DESIGNING CULTURALLY-AWARE TUTORING SYSTEMS WITH MAUOC, THE MORE ADVANCED UPPER ONTOLOGY OF CULTURE

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TEL systems are reaching societies where they were almost completely unavailable previously. This makes the importance of culture in TEL systems more salient as they need to accommodate an expanding cultural-geographical user base. Indeed it is known that culture has a huge impact on educational expectations and norms, and the way people efficiently learn. However, culture remains a difficult concept to integrate into the already complex TEL microcosm, and the design and development of theory-grounded Culturally-Aware Tutoring Systems (CATS) thus requires guidance. The More Advanced Upper Ontology of Culture (MAUOC) is introduced in this paper as a way to address the theoretical gap. It concentrates and structures in one place the many scientific-grade notions needed to get a coherent view of the cultural domain while translating them into a common ground. As such, it offers theory-grounded guidelines for culture integration in TEL.

Keywords: Culture; heavyweight ontology; knowledge representation; technology-enhanced learning; adaptive systems; interoperability.

1. Introduction

The World we are living in is rapidly evolving. Computer processing power is becoming cheaper and advanced information technologies are spreading to environments and societies that were almost completely cut off from the information society. In other words, access to modern technology is improving and it can be argued that it results in a shrinking of the Digital Divide to some extent. This is a time of great promises and great opportunities for the Technology-Enhanced Learning (TEL) community, a moment where decisions in this research field could have a greater impact than ever, a moment where our community could be key in providing previously disadvantaged populations with access to efficient training and teaching opportunities on state-of-the art academic or vocational topics and expertise.

This is also a moment where risks exist to choose paths that would foster what could be referred to as neo-imperialistic approaches in education. In other words, educational problems and their technological solutions may be identified, analyzed and addressed from the sole viewpoint of dominant TEL research countries, eventually resulting in educational theories and practices, and related TEL systems being applied in settings in which they are not fully adequate, efficient, and respectful.

Indeed, learning-related elements such as common affective appraisal patterns, collaboration schemes, interaction practices, efficient motivational strategies, social norms, or accepted and promoted educational practices have been extensively documented to vary from a cultural setting to another one (e.g. Henrich, Heine, & Norenzayan, 2010; Hofstede, 2008; Hofstede, Hofstede, & Minkov, 2010; Jost & Hamilton, 2005; Mesquita, Frijda, & Scherer, 1997; Nisbett & Norenzayan, 2002). Consequently, this paper starts by pinpointing the importance that the TEL community must give to better consider the cultural dimension of both educational practices and learners before discussing the current research trend in TEL and culture, which is still in its early stages.

It is indeed extremely challenging for potentially interested new players to find the proper way to contribute to this burgeoning field since culture is a hard topic on its own. It is multifaceted especially in the sense that culture-related features are central research foci of various disciplines such as anthropology, sociology, business and leadership, psychology, archaeology, communication, etc. Each of these disciplines has adopted a different vocabulary, and has designed and agreed upon specific tools and methods to deal with culture, which leads to parallel approaches reflecting different, sometimes hardly comparable, perspectives.

Most TEL scholars have limited-to-no expertise on state-of-the-art scientific approaches to culture. Considering the variety of perspectives, it is thus extremely challenging for them to properly assess cultural frameworks and adopt adequate ones for embedding cultural considerations in their specific TEL systems. This state of affair has been the initial motivation for the development of the *More Advanced Upper Ontology of Culture* (MAUOC) presented in the second part of this paper.

The MAUOC project is a heavyweight ontology engineering initiative to obtain a neutral, theory-driven, conceptualization of the cultural domain, and as such it intends to address several objectives related to the development of culturally-aware technology (Blanchard & Mizoguchi, 2008; Blanchard, Mizoguchi, & Lajoie, 2010):

- To allow design and development teams to deal with cultural considerations in a scientifically-sound and interdisciplinary way, i.e. to propose appropriate guidelines to correctly model and manage key aspects of a specific cultural issue;
- To suggest ways of appropriately computerizing cultural features by suggesting templates for theory-driven data structures and data management processes;
- To promote interoperability by enforcing the consistency of cultural data modelling between systems, thus facilitating reuse of computerized cultural data; and

- To promote cultural automatic reasoning, thus allowing systems to take culturally-informed decisions that may impact on their internal processing as well as on human-computer interaction.

The MAUOC version discussed in this paper, whose precise codename is *MAUOC-07-2013*, is the first mature release of five years of heavyweight ontological comparative analyses of several major cultural frameworks. It includes significant changes and improvements as compared to previously published pre-versions (see Blanchard, Mizoguchi, & Lajoie, 2009; Blanchard et al., 2010) and is intended to a general TEL audience. Consequently and following a short outline on heavyweight ontology engineering and its differences with the more common approach of semantic ontologies (that ontologists frequently refer to as lightweight ontology), this paper intentionally avoids overly complex heavyweight ontology topics.

Guarino, Oberle, and Staab (2009) state that "*the backbone of an ontology consists of a generalization/specialization hierarchy of concepts, i.e., a taxonomy*". As an introduction to MAUOC, this paper is thus centered on the core taxonomy of MAUOC that is intended at remaining mostly stable in future necessary revisions and iterative improvements expected in any normal heavyweight ontology lifecycle. Identities of concepts mentioned in this taxonomy are provided in a textual form as a way to remain accessible to non-experts in heavyweight ontology engineering. As a side effect, some advanced details are not covered in this paper and should be more thoroughly described in subsequent publications.

Finally, and as it will be explained further in this paper, the development of a heavyweight ontology is focused on providing an appropriate and quasi-philosophical modeling of a domain (Smith, 2008; Mizoguchi, 2003; Guarino et al., 2009). In the case of upper ontologies like MAUOC, this results in quite abstract models that have the advantage of providing useful information for designing and developing a broad and varied range of applications and their interoperability. However the drawback is that using such abstract conceptual models will require application-related specializations. As a conclusion to this paper, clarifications are thus provided on the proper way to benefit from MAUOC in future design and development efforts in order to provide situated TEL.

2.   On the Importance of Addressing Culture in TEL Research

2.1.   *No TEL system can properly care without cultural considerations*

In 2009, the *International Conference on Artificial Intelligence in Education* (AIED), one of the leading biannual events for the TEL community, had been subtitled '*Building Systems that Care*'. This subtitle highlighted the growing agreement in this research community that solutions for obtaining efficient TEL activities had to not only address the cognitive dimension of learning and teaching but also other 'human' features such as affect and motivation. '*To care*' is defined in the *Oxford dictionary* as "*to feel concern or interest; to attach importance to something*" and '*to care for*' as "*to look after and*

provide for the needs of"[1]. Overall and depending on the context, '*to care*' may indicate that someone is aware of specific characteristics of someone/something else, that (s)he accepts and respects them, and that (s)he tries to take them into account in order to interact in a fruitful and non-harmful way.

As TEL is a research field that strives to figure out solutions to improve education at large, its focus and expected markets of application are not restricted to the limited number of countries whose scholars are currently able to impact and influence the development of the field (see Blanchard, 2012a). Considering the '*need to care*' stated above, a natural follow-up question thus emerges: do globally-efficient 'educationally-caring' approaches exist? In other words, could strategies be identified and computerized for TEL systems to properly interact with any user worldwide, to properly assess and efficiently adapt to them, and to appropriately value and respect their identity in any circumstances? For anybody who is experienced at travelling and interacting with individuals with different cultural mindsets, the answer is obviously 'NO'.

It is frequently mandatory to apply a lot of contextual fine-tuning in order to be respectful to and interact appropriately with human beings from other parts of the world. In other words, cultural relativity must be assumed in any interaction practice unless strongly proven otherwise. There is absolutely no reason to think that TEL, as a research field dealing with interactive systems for education, would be immune to this cultural relativity of interactions. Design decisions, research questions deemed of interest, potential solutions to be explored, assessment strategies and metrics considered appropriate, affect, motivation, etc. are some of many TEL-related features that are open to cultural influences (Henrich et al., 2010; various authors, 2010), and three general axes supporting the idea of making education more culturally-caring have also been listed by UNESCO (2007):

- To respect "*the cultural identity of the learner through the provision of culturally appropriate and responsive quality education for all*",
- To provide "*every learner with the cultural knowledge, attitudes and skills necessary to achieve active and full participation in society*",
- To provide "*all learners with cultural knowledge, attitudes and skills that enable them to contribute to respect, understanding and solidarity among individuals, ethnic, social, cultural and religious groups and nations*".

Indeed, education is culturally-varying in many ways, which is briefly discussed in the next section.

2.2. *Cultural variations in education*

Culture is deeply embedded within various aspects of educational activities:
- Teachers and learners get involved in an educational activity at a certain moment in their lives. Their personal development has been influenced by various conscious and

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[1] http://oxforddictionaries.com/definition/english/care

unconscious features they have learned during previous social experiences. During the activity, these influences do not just simply vanish but remain active at influencing cognitive processes such as categorization, interpretation, judgment, decision making, etc. (Henrich et al., 2010).

- Illustrations and examples that rely on local customs and environments are commonly used during educational activities. Local actors frequently know and internalize these examples more readily—they are perceived as more meaningful and relevant—than do outsiders (e.g. Biggs, 2001).
  - Strategies to convey educational content depends on norms and standards that may vary from one country to another, from one educational institution to another, and from professors to professors according to what is locally believed to be needed, educationally appropriate and acceptable according to social communication practices (see Tables 1 and 2).

In order to provide some indications about cultural variations in education-related features, we refer to the body of research related to the *Framework of National Cultural Dimensions* created by Geert Hofstede (FNCD-H), by far the most frequently used framework for cultural comparisons nowadays. The principle of FNCD-H and other so-called systems of cultural values (e.g. House et al., 2004; Schwartz, 1994) is to identify a certain number of cultural dimensions posited to be "*the stable core of cultures*", and to compute related scores for various groups. This provides an easy tool for between-cultural-groups comparisons. In the following tables, only the four initial and most documented dimensions of FNCD-H are used. These dimensions are[2]:

- Uncertainty Avoidance. This dimension expresses "*the degree to which the members of a society feel uncomfortable with uncertainty and ambiguity. The fundamental issue here is how a society deals with the fact that the future can never be known: should we try to control the future or just let it happen?*"
- Power Distance. This dimension expresses "*the degree to which the less powerful members of a society accept and expect that power is distributed unequally. The fundamental issue here is how a society handles inequalities among people*".
- Collectivism/Individualism. "*Individualism can be defined as a preference for a loosely-knit social framework in which individuals are expected to take care of themselves and their immediate families only. Its opposite, Collectivism, represents a preference for a tightly-knit framework in society in which individuals can expect their relatives or members of a particular in-group to look after them in exchange for unquestioning loyalty*".
- Masculinity/Feminity. "*The masculinity side of this dimension represents a preference in society for achievement, heroism, assertiveness and material reward for success. Society at large is more competitive. Its opposite, femininity, stands for a preference for cooperation, modesty, caring for the weak and quality of life. Society at large is more consensus-oriented*".

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[2] Definitions of the dimensions are taken from http://geert-hofstede.com/dimensions.html (retrieved July 5, 2013). Since the latest release of FNCD-H (Hofstede et al., 2010), two additional dimensions are also described.

Table 1 presents a categorization of several countries according to these four initial dimensions of FNCD-H, whereas Table 2 lists variants in educational features that have been associated to these dimensions through FNCD-H related studies (see Hofstede, 2008).

FNCD-H has its pros and cons. One of the frequent criticisms is that the '*country*' level of granularity[3] is very large and consequently, FNCD-H does not account for many inner-group sources of influence like sub-sociocultural groups (McSweeney, 2002). A related weakness especially critical for TEL researchers is that, since FNCD-H has been developed at a group (country) level, it cannot be applied at the individual level, e.g. for individualized interaction, without proper care. This is a common misuse of FNCD-H that has been criticized by Hofstede himself. It is also important to consider that many FNCD-H studies have not been performed in an education context, and their naive use in TEL systems may not lead to similar effects as those previously documented (Blanchard, Roy, Lajoie, & Frasson, 2009).

However, on the positive side, FNCD-H has been very popular for over 30 years. Consequently, many findings have been corroborated in several studies and fields (see Kirkman, Lowe, & Gibson, 2006). The challenge for FNCD-H users thus lies essentially in correctly interpreting the meaning of data that this model provides to them, and its scope of use.

Table 2 is an easy-to-read overview of many cultural variances in educational norms and policies that have been identified through studies related to FNCD-H, and TEL experts should have no problem identifying that many of them have been and are directly influential in TEL-related designs and interaction choices. However, as observed, it remains extremely important to correctly interpret these findings. They must not be read

Table 1. Classification of countries according to the four initial FNCD-H dimensions.

	Small Power Distance	**Large Power Distance**
Weak Uncertainty Avoidance	Nordic countries, English speaking countries, USA, Netherlands	China, India
Strong Uncertainty Avoidance	German speaking countries, Baltic states, Hungary, Israel	Latin countries, Czech Republic, Poland, Korea, Japan, Russia

	Masculinity	**Femininity**
Individualism	Czech Republic, Poland, Hungary, Italy, German speaking countries, English speaking countries, USA	Spain, France, Netherlands, Baltic countries, Nordic countries
Collectivism	China, Japan, Mexico, Venezuela, Arab World, Greece	Thailand, Korea, Costa Rica, Chile, Russia, Bulgaria, Portugal

[3] Individual scores for most of the country groups stated in Table 1 are available - see http://geert-hofstede.com/countries.html. However some countries are only considered as part of a country cluster (e.g. the Arab World), which is not ideal. In Hofstede et al. (2010), scores are listed for 76 countries.

Table 2. Identified cultural variations in education according to four FNCD-H dimensions.

Weak Uncertainty Avoidance	Strong Uncertainty Avoidance
Students want good discussions	Students want to know right answers
Teachers may say "I don't know"	Teachers supposed to have all answers
Emotions should be controlled anywhere	Emotions in class can be expressed
Tolerance for differences in class	Pressure among students to conform
Teachers involve parents	Teachers inform parents
Small Power Distance	**Large Power Distance**
Teachers treat students as equals	Students dependent on teachers
Students treat teachers as equals	Students treat teachers with respect
Student-centered education	Teacher-centered education
Students initiate some communication in class	Teachers initiate all communication in class
Teachers are experts who transfer impersonal truths	Teachers are gurus who transfer personal wisdom
Individualism	**Collectivism**
Purpose of education is learning how to learn	Purpose of education is learning how to do
Students' individual initiatives encouraged	Students' individual initiatives discouraged
Students are expected to speak up in class when they need or want to	Students only speak up in class when sanctioned by group
Students associate according to interests	Students associate according to in-groups
Diplomas increase economic worth and/or self-respect	Diplomas provide entry to higher-status group: are sometimes bought
Masculinity	**Feminity**
Brilliant teachers admired	Friendly teachers most liked
Best student is norm	Average student is norm
Competition in class	Over-ambition unpopular
Praise for good student	Praise for weak student
Students over-rate own performance	Students under-rate own performance
Competitive sports belong to curriculum	Competitive sports extra-curricular
Failing in school is a disaster	Failing in school is a minor incident

as a list of rock-solid statements that would necessarily apply to all countries labeled a certain way in Table 1. Furthermore, FNCD-H considers 'dimensions' and provides numerical scores (most of the time between 0 and 100) on a continuum, not boolean ones. This means that significant differences may exist between some of the countries that appear in the same cell of Table 1. Consequently they must be seen as trends about educational norms, orientations, policies, etc. that are more likely to be true than false if the targeted country has the related categorization. This way, Table 2 provides a helpful account of cultural diversity in education.

This concludes the section listing some of the main reasons and incentives for considering cultural features in TEL research. The next section is dedicated to discussing the current status of research efforts for merging cultural features into TEL systems.

3. Current Research Efforts on TEL and Culture

3.1. *A culturally- imbalanced research production*

Arnett (2008) provided data that demonstrate without possible doubts that research production (authorship, samples) in major psychology journals is strongly dominated by Western societies [4] which are not cognitively representative of the whole mankind (Henrich et al., 2010).

Blanchard (2012a) adapted Arnett's approach to similarly analyze ten years of research production in two premier TEL events: *the International Conference on Intelligent Tutoring Systems* (ITS) and the *International Conference on Artificial Intelligence in Education* (AIED)[5]. Extracted from (Blanchard, 2012a), Table 3 presents the national affiliation of first authors in these two conferences while Table 4 presents the national origin of human samples when psychological features in TEL-related context were analyzed.

Tables 3 and 4 clearly demonstrate a Western imbalance in research production. This state of affair is of course unintentional. Similarly as what Arnett (2008) suggested for psychology, it can be partly explained i) by a self-sustaining dominance of a Western philosophy of science that favors Western researchers who find it natural/normal, and ii) by economic differences between countries and variations in state support of TEL research. Further explanations exist for this state of affair, such as a better mastery of English in the Anglo-Saxon World. These data must also be considered cautiously since more regional TEL-related conferences of excellent quality exist such as *the European Conference on Technology Enhanced Learning* (Europe) or the *International Conference on Computers in Education* (Asia and Pacific) and are thus likely to attract a significant part of regional research production.

Nevertheless, ITS and AIED are de facto major global fora for TEL research, and such a massive Western imbalance in forefront TEL production is disturbing when considering that:
- According to Table 3, the overdominance of Western authors in TEL-related conferences is similar to the one depicted for psychology (Arnett, 2008) which Henrich and colleagues (2010) described as detrimental to science since it "*may cause researchers to miss important dimensions of variation, and devote undue attention to behavioral tendencies that are unusual in a global context*".

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[4] In Arnett's 5 years analyses of research production in six major APA journals (Arnett, 2008), 96% to 99% of first authors came from Western institutions, and 98% to 100% of samples were based on Western subjects.
[5] ITS2002 occurred in France/Spain, AIED2003 in Australia, ITS2004 in Brazil, AIED2005 in the Netherlands, ITS2006 in Taiwan, AIED2007 in USA, ITS2008 in French Canada, AIED2009 in the UK, ITS2010 in USA and AIED2011 in New Zealand.

Table 3. National affiliation of first authors in ITS and AIED conferences*.

	2002	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*Total*
Total	93	40	73	89	67	60	62	68	61	49	662
USA	26%	40%	41%	46%	37%	70%	56%	49%	74%	63%	49%
English Countries	26%	20%	22%	26%	28%	17%	19%	30%	15%	18%	23%
Europe	40%	25%	21%	16%	16%	8%	13%	13%	5%	12%	19%
Asia	4%	10%	5%	10%	15%	3%	11%	9%	7%	4%	8%
Latin America	4%	5%	11%	1%	3%	2%		1%			3%

* Similar as in Arnett (2008), '*English countries*' refers to Australia, Canada, New Zealand, and UK

Table 4. National origin of considered samples in ITS and AIED conferences.

	2002	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*Total*
Total	41	20	28	48	29	47	40	50	47	36	386
USA	34%	50%	61%	54%	55%	79%	75%	52%	81%	61%	61%
English Countries	37%	35%	29%	27%	28%	9%	13%	24%	6%	17%	21%
Europe	27%	10%	11%	13%	3%	9%	5%	10%	4%	14%	11%
Asia				4%	10%	4%	8%	10%	6%	8%	5%
Latin America	2%	5%		2%	3%			4%	2%		2%

- The overdominance of Western subjects in analyzed samples as noted in Table 4 raises strong assumptions of cultural biases already influencing the TEL research field[6] since Western subjects, especially those typical in research samples, "*are some of the most psychologically unusual people on Earth*", and consequently "*may often be the worst population from which to make generalizations*" (Henrich et al., 2010).
- A significant (major?) part of future TEL markets are in non-Western economies, especially fast growing countries like China, India, or Brazil.

It can be hypothesized from Tables 3 and 4 that non-Western educational needs, ideas and approaches currently remain largely unknown and neglected by the TEL community. In order to appropriately address them and as suggested in part 2, it is important for the TEL community to keep enforcing a user-centered approach, and place more emphasis in developing TEL systems with cultural abilities. These systems, referred to as *Culturally-Aware Tutoring Systems* (CATS), are introduced in the next section.

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[6] The strong reliance on the psychology domain in TEL research is likely to be another indirect source of cultural imbalance. As stated by Arnett (2008) and Henrich et al. (2010) there is a problematic Western dominance in psychology worsened by the fact that many researchers tend too easily to broaden the applicability of their results to the whole of mankind.

3.2. *Culturally-Aware Tutoring Systems*

Blanchard (2009) proposes to distinguish two varying CATS approaches:

- *Adaptation-Oriented CATS* are systems that try to understand the cultural profile of learners and adapt to it. Such systems are aimed at expressing some kind of cultural intelligence i.e. a "*seemingly natural ability to interpret someone's unfamiliar and ambiguous gestures the way that person's compatriots would*" (Earley & Mosakowski, 2004). For instance, Blanchard (2009) described the architecture of a multiagent system that adapts the displayed multimedia content according to dynamically-evolving cultural profiles of learner and cultural rules extracted from cross-cultural studies (e.g. Hofstede et al., 2010, House et al., 2004).
- *Acquisition-Oriented CATS* are systems that try to situate a learner in a culturally-relevant environment in order to teach intercultural skills and knowledge. For instance, the Operational Language and Culture Training System (OLCTS) developed by *Alelo* (Johnson, Friedland, Watson, & Surface, 2012) aims to provide situational learning to people by confronting them with pedagogical agents that can express cultural gestures and interact in a specific foreign language. It is worth noticing that acquisition-oriented CATS can benefit from adaptation-oriented CATS features since different cultural groups may develop different awareness about a target culture. Their members should consequently be trained according to different culturally-adapted approaches.

CATS are culturally-enhanced Intelligent Tutoring Systems. In a more thorough overview of CATS, Blanchard and Ogan (2010) have clarified how culture intersects with the typical modules of such TEL systems i.e. the curriculum, the tutor, the student model, and the graphical user interface, and it is one of the objectives of MAUOC to offer formalized and theory-grounded guidelines for creating properly enculturated versions of such modules.

4. MAUOC: The More Advanced Upper Ontology of Culture

4.1. *Motivation*

A significant (major?) share of the burgeoning projects on culturally-aware (educational) technologies has not been designed around solid theoretical groundings. The main reason for this state of affair is that there is a limited awareness among TEL designers and researchers on the variety and depth of cultural domain conceptualizations, which also certainly accounts for the frequent categorization of culture as an ill-defined domain.

Despite the obvious existence of many related ill-structured problems (Simons, 1974), the cultural domain is not as ill-defined as TEL scholars frequently believe (including the authors of this paper in the past). However the diversity and complexity of explanatory sources makes it hard for newcomers to distinguish the valid scientific ones from the far more common "folk" approaches. Parallely considering these scientific frameworks of interest to obtain a coherent ecology of complementary concepts brings even more challenges, and acquiring such a general scientific understanding of the cultural domain

consequently remains an intellectually intense and time-consuming task. Yet, having a coherent global view of the cultural domain is essential in order to ensure that design and development choices remain in-line with the objectives of a culture-related project, that they have been obtained on the basis of the most appropriate scientific knowledge available, and that they do not reflect oversimplistic or stereotypical approaches to culture.

As a heavyweight ontology project, MAUOC's first objective is to obtain a theory-grounded neutral and interdisciplinary conceptualization of the cultural domain by identifying scientifically-sound frameworks, extracting their common backbone, and formalizing these various sources under a unique and unified model. MAUOC consists of a set of formal definitions of complementary concepts to design and develop culturally aware systems that could address any kinds of cultural issues including those pertaining to the educational domain.

The next section provides an introduction to heavyweight ontology engineering. It serves the purpose of helping readers to better grasp characteristics of MAUOC as a heavyweight ontology project, as compared to lightweight ontologies such as most semantic web approaches.

4.2. *On heavyweight ontology engineering*

There are several ways of dealing with ontology engineering. This is frequently denoted by the use of *lightweight* and *heavyweight* qualifiers. People working on lightweight and heavyweight ontologies aim at producing an artifact they all refer to as '*ontology*'. Yet the meaning they give to this term drastically differs, which leads to strong variations in typical development procedures.

According to prominent ontologists (Smith, 2008; Mizoguchi, 2003), a major difference between lightweight and heavyweight ontology engineering approaches is that the former strives to find the solution to a problem known a priori whereas the latter attempts to remain as much domain and application-independent as possible. In heavyweight ontology engineering, future envisioned uses of the resulting ontology must not influence the conceptualization process itself and, rather than trying to achieve an operational model in a constrained time delay, experts focus on producing an account as objective and accurate as possible of the targeted domain or task.

Another major difference between lightweight and heavyweight ontologies lies in efforts to explicitly elicit the '*identity*' of concepts. In lightweight ontologies, it is common practice to inform concept identity just with the label naming the concept, and to rely on its '*expected proper meaning*', commonly the one considered by the ontology creator. This brings forth risks of inaccuracy, of varying concurrent interpretations and of lack of a cohesive approach in the whole ontological conceptualization.

In heavyweight ontology, concept identity refers to the minimal inner structure of essential parts and properties that makes a mistaken categorization of an instance as another concept impossible. This explicitly elicited inner structure is based on concepts similarly defined in the ontology, and is considered as far more important for grasping

concept identity than any label naming the concept. Furthermore, heavyweight ontologies being philosophy-friendly, generally make extensive use of concepts whose identity has been thoroughly discussed, analyzed and challenged for centuries. People consulting a heavyweight ontology thus have to be careful to consider philosophical rather than common-sense and folk definitions of terms labeling both a concept and its essential parts and properties.

Although competing schools of thinking exist, major philosophy trends propose coherent ecologies of concepts whose related identities are documented e.g. in the *Stanford Encyclopedia of Philosophy* (SEP, 2013). Here lies an important remark: several heavyweight ontologies can provide different-yet-correct conceptualizations of a domain by adopting different philosophical perspectives. The overall quality of a heavyweight ontology eventually depends on the coherence of the whole conceptualization and on its ability to offer elegant solutions to any problems and challenges pertaining to the targeted domain.

In depth and erudite works on heavyweight ontology normally make use of a specific type of ontology referred to as '*top ontologies*'. They can be perceived as translations of philosophical traditions into an ontology-friendly format, and avoid ontologists needing to reinvent the wheel each time they start a new ontological project. Noticeable examples of top ontologies are the *Basic Formal Ontology (*BFO)[7], the *Descriptive Ontology for Linguistic and Cognitive Engineering* (DOLCE)[8] and the *Yet Another More Advanced Top-level Ontology* (YAMATO)[9]. They each provide a common ground for a galaxy of ontologies such as the *Open Biomedical Ontologies Foundry* for BFO (Smith, 2008). Though their respective pros and cons will not be compared in this paper, readers must be aware that YAMATO has been chosen as the grounding of our ontological analysis of the cultural domain especially for its strengths at conceptualizing representations, informational objects, and properties.

Besides adopting a top ontology as a philosophical grounding, another type of ontology referred to as '*upper ontologies*' contributes to better structuring ontological efforts. Upper ontologies are to be perceived as analogous to scientific theories (Smith, 2008) or even to meta-theories striving to identify the common core of several competing-yet-complementary frameworks considering the same domain from different perspectives. Well designed upper ontologies can thus act as bridges between disciplines and allow information collected by different communities to be efficiently transcribed on a common ground. Furthermore, upper ontologies are used to guide the development of lower-level ontologies focusing on specific disciplines/frameworks, these ones eventually leading to the development of '*application ontologies*' used to achieve operational solutions. Adopting such a hierarchical approach for ontological development efforts

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[7] Basic Formal Ontology: http://www.ifomis.org/bfo
[8] Descriptive Ontology for Linguistic and Cognitive Engineering: http://www.loa.istc.cnr.it/DOLCE.html
[9] Yet Another More Advanced Top-level Ontology:
http://www.ei.sanken.osaka-u.ac.jp/hozo/onto_library/upperOnto.htm

eventually ensures interdisciplinary and intra-disciplinary cohesions while facilitating the release of operational theory-grounded models.

It should now be obvious that heavyweight ontology engineering is far more time consuming than its lightweight counterpart, but it is also far more objective if done properly. The additional time conceded for such a thorough analysis and conceptualization eventually leads to massive qualitative gains (Smith, 2008), especially on the reuse, extension, and interoperability aspects.

4.3. *Design and development of the More Advanced Upper Ontology of Culture*

MAUOC is a heavyweight upper ontology. As such and as explained in the previous section, it strives to identify common core concepts of several cultural disciplines. In the course of creating the first stable version of MAUOC presented in this paper, several major frameworks from different disciplines have been carefully analyzed with the main sources of inspiration being listed in Table 5. The overarching goal of these parallel analyses was to figure out notions and principles actually referring to *natural concepts* (also called natural kinds, Jost and Hamilton, 2005) i.e. concepts that innately exist in nature and are not interpretations, adaptations, simplifications, or artificial merging of concepts.

As an upper ontology, MAUOC also remains abstract and must be positioned into a larger ontological effort whose aim is to scaffold the development of future operational solutions for developing culturally-aware technology. We refer to this hierarchical ontological approach as the MAUOC Ontological Ecology (MOE, see Figure 1) and as readers will understand, it will be a long-term endeavor.
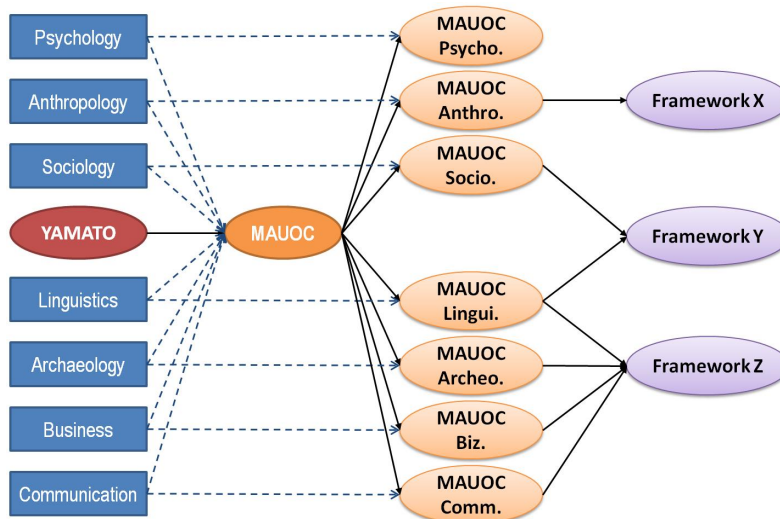

Figure 1. The MAUOC Ontological Ecology.

Table 5. Main cultural frameworks and sources of inspiration in MAUOC development.

Main references	Brief description
Memetic Theory (Dawkins, 2006)	A theory that suggests that cultural evolution shares similarities with genetic evolution. It is centered around the notion of 'meme' as basic cultural units i.e. the cultural counterpart to 'gene'.
Dual Inheritance Theory. See (Henirch & McElreath, 2007) for an overview	A prominent contemporary approach to culture in evolutionary/cognitive anthropology.
Sperber's Epidemiology of Representation (Sperber, 1996)	Another influential theory in evolutionary/cognitive anthropology that is inspired by the epidemiology field and does not imply the notion of cultural replicators.
Distribution of cultural conceptualizations (Scharifian, 2003)	A psychology-based discussion on the notion of cultural conceptualizations, and on their distributions within cultural groups.
Culture and Cognition (Nisbett & Norenzayan, 2002)	A psychology-based overview of cultural influences on cognitive processes
System of Values of Hofstede (Hofstede et al., 2010). See Kirkman et al. (2006) for a 25-year review of related studies.	Originally developed in the field of business/leadership, this system of values remains the most commonly used framework in attempts to integrate cultural considerations in technology.
GLOBE system of values (House et al., 2004)	A system of values including both group and individual analyses. The main challenger of Hofstede's approach in business and leadership.
Schwartz Value Inventory (Schwartz, 1994)	Another system of values.
Cultural Intelligence (Earley & Mosakowski, 2004; Ang & Van Dyne, 2010)	Construct proposed in business/leadership to express, assess and improve behavioral, cognitive and affective intercultural skills.
Cultural framework of Alwood (Alwood, 1985)	A cultural framework that includes, but is not limited to, considerations for intercultural communication.
Schramm model of communication (Schramm, 1954)	A model of communication that insists on the importance of sharing fields of information for signal transmissions. It also describes a feedback loop to explain dynamic adaptations occurring in the course of a communication.
Berlo's model of communication (Berlo, 1960)	A model of communication that describes internal features of four essential part of a communication process (source, message, channel, receiver), and insists on the importance of culture for encoding/decoding.
Framework for intercultural training of Bennett (Bennett, 1986)	An approach for intercultural training that proposes a developmental model of intercultural sensitivity.
Cultural Framework of Hall (Hall, 1983)	A cultural framework that suggests that *space, context* and *time* are essential dimensions to understand how people behave, communicate and impact on their living environment.
Theories linking Culture and Psychology (Cooper & Denner, 1998)	An overview of major frameworks attempting to link culture and psychology. This includes individualism-collectivism theories, ecological systems theories, cultural-ecological theories of adaptation in stratified societies, social identity theories, ecocultural and sociocultural theories, theories of structure, agency, and social capital, and *multiple worlds* theories.
Politeness Theory (Brown & Levinson, 1988)	A theory that suggests that there are universalisms in ways of ensuring politeness in interpersonal communication.
Community of practices (Lave & Wenger, 1991)	An approach centered around the notion of community of practices as groups of individuals who share a craft or a profession.
Universals and cultural differences in facial expression (Ekman, 1972)	Research suggesting that human beings have an innate body of unconscious facial reactions to affective antecedents, and also that cultural differences exist on the way human beings deal with their emotions.
Culture and Emotion (Mesquita et al., 1997; Mesquita & Leu, 2007; see also Elfenbeim & Ambady, 2003)	A review of research finding, essentially in humanities, that investigate the interplay of affect and culture.
Pyysiainen's Ontology of culture (Pyysiainen, 2002)	A contemporary philosophical reflection on the nature of culture.
Allport inspired studies (Oishi, 2004; Jost & Hamilton, 2005)	Research studies realized by several distinct researchers on the nature of sociocultural stereotypes or the relation between culture and personality.
Stanford Encyclopedia of Philosophy (SEP, 2013)	A repository of theory-grounded definitions of philosophical concepts and knowledge.

Following MAUOC development itself, the second step of MOE consists in creating MAUOC-based ontologies of cultural disciplines i.e. ontologies that should make use of terms acknowledged by discipline-specific communities, and also integrate discipline-specific constructs that do not appear in MAUOC because they are not natural ones. These discipline-specific ontologies will thus require extensive knowledge of both the targeted discipline and the MAUOC ontology.

The third step of MOE consists of creating the ontological translations of cultural frameworks by using concepts defined in one or more discipline-specific ontologies or directly in MAUOC. The direct translation of a cultural framework with MAUOC concepts only is also possible.

This whole process will also be the occasion to iteratively improve and validate MAUOC. In this paper, only the first stable version of MAUOC is presented but the next development stages are graphically summarized in Figure 1.

MAUOC can be seen as a culture-focused layer complementing YAMATO. As such it is grounded on concepts defined in this top ontology. In order for readers to have the necessary knowledge to understand MAUOC, a succinct overview of YAMATO is provided in the next section.

4.3.1. *An overview of YAMATO*

Figure 2 presents a taxonomy of YAMATO concepts that are further refined in MAUOC.

In order to limit the complexity of this overview, only concepts of direct interest for the upcoming presentation of MAUOC are mentioned i.e. some intermediate concepts have been voluntarily removed from the taxonomy. Readers can consult Mizoguchi (2010) for a complete presentation of YAMATO.

In the tree hierarchy in Figure 2, any concept *B* appearing as a branch of another concept *A* must be understood as a specialization of *A* i.e. a full *A* with additional parts and properties. Since YAMATO and other top ontologies have been designed according to long-lasting philosophical works and despite differences, concepts similar to most of those presented in Figure 2 can be found in other major top ontologies.

In YAMATO, an **entity** refers to something existing in the real world, independently of any other thing whereas a **dependent entity** refers to something that cannot exist independently i.e. it has to be bounded to another **entity**. One specialization of **dependent entity** is referred to as **property** (e.g. width, height, age, etc.). This is the only one that has been further refined in MAUOC.

YAMATO identifies three specializations of **entity**, the first two of them (**abstract** and **physical**) being commonly discussed in the ontology literature.

- **Abstract** are **entities** that *neither need 3D space nor time to exist* (e.g. *truth*). This concept is mentioned for information purpose only since MAUOC does not consider any further specializations of **abstract** besides those already defined in YAMATO that will not be discussed for clarity purpose.
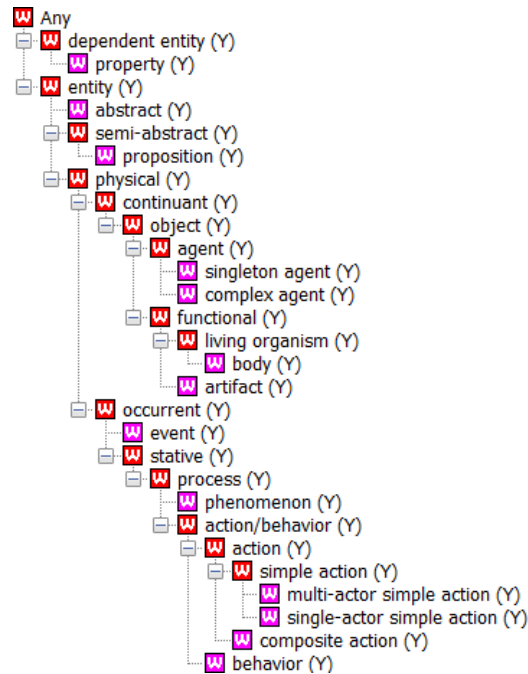
Figure 2. Simplified and limited taxonomy of YAMATO.

- **Physical** are **entities** *that need both 3D space and time to exist*. **Continuant** refers to any **physical** whose main dimension to be considered for identity attribution is *3D space*, whereas **occurrent** refers to any **physical** whose main dimension to be considered for identity attribution is *time*.

  Among specializations of **continuants**, **objects** are the ones that are constituted of substance with **agents** referring to the specific **objects** that possess a mind to manage intentions. YAMATO also differentiates **singleton agent** from **complex agent**, the former pointing to an individual agent whereas the latter referring to a group of **singleton agents** that act as if they had a shared mind and were moved by group-level intentions. Besides **agents**, **functionals** refers to **objects** whose identity depends first on their function. **Living organisms** like a **body** have a genuine life-related function and have emerged from natural evolution whereas **artifacts** are artificial **functionals** that have been designed and created by **agents**.

  Among specializations of **occurrent**, **events** are the ones that *are state-less and must exist as a whole*. No additional event specialization is defined in MAUOC. The other kind of **occurrent** is referred to as **stative**, which means it can have different states. Among the important **statives** for MAUOC are **situations** which

are described as "*interaction patterns between participants*" and **processes** which consist in time-directed state-to-state evolutions. Distinctions between two **process** specializations are particularly important. On one hand **phenomena** refers to **processes** that have no doer. On the other hand **actions/behaviors** refer to **processes** performed by a doer with **action** being used when the doer is an **agent** (it has intention), and **behavior** being used when the doer has no intention (typically when it is an **artifact**). **Composite actions** and **composite behaviors** refer to actions and behaviors that are respectively constituted of sets of **simple actions** and **simple behaviors**. **Single actor simple actions**, done by an individual actor, are also distinguished from **multi-actor simple actions** that require the involvement of more than one actor.

- **Semi-abstract** is a specific category of **entities** introduced by YAMATO. It is defined as an entity that "*needs only time to exist*". A particularly important type of **semi-abstract** is **proposition**. This is a complex notion that is central to philosophy, and is sometimes referred to as "*the primary bearers of truth and falsity*" (McGrath, 2012). Readers can consider '*innate idea*' as a lousy definition to **proposition** in the reminder of this paper. However it is strongly advised to consult (McGrath, 2012) for a broader overview on this important philosophical notion.

4.3.2. *MAUOC extensions of YAMATO*

As pointed out earlier, MAUOC is not created from scratch. Rather, it is grounded on the huge ontological efforts already performed for YAMATO development. In other words, MAUOC can be seen as a pluggin to YAMATO with additional YAMATO concept specializations and explicit descriptions of core-cultural concepts. The presentation of MAUOC additional concepts is structured according to key branches of YAMATO taxonomy. As mentioned in the previous section, there is currently no MAUOC extension for the 'abstract' branch. Consequently:

- Figure 3 presents **semi-abstract** extensions where key concepts to explain the identity of the **culture** concept are defined.
- Figure 4 presents **physical** extensions to clarify processes directly or indirectly related to culture as well as cultural manifestations.
- Figure 5 presents **dependent entity** extensions with a particular focus on **properties** used to better characterize the identity of several key concepts.
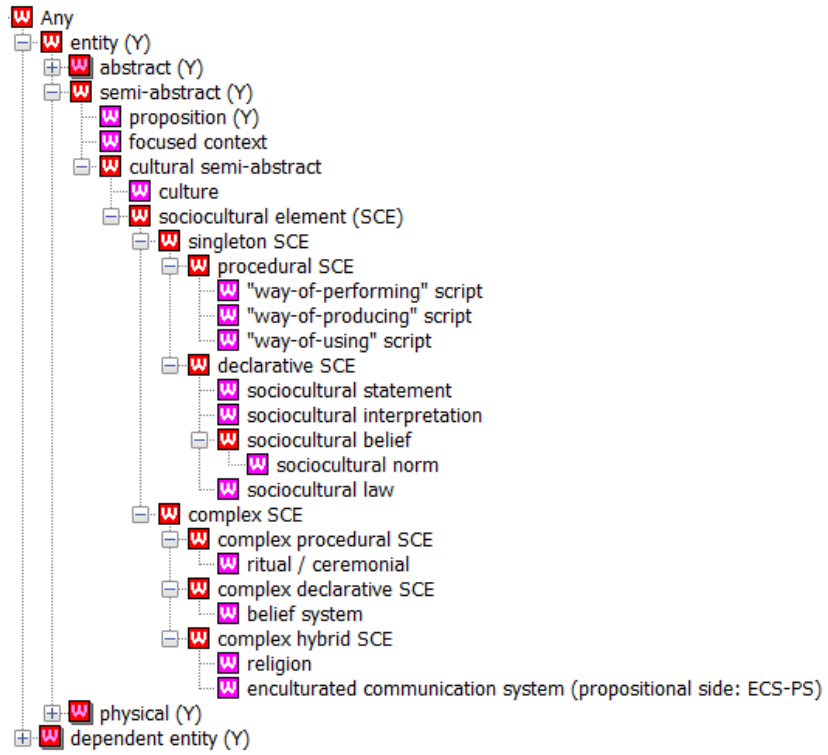
Any
- entity (Y)
  - abstract (Y)
  - semi-abstract (Y)
    - proposition (Y)
    - focused context
    - cultural semi-abstract
      - culture
      - sociocultural element (SCE)
        - singleton SCE
          - procedural SCE
            - "way-of-performing" script
            - "way-of-producing" script
            - "way-of-using" script
          - declarative SCE
            - sociocultural statement
            - sociocultural interpretation
            - sociocultural belief
              - sociocultural norm
            - sociocultural law
        - complex SCE
          - complex procedural SCE
            - ritual / ceremonial
          - complex declarative SCE
            - belief system
          - complex hybrid SCE
            - religion
            - enculturated communication system (propositional side: ECS-PS)
  - physical (Y)
- dependent entity (Y)

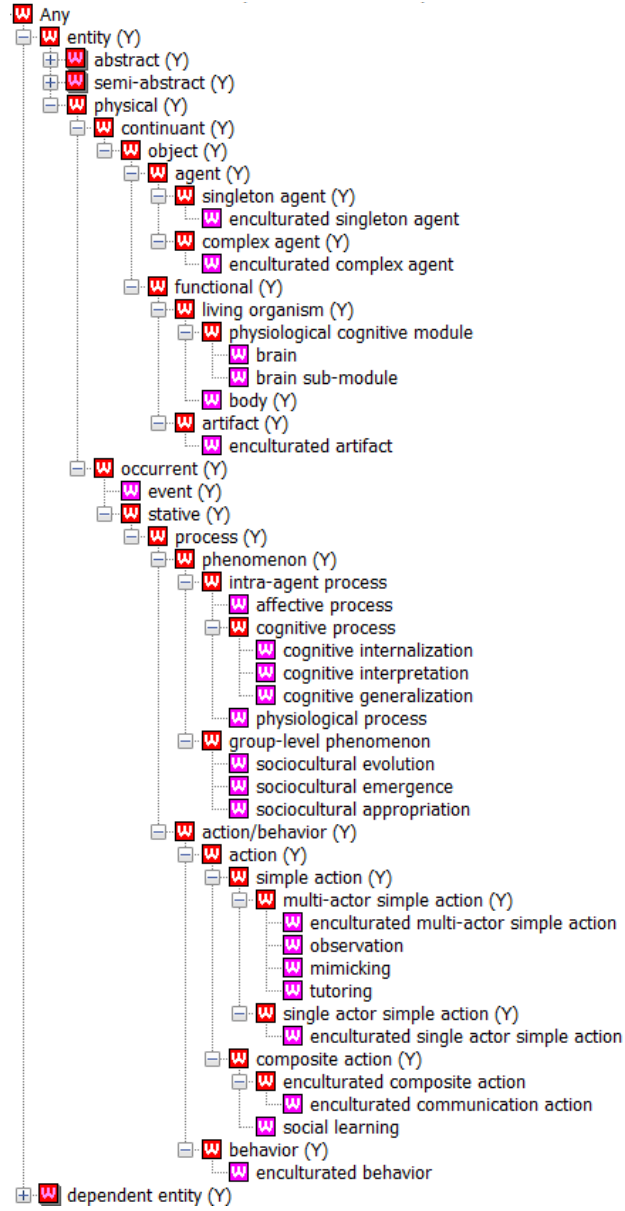Figure 3. 'Semi-abstract' extensions in MAUOC.
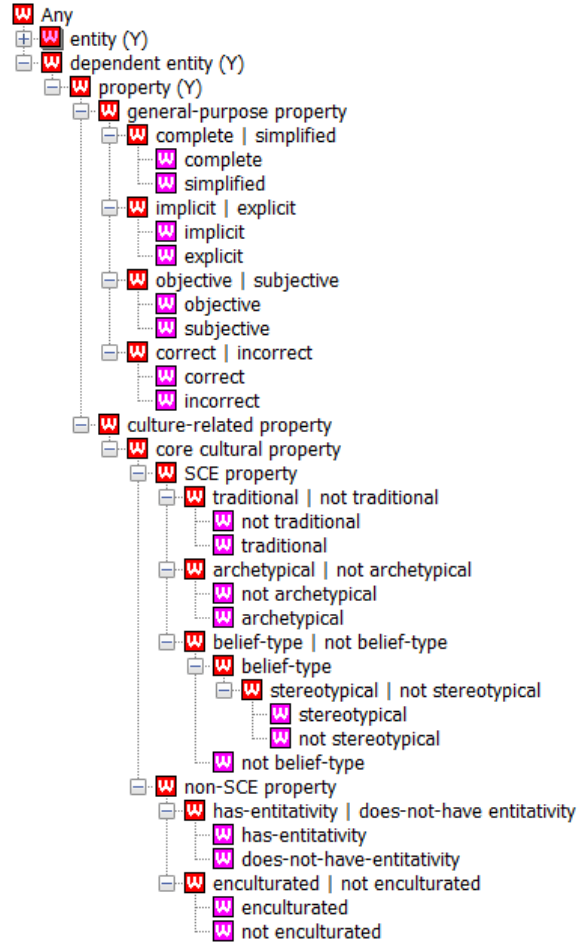
Figure 4. 'Physical' extensions in MAUOC.

Figure 5. 'Dependent entity' extensions in MAUOC.

Although we have split the MAUOC taxonomy in three figures, this heavyweight upper ontology is an ecology of concepts with complex intertwining. Consequently, in the following description of MAUOC, readers must expect to go back and forth between these figures to get the global understanding of this model.

As a semi-abstract extension of YAMATO, MAUOC first defines a concept referred to as **focused context** since it is commonly essential to consider cultural elements and experiences within their context in order to grasp their proper nature and **focused context** is generally similar to just '*context*' in natural language but, by using the '*focused*' adjective, we insist on the fact that it is to be defined from the perspective of a *center-of-focus* (e.g. the context of a car, a person, an idea, an epoque, a country).

Focused context is grounded on the idea that "*contexts have an infinite dimension hence they cannot be described completely*" (Dichev, Dicheva, & Fischer, 2007). Dourish (2001) especially advocates the interest of not only considering spatio-temporal dimensions but also other dimensions such as the social one or the cultural one. **Focused context** must thus be seen as a **simplified**-yet-**objective** account of the context of its center-of-focus that concentrates on the description of the specific *dimensions* that are relevant to its expected usage (for instance the spatial dimension, the social one, the geographical one, the political one, and so on). The definition of a dimension is organized around the *facet* of its center-of-focus in this dimension, facets of surrounding elements in this same dimension, and a list of *dimension-specific relations* linking the center-of-focus facet to the surroundings facets.

In MAUOC, no distinction is made between context and situation. Strictly speaking, disambiguating context and situation refers more to a terminological issue than to a conceptual one since these terms are used interchangeably most of the time and the internal structure of both of them (their identity) does not seem to be significantly different. **Focused context** was originally named as *centered context* in Blanchard et al. (2010) where a more thorough definition can also be found.

In **semi-abstract** extensions also lie the main thrust of MAUOC that we have grouped under the category **cultural semi-abstract** i.e. all the **semi-abstract** concepts that constitute all the inherent parts of cultures, referred to as **sociocultural elements (SCE)**, as well as the **culture** concept itself. Indeed, **culture** is a semi-abstract concept itself since all its parts, the **SCEs**, are of this kind. We defend this statement by insisting on one key property of culture: it is socially learned. As a **multi-actor group phenomenon**, **social learning** has been thoroughly discussed and clarified in anthropological theories (see Henrich & McElreath, 2007; Sperber, 1996). Its frequent assimilation to a download process is an inadequate and dangerous oversimplification (see Henrich & McElreath, 2007) that is discarded in MAUOC. Rather, social learning is an imperfect process of transmission of information and recreation from **brain** to **brain** and only **propositions** can indirectly and imperfectly transfer in such a way. **Propositions** manifest as **cognitive process(es)** within a brain and **social learning** thus consists of:

(a) a potentially imperfect manifestation of a **proposition** as **cognitive processes** in the emitter's brain;
(b) a potentially imperfect transcription of these cognitive processes as manifestations external to the brain through the use of various effectors of the emitter such as the body (for an implicit or explicit **action**) or the mouth (for spoken language);
(c) a potentially imperfect capture of the signal by sensors of a receiver in implicit or explicit social learning practices such as **observation** or **tutoring**;
(d) a potentially imperfect interpretation of this signal during the internalization phase that transforms it into cognitive processes within the receiver's brain.

An SCE can be socially transmitted since it consists only in a **proposition** that has the **archetypical** property (that will be referred to as archetype for the remainder of this paper) associated to a specific cultural group (to be clarified later). By archetype, we refer to the version of this **proposition** that is perceived as its proper/pure model. Associating an archetype *A* to a cultural group and eventually describing an **SCE** thus means that a significant share of group members internalize **cognitive processes** whose identity pattern is close-enough to *A* (Blanchard, 2012b) and can consequently be categorized as congruent to *A* through a **cognitive generalization** process. In computer science, *supervised clustering algorithms* can be seen as an operationalization of this phenomenon.

SCEs are specialized either as **singleton SCEs** or **complex SCEs** and two **singleton SCE** specializations are identified, **declarative SCE** when the related archetype is of declarative nature, and **procedural SCE** when it is of procedural nature.

Declarative SCE is also referred to as *core-cultural ideas* (Cooper & Diener, 1998) and MAUOC distinguishes the following kinds:
- **sociocultural statements** when they are culture-specific ideas with no precise target.
- **sociocultural interpretations** when their function is to provide a specific meaning to a natural target and/or to establish connections between SCEs. They may also have affective implications.
- **sociocultural norms** when they are rules and guidelines whose function is to express what is right or wrong (good or bad) from the perspective of the cultural group. Depending on groups, many sociocultural norms can be **implicit**.
- **sociocultural laws** when they are **explicit** rules and guidelines enforced by institutions of the cultural group.

Besides being **archetypical**, some **sociocultural statements** and **sociocultural interpretations** can also be characterized as **belief-type** when group members expect their content to be true despite it could actually be false (Schwitzgebel, 2010) and **stereotypical** when they are not only **belief-type** but also simplified and potentially incorrect. It is worth noticing that stereotypes can be positive or negative (see Jost and Hamilton (2005) for an overview of research on stereotypes).

Procedural SCEs are currently categorized along three types of sociocultural script in MAUOC[10]. They are scripts as defined in Schank and Abelson (1977) however MAUOC insists that most scripts are not culture-free and are related to specific cultural settings. The sociocultural script concept was first introduced in social sciences (Triandis, Marin, Lisansky, & Betancourt, 1984) and linguistics (Goddard & Wierzbicka, 2004), but MAUOC proposes a more generic approach to it as scripts that inform **archetypical** cultural manifestations such as **enculturated actions**, **enculturated behaviors** or **enculturated artifacts**:
- **way-of-performing scripts** describe the archetypical way that members of a specific group have of doing an **action**.

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[10] Currently MAUOC only includes the three mentioned sociocultural scripts and their related specializations, but we have not completely given up the idea that other families of sociocultural script exist as well.

- **way-of-creating scripts** describe the archetypical way that members of a specific group have of conceiving/creating/crafting an **artifact** and its related **behaviors**[11]
- **way-of-using scripts** describe the archetypical way that members of a specific group have of using an **artifact**.

A **complex SCEs** refers to a set of intricate **singleton SCEs**. This set can include either exclusively **SCEs** of the same kind i.e. a **complex declarative SCE** such as a **belief system** and a **complex procedural SCE** such as a **ritual/ceremonial, or SCEs** of different kinds (both declarative and procedural) in the case of **complex hybrid SCEs** such as **religion** or **SCEs** related to a **communication system** that could manifest both through verbal and nonverbal channels.

The **enculturated** property can now be clarified as an explicit account that a **physical** of any kinds is attached to one or more **SCEs**. In other words, any **physical** defined in YAMATO (e.g. **artifact**, **behavior**, **action**, **event**) can be **enculturated** if a cultural group is likely to *perform/create/use/interpret* it following a specific archetypical script. There is however a special meaning of **enculturated** when applied to agents.

- **Enculturated singleton agent** is viewed as an agent whose identity depends on various cultural influences i.e. it internalize **SCEs** possibly associated with different groups (Blanchard, 2012b). All human beings are indeed **enculturated singleton agents** and can be categorized as members of more than one cultural group (Blanchard, 2012b).
- **Enculturated complex agent** is the formal term for a cultural group in MAUOC. It is a set of **enculturated singleton agents** whose identity depends on possessing the **entitativity** property. **Entitativity** may rely on various cues such as proximity, similarity, cohesiveness, or interdependence (Jost & Hamilton, 2005; see also Castano, Yzerbyt, & Bourguignon, 2003; Hamilton, Sherman, & Castelli, 2002; Lickel, Hamilton, Sherman, & Uhles, 2000). **Enculturated complex agents** also possess a specific repository of **SCEs** (their specific **culture**) that can be more or less precisely and explicitly identified as such by its own members and outsiders. From this definition, one can see that enculturated complex agents not only exist at country level (as used in FNCD-H) but can be defined in many ways and according to an (infinite) variety of criteria as long as **entitativity** is achieved either from the perspective of insiders and/or outsiders.

Characterizing instances of **enculturated complex agents** and **enculturated singleton agents** is thus a complex intertwined back-and-forth process where new cognitively-manifested versions of archetypes appear and spread at the **enculturated singleton agent** level as results of imperfect **social learning** transfers, and eventually lead to (implicit) acknowledgements of new archetypes by sets of agents that have **entitativity**. Effects of this process, referred to as **cultural emergence**, are thus visible at the **enculturated complex agent** level.

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[11] As a reminder, **behaviors** in YAMATO as well as in MAUOC are related to **artifacts**, not to **agents**. In the later case, **action** is the proper concept to be used.

Finally, continuous and dynamic **cultural emergences** along with other group-level processes such as the **appropriation** by **enculturated complex agents** of **SCEs** that have originally emerged in other groups cause cultures to change in a process referred to as **cultural evolution**.

5. Conclusion

In this paper, we have described a heavyweight ontology effort to abstract notions of many major cultural frameworks and research from different disciplines into a unique, coherent, and theory-grounded model of the cultural domain referred to as the *More Advanced Upper Ontology of Culture* or MAUOC. As such, MAUOC can thus be seen as a meta-theory of culture, and as far as we know, it is the first and only existing endeavor of this kind.

Though we agree that MAUOC requires some time to be properly understood and mastered, we believe that the related positive outcomes are very significant for newcomers willing to develop Culturally-Aware Tutoring Systems (CATS) since it concentrates and structures in one place the many scientific-grade notions needed to get a coherent view of this domain while translating them into a common ground.

MAUOC is thus a particularly relevant source from which to extract guidelines for CATS development. As examples, it provides theory-supported structures that explain:

- the central role of cognitive processes into the culture phenomenon (see Henrich & McElreath, 2007; Sperber, 1996), which facilitates hybridizations with models of human features such as cognition, affect, motivation, behaviors, and personality, that are already popularly used in TEL design and development. This should also inform new cognition-friendly TEL strategies and architectures as well as original developments in the emerging field of enculturated (pedagogical) agents (see Rehm, 2010) that are genuinely cognitive,
- transitions of innately individual cognitive processes into group-level sociocultural phenomena, and the opposite as well. This is a critical step for developing non-overly simplistic approaches to properly use cultural information collected at group level (e.g. Hofstede et al., 2010; Schwartz, 1994) into TEL systems that target individuals,
- how elements of the World are eventually linked to specific cultural groups to become cultural manifestations. In educational settings, this could for instance help categorizing locally-relevant practices, establishing distances between them, and making hypotheses about their level of appropriateness in contexts other than the one of origin.

The deep and thorough analysis of the cultural domain performed in the context of MAUOC development also enlightens reasons for varying efficiencies of TEL systems when deployed in new environments i.e. they may not be culturally-adequate to the local educational situation. This is directly in line with this special issue focusing on ways to situate learning transfers. Currently and as it has been shown in this paper, TEL research is Western-dominated. With TEL systems reaching societies where they were almost

completely unavailable previously, it is important for the research community to find ways to better integrate locally respectful and efficient educational paradigms and strategies while ensuring that this integration process still matches a solid scientific approach. However such a goal is complicated by the important number of cultural frameworks and approaches in the literature. With MAUOC, TEL practitioners now possess a conceptual tool to transcribe on a common ground educational practices that are characteristics of different cultural contexts, and to figure out i) mechanisms for evaluating their ability to offer efficient learning transfer opportunities in different settings, or ii) proper means to adapt them to new culturally-distinct learners.

MAUOC is the keystone to a more complex ontological effort, referred to as the MAUOC Ontological Ecology (MOE) which is currently in its early stages. It can be seen as the reverse process of the one that resulted in MAUOC in that it was created from many distinct cultural sources. Indeed, the objective of MOE is to develop MAUOC-based lower-level ontologies where notions and principles of cultural disciplines and frameworks are transcribed on a common MAUOC-based conceptualization ground. The overarching goal of MOE is thus to permit easy interoperability of cultural data and applications even though they have been collected or created in different disciplines and frameworks, and even though they may look incompatible at first sight. Finally, since it can also be understood like a retro-engineering loop, the development of these lower level ontologies will also help to validate and improve the overall quality and coherence of MAUOC.

In order for MAUOC to drastically improve theory-grounded CATS development, we plan to release a dedicated communication center in the form of a website, which will be available in the near future. It serves the purpose of allowing people interested in CATS development and MAUOC to organize as a community and share views, thoughts, development efforts, and opportunities for collaboration.

As stated earlier, heavyweight ontology experts will develop MAUOC-based ontological transcriptions of cultural frameworks and models in the context of MOE. However, we are aware that it is difficult for many TEL scholars to achieve operational solutions directly from heavyweight ontologies since much of the TEL community is not familiar with this kind of precise artifact. In order to address this, we plan to initiate discussions for developing and releasing MOE-grounded tools that would hide the more theoretical ontological aspects to end-users, and concentrate on providing them with practical support for CATS development.

Finally the end-user community will also be key in the future evolution of MOE. We plan to develop crowd-based tools to identify and correct limitations and weaknesses of MOE ontologies following the empirical use of MOE-related products. These tools could also reveal additional features and suggest future ontological expansions to heavyweight ontology experts cited above.

The emerging field of CATS research is very appealing and one can make optimistic forecast about its influence on education in the World of tomorrow. It is a means to offer innovative educational opportunities in developing environments, or to enhance the

ability of TEL systems to successfully and efficiently penetrate new culturally-specific markets. If MAUOC does not provide directly operational solutions, its benefit is elsewhere: it offers the opportunity for the emerging CATS community to talk the same theory-grounded language and there is possibly no better way for it to be acknowledged as a scientific research field.

Acknowledgments

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