Ontological Support for the Cultural Contextualisation of Intelligent Learning Environments for Adaptive Education

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Abstract. Within ITS research, most systems rely on data in order to train models for decision making and for customising system behaviour. The inherent bias has been traditionally in favour of developed nations. This paper examines the issues involved in contextualising interactive intelligent educational systems using a semantic approach that leverages the meaning of data rather than common patterns within data. It presents a trio of ontologies for relating conceptual knowledge to sociolinguistic terms in the context of a student's cultural influences and background. The paper argues that if an ITS can model students culturally, model their languages, and model their cultural concepts, then it would be possible for an ITS to start communicating with students socially and conceptually in a culturally appropriate way. The paper explains the rationale behind the need for ontological concepts when adapting aspects of instruction, how they relate to cultural lexical terms, and examples of when these terms may be suitable for use in educational content and instructional events.

Keywords: Ontologies, Cultural Semantics, Student Modelling, Sociolinguistic Contexts, Content Adaptation, Semantic Analysis

1. Introduction

In 2010, there were approximately 1,991 million Internet users worldwide [11]. Compared to 2016, that figure increased to 3,385 million. Not only has the sheer volume of users increased, the cultural backgrounds of these users are being quickly diversified. In just under 10 years, the proportion of Internet users from the developing world has almost doubled in relation to those from the developed world. In 2008, the ratio of developed world users to developing world users was approximately 4.2. In 2017, that ratio is now 2.0. Moreover, 70% of the world's youth (aged 15-24) are online and they make up the largest group of Internet users [11]. Two interesting points arise from these statistics. Firstly, a lot of data is being generated daily and this will continue to increase. Secondly, as the human sources of this data change, so does the quality of the data, and more importantly the cultural bias.

Within ITS research, most systems rely on data in order to train models for decision making and for customising system behaviour. The inherent bias has been tradi-

tionally in favour of developed nations [2] and this makes sense since most users in the past have been predominantly from these areas. ITS research would have therefore been driven by the cultural backgrounds and biases of the researchers who produced the systems and the student users who produced data that fed the research. The problem here is that data biases affects the design of an ITS and the eventual decisions made by the system. The bias can be positive or negative, and educational systems need to be more acutely aware of this because of the impact on learning and rates of success. For instance, statistical analysis of large amounts of data allows prediction of various types of instructionally relevant events that might take place next with a fair level of accuracy. This allows models to be built based on the observation of patterns in the data which help to give an indication of the details of some domain of interest. The flexibility of the patterns that are detected however, depend heavily on the kinds of data that the models are trained on which in turn affects the scaleability of the system overall [8].

Culturally-aware ITS design is a reasonable way of dealing with this lack of flexibility since, as the statistics show, the landscape of the student audience is changing and systems need to evolve or risk irrelevance. It is difficult however to transfer and extend intelligent learning environments to different cultural contexts for several reasons [14,19]. Diversity arises from differences between cultures. While tangible and concrete in many instances, such as language, dress, food, gestures, and music, culture at its deepest level is intangible and non-deliberate. Furthermore, the multiple factors and influences that shape an individual person's cultural awareness come through interactions, perceptions and knowledge of other cultural groups. Culture itself is therefore challenging to model computationally in a holistic sense and even more complex when aiming to do this for an individual learner within an ITS. It necessitates organising cultural semantics and data from heterogenous sources to reduce bias and also because individual data points such as country of origin or language are insufficient for meaningful modelling.

Semantic web technologies have been around for many years but widespread uptake has not been achieved [18]. This is subject to change in the upcoming years as the importance of linked data becomes evident with the need to organise and structure data [5]. This paper argues that rather than taking a data centric approach towards cultural inclusiveness, a semantic approach is preferable since it allows the meaning of the data to be leveraged rather than common patterns. Ontological modelling of cultural contexts would allow data from heterogenous sources to be filtered, disambiguated and combined. The paper describes a trio of ontologies that were developed for modelling cultural contexts in intelligent learning environments. The ontological representations covers three main areas: modelling a student's cultural context, modelling a student's language and cultural expressions, and modelling the cultural concepts (metaphors, idioms, concepts) that are relevant to a student. Each ontology is useful in isolation for various purposes, however when all three are merged, they give insight regarding how to communicate with a student using appropriate sociocultural concepts and language.

The rest of the paper is organised as follows. Section 2 defines the process of cultural contextualisation. Section 3 describes the trio of ontologies: CSM, CERA and

VELO. Section 4 illustrates how concept chains produced when the ontologies are merged result in the identification of appropriate cultural terms and concepts for a given students. It also gives examples of how these may be used in instructional events. The paper concludes in Section 5.

2. Defining Cultural Contextualisations

Culture refers to a cognitive and linguistic framework within which humans interact with and relate to their environment [10,13]. Interactions are governed by societal and ideological systems of thought [12] and result in the construction, distribution and assimilation of shared meanings that originate from individual and group level perceptions. These shared meanings, also called *cultural conceptualisations* [17], result from human cognitive processes of categorising observations and experiences under familiar conceptual categories. These categorisations are intrinsically linked to language which conveys cultural knowledge and allows individuals to understand each other's perspectives when communicating. *Contextual groups* are defined as collections of individuals with common beliefs, characteristics and values who reference cultural conceptualisations through shared linguistic terms. *Cultural contextualisation* is therefore defined as the process of integrating one or more cultural conceptualisations into aspects of a digital learning environment [16]. Cultural conceptualisations manifest as concrete representations of abstract concepts and are comparable to *cultural elements*. Defined in the literature as an observable manifestation of culture, *cultural elements* are categorised as material artefacts or non-material cultural products which represent or embody the shared meanings of a cultural group [4]. For the purposes of this paper, cultural elements and contextual elements are used interchangeably.

3. Ontological Descriptions of Cultural Context

An intelligent learning environment that aims to model cultural contexts will rely heavily on semantic metadata. This is necessary in order to reason about the cultural contexts of educational resources and relate these contexts to a student's cultural background. Many standard upper-level ontologies define general knowledge concepts that relate to cultural descriptions of real-world phenomena and provide foundational semantic bridges between intermediate levels of cultural knowledge abstraction. Upper ontologies have not been designed with the intention of structuring cultural knowledge in particular. Recent work by Blanchard and Mizoguchi [3] describes high-level cultural conceptual entities in an upper ontology of culture (MAUOC) and identify several categories of cultural elements that manifest in a culture. In addition, ontological concepts should be defined such that lexical entries irrespective of the source language are all accessible by these concepts, that is, through ontological mapping and merging. The following subsections describe the trio of ontologies introduced in this paper using UML notation.

3.1. Contextual Student Model (CSM) Ontology

The ontological structure of the CSM is extensible for capturing and modelling multiple cultural backgrounds. Figure 1 shows the main concepts and relationships in the CSM ontology. It is partitioned into three layers consisting of factors and influences originating from various sources. The first layer stores personal demographic data that define a student's core identity. The second layer consists of dimensions from immediate socio-cultural units that play formative roles in a student's life such as family members and close friends. The third layer consists of dimensions from neighbouring socio-cultural units that are of lesser influence but still contribute towards a student's awareness of and exposure to cultural contexts. This is possible because the *Guardian* and *Contextual_Group* concepts (and related attributes) and relationships can be instantiated any number of times with dimension data. This implies that a student's cultural background can be modelled not only from a single temporal perspective indicated by the student's age, but also from a chronological perspective where his/her cultural background may change with age.

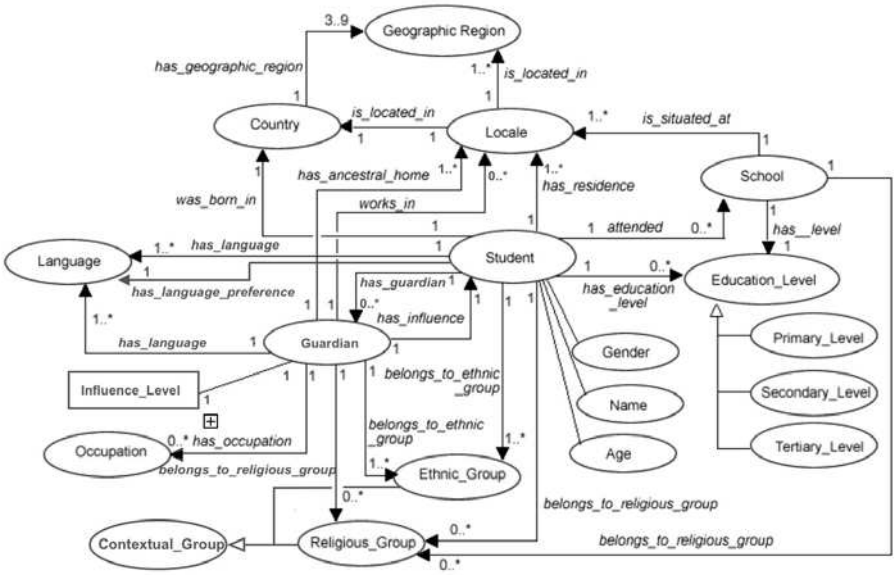

Fig. 1. The Contextual Student Model Ontology

3.2. Contextual Element Resource Annotation (CERA) Ontology

Observable manifestations of culture have been referred to as cultural elements, or more generally, as contextual elements [4]. High level categories that represent language independent abstractions of real world phenomena are described in [3, 15]. Based on these abstractions, the Contextual Element Resource Annotation (CERA) ontology specifies the ontological concepts and relationships that describe the nature

and background of a contextual element which is referred to as an *Entity* in Figure 2 which shows the ontological signature of CERA. The More Advanced Upper Ontology of Culture (MAUOC) [3] and SUMO[1] (Suggested Upper Merged Ontology) were used to build the semantic backbone of CERA. SUMO provided a comprehensive hierarchy of spoken human languages used by members of a contextual group and helped to define the language origin of linguistic concepts that are used to describe one or more contextual elements (identified as dark grey concepts in Figure 2). The MAUOC on the other hand, provided high-level classifications of entity abstractions (identified as light grey concepts in Figure 2) namely *Physical Entity, Continuant Entity, Abstract Entity, and Semi-Abstract Entity* concepts which were subsumed by the *Entity* concept in CERA. The Entity concept is linked to a *Contextual_Group* concept.

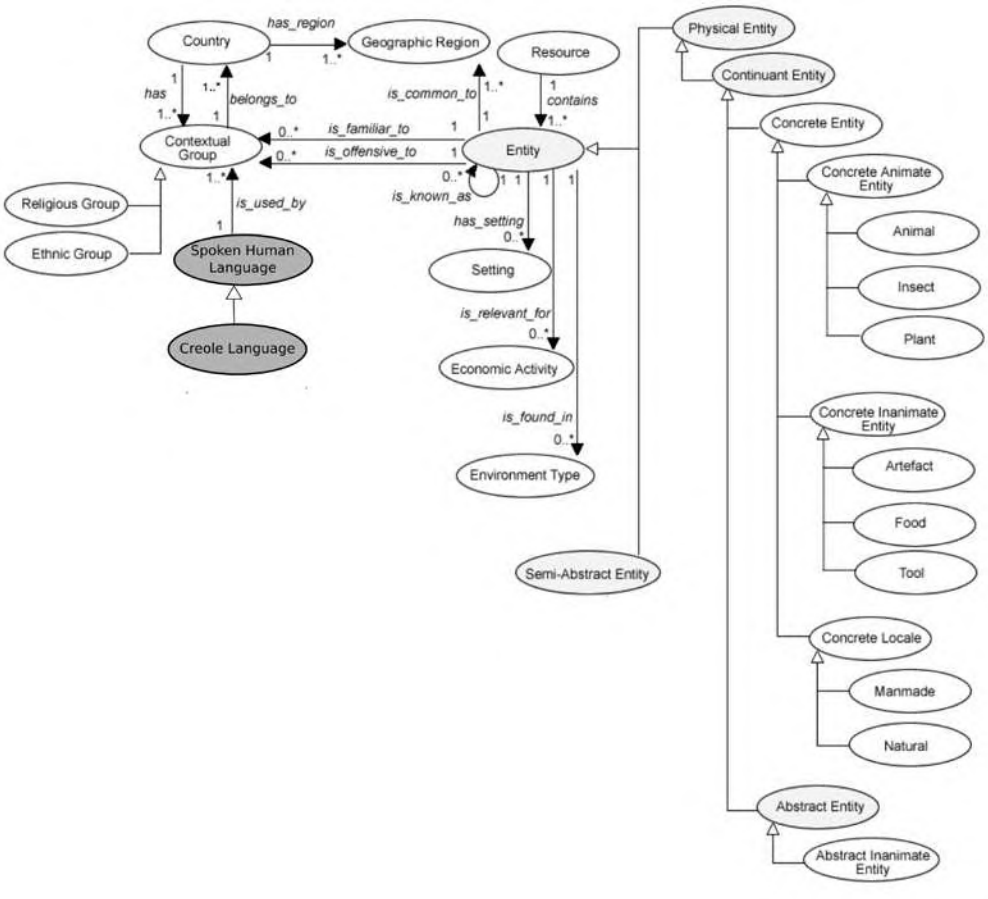

Fig. 2. The Contextual Element Resource Annotation Ontology

[1] http://www.ontologyportal.org/

3.3. Vocabulary Equivalence Lexicon Ontology (VELO)

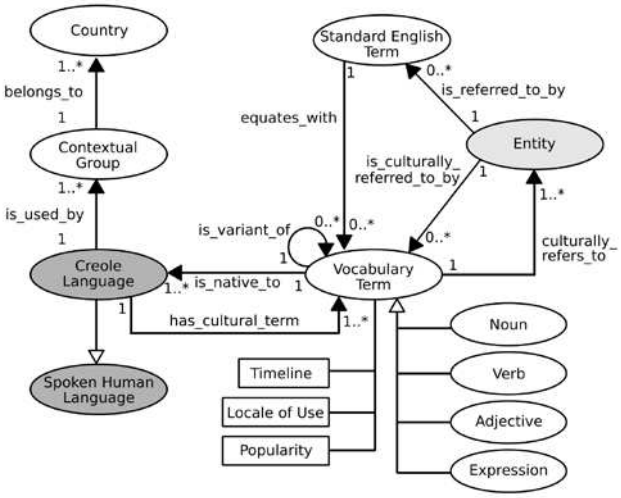

Fig. 3. The Vocabulary Equivalence Lexicon Ontology

The main concepts of VELO, the relationships between the concepts, and the attributes of the concepts are shown in Figure 3. VELO was designed to facilitate the mapping necessary for equating multiple vocabularies accurately. The ontology is based on the conceptual-linguistic approach described by [1], and adopts a similar structure to the ontologies in the DOSE platform [6] and the KYOTO project [21] by referencing upper-level concepts from SUMO and DOLCE. The intention behind VELO is to equate/map Standard English vocabulary to localised equivalents. It specifies the base concepts and relationships needed for achieving lexical equivalence across languages at the semantic level through the *Entity* concept. This can then be used for facilitating queries on communicative acts, language concepts, metaphors, and idioms that are culturally appropriate for a student using an ITS.

4. Deployment in Intelligent Learning Environments

4.1. Ontological Mapping and Merging

Ontological mapping and merging is necessary in order to combine the information distributed across the three ontologies described in the previous section. Figure 4 shows a partial snapshot of the important concepts in the ontological signature of the merged ontologies. Correspondence throughout the merging process is facilitated based on the use of the *Entity* concept in both VELO and CERA. Using the concept chain illustrated in Figure 4, it is possible to determine which contextual elements (referenced by *Entity* concepts) are suitable for a student based on familiarity through

a student's affinity to one or more contextual groups in a society. Furthermore, the specific language terms that reference the concept can now be identified, leveraged and integrated into instructional events using rules.

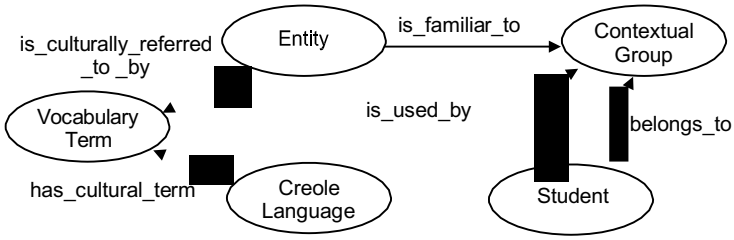

Fig. 4. Merged Partial Ontological Signature of the VELO, CERA and CSM Ontologies

To illustrate, consider two original sentences S1 and S2 which might be used in an ILE to respectively set the frame for a problem description, and give feedback to a student with a Trinidadian cultural context.

S1: Every week, John gives away free apples to the customer with the largest purchase.
S2: You did not answer the question correctly.

When S1 is provided as input to an ILE that uses the trio of ontologies, the resultant sentence S3 below would be produced for the student used in this example.

S3: Every week, John gives away free zabocas to the customer with the largest purchase.

In S3, the cultural reference to 'zabocas', would be matched conceptually under same semantic category through a shared higher level *Entity* concept as that of 'apple'. This cultural term would be used if a Trinidad English Creole vocabulary base is activated in VELO. Consequently, the general reference (apple) in S1 would be replaced with a more culturally-specific and culturally appropriate reference based on the student's cultural background as in S3 using rules. This demonstrates how the cultural semantic context of the educational material was changed while still preserving the learning context. When S2 is provided as input, there are several possible resultant sentences as shown in S4, S5 and S6 below.

S4: You did not answer the question correct.
S5: You eh answer the question correct.
S6: Yuh eh answer the question correct.
S7: Yuh eh answer d question correct.

In S4, the underlined words would be changed by grammatical rules loaded due to the activation of a Trinidad English Creole rule base since the student has a Trinidadian context. This gives an ILE the ability to produce appropriate localised variants of a source text when a particular level of formality is specified. For example, if formal variants are requested for S2, then only S4 would be generated. If very informal, col-

loquial variants are requested for S2, then S7 would be generated. It should be noted that the rules and ontologies facilitate different languages and cultural backgrounds. The design is not tied to a particular implementation as in this example. Therefore, if a student has a Jamaican context or a Singaporean context, the cultural references used would vary and therefore the output produced would vary.

4.2. Integration into Instructional Events

Instructional design models specify instructional events that take place during the learning process. A popular model often used in educational software was developed by Gagné [9] who identified nine instructional events. Based on the work of Branch [7], who linked culturally-aware instruction to these events, Table 1 was developed. It lists practical ways of using different types of contextualised content produced using the trio of ontologies for some of these types of instructional events.

Table 1. Using Contextualised Content for Instructional Events

Instructional Event	Contextualised Approach
Gaining the learner's attention	Integrate contextual elements, that are appropriate for the student, into instructional content as a form of stimulus change
Informing the learner of instructional objectives	Use a formal language variety that the student approves of and can relate to when stating instructional objectives
Presenting material to be learned	Use cultural references, scenarios, analogies in text, audiovisual or multimedia content
Providing learner guidance	Use a language variety that the student can relate to when giving instructional hints, directions or tips in order to provide meaningful context
Drawing out learner performance	Use familiar language expressions to encourage the learner to reflect using learning probes such as review quizzes
Providing informative feedback	Use familiar language expressions to phrase corrective feedback and inform the learner of the degree of answer correctness

For example, when providing informative feedback or drawing out learner performance for students who use a particular language variety in everyday life, the contextualised intensity of text-based sentences can be varied to create emotive feedback ranging from formal to informal, and also varying in the number of cultural references, metaphors and idioms used.Another example is the use of contextualised images when aiming to enhance retention and transfer or gain the student's attention. Images that depict contextual elements that the student is familiar with and which match the student's cultural background can be used to increase the relevance of the instructional content from a cultural perspective. A final example is the use of contex-

tual elements in unexpected but instructionally and semantically appropriate places within text-based content. These elements when inserted in place of similar, semantically-relevant references in scenarios or questions descriptions can be used to gain a learner's attention or enhance the presentation of the learning material. The approach in the paper is currently suitable for an individual learner using an ILE. Collaborative learning challenges are more complex and require a different strategy for customising an ILE to deal with multiple learners with different cultural influences.

5. Conclusion and Future Work

The self-contained model of a traditional ITS is changing. In the past, the focus was on ensuring quality regarding what students learned. This has progressed to coaching to ensure that students learn effectively [20], and now the focus is on the kinds of students that are involved in learning from an ITS. If we can model students culturally, model their language, and model their cultural concepts, the focus would then be to communicate with them socially and conceptually in a culturally appropriate way. The next steps to consider are whether it is acceptable to communicate in culturally informed ways, and to determine when such communication is acceptable or not. The need to consider cultural ethics and privacy is more important now than ever. For example, students from some cultures may be reserved and having an outward display of (somewhat privately-used) cultural realism in an ITS can be frightening and startling. This might make users uncomfortable and suspicious and which could eventually affect successful usage and uptake of such an ITS in a practical way. The ontologies described aim to mitigate such effects and extend the current efforts to model cultural knowledge for intelligent learning environments. They are a first step in addressing the need for practical, reproducible approaches towards cultural contextualisation from conceptual, linguistic, and cultural perspectives.

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