Enhancing Human Robot Interaction Through Social Network Interfaces: A Case Study

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Abstract. Recently we have assisted to the rise of different Social Networks, and to the growth of robots for home applications, which represent the second big market opportunity. The use and the integration of robotics services in our daily life is strictly correlated with their usability and their acceptability. Particularly, their ease of use, among other issues, is linked to the simplicity of the interface the user has to interact with. In this sense social networks could enrich and simplify the communication between the user and technology avoiding the multiplication of custom interfaces. In this work the authors propose a system to enHancE human RobOt Interaction through common Social networks (HeROIS). HeROIS system combines the use of cloud resources, service robot and smart environments proposing three different services to help citizens in daily life. In order to assess the acceptability and the usability levels, HeROIS system and services have been tested with 13 real users (24–37 years old) in the DomoCasa Lab (Italy). As regards the usability, the results show that the proposed system is usable for 4 participants (30.77 % M = 79.69 SD = 3.13) and excellent for 9 participants (69.23 % M = 90.05 SD = 3.72). Concerning the acceptability level, the results show that the proposed system is acceptable for 8 volunteers (61.54 % M = 77.02 SD = 4.23) and excellent for 5 participants (38.46 % M = 89.71 SD = 6.06).

Keywords: Service robots · Social network · Cloud robotics · Acceptability

1 Introduction

In recent years there has been a significant increase in the use of Social Networks [1]. The usage statistics indicate growing popularity for both Twitter and Facebook, with Twitter growing significantly faster than Facebook [2]. The rapid development and deployment of personal smart devices [3] helped to ensure that the social networks permeate anytime and anywhere in our life.

On the other side, ABI Research [4] highlights how robots for home applications represent the second major potential market opportunity for personal robotics. Several solutions show how robots could be integrated into smart homes and smart

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environments supporting the activities of daily life [5]. The use of robotic solutions in our daily life is consequent to the acceptability and usability of the proposed technology. Concerning the acceptability of the robot, three main issues are involved; that are the real willingness of the autonomous machine to be integrated, the positive attitude toward it in terms of appearance and services offered by the technology and a sufficient ease of use [6].

The ease of use of robotic solution as well as other smart devices is linked, above other issues, to the interface the user has to interact through and to the simplicity of this interface. Often different technologies have custom applications the user has to learn to use, making the usage of smart devices and robots more difficult. The use of several applications for each technologies decrease the ease of use of the smart environment itself.

In this context social networks could enrich and simplify the communication between the user and the smart technologies. In particular, in this work social networks are used to communicate with a smart home which integrated robot and smart environment.

Instead of using a new interface to manage smart home, the use of an already known one will help the user in using it.

2 Related Works

In literature there are examples on social networks integration with robotic agents. In [7] the authors compared the efficacy of Twitter to speech synthesis in communicating to waitress robot in a noisy environment. However the authors noted that the users involved in the experimentation don't like use Twitter to communicate to robot in the same room, but they preferred to use speech synthesis. Ma et al. [8] proposed a system composed by different social networks (Twitter, Google Calendar, MSN and SMS) to give instruction to the robot to accomplish surveillance and cleaning services. Nevertheless this system did not provide feedbacks to the user and not include external environmental network to extend robot sensing capabilities. Bell et al. [9] demonstrated the feasibility of producing "action" by a robot from social data. Particularly, in this work the user used Twitter to move the robot in the same room and to take a picture. They test their system with real end-user to analyze the feasibility of proposed service based on natural languages and social networks. However they underline the inefficacy to use tweet to command robot instead of voice recognition or other natural languages. Furthermore, another possible use of social networks in robotic applications was shown in [10]. In this work social networks were used as a resource of crowdsourcing allowing robot to access to the vast information available on Twitter.

Therefore, in this context, this paper aims to improve the state of the art by implementing a system which enHancE human-RObot Interaction by means of the inclusion of common Social Networks(HeROIS). HeROIS proposes a method to manage the remote interaction between the user and robotic agents creating a "link" between innovative services and already existing user interface in order to achieve the following advantages: (i) the user is able to exploit new services using social networks with which is already expert; this avoids the growth of new interfaces, each one specific

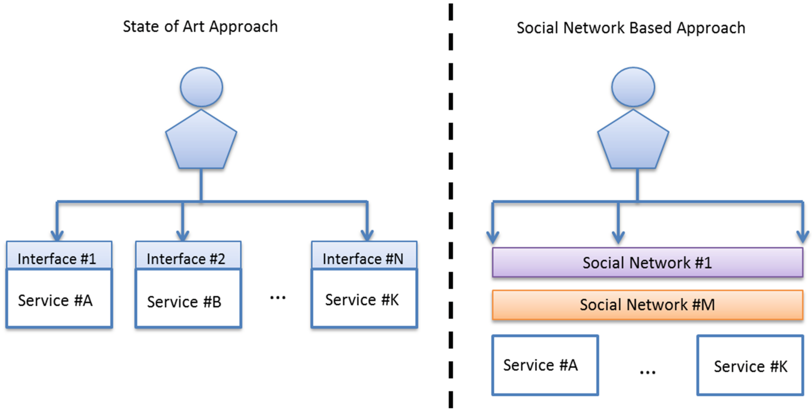

Fig. 1. Enhancing robotic services integrating common social networks in the system to avoid the multiplication of interfaces for the remote management of robotic services.

for a service (Fig. 1); (ii) the user is able to communicate with robotic agents both in the same environment and remotely, also overcoming problem of visibility under different networks. Moreover HeROIS system provides feedbacks to users.

HeROIS combines the use of cloud computing services (both commercial and custom), a domestic robot, called KuBo, a smart environments, to extend robot sensing capabilities, and two common Social Networks (Twitter and Google Services). The cloud resources include the indoor user localization algorithm, the social networks modules and a MySql database. KuBo exploits cloud robotics paradigm [11] because of several features rely on the cloud in order to increase the modularity of the overall system and to add other computational capabilities (see System Overview). Furthermore, this work aims also to qualitatively and quantitatively test the technological solution with real users in realistic scenarios to assess usability and acceptability levels. Particularly, the authors propose three robotic services to help citizens in reminder and surveillance tasks. The user by means of two interfaces (Google Calendar and Twitter) can access the HeROIS services and by means of Google Calendar on his smartphone can set important events anywhere and anytime; if the user is at home, at the proper time, the robot autonomously reaches the user acting as a physical reminder increasing the efficiency of the task. Furthermore, if the user is not at home he can receive information about the status of the house, and alarms on Twitter. Additionally, by means of Twitter message he can move the robot to remotely check the status of the house, through its autonomous navigation system.

3 Methodology

The evaluation of HeROIS performance was based on a specific experimental protocol, which envisaged the involvement of end-users, the use of a realistic living lab and the measure of appropriate metrics concerning the acceptability and usability of the entire service.

3.1 Experimental Settings

The proposed services were realistically tested in the DomoCasa Lab (Peccioli, Italy), which reproduces a fully furnished apartment of 200 sqm with a living room, a kitchen, a bathroom and two bedrooms [12]. DomoCasa is endowed with a service robot (KuBo robot) and two sensor networks (for further details see next paragraph). Furthermore, a gateway is used to gather sensor data to send to the cloud.

The experimentation was conducted with 13 young subjects (10 females and 3 males), whose ages ranged from 24 to 37 (29.62 ± 3.82). For which concerns marital status 9 (69.23 %) were single and 4 (30.77 %) married. Regarding educational level, 6 (46.15 %) participants attended the high school and 7 (53.85 %) graduated. About attitude towards the current technology, all participants were very familiar with PC, Smartphone and Tablet. Furthermore at least for hearsay, everybody had knowledge of most popular social networks such as Facebook, Twitter and Linkedin; however only 4 (30.77 %) and 5 (38.46 %) of them used respectively Twitter and Google Calendar.

3.2 Scenario Implemented During the Experimentation

In order to test the usability and the overall acceptance of the system, three different scenarios were implemented and tested with the users.

– **Environmental Alert:** user is not at home and the HeROIS system detects a critical unsafe situation, i.e. a window is open. It sends a tweet to the user and he can request a picture of the scene with a private message. For this particular scenario, the user was asked to be out of the DomoCasa holding a tablet.
– **Home Automation:** user is coming back to home. Through a *direct message* to the house Twitter account, or tweeting a new status adding the hashtag "*#kubo_service*" or tagging the Twitter DomoCasa account, the home is alerted to warm the environment. If the geolocalization is allowed, the smart home is also able to delay the operation based on the estimated time given through an interrogation to the Google Map service. In this scenario the user is out of the DomoCasa Lab, and send a tweet to the domocasa.
– **Robotic Reminder:** using Google Calendar tool, user can schedule appointments, drug therapies, etc. The system automatically addressed a robotic reminding service at the scheduled time, to remind through tweets the user about appointment or medication. In the experimentation phase, this scenario was divided into two part. In the first part the user was asked to call the robot to set an appointment in Google Calendar by means of the robot tablet. In the second part of the scenario, at the proper time, the robot act as a physical reminder for the user. In both case, the robot automatically reached the user. The scenario was concluded when the user gave to robot a voice feedback.

3.3 Metrics for Assessing the Acceptance of the Services

Acceptability has been defined as the "demonstrable willingness within a user group to employ information technology for the task it is designed to support" and the aim of acceptability is to understand the "factors influencing the adoption of technologies as planned by users who have some degree of choice" [13]. In order to understand the factors which determine the acceptability of ICT and robotics solutions, the issue should be addressed by borrowing social-psychology theories, a branch of the social sciences.

One of the first models developed to study the acceptance of the technology by an individual is the Technology Acceptance Model (TAM) [14] grown out of Theory of Reasoned Action (TRA) [15]. The TAM is based on the Perceived Usefulness and Perceived Ease of Use constructs which determine attitudes to adopt new technologies. This model was applied to the processes of adoption and use of many technology even if the social and normative variables are not taken into account. Progressively in order to provide a unified theoretical basis from which to facilitate research on technology adoption, the Unified Theory of Acceptance and Use of Technology (UTAUT) [16] was developed. The UTAUT is one of the most applied model and it is composed by four main constructs and four moderating variables. However UTAUT was developed for using technology at work so it doesn't always match with the purpose of studies about ICT and robotics solutions in everyday life. For these reasons in order to overcome this limit the UTAUT was adapted by Heerink et al. [17] to the specific technology of assistive and social robots. Starting from UTAUT and Heerink's study, we developed a specific and suitable questionnaire for the HeROIS system, based on a five point Likert scale, in order to investigate the usability and acceptability. In our study some constructs were omitted and others, such as Aesthetics and Perceived effectiveness were added.

The Table 1 shows the constructs of HeROIS questionnaire. Data from the survey were processed applying the following procedure. The construct reliability of the developed questionnaire was validated using the Cronbach's Alpha calculation [18], and a unique metric, ranged from 0 to 100, was defined for usability and acceptability score in order to identify three levels, i.e. not good (score $<$ 65), good (65 $\leq$ score $<$ 85) and excellent (score $\geq$ 85) [19]. A correlation analysis was performed in order to discover the relationship between data and, at this scope, the Mann-Whitney U and the Kruskal-Wallis tests were applied in order to compare different conditions and users.

4 System Overview

The architecture of the system, as depicted in Fig. 2, is based on three components: KuBo, the smart environments, and the cloud resources. The user by means of common social networks interfaces can access to proposed services. Particularly the system integrated two common social networks: Twitter (through the REST and Streaming APIs [20]) and Google Calendar (by Google API [21]).

Table 1. The HeROIS questionnaire constructs used in the experimentation

	Code	Construct	Definition
Acceptability	ATT	Attitude	Positive or negative feelings about the appliance of the technology
	ANX	Anxiety	Evoking anxious or emotional reactions when using the system
	PENJ	Perceived enjoyment	Feelings of joy or pleasure associated by the user with the use of the system
	AES	Aesthetics	Emotional reactions to the system appearance
	ITU	Intention to use	The outspoken intention to use the system over a longer period in time
Usability	PU	Perceived usefulness	The degree to which a person believes that using the system would enhance his or her daily activities
	PEOU	Perceived ease of use	The degree to which the user believes that using the system would be free of effort
	PE	Perceived effectiveness	The degree to which the user believes that the system would produce an intended or expected outcome

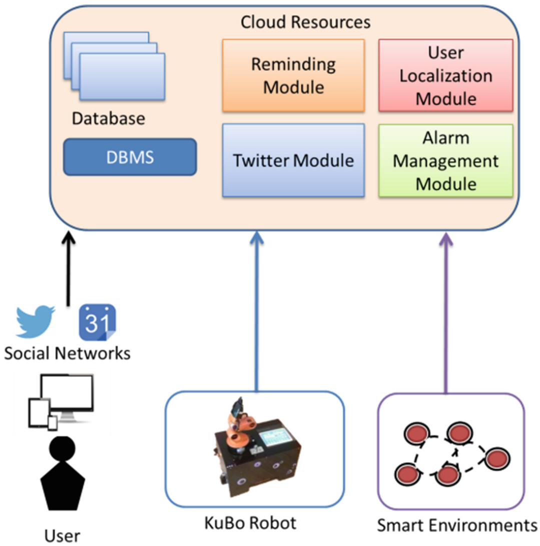

Fig. 2. HeROIS system architecture

4.1 KuBo Robot

During the design process of the platform two key points have been considered primarily: reduced dimensions to move easily in domestic environments, and high friendliness to enhance the robot acceptance. Hence, the robot is based on the youBot

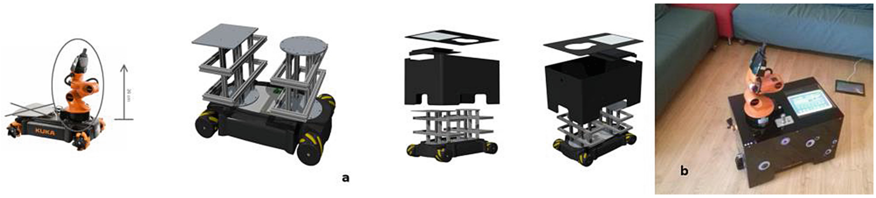

Fig. 3. (a) Design process of the KuBo robot. The overall height of the robot is elevated of about 30 cm and a new cover, made of black opal methacrylate, is mounted to an internal frame. In the last figure (b) is reported the final version of the KuBo robot with the KuKa arm.

[22], produced by KUKA, a small-sized holonomic mobile platform. In order to increase its acceptance, the original platform is modified with a design inspired by a typical “coffee table”, a furniture commonly present in homes (see Fig. 3). The overall height of the robot is elevated of about 30 cm and a new cover, made of black opal methacrylate, is mounted to an internal frame. The final version of the robot, called KuBo (KUka roBOt) is shown in Fig. 3 and it can be with or without the KUKA arm. KuBo is equipped with an Hokuyo laser scanner, an Asus Xtion Pro Live RGB-D sensor, speakers, wireless microphone and a tablet. All the software modules are implemented in ROS [23]. KuBo is conceived as a platform with low computation capabilities that has to exploits cloud resources to carry out its task. The only on-board ability is the autonomous indoor navigation, which relies on the ROS navigation stack and uses the Dynamic Window Approach [24] for local planning and the Adaptive Monte Carlo [25] for indoor localization.

The other software functionalities rely on cloud resources, The text-to-speech module uses the Acapela service for the unknown sentences, otherwise they are stored locally to reduce the response time. The speech recognition module relies on the Google Recognition API. Using this tool, the robot has the potentiality to manage multi-languages without the need of specifics acoustic speech model.

4.2 Smart Environments

The smart environment is composed by two ZigBee Wireless Sensor Networks (WSNs). One WSN monitors the environment by means of several type of environmental sensors spread in the home. For instance Passive InfraRed (PIR) sensors, pressure sensor are placed under chairs or bed, switches on doors or drawers, GAS and water leak sensors are placed in strategic points of the house, while temperature, humidity and light sensors are distributed all over the house to monitor the status.

The second WSN is designed [12] to locate multiple users at the same time, using Received Signal Strength (RSS) [26]. It is composed of a ZigBee coordinator, a Data Logger, a wearable mobile node and a set of fixed ZigBee routers, also called anchors. Each anchor is located in a fixed place and computed the RSS as the ratio between the received and transmitted electromagnetic power on the received messages and transmitted this value to the data logger.

These two WSNs are set on different channels to avoid interferences. The data logger is connected to a PC through USB connection to collect data.

4.3 Cloud Resources

The cloud resources implemented are: the remind module, the twitter module, the user localization module and the alarm management module (Fig. 2). Furthermore a DataBase (DB) collects and stores data related to the environment, the alarms and user positions. A database management software (DBMS) manages the external queries to the database. This integration of physical agents with the cloud resources empowers the robot to outsource part of the software in the cloud [27].

4.3.1 Remind Module

The remind Module is based on Google Calendar API v3 with JSON data object for. NET. Using this API, it is possible to search and retrieve calendar events. Authenticated sessions can access private calendars, as well as create, edit, and delete both events and the calendars that contain them. Thus this module is able to link google calendar service with KuBo robot. The user set appointments through Google Calendar web page or the calendar of his mobile devices (if synchronized with google calendar); at a proper time this module sends a message to the robot activating the physical reminding services. In this experimental setting a provisional google account was created, thus the user can use it to set the appointments by means of KuBo tablet.

4.3.2 Twitter Module

The Twitter module is based on Twitter API for Python, which allows the use of both Twitter's Streaming and REST APIs. A provisional Twitter user was created in order to have an "entity" that could interact with users; during the description it is referred as KuBo_Tweet. The Streaming API could be used to create streams of the public data flowing through Twitter; for example, it was used to track any post on Twitter with hashtag #KuBo_Tweet or that had tagged @KuBo_Tweet. The REST API provided the programmatic access to read and write Twitter data; for example, it was used to reply to the users or to post Tweets with attached medias after a user's request. Using the Twitter Module a command line was created through an already known and spread interface, such as Twitter's web site or Twitter's app for mobile devices. In order to achieve a more natural communication, each users' request was interpreted in commands using a keyword approach through a regular expression search, to avoid problems as lower/upper case differences. Studies on use of semantic searches, for example using NLTK – Natural Language Toolkit [28] are planned, but a good trade-off has to be found in order to have a fast response for keyword research. About the privacy of sensitive information, such as photos of the home, settings on Twitter's account were used in order to limit the visibility of posts to a an ad hoc set of users.

4.3.3 User Localization Module

This module provides numeric (x, y) and semantic information (kitchen, bedroom …) on users position, to drive the KuBo robot and accomplish required services, by means of a sensor fusion algorithm and a Kalman Filter approach exploiting both range-free [29] and range-based [30] approach as suggested in [12]. User localization is performed by fusing heterogeneous information from the two WSNs. In case of sensor faults, the user position is estimated by fusing data from the remaining ones, improving the reliability and robustness of the service. The user position is stored into the DB and makes available for agents and users who need.

4.3.4 Alarm Management Module

The alarm management module analyses the data coming from the environmental WSN in order to identify potential danger situations or critical intrusions. In this system implementation several common alarm procedures are included such as door opening during night, water or gas leak and door/windows open when user is outside. When this module reveals a critical situations and the user is not at home, it activates the twitter module to alert the user. Instead if the user is at home, the KuBo robot is activated.

5 Results

The Cronbach's alpha is calculated to test the construct reliability and the cut-off value for being acceptable is 0.7 [31]. The Table 2 shows that reliability of the constructs is high, except for ANX and ITU. However values below even 0.7 can be expected because of the diversity of constructs being measured when dealing with psychological constructs [32].

The results of the questionnaire reveal interesting situations. As regards the usability (Fig. 4b), the results show that the proposed system is usable for 4 participants (30.77 % M = 79.69 SD = 3.13) and is excellent for 9 of them (69.23 % M = 90.05 SD = 3.72). In particular female participants perceive the HeROIS system more usable than male ones ($p < 0.05$) and also there is a statistically significant difference between married persons and singles in usability evaluation ($p < 0.05$). In effect, the high usability score is confirmed also by the score of each constructs, because the utility (PU M = 4.52 SD = 0.59), easiness (PEOU M = 4.63 SD = 0.56) and effectiveness (PE M = 4.18 SD = 0.56) are well evaluated by participants. Using a correlation analysis, there are no effects of gender, marital status and education level except for gender factor on PU results ($p < 0.05$) (Fig. 4a).

Table 2. Reliability of constructs

Code	Alpha Cronbach	Mean	DS
ATT	0,81	4,28	0,65
ANX	0,64	2,02	1,21
PENJ	1,00	4,85	0,37
AES	0,74	4,36	0,68
ITU	0,52	4,04	0,77
PU	0,86	4,52	0,59
PEOU	0,72	4,63	0,56
PE	0,78	4,18	0,56

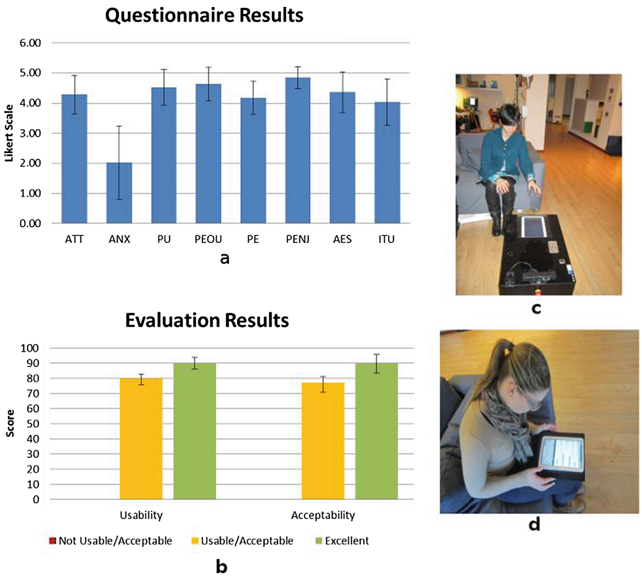

Fig. 4. (a) HeROIS questionnaire constructs results (b) The usability and acceptability results (c, d) Show the experimentation with real users in DomoCasa.

As regards the acceptability, the results show that the proposed system was acceptable for 8 volunteers (61.54 % M = 77.02 SD = 4.23) and excellent for 5 participants (38.46 % M = 89.71 SD = 6.06). In particular female participants evaluated the HeROIS system more acceptable than male ones ($p < 0.05$). About the intention to use (ITU M = 4.04 SD = 0.77), the sample would use this system every day and would pay an appropriate price for it, because the services provided by HeROIS are very useful and easy to use for them as confirmed by PU and PEOU results (Fig. 4a). Females were more likely than males to report using HeROIS system ($p < 0.05$). Furthermore this data was confirmed by the positive results about the appliance in everyday life of these service (ATT M = 4.28 SD = 0.65), especially for married persons ($p < 0.05$). Notably just low level of anxiety or negative emotional reactions were evoked (ANX M = 2.02 SD = 1.21) when volunteers used the system. On the contrary, feelings of pleasure were associated by the participants with the use of the system and the interaction of KuBo (PENJ M = 4.85 SD = 0.37) and in particular there was a statistically significant difference between man and woman ($p < 0.05$). In closing the aesthetics of KuBo was well judged (AES M = 4.36 SD = 0.68) because the KuBo was considered aesthetically appealing and suitable for a domestic use.

6 Conclusion

This paper presented HeROIS system which aims to enhance the human-robot interaction with the integration of social networks. The system presented was based on KuBo robot, smart environments and cloud resources. In general, the proposed system was considered usable and acceptable by all participants, especially for women because females were more likely than males to spend time on Social Networks [33]. Furthermore in some cases there was a statistically significant difference between married persons and singles, maybe because married persons have a more busy life and the services provided by HeROIS system could be very useful for them. Nobody found the services "not usable" and "not acceptable". Furthermore the results highlighted how also persons which don't use social networks can use the system proposed without any problems. Future system development should include the analysis of privacy issues and the involvement of a large number of participants in the experimental settings.

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