A Multi-agent System Architecture for Modeling Multicultural Interaction

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Abstract

This paper presents an approach for managing a synthetic model of culture based on the cognitive processes that allow humans to display culturally biased behaviors. We present cognitive agents as the underlying methodology for simulating such processes, introducing their main capabilities and using them to simulate the main processes involved in culture management. We present the architecture of an agent with cultural background based on the OMAS cognitive agent architecture. As a study case, we give some examples showing how cultural conflicts in intercultural interactions are recognized.

Keywords: *Culture, cognitive agents, models of culture.*

1. Introduction

Culture is an integrated pattern of knowledge, beliefs, and behaviors, shared by people in a place or time [1]. According to this definition, culture is an aspect that depends to a considerable extent on the regions and countries where individuals are located.

Different phenomena, like globalization, migration, and distribution of workforce, in addition to new and more efficient communication channels allow people from different regions -and necessarily with different cultural backgrounds- to interact on a daily basis in both distributed and co-located environments. In such global interactions, cultural differences must be taken in account. Such differences, ranging from superficial manifestations like language and jargon to deeper beliefs, are a common source of misunderstandings and conflicts, which can reduce performance and even break down interactions.

Different studies presenting common cultural conflicts have been made. However, most of such studies are limited to providing theoretical explanations based on assumptions about cultural differences. This is derived from the wide and ambiguous nature of the concept of culture, which represents a main barrier for developing formalisms or tools for understanding, managing, and reducing the impacts of conflicts, misunderstandings, and uncommon behaviors arising from cultural differences.

This paper presents a synthetic model of culture based on a multi-agent system composed of cognitive agents. The objective of the model is to work as an underlying platform for the development of different cultural-aware applications that may range from simulations, to conversational agents, to human-human interaction facilitators.

Formalizing a concept like culture necessarily implies a trade-off between complexity and realism. We decided to base our approach on cognitive agents because they present several capabilities allowing them to simulate different culture-related processes unconsciously performed by humans.

Our agents are based on the OMAS agent architecture, a cognitive agent architecture developed by Barthès [2]. Our approach consists in simulating human management of culture through capabilities of cognitive agents. First, we present a literature research about the main features of culture, highlighting the involved mental processes. Then we introduce cognitive agents and the features that make them suitable for simulating culture management. Then, we describe the OMAS agent architecture, as well as the proposed approach for simulating the management of culture. Finally, we present a study case of an application for supporting intercultural human-human collaboration. This application was developed using the proposed architecture and adding some application-specific functionalities.

2. Formalizing Culture

As mentioned before, cultural conflicts are the result of differences among beliefs of individuals. Several anthropologists characterized and grouped such beliefs into what are called *cultural dimensions*. Depending on the scope of their studies, different authors propose different sets of cultural dimensions [3, 4, 5, 6, 7, 8].

In short, cultural dimensions describe, in a measurable way, how common practices are oriented regarding opposite reference points. Some examples are: *time management* (monochronic vs. polychronic), expressing the preference of people for managing tasks concurrently or sequentially [8]; *individualism* (individualist vs. collectivist), expressing if people prefers working isolated or as members of a team [3]; and *universalism* (universalist vs. particularist), expressing the degree in which people prefer following rules or making exceptions [4].

Authors proposing cultural dimensions abstract culture as sets of such cultural dimensions. Sets proposed by researchers depend on the scope of their research. Among the most utilized, we can cite the set proposed by Hofstede [3], whose dimensions are related to organizational collaboration; Hall [6, 7, 8], whose dimensions are related to non verbal communication; Trompenaars [4], whose dimensions are related to human-human, human-time, and human-environment interactions; and Schwartz who developed a model based on the importance given by humans to typical goals like power, independence, or security [5].

Such abstractions of culture have been used in the development of different culture-aware applications. Rehm et al. [9] propose a model for deriving the cultural background of a user based on his observable multimodal behavior while interacting with an embodied conversational agent. Nazir et al. [10] developed an agent model whose combination of culture, personality and emotions influences the decision making process. Shi et al. [11] propose a framework to simulate the behavior of individuals based on fuzzy rules. Finally, Hodgson et al. [12] researched the effects of culture on military missions and developed a tool for calculating ideal cultural profiles for different missions. Jan et al. [13], propose a model for providing a cultural background to conversational agents which allow them to show more realistic nonverbal behaviors related to aspects like gaze, overlap turn taking, and physical distances.

3. Culture and Cognitive Processes

Features proposed as cultural dimensions differ dramatically depending on the scope of each research; however, at the same time they present similarities that allow groups to learn, express, and share them in similar ways. How is culture managed? Or in other words, what are the processes and activities allowing humans to show culturally biased behaviors? This

section summarizes some agreements on these topics, obtained from evidences found in the literature.

Culture is collective; we construct a cultural configuration by mixing the cultural influences of different groups where we belong. Hofstede [3] affirms that there are groups inside a culture, like family, school, religion, and work that can be considered as subcultures influencing the behavior of individuals in different ways. Vatrapu [14] states that culture is shared knowledge created by groups for ruling the way in which people perceive, interpret, and express the reality around them. Straub [15] states that culture is shared by individuals who share the same space and engage in similar activities. These authors also agree that fundamental cultural features are acquired from groups during childhood, and after that, changing culture becomes increasingly complicated as time passes.

Culture is personal and unique; although culture is always a collective phenomenon, personal features and experiences produce variations in cultural values which derive in unique cultural configurations for each individual. Hofstede [3] recognizes the mutual influence of personality and culture, which produces unique cultural configurations. Schall [16] affirms that when members from different cultures meet and interact, they are mutually influenced, producing changes in each of their cultures. In addition, Scherer [17] considers that own beliefs and thoughts inherently change as time passes, producing an evolution in culture. Keesing [18], Vatrapu [14] and Schall [16] prioritize the influence of context in culture, so the environments to which an individual is exposed play an important role on his culture.

Culture is subjective; we modify our perception about the context by applying a cultural filter. Boas [19] affirmed that our ideas and conceptions are true only in the groups to which we belong. Sumner [20] developed the term ethnocentrism, stating that own culture is particularly important, and that other cultures are normally judged in relation to one's own. Herskovits [21] affirms that judgments are based on experience, which is strongly biased by the enculturation of each individual.

Culture is dynamic; individuals of the same groups are exposed to similar influences, and therefore they change their cultural preferences in similar directions. As consequence, culture of new group members evolves according to influences to past members. Keesing [18] states that culture evolves as result of technological development and economic, politic, and social changes. Hall [7] affirms that groups develop their main culture, maintaining a continuous process for adapting it, according to the evolution of the context. Vatrapu [14] considers culture as a dynamic and continuous process, instead of a static and defined one. Hofstede [3] states that culture is changeable as members of groups are exposed to external influences.

Culture influences behaviors, emotions, and cognition; our decision making processes are highly influenced by cultural values. Several theories even construct models of culture based on observable behaviors. For example, Hofstede [3] describes culture in terms of five cultural dimensions, each of them explained in terms of attachment to stereotypical behaviors. Trompenaars [4] studies culture in terms of the way in which people solve problems. Hall [7] studied the influence of culture in physical distances and gazes while people communicate. Schall [16] identifies cultural differences as the main influence in the way in which people obtain, interpret, and share information. Regarding emotions, several studies state that culture represents a high influence in the way in which people manage and express emotions; Trompenaars [4] even identifies certain patterns of behavior defining whether expressing emotions is acceptable or not within a given culture.

4. A Culture-Aware Agent Architecture

The previous section shows that management of culture involves different processes and activities allowing humans to display cultural biased behaviors. We propose using cognitive agents because of their suitability for emulating such processes. This section describes the advantages of using cognitive agents along with details about their implementation specifically in the OMAS agent architecture [2].

The OMAS platform provides three kinds of built in agents: personal assistants, service agents, and transfer agents. Personal assistants are in charge of interfacing users, service agents provide diverse services depending on the application, and transfer agents are in charge of network communications and interfacing external systems like other multi-agent systems or web services. Specifically, the inclusion of personal assistant agents makes OMAS a suitable platform for developing systems highly dependent on user interaction, like the case of supporting multicultural collaboration.

4.1. OMAS Agents Cognitive Capabilities

A cognitive agent is a software component which proactively acts in order to reach some objectives based on its knowledge, the skills it possesses, and the information it retrieves from its context. This section describes some capabilities of OMAS cognitive agents which allow them to display such behavior.

4.1.1. Autonomous execution and proactive behavior: OMAS agents execute autonomously in the background and respond to stimulus by means of their *skills*. Skills are predefined behaviors which can be executed by an agent when it receives a request from other agent or from another element in the environment. This capability allows agents to constantly analyze user interactions and timely react whenever a potential cultural conflict is detected.

They can also display goal-oriented behaviors; an agent possesses a predefined set of goals, and given a scenario they can construct a plan for achieving them, which can involve activities from other agents. Furthermore, an agent can build goals dynamically. For example, an objective of agents supporting demographically similar users is to emulate the evolution of the corresponding culture by maintaining a shared representation reflecting changes of the whole group.

4.1.2. Structuring and Storing Knowledge: OMAS agents structure their knowledge by means of ontologies, which are formalized with the MOSS knowledge representation language. They include definitions of different ontologies related to their built-in functionalities, and also can be provided with other ontologies required for the specific functionality of each agent. It is by means of ontologies that our agents manage knowledge about their cultural profiles and about the cultural profiles of other agents.

4.1.3. Perception of the Environment: OMAS agents can perceive contextual information in order to update their knowledge and adapt their behaviors accordingly. Such perception is done by incoming messages. As an example, users can interact with personal assistants through a vocal interface, and user utterances are delivered as messages to personal assistants. Another example is the project proposed by Sugawara [22], in which agents are aware of changes in the workspace of the user by receiving information coming from sensors in the environment. Culture is product not only of the influences of other agents, but also is result of the influence of symbols and static elements in the environment. Our agents can receive messages emulating cultural influences becoming from the environment and modify their cultural profiles accordingly.

4.1.4. Reasoning Capabilities: cognitive agents possess inference mechanisms allowing them to produce new knowledge by reasoning over their knowledge base. OMAS agents have a persistent store for keeping their knowledge bases and can make inferences over them. In addition, the MOSS formalism allows performing specific queries which can be answered by the same agent or sent to other agents. This capability allows agents to consider their cultural configuration while choosing their actions.

4.1.5. Learning Capabilities: OMAS agents can implement skills for learning from experience. With such skills, OMAS agents can evaluate the results of certain actions, and they can adapt their behaviors in order to improve performance. Culturally enriched agents use this capability in order to adjust the cultural profile of the user based on his history of actions.

4.1.5. Collaboration: OMAS agents can work together in order to reach common goals. They can send and receive messages, and in this way they share information and make requests for executing skills. In addition, OMAS agents are aware of the existence and the capabilities of other agents, and they can generate plans involving the execution of skills from several agents. Our agents collaborate in order to maintain a shared representation of interactions composed by several individual actions. In addition, they share information about the cultural configurations of other users in order to detect cultural differences and derived cultural conflicts.

4.2. OMAS Agent Architecture

There are different modules in the architecture of agents. Depending on its type, an agent may or may not possess some modules.

The *net interface* module is in charge of handling message communication; the *skills* module contains the definitions of the skills that the agent can perform; the *world* module contains a description about other agents in the system; the *ontology* module contains the definition of ontologies and associated knowledge bases; the *self* module provides a self-description of the agent and stores the agent memory; the *control* module contains definitions of internal structures required for the functioning of the agent; the *user* module is included in personal assistants and provides a description of the user; finally, the *user interface* module is included in personal assistants for handling communication with the user, allowing vocal or typed interactions.

5. An Agent with Cultural Capabilities

This section describes our approach for an agent with cultural capabilities. The main objective of this architecture is to work as the underlying platform for diverse applications affected by culture. We base our approach on the analysis about culture presented in Section 3 and the capabilities of OMAS agents presented in Section 4.

5.1. Representation of Culture

In order to display culturally biased behaviors, our agents must be able to maintain a representation of their culture. Such a configuration must be quantifiable and at the same time flexible enough for expressing a subjective aspect like culture.

We use cultural dimensions for representing culture given that they provide a quantifiable model with strong theoretical foundations; in addition we quantify cultural dimensions based on linguistic variables, which adds flexibility to the model. Zadeh [23] defines linguistic

variables as "*a formalism for dealing with complex and ill-defined systems, whose behavior is strongly influenced by human judgment, perception, or emotions"*. We consider that this definition fits appropriately with the concept of culture: there is no rigid definition about culture and how to measure it, and the perception about it is completely dependent on judgment.

Thus, our agents are provided with cultural profiles composed by one or more cultural dimensions. The set of dimensions selected for composing cultural profiles depends on the domain of application. Formally, for an application considering n cultural dimensions, each agent A owns a cultural profile p_A composed of n values $d_{k,A} \in k\{1,2,...,n\}$, each of them representing its preferences about a cultural dimension.

Each cultural dimension in the cultural profile is managed by the agent as a linguistic variable. Using linguistic variables allows profiling an agent with values like *"very individualist and more or less risky";* something more natural than real numbers for a subjective aspect like culture.

In general, cultural dimensions measure a preference between two opposite points; anthropologists often explain such opposite points in terms of two sets of completely contrasting stereotypical behaviors and reactions to certain situations. For example, an extremely individualistic person would never pay attention to a collective task if he has a pending personal task. On the other hand, an extremely collective person would always contribute to a collective task, regardless of his personal tasks. Of course, in practice the decision of performing individual or collective tasks is influenced by many factors, and no one behaves as one of such extremes.

We propose modeling a cultural dimension as a linguistic variable with two primary terms, one for each extreme of the cultural dimension. We limit the measurement of a cultural dimension to the domain [0,100], with boundary values representing completely opposite points and values near 50 representing individuals who in general are not clearly biased to a stereotype.

The compatibility function of each primary term follows a sigmoid curve. Sigmoid curves are usually used in researches measuring personality traits like emotions, abilities and attitudes [24]. Specifically, our compatibility functions are characterized by the logistic function given by:

$$f(x)=1/(1+e^{-a(x-b)}),$$

where:

- *b* is the position of the center of the curve, i.e., the value between [0,100] which is considered as the equilibrium in preferences.
- *a* determines the smoothness of the curve, i.e., how dramatic is the change in preferences as values move away from the center of the curve. Note that the value of *a* is proportional to the slope of the curve in *b*.

Linguistic hedges are managed as proposed by Zadeh in [25], Boolean functions are managed using *min*, *max*, and *complement*, the most commonly used set of operations satisfying the required set of axioms [26].

Internally, each agent maintains an ontology with definitions of the different dimensions composing a cultural profile. Such ontology defines the parameters which determine the shape of the compatibility function for each of the involved cultural dimensions, as well as values determining the cultural preferences of different users. Values stored in the derived knowledge base and all computations are performed over defuzzified values.

Let us take as an example a cultural profile composed by three dimensions: time management, individualism, and universalism. An agent could be profiled as *"slightly particularist, more or less monochronic, and individualist but not very individualist"*. Figure 1 shows the compatibility functions of each of these values. The horizontal axis represents the value of the cultural dimension and the vertical axis denotes the compatibility of such value with the associated linguistic value.

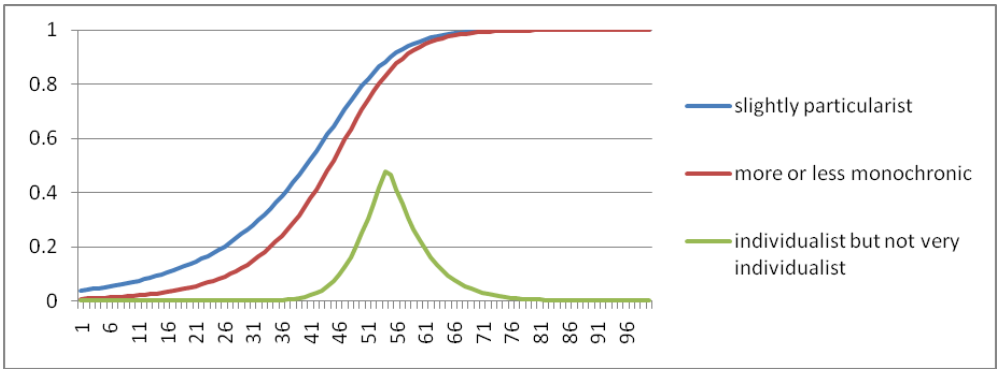

Figure 1. Examples of Typical Values in a Cultural Profile

5.2. Collective Cultural Profiles

Culture of individuals is strongly characterized by the groups to which they belong. Regarding to our agents, we model this phenomenon by assigning them initial cultural profiles based on their demographic information, which defines influences of groups like nationality, religion, generation, or education.

In order to compute such initial cultural configurations we use the method proposed by Hofstede [3] who computed cultural profiles for stereotypes of members of different countries. Hofstede designed a questionnaire for measuring his set of cultural dimensions and applied it to a sample of individuals in different countries. Then, he analyzed results statistically, obtaining a set of stereotypical cultural profiles for different countries [27].

Although the hypothesis of groups as big as national populations sharing a common culture has been questioned [28], national cultures provide an acceptable starting point for profiling users. Like Hofstede, we compute national cultural profiles statistically based on questionnaires applied to samples of individuals; however, we propose applying questionnaires to social network users, which provides some remarkable advantages regarding the samples used by Hofstede. For example, Bryman [29] states that samples used by Hofstede are not representative of some countries; however, given the huge amount of social network users from each country around the world, representative samples can be easily obtained. McSweeney [28] argues that Hofstede neglected the diversity of subcultures inside a country; however, given the facility for accessing user's information in social networks, profiles of more specialized groups can be obtained by segmenting respondents using features like age, sex, religion, or education level. Finally, values obtained by Hofstede date from early 70's; new respondents will produce fresh values reflecting the effects of social changes of last years.

The model of culture proposed by Hofstede is composed by five cultural dimensions:

- Individualism vs. Collectivism (IDV). Degree in which people prefer acting by themselves, or as members of a group or organization.

- Power Distance (PDI). Degree in which it is accepted in a society that people have different privileges according to their social or economical position.
- Masculinity (MAS). Extent to which a society tends to be more interested in material possessions than in personal relationships and quality of life.
- Uncertainty Avoidance (UAI). Degree in which a society accepts uncertainty and risk.

We applied Hofstede's questionnaire to a sample of around 600 Mexican Facebook users. Figure 2 shows the values for cultural profiles for Mexicans proposed by Hofstede along with new values obtained for Mexicans segmented by age and sex.

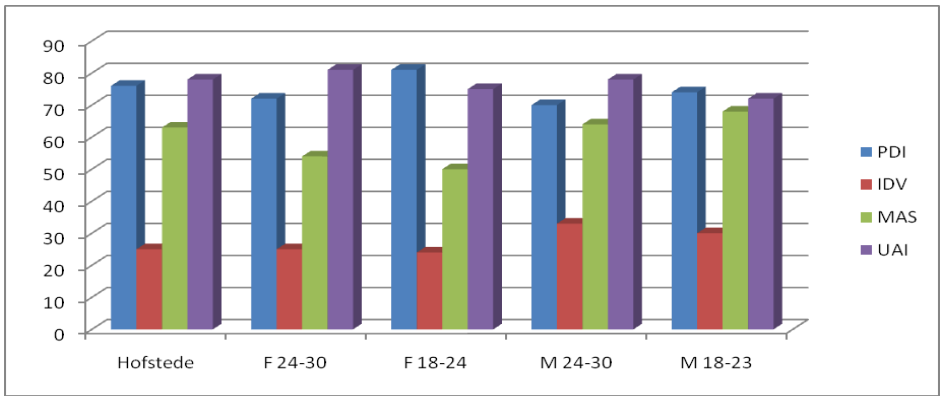

Figure 2. Mexican Cultural Values Segmented by Age and Sex

5.3. Personalizing Culture

As mentioned in Section 3, unique cultural configurations are derived from personal features and from experiences that characterize each human being. In order to simulate such cultural individuality, we let our agents update their cultural profiles based on their perception of cultural influences around them. In general, external influences are represented by other agents who also possess a cultural profile.

Simulating the process of acquiring culture involves a gradual evolution of a cultural profile, which is result of the influences to which an agent has been exposed until a given moment. Each time two agents interact, they exchange the information stored on their cultural profiles. Then each agent compares its own cultural profile and the received cultural profile in order to compute the effects of the received influence and update the knowledge base representing his cultural configuration.

If agents A and B interact, each of them must be capable of updating its cultural profile in order to reflect the influence of the other. We use three main assumptions in order to present a simplified model for computing an influenced cultural profile: (i) cultural dimensions are independent; (ii) the strength of different influences is variable; and (iii) the impact of an influence depends on how mature is the influenced cultural profile.

Cultural dimensions are conceived as independent indicators for different kinds of behaviors. Moreover, there are researches where cultural dimensions have been isolated from their models for explaining several human behaviors. Following this idea, the influenced cultural profile is obtained by independently computing the influence on each cultural dimension and then gathering such values for composing an updated cultural profile.

The impact of an external influence on the culture of an agent varies depending on the context of the interaction. For example, the duration of the interaction, the status of the

influencing agent, the internal state of the influenced agent, or the state of an external element in the environment. This is modeled by considering a variable $0 \leq s_{AB} \leq 1$, representing the strength of the influence of *A* on *B* while they interact. Notice that in an interaction between agents *A* and *B*, s_{AB} is not necessarily the same as s_{BA}.

Finally, the more mature the culture of an individual, the less severe is the impact of external influences. So we must consider the degree of maturity of the influenced profile while computing the impact of an influence. In order to do so, we take into account the current iteration *i* of a cultural profile, which weights the strength of the influence.

According to the mentioned aspects, the formula for computing the culturally influenced profile of A, after an interaction with agent B is:

$$p_A = U_{k=1,2,\ldots,n} |d_{k,A}(\,^{i}/_{i+1}) - d_{k,B}\, s_{BA}(\,^{1}/_{i+1})|$$

where

- $d_{k,A}$, $d_{k,B}$, are values of the same dimension *k* in profiles p_A and p_B respectively,
- *i* is the number of influences applied in the past to the profile p_A
- s_{BA} is the strength of the influence of agent *B* over agent *A*, and
- *n* is the number of cultural dimensions considered in the cultural profiles.

5.4. Affecting Behaviors

Agents with cultural background must show behaviors influenced by their cultural configuration. As OMAS agents act by means of their skills, cultural influences are considered in the implementations of such skills.

Given that cultural profiles are modeled using linguistic variables, agents can take advantage of fuzzy conditional statements, fuzzy rules and approximate reasoning algorithms in order to choose and execute the most adequate skill given their cultural configuration. Therefore, an agent could respond in several ways to a given input message depending on its cultural configuration.

The simplest option for displaying cultural biased behaviors is to define ranges determining the skills the agent should perform as responses to a given input message. Such ranges are defined using values on cultural dimensions, so they can be defined using linguistic variables. For example, if a response depends on the individualism of an agent, the next set of rules would allow the agent *A* to determine how to respond to a given message:

If $d_{individualism,\,A} <$ *"Slightly individualist"* then exec(skill1), else

If $d_{individualism,\,A} <$ *"More or less individualist"* then exec(skill2), else

If $d_{individualism,\,A} <$ *"Extremely individualist"* then exec(skill3), else

exec(skill4)

Another option is to define a set of fuzzy rules over different values in cultural profiles, and to apply approximate reasoning [23] over such rules in order to compute the most compatible skill to be executed given the cultural profile of the agent. For example, if a reaction depends on the individualism and the universalism of an agent, a set of fuzzy rules could be defined as follows:

if *A* is *very collectivist* then exec(skill1),

if *A* is *more or less individualist* then exec(skill2),

if *A* is *slightly individualist* then exec(skill3),

if *A* is *particularist* then exec(skill1),

if *A* is *universalist* then exec (skill3)

All agents could have the same set of rules defined in their knowledge bases; however, which skill to execute will depend on the degrees of individualist and particularism of each of them.

6. Case Study: Managing Cultural Conflicts

As a study case, we present an application for recognizing the occurrence of cultural conflicts in intercultural interactions. In this application, agents with cultural background model the culture of users and work as cultural brokers recognizing potential cultural conflicts and giving advices to users about them. Cultural profiles in this application are modeled according to the model proposed by Hofstede [3]. A set of cultural conflicts prone to occur are defined in terms of cultural differences and interactions are formalized using the Language/Action Perspective (LAP) [30].

6.1. Cultural Dimensions

For the purpose of the case study, which is to provide a framework for supporting collaboration and communication, we use the model proposed by Hofstede [3]. The model is derived from studies on organizational culture, the way in which people interact in organizations [31], and contains four cultural dimensions:

6.2. Formalizing Interactions

As mentioned, a method is required for formalizing interactions. Such formalization will allow us to define and detect cultural conflicts. The approach we adopt is the language action perspective (LAP) [32]. The main idea behind LAP is that interactions can be treated as conversations among users, where each turn in the conversation represents an action of a user. For example, by pronouncing an utterance we can promise, request, apologize, declare, make an offer, make a counteroffer, ask, etc.

Common patterns of interaction are modeled as state transition diagrams with different paths whose inputs represent the sequences of actions that can be followed in a common pattern of interaction. The LAP is suitable because of three main reasons: (i) it is an easy and intuitive method for defining interactions, which can be used by common users for defining new patterns of interaction; (ii) the great number of speech acts, as proposed by Searle [31] makes it a convenient method for modeling complex and varied patterns of interaction; and (iii) usage of state transition networks allows defining conflicts in any state of the network, i.e. at the beginning, end, or any intermediate point of the interaction.

A simple example [30] is the interaction where user A makes a request to user B, presented in Figure 3. This pattern of interaction starts when user A makes a request; then user B can accept, decline or make a counter-offer; each of the options provides new possibilities of action for A, then B has new possibilities, and so on until reaching a final state.

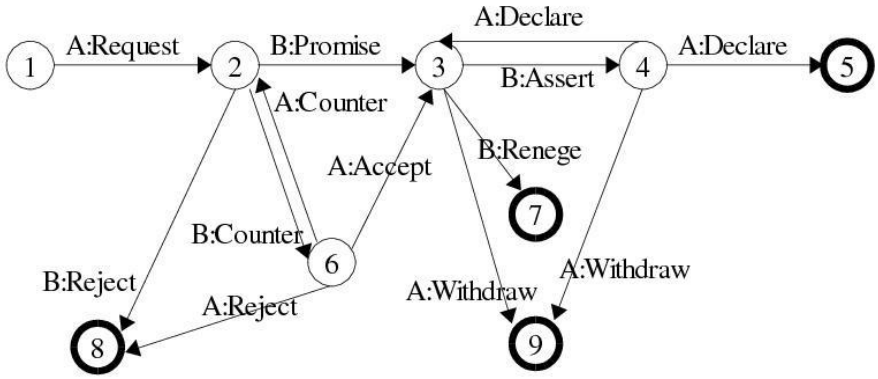

Figure 3. Model of a Request-Promise-Response Interaction

6.3. Defining Cultural Conflicts

For this case study, cultural conflicts will be defined within nodes of the interaction as *if-then* rules. Conditions in the rules express cultural differences defined in terms of values of cultural profiles. When conditions are met, the agent executes a skill that may vary from quite simple behaviors, like showing messages to users, to very complex ones, like executing fuzzy algorithms and updating cultural profiles.

The easiest way for expressing cultural conflicts is by using linguistic values directly, expressing cultural differences among agents using Boolean operators. For example:

if A is very individualist and B is very collectivist then exec(skill$_x$)

The second possibility is to use fuzzy relations for expressing relative differences in cultural profiles, which allows defining conflicts using conditions like:

if collectivism of B is much greater than collectivism of A then exec(skill$_x$)

Next we present examples illustrating different ways for defining cultural conflicts. Such cultural conflicts were identified by Hofstede as prone to occur in intercultural collaborations.

- **Expressing contradictory points of view**. Individualist users express points of view, even if they are contradictory. On the other hand, collectivist users prefer avoiding conflicts and therefore they are not used to express contradictory points of view. This situation may cause a conflict in the interaction presented in Figure 3. Suppose the interaction is in state 2, and user *B* is collectivist, he could response with a promise, even one that he knows that is hard to fulfill. Such conflict is defined in the knowledge base of the agent supporting user *B*. A possible way of defining such conflict is:

  if B is highly collectivist and priority(request)="high" then exec(suggest_counteroffer)

  Note the usage of additional knowledge (about the request) that the agent can use in order to define a cultural conflict.

- **Responding on time**. Importance given to own and group goals differs according to the degree of individualism of the user. According to this, collectivist users are likely to respond and expect responses more quickly than individualist users. In the context of node 3 in the interaction of Figure 3 (supposing *B* is highly individualist and *A* is collectivist), it is likely that user *B* will take longer than *A*

expectations for accomplishing his promise. Such a conflict may be defined in the knowledge base of the agent supporting user *A* as:

if B is highly individualist and A is collectivist then exec(warning_delay)

- **Starting Interactions**. In high power distance cultures, interactions are supposed to be initiated by superiors only. A cultural conflict caused by this situation may be defined in state 1 of the interaction of Figure 3. If the power distance of *A* is much lower than power distance of *B* and user *A* starts an interaction, the conflict may arise. This can be defined in the knowledge base of the agent supporting *A* as:

if power_distance of A is much lower than power_distance of B and boss(B,A) then exec(check_request_priority)

6.3. Evaluating Conflicts

Linguistic values in cultural profiles must be converted to numbers in order to allow computations. This process is called defuzzification and there exist several methods for performing it. The most widely used is by obtaining the centroid of the compatibility function:

$$z_X = (\Sigma_{u \in U}\, c_X(u) \cdot u)/(\Sigma_{u \in U}\, c_X(u))$$

Basically the centroid method consists on finding the point along the x axis such that the compatibility function can be divided in two parts of equal area. For example, the defuzzification process of the linguistic value "*Individualist but not to individualist"* with the parameters $a = 0.25$ *and* $b = 70$, showed in figure 4 is the following:

$$c_{ind}(u) = 1/(1 + e^{-0.25(u-70)})$$
$$c_{verying}(u) = c_{ind}(u)^2$$
$$c_{notverying}(u) = 1 - c_{verying}(u)$$
$$c_{indbutnotverying}(u) = min(c_{ind}(u), c_{verying}(u))$$
$$z_{indbutnotverying} = \Sigma\, c_{indbutnotverying}(u) \cdot u \,/\, \Sigma\, c_{indbutnotverying}(u)$$
$$z_{indbutnotverying} = 74.52$$

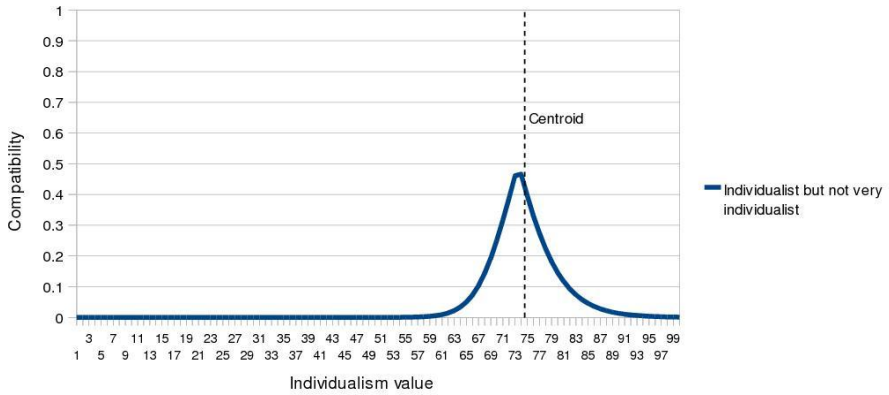

Figure 4. Defuzzification by the Centroid Method.

Once linguistic values are defuzzified, agents are able to evaluate conditions in cultural conflict definitions. Conditions of the type *"if A is individualist and B is*

collectivist", whose components are direct assignations on cultural dimensions, are evaluated by computing the degree of compatibility between the condition and the actual cultural profiles of the agents involved in the interaction.

Take as example the rule mentioned in the last paragraph. The first step is to deffuzify the linguistic values contained on its condition:

$z_{ruleA} = z_{ind} = 15.61$

$z_{ruleB} = z_{col} = 84.39$

Then, the actual cultural values of the involved users are defuzzyfied. Suppose user A is profiled as *"individualist but not very individualist"* and user B is profiled as *"extremely individualist*":

$z_{userA} = z_{indbutnotveryind} = 74.52$

$z_{userB} = z_{extremelyind} = 87.59$

Finally, the average difference of profiles between the condition and the actual cultural profiles of involved users is computed:

$$avg = (|z_{ruleA} - z_{userA}| + |z_{ruleB} - z_{userB}| + \ldots + |z_{rulen} - z_{usern}|)/n$$

Which for the values given in the example is:

$avg = (58.91 + 3.2)/2 = 31.055$

The smaller the value of *avg*, the bigger the fulfillment of the condition, and therefore the bigger the probability of the occurrence of the conflict.

Conditions like "*if power distance of A is much lower than power distance of B"*, involve the evaluation of the fuzzy relations *lower* and *greater* which are given by a threshold function.

$$c_{lower}(x, y) = min(1, [(x - y)/a]^2), \quad x > y$$
$$c_{greater}(x, y) = min(1, [(x - y)/a]^2), \quad x < y$$

where the parameter *a* determines the steepness of the threshold.

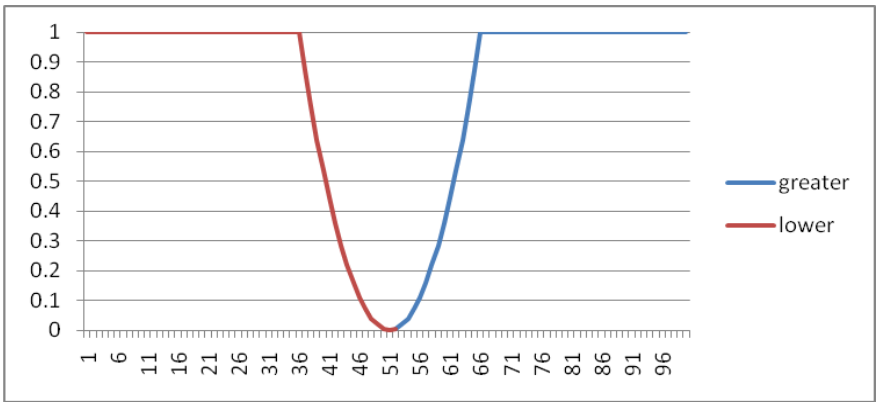

Figure 5. Graphic of $c_{lower}(x,y)$ and $c_{greater}(x,y)$ with $y=50$ and $a=15$

First the cultural values of the two involved users are deffuzified. Suppose that user *A* is profiled as *"very hierarchical"* and user *B* is profiled as *"very equitative"*:

$z_{userA} = 13.44$

$z_{userB} = 86.56$

Then the compatibility function of the involved fuzzy relation is obtained. For the example, the relation is *much lower*.

$c_{lower}(x, y) = min(1, [(x-y)/a]^2)$

$c_{muchlower}(x, y) = c_{lower}(x, y)^2$

Then the function is evaluated for $x = z_{userA}$ and $y = z_{userB}$. Assuming $a = 15$ we have:

$c_{muchlower}(13.44, 86.56) = (min(1, [(13.44 - 86.56)/15]^2))^2 = 1$

The higher the obtained value, the bigger the compatibility with the rule, and therefore the higher the probability of occurrence of the conflict.

7. Conclusions

We proposed an architecture for enriching cognitive agents with a synthetic model of culture. Our approach is based on the cognitive processes required by humans for displaying culturally biased behaviors and on the capabilities of cognitive agents for simulating such processes. With the objective of providing a general platform which can be used in different domains, we proposed cultural profiles composed by several cultural dimensions which vary depending on the scope of each application. Cultural dimensions provide strong theoretical foundations from the anthropological perspective, and we propose managing them as linguistic variables, which allow storing and making computations over cultural profiles and at the same time provides a natural mechanism for managing a subjective aspect as culture. As a case study, we presented a multi-agent system aimed at managing cultural conflicts on human-human interactions.

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