Path planning in service robotics considering interaction based on augmented reality

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Resumen This research presents how the augmented reality can be used in assistance tasks in indoor environments. The approach of human-robot interaction supported in AR arises two classical questions in robot navigation: What does the robot need to do to show the AR? (task planning) and, which are the best movements to reach the destination allowing the user get the AR information? (path planning). In addition, a constraint in relation to assistance environments has to be considered: How can the robot perform the task to improve the interaction? Along the paper we addressed these problems and how the augmented reality can improve the interaction an therefore the human experience with the robot. An architecture with an adaptative navigation model to offer an augmented reality system is presented in this paper. The first experiments developed with this system are still performed in the gazebo simulator.The solutions proposed will be taken thinking in the low cost platform developed for elderly assistance in the University of León that already uses the augmented reality for some assistance task.

Keywords: Navegación, path planning, AR, Human-Robot Interaction

1. Introduction

Human-robot interaction (HRI) is a branch of robotics which has been working for years to improve dialog between humans and robots. Based on some motivational features from human-human interaction (HHI) [1], HRI tries to improve human robot dialog: proxemics, movements and body position, postures, gaze or engagement, and gestures are some of the features in HHI defined by Hall.

Since, in some situations, robot navigation can be adapted to improve dialog as part of interaction with humans, this research focuses in movements and body position: a robot with a face should be looking at his human listener and an arm-equipped robot should be able to point objects. Since our robot interacts with

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humans using augmented reality (AR), a valid display position has to be offered to the user.

Human gaze and proxemics have been taken into account for this work. Gaze has been proved to be useful for HRI in many works such as [3] or [2]. In Yoshikawa [5] works, human gaze control is utilized by the robot to improve human response; another example is the application of human gaze to improve robot gesture in ELIAS platform[4].

Proxemics is a HHI field which focuses in the space between individuals in the moment of interaction [6]. It can be considered as the personal space of the individual, defined by Hall in [7], or the individual territoriality [1]. This feature is relevant because the robot must remain inside a secure space while showing its display to the human.

In a regular HRI situation, dialog can be adaptad for either explicit or implicit communication, as defined by Breazeal [11]: spoken dialogs (conversations, casual talk) or pointing tasks (Kanda [8]) can be defined as explicit communication. A robot taking decisions while paying attention to human gaze is an example of implicit communication.

This research introduces a method to improve human robot interaction using explicit communication models, specifically augmented reality. A system to define navigation paths has been developed, it has to offer a safe path while the robot interacts with humans using AR and also maintain the human territoriality during the dialog.

During last years many researchers have been working in human robot dialog and robot pose to improve the interaction between humans and robots. In the research of Jorge Rios-Martinez [9], they present a path planning system using an algorithm called Risk-RTT. It focus the path planning estimation in a proxemics safe way and avoiding human disturbance or collisions problems following three rules proposed in Lam work [10]: collision free rule, interference free rule, and waiting rule.

If we pay attention in the tasks that the robot and the human can do together, the work of Krus[13], presents a way of path planning calculation focused in human requirements and improving the human aware navigation planner. To do this they modified the HANP algorithm, that is oriented to build paths in environments, to have more human awareness functionality.

The overall basis in this work is like in others reasearch: initiation, attention and position. The differences according the other research's could be enumerate as:

- The platform. We have no physical embodiment or personification in the robot.
- The initiation point it is not casual, the robot is not searching the individual, and the robot only has a pre-defined cases of assistance.
- The attention: the view points of the robot and the view points of the individual are differents and has to be defined working with the clasical deixis problem ([12]).

- The position and navigation: In our proposal path planning design has to be performed according to augmented reality. The navigation takes place in a defined position where the human can reach the display so this position is related to robot morphology.

AR is benefitial for HRI in several aspects, for instance, an arm is not needed to point things, regions, or interesting points, since a display can be used instead, avoiding the problems of deixis since a virtual signal is being overlapped over the goal and the user has the exact points that he needs to know. Also, extra virtual information can be offered to the user to ease task performance; for instance, environmental data or a map can be presented to the user for a task consisting of arriving at a given location where and object is located at.

The paper is organized as follows, the section 2 defines the hardware and control software characteristics of the platform used to this research. The section 3 defines some traditional navigation strategies in general HRI situations. In section 4 we define the strategies available for the robot using AR and that allow us to improve the interaction. An experiment with gazebo is presented in section 5 and conclusions are given in section 6.

2. Overall approach

In this section we define how does the robot work from two points of view: the hardware and the control system. From the hardware side, the whole platform is described. From the control side, the control architectue deployed deployed in the robot is analyzed.

2.1. Robot Configuration

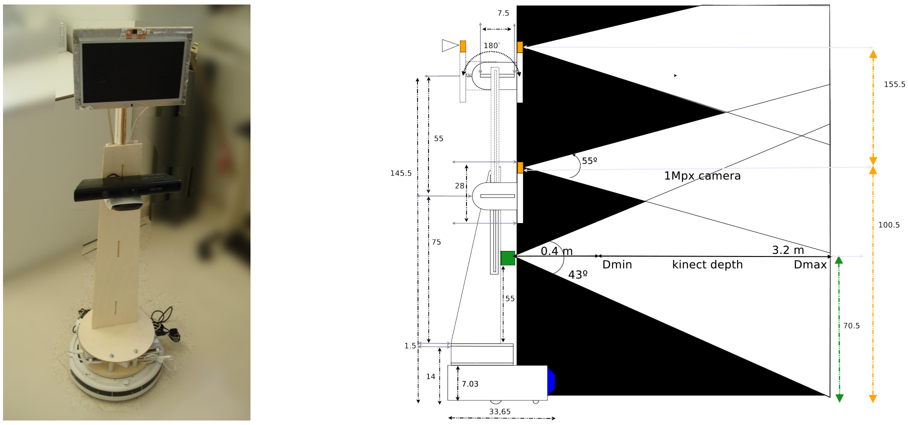
All the research has been made around platform based in iRobot base solution. We use two versions of this platform, iCreate and Roomba, the iCreate version is used in turtlebot platform and the Roomba base is used with our platform MYRABot. The first one differs from second one in the parallel port available to plug more stuff.

These platforms has two wheels independently powered working in a differential way, it means that each wheel can run independently of the other. The two wheels are non steered and are situated in opposite position of the platform. The robot also has a caster wheel.

It is also worth noting that the robot is supposed to always move on a regular non-slippery floor without unexpected objects to simplify the experiments.

In the picture 1b it is presented the robot configuration available for this research. The components of our robot can be enumerated as:

1. Kinect Camera: The one in the front part of the platform is used.
2. iRobot Base: Represents the base that used for the research.
3. Display and webcam: the laptop display and camera in the top of the robot are used.



a) MYRABot platform b) MYRABot morphology

Figura 1: Robot Configuration

The location of these components is a limitation to our navigation model using HRI. In figure 1a one robot configuration is presented, the display is working at robot front. According to the display position navigation has to be carried out in one way or another as it is explained in section 4.

2.2. Control configuration

The robot control architecture is based on a hybrid tree layer architecture. Its high level representation is presented in figure 2.

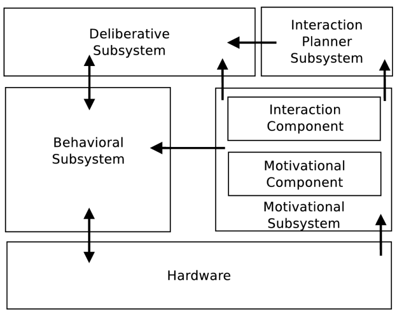


Figura 2: Robot Control Architecture.

The low level part represents the robot configuration defined previously. This control architecture defines four main components:

1. The Behavioral Subsystem: It is in charge of reactive behaviours and performs actions defined by the deliberative layer

2. The Deliberative Subsystem; It defines long term actives in the system.
3. The Motivational Subsystem: It has two components, one oriented to robot motivation and another oriented to HRI motivation.
4. The Interaction Planner Subsystem: It defines the basic controllers to manipulate the deliberative behaviours in a more effective interactional way.

3. Navigation strategies

The navigation strategies are always restricted to robot morphology, sensors and actuators on one side and the environment on the other side. Our robot restrictions are: the steering base, the sensors disposal and the display position. First of all we define an example of robot navigation in order to know how to apply models of navigation with augmented reality. Then we make two proposal to improve the user experience supported in AR.

3.1. Basic navigation in known environment

This type of navigation takes place in a well known region defined in a map. The robot is placed in a given start position and then asked to reach a goal. The robot then makes different path planning and chooses the best path to try to reach the goal.

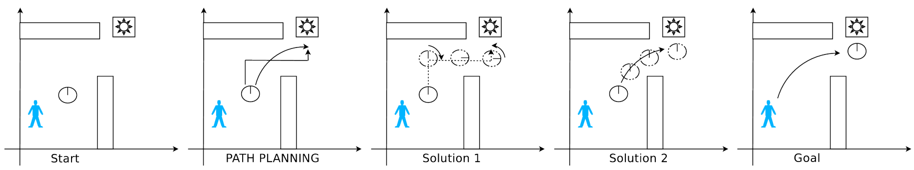


Figura 3: Clasical navigation system.

In figure 3, the classical navigation in well known environment without external could be defined in these five points, 1) star point, the user demands a goal, 2) path planning, the robot calculate the best paths to the goal. 3,4) The robot choose best of path to arrive to the goal and go there, 5) the robot is in the goal point and the user follows the robot.

In our enviroment we proposed this with the turtlebot in the gazebo simulator, ROS and RVIZ. The map it is calculated a priori to be used in the test. The localization system used in our system is the adaptative Monte Carlo localization method proposed by Dieter Fox. The navigation planner implements the Trajectory Rollout and Dynamic Window approaches to local robot navigation on a plane. Both are ROS packgaes defined in the navigation stack.

In the picture 4, we can see the proposed routes to a point near the table. In both cases the yellow line defines the total route and the green line that overlaids the yellow defines the local cost map to reach that point.

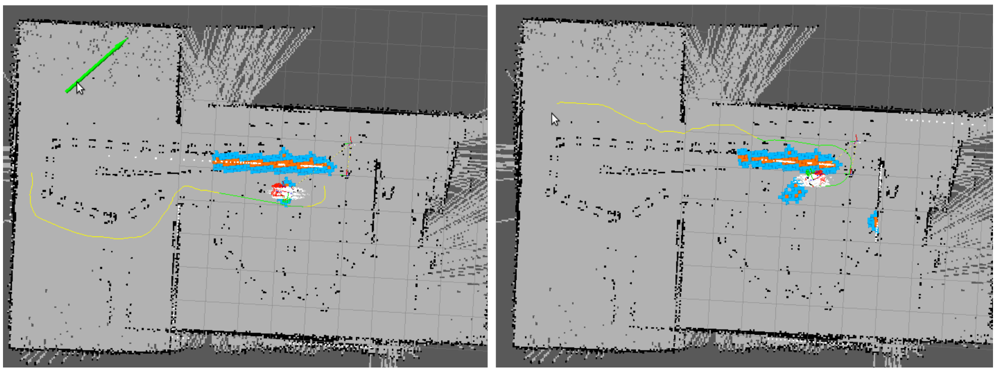
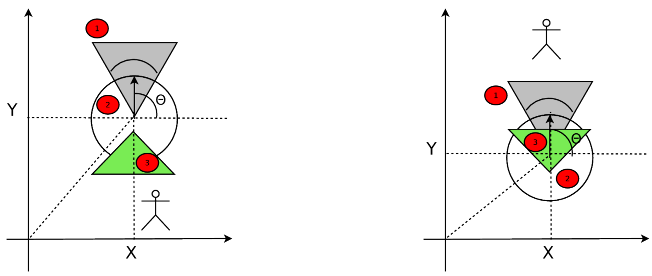


Figura 4: Path planning.

4. HRI oriented navigation strategies using AR

When we want to use the augmented reality system to improve the user experience we have to take into account where is the display in the robot. The reason is that the strategy will be different according each case.



a) The display is oriented backwards b) The display is oriented forward

Figura 5: Display configurations in the plataform.

We define according to our robot morphology two differents cases (figure 5). The numbers define the kinect sensor, the iRobot Base and the display plus webcam respectively. The picture 5a shows the display oriented to the back part of the robot. The picture 5b shows the display oriented to the front part of the robot. The human are represented en each picture with the needed position to get AR marks. In this way, these two cases define the two main strategies:

1. Back strategy
2. Front strategy

These strategies had to answer the two questions defined at the beginning of the research the task planning and the path planning questions.

4.1. Task Definition

The human needs something that is somewhere at home and the robot knows the position. The robot knows where is situated in the map and has to reach this position to advice the human. According to the choosed way (classical or with AR) the task plan defined is:

The classical is defined as: a) the robot starts, b) the human ask about the object, c) the robot make the path to the object, d) the robot starts the navigation e) the human follows the robot (optional) f) the robot reach the object and g) notice the human.

The task with AR is defined as: a) the robot starts, b) the human define the task, c) the robot shows a message in the display c) the robot make the path to the object, d) the robot starts the navigation e) the robot shows virtual arrows in the display with the route to the goal f) the robot has to control the human position during navigation g) the robot reach the object h) the robot choose the best place to notice the human with AR.

The main problems to take into account solving the tasks using AR are:

- Problem oriented to proxemics (figure 6): task f) the robot has to control the human position during navigation. we have to use a PID to manage the human position while is following the robot. In this way we have to manage the proxemics problem and the human territoriality space to offer a safe AR solution.

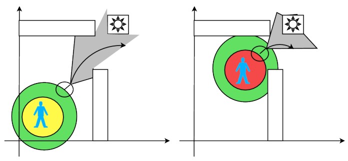


Figura 6: Generic example of proxemic problem.

- Problem oriented to deixis (figure 7): task h) the robot choose the best place to notice the human with AR . The robot has to show where the object is on the table but it doesn't have an arm mounted onboard to point it. Given the deictic problem of "the object is on the table“ or "the object is here“ needs to be avoided since not all people has the same point of view of the scene, the augmented reality system has been added: when we need to point to something, a virtual marking signaling the goal is shown in the screen of the robot.

4.2. Back Strategy

This section explains the "Back Strategy". In this case the display and the webcam are in the back position of the robot and the kinect is pointing to the front part.

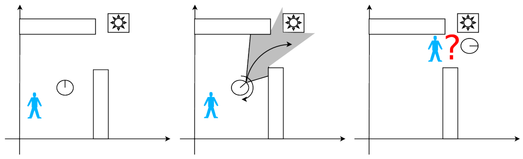


Figura 7: Which is the best place to show the AR mark?.

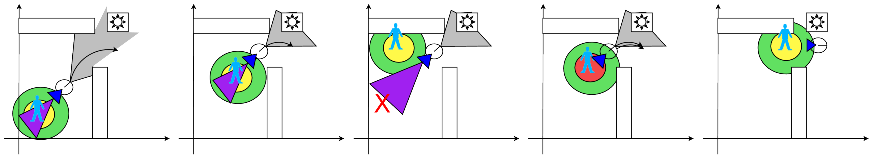


Figura 8: Back Strategy navigation

For the proxemics problem the system has to use the webcam installed in the display. The control system has to take into account if the human is too near or too far to regulate the robot velocity. If the robot get personal distance (less than 1.2 m), then an action has to be done like increase the velocity, stops the platform or change the path plan.

The figure 8 presents this situation, 1) the robot recognized the individual and starts the navigation, 2) the robot continues the navigation 3) the human disappears, the robot stops or not it deppends of interaction configuration, 4) the robot is in the private zone, the robot need to increase velocity, 5) the robot reach the goal.

The next strategy has oriented to the final position that the robot has to reach to be able to show the AR to the user. When the robot estimate the final position to be reach, it would be made taking into account the AR or not, it depends of motivational and if it is activate or not. The solution is fully human oriented and we have to figure out where will be the human in the scene.

The figure 9 shows the possible solutions presented in this research, we worked with two modes of AR presentation:

1. Mode 1: The robot is staring the object. The object is presented in the screen. The robot occludes the object.
2. Mode 2: The object is presented in the screen and it can be seen in front of the human.

The problem with mode 1 is that we are using the kinect, and the heigh is is not enought to reach some tables. A middle point solution is that during the path navigation we take a picture of the table and then we show it to the human. The benefits to choose the mode 2 is that we can use the webcam sensor available to get images from the table and show the AR in the display.

Therefore when the goal point is reached we can get infinite solutions, the system only has to avoid the possible obstacles. An example can be seen in figure 9.

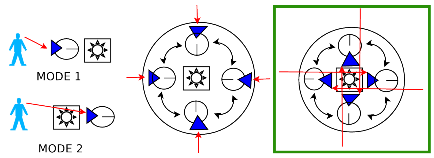


Figura 9: Solutions available for BS

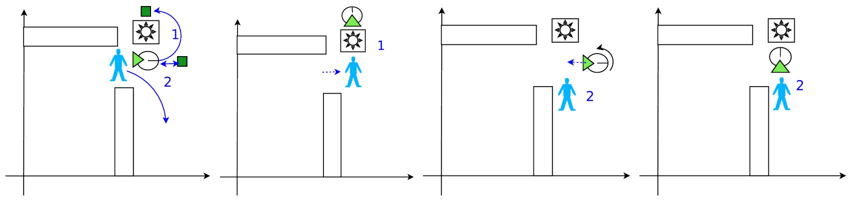


Figura 10: Two possible solutions taking into account the AR and the environment

4.3. Front Strategy

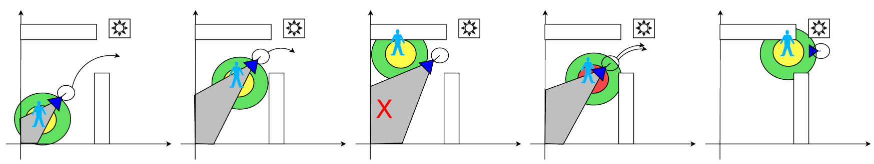


Figura 11: Front Strategy navigation

For this strategy the display and the webcam are in the fron position, also the kinect position is in the front. The figure 11 shows the posibilities. Again during the navigation if the robot sees the individual, the navigation plan continues or not according to overall system, for instance we can force the system to wait until the human is in front of the robot.

We have to watch over the personal space with the human (less than 1.2 m), if the robot is too near the human, the velocity is increased to stay outside the personal zone. Again the deixis problem is solved in the same way that back strategy. The general modes are presented in figure 12 and the favourite mode to use should be the mode 2.

The big problem of this solution is the reactivity, actually the robot morphology doesn't have any sensor in its back so we haven't got the ability to reacts in a dynamic environment. In this way this method should be revised with a different robot morphology to improve the backwards navigation.

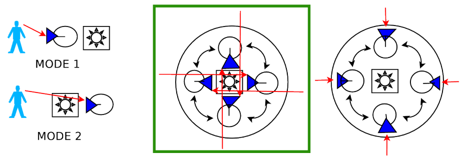


Figura 12: Solutions available for Front Strategy

5. Experiments

We developed this experiments using gazebo simulator, ROS and the turtlebot plataform assuming that the computer is open on top of the platform. The experience constraints are:

- Task goal: the robot has to reach an object that is on the table. The robot has to navigate for the environment guiding the human until it reaches the object and alert the user about the object.
- Strategy: The strategy defined for this experiment is the Back Strategy.
- Description: The robot make the necessary signals to advise the user during the travel to reach the object. The human should be following it in safe conditions.
- Restriction: We haven't got human in this experiment. We are showing how the deictic problem is solved. We use a turtlebot for this simulation and we define that the lapt should be on top of the platform and showing the display to its back.

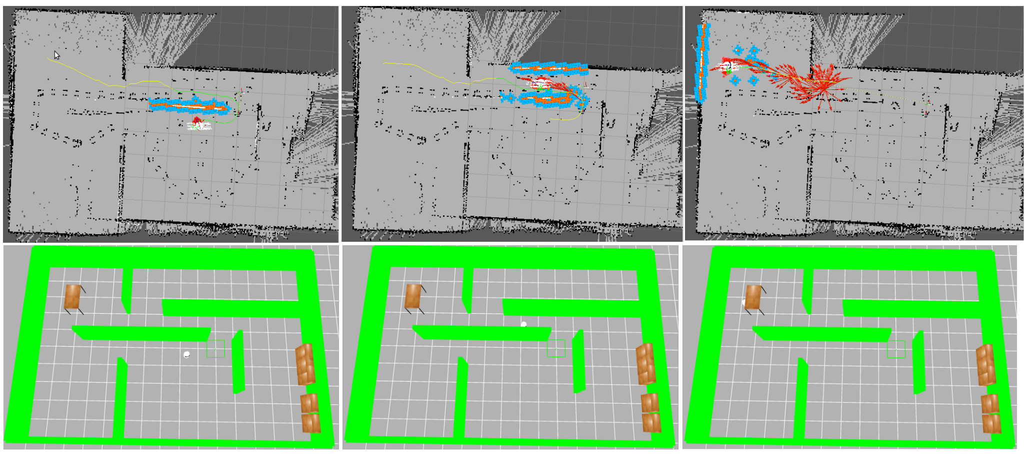


Figura 13: Simple scenario simulator navigation

The left picture in figure 13 shows the initial path planning to reach the goal, the middle picture shows the robot route and the pose during its travel and finally a correction is applied to improve the experience and the position behind the table is reached. With our robot and the defined morphology the human should be seen the display at the same height as the table.

We also made a simple test with an actor (figure 14) and these were the problems:

- The first one was the final position in the environment. Sometimes, the robot reach approximately the final position, it see the human and do not see the table, so the estimation agree with the goal of our algorithm.
- The second problem is related to proxemics, undefined human movements and recognition problems. If the human change the velocity and we lose the human in our camera, the human can collision with the robot. The problem is presented in the right part of the figure 14.

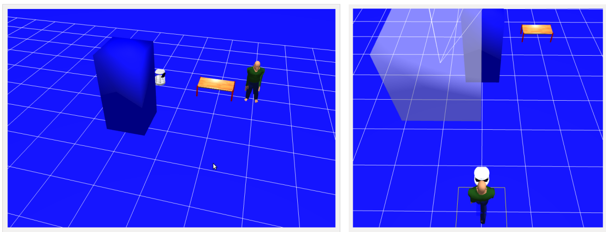


Figura 14: Problems in the simulation

6. Conclusions

We presented a novel approach to improve the explicit HRI dialog using augmented reality. Due to the robot morphology restrictions the tasks to improve the dialog using the AR are increased and the path planning is modeled to offers the best point of view to human.

We presented two strategies according to the robot restrictions, "Back Strategy" and "Front Strategy". In both strategies proxemics and deixis problems are considered.

One of our contributions is the navigation control to get a goal according the human distance and to reach a right position near the goal to show the augmented reality effectively. In this way we can say that the second contribution consists in the aplication of the augmented reality as a tool to mark objects in a environment in a explicit dialog.

This research is still in earlier phases, a mathematical approach has to be done. Also a experienements with the real platform should be performed to validate the utility of the augmented reality in guidance assistance task.

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