Designing an Experimental and a Reference Robot to Test and Evaluate the Impact of Cultural Competence in Socially Assistive Robotics

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***Abstract*— The article focusses on the work performed in preparation for an experimental trial aimed at evaluating the impact of a culturally competent robot for care home assistance. Indeed, it has been estabilished that the user's cultural identity plays an important role during the interaction with a robotic system and cultural competence may be one of the key elements for increasing capabilities of socially assistive robots.**

Specifically, the paper describes part of the work carried out for the definition and implementation of two different robotic systems for the care of older adults: a *culturally competent* robot, that shows its awareness of the user's cultural identity, and a *reference* robot, non culturally competent, but with the same functionalities of the former. The design of both robots is here described in detail, together with the key elements that make a socially assistive robot culturally competent, which should be absent in the non-culturally competent counterpart. Examples of the experimental phase of the CARESSES project, with a fictional user are reported, giving a hint of the validness of the proposed approach.

***Index Terms*— Culture, Human Robot Interaction**

I. INTRODUCTION

The article describes the work performed in preparation for a trial performed in UK and Japan[1], aimed at evaluating the impact of a socially assistive robots assisting older persons in a care home.

The concept of Socially Assistive Robotics has been firstly introduced in [1], as the intersection of Assistive Robotics, i.e. Robotics that provides aid or support to a human user, and Socially Interactive Robotics, i.e. Robotics whose main task is some form of social interaction. Given this definition, older adults care may have a strict connection with Socially Assistive Robotics. Indeed, in the care of older adults, health and psychological assistance are strictly related [2]: in this context, socially assistive robots may provide companionship, enhancing wellbeing of older persons [3][4].

The CARESSES project[2] is a 37-month-long multidisciplinary project, aimed at implementing socially assistive robots that are culturally competent, i.e. able to apply an understanding of the culture, customs and etiquette of the person they are assisting, while autonomously reconfiguring their way of acting and speaking [5].

This is motivated by the observation that cultural competence is of the utmost importance in the context of Nursing [6], to the extent that it gave birth to a dedicated research field known as Transcultural Nursing [7]: the development of companion robots conceived to assist older adults in daily life cannot neglect this aspect. Despite this, the concept of cultural competence has only been marginally considered in the Socially Assistive Robotics domain.

Generally speaking, Culture-Aware Technology, i.e. systems where culture-related information has some impact on design, internal processes, structures, and/or objectives [8] has recently received attention. Many works in this field consider a main aspect of culture the fact that groups of individuals have a shared repertoire of heuristics that are employed for interpreting and generating verbal and non-verbal signals in interaction. In this direction, and more specifically related to the robotic domain, the study conducted in [9] explores cultural differences in the definition of emotional expressions, collecting a cross-cultural database for the emotional connotation of movements. Culture-dependent acceptance and discomfort in relation with greeting gestures can be found in [10], which presents a comparative study with Egyptian and Japanese participants. Insights reported in the study subsequently led to the development of a novel greeting selection system for a culture-adaptive humanoid robot [11]. Cultural factors in robotics have been also investigated in [12], even if not with the objective of designing a culturally competent robot: findings suggest that people from different cultures, when verbal interaction is involved, tend to prefer robots better complying with the social norms of their own culture. The works of [13][14] have been focused on the effects of different cultural identities on robot navigation and interpersonal distance: also in this case, results suggest that people tend to prefer a robot that, when approaching them, conforms to their social norms. Finally, the analysis of [15] shows that sensitivity and adaptation to salient cultural factors, rather than designing robots for specific cultures, is a key requirement for an effective and sustainable cultural robotics.

The article describes the decision taken and the technical steps performed, in the context of the CARESSES project, in order to design two robotic systems to be tested and compared during the experimental trials of the project in UK and Japan [16]: a culturally competent experimental robot and a non culturally competent reference robot. It should be noticed that the design of a culturally competent robot is a very complex task, which has been explored in the whole context of the project and has been already discussed in [17][18][19][20][21]; however, it turns out that designing a

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reference robot which is *culturally neutral* (but has the same basic functionalities of the experimental robot) is equally difficult. Indeed, when trying to design a reference robot which is not specifically tailored to the cultural identity of a specific user, we need to pay attention that the robot verbal and non-verbal interaction are not biased towards the cultural identity of the roboticists that designed it.

The article is structured as follows. While Chapter II presents a brief decription of the project, Chapter III and Chapter IV focus on a detailed analysis of how the two robotics systems, which will be employed in the experimental trial phase, have been conceived and implemented. Finally, Chapter V discusses preliminary outcomes of the proposed approach and Chapter VI presents conclusions.

II. CASE STUDY: THE CARESSES PROJECT

The main hypothesis of the CARESSES project is that the interaction with socially assistive robots that are sensitive to the user's cultural identity could definitely improve quality of life and reduce loneliness of older adults (and thus reduce informal caregiver burden). Nine research partners (six European and three Japanese) are involved in the project. Indeed, the intrinsic multidisciplinarity of the project pushed towards the integration of researchers with different backgrounds, such as Robotics, AI, Human-Robot Interaction, Transcultural Nursing, Social Psychology, Mental Health, Evaluation of complex Public Health interventions, and professional Healthcare.

In order to achieve its final aim, the project has been structured by interconnected steps. First, researchers in Transcultural Nursing have developed a number of *scenario tables*, i.e. simple summaries of daily life situations involving older people with different cultural identities, where the robotic capabilities needed to assist the older person in a culturally appropriate, sensitive and acceptable way were clearly identified and analyzed, in a closed-loop approach between roboticists and Transcultural Nursing researchers [17]. Second, this work helped to define the general attitude that a culturally competent robot must exhibit towards people in order to consider their culture by avoiding stereotypes, i.e., the so called ADORE model (Assess, Do, Observe, Revise, Evaluate). Also, it led to the development of specific guidelines for implementing the robot's behavior, in terms of robot goals, actions, actions' parameters, social norms and topics of conversation. Third, using the same approach as before, i.e. through iterative revisions incorporating feedbacks of Transcultural Nursing and Health-Care experts, these guidelines have been encoded in the CARESSES software for controlling the robot [20].

Finally, and more related to the work described here, the project foresees a testing phase where the assistive robot directly interacts with a number of older persons. The experimental phase is crucial to evaluate whether and how robots are perceived as culturally competent, and - as such - they may improve the health and wellbeing of older adults residing in long-term care homes.

In order to test the system, older people who primarly identify themselves as belonging to one of three cultural groups (English, Indian or Japanese) are being recruited from UK-based (English and Indian only) and Japanese-based testing sites. By ignoring details about the experimental protocol [16], the trial analyses human-robot interaction with two groups:

- **Experimental Group**. Residents allocated to this group receive a culturally competent robot. This means that the robot knows in advance the cultural background of the participants, and it interacts with them based on its complete knowledge about their culture as well as the feedback that it receives from them: i.e. it is able to learn and adapt its knowledge to the individual's specific cultural values and preferences. In the following, we are referring to this robot as the *Experimental* robot.
- **Control Group**. Residents allocated to this group receive a robot that is not culturally competent: however, as like as the *Experimental* robot, it is able to learn and adapt its knowledge to the participant's specific cultural values and preferences, although the way in which it adapts to the participants' cultural identity is different. The robot does possess the same suite of technical functionalities as the *Experimental* one. In the following, we are referring to this robot as *Reference* robot.

For both groups, the Pepper humanoid robot [22] is used as a platform to implement the two different behaviors above.

III. PROBLEM STATEMENT

The *Experimental* and *Reference* robots consist of the same hardware and technical functionalities, but differ in terms of cultural competence. Designing different behaviors required a detailed definition of the most relevant factors for achieving cultural competence in a socially assistive robot. Moreover, the definition of the two robots has been guided by the ethical principle of clinical equipoise: i.e. the two robots shall be designed in such a way that there is genuine uncertainty over whether the *Experimental* robot will be more beneficial than the *Reference* robot. Practically speaking, the differences between the two robots must not be purposely designed in order to straightforwardly achieve that the *Experimental* robot produces better results than the *Reference* one.

A deep analysis of the factors that contribute to cultural compentence have been conducted and described in [17] and [20], and led to the implementation of the *culturally competent* robot. However, as anticipated, it is equally complex to define the behavior of a *non culturally-competent* robot.

In order to define which elements the *Reference* robot should not possess with respect to the *Experimental* robot, we need to give an answer to two main research questions:

1) *What are the most visible elements that make a socially assistive robot culturally competent, which should be absent in its non-culturally competent counterpart, by guaranteeing clinical equipoise?*

2) *Which are the technological solutions to practically implement (or non implement) these elements in a socially assistive robot?*

The following sections A and B, and Chapter IV will discuss the two research questions.

Based on all the work performed so far [17][19][20], the following key elements have been identified as relevant to answer the research question (1).

A. Chitchatting Capabilities

Given the nature of *companion robot*, the dialogue is surely one of the most crucial aspects. Indeed, the CARESSES robot is expected to talk frequently with the user, for a number of reasons: to keep the interaction alive and increase the participant's level of engagement, to acquire information about the participant's preferences, beliefs and values, social norms, preferred activities (which is fundamental to avoid a stereotyped representation of cultures) and to suggest activities to be performed. In this context, three main key elements directly related with cultural competence have been identified:

Probability of conversation topics. Different cultures might have different histories, customs and traditions, which influence the lifestyle of people. While verbally interacting with the participant, the robot should be aware of these differences and choose conversation topics which are appropriate to them. For instance, the topic of religion with an Indian person may be a reasonable choice, and, when talking about religion, the robot should be aware that Hinduism is one of the most widespread religion in India. However, stereotypes should also be avoided, and therefore each topic should not be deterministically chosen by the robot, but according to a given *probability value*. Finally, once again for the sake of avoiding stereotypes, the robot will never take for granted that any aspect related to a culture holds for a specific person, but it will always ask the person for confirmation (see [17] for a more detailed discussion about the ADORE model and its implementation).

Sentences. While talking with the participant about something, the robot should clearly show that it is aware of the participant's cultural identity by making statements that reflect the set of beliefs, preferences, habits, which hold for that cultural identity. A possible dialogue pattern involving the robot and an Indian participant talking about religion would be the following (please notice that all examples in this article correspond to possible dialogue patterns generated in real-time by the CARESSES system during the interaction [19][20], i.e. they are not pre-written scripts):

ROBOT: I know that in Hinduism, if the karma of an individual is good enough, the next birth will be rewarding. Are you Hindu?

PARTICIPANT: Yes, I am.

ROBOT: Hinduism has numerous gods and goddesses, including Brahma, Vishnu, and Shiva. I know that they represent one or more of Brahman's aspects.

PARTICIPANT: Yes, that's true.

Level of detail. Finally, the robot should have a deep knowledge of the conversation topics relevant for the cultural identity of the participants. As a follow-up to the previous dialogue, the robot will probably carry on the conversation talking about some related aspects, such as festivities, thus engaging the user in a complex conversation. The following is a possible continuation of the script above:

ROBOT: There are so many Hindu festivals. I know that Diwali is celebrated in autumn, and even though it is more common in the North of India, it is a very popular festival for all Indians around the world. Do you celebrate any festival?

PARTICIPANT: Yes, I love the Diwali festival.

ROBOT: Diwali is the festival of lights that celebrates new beginnings and the triumph of good over evil and light over darkness. Please tell me more about it.

PARTICIPANT: During Diwali, houses are decorated with candles and colourful lights.

ROBOT: I see, very interesting. Would you like to get some diyas for Diwali?

B. Actions and parameters

Besides talking, the robot should be able to perform some basic activities, informing, helping or entertaining the user. *Actions* are defined as all the robot's activities necessary for meeting specific user's requests and achieving general goals. In this context, three additional key elements have been identified as crucial for designing both robots:

Type of actions. Some objectives (or user's requests) may be achieved by different variants of an action, where the redundancy is due to the fact that different cultures may have different ways to reach the same goal. As an example, consider the *greeting* scenario, which involves different type of gestures for different cultures (bowing, hand-waving, doing namaste, ...). A culturally competent robot should know what it is the most appropriate type of action to be executed, being also able to learn the specific user's preference and to (eventually) update its behavior accordingly [21].

Actions' parameters. Any action executed by the robot should require a set of parameters defining how the action should be executed. Examples may be the distance between the robot and the person, the speech volume, the waiting time, and many others. Cultural competence plays an important role here: the robot should be endowed with knowledge about the parameters values that are more appropriate according to the cultural identity of the person. However, as in the previous case, the robot should also be able to learn the individual preferences about each parameter.

Suggestions. *Suggestions* are, technically speaking, a particular type of parameter: in all actions requiring a user's choice, the robot may proactively suggest some options to the participant. While doing that, cultural competence plays a key role: the robot may suggest activities that are likely to be appreciated by the participants, given their cultural identity; similarly, it may suggest music, games, movies that relate in some way to the cultural background of the participants.

C. Learning and propagation

While learning the participant's individual preferences, beliefs, habits, norms and values, the system should have the capability of analyzing and processing information by taking into account relationships between different knowledge areas. Recalling the previous example about religion and festivities, after the robot had acquired knowledge about the user's religion, Hinduism, it may infer that the user probably has a puja room in his home, i.e. a room dedicated to Hindu prayers. According to this approach, culturally competent learning involves propagation, i.e. improving knowledge in one area of the cultural knowledge automatically leads to reasonable knowledge improvements in related areas. Again, nothing will be taken for granted, and the knowledge inferred will always be confirmed by directly asking the user.

IV. ROBOTIC IMPLEMENTATION

In order to understand how these elements can be implemented in a robotic system, the CARESSES architecture should be described at a glance. The system is mainly composed by three software blocks: the Cultural Knowledge Base (CKB), the Cultural Sensitive Planner and Execution Module (CSPEM) and the Culture-Aware Human-Robot Interaction Module (CAHRIM).

A detailed description of the CARESSES system may be found in [18]. Here the focus will be on the working principles of the first block, the CKB.

The CKB contains a-priori general knowledge in the form of an OWL2 Ontology (a formal naming and definition of the types, properties and interrelationships of the entities that exist for a particular domain of discourse [23]). Generally speaking, the Ontology can be conceptually represented as a combination of a Terminological Box (TBox) describing concepts (classes) and an Assertional Box (ABox) describing individuals (instances of concepts)[3].

In the CARESSES Ontology, the TBox is used to represent information that is culture-independent. All culturally relevant concepts, including conversation topics, actions, parameters, etc.) are represented with classes derived from the superclass *Topic*. As usual, classes are organized in a hierarchical way, i.e. a class can have subclasses that represent concepts that are more specific than the superclass.

Instances in the ABox may be of two kinds: culture-specific instances and person-specific instances. Culture-specific instances encode the most appropriate conversation topics, actions, parameters, etc. for a given culture, and are actually used to build the dialogue tree, a graph used by the underlying dialogue algorithm to manage the conversation: if a culture-specific instance exists for a given class and a given culture, then the robot may decide to talk about that topic with a person (declaring to belong to that culture) according to a given probability. Person-specific instances are used to store specific information about the person, either encoded a priori or acquired during the interaction.

[3]https://www.w3.org/TR/owl2-overview/

Summarizing, all sentences that a robot may pronounce are properties of culture-specific or user-specific instances. Indeed, they may be encoded in: classes in the TBox, storing culture-independent sentences about topics that are valid for all cultures; culture-specific instances, storing sentences that are appropriate for a given culture; user-specific instances, storing sentences that are appropriate for a given user (i.e., taking into account their name, birthdate, relatives, etc.)

The description of the CKB given here is not complete, since it has been focused only on basic elements, necessary for understanding the following analysis. For an exhaustive discussion about the Ontology structure and the dialogue algorithm please refer to [19][20].

To address the research question (2), all of the aforementioned key elements are next considered, by discussing how they can be used to differentiate between the *Experimental* and the *Reference* robot. Fig.1 shows how these implementation differences effect the dialogue tree's stucture, while Table I summarizes all the differences between the two systems. Fig. 2 shows two users interacting with the Pepper humanoid robot during experiments.

A. Chitchatting Capabilities

Probability of conversation topics. Each culture-specific instance is associated to the data property *hasLikeliness*, describing the probability that the person has a positive attitude towards that topic of discussion, given that we know that she belongs to that culture. *Experimental robot*: each topic in the Ontology is assigned a different probability of being explored by the robot during the dialogue, thus producing a non-uniform random distribution over topics that depends on the person's culture. *Reference robot*: all conversation topics are assigned a uniform probability to be explored, notwithstanding the person's culture.

Sentences. Sentences are encoded into data properties. However, they can be assigned to instances in two ways: they can be (i) directly encoded in the instances, or (ii) inherited from the class to which the instances belong, (which, as the reader remembers, are culturally-independent). Sentences of type (i) allows the robot to exhibit its cultural competence, since these sentences are used only with a person belonging to that specific culture. Sentences of type (ii) are more generic, since in principle they could be used with a person belonging to any culture. *Experimental robot*: both types of sentences are available to be used; if both types are present within the same instance, sentences of type (i) are preferred by the dialogue algorithm. *Reference robot*: only sentences of type (ii) are used.

Level of detail. The Ontology is the starting point for creating the dialogue tree, based both on subsumption relationships between classes and on object properties that put classes and instances in relation to other classes and instances. In particular, the dialogue tree is rooted in a node representing the person's culture, and the depth of its branches represent to what level of detail the conversation may be carried out for each topic. Generally speaking, increasing the number of hierarchy levels in the Ontology (i.e.

Robot activity	Experimental Group		Control Group	
	Protocol	*Technical Implementation*	*Protocol*	*Technical Implementation*
Chitchatting Capabilities	*Probability of conversation topics.* The robot should be aware that different cultures might have different customs, habits, traditions, and it should accordingly choose conversation topics.	*Probability of conversation topics.* Different values for the *hasLikeliness* property are used to propose culturally relevant topics of conversation.	*Probability of conversation topics.* The robot should randomly choose the conversation topics.	*Probability of conversation topics.* *hasLikeliness* values are identical for all instances belonging to subclasses of the class *Topic*, thus producing a completely random behavior (with uniform probability) when proposing topics of conversation.
	Sentences. The robot should clearly show that it is aware of the participant's cultural identity, by making specific statements that reflect the set of beliefs, preferences, values, which hold for that culture.	*Sentences.* In order to build the dialogue tree, the system considers both sentences stored in the TBox (and then inherited by all culture-specific instances) and sentences stored in the culture-specific and user-sepcific instances.	*Sentences.* The robot will pronounce generic sentences, without demonstrating any specific cultural knowledge.	*Sentences.* In order to build the dialogue tree, the system considers only sentences stored in the TBox (and then inherited by culture-specific and user-specific instances).
	Level of detail. The robot should have a deep knowledge of the conversation topics that may be relevant for the cultural identity of the participants, engaging them in complex conversations.	*Level of detail.* All culture-specific instances nd user-specific instances are used to build the dialogue tree (e.g., every topic is reachable through the exploration algorithm).	*Level of detail.* The robot will keep the discussion of the various topics at a generic level.	*Level of detail.* A fixed value has been set for the maximum depth of each branch of the dialogue tree: all instances that would increase the depth of their branch to a value greater than the threshold are not considered.
Actions and Parameters	*Type of action.* In case of a multiple set of actions achieving the same goal, the robot will choose the more appropriate action for the participant's culture. If estabilished, the robot will respect the participant's preference.	*Type of action.* The value of the property *hasLikeliness* associated to culture-specific (and user-specific, if existing) instances are used to discriminate among actions.	*Type of action.* In case of a multiple set of actions achieving the same goal, the robot will randomly choose one of the possible actions. If estabilished, the robot will respect the participant's preference.	*Type of action.* The value of the property *hasLikeliness* are identical for all culture-specific instances belonging to subclasses of the class *Topic* (e.g. the class *Action*).
	Actions' parameters. For each action involving parameters, the robot will adopt values that are most likely to be conforming with the cultural identity to which the participant belongs. If estabilished, the robot will respect the participant's preferences.	*Actions' parameters.* The value of the property *hasLikeliness* associated to culture-specific (and user-specific, if existing) instances are used to choose the more appropriate values of the actions' parameters.	*Actions' parameters.* For each action involving parameters, the robot will adopt values randomly chosen among the possible ones. If estabilished, the robot will respect the participant's preferences.	*Actions' parameters.* The value of the property *hasLikeliness* are identical for all culture-specific instances belonging to subclasses of the class *Topic* (e.g. the class *Parameter*).
	Suggestions. For each action involving Suggestions, the robot will suggest activities that are likely to be appreciated by the user, given his cultural identity. If estabilished, the robot will consider the participant's preferences.	*Suggestions.* The value of the property *hasLikeliness* associated to culture-specific (and user-specific, if existing) instances are used to choose the more appropriate options to be suggested.	*Suggestions.* For each action involving Suggestions, the robot will suggest activities randomly chosen among the possible ones. If estabilished, the robot will respect the participant's preferences.	*Suggestions.* The value of the property *hasLikeliness* are identical for all culture-specific instances belonging to subclasses of the class *Topic*.
Learning and Propagation	The robot will be able to learn specific preferences of the participant. Moreover, learning will include propagation, in the sense that acquiring knowledge in one area automatically leads to knowledge improvements in other related areas.	User-specific instances are used to encode user's information. A Bayesian Network is associated to the dialogue tree, being the user's culture the root node.	The robot will be able to learn user's specific preferences. Learning will not include propagation, thus acquiring knowledge in one area will not have any impact in other areas.	User-specific instances are used to encode user's information. No Bayesian Network is used.

TABLE I

DIFFERENCES BETWEEN THE EXPERIMENTAL AND THE REFERENCE ROBOT

subclasses and related culture-generic instances) allows the robot to engage the person in a more complex conversation. *Experimental robot*: the full dialogue tree is available for conversation, under the assumption that the deeper are the nodes, the more culture-dependent is the information they store. *Reference robot*: a maximum depth for the dialogue tree branches is introduced, so that conversation topics may only be discussed at a generic level.

B. Actions and Parameters

Type of actions. In the CARESSES Knowledge representation, the subclasses of the class *Action* represent all activities that may be executed by the robot (e.g. *GreetAction*, *GoToAction*). In case of a multiple set of actions achieving the same goal (e.g. greeting), the lower level of the hierarchy is composed of all different types of actions that may be performed to achieve that goal (e.g. subclasses *GreetBowAction*, *GreetWaveAction*, *GreetNamasteAction*). In this case, the values of the property *hasLikeliness* for all culture-specific instances belonging to subclasses of *Action* allow the robot to select the most appropriate type of action for a given culture. *Experimental robot*: each action instance is assigned a different probability of being chosen by the robot, thus producing a non-uniform random distribution over actions that depends on the person's culture. *Reference robot*: actions are assigned a uniform probability to be chosen, notwithstanding the person's culture.

Actions' parameters. All culture-specific instances belonging to subclasses of *Action* may be linked to culture-specific instances of the class *Parameter*. For example, instances of the *PlayMusicAction* instance for the English culture may be connected, among the other parameters, to instances of the classes *HigherSpeechVolume*, *MediumSpeechVolume*, *LowerSpeechVolume*. Similarly to actions, the values of the data property *hasLikeliness* allow the robot to choose the right parameter depending on the person's culture. *Experimental robot*: each parameter value is assigned a different probability of being chosen by the robot. *Reference robot*: parameter values are assigned a uniform probability to be chosen.

Suggestions. Suggestions about available actions to be performed are a particular type of parameter, and therefore the mechanism described in the paragraph above applies in this case as well. For example, the *PlayMusicAction* instance for the English culture may be connected to instances of *BritishPop*, *BollywoodMusic*, and *JapaneseTraditionalMusic*, corresponding to music genres that the robot may suggest depending on the person's culture: different music genres have different *hasLikeliness* values for the *Experimental robot* and identical values for the *Reference robot*.

It is worth stating that both classes *Action* and *Parameter* are subclasses of the class *Topic*. Thus, they are possible topics of conversation for the robot, and user's specific preferences may be acquired during verbal interaction.

C. Learning and propagation

User's data manually added during the setup phase, as well as specific information about the user's preferences acquired in run-time during the interaction, are encoded in user-specific instances. From the technical perspective, each time a new user's feedback is received, an user-specific instance is created, with the *hasLikeliness* value properly set according to the user's feedback. *Experimental robot*: a Bayesian Network is associated to the ontology, built starting from the dialogue trees of all cultures encoded in the ontology [20]. By ignoring details, the user's cultural profile can now be initialized a probabilistic distribution over a mixture of different cultures, under the assumption that people do not belong to a unique cultural profile in a deterministic way. The underlying Bayesian representation determines probabilistic relationships between some nodes/areas of the ontology with other nodes/areas. Then, when new evidence is acquired concerning one node, it is possible to update the posterior probabilities of all other nodes: as a consequence, knowledge acquired in some areas may lead to knowledge improvements in other related areas. *Reference robot*: learning does not include propagation, since no Bayesian Network is used.

V. EXAMPLES AND DISCUSSION

Two interaction examples between the robot and a fictional English participant, Mrs Smith, with the *Reference* robot (Example 1) and with the *Experimental* robot (Example 2) are next reported and discussed. Please check the footnotes as a guide to understand how the principles discussed throughout the article work in practice. As usual, the following examples correspond to dialogue patterns generated in real-time by the CARESSES system.

Reference Robot

ROBOT: Namaste auntie[4] [ROBOT *bows to Mrs Smith by making the Namaste gesture*[5] *and comes quite close*[6] *to her. It is speaking in a rather loud*[7] *voice.*]

MRS SMITH: Hello!

ROBOT: It's important to me to know how I should call you. I want to address you properly. If you don't mind, I will ask you a question. Can I call you with your given name[8]?

MRS SMITH: No, call me Mrs Smith.

ROBOT: I only know a little about this. May I call you Mrs Smith?

MRS SMITH: Yes, please.

ROBOT: I will call you Mrs Smith. Please tell me what to do, I am here for you. As a suggestion, I could set a reminder for making an audio or video call.

MRS SMITH: I want to watch a movie clip. [ROBOT *asks for confirmation by using its tablet.* MRS SMITH *answers Yes by using the tablet.*]

ROBOT: I am happy to be helpful. I can show you Rashomon[9], Titanic, and many other film-clips. Please tell me what film-clip you would like to watch

MRS SMITH: Show me the options please

ROBOT: I will show you the options on my tablet. [*A list of movies appear on the robot's tablet.* MRS SMITH *does not know any movie on the list, so she clicks on the Next Button. After a while, she finds one of her favourite movies, and she selects it.*]

ROBOT: Alright, I'll play The Ladykillers. Please wait a few seconds while I load the video on the tablet. It might take a while, so please be patient.

MRS SMITH: Ok, no problem.

[ROBOT *shows the movie on its tablet. After a while,* MRS SMITH *touch the robot on its head, signaling it to stop. There are few seconds of silence*]

ROBOT: It's interesting to know more about things that you like! Can I ask you something about your food preferences?

MRS SMITH: Yes!

ROBOT: Great. Talking about what we eat is entertaining and also very important. Do you like typical Japanese food[10]?

MRS SMITH: No, not really.

ROBOT: You are very patient. I hope you enjoy our conversation

Experimental Robot

ROBOT: Hello Mrs Smith[11] [ROBOT *waves*[12] *at Mrs Smith and approaches her keeping a certain distance*[13]. *It is speaking in an intermediate tone of voice*[14].]

MRS SMITH: Hello!

ROBOT: It's important to me to know how I should call you. I want to address you properly. I am aware that older English people usually prefer to be called by their surname. Should I call you Mrs Smith[15]?

MRS SMITH: Yes, please.

ROBOT: I understand that you will be pleased to be called Mrs Smith. Please tell me what I can do for you. As a suggestion, I could show you the weather forecast in York[16].

MRS SMITH: I want to watch a movie-clip. [ROBOT *asks for confirmation by using its tablet.* MRS SMITH *answers Yes by using the tablet*]

ROBOT: Ok! Let's do that. I can show you The Bridge on the River Kwai, The Ladykillers and many other film-clips[17]. Please tell me what film-clip you would like to watch.

MRS SMITH: The Ladykillers! I love that movie.

ROBOT: Alright, I'll play The Ladykillers. Please wait a few seconds while I load the video on the tablet. It might take a while, so please be patient.

MRS SMITH: Ok, no problem.

[4] Not culturally appropriate topic of conversation: the use of the term "auntie" is appropriate in the indian culture, but not for an English lady.

[5] Not culturally appropriate greeting action.

[6] Not culturally appropriate parameter: a higher distance is preferrable.

[7] Not culturally appropriate parameter: a lower volume is preferrable.

[8] Not culturally appropriate topic of conversation: use of surname is preferrable with an English lady.

[9] Not culturally appropriate suggestion.

[10] Not culturally appropriate topic of conversation.

[11] Culturally appropriate topic of conversation.

[12] Culturally appropriate greeting action.

[13] Culturally appropriate parameter.

[14] Culturally appropriate parameter.

[15] Culturally appropriate topic of conversation.

[16] Culturally appropriate suggestion.

[17] Culturally appropriate suggestions.

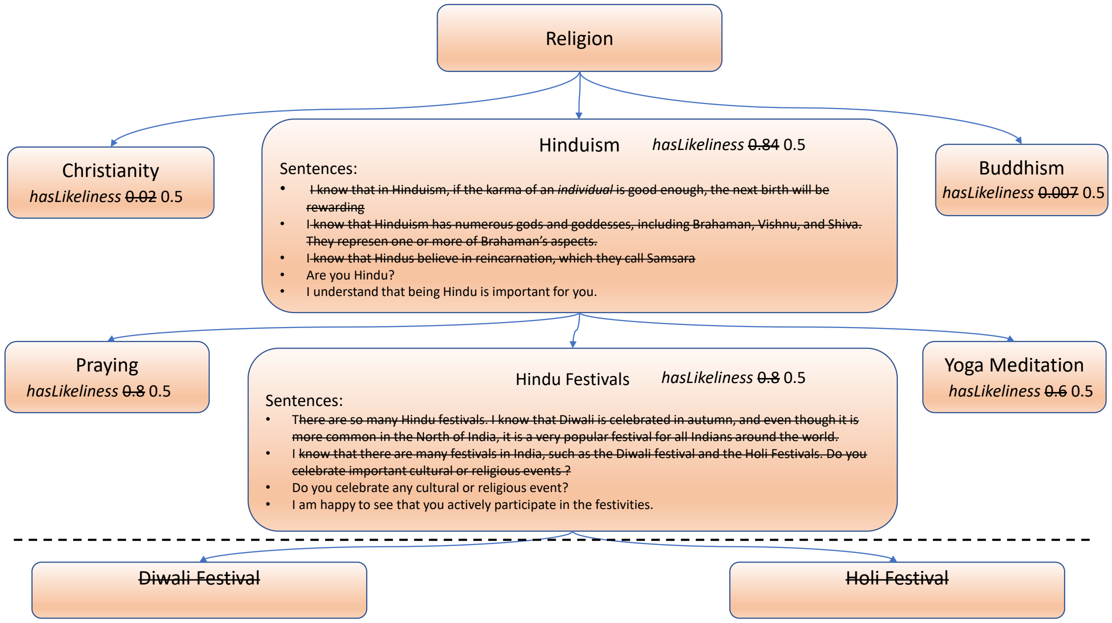

Fig. 1. Effects of implementation differences to the dialogue tree between the *Experimental* Robot (full tree) and the *Reference* robot (tree with cancelled elements). In the *Reference* robot, *hasLikeliness* values are all identical (uniform probability). Only general sentences inherited from classes are considered, whereas culture-specific sentences directly encoded in the instances are discarded. Finally, hierarchical levels under *Hindu Festivals* are not considered.

[ROBOT *shows the movie on its tablet. After a while,* MRS SMITH *touch the robot on its head, signaling it to stop. There are few seconds of silence.*]

ROBOT: I am aware that English people are generally tolerant about other people's preferences in drink, movies, music, books, sport, food. Can I ask you something about your food preferences[18]?

MRS SMITH: Yes, why not?

ROBOT: A full English breakfast is a breakfast meal that typically includes bacon, sausages, eggs and coffee or tea. Do you like typical English food[19]?

MRS SMITH: Sure!

ROBOT: Do you want me to show a video recipe to prepare something English for breakfast now[20]?

MRS SMITH: Yes please [ROBOT *asks* MRS SMITH *to wait few seconds, then an instructions video about English breakfast is displayed on the tablet.*]

The scripts presented above are just examples; the interaction may be different every time, given the presence of random components in the underlying algorithms. Notice also that, for the sake of comparison, the same conversation topics have been selected in both examples[21].

The reader may easily notice the differences between the two interaction patterns. The second robot, through its actions and words, shows awareness of the expected habits, preferences and beliefs of Mrs Smith (it greets her in the appropriate way, it suggests reasonable activities and options, it knows about English breakfast). On the opposite, the first robot behaves as if it is were completely unaware of her cultural identity (sometimes with weird results, as when it addresses Mrs Smith as ‘auntie", which is appropriate in the indian culture, but not for an English lady).

As previously stated, in order to have a fair comparison in the experimental phase (required for clinical equipoise) both robots possess the same functionalities: indeed, in both cases Mrs Smith is able to watch a video clip on the robot's tablet, even if, with the *Reference* robot, more steps have been required to achieve the same goal.

Please notice that the two dialogue patterns refer to the first interaction between the robot and the user. Thus, execept for basic information such as the gender, name and Nationality, the robot does not possess any other information about the person. Conversation topics, actions, parameters and options to be suggested are therefore chosen (by the *Experimental robot*) only on the basis of culture-specific information.

However, during the interaction, both robots update their knowledge with user specific information, by means of the feedback given by the user to the robot's questions. This means that, after a sufficiently long interaction, the two robots will choose similar conversation topics and actions (with similar parameters and options to be suggested). This is due to the fact that, after a long interaction, almost all *hasLikeliness* values will be related to user's specific instances. In other words, when the robot has learned something about the user, what the robot knows about this specific user will have a higher priority with respect to what the robot initially assumed depending on the user's culture: this goes hand in hand with the aim of avoiding stereotypes.

Finally, please notice that the effect of propagation

[18]Culturally appropriate topic of conversation.
[19]Culturally appropriate level of detail.
[20]Culturally appropriate suggestion.
[21]Recent videos recorded in a CARESSES laboratory with the *Experimental robot* can be seen here https://youtu.be/jmfmuytMj-4)

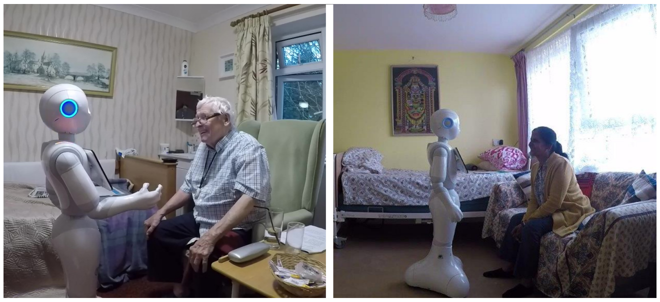

Fig. 2. Two users interacting with the Pepper humanoid robot used in the experimental phase of the project, both as *Experimental* and as *Reference* robot (with different software).

involved in the learning process is not shown in the scripts above, since it would require a longer interaction to emerge[22].

VI. CONCLUSION

In the article, the definition of two robotic systems has been described in detail: an Experimental *culturally competent* robot, that shows its awareness and sensitivity for the user's cultural identity, and a *Reference*, non culturally competent robot, but with the same functionalities of the former. The work has been carried out in the context of the CARESSES project, in preparation for an experimental trial to be performed in UK and Japan, aimed at evaluating the impact of cultural competence in Robotics. Examples of interaction patterns involving users interacting with both robots have been reported in the article, giving a preliminary idea of the approach followed.

During Spring and Summer of 2019, the two systems are being used for experimental trials in UK and Japan [16]. A systematic analysis to evaluate the effects of cultural competence in Socially Assistive Robotics will be reported in future publications.

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[22]For a practical demonstration of this concept, see the video here https://youtu.be/WQJ0d5yXD0A