Paving the Way for Culturally Competent Robots: a Position Paper

Barbara Bruno[1], Nak Young Chong[2], Hiroko Kamide[3], Sanjeev Kanoria[4], Jaeryoung Lee[5], Yuto Lim[2], Amit Kumar Pandey[6], Chris Papadopoulos[7], Irena Papadopoulos[8], Federico Pecora[9], Alessandro Saffiotti[9] and Antonio Sgorbissa[1]

***Abstract*— Cultural competence is a well known requirement for an effective healthcare, widely investigated in the nursing literature. We claim that personal assistive robots should likewise be culturally competent, aware of general cultural characteristics and of the different forms they take in different individuals, and sensitive to cultural differences while perceiving, reasoning, and acting. Drawing inspiration from existing guidelines for culturally competent healthcare and the state-of-the-art in culturally competent robotics, we identify the key robot capabilities which enable culturally competent behaviours and discuss methodologies for their development and evaluation.**

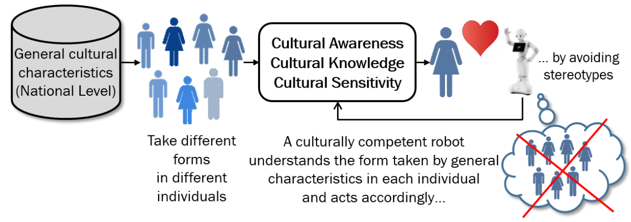

Fig. 1. The rationale for a culturally competent robot.

I. Introduction

Designers of social and assistive robots are often faced with questions such as: "How should the robot greet a person?", "Should the robot avoid or encourage physical contact?", "Is there any area of the house that it should consider off-limits?". Intuitively, the correct answer to all those questions is "It depends", and more precisely, it depends on the person's values, beliefs, customs and lifestyle, i.e., the person's own *cultural identity*.

The need for cultural competence in healthcare has been widely investigated in the nursing literature [1]. The fields of Transcultural Nursing and Culturally Competent Healthcare play a crucial role in providing culturally appropriate nursing care, as the presence of dedicated cultural competence international journals and worldwide associations reflects [2], [3]. In spite of its crucial importance, cultural competence has been almost totally neglected by researchers and developers in the area of assistive robotics. Today it is technically conceivable to build robots —possibly operating within a smart ICT environment [4]— that reliably accomplish basic assistive services. However, these robots only address the problem of "what to do" to provide a service, and produce rigid recipes which are invariant with respect to the place, person and culture. We argue that this is not sufficient and necessarily doomed to fail: if service robots are to be accepted in the real world by real people, they must take into account the cultural identity of their users in deciding "how" to provide their services.

In this position paper we discuss the concept of a *culturally competent robot*. We claim that cultural competence is a key factor for social, personal and assistive robots, which has been mostly neglected so far. Figure 1 illustrates the concept of a culturally competent robot. Such a robot (i) knows general cultural characteristics, intuitively, those characters that are shared by a group of people; (ii) it is aware that general characteristics take different forms in different individuals, thus avoiding stereotypes; and (iii) it is sensitive to cultural differences while perceiving, reasoning, and acting. These robots will be able to adapt how they behave and speak to the culture, customs and manners of the person they interact with. We believe that cultural competence is especially important in assistive robots, where it can increases their acceptability and effectiveness, which will help to improve the quality of life of users and their caregivers, support active and healthy ageing, and reduce caregiver burden.

The contribution of this article is three-fold: (i) to provide a precise definition of cultural competence in robotics, together with an overview of current efforts in culturally competent robots; (ii) to analyse the capabilities which are needed to enable culturally competent robot behaviour; and (iii) to propose a concrete methodology for their development and evaluation. The methodology is grounded in the work currently performed in the *CARESSES* project, a joint EU-Japan effort started in 2017 which aims to develop and evaluate a culturally competent robot for elderly assistance (see `www.caressesrobot.org`).

The next sections introduce the three contributions men-

[1] B. Bruno and A. Sgorbissa are with the University of Genova, Via Opera Pia 13, 16145 Genova, Italy.
[2] Y. Lim and N.Y. Chong are with the Japan Advanced Institute of Science and Technology, 1-1 Asahidai, Nomi, Ishikawa 923-1292, Japan.
[3] H. Kamide is with Nagoya University, Furocho, Chikusaku, Nagoya, Aichi 464-8601, Japan.
[4] S. Kanoria is with Advinia Health Care Limited LTD, Regents Park Road 314, London N3 2JX, United Kingdom.
[5] J. Lee is with Chubu University, 1200 Matsumoto-cho, Kasugai, Aichi 487-8501, Japan.
[6] A.K. Pandey is with Softbank Robotics Europe SAS, Rue Colonel Pierre Avia 43, 75015 Paris, France.
[7] C. Papadopoulos is with the University of Bedfordshire, Park Square, Luton LU1 3JU, United Kingdom.
[8] I. Papadopoulos is with Middlesex University Higher Education Corporation, The Burroughs, Hendon, London NW4 4BT, United Kingdom.
[9] F. Pecora and A. Saffiotti are with Örebro University, Fakultetsgatan 1, S-70182 Örebro, Sweden.
Corresponding author's email: `antonio.sgorbissa@unige.it`

tioned above, followed by a discussion on the testing and evaluation methodology and by some concluding remarks.

II. Robots and Cultural Competence

In order to make the concept of a culturally competent robot precise enough to discuss its technical requirements, we first introduce several notions related to cultural competence in general.

A. Facets of cultural competence

Culture and cultural competence are difficult terms to define. In our work, we adopt the following definitions taken from the field of transcultural health and social care [5].

Culture. All human beings are cultural beings. Culture is the shared way of life of a group of people that includes beliefs, values, ideas, language, communication, norms and visibly expressed forms such as customs, art, music, clothing, food, and etiquette. Culture influences individuals' lifestyles, personal identity and their relationship with others both within and outside their culture. Cultures are dynamic and ever changing as individuals are influenced by, and influence their culture, by different degrees.

Cultural identity. The concept of identity refers to an image with which one associates and projects oneself. Cultural identity is important for people's sense of self and how they relate to others. When a nation has a cultural identity it does not mean that it is uniform. Identifying with a particular culture gives people feelings of belonging and security.

Cultural awareness. Cultural awareness is the degree of awareness we have about our own cultural background and cultural identity. This helps us to understand the importance of our cultural heritage and that of others, and makes us appreciate the dangers of ethnocentricity. Cultural awareness is the first step to developing cultural competence and must therefore be supplemented by cultural knowledge.

Cultural knowledge. Meaningful contact with people from different ethnic groups can enhance knowledge around their health beliefs and behaviours as well as raise understanding around the problems they face.

Cultural sensitivity. Cultural sensitivity entails the crucial development of appropriate interpersonal relationships. Relationships involve trust, acceptance, compassion and respect as well as facilitation and negotiation.

Cultural competence. Cultural competence is the capacity to provide effective care taking into consideration people's cultural beliefs, behaviours and needs. It is the result of knowledge and skills which we acquire during our personal and professional lives and to which we are constantly adding. The achievement of cultural competence requires the synthesis of previously gained awareness, knowledge and sensitivity, and its application in the assessment of clients' needs, clinical diagnosis and other caring skills.

B. Cultural competence in robotics until today

An analysis of the literature on personal, social and assistive robots reveals that the issue of cultural competence has been largely under-addressed, and a lot of work is still to be done to pave the way to culturally competent robots.

It is an established fact that robots are generally treated by people as social actors and expected to comply with social norms [6]. As an example, two different studies on the interpersonal distance between a person and a robot report that people (i) mostly conform to Hall's social zones when approaching a robot, thus acknowledging it as a social actor [7] and (ii) prefer a robot that stays out of people's intimate space zone, thus expecting it to behave as a socially-competent actor [8]. A study on the acceptability of a robot navigating a human environment found that a robot programmed to respect four basic social conventions was preferred over one lacking this knowledge [9].

A number of studies support the hypothesis that people from different cultures not only (i) have different preferences concerning how the robot should be and behave [6], but also (ii) tend to prefer robots better complying with the social norms of their own culture, both in the verbal [10], [11] and non-verbal behaviour [12], [8]. This preference does not merely affect the robot's likeability. In a series of experiments on the influence of culture on Human-Robot Interaction, participants from the USA and China were asked to solve a task with the possibility of using the suggestions of a robot assistant [6]. Experimenters analysed the level of trust, comfort, compliance, sense of control and anthropomorphism inspired by the robot and found that participants had more trust and a more effective interaction with the robot complying with the norms of their own culture [10].

Lastly, an innovative take on the analysis of the effect of culture on the interaction between a person and a robot investigates whether cultural similarities entail similar preferences in the robot's behaviour. An experiment with Dutch participants and two robots, respectively customized for the German and Japanese culture, provides preliminary support to the hypothesis that acceptance of a robot could be directly proportional to cultural closeness [13].

Despite the aforementioned findings, little work has been reported on how to build robots that can be easily adapted to a given cultural identity.

Torta et al. [14] propose a method to parametrize the interpersonal distance and direction of approach that the robot should use when talking to a person. They first define a function (Region of Approach) with higher values for distances and orientations which are found to be comfortable for the user and lower values for other distances and orientations. Then, they combine this function with path planning information in a Bayesian inference mechanism to identify a suitable target pose for the robot.

A complex example of cultural adaptation explores a framework for the learning and selection of culturally appropriate greeting gestures and words [15]. In the proposed architecture, an initial set of gestures and words is extracted from video and text corpora, and initial associations between gestures and words and cultural factors are drawn from literature in social studies and expressed as conditional probabilities in a Naive Bayes classifier. At run-time, the user's

TABLE I

INTRODUCTION SCENARIO: MRS CHRISTOU, A 75 YEARS OLD GREEK CYPRIOT WHO MIGRATED TO THE UK WHEN SHE WAS 20 YEARS OLD.

Scenario	Robot skills	Cultural competence
ROBOT: Hello Mrs. Christou!	Perception (Face recognition)	
The robot hugs Mrs. Christou	Moving (Arms)	
MRS CHRISTOU: Hello!		
Mrs. Christou smiles and hugs the robot		
ROBOT: Would you prefer me to call you Kyria Maria?	Speaking (Asking for yes/no confirmation)	[Cultural Knowledge: general (1)] The Greek Cypriot culture is very similar to that of Greece, in which hierarchy should be respected and some inequalities are to be expected and accepted.
MRS CHRISTOU: Yes, that's how one calls an older woman in Cyprus. What is your name?		[Cultural Awareness (2)] Mrs. Christou values her culture and its customs. She expects others to treat her older age status with some respect: this is why she likes that the robot calls her Kyria Maria (Kyria is Greek for Mrs).
ROBOT: I don't have a name yet. Would you like to give me a name?	Speaking (Catching key words and reacting)	
The robot leans slightly forward	Moving (Body posture)	
KYRIA MARIA: I will call you Sofia after my mother, God rest her soul.		[Cultural Awareness (3)] She names the robot after her mother, a common custom to name one's children. She shows her respect to the dead through signs of her religiosity.
The robot asks for confirmation for the name, infers that Sofia is the name of Kyria Maria's mother and asks for confirmation	Speaking (Catching key words; asking for yes/no confirmation)	
ROBOT SOFIA: Thank you, I like the name. I am honoured to be called after your mother.		
The robot smiles and hugs Kyria Maria	Moving (Arms)	

cultural background, stored as a vector of cultural factors, is used to identify the greeting gestures and words which better match his/her profile. A post-interaction questionnaire is then used as a feedback for the classifier, to allow for an on-line update of the association between cultural profiles and greeting gestures and words.

Both of the reported works consider adaptation at a personal level, and follow a "bottom-up" approach, i.e. they identify nations as clusters of people with similar cultural profiles. The major limitation of this approach is that it is not well suited for encoding cultural information expressed at national-level, nor how such information influences preferences in the robot behaviours. As such, adaptation to a different culture is a demanding process which requires either a long time, or a large corpus of data to begin with.

A first attempt at developing a "top-down" approach explores the use of national-level cultural information for the cultural customization of the gestures and facial expressions of a virtual agent [16]. Among the most popular metrics for the description of culture at a national-level, Hofstede's dimensions for the cultural categorization of countries are six scales in which the relative positions of different countries are expressed as a score from 0 to 100 [17]. As an example, the dimension of *Individualism* examines whether a nation has a preference for a loosely-knit social framework, in which individuals are expected to take care of only themselves and their immediate families, or for a tightly-knit framework, in which individuals can expect their relatives or members of a particular in-group to look after them, a notion which Hofstede called *Collectivism*.

More recently, Hofstede's dimensions have been used to express the influence of culture on the gestures and words that a robot should use at a first meeting with a person [18]. The proposed framework is among the very first attempt at merging the "top-down" and "bottom-up" approaches, since the system makes use of empirical data (a corpus of tagged video recordings of pairs of people from the same country meeting for the first time) to complement the theoretical values given by Hofstede's dimensions.

III. REQUIRED CAPABILITIES FOR A CULTURALLY COMPETENT ROBOT

The concepts related to cultural competence that we have defined in the previous section are necessarily general. In order to arrive to a set of concrete technical requirements for cultural competent robots, we have grounded those concepts in three tangible examples, summarized in Tables I, II and III. Each example describes a possible scenario of interaction between a culturally competent assistive robot and an elderly person. The examples have been written by experts in Transcultural Nursing and draw inspiration from the rationale and actions of culturally competent (human) caregivers.

Each table reports a pattern of sensorimotor and/or verbal interaction, the required robot skills, as well as the cultural competence (in terms of cultural awareness, cultural knowledge and cultural sensitivity) that may contribute to determine the robot's behaviour. Albeit short, the scenarios show that the following capabilities are key for a robot to exhibit a culturally competent behaviour.

a) Cultural knowledge representation: This refers to the capability of storing and reasoning upon cultural knowledge, see for example the interaction between the robot

TABLE II

HEALTH-CARE SCENARIO: MRS SMITH, A 75 YEAR OLD ENGLISH LADY, A FORMER SCHOOL TEACHER.

Scenario	Robot skills	Cultural competence
The robot Aristotle detects that Mrs. Smith is in a bad mood and adopts a more cheerful voice	Perception (Understanding facial expressions)	
ROBOT ARISTOTLE: How do you feel today Dorothy?		
MRS DOROTHY SMITH: I feel OK but it's time for my tablets. I have diabetes.		[Cultural Knowledge: general (4)] The UK has a pragmatic orientation.
A: Do you take tablets for diabetes?	Speaking (Catching key words; asking for yes/no confirmation)	[Cultural Knowledge: specific (5)] The robot is matching what Mrs. Smith says with pre-stored knowledge about her health.
D: Yes.		
A: Do you want me to remind you to take them?		
D: Yes! I take them three times a day: morning, midday and evening. But sometimes I forget them.		
A: OK. I will remind you! Please select your schedule on my screen.	Planning (Reminder)	[Cultural Knowledge: specific (6)] The robot knows that Mrs. Smith, a former school teacher, is already familiar with using a tablet.
The robot leans forward. Mrs. Smith selects morning, midday and evening on the screen	Moving (Body posture), Multimodal Interaction (Using multiple input modalities)	
A: Is there anything I can do for you? Can I get you some water for the tablets?		[Cultural Knowledge: specific (7)] The robot is acquiring knowledge about what it means to Mrs. Smith to have diabetes.
D: Yes. That would be very nice Aristotle.		
The robot goes to fetch a glass of water	Planning (Retrieving an object), Perception (Locating an object), Moving (Legs, hands)	

Aristotle and Mrs. Smith in Table II, in which the robot first uses knowledge (6) about Mrs. Smith 's work experience to tune how to introduce a new interaction modality (its tablet), and later acquires new knowledge about her habits and medical prescriptions (7).

b) Culturally-sensitive planning and execution: This refers to the capability to produce plans and adapt such plans depending on the cultural identity of the user. Cultural sensitivity, in the interaction between the robot Yuko and Mrs. Yamada in Table III, allows the robot for planning to help Mrs. Yamada make a video call (10).

c) Culture-aware multi-modal human-robot interaction: This refers to the capability of adapting the way of interacting (in terms of gestures, choice of phrases, tone and volume of voice, etc.) to the user's cultural identity. Cultural sensitivity makes the robot avoid asking direct questions to Mrs. Yamada (see Table III) and perform the proper greeting gestures with Mrs. Christou (see Table I).

d) Culture-aware human emotion and action recognition: This refers to the capability to interpret sensor data acquired by the robot during the interaction in light of cultural knowledge. As an example, in Table II the robot Aristotle correctly labels Mrs. Smith's facial expression as indicative of a bad mood, while in Table III the robot Yuko relies on Mrs. Yamada's facial expression to get feedback on its suggestion to make a video call.

e) Cultural identity assessment, habits and preferences detection: This refers to the capability to adapt general cultural knowledge and acquire new knowledge to better fit the individual profile of the user. As an example, in Table I the robot Sofia uses knowledge about the Greek culture to guess how Mrs. Christou would like to be addressed (1), and uses her answer to validate its hypothesis (2). In Table II, the robot Aristotle learns Mrs. Smith's habits in dealing with her medical prescriptions (5), and in Table III the robot Yuko brings up the topic of video calls (8) to learn about Mrs. Yamada's family.

IV. DEVELOPMENT METHODOLOGY FOR A CULTURALLY COMPETENT ROBOT

The next and last step in our discussion is to propose a methodology to develop culturally competent robots. In order to make the discussion more concrete, we assume that the capabilities discussed above are organized in the functional architecture shown in Figure 2. Cultural knowledge is provided offline by experts and online by users (orange arrows) and processed to perform a cultural identity assessment of the user. The assessment allows for better matching to the user's preferences the commands and parameters for the robot (blue arrows), as well as for any smart device eventually distributed in the environment (yellow box).

A. Bootstraping cultural knowledge

As Figure 2 shows, the robot's attitude towards the user is initially created based on experts knowledge from the fields of Transcultural Nursing and Culturally Competent Healthcare. National-level cultural information, such as Hofstede's dimensions [17], complemented with specific information about the user's cultural group, allow for making preliminary assumptions about the expected behaviour of a cultural competent robot, described in terms of Cultural Awareness, Cultural Knowledge and Cultural Sensitivity [5]. This preliminary assessment can be refined on the basis of the cultural behavioural cues collected, for example, from

TABLE III

HOME AND FAMILY SCENARIO: MRS YAMADA, A 75 YEARS OLD JAPANESE LADY WHO PERFORMED TEA CEREMONY IN KOBE FOR 40 YEARS

Scenario	Robot skills	Cultural competence
ROBOT YUKO: It is possible to test the video call with your family, if you like it. *The robot checks for Mrs. Yamada's reaction. She smiles.*	Speaking (Avoiding direct qques-tions) Perception (Understanding facial expressions)	
MRS NAOMI YAMADA: Really? My son and daughter both live in Tokyo. My son is always busy, but he visits me during holidays. I miss my daughter so much. Her husband is Korean so she often goes to Korea. I want to call my husband, but he's now giving a lecture at school.		[Cultural Knowledge: specific (8)] Naomi provides her personal details only when the robot brings up the topic.
Y: I can make a video call to your daughter, son or husband if you want. *The robot checks for Mrs. Yamada's reaction*	Speaking (Catching key words and reacting) Perception (Understanding facial expressions)	
N: Maybe later. I don't know how to do it. Can you give me a manual on how to do it?		[Cultural Knowledge: general (9)] Japan is one of the most uncertainty avoiding countries on earth.
Y: Just tell me who you want to call, then I can help you. You are welcome to try.	Planning (Video call)	[Cultural Sensitivity (10)] Empowering: the robot is sensitive of the fact that Naomi is frightened by using unknown technology, and encourages her.
N: Ok, let's try. You will be my assistant!		

video recorded encounters between older people living in sheltered housing and their caregivers, carefully analysed to avoid stereotypic notions [19].

The knowledge acquired in all these steps shall ultimately produce guidelines describing how culturally competent robots are expected to behave in assistive scenarios. Moreover, in the perspective of a commercial exploitation, it can allow the development of robots that are able to autonomously acquire information and update their own knowledge about the cultural context in which they are operating and –ultimately– to re-configure their approach towards the user.

B. Cultural Knowledge Representation

Properly encoding guidelines for cultural competence in a framework for knowledge representation requires to take into account both methodological and architectural aspects.

Methodological aspects include: (i) how to represent the relationship between quantitative and qualitative knowledge about different cultural groups; (ii) how to avoid stereotypes by allowing for differences among individuals, while using the information about their national culture as a hint about

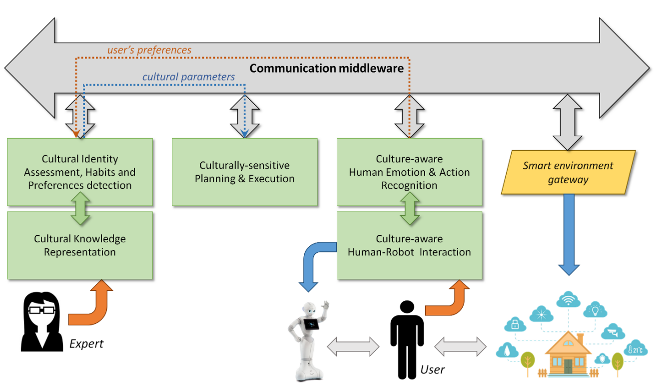

Fig. 2. The functional architecture of a culturally competent robot.

their cultural identity; (iii) how to automatically reason on cultural knowledge for producing a culturally competent robotic behaviour, i.e., plans and sensorimotor behaviours aligned with the user's cultural identity; and (iv) how to update the knowledge base as long as new cultural knowledge is acquired through user-robot interaction.

Technical aspects include: which languages and tools should be used for cultural knowledge representation, which languages and tools should be used for querying the knowledge base, which reasoning tools should be adopted, and which Application Programming Interfaces, data formats, and protocols should be used to allow the robot to access the knowledge base. The field of Artificial Intelligence (AI) has a rich repertoire of formalisms and tools for knowledge representation and reasoning [20], but how these can be applied to the specific case of *cultural* knowledge is an open and as yet unexplored issue.

A key problem here is how to define procedures for the knowledge base creation and updating. In general, cultural knowledge can be defined and introduced in the system *a priori* by experts in Transcultural Nursing or by formal and informal caregivers; or it can be acquired at run-time through robot-user interaction; or both. Run-time knowledge acquisition raises the most important methodological and technological issues, e.g., which questions should be posed to the user, how answers should be interpreted, how the information retrieved should be used to pose subsequent questions and to update the Knowledge Base itself. It also raises issues on how general cultural information known a priori (e.g., at national level) impacts on individual characteristics, and how the information acquired during robot-user interaction (i.e., through explicit communication) can be merged with the already available knowledge in order to perform a more accurate cultural assessment.

Finally, the inclusion of personal knowledge in the cultural knowledge base raises ethics issues in data privacy and protection, which are even more compelling since the system may store sensitive information not only about the users, but also about their family (e.g., names, health status).

C. Culturally-Sensitive Planning and Execution

Once cultural knowledge has been explicitly produced, the challenge is to make the robot use this knowledge to modulate its own behaviour to match the cultural identity of the user. Technically, the ability of the robot to "modulate its own behavior" translates into the ability to: (i) form plans to achieve the robot's goals while being aware of, and sensitive to, the user's culture; and (ii) execute the actions in these plans in a way that is also culturally aware and sensitive. As an example, the three robots in Tables I, II and III may have the same goal to help preparing the lunch, but they may achieve this goal using different plans. These plans may include different actions (e.g., Aristotle may help Mrs Smith by ordering the food online, whereas Sofia listens to Mrs Christou chatting about cooking), or different ways to perform an action (e.g., Yuko collaboratively prepares the lunch with Mrs Yamada).

The field of AI has a long tradition in developing techniques for the automatic generation and execution of action plans that achieve given goals [21]. Cultural aspects can contextually influence the generation and execution of action plans in three ways:

- Discourage the use of certain actions; for example, to avoid suggesting recipes to Mrs Christou;
- Include additional preconditions or goals, which may result in the inclusion of new actions; for example, with Mrs Yamada, the robot Yuko performs an inquiry action before committing to one action plan or another;
- Induce a preference for some actions; for example, Yuko may encourage Mrs Yamada to cook instead of ordering food online, because this better complies with Mrs Yamada's need to make physical activity.

To take these influences into account, state-of-the-art approaches to constraint-based planning [22] shall be considered. In addition to requirements in terms of causal preconditions (e.g., the robot's hand must be empty to grasp an object), spatial requirements (e.g., the robot must be in front of the user in order to interact), and temporal constraints (e.g., the tea must be served before it gets cold), constraint-based planning can also include constraints that pertain to the human-robot relation, e.g., to encode the fact that the robot should never clean a room where the user is standing: this extension of constraint-based planning is particularly suited to generate plans that take into account cultural constraints and, in general, "human-aware planning" [23].

D. Culture-aware multi-modal Human-Robot Interaction

Once a proper course of actions (including both motion and speech) has been planned taking into account the user's cultural identity, actions must be executed and feedback must be considered to monitor their execution. In this context, Human-Robot Interaction plays a crucial role in enabling the robot with cultural competence. On the one hand, the way the robot behaves and speaks can produce different impacts and subjective experiences on the user; on the other hand, what the user says and does is the key for the robot to acquire new knowledge about the user, and consequently refine and improve its cultural competence. As a prerequisite, the robot shall be equipped with motor capabilities that are sophisticated enough to allow it to exhibit its cultural competence through motions, gestures, posture, speech; similarly, it is mandatory that the robot (and possibly the environment) is equipped with sensors and devices for multimodal audio / video / haptic interaction that allow providing feedback to the modules for planning, action execution and monitoring, as well as perceiving the nuances of human behaviour in different cultures. Moreover, communication devices allowing for a simplified interaction may also be fundamental for frail older adults.

The role played by robot-user *verbal communication* shall be carefully considered, as it is the primary way of interaction, possibly allowing to acquire new knowledge and update the Cultural Knowledge Base. We argue that, due to the current limitation in natural language understanding, semantic comprehension shall be limited to the recognition of relevant keywords, that the robot will use to react accordingly, by asking a confirmation through a simple multiple choice (e.g., yes/no) question. Additional touchscreen-based interfaces (either embedded on the robot or carried by users, e.g., tablets and smartphones) might be used to complement the verbal interaction modality.

E. Culture-aware Human Emotion and Action Recognition

The robot's perceptual capabilities shall include the ability to estimate human *emotions* (joy, sadness, anger, surprise) and recognize human *actions*. If the robot operates in a smart ICT environment, the usage of lightweight wearable sensors that do not interfere with daily activities shall be explored (e.g., smartwatches or sewable sensors).

Lastly, the robot shall be equipped with a module to detect and recognize *daily activities*, i.e., combinations of primitive actions performed in different contexts and places of the house (e.g., walking, cleaning, sitting on a sofa, etc.) [24].

F. Cultural Identity Assessment, Habits and Preferences detection

As time progresses and the robot has more and more interactions with the user, daily activities and manners (a subset of social norms that regulate the actions performed by the user towards other humans, or even the robot itself) may be assessed to determine the long-term *habits* of the human companion. Verbal interaction, as well as the assessment of user's, emotions, actions, daily activities, manners, and habits, will ultimately provide an input to perform a cultural assessment of the user, updating the knowledge that the robot has about the user's cultural identity.

The aforementioned capabilities shall involve procedures to merge and interpret sensor data acquired by the robot and by the smart ICT environment at the light of cultural knowledge that is already stored in the system. Indeed, cultural knowledge can play a fundamental role at all levels of perception, ranging from basic object recognition to the detecting of daily activities, manners and habits. For instance, if the system is uncertain if a purple object in the fridge is a slice of pig liver or an eggplant, cultural information about the alimentary customs of the users (that maybe are vegetarians) could help to disambiguate.

V. Testing and Evaluation

Once the technology for a cultural competent robot are in place, its impact on the target user group shall be empirically evaluated. A typicaly protocol would divide participants in an experimental arm, interacting with robots with cultural customization, and a control arm, interacting with robots without cultural customization. Beside the cultural customization, the two arms should be use setups that as as similar as possible.

In the case of evaluation with elderly participants, an ethically sensitive and detailed protocol that describes the screening, recruitment, testing and analytical procedures must be produced and scrutinised by relevant ethics committees. Testing should involve older adults belonging to different cultural groups, who possess sufficient cognitive competence to participate and who are assessed as sufficiently unlikely to express aggression during the testing period, together with nominated key informal caregivers (e.g. close family members).

End-user evaluation shall be aimed at evaluating the capability of culturally competent systems to be more sensitive to the user's needs, customs and lifestyle, thus impacting on the quality of life of users and their caregivers, reducing caregiver burden, and improving the system's efficiency and effectiveness. Quantitative outcomes of interest and measurement tools shall include the following (pre and post testing).

f) Client perception of the robot's cultural competence: Measurement tool: Adapted RCTSH Cultural Competence Assessment Tool (CCATool) [25]. The tool measures clients' perceptions of the robot's cultural awareness, cultural safety, cultural competence and cultural incompetence, and includes items associated with dignity, privacy and acceptability.

g) Client and informal caregiver health related quality of life: Measurement tool: Short Form (36) Health Survey (SF-36) [26]. The SF-36v2 is a multi-purpose, short-form health survey proven to be useful in surveys of general and specific populations, including older adults. It measures general health, bodily pain, emotional role limitation, physical role limitation, mental health, vitality, physical functioning and social functioning. Each dimension score has values between 0 and 100, in which 0 means dead and 100 perfect health.

h) Informal caregiver burden: Measurement tool: The Zarit Burden Inventory (ZBI) [27]. The ZBI is a widely used 22-item self-report inventory that measures subjective care burden among informal caregivers. Its validity and reliability have been widely established. The scale items examine burden associated with functional/behavioural impairments and care situations. Each item is scored on a 5-point Likert Scale, with higher scores indicating higher care burden among informal caregivers.

i) Client satisfaction with the robot: Measurement tool: Questionnaire for User Interface Satisfaction (QUIS) [28]. This scale evaluates whether the clients are satisfied with the interaction process including its efficiency and effectiveness. It should be adapted so that "the software" is replaced by "the robot".

Clients and their informal caregivers shall also be invited to participate in qualitative interviews to elicit discussions about their perceptions of the robot's cultural competence, quality of service provided, impact upon independence and autonomy, as well as — very importantly — experiences related to configuring the system by injecting cultural knowledge before operations.

VI. Discussion and Conclusions

This position paper has discussed foundations, rationale and a possible methodology for developing and evaluating a culturally competent robot, i.e., a robot able to autonomously re-configure its way of acting and speaking, when offering a service, to match the culture, customs, and etiquette of the person it is assisting. We believe that cultural competence is a necessary, although so far understudied, ingredient for any social, personal or, and especially, assistive robot.

The methodology proposed in this article is being implemented in the project CARESSES which is, to the best of our knowledge, the first attempt to build culturally competent robots. CARESSES' starting technology includes the humanoid robot *Pepper*, produced by Softbank Robotics Europe, as well as the *iHouse*, a Japanese-based duplex apartment fully embedded with sensors and actuators for home automation developed by the Japan Advanced Institute of Science and Technology.

In its current stage of development, CARESSES has gone through an initial investigation phase aimed at producing guidelines for Transcultural Robotic Nursing, as described in Section IV-A, and followed by a development phase aimed at designing and implementing components that realize the key technical capabilities discussed in Sections IV-B, IV-C, IV-D, IV-E and IV-F above. These components will be integrated in universAAL [29], a software platform for open distributed systems of systems that resulted from a consolidation process conducted within an EU Project. Testing and end-user evaluation will follow the procedure in Section V and include at least: ten clients who primarily identify themselves with the white-English culture, ten clients who primarily identify themselves with the Indian culture, and ten clients who primarily identify themselves with the Japanese culture. Each client will adopt a Pepper robot for a total of 18 hours over a period of two weeks, which should allow for enough time for a culturally customized Pepper robot to acquire knowledge about the individual cultural characteristics of the assisted person and provide culturally competent interactions and service, which will then be evaluated through quantitative tools and qualitative interviews.

CARESSES only aims at producing a first prototype, which shall be further evaluated and refined before drawing definitive conclusions about the impact of cultural competence in assistive robotics. Nonetheless, we strongly believe that the CARESSES pilot will be a foundational breakthrough in culturally competent robotics, and it will be invaluable in paving the way for future similar studies.

Acknowledgement

This work has been supported by the European Commission Horizon2020 Research and Innovation Programme under grant agreement No. 737858, and from the Ministry of Internal Affairs and Communication of Japan. We thank all the members of the CARESSES consortium, listed in the project homepage www.caressesrobot.org.

References

[1] M. Leininger and M. McFarland, *Transcultural nursing: concepts, theories, research and practice. 3rd ed.* McGraw-Hill, 2002.

[2] European transcultural nursing association. [Online]. Available: http://europeantransculturalnurses.eu/

[3] Transcultural C.A.R.E. associates. [Online]. Available: http://transculturalcare.net/

[4] K. Wongpatikaseree, M. Ikeda, M. Buranarach, T. Supnithi, A. Lim, and Y. Tan, "Activity recognition using context-aware infrastructure ontology in smart home domain," in *Proceedings of the 7th International Conference on Knowledge, Information, and Creativity Support Systems (KICSS'12)*, 2012, pp. 50–57.

[5] I. Papadopoulos, *Transcultural health and social care: development of culturally competent practitioners*. Elsevier Health Sciences, 2006.

[6] V. Evers, H. Maldonado, T. Brodecki, and P. Hinds, "Relational vs. group self-construal: untangling the role of national culture in HRI," in *Proceedings of the 3rd ACM/IEEE International Conference on Human-Robot Interaction (HRI'08)*, 2008, pp. 255–262.

[7] M. L. Walters, K. Dautenhahn, R. Te Boekhorst, K. L. Koay, C. Kaouri, S. Woods, C. Nehaniv, D. Lee, and I. Werry, "The influence of subjects' personality traits on personal spatial zones in a human-robot interaction experiment," in *Proceedings of the 14th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN'05)*, 2005, pp. 347–352.

[8] M. P. Joosse, R. W. Poppe, M. Lohse, and V. Evers, "Cultural differences in how an engagement-seeking robot should approach a group of people," in *Proceedings of the 5th ACM International Conference on Collaboration Across Boundaries: Culture, Distance & Technology (CABS'14)*, 2014, pp. 121–130.

[9] A. K. Pandey and R. Alami, "A framework for adapting social conventions in a mobile robot motion in human-centered environment," in *Proceedings of the International Conference on Advanced Robotics (ICAR'09)*, 2009, pp. 1–8.

[10] L. Wang, P.-L. P. Rau, V. Evers, B. K. Robinson, and P. Hinds, "When in Rome: the role of culture & context in adherence to robot recommendations," in *Proceedings of the 5th ACM/IEEE International Conference on Human-Robot Interaction (HRI'10)*, 2010, pp. 359–366.

[11] S. Andrist, M. Ziadee, H. Boukaram, B. Mutlu, and M. Sakr, "Effects of culture on the credibility of robot speech: A comparison between english and arabic," in *Proceedings of the 10th ACM/IEEE International Conference on Human-Robot Interaction (HRI'15)*, 2015, pp. 157–164.

[12] G. Eresha, M. Häring, B. Endrass, E. André, and M. Obaid, "Investigating the influence of culture on proxemic behaviors for humanoid robots," in *Proceedings of the 22nd IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN'13)*, 2013, pp. 430–435.

[13] G. Trovato, J. R. Ham, K. Hashimoto, H. Ishii, and A. Takanishi, "Investigating the effect of relative cultural distance on the acceptance of robots," in *Proceedings of the International Conference on Social Robotics (ICSR'15)*, 2015, pp. 664–673.

[14] E. Torta, R. H. Cuijpers, J. F. Juola, and D. van der Pol, "Design of robust robotic proxemic behaviour," in *Proceedings of the International Conference on Social Robotics (ICSR'11)*, 2011, pp. 21–30.

[15] G. Trovato, M. Zecca, M. Do, Ö. Terlemez, M. Kuramochi, A. Waibel, T. Asfour, and A. Takanishi, "A novel greeting selection system for a culture-adaptive humanoid robot," *International Journal of Advanced Robotic Systems*, vol. 12, 2015.

[16] M. Rehm, N. Bee, B. Endrass, M. Wissner, and E. André, "Too close for comfort?: adapting to the user's cultural background," in *Proceedings of the ACM International Workshop on Human-centered Multimedia (HCM'07)*, 2007, pp. 85–94.

[17] G. Hofstede, G. J. Hofstede, and M. Minkov, *Cultures and organizations: Software of the mind. Revised and expanded*. McGraw-Hill, 2010.

[18] B. Lugrin, J. Frommel, and E. André, "Modeling and evaluating a Bayesian network of culture-dependent behaviors," in *Proceedings of the International Conference on Culture and Computing (Culture Computing '15)*, 2015, pp. 33–40.

[19] M. Makatchev, "Cross-cultural believability of robot characters," Ph.D. dissertation, Robotics Institute, Carnegie Mellon University, Pittsburgh, PA, January 2013.

[20] F. Van Harmelen, V. Lifschitz, and B. Porter, *Handbook of Knowledge Representation*. Elsevier, 2008.

[21] M. Ghallab, D. Nau, and P. Traverso, "The actor's view of automated planning and acting: A position paper," *Artificial Intelligence*, vol. 208, pp. 1–17, 2014.

[22] M. Mansouri and F. Pecora, "A robot sets a table: a case for hybrid reasoning with different types of knowledge," *Journal of Experimental & Theoretical Artificial Intelligence*, vol. 28, no. 5, pp. 801–821, 2016.

[23] U. Köckemann, F. Pecora, and L. Karlsson, "Grandpa hates robots - interaction constraints for planning in inhabited environments," in *Proceedings of the 28th AAAI Conference on Artificial Intelligence (AAAI'14)*, 2014, pp. 2293–2299.

[24] B. Bruno, F. Mastrogiovanni, A. Saffiotti, and A. Sgorbissa, "Using fuzzy logic to enhance classification of human motion primitives," in *Proceedings of the 15th International Conference on Information Processing and Management of Uncertainty in Knowledge-Based Systems (IPMU'14)*, 2014, pp. 596–605.

[25] I. Papadopoulos, M. Tilki, and S. Lees, "Promoting cultural competence in health care through a research based intervention," *Diversity in Health and Social Care*, vol. 1, no. 2, pp. 107–115, 2004.

[26] R. Hays, C. Sherbourne, and R. Mazel, "The RAND 36-item health survey 1.0," *Health Economics*, vol. 2, no. 3, pp. 217–27, 1993.

[27] S. Zarit, K. Reever, and J. Bach-Peterson, "The RAND 36-item health survey 1.0," *Gerontologist*, vol. 20, no. 6, pp. 649–55, 1980.

[28] J. Chin, V. Diehl, and K. Norman, "Development of an instrument measuring user satisfaction of the human-computer interface," in *Proceedings of the SIGCHI conference on Human factors in computing systems (CHI'88)*, 1988, pp. 213–218.

[29] E. Ferro, M. Girolami, D. Salvi, C. Mayer, J. Gorman, A. Grguric, R. Ram, R. Sadat, K. M. Giannoutakis, and C. Stocklow, "The universAAL platform for AAL (ambient assisted living)," *Journal of Intelligent Systems*, vol. 24, no. 3, pp. 301–319, 2015.