Significance of Semantic Web in Facilitating HCI in Mobile and Ubiquitous Learning

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***Abstract*—Mobile devices are being widely used in education for many purposes such as an instruction tool for learning. However, mobile devices suffer from the limitation of capabilities and resources. Potential solutions to this issue must consider the mobility and personal characteristics of potential education seekers. This paper theoretically describes how Semantic Web might be used to facilitate the interaction between mobile devices and learners in mobile and ubiquitous learning environments to provide mobile learners with the best learning experience.**

Keywords- Mobile learning; m-learning; ubiquitous learning; u-learning; pervasive learning; p-learning ; HCI ; semantic web.

I. INTRODUCTION

The rapid development of wireless networks and mobile technologies play a vital role in extending the use of mobile devices for different purposes. Current mobile devices are able to deal almost with any kind of data, ranging from text to heavy streams of multimedia. Consequently, this ability to deal with a variety of data plays a key role in increasing the value of handheld devices. In addition, contemporary technological capabilities have encouraged the concept of learning through mobile devices, widely known as mobile learning or m-learning. They have also encouraged the implementation of ubiquitous computing in education, for example, to provide context-aware educational applications. These are widely referred to as ubiquitous learning (u-learning), or pervasive learning (p-learning). Mobile device has been used to serve many educational purposes such as language learning, music education, student reminders and personal timetabling, work-based training and lifelong learning. All of these approaches are based on a different kind of technology of mobile handheld devices. The growth in the number of mobile users is rapidly increasing. It is estimated that there are over five billion mobile subscriptions around the world [1]. The unique characteristics of mobile devices play a role in providing new ways of learning and training. Indeed, these characteristics facilitate the delivery of knowledge to nomadic learners who live remotely or are unable to attend classroom-based learning. Five major characteristics of mobile devices have been identified as (i) portability, mobile devices can be transported with the user and used anywhere at any time as a result of their small size and weight (ii) social interactivity, mobile devices can facilitate any aspect of communication for individuals exchanging data, including voice messages which helps friends stay in contact(iii) context sensitivity, mobile devices can interact with contextual information from their current location which can be achieved by using many integrated sensing technologies(iv) connectivity, mobile devices can be connected with other devices, data collection tools and ordinary networks (v) individuality, mobile devices can provide contents that can be personalised to meet individual requirements and conditions [2,3]. Despite the physical constraints of mobile devices, much research has been undertaken which considers the value of this technology in the context of the learners' mobility. However, most of these research efforts rely on the bounded group of databases in which learners can obtain preloaded learning materials. These approaches may have some limitations, such as lack of interoperability, scalability, which might make these applications limited to specific predetermined restricted information. With the current deluge of information from disparate resources, a mechanism needs to be developed to provide personal information. This mechanism is needed to overcome the mobile devices constraints. Recently, the most promising technology to overcome some of these inherent mobile device limitations is the Semantic Web [2,4]. The Semantic Web consists of a group of technologies and standards that facilitate the sharing, organisation, integration, matching and reusing of information automatically. These facilitations can be justified by looking at the abilities of the Semantic Web, in which it provides different methods to describe the information to allow the machine to understand it [5, 6].This description allows the machine to automatically acquire, reuse, evolve and combine knowledge. In this way, the Semantic Web can provide "a framework where the actual integration details of "mash-ups" can be worked out automatically rather than by a programmer" [2].

Many studies have shown the benefits of combining the technology of the Semantic Web with mobile and ubiquitous computing. However, there has been little research to determine what mobile learners really need from Semantic Web technology. In other words, how can the Semantic Web help facilitate the interaction between mobile devices and learners in m-learning and u-learning environments. This paper theoretically describes how the Semantic Web can be used to enhance better interaction between mobile devices and learners in both environments.

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In this paper the first five sections provide necessary fundamental information pertaining to its issues to increase the understanding. Section II briefly describes the concept of ubiquitous computing. Section III explains the difference between the context and the situation. Section IV highlights the major activities of mobile learners. Section V briefly explains the concept of the Semantic Web along with highlighting two of the core elements of the Semantic Web, namely Resource Description Framework (RDF) and ontology. Section VI describes the concept of linked data as a practicable implementation of the Semantic Web and also discusses the difference between Web of documents and Web of linked data. Finally, Section VII theoretically highlights the implications of the Semantic Web in facilitating Human-Computer Interaction (HCI) in M-learning and U-learning environments.

II. UBIQUITOUS COMPUTING

The concept of ubiquitous computing was originally introduced by Weiser: "the most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it" [7]. He clearly describes ubiquitous computing as a phenomenon that takes into account the natural human environment and allows the computer itself to fade into the background [8]. Moreover, his vision refers to the collaborative or collective use of computer devices that might be embedded in a specific predetermined physical environment, thereby allowing users to interact invisibly with them. The main aim of this idea is to create an environment in which the connectivity of devices is embedded in such a way that it is unobtrusive and always available. Weiser's vision involves introducing computers into people's lives, that is, putting computers into a daily living environment instead of representing the everyday environment in the computer [9]. When computing becomes ubiquitous, learning may become more active and contextual. Moreover, the direct interaction between learners and computers is improved by helping learners focus more on the task itself rather than on how the task is performed.

III. CONTEXT AND SITUATION

Understanding the context of the entities involved in an applied ubiquitous application is the most important component of ubiquitous computing which provides learners with suitable information. The concept of context can be considered differently based on many factors such as the circumstance and the intended objectives of the designed application. The consideration of what can be regarded as context varies from one application to another. However, the useful definition of context was defined by Dey: "Context is any information that can be used to characterise the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves" [10]. Considering the context in this way could play an important role in increasing the intelligence of the interaction between computers and humans, which helps users to focus more on performing the intended task to a higher level. Each context-aware application is pre-programmed to collect only the contextual information needed, using sensing technologies (e.g. Global Positioning System (GPS), sensors, Radio-Frequency Identification (RFID), etc.) to determine the situation applicable to the current entity. In [10], the situation is defined as "a description of the states of relevant entities". Therefore, the relationship between context and situation in the ubiquitous environment relates to the group of contextual information affecting the intended entity that leads to an understanding of the situation.

IV. MAJOR ACTIVITIES OF MOBILE USERS

Mobile devices are used for many purposes, however in this paper two of the major usages of mobile devices by users on the move are considered. This is based on the scenario in which users use their mobile devices to retrieve required information from different resources. These two activities are specifically mentioned to draw attention to the importance of implementing the Semantic Web [6, 11].

A. Searching

As mentioned, mobile devices suffer from many limitations. One of these limitations is small screen size. This may prevent users interacting with mobile devices for a long time, especially for reading. Using the internet to search for information for mobile users using search engines is a very difficult task. To clarify this, consider a situation in which a user wants to find information about the term 'orange', but with specific reference to the fruit, using the Google search engine for example.

Unfortunately, the number of returned results is about 1,380,000,000. Most importantly, the returned results will not be accurate, as they contain information about any page that contains the 'orange' term, which could refer to Orange, the company; the place named Orange; or the fruit itself.

There are many problems associated with this method of finding information, known as keyword-based search, because it only searches the documents that contain the given keyword. Mobile users need to spend time to find out the required results, which is not an easy task to do.

B. Data Integration

The location of mobile users can be specified through the utilisation of integrated sensing technologies of mobile devices. For instance, it is possible to build a mobile application that can send the coordination of mobile devices using integrated GPS technology to locate the user. Many sensing technologies have been utilised to provide the mobile user with the right information based on their current context. This is one of the fundamental goals of ubiquitous computing.

To clarify the data integration problem, consider that a user wants to find the closest restaurant to his current location. Many applications can provide this information. However, what if he wanted to find a review of this

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particular restaurant, or if one of his friends had visited it before, or if he wanted to compare the menus of selected restaurants.

Problems arise in this scenario because of the need for automatic information integration. Furthermore, retrieved information is merely one single page without any intelligent relation between information from different sources. Indeed, to conduct this kind of information integration manually is a somewhat boring and difficult task, especially for mobile users.

V. SEMANTIC WEB

One of the drawbacks of the Web is that it is only understandable by humans. Machines cannot understand the Web as humans can [5]. Machines deal with the Web as a group of connected documents using Hypertext Transfer Protocol (HTTP) links. The Web is built for human consumption. Therefore, it is difficult to automate the integration of information from different resources as well as obtaining accurate results when searching the internet using keyword-based tools [12]. As mentioned previously, the problems encountered in mobile search and data integration can be resolved extensively if the resources were semantically annotated.

The term of Semantic Web was originally introduced by Tim Berners-Lee: "an extension of the current Web in which information is given a well-defined meaning, better enabling computers and people to work in cooperation" [5]. The Semantic Web provides ways of describing information so as to be understandable and readable by machines. The Semantic Web aims to allow the seamless interoperability among applications to happen. To achieve this goal, the Semantic Web does not rely on text-based information, which can only be interpreted by humans, but rather it relies on structured formats, which can be interpreted by machine. This format is presented by RDF.

Using RDF allows for any piece of information to be described or expressed in such a way that it is structured enough to processed by machines automatically. The abstract module of RDF contains three basic elements (Subject, Predicate, Object), whereby each element has its own unique identifier in the form of an HTTP Uniform Resource Identifier *(*URI). There are many benefits to using URI as an identifier for each element of RDF. Firstly, it helps to avoid semantic ambiguity. For instance, consider a situation where users are asked to write a review about a restaurant called 'food for you'. When people review it, it is quite possible that different reviewers may use different names for the same restaurant such as 'food 4 you'; or it might be named differently in another documents. Therefore, it will be impossible to aggregate the reviews about this restaurant without using URI as a unique identifier. Secondly, the resources will be reachable and globally accessed.

Besides using explicit metadata presented by RDF, ontology is a core element of the Semantic Web. Kalfoglou defined ontologies as follows [13]: "…an explicit representation of a shared understanding of the important concepts in some domain of interest. The role of ontology is to support knowledge sharing and reuse within and among groups of agents (people, software programs, or both). In their computational form, ontologies are often comprised by definitions of terms organized in a hierarchy lattice along with a set of relationships that hold among these definitions. These constructs collectively impose a structure on the domain being represented and constrain the possible interpretations of terms". This definition highlights the usefulness of using ontologies to have a common understanding among different applications to build intelligent applications. Ontologies work as a guideline or blueprint that provides vocabularies and taxonomical conceptual hierarchies. Furthermore, the ontology provides a logical statement which clarifies the meaning of terms and how these terms are related to each other. The benefits of ontologies can be summarised [6, 11]:

Firstly, ontology is domain based, which can be any domain, such as education, meaning that it provides the description for a specific area of knowledge, so it can be reused in many applications to represent this area. Secondly, ontology facilitates the interoperability and the sharing of understanding among different applications. This can be done by mapping the ontologies with each other. In this way, the collaborative use of ontologies allows them to extend each other to infer new knowledge. Finally, ontological description language allows for the encoding of knowledge in machine understandable format. Consequently, this plays a key role in extending the possibility of automatic wide scale machine processing.

VI. LINKED DATA

Linked data refers to the best practice of publishing structured data on the Web and linking them together to obtain new knowledge from different resources [14]. These sets of structured data are published in such a way that it is machine readable. The meanings of these datasets are explicitly defined, which allows them to be linked with each other forming what is known as the Web of linked data [6, 15]. These structured data sets are independently available, meaning that it is not required to visit a particular website to be able to use them. Linked data is a collection of RDFs. Each RDF identified by HTTP URI. Each HTTP URI uniquely represents the resource which can be anything, such as person, event, place, etc.

The linked data principle was shaped by Tim Berners-Lee as a step towards achieving the goal of the practical implementation of the Semantic Web. This goal is not only about giving a description of data using RDF, but also about linking available data to build relationships between them to facilitate the acquiring of new knowledge from different external or internal resources as mentioned before. The common feature between the Semantic Web and linked data is that both are based on machine readable data which is made to be understood by a machine. However, confusions

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sometimes arise because of the differences between the Web of linked data and the current Web which is called the Web of documents. There are many differences between them, and four will be outlined [6, 12, 14, 15].

A. Freedom of publishing

In both Web of documents and Web of linked data, users are not restricted in the type of resources they publish. Neither are they restricted by time or location However, in the Web of documents, the published documents can be understood by humans and the integration of data is performed manually. However, in the Web of linked data, the published documents are in the form of RDF documents to be consumed by machines, not humans. This allows the machine to automatically and actively provide the users with the information they need without relying on the text-based type of search which leads to retrievals of lots of irrelevant results. Furthermore, it allows it to intelligently integrate the knowledge based on users' needs from different resources.

B. Accessibility of resources

Both of them offer ways of accessing the intended Web resources using Web browsers. However, in the Web of documents a browser can understand HTML documents. In contrast, the Web of linked data uses a browser that can understand the RDF documents.

C. Everything on the Web is linked together

This applies to both of them; however the Web of documents makes use of HTTP Uniform Resource Locator (URL) to identify the page on the Web. Using HTTP URL allows access to a resource which can be directly retrieved. For instance, we can type any URL to retrieve any personal website directly. However, the same URL cannot be used to retrieve the person who owns a particular website. In contrast, the Web of linked data makes use of HTTP URI to retrieve any resource from the Web. For instance, in the previous mentioned example, it is possible to assign the unique URI identifier to reach the person on the Web. To clarify this point, the Web of document uses un-typed hyperlinks, whereas the Web of linked data uses typed links which can directly denote any resource on the Web.

D. Both can provide structured data

Prior to the introduction of the linked data principle, although the access to databases through Web Application Programming Interface (API) was provided by many major Web data sources such as Google, setting hyperlinks between data forms different to Web APIs resources was possible. However, it has some drawbacks and may lack scalability. For instance, each Web API relies on different recognition mechanisms and varieties of access mechanisms, and it may also have its own way of representing the retrieved data in different formats. These issues divided the Web into different data soils, which might prevent a developer from being able to build applications to retrieve data from different data sets provided by different vendors on the Web. This collective use of API is called mashups. In contrast, in Web of linked data, the mashup is based on the semantic meaning of the explicitly provided definition of the thing and as such it called semantic mashups. Here, datasets interact with each other which allows for the building of more scalable applications which do not rely on bounded groups of data bases.

VII. DISCUSSION

It is important to clarify one point as a contextual prelude to considering how the Semantic Web might enhance or facilitate the interaction between learners and mobile devices in mobile and ubiquitous learning environments. In our previous work [16], we clarified why understanding the nature of interaction between the learner and mobile devices in m-learning and u-learning environments is crucial. It plays a significant role in drawing attention to the needs of mobile learners, the entity of essential importance in these two learning environments. The key issue which needs to be addressed before designing any application is the analysis of learners' characteristics. All types of learner should be taken into account, including children, adults and elderly users, especially those who do not consider mobile technologies as useful tools for learning or training, or are inexperienced in their use. In an m-learning environment the learner needs to interact directly with the small screen of a mobile device. This interaction is called explicit human computer interaction (eHCI) [3]. In this case, the learner is required to explicitly provide necessary details to interact with m-learning applications (for example user name, password, etc.). Consequently, the interaction that best distinguishes m-learning applications is eHCI. In contrast, u-learning environment makes use of eHCI and implicit HCI (iHCI), which is defined as "the interaction of a human with the environment and with artefacts which is aimed at accomplishing a goal. Within this process the system acquires implicit input from the user and may present implicit output to the user" [17]. U-learning applications first collect contextual information about many relevant elements for the interaction, such as learner identity, location and environment to understand the context of the learner. This collected contextual information is worked as 'implicit inputs' which is used for the implicit interaction with learners. Then learners can interact with u-learning, explicitly eHCI, which will be continually enhanced by the implicit HCI (iHCI). In the following points, the value of the Semantic Web in enhancing the interaction between mobile devices and learners in both m-learning and u-learning is explored. There are many values for such a combination from different perspectives. However, for the purpose of this paper, the problems of learners are considered to be based on

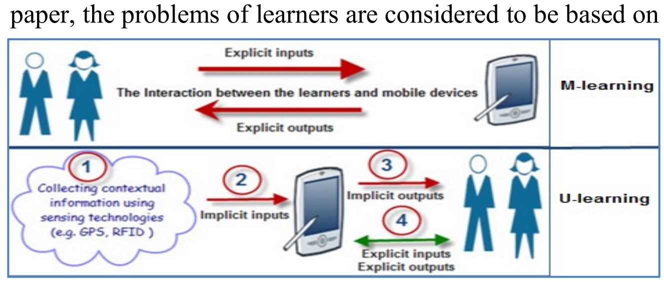

Figure 1. The interactions between learners and mobile devices in m-learning and u-learning environment [16].

the aspects of interaction with mobile devices.

A. *Implications of Semantic Web in facilitating eHCI in M-learning environment*

In the m-learning environment, the interaction with the small screen of mobile devices might be a very difficult task for mobile learners. As the mobility of learners increases, the need to access information on the move also increases. As mentioned, a keyword-based kind of search is an obstacle. It makes the obtaining of information a very tedious process. Furthermore, it forces the learner to spend much time interacting with a mobile device to find the desired information. Likewise, the restricted group of m-learning materials which can be adaptive, based on learners needs, plays a role in restricting the possibility of expanding these learning materials despite their benefits. In other words, these learning materials are bounded by a restricted group of relational databases which need direct human intervention to grow. Therefore, the Semantic Web should be considered a response to these drawbacks.

The Semantic Web can help machine and software systems to be able to automatically do many tasks 'on behalf of their human users' [2]. As mentioned before, Semantic Web supports the collaborative between human and machine toward obtaining the required information. This collaboration is much needed to enable mobile learners to learn on the move. The Semantic Web provides many benefits to overcome the problems which mobile learners have with the eHCI in an m-learning environment. Learners in this environment need to be provided with unrestricted adaptive learning materials that suit their profile (for example learning styles, time preference, proficiency level, etc.), and also the functionality of their mobile devices. The learning materials which are designed to be presented in powerful machines might not be suitable for mobile devices. The ability of the Semantic Web to describe knowledge in understandable formats for machines has played a role in increasing the automatic reasoning of knowledge. For instance, one of the core elements of learning is learning objects.

Wiley defines the learning object as a part or element of a modern type of instruction, supported and enhanced by a computer, which are based on the object-oriented model of computer science [18]. Learning objects are considered to be small educational materials which can be readily re-used in different learning contexts. Therefore, teachers can benefit from the size of these educational materials by chunking and reassembling them to support individual instructional objectives. This can be considered as an entity of digital information which can be effectively delivered over channels such as the Internet to benefit unlimited users simultaneously.

These learning objects can be semantically annotated. This annotation allows the machine to automatically link this learning following communally a group of agreed ontologies without any human intervention. Furthermore, others learning resources related to learning objectives can be linked too. Consequentially, this allows the automatic integration of knowledge from different resources, which helps mobile learners to obtain the right information which suits their needs directly. Indeed, the use of ontologies facilitates the reuse and sharing of these learning objects. Furthermore, it increases the accuracy of automatic searches for required learning materials adapted to different learners' needs [19].

B. *Implications of Semantic Web in facilitating the eHCI and iHCI in U-learning environment*

Two possible ways of interaction are utilised by u-learning, namely iHCI and eHCI. Besides providing the learner with information which suits their profile, u-learning aims to provide learners with information which suits their current context. U-learning environments consist of a group of devices interacting collaboratively with each other. Their interaction is vanished in such a way that makes the learners and their tasks the central focus. This interaction involves different kind of information originating from different resources (for example user, environment, sensors, etc.). The problem here is that such information is varied in terms of the formats and language, and is not processed by machine. This exchanged information should be collected, shared, and interpreted against each other to achieve the goal of seamless and unobtrusive connectivity of ubiquitous environment.

The use of the Semantic Web is essential to facilitate the interoperability in this heterogeneous environment. Besides organising the learning materials, the Semantic Web can be used to organise the reasoning of the collected contextual information [20]. Many relationships between the elements of u-learning heterogeneous environment can be represented using groups of ontologies such as learner, context, environment etc. Using the Semantic Web, these ontologies can then be mapped to each other to provide the learner with the needed materials based on their current situation for example. This allows the machine to automatically update the learning materials without any human intervention needed, meaning that learners do not need to concern themselves with manual data integration to fulfil their learning requirements. In this way the direct interaction between the small screen of mobile devices and learners might decrease which helps learners to learn in convenient ways.

There are many successful examples of the combination of the Semantic Web with mobile devices which make the interactions between users and mobile more intelligent. For instance, in [21], the Person Matcher mobile application allows users to find other users which have the same interests in using their FOAF profiles. As the mobile user is walking around, the Person matcher application is thus continuously provided with FOAF profiles of persons in his vicinity. Furthermore, another good example in [22], is the COIN (COntext-aware INjection), which was built to make existing websites context-aware on-the-fly and to facilitate the browsing of websites in a way guided by relevant content.

There are many examples of integration between mobile devices and linked data; the most famous example is DBpedia mobile, which is a location-centric DBpedia client

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application for mobile devices. It consists of a map view and a Fresnel-based Linked Data browser. The DBpedia dataset is taken from Wikipedia. The location dataset of DBpedia contains more than 300,000 locations. Most importantly, this dataset is linked to other datasets which enrich its location information. This collective use of datasets is a useful way to acquire knowledge from different resources. In addition, DBpeadia allows the user on the move to publish data about his location to be used by others. Indeed, linked data has great potential in overcoming the limitation of mobile devices and supporting the growth of any application which deals with unbounded groups of databases [23].

VIII. CONCLUSION

This paper has theoretically provided useful insights into the importance of the Semantic Web in enhancing the interaction between mobile learners and mobile devices in mobile learning (m-learning) and ubiquitous learning (u-learning) environments. In m-learning environment, learners interact explicitly with mobile devices. This is called explicit Human-Computer Interaction (eHCI). Whereas, u-learning makes use of the two ways of interaction: eHCI and implicit HCI (iHCI). Both environments suffer from some obstacles which might prevent learners to learn effectively. For instance, the explicit interaction in m-learning environment might be difficult for mobile learners especially with a small screen on a mobile device. Furthermore, the u-learning environment is heterogeneous which makes interaction between learners, mobile devices and environment complicated. The Semantic Web can address these obstacles in both environments by providing different methods to describe information which allows machine to understand it. Most importantly, this description allows the machine to automatically acquire, reuse, evolve and combine learning materials from different resources. Furthermore, the Semantic Web organises learning materials conceptually based on their meaning, which allows different applications to use them by acquiring them semantically which helps learners to use learning materials from different resources. Moreover, the Semantic Web plays a key role in facilitating the sharing of learning applications and services in such automated and easy ways. These learning materials and services can be integrated by resolving differences in terminology through mappings between ontologies across applications, thereby providing a more seamless learning experience. More research should be conducted to investigate the affordability of Semantic Web as a method to facilitate the interaction between mobile devices and mobile learners and also as a practical way to overcome the constraints of mobile devices.

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