A Linked Data Approach for Enriching Emerging Learning Objects with Contextual Metadata

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Abstract: **The latest evolution of mobile technologies has increased the possibility for users to generate digital content at any location and time. In this paper, we present our thoughts related to the ability to enhance digital content that emerges when mobile devices are used to support different learning activities. We believe that these emerging learning objects should be enriched with contextual characteristics in a machine interoperable and interpretable manner in order to preserve the meaning, or semantics, of those features. There a number of approaches to tackle this problem but we have chosen to focus on Linked Data as it seems to be a promising solution for enriching these kinds of emerging learning objects with contextual metadata.**

I. EXECUTIVE SUMMARY

The increased portability of mobile devices has resulted on the fact that they are not anymore perceived as distinct objects but more as integrated tools in our everyday activities. Furthermore, technological advancements have generated a major shift referred to as "*technological convergence*", where the functionality of different devices has been blended to a single one. This converging technological evolution has generated, as suggested by Milrad [1], a "*new mobile landscape*". Mobile devices nowadays are not being used for communication purposes only but also as content creation devices. They are not only perceived as phones or PDAs but they are also music players, radios, cameras, Internet platforms etc. [2]. This convergence has resulted on mobile devices becoming a central tool to support different human activities. Learning, as one of these activities, has been also subject to changes as a result of using these technologies. In our latest research, we have been exploring novel ways to use mobile devices to support communication and content creation during a wide range of learning activities.

Moreover, current mobile devices are increasingly enhanced by different type of sensor technologies. Campbell and colleagues [3] suggest that these emerging trends will turn mobile phones into global sensing devices. Furthermore, they argue that these trends will develop into what they call "*the new era of people-centric sensing*". Sheth [4] defines the notion of "*citizen sensing*" as the combination of mobile sensors and human computing. The main idea behind this view is the fact that humans are acting as sensors by contributing with digital content on the Internet through the use of different social media applications (such as Youtube, Twitter, Facebook etc.).

Digital mobile content created in this manner is usually enriched with different spatiotemporal and profile metadata features provided by different built in sensors in mobile devices (such as GPS, hear rate, etc.). These set of metadata may provide us with the ability to depict the context of the users. Metadata as "an annotation tool" are closely related to the notion of semantics that aims toward making data and content more meaningful for both; human and machine consumption [4]. The importance of contextual metadata is evident in the field of technology-enhanced learning (TEL) since contextual characteristics can serve as descriptors for the digital content that emerge during the learning process. In our research efforts, mobile learning activities usually take place in informal settings, meaning that there is no formal control over the content that has been generated. We refer to digital content created in this manner as "*emerging learning objects*" (ELOs) [5]. The fact that there is no formal control over this creation makes the interoperability and expressiveness of ELOs an important research issue.

The context in which these ELOs are created plays a crucial role to address the issue of their interoperability and expressiveness. In our previous work, we have developed a context model that could be expressed using XML Schemas to illustrate metadata structure [6]. While the notion of contextual metadata has been around for many years [7], a recent study of on-going efforts enriching digital content with contextual metadata show that there is very little consensus concerning metadata terms used and their semantic mapping [8]. This fact raises the challenge of *how to enrich emerging learning objects with contextual characteristics in a machine interoperable and interpretable manner, so that it is possible to preserve the meaning or semantics of these features*.

A comprehensive survey on context modelling in ubiquitous computing environments highlights approaches such as key-value models, markup scheme models and ontology-based models [9]. While a system supporting key-value representations of contextual characteristics can be considered straightforward to implement, the solution suffers when it comes to semantic interoperability, ambiguity of metadata terms [8] and sophisticated data structuring [9]. Markup scheme models help to resolve metadata interoperability between systems through concept definitions in schemas. One of the more renowned technologies in this area is the XML Schema validating the structure and syntax of XML

documents. In the field of TEL, the IEEE-LOM[1] metadata specification is a popular standard for enriching learning content with metadata to promote their reusability, discoverability and interoperability. Another approach to address the reusability and interoperability of multimedia content was introduced with the MPEG-7 and MPEG-21 standards [10]. As with IEEE-LOM also MPEG standards deal more with the interoperability at the syntax level and do not provide flexibility when it comes to the emergent aspects of learning objects. Markup standards and recommendations shine when it comes to interoperability; applications can be tailored to fit the expected structure and syntax defined by the standards. On the other hand, when stepping out of the metadata terms supported by the schemas, there is a challenge to maintain the semantics of metadata between systems. Moreover, the interpreting applications are responsible to resolve incompleteness and ambiguities [9].

Technologies frequently seen in research using the ontology-based approach are OWL (Web Ontology Language) and RDF (Resource Description Framework) Schema, which constitute a set of knowledge representation languages for defining ontologies on the Semantic Web. Ontologies address semantic interoperability and ambiguity issues in that they constitute "a formal, explicit specification of a shared conceptualization" [11] and has been considered promising in the area of ubiquitous computing environments [9]. A research effort applying these powerful mechanisms in the domain of learning can be seen in [12]. Moreover, Nešić and colleagues [13] describe a novel approach in which Semantic Web technologies are used to enhance office documents with semantic and social context metadata.

Things on the Semantic Web are defined as URIs (Uniform Resource Identifiers), which, if formatted as HTTP URIs, can facilitate data integration via the readily existing Web infrastructure. This fact is connected with a relatively new concept referred to as Linked Data[2], which define best practices on how to expose, share and connect data on the Semantic Web. These important recommendations contribute to interoperability aspects of Semantic Web applications through advocating common guidelines. Therefore, Linked Data provide means to depict emerging learning objects with contextual metadata comprised of instances of classes and properties defined in ontologies with clear guidelines for integrating Linked Data applications via the Web infrastructure. We have recently implemented a system in which emerging learning objects can be enriched with RDF formatted metadata according to the Linked Data guidelines [14]. While the system has not yet been tested in realistic learning settings, the initial findings indicate that our approach could be a flexible solution in terms of metadata expressivity, interoperability and data distribution. Overall, we consider Linked Data to be a promising solution for enriching emerging learning objects with contextual metadata because of the ability to decentralise and interlink systems via resources and their metadata according to the Linked Data guidelines, along with the inherent features of ontology-based approaches.

Even if the Linked Data approach shows a great potential, there are still a number of remaining challenges directly associated to the distributed data features of Linked Data; how do we perform queries and assertions when the relevant data are spread out over several distributed systems? how can we control CRUD (Create, Read, Update and Delete) operations on resources in our Linked Data applications and still maintain interoperability between such systems? And what about the authentication and authorisation processes of sensitive resources. These important points are still remaining challenges that we plan to address in our coming research efforts while trying to promote and improve the reusability of emerging learning objects.

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[2] http://linkeddata.org