A social navigation system in telepresence robots for elderly*

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Abstract. TERESA is a socially intelligent semi-autonomous telepresence system that is currently being developed as part of an FP7 project funded by the European Commission. The ultimate goal of the project is to deploy this system in an elderly day centre to allow elderly people to participate in social events even when they are unable to travel to the centre.

In this paper, we present the navigation architecture of the TERESA robot, which integrates and combines several functionalities in order to achieve altogether social behaviors of interest for the telepresence application. The architecture has two levels: a higher level with a behavior manager based on a Finite State Machine, which is in charge of selecting different macro-actions in an intelligent manner; and a lower level which implements those macro-actions as socially-compliant navigation functionalities.

1 Introduction

Nowadays, more and more mobile robots are coexisting with us in our daily lives. As a result, the creation of motion plans for robots that share space with humans in dynamic environments is a subject of intense investigation in robotics. Robots should respect human social conventions, guarantee the comfort of surrounding persons, and maintain legibility, so humans can understand the robot's intentions [5]. This is called human-aware navigation.

Telepresence robots are also gaining an important role in robotics [4]. These robots are called "Skype on stick" because they combine the conversation capabilities of teleconference software and the mobility of the robots controlled by humans to allow for a better social interaction. In particular, we consider in this work the application of telepresence robots for elderly [10]. However, maintaining a social interaction and, at the same time, controlling the low-level navigation of the robot overloads the cognition level required by the user, which is specially

* This work is supported by the EC-FP7 under grant agreement no. 611153 (TERESA).

Fig. 1: Two persons interacting through the TERESA robot.

critical for elderly. Therefore, the main goal in TERESA project[3] is to develop a semi-autonomous telepresence robot for elderly centers, increasing its autonomy in such a manner that users are relieved from lower-level navigation tasks. At the same time, the social intelligence of the robot is improved, providing additional functionalities of interest for the application, such as navigating autonomously to pre-defined goal points, approaching people in a social way, or walking side-by-side during a conversation. Figure 1 shows some elderly people interacting by using the TERESA robot.

This paper presents the architecture for the social navigation system of TERESA, which is a two-level decision-making system which combines different social behaviors (encoded as macro-actions) in an intelligent manner. Learning algorithms are developed at the macro-action level to learn the social navigation skills of the robot in different behaviors.

The paper first introduces the architecture of TERESA for social navigation, describing briefly the different navigation functionalities. Then, some conclusions and future work are discussed.

2 TERESA Architecture for Social Navigation

Most commercial telepresence robots require users to be able to teleoperate manually the robot to the desired places and positions [4]. This procedure implies a high cognitive load, preventing the remote user from focusing on the primary objective, which is establishing social interactions during a conversation. This cognitive overload is even more critical in some sectors of population like elderly people, who may have more problems to understand and control this kind of technologies.

For these reasons, freeing remote users from some navigation tasks is of interest in telepresence robots applications. TERESA enhances the telepresence

[3] http://www.teresaproject.eu.

system by adding social navigation functionalities (e.g., approaching a person to talk to in a social manner, walking side-by-side with a person during a conversation, etc.) that increase the level of autonomy and intelligence of the robot.

The navigation architecture of TERESA has two levels of decision making, and it is based on a set of behaviors encoded by macro-actions. At the highest level there is a *Behavior Manager* in charge of selecting the different macro-actions; at the lower level, each macro-action represents a navigation behavior. Some of those behaviors are previously learnt to navigate the robot socially. The next sections describe the components of the navigation architecture, namely the Behavior Manager, and the different macro-actions.

2.1 Behavior Manager

The *Behavior Manager* represents the top level decision-making component, and is in charge of implementing navigation functionalities through the concept of macro-actions, which can be implemented in different manners, such as Finite State Machines (FSM), control-based, decision-theoretic-based, etc. The whole architecture is based on the ROS middleware[4]. Each macro-action must provide an interface based on the ROS actionlib for the rest of the system, acting as services. These macro-actions are then activated when certain events happen and/or inputs are received from the user. The Behavior Manager is encoded as a Finite State Machine (FSM) that produces the adequate transitions between macro-actions.

Figure 2 shows a general diagram of the eight macro-actions implemented, along with the available transitions between them according to the events that may occur. The initial macro-action is "Wait for goal", where the robot waits for an event that initiates a transition. At any moment, the remote user can indicate through the control interface the following events:

- The desire of moving to certain room by selecting a room of the waypoint list (event "New Goal"). This triggers the macro-action "Navigate to Waypoint" in which the robot socially navigates to the desired room.
- The desire of approaching a certain person to initiate a conversation by clicking the person on the image. In this case, the event "New IT", where IT means Interaction Target, starts the macro-action "Navigate to Interaction Target" in which the robot will approach the indicated person in a social way.
- The desire of keeping the conversation while walking with an interaction target to another place. To do that, the user can activate the walk side-by-side module ("Walk with IT" event), which triggers the transition to the macro-action "Walk side-by-side". In this case, the robot will try to accompany the person walking together to other room or place.
- Finally, the user can also drive the robot as an usual telepresence robot but in this case, a driving assistant is launched (macro-action "Assisted steering").

[4] http://www.ros.org.

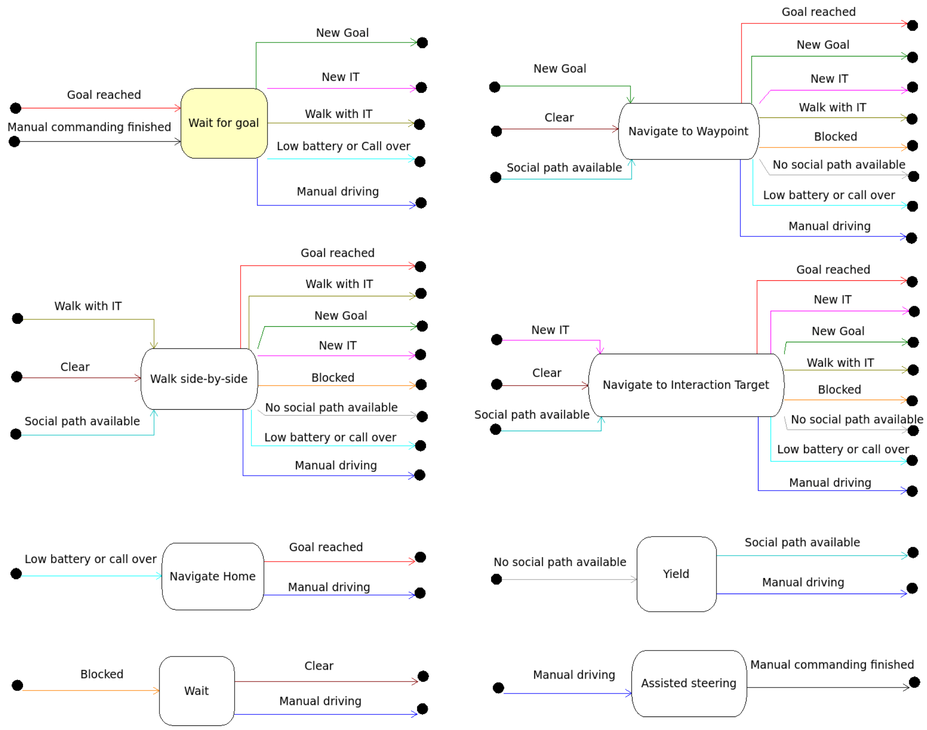

Fig. 2: Diagram of the finite state machine for social navigation. The initial state is shown in yellow.

The macro-action is activated whenever the user try to control the robot through his control interface provoking the "Manual driving" event. This assistant is in charge of the evaluation the velocity commands sent by the user by checking the possible collisions and generating smooth valid commands if possible.

Moreover, there is another group of macro-actions that are transitioned by events independent of the user actions. They are:

– Yield. While the robot is navigating, if any person is crossing the pathway of the robot in narrow passages like doorways, the robot will retreat to a position that allows the person to pass. In this case, the "No social path available" event occurs. Once the pathway is free again, the "Social path available" event allows for resuming the previous action.
– Wait. While the robot is navigating, if the robot is not able to move because all the posible movements can provoke collision, a "Blocked" event occurs and the "Wait" macro-action is initiated. This keep the robot stand still for a pre-defined time, trying to resume the navigation after the waiting time is expired.

– Navigate Home. This macro-actions is triggered whenever the battery level of the robot is under a certain threshold ("Low battery" event). In that case, the robot should go back to a pre-defined position where the docking station is installed to charge. This navigation action is also triggered when the user call is over ("Call over" event).

2.2 Social Navigation to Waypoint

This action allows the robot to navigate socially towards a waypoint in the scenario (usually a different room) indicated by the user through the control interface. Moreover, this action can also be used to navigate the robot to its home position, just by commanding the corresponding waypoint.

The robot navigation system is able to deal with dynamic and static obstacles in a social fashion. An Optimal-RRT planner (RRT*) [3] is employed to calculate the path to the goal. This planner builds a path that minimizes a cost function which is a linear combination of social navigation features that take into account the people in the vicinity of the robot [9]. This allows the planner to obtain a social path to the goal.

Instead of manually fixing the weights of the cost function, these weights are learned from data. A novel learning algorithm has been developed to learn the weights of the cost function from human trajectory demonstrations [6]. This algorithm combines Inverse Reinforcement Learning (IRL) techniques with the RRT* planner to perform the learning.

2.3 Approach Person

The navigation to an interaction target requires that the robot approaches the person taking into account the orientation of the person and re-calculating the goal if the person moves or changes his position.

To perform the approaching person in a social way, a set of human trajectories approaching other people has been used to learn the task. In particular, a model in feature space has been learned from the human demonstrations and encoded as a Gaussian Mixture Model (GMM). Then, this GMM is employed to bias the sampling of the Optimal-RRT planner [3] to direct the planner to the correct areas to perform the approaching. Further details can be seen in [8].

2.4 Walking Side by Side

Another aspect considered in the Social Navigation module is the option to accompany a person walking side-by-side to a destination. To achieve this, a controller based on social forces models has been developed [2, 1]. In particular, to accompany a person while walking, the person and the robot are modeled as a group by adding attraction forces between them besides other forces related to obstacles, other people around and goals to reach.

Moreover, a Hidden Markov Model is used to infer people's destinations [7]. This model is learned from data, and then used into a decision-making algorithm based on partially observable Markov decision process (POMDP), which is combined with the low-level controller to move towards the destination.

3 Conclusions and Future Work

The architecture for the social navigation system employed in the TERESA project has been presented. The architecture combine a set of different navigation behaviors. Learning is used in the different modules to incorporate social awareness. This architecture will be tested in the final experiments of the project, programmed to the end of October 2016, in a adult day-care center in France.

As a future work, the addition of new macro-actions and the use of more advanced decision-making techniques to implement the behavior manager will be studied.

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