefore to allow Sabine and the other learners with various needs to benefit at the same time from different services provided by a given ITS's configuration and its upgraded versions, to share services between each other and equally to benefit from services available in the surrounding environment.

Moreover, a part of the previous technical requirements, some pedagogical considerations could also be taken into account. For instance, if Sabine is moving and do not have enough time to take long assessment tasks or when she needs to learn other specific expressions and terminology the ITS's should provide the best fitted service.

The intended scenarios are therefore that devices speak to each others, with buildings, campus facilities, etc. take account the user's context and so provide her with the best experience.

As a conclusion, following requirements are highlighted (1) A new ITS's architecture is needed. This architecture should be flexible, adaptable, re-configurable and also lightweight to fit into mobile constrained devices. Moreover ITSs components should be fine grained to allow rich and efficient adaptability and re-usability. (2) A mechanism that facilitates to handle the mobile context and allows users to acquire or exchange services at runtime. It should also allow fitted services provision to learners as well to tutors taking account their mobile contexts (preferences, strategies, disabilities etc.). (3) A unified description of the context, the context awareness facilities allowed by the mobile device as well as the ITS's services and content.

The learning/ supporting approach and the ITS's specific behavior

The learning approach proposed deals with two kinds of scenarios; formal and informal. In formal scenarios, the learner is provided with activities allowing her to improve and acquire relevant reading, writing, speaking, listening and understanding skills. Activities are classified as illustrated in Figure 1 where each kind of skill is addressed by learning as well as assessment activities. Relevant resources and content are also provided.

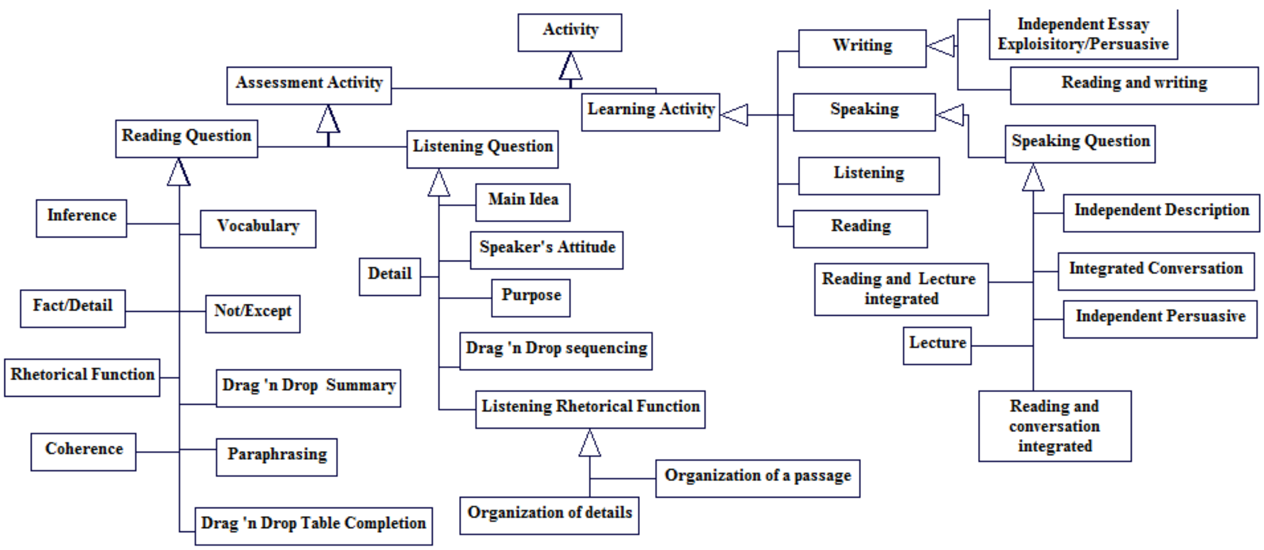

Figure 1. Taxonomy of activities

To carry out successfully these activities the ITS provides relevant pedagogical strategies. An example of such a strategy is illustrated in Figure 2 where the learner receives hints and recommendations concerning writing activities. For instance, the learner is assisted to use and vary the relevant vocabulary, to avoid redundancy and also to use the correct voice either passive or active.

Besides in informal scenarios, communication skills (i.e., speaking, listening and understanding skills) are mostly addressed. Moreover, the learner is assisted in a situation driven manner. Indeed, accordingly to the learner's location, the person or group of person with whom she will engage a conversation, the topic and the domain of the conversation, relevant vocabulary, explanations and useful linguistic expressions are displayed to the learner and allow her to train herself in such settings. More specifically, the system considers the person's profile and her disabilities, to adapt the learning activities and content. For that aim the ITS (i.e., the learner model) diagnoses and builds progressively the learner profile by making use of the IMS ACCESS LIP standard (IMS, 2003), which will extend the user's context illustrated in Figure 3.

For instance, people having ASD present disabilities that vary from one person to another. Signs such as hearing loss, verbal or non verbal communication skills, visual impairment, etc. constitute input information given to the system. This information allows the system to be aware of the kind of disability. Additional specific services are added compared to those used with common learners. These services concern specifically, the interaction mode provided by the system which is mainly implemented by the mobile ITS's interface model.

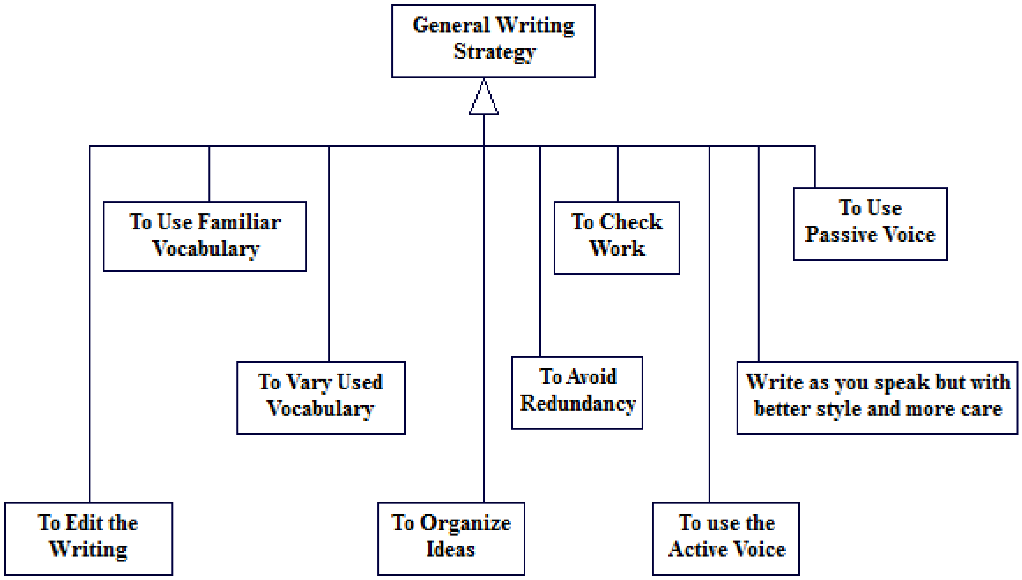

Figure 2. Example of strategies

Underlying technologies for building the ITS app

Three kinds of requirements have been highlighted in previous sections. To give answers to requirement (1), middleware solutions allowing software applications auto-configuration are the most relevant. For that aim, a ported OSGi middleware on Android platform is chosen. To handle context (requirement (2)), the solution attempts to take advantages of both OSGi and Android platforms for capturing context and extracting information about it, in a loosely coupled way. For that aim and also to answer to requirement (3), more semantics are needed namely for firstly knowledge representation, requesting and reasoning features, and secondly for automatic and dynamic discovery, composition and execution of OSGi services. A thorough and unified description for terminology related to OSGi, Android, Learning, adaptability and context awareness is therefore needed.

This unified description requires to be machine comprehensive. Therefore a semantic and ontological description of the overall mobile environment as well as accurate and efficient reasoning functionalities to enable this context awareness should be provided.

Details of this proposal are given in the following sub-sections and in the "Semantic descriptions needed by the ITS app" section, as well as in the "Implementation and validation" section.

OSGi terminology and models

The OSGi technolog, provides specifications for supporting dynamic services deployment, (re)-configuration and maintenance of software architectures based on components. It defines a standardized component oriented computing environment (i.e., a component model and a run time framework) for Java applications development and execution that simplifies configuration process and allows multiple java based components to efficiently cooperate in a single Java Virtual Machine (JVM).

The Table 1, summarizes main OSGi concepts and their definitions while the Table 2, main services provided by an OSGi Framework are presented.

Table 1. Terminology related to components specification

Concept	Definition
Bundle	A modular unit of packaging and deployment, composed of Java classes and other resources
Manifest	Describes the content of the JAR file and provides information about the bundle's dependencies and its Activator class
Service	Is implemented by a Java class. It is accessible through at least one *Interface*
Service's properties	Allows a service to be dynamically advertised and searched, using the framework's services
Interface	A Java Interface describing methods to be implemented by a service
Package	Java packages exported or imported by a bundle
Bundle activator	Implements the start/stop of a bundle
Service registry	Used for managing services and their properties
Bundle's context	Specifies the current context of a bundle
Event	Triggered when a service is registered/unregistered
Bundle's dependencies	The resources needed for the bundle to run correctly

Table 2. Terminology related to OSGi frameworks services

Service	Role
Installation	Implements the process of loading the JAR file corresponding to the bundle into the framework.
Resolution	Implements the binding process, in which each package declared as imported is *wired* to an exported package of a resolved bundle.
Starting/Stopping	For starting/stopping respectively inactivated/activated bundles
Updating	A Bundle is modified to produce a new version
Class loader	A specific class corresponding to a resolved bundle allowing it to be activated
Register/Unregister	Applies on services
Listener	Observes events
Service tracker	Observes events on bundles services

It is worth noting that the OSGi service architecture is dynamic, i.e., services may appear or disappear at any time especially for the case of mobile platforms or shared registries.

It provides also a flexible deployment API for controlling components lifecycle, as well as a cooperative model where applications can dynamically discover and use services provided by other applications running inside the same OSGi platform.

Thanks to its bundle packaging, applications could be much fine grained than applications for other Java platforms. For instance, new functionalities provided by new downloaded bundles, could be installed, started, stopped, updated while useless (no more used) bundles could be uninstalled without restarting the OSGi framework.

However, even though the OSGi specification offers a high level dynamicity, bundles and their services descriptions remain syntactic and unlike in Semantic Web services Frameworks (Barros et al., 2011), the OSGi services discovery relies on syntactic properties matching.

Android features and mobile context awareness

The availability of sensors is one features Android devices have that makes them different from computers. Thanks to sensors' capabilities, which could also be enriched by other user's inputs as her agenda or other kinds of sensors, persons engaged in a conversation and the topic of the conversation, the user's context could be captured. Context analysis allows thereafter the system to react in a relevant manner especially by supporting the learner to acquire new skills.

Since most of sensing capabilities required in the context of this work are derived from the available hardware on the Android device, and thanks to the abstraction provided by the Android platform and APIs for invoking accurately the services provided by these sensors, a context model is established and corresponding mechanism is provided.

The Figure 3 illustrates this abstraction and makes the basic concepts of the user's context and context awareness dealt with in "Semantic descriptions needed by the ITS app."

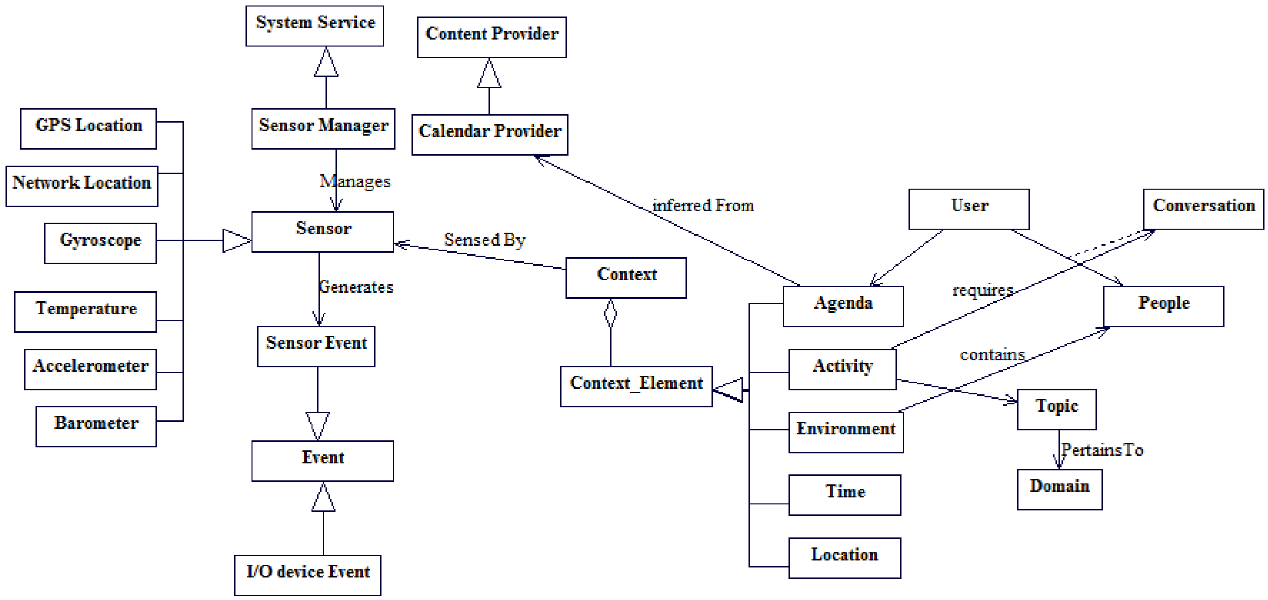

Figure 3. Android Sensing capabilities related to some context elements

Proposed configuration and adaptation mechanism

The mobile ITS interacts with an external environment which is considered as the user's context including the user, other people present in the environment, etc.

As defined in the literature, ITSs model is mainly composed of four components (Buche, 2005). Compliant to that model, each module is considered as an assembly of components designed to fulfill intended functions by the provision of a set of services.

The aim of (re)-configuration or adaptation is to render needed components available accordingly to the user's current context. Observation and context awareness is performed by a specific manager that is attached to each ITS module component and decides whether the configuration or reconfiguration is needed. This manager has the responsibility to implement the configuration and the adaptation policies (as for example Selecting relevant components to be used, Elaborating the components activation plan; Adding removing or replacing a component).

Moreover, each OSGi bundle in the ITS provides a kind of interceptor or listener (sensor) placed on parameters or monitored variables that could be changed when a context element changes and so a specific handler (actuator) is activated to respond to those changes. Thus the ITS's context manager, will interact with each module manager.

Since the ITS is OSGi based and ported on the android platform, the ITS's context manager is implemented as an android service running as a background task and which is bound to the main ITS activity as illustrated by the Figure 6. It should have reasoning capabilities to reason about context and decide which module manager it should notify and on which context element it operates changes.

Managed bundles or components subscribe to context elements they are concerned with and so when the specific context element changes, the context manager notifies the module manager which in turn notifies the managed bundle subscribed to the context element if it is available otherwise the module manager decides for applying the adaptation policy which could apply on the structure of the module or notifies managers of other modules.

Semantic descriptions needed by the ITS app

Semantic description of OSGi

In order to make the Android ported OSGi based middleware semantically richer; it has been fully based on ontologies in a manner inspired from Semantic Web Services approaches (Domingue, Cabral, Hakimpour, Sell, & Motta, 2004; McIlraith, Son & Zeng, 2001). Main aims are to provide more machine-understandable bundles/services descriptions. This could enable a more dynamic usage of OSGi services as automatic discovery, selection, composition, invocation and monitoring based on sound meaning of their capabilities.

Semantic descriptions are provided on top of the OSGi bundles registry to semantically describe bundles and services capabilities resulting therefore on an OSGi Bundles/services ontology (Figure 4).

In addition three other kinds of ontologies are equally used. Those ontologies are (1) The Context ontology for reasoning on context. (2) The Goals ontology for expressing users' objectives independently from provided services as illustrated in Figure 4. Goals instances are derived namely from the context ontology. And finally (3) The Domain ontologies, for knowledge representation and data exchange between the systems components.

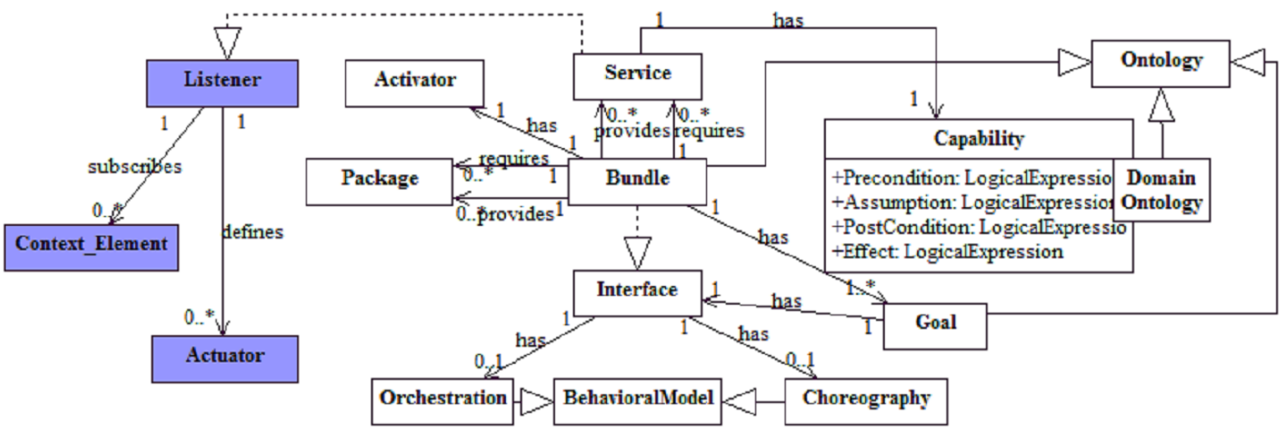

Figure 4. OSGi bundles/services ontology

Semantic description of context

Figure 5 illustrates a more complete view to context elements provided in Figure 3. The aim of the context ontology is to describe contextual entities related to the user, her profile accordingly to the IMS ACCESS LIP standard, her devices, location, the learning scenario, the current activity, the surrounding environment, social groups, people, conversation, topic, etc. The main aspect of this ontology is that it allows to infer new Goals from the actual context and conversely an achieved Goal could act on that context and let it evolve over time.

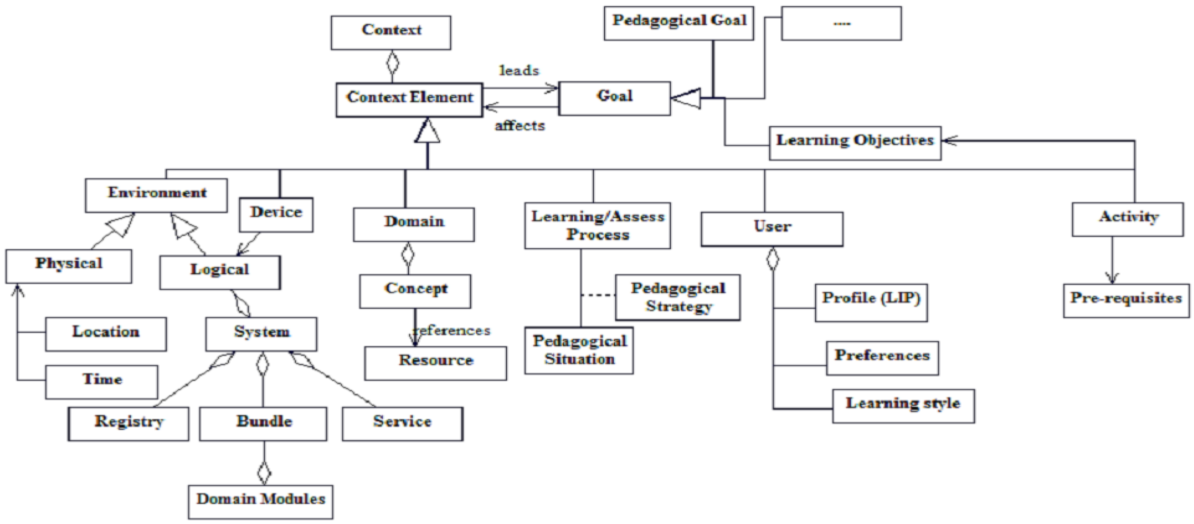

Figure 5. The context ontology

The domain ontologies

The set of domain ontologies comprises all the ontologies needed by the ITS as the pedagogical ontology expressing pedagogical strategies, and the taught domain ontologies. These ontologies are semantically related to the context ontology, and the goals ontology. In the context of the present work, the taught domain is formed by a set of domain specific ontologies representing the specific vocabulary and linguistic expressions of that domain and which is intended specifically for autistic people needs. Whenever, the user is faced to a certain situation especially in informal settings, the corresponding ontology is loaded allowing the user to acquire new expressions and vocabulary.

The mobile ITS app context aware architecture

The mobile app architecture proposed, provides two categories of Android components (Figure 6); Android activities and Android services.

Android activities are dedicated to manage the user's interface, they implement therefore only components for visualizing information or capturing the user's inputs.

Main heavy processing are running as background tasks (i.e., Android services). One first task implements components for capturing the mobile context and reasoning on it thanks to the semantic reasoning engine deployed on it. The second one embeds the OSGi Framework. Both components interact with each other for context acquisition, handling, reasoning and domain services provision.

The OSGi Framework contains all bundles implementing the ITS's components and ontologies. To allow loose coupling between bundles' services, relevant services are advertised in the OSGi services registry. Semantic descriptions of those services are also updated within the OSGi bundles/services ontology to allow further reasoning on the services' semantic capabilities and goals which could be queried thanks to the reasoning engine service. So, core bundles of each module are developed while other domain specific functionalities could be added accordingly to the specific domain needs or to the user's mobile context.

Services are organized on infrastructure services (the installer service, the update service, etc.), module managers services corresponding to the ITS's modules as well as specific ITS services (e.g., knowledge assessment service, user interface service, learning process manager service).

Specific ITS Ontologies are used jointly to their corresponding ITS modules (e.g., the learner module makes use of the learner ontology which is part of the context ontology for handling one's learner specificities and for reasoning and providing the best fitted services; The domain ontology specifies the concepts of the domain to be taught (learned). It is used by the domain module bundles, etc.). While the more generic ontologies as the Context ontology, the Goal ontology and the Bundles/Services ontology are organized in the semantic layer.

Accordingly to context and decisions made on it the ITS could exchange Bundles and resources either from peer's devices or over the air from distant repositories. These could eventually be deployed on the Cloud.

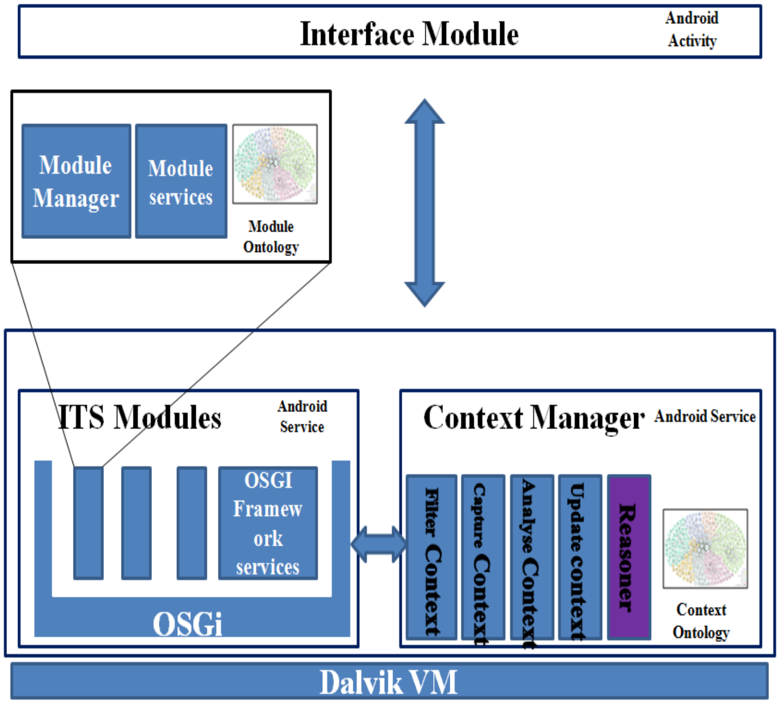

Figure 6. Proposed architecture

Implementation and validation

In this section as a proof of concept, an implementation and a use case that illustrates the provided solution are presented.

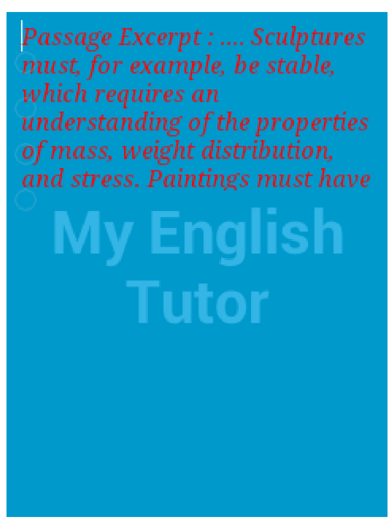

Figure 7. Proposed reading activity

Firstly, to implement the proposed mobile ITS app, following software are used; the Android SDK for Android app development, the Felix OSGi framework for OSGi bundles deployment and execution, Protégé for ontology development and AndroJena plug-in for reasoning among and querying ontologies.

Several mobile learning scenarios are possible. They begin when the learner initialize a learning session. The system proposes hints, exercises or possible useful expressions. The learner uses her/his specific interface to send results to the system. The system assesses those results and returns feedbacks.

The application (Figure 7) begins the learning scenario by showing a paragraph on which the student will be asked some questions. Interface (Figure 8) proposes to the learner a list of answers and requests her to choose the answer she finds suitable to the question.

Figure 8. Multiple choice question

```
PREFIX ns: <http://www.owl-ontologies.com/OntologyGoal.owl#>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX tg:<http://www.turnguard.com/functions#>
SELECT ?D_Assumption ?D_Effect ?D_Postcondition ?D_Precondition
WHERE {
?Goal rdf:type ns:Goal .
?Goal ns:Description ?Description .
?Goal ns:GoalHas ?GoalHas .
?Capability rdf:type ns:Capability .
?Capability ns:Has_Assumption ?Has_Assumption .
?Capability ns:Has_Effect ?Has_Effect .
?Capability ns:Has_Postcondition ?Has_Postcondition .
?Capability ns:Has_Precondition ?Has_Precondition .
?Assumption rdf:type ns:Assumption .
?Assumption ns:Description ?D_Assumption .
?Effect rdf:type ns:Effect .
?Effect ns:Description ?D_Effect .
?Postcondition rdf:type ns:Postcondition .
?Postcondition ns:Description ?D_Postcondition .
?Precondition rdf:type ns:Precondition .
?Precondition ns:Description ?D_Precondition .
FILTER (?GoalHas = ?Capability) .
FILTER (?Has_Assumption = ?Assumption) .
FILTER (?Has_Effect = ?Effect) .
FILTER (?Has_Postcondition = ?Postcondition) .
FILTER (?Has_Precondition = ?Precondition) .
FILTER (?Description = 'Code Scan') . }
```

Figure 9. SPARQL Query for service discovery

In case that the user is moving and the Context acquisition service detects, thanks to location service based on GPS that the learner is very close to the library building where practical books are available. The system notifies the learner who decides to enter the library building. Unfortunately the mobile app deployed on the learner's device does not contain the client's service that could scan books' Barcode or QR Code to obtain much more information on a book on hand. Fortunately, a learner's peer's is very close and via specific authorization, a SPARQL query of Figure 9. Lines 9-30 using the goals and services ontologies is sent to the peer's device. The purpose is to find the relevant service's URL having equivalent capabilities to the given goal.

The Figure 10 illustrates that two (bundles) having the corresponding services are available and the learner's device could again choose one of them to download.

```
System.out  ----------------------------------------
System.out  | URL                                  |
System.out  ========================================
System.out  | "data/felix/bundle/QRCode Scan.jar"  |
System.out  | "data/felix/bundle/Bar Code Scan.jar" |
System.out  ----------------------------------------
```

Figure 10. URLs of discovered bundles

The downloaded bundle is automatically installed and started in OSGi Framework.

Conclusion and future work

Due to diversity of disabilities, the need to individually support each user and the lack of sufficient specialized and qualified human resources, one size fits all approaches are no more suitable.

Research realized in this paper which was based on literature review as well as scenario elaboration and analysis have concluded that even if in one-on-one learning systems the content and the learning approach may be easily adapted, learning/supporting services requiring new development or reconfiguration are not easily rendered available, especially due to the lack of standards promoting unified ways to develop services and hence to re-use them.

To overcome these issues, dynamic adaptability as well as mobility issues of ITS features at runtime have been addressed. The proposed solution presents several advantages. First, the learning approach provided, allows the learner with specific needs to take advantages of learning services both in formal or informal settings. This was possible thanks to the use of several specific domain ontologies that are uploaded accordingly to the user's context, specific disabilities and situation.

Second, it allows fine grained services development and deployment at runtime as well as semantic discovery, composition and execution of those services. Third, it allows formal knowledge representation about the ITS's components, content as well as the user's mobile context and her specific needs and disabilities. Therefore, semantic reasoning and inferences are rendered possible over that knowledge. Thanks to the underlying OSGi framework which is mainly intended to small devices, ITSs components and services based on the solution are lightweight and so the ITS's configuration and re-configuration could be customized or adapted accordingly to the user's context.

Finally, the specific manager allocated to each module of the ITS, allows automatic data collection about the system's behavior, self monitoring, reasoning and therefore provides an efficient way to draw conclusions and operate adaptation of the proposed solution.

Possible future extensions of this work are to integrate text-to-speech as well as intelligent conversational behavior between the system and the learner. Currently, an extension is being done to create possible interactions of the system with mobile affect devices and therefore collect other contextual data about the user. Experiments dealing with more frequent change of context have to be realized and evaluation of time and performances during services exchanging between peers should be done.

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