A SOCIAL ROBOT FOR FACILITATING HUMAN RELATIONS IN SMART ENVIRONMENTS

Berardina De Carolis, Nicole Novielli, Irene Mazzotta and Sebastiano Pizzutilo
Dipartimento di Informatica, Università degli Studi di Bari "Aldo Moro", Bari, Italy

Keywords: Social robots, Social facilitator, Social network analysis.

Abstract: This paper describes how a robot may use social network analysis measures for facilitating social relations when acting as a "host" in a smart environment. The robot's main goal consists in welcoming people, facilitating contacts and information sharing among people present in the environment. It uses knowledge on the structure of the social network for selecting the most appropriate strategy to create new relations or to spread information in the most effective way. To this aim, a multiagent system has been implemented for simulating and evaluating the functioning of the social facilitator.

1 INTRODUCTION

According to several research studies, Ambient Intelligence (AmI) should be used not only for providing task-oriented services but it should include also social-oriented assistance in order to facilitate human contacts, information broadcasting and sharing, and to enhance community-oriented services (Shadbolt, 2003). We developed a multiagent system that aims at facilitating the communication, interaction and sharing between people in a Social Network (SN) located in the same physical place (e.g. recreation places for elderly people, meeting rooms, parties, fitness centers). As interface, we employ a robot acting as Social Facilitator (SF) among people present in the environment and between them and the environment services: social robots, in fact, can provide an appropriate medium for facilitating relations in public spaces due to their presence (Sakamoto et al., 2007). In particular the SF can be seen as a "host" that welcomes and guides people in the environment, in order to facilitate the establishment of social relations between people that do not know each other, and to favour information spreading and sharing among peers. To this aim, the SF has to exhibit social competencies and, therefore, it has to understand the existing relations among peers, using Social Network Analysis (SNA) (Scott, 1991).

The system has been tested through a simulation of a "recreation center for elder people". Results obtained so far show that the adopted approach is successful for improving social relations in the place, integrating isolated people and connecting subgroups.

The paper is structured as follows: Section 2 presents the architecture of the system and provides an example of application. A framework for the system evaluation, conclusions and future work directions are discussed in Section 3.

2 SYSTEM ARCHITECTURE

The system has been implemented using JADE (http://jade.tilab.com/) and JUNG (http://jung.sourceforge.net/index.html) and it is composed by: *Peer Agents,* representing people in the smart environment, the *SNA Agent*, handling information about the SN, the *Social Facilitator* (SF), which has the main goal of increasing the cohesion of the social network, the *Sniffer*, which observes exchanges among peers. Let's see the structure of these agents in more details.

Peer Agent: represents a person in the smart environment. It maintains dynamically the model of the interests, preferences, friendship, liking and disliking relations of the person it represents. The profile is updated dynamically according to the creation of new relations among peers. It is structured as follows: *Id* of the peer in the network, *Personal data* (name, email, age, profession), *Relations* with other people in the environment,

De Carolis B., Novielli N., Mazzotta I. and Pizzutilo S..
A SOCIAL ROBOT FOR FACILITATING HUMAN RELATIONS IN SMART ENVIRONMENTS.
DOI: 10.5220/0003142403800384
In *Proceedings of the 3rd International Conference on Agents and Artificial Intelligence* (ICAART-2011), pages 380-384
ISBN: 978-989-8425-41-6

Liking and *disliking* of other members, *Spoken language* (used a peer when communicating), *Known languages* (the other languages that the peer knows), *Disabilities* in hearing, seeing, speaking and moving, *Interests* (e.g. hobbies, recreational activities, and so on, expressed as a confidence level), *Preferences* (e.g. food, movies, etc.), *Privacy issues* (the profile can be made accessible to nobody, to the environment, to everybody or only to friends). To test our system in a real environment we have associated a RFID to each person that enters in the place. In this way we can dynamically monitor the presence of that person in the environment and activate the corresponding peer agent. At the moment the member's profile is acquired explicitly through an interface when the RFID is associated to a person.

The **SNA Agent** monitors the evolution of the network by gathering information about each member. It uses this information to compute measures useful for understanding the various roles and groupings in the network, e.g. who is the leader, which agents act as connectors, which are the isolated peers and so on. The main behaviours of this agent are:

***a. Information Gathering*:** in this phase the SNA collects information about each member of the SN from the corresponding Peer agent. Moreover, for debugging purposes, it provides a graphical visualization of the current state of the SN.

***b. SN Elaboration*:** it calculates the requested sociometric measures (Haythornthwaite, 1996; Scott, 1991). In the proposed application context the following measures are considered:

- *Density* indicates the degree of cohesion of the network. It allows verifying that SF actions are actually improving social relations in the community*;*
- *Connectivity of a node* expresses the number of nodes that should be deleted from the network to disconnect two persons. It can be used to find the highly popular members that can help to foster information spreading or the integration of isolated peers in the network;
- *Geodetic distance* represents the shortest path between two nodes. It can be used by the SF to put in contact an isolated peer with the closest network member with which he shares some interests;
- *Centrality* can be used to evaluate the importance of each member of the network (i.e. the leader of a group). Centrality can be specialized as: Degree centrality, to measure the number of direct connections; Closeness centrality, to identify the shortest path to other nodes; Betweenness centrality, to identify intermediary members between important portions of the network. For example, people with high closeness centrality are very effective for spreading and monitoring information flow while members with high betweenness centrality can be seen as good brokers and therefore have a great influence on information flow between subgroups;
- *Similarity* among members of the network can be used for integrating isolated peers. Among the several similarity measures that can be used, we decided to employ the Pearson correlation coefficient (Rodgers and Nicewander, 1988), taking into account the profession and the interests present in the member profile*;*
- *Clique Analysis* allows identifying subgroups in the SN. It can be used for connecting subgroups.

***c. Communication*:** the SNA agent exchanges messages with the other agents and in particular with the SF about the overall SN situation.

Social Facilitator Agent: it acts as an intermediary among the network members. Its main goal is to select communication forms and artefacts according to the situation of the social network. It has been modelled and implemented as a BDI agent (Rao and Georgeff, 1991), whose beliefs are facts about the state of the SN. Beliefs are represented as **BEL** SF ***u***, where ***u*** is a fact concerning:

– one of the *measures* provided by the SNA agent (e.g. ***Density***(*n*, 0,76) represents the fact that the density of the network *n* is 0,76);

– *friendship* relations among network members (e.g. ***Friend***(u_i,u_j) indicates that there is a binary friendly relation between the members $\boldsymbol{u}_i$ and $\boldsymbol{u}_j$);

– *dislike* relations (e.g. ***Dislike***(u_i,u_j) indicates that there is a unidirectional relation indicating that $\boldsymbol{u}_i$ dislikes $\boldsymbol{u}_j$);

– *predicates* about members (e.g. ***Predicate***(u_i,z) where *z* is a value or a fact; for instance *Is-Interested*(u_1,fishing)).

The SF Goals are of two types: *Persistent Goals* (P-GOALs) denote the agent's nature and mission, and guide its reasoning while *Contingent Goals* are triggered by the situation.

The SF has the P-GOALs of *taking care of people present in the environmen*t and *increasing the number of relations among members in the environment*. The first goal may be formalized as: (P-GOAL SF (BEL SF (welcomed($\boldsymbol{u}_i$)))) AND (P-GOAL SF (BEL SF (confortable($\boldsymbol{u}_i$)))) AND (P-GOAL SF (BEL SF (NOT(isolated($\boldsymbol{u}_i$))))) where $\boldsymbol{u}_i$ represents a member of the SN. The second goal may formalized as the achievement of the maximum density of the SN, (P-GOAL SF (BEL SF (Density(net,max)))). This goal can be achieved by modifying the initial state of the SN until all members are connected. However reaching a density equal to 1 may not be always possible since, for instance, there can be members that really dislike each other or that do not have anything in common or that pursue different goals. The SF will abandon a persistent goal when it has been achieved or when it believes it is not possible to achieve it.

Contingent goals are triggered by contextual needs (e.g. satisfying a request of a member or a request of the environment of spreading important information as quickly as possible, solving conflicts, etc.). To achieve these goals, the SF executes conditional plans stored in a library (Cavalluzzi et al., 2003). At this stage of the project we have defined plans for the three contingent goals: a) integrating isolated peers, b) connecting subgroups, c) spreading information.

***a. Integration of isolated Peer*:** The SF should integrate isolated peers in existing groups or it should connect isolated peers among them for creating a new subgroup. To integrate an isolated peer, the SF puts her in contact with another member by promoting a conversation.

The selection of the most appropriate node, among those similar to the isolated one, is made as follows: after receiving the ordered list of similar nodes, the SF evaluates the *appropriateness* of a node by considering its *centrality*, *connectivity* and *betweeness* centrality. Then, the SF selects the member that is more popular by calculating a rank as

rank=sim****sum***(a*f(*centrality)*,b*f(*connectivity)*,c*f(*betweeness*)) (1)

where coefficients *a*, *b*, *c* allow tuning the function according to the situation. In our evaluation scenario we gave a higher priority to centrality and connectivity than to betweeness by setting the value of *a* and *b* to the double of the value of *c*.

Once the node has been selected, the SF has to find an artefact for promoting a conversation with the isolated one. To this aim it proposes arguments considering the minimum gap between the confidence values among their common interests.

If they do not have any common interest the SF tries with another member (with the rank immediately lower) otherwise it will decide to connect the isolated peer to the member with the most popular member (highest value of centrality).
The dialog management strategy adopted by the SF is an extension of the methodology proposed in (De Carolis and Cozzolongo, 2007).

b. Groups Connection: The SF may decide to connect two different groups to facilitate the interaction among their members. In this case the strategy involves selecting (i) members with the highest betweeness centrality in the two groups and (ii) a topic taking into account interests of the two subgroups. As group modelling strategy (Masthoff, 2004) for understanding interests of subgroups, we applied a weighted average of preferences. Then, if there is a common node between two groups, this is used as a bridge for promoting common arguments; on the contrary, the ones with the highest leadership (calculated as in (1)) can be put in contact with each other, using the same strategy described for the integration of isolated peers.

***c. Spreading Information*:** The strategy we implemented so far is the following: a list of peers belonging to every group of the SN is created according to their degree of betweeness centrality. Then the SF starts contacting those belonging to the largest groups and selects among them the node that is closest in terms of distance to this one, and so on. If there are isolated peers that have not been integrated in the SN yet, the SF will contact each of them and communicate the information. In all plans the SF communicates with the SNA for requesting data and measures concerning the situation of the network or for informing the SNA of its action effects.

Sniffer Agent: its main goal is to constantly monitor the SN through overhearing (Fan and Yen, 2005; Busetta et al., 2001). The Sniffer has to understand the shallow dialogue dynamics of the networks: this monitoring activity should be conducted continuously to have, at every time of the interaction, the updated image of what is going on in the SN. The Sniffer will apply conversational analysis techniques, enabling the SF to both (i) prevent (or even solve) conflicts and (ii) favour fruitful exchanges among peers with similar features and goals. In this perspective it is also important to understand what is the task of each interaction among couples or groups of peers (e.g., Information Seeking, Negotiation etc.) and what is the attitude the interlocutors are showing towards each other (e.g., cooperative vs. individualistic, or warm vs. cold, etc.). The history of the interaction will serve as a basis for conversational analysis. In particular, our Sniffer agent will employ Hidden Markov Models for dialogue pattern analysis, using an approach similar to the one described in (Novielli, 2010).

2.1 An Example

Let's consider the scenario of a recreation center for elderly people. The SF, represented by AIBO, interacts with 14 people; 13 of them are divided in 3 subgroups that are in 3 different rooms of the place: G1=(A,B,C,D), G2=(E,F,G,H,I) and G3=(L,M,N,O); some members know only some elements of each group as described in Figure 1.

The initial density of the graph is 0.37. *X* just arrived in the center and can be considered an isolated peer. The SF constantly monitors the state of the SN by asking information to the SNA and it receives the information regarding the fact that *X* is isolated. Therefore the SF tries to integrate it by applying the strategy described in Section 2.

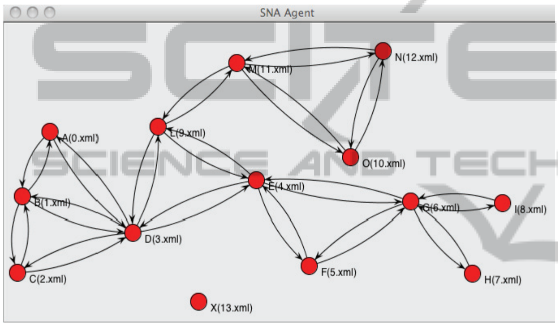

Figure 1: The SN sociogram.

Let's assume that A, B, H, D, L are, in the order, members that are more similar to X (in the current setting, nodes with a similarity level above or equal to 0,5 are considered). Taking into account their rank (see Table 1), the peer represented by the node D results as the most suitable to be contacted by the SF and for promoting a conversation about a common interest.

Table 1: Selection of the best candidate of the sociogram.

ID	Centrality	Connectivity	Betweeness	Similarity(X)	Rank	
A	(3) 4,17	(3) 4	(1) 0	0,8	10,4	7
B	(8) 8,26	(8) 6	(8) 1	0,75	30	2
D	(12) 120,44	(12) 10	(12) 55	0,65	39	1
H	(1) 2,08	(1) 2	(1) 0	0,7	3,5	9
L	(11) 114,26	(8) 6	(11) 54	0,5	24,5	3

Let's suppose that the best common interest between X and D is "Art". Then the SF introduces X to D, promoting a conversation about Art. An example of possible move by the SF is: *'Good Morning D, I'm pleased to introduce you X. She is just arrived. X, like you, is interested in art.'* In case of conversation between D and X failing because of lack of interest in the proposed argument or because of some kind of resistance to start the friendship relation, the SF tries with the next candidate node in the list. When the integration succeeds the SN and the SF beliefs are updated accordingly.

3 CONCLUSIONS

The described framework allows simulating and evaluating the behaviour of a robot acting as social facilitator in a smart environment. The system has been evaluated through the simulation of 25 different scenarios in the described domain. For each scenario we formalized the peer profiles and, consequently, the structure of the social network and a set of rules describing the dynamic of the interaction among peers. Randomly we assigned a level of resistance in order to establish a friendship relation (0, no resistance – 1, resistance). Results show that in the majority of cases (16) the social facilitator's strategies successfully increased the density of the network. In the rest of cases, the integration of isolated peers and the subgroups connection failed due either to absence of common arguments or to antipathy (simulated through the resistance variable) towards the isolated peer or among leaders of subgroups.

In our future work, besides enriching the formalization of the peer agent mental state with extra-rational factors (personality traits, moods, emotions), we intend to endow it with the ability of reasoning by taking into account these factors to simulate social intelligence towards other peers.

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