The CARESSES EU-Japan Project: Making Assistive Robots Culturally Competent

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Abstract The nursing literature shows that cultural competence is an important requirement for effective healthcare. We claim that personal assistive robots should likewise be culturally competent, that is, they should be aware of general cultural characteristics and of the different forms they take in different individuals, and take these into account while perceiving, reasoning, and acting. The CARESSES project is a Europe-Japan collaborative effort that aims at designing, developing and evaluating culturally competent assistive robots. These robots will be able to adapt the way they behave, speak and interact to the cultural identity of the person they assist. This paper describes the approach taken in the CARESSES project, its initial steps, and its future plans.

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1 Introduction

Designers of personal 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. In one word, it depends on the person's own *cultural identity*.

The need for cultural competence in healthcare has been widely investigated in the nursing literature [17]. The fields of Transcultural Nursing and Culturally Competent Healthcare play a crucial role in providing culturally appropriate nursing care, as the presence of dedicated international journals and worldwide associations reflects [7, 24].

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 [28], that reliably accomplish basic assistive services. However, state-of-the-art robots consider only the problem of "what to do" in order to provide a service: they produce rigid recipes, which are invariant with respect to the place, person and culture. We argue that reasoning only about "what to do" 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 the assisted person in deciding "how" to provide their services.

The CARESSES project[1] is a joint EU-Japan effort that will design culturally aware and culturally competent elder care robots (see the Fact Sheet in Fig. 4 at the end of this paper). These robots will be able to adapt how they behave and speak to the culture, customs and manners of the person they assist. The CARESSES innovative approach will translate into care robots that are designed to be sensitive to the culture-specific needs and preferences of elderly clients, while offering them a safe, reliable and intuitive system, specifically designed to support active and healthy

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[1] Culture-Aware Robots and Environmental Sensor Systems for Elderly Support, www.caressesrobot.org.

ageing and reduce caregiver burden. Moreover, from a commercial perspective, the cultural customization enabled by CARESSES will be crucial in overcoming the barriers to marketing robots across different countries.

The rest of this article describes the CARESSES project. We start by clarifying, in Sect. 2, the type of "cultural competence" that we address. Section 3 gives an overview of the CARESSES approach. The following three sections present the developmental methodology, the technical solutions, and the evaluation strategies, respectively. Finally, Sect. 7 discusses the project's status and future plans, and Sect. 8 concludes.

2 Facets of Cultural Competence

Culture is a notoriously difficult term to define. In the CARESSES project, we have adopted the following definitions [22] in order to make our discussion precise and to help us identify the key components of a culturally competent robot.

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.

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

Several studies support the hypothesis that people from different cultures not only (i) have different preferences concerning how the robot should be and behave [8], but also (ii) tend to prefer robots better complying with the social norms of their own culture [25], both in the verbal [1, 27] and non-verbal behaviour [6, 13]. Despite these findings, little work has been reported on how to build robots that can be easily adapted to a given cultural identity. An interesting example is the framework for the learning and selection of culturally appropriate greeting gestures and words proposed by Trovato et al. [26]. This work, like the ones mentioned above, considers adaptation at a personal level, and follows a "bottom-up" approach, i.e., which identifies nations as clusters of people with similar cultural profiles. 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 "top-down" approach would be better suited for encoding cultural information expressed at national-level, and how such information influences preferences in the robot behaviours. Among the most popular metrics for a top-down 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 [12]. As an example, the dimension of *Individualism versus Collectivism* 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*. Hofstede's dimensions have been used in the field of assistive robotics to express the influence of culture on the gestures and words that a robot should use at a first meeting with a person [16], or to decide certain motion parameters like the approach distance depending on the cultural profile of the person [3].

3 The CARESSES Approach

The CARESSES approach to design *culturally competent robots* combines the above top-down and bottom-up approaches. When a robot interacts with a person for the first time, it uses a top-down approach to bootstrap its behavior using a cultural identity based on his or her cultural group; over the course of time, the robot then uses a bottom-up approach to refine this cultural identity based on the individual preferences expressed by that person.

Figure 1 illustrates this concept. For CARESSES, a culturally competent robot: (i) knows general cultural characteristics (intuitively, characteristics that are shared by a group of people); (ii) is aware that general characteristics take different forms in different individuals, thus avoiding stereotypes; and (iii) is sensitive to cultural differences while perceiving, reasoning, and acting.

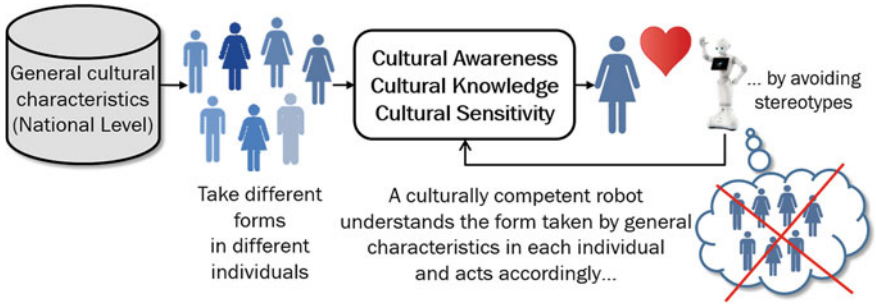

Fig. 1 The CARESSES concept of a culturally competent robot

More concretely, the culturally aware solutions developed in CARESSES will be used to expand the capabilities of the Pepper robot, which is designed and marketed by Softbank Robotics, a partner of the project. The new culturally aware capabilities will include:

- communicating through speech and gestures;
- moving independently;
- assisting the person in performing everyday tasks, e.g., helping with to-do lists and keeping track of bills, suggesting menu plans;
- providing health-related assistance, e.g. reminding the person to take her medication;
- providing easy access to technology, e.g., internet, video calls, smart appliances for home automation;
- providing entertainment, e.g., reading aloud, playing music and games.

One of the key questions addressed in CARESSES is what added value does cultural competence bring to an assistive robot. In order to precisely answer this question, the CARESSES culturally competent robots will be systematically evaluated at different test sites in Europe and in Japan, namely: the Advinia Health Care care homes (UK; project partner); the HISUISUI care home (Japan); and the iHouse facility at JAIST (Japan; project partner). These facilities play complementary roles in the evaluation: the Advinia and HISUISUI care homes provide access to real end users, who will take part in the evaluation; the iHouse, a duplex apartment fully equipped with sensors and smart appliances for home automation, will allow us to explore the integration of culturally competent robots in smart environments.

The ambitious role of CARESSES requires the close interaction of actors from different areas and different sectors. Accordingly, the CARESSES consortium includes experts in Transcultural Nursing, in Robotics, in Artificial Intelligence, in Human-Robot Interaction, and in the evaluation of technologies for the elderly. These are complemented by end users, and by a company with a long experience in developing and marketing assistive, social, educational and entertainment robots. Figure 2 shows the competences and geographical distribution of the partners in the CARESSES consortium.

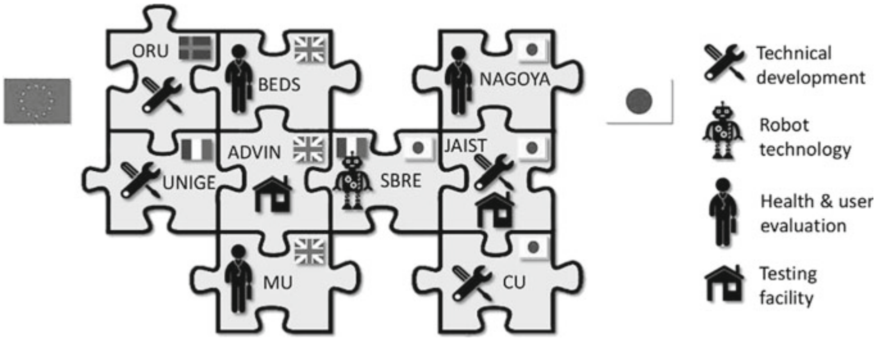

Fig. 2 The CARESSES consortium. See the Facts Sheet in Fig. 4 for the list of partners and their short names

Cooperation between the EU and Japanese partners is key for the successful accomplishment of the objectives of CARESSES. First, it offers the possibility to investigate the outcomes of interest of CARESSES through a robust user-testing approach: the impact of cultural competence in assistive robotics will be evaluated in very different cultural contexts in the EU and Japan. Second, it allows CARESSES to benefit from the complementary competences and resources of EU and JP partners. Among the others, EU and JP participants will pool two extremely valuable resources for system integration and testing: (i) the universAAL software platform for open distributed systems of systems, developed in the context of EU projects [9]; and (ii) the aforementioned iHouse facility at JAIST. Finally, this cooperation is expected to foster Transcultural Studies in Japan. While the study of Transcultural Nursing is supported by international journals and associations in the EU [7], similar studies and associations do not yet exist in Japan. As the number of foreign residents in Japan is significantly increasing, CARESSES will contribute to draw the attention of health-care professionals and public decision-makers on the role of cultural competence in health-care.

The project management structure has been designed to adequately address the peculiarities of CARESSES, a joint EU-Japan project whose research activities are performed in the context of two coordinated projects funded by different agencies: the EU Commission and the Japanese Ministry of Internal Affairs and Communications. The management of CARESSES also benefits from the support of an Ethical Advisor, an Exploitation, Dissemination, and IPR Board, and an External Expert Advisory Board.

4 Development Methodology

CARESSES follows a strongly user-driven methodology to develop relevant technological solutions, where requirements and knowledge come from the end users and domain experts, and validation is done with the end users.

The research in the areas of Transcultural Nursing and Culturally Competent Healthcare constitutes the theoretical foundations of CARESSES, paving the way to the development of culturally competent robots. The robot's attitude towards users initially relies on data available on the Hofstede's dimensions [12], complemented with specific information about the user's cultural group. This allows for making preliminary assumptions about the expected behaviour of a culturally competent robot, described in terms of Cultural Awareness, Cultural Knowledge and Cultural Sensitivity [22].

4.1 Initial Scenarios

In order to arrive to a set of technical requirements, we have grounded the above concepts in concrete examples. These are summarized in Tables 1, 2 and 3, that describe possible scenarios of interaction between a culturally competent assistive robot and an elderly person. The scenarios have been written by experts in Transcultural Nursing and draw inspiration from the rationale and actions of culturally competent 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.

Table 1 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)	

Table 2 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)	

Table 3 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.	Speaking (Avoiding direct questions)	
The robot checks for Mrs. Yamada's reaction. She smiles.	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.	Speaking (Catching key words and reacting)	
The robot checks for Mrs. Yamada's reaction	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!		

Albeit short, these scenarios show that the following capabilities are key for a robot to exhibit a culturally competent behaviour:

- *cultural knowledge representation*, this refers to the capability of storing and reasoning upon cultural knowledge, see for example the interaction between the robot Aristotle and Mrs. Smith in Table 2, 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);
- *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 3, allows the robot for planning to help Mrs. Yamada make a video call (10);

- *culture-aware multi-modal human-robot interaction*, this refers to the capability of adapting the way of interacting (in terms of gestures, 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 3) and perform the proper greeting gesture with Mrs. Christou (see Table 1);
- *culture-aware human emotion and action recognition*, this refers to the capability of interpreting sensor data acquired by the robot during the interaction in light of cultural knowledge. As an example, in Table 2 the robot Aristotle correctly labels Mrs. Smith's facial expression as indicative of a bad mood, while in Table 3 the robot Yuko relies on Mrs. Yamada's facial expression to get feedback on its suggestion to make a video call;
- *cultural identity assessment, habits and preferences detection*, this refers to the capability of adapting general cultural knowledge and acquiring new knowledge to better define the individual profile of the user. As an example, in Table 1 the robot Sofia uses knowledge about the Greek culture to guess how Mrs. Christou would like to be addressed (1), and her answer to validate its hypothesis (2). In Table 2, the robot Aristotle learns Mrs. Smith's habits in dealing with her medical prescriptions (5), and in Table 3 the robot Yuko brings up the topic of video calls (8) to learn about Mrs. Yamada's family.

4.2 Elicitation of Guidelines

To ground the assumptions into observations in real-world scenarios, the robot's cultural competence is now undergoing a process of iterative refinement on the basis of the cultural behavioural cues collected from video-recorded encounters between older people living in sheltered housing and their caregivers. Specifically, having identified and verified the relevant verbal and non-verbal behavioural cues, a panel of experts shall refine the assumptions made and update the prototype robot's cultural competence. In doing this, a great care should be paid to eliminate stereotypic notions [18].

This process will ultimately produce *guidelines* describing how culturally competent robots are expected to behave in assistive scenarios. The knowledge acquired in all these steps, both through comprehensive literature reviews on the topics and video-recorded encounters, shall be formalized using tools for knowledge representation, as the availability of formal languages for knowledge representation constitutes the basis for the robot to exhibit autonomous reasoning, planning and acting skills depending on such knowledge. Also, in the perspective of a commercial exploitation, it will 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.

5 Technical Solutions

From a technological point of view, the first steps of CARESSES have been: (i) to identify the basic technical capabilities required for cultural competence; (ii) to define a system architecture that enables the integration of these capabilities into a fully autonomous assistive robot, possibly embedded in a smart environment.

5.1 System Architecture

Figure 3 shows the main modules of the CARESSES architecture: the *Cultural Knowledge Base*, the *Culturally-sensitive Planning & Execution*, and the *Culture-aware Human-Robot Interaction*, which are briefly described in the next sections.

All the components are integrated in universAAL [9], a software platform for open distributed systems of systems that resulted from a consolidation process conducted within an EU Project. The universAAL platform allows the seamless integration of heterogeneous components within an environmental network through the extensive exploitation of two base concepts, that turn out to be very well suited for the integration of components developed by different partners of a complex RTD project: (i) the usage of ontologies to define the services provided by network nodes as well as the procedures and data formats to access such services; (ii) the usage of three dedicated communication buses for topic-based communication among network nodes, namely a Context Bus, a Service Bus, and a User Interface Bus.

A bridge between universAAL and ECHONET [20], the Japanese standard for home automation, is being designed. This will allow the robot to communicate with a smart environment. In CARESSES, this will be provided by the iHouse, a Japanese-based duplex apartment fully equipped with sensors and actuators for home automation.

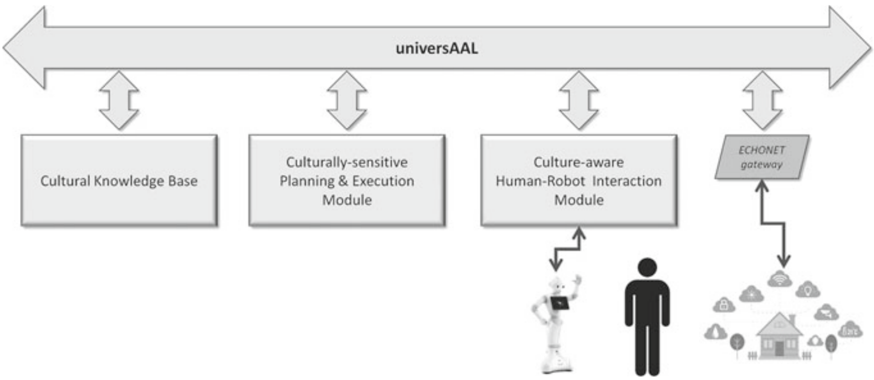

Fig. 3 A coarse view of the CARESSES architecture

5.2 Cultural Knowledge Base

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 their cultural identity; (iii) how to automatically reason on cultural knowledge to produce 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 new cultural knowledge is acquired through user-robot interaction.

Architectural aspects include: (i) which languages and tools should be used for knowledge representation, e.g., Description Logics [2], Bayesian networks [23], OWL probabilistic extensions such as PR-OWL [15]; (ii) which languages and tools should be used for querying the knowledge base: e.g., standard OWL functions, SPARQL[2]; (iii) which reasoning tools should be adopted, e.g., basic mechanisms such as subsumption or instance checking, rule-based languages such as SWRL,[3] Bayesian inference; and (iv) which Application Programming Interfaces, data formats, and protocols should be used to allow the robot to access the knowledge base.

CARESSES will consider the above aspects to produce a portfolio of solutions to be included in the general framework for Knowledge Representation. It will also define procedures for the knowledge base creation and updating. Indeed, Cultural Knowledge can be: (i) defined and introduced in the system a priori by experts in Transcultural Nursing, formal and informal caregivers; (ii) acquired at run-time through user-robot interaction. Specifically, run-time knowledge acquisition raises the most important methodological and technological issues, e.g., in terms of 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. It also raises issues on how general cultural information known a priori (e.g., at National level) impact on individual characteristics, and how the information acquired during interactions (i.e., observed through sensors or direct communication) can be merged with the already available knowledge in order to perform a more accurate cultural assessment.

Finally, Knowledge Representation raises ethical issues in data privacy and protection, which are all the more relevant whenever the system stores sensitive information not only about the user, but also his/her family (e.g., names, domicile).

[2]https://www.w3.org/TR/rdf-sparql-query/.

[3]https://www.w3.org/Submission/SWRL/.

5.3 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, this 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 1, 2 and 3 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 helps 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 Artificial Intelligence has a long tradition in developing techniques for the automatic generation and execution of action plans that achieve given goals [10]. 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 [19] have been 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" [14].

5.4 Culture-Aware 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 endowing 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 provide feedback to the modules for planning, action execution and monitoring, and are able to perceive 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* has been carefully considered, as it is the primary way of interaction, possibly allowing for acquiring new knowledge and update the Cultural Knowledge Base. Due to the current limitations in natural language understanding, semantic comprehension is limited to the recognition of relevant keywords, that the robot will use to react 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) are used to complement the verbal interaction modality.

The robot's perceptual capabilities include the ability to estimate human *emotions* (joy, sadness, anger, surprise) and recognize human *actions*. As the robot operates in a smart ICT environment, the usage of lightweight wearable sensors that do not interfere with daily activities is explored (e.g., smartwatches or sewable sensors). The robot will 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.) [4]. 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 person.

Verbal interaction, as well as the assessment of the 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 involve procedures to merge and interpret sensor data acquired by the robot and by the smart ICT environment in 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 detection 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 (who may be vegetarians) could help to disambiguate.

6 Evaluation Strategy

For the testing and evaluation with elderly participants, an ethically sensitive and detailed protocol that describes the screening, recruitment, testing and analytical procedures is being produced and scrutinised by relevant ethics committees. Once ethical approval is obtained, testing will commence. Testing will 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. Nominated key informal caregivers (e.g., close family members) shall also be recruited.

The impact of cultural competence will be quantitatively evaluated by dividing participants in experimental and control arms, i.e., interacting with robots with and without cultural customization, and by using state-of-the-art quantitative tools to measure the impact of healthcare interventions.

End-user evaluation will 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. The evaluation will take place at the Advinia Health Care network of Residential and Nursing care homes (UK) as well as in the HISUISUI care facility (Japan). The evaluation in the UK care homes will include at least ten clients who primarily identify themselves with the white-English culture and ten who primarily identify themselves with the Indian culture, while the evaluation in Japan will include at least ten clients who primarily identify themselves with the Japanese culture. Each group will be divided into an experimental and a control arm. Each client will adopt a Pepper robot for a total of 18 h over a period of two weeks. This shall 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 services, which will then be evaluated through quantitative tools and qualitative interviews. Quantitative outcomes of interest and measurement tools shall include (pre and post testing):

- Client perception of the robot's cultural competence. Measurement tool: Adapted RCTSH Cultural Competence Assessment Tool (CCATool) [21] that shall measure clients' perceptions of the robot's cultural awareness, cultural safety, cultural competence and cultural incompetence, and shall include items associated with dignity, privacy and acceptability.
- Client and informal caregiver health-related quality of life. Measurement tool: Short Form (36) Health Survey (SF-36) [11]. 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.

- Informal caregiver burden. Measurement tool: The Zarit Burden Inventory (ZBI) [29] is a widely used 22-item self-report inventory that measures subjective care burden among informal caregivers. Its validity and reliability has 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.
- Client satisfaction with the robot. Measurement tool: Questionnaire for User Interface Satisfaction (QUIS) [5]. This scale evaluates whether the clients are satisfied with the interaction process including its efficiency and effectiveness. It will be adapted so that "the software" is replaced by "the robot".

The clients and their informal caregivers will also be invited to participate in qualitative interviews to elicit discussions about their perceptions of the robot's cultural competence, the quality of provided service, and its impact upon independence and autonomy. Discussions with informal caregivers shall focus upon caregiver burden, impact on quality of life, and experiences related to configuring the system by injecting cultural knowledge before operations.

During evaluation, differences between the pre- and post-testing measures shall be considered. However, given that, to the best of our knowledge, this is the first time that the above tools are proposed to be applied in a robotic context, there are no sufficiently similar previous experimental outcome data to use to statistically power our trial in order to sensitively detect clinically meaningful differences in pre- and post- outcome measures. Therefore, we shall describe observed statistical differences in outcome measures within and between arms, and report, using appropriate inferential tests, whether these differences are statistically significant.

7 Current Status and Future Work

The CARESSES project started on January 1, 2017 (Fig. 4). Its workplan spans 37 months, implementing the methodology discussed above. The starting technology includes the Pepper robot[4] as well as the *iHouse*, a Japanese-based duplex apartment fully embedded with sensors and actuators for home automation.[5] Cultural competence will be achieved through an investigation phase aimed at producing guidelines for Transcultural Robotic Nursing[6] as described in Sect. 4, and then through the development of three main technological components described in Sect. 5 above,[7]

[4]Pepper is produced by SoftBank Robotics Europe.

[5]The iHouse has been developed by the Japan Advanced Institute of Science and Technology.

[6]This investigation phase will be led by Middlesex University (UK) with the deep involvement of Nagoya University (Japan).

[7]The development of these three components will be led, respectively, by University of Genova (Italy), Örebro University (Sweden), and Japan Advanced Institute of Science and Technology, with the deep involvement of SoftBank Robotics Europe (France) and Chubu University (Japan).

CARESSES

EU-Japan coordinated research project "CARESSES" - Fact Sheet

Full name: Culture-Aware Robots and Environmental Sensor Systems for Elderly Support (CARESSES)

Duration and starting date: 37 months from 1st January 2017

Funding:

- 2,084,248.75 EUR from the EU Commission: this project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 737858;
- 60,000,000 JPY from the Ministry of Internal Affairs and Communication of Japan.

Partners:

CARESSES is a multidisciplinary project involving researchers from different European countries and Japan, with backgrounds in Robotics, Human-Robot Interaction, Artificial Intelligence, Smart Home Automation, Transcultural Nursing, Culturally Competent Healthcare, Social Psychology, Human-Behaviour Analysis, Evaluation of Health- and Wellbeing-related Technology, along with a world leading Robotics Company, and a Network of Residential and Nursing Care Homes.

Joint/EU Coordinator:

- UNIGE: University of Genova, Italy (**Robotics, Artificial Intelligence**).
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- BEDS: University of Bedfordshire, UK (**Evaluation of Health- and Wellbeing-related technology**)
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- SBRE: Softbank Robotics Europe, France (**Robotics company**).
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  Contact person: Prof. Jaeryoung Lee, jaeryounglee@isc.chubu.ac.jp

Fig. 4 CARESSES Facts Sheet

and integrated in universAAL. Testing and end-user evaluation will follow the procedure in Sect. 6.[8]

In the first months of the project, all partners of the consortium have closely cooperated to define the initial specifications, produce scenarios of human-robot encounters, and design the system's architecture in all its details. A skeleton

[8]End-user evaluation will be led by Bedfordshire University (UK), with the deep involvement of Nagoya University.

implementation of this architecture, embedded in the universAAL framework, has been produced.

The definition of scenarios is particularly important, as it has driven the investigation of guidelines for cultural competence in robotics, the technical development of the required robotic capabilities (in terms of motion, perception, planning, knowledge representation, etc.) as well as the design of experiments for testing and evaluation since the early stages of the project. All partners of the consortium, led by Middlesex University, have cooperated to the production of these scenarios using online tools for collaborative working (e.g., Google Drive and the CARESSES GitLab repository). The close collaboration of domain experts with the technical partners has been pivotal to the success of this stage, as it has been the close collaboration between the EU and Japanese partners.

The CARESSES project is centred around the following major milestones:

October 2017 The basic guidelines for the development of culturally competent robots are ready to be used to start populating the cultural knowledge base. On the technical side, a fully integrated, albeit simplified version of the CARESSES system is implemented and integrated in the universAAL application layer. This includes a basic version of the Cultural Knowledge Base, the Culturally Sensitive Planning and Execution Module, and the Culture-aware Human-Robot Interaction Module. The latter includes the main motion and perception capabilities required by Pepper in the scenarios. Each component will subsequently be iteratively expanded, standalone debugged and tested, and refined up to its final form.

October 2018 The detailed protocol that describes the screening, recruitment, and testing procedures is complete and approved by Ethics Committee. On the technical side, the culturally competent robot is ready for final integration, deployment testing and evaluation. All the software modules have been properly integrated in universAAL and standalone tested as they were developed, and can be properly configured to produce the desired culturally competent behaviour. The Cultural Knowledge Base has been populated with the guidelines for culturally competent robots.

August 2019 The tests in Health-Care Facilities and iHouse are completed. Data and logs of robot-user encounters have been collected. These include data from pre- and post-testing structured interviews as well as post-testing qualitative semi-structured interviews with clients and informal caregivers, and are ready to be analysed.

The CARESSES project will end in January 2020. It will release its technical components for culturally competent robots as Open Source, in a form suitable to be executed in the application layer of universAAL. Most of the CARESSES deliverables are public and they will be widely disseminated. The current status of the project and related material can be accessed at the CARESSES web site www.caressesrobot.org.

8 Conclusions

Assistive robots can help foster the independence and autonomy of older persons in many ways, by reducing the days spent in care institutions and prolonging time spent living in their own home. Cultural competence allows assistive robots to be more acceptable by being more sensitive to the user's needs, customs and lifestyle. In this article, we have discussed the notion of cultural competence that is put forward in the context of the CARESSES joint EU-Japan project. We have provided an overview of the project, discussed the problems that it has to address and its methodology, and presented its initial steps.

To the best of our knowledge, CARESSES is the first attempt to build culturally competent robots. We believe that cultural competence is a necessary, although so far understudied ingredient for any social, personal or assistive robot. In this respect, we are persuaded that CARESSES is a ground-breaking project. Even if CARESSES only produces a prototype that shall need to be further evaluated and refined before drawing definitive conclusions about the impact of cultural competence in assistive robotics, we claim that our pilot will be invaluable in paving the way for future similar studies.

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