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Robotic Assistants for Health Care

R. Barea, L.M. Bergasa, Member IEEE, E. López, M. Ocaña, D. Schleicher and A. León

Department of Electronics
University of Alcala
Alcala de Henares, Spain

{barea&bergasa&elena&mocaca}@depeca.uah.es

Abstract - **The main objective of this work is to develop a robots´ fleet working together to make assistance tasks in a hospital, geriatric or home in a collaborative way. This paper focus on multi-robot mapping and localization system for robotic assistants and a camera based system for tracking people. This paper presents a method to detect, recognize and track people using mount cameras fixed on a building and an algorithm for collaborative mobile robot mapping and localization based on probabilistic methods. The performance of this system has been tested successfully. Some experimental results and conclusions are presented.**

Index Terms - Health care, Patient monitoring, Multi-robot SLAM, Monte Carlo Localization, PCA.

I. INTRODUCTION

Health care assistants carry out the routine care tasks required to look after patients who are staying in hospital or at home. It is hoped that in the future teams of robots working together may be used to help on hospitals or geriatrics and free staff to spend more time with patients.

The developed countries are facing an explosion of costs in the health-care sector for elderly. Current nursing home costs range between $30,000 and $60,000 annually. Over the last decade along, costs have more than doubled. The dramatic increase of the elderly population along with the explosion of costs poses extreme challenges to society. The current practices of providing care for the elderly population are already insufficient. Undoubtedly, this problem will multiply over the next decade.

The society needs to find new technologies and alternative ways of providing care to the elderly, where the need for personal assistance is larger than in any other age group. Several factors suggest that now is the time to establish new applications in the home-care sector: firstly, we actually have the technology (internet) to develop new applications in home health-care sector. Secondly, at the currently, the robots exhibit the necessary robustness, reliability, and level of capability. Thirly, the need for cost-effective solutions in the elderly care sector is larger than ever before. For this reason, assistant robots have received special attention from the research community in the last years. One of the main applications of these robots is to perform care tasks in indoor environments such as houses, nursing homes or hospitals, and therefore, they need to be able to navigate robustly for long periods of time. Nowadays exist several research groups working in this area, and some important projects such us “Nursebot” [1] and “Morpha” [2]. Basically, the goal of these projects is the development of personal robotic aids that serves high level services specially though for assisting the elderly such us tele-presence, tele-medicine, intelligent reminding, safeguarding, mobility assistance and social interaction [3].

In order to offer a solution for described problem, a research group of Electronics Department at the University or Alcalá is working in a project called LOMUCO (spanish acronym for Collaborative Multi-robot Localization for Elderly Assistant) and “ROBOCITY 2030” (spanish acronym for Service Robots Upgrading Urban Standards of Living) [4].

On the other hand, learning maps and efficient exploration of unknown environment is a fundamental problem in mobile robotics. This problem is usually called SLAM (simultaneous localization and mapping problem) [5-10], which includes estimating the position of the robot relative to the map and building a map using the sensory input and the estimated robot´s pose.

The problem of exploration of an unknown environment has been extensively studied, firstly using single robot systems with a variety of sensors and later using teams of robots. The first implementations of multirobot exploration systems were simple extensions of the single robot implementations. Multiple robot systems are more complex than other distributed systems because they have to deal with a real environment, which is more difficult to model since it is dynamic, unpredictable, noisy, etc. Therefore, the extension to multiple robots systems brings several new challenges and difficulties [11-12]: coordination of robots, integration of information collected by different robots into a consistent map and dealing with limited communication.

Multirobot exploration systems are usually classified as centralized and decentralized. Centralized systems obtain solutions close to the optimal but are computationally intensive and have a single point of failure. Decentralized systems are flexible and robust, but frequently achieve significantly suboptimal solutions. Therefore, the difficulty of the coordination task strongly depends on the knowledge

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of the robots. If the robots know their relative locations and share a map of the area they explored so far, then effective coordination can be achieved by guiding the robots into different, nonoverlapping areas of the environment [13-15]. However, if the robots do not know their relative locations, then it is far less obvious how to effectively coordinate them, since the robots do not share a common map or frame of reference [11].

Map merging task consists on building a consistent model of an environment with data collected from different robots. If the initial locations of the robots are known, map merging is a rather straightforward extension of a single robot mapping [16-18]. If robots do not know their relative locations is more difficult, since it is not clear how and where the robots' traces should be connected.

This paper describes the general architecture of the system (section II) and comments the learning maps (section III) and localization process (section IV). Finally, in section V and VI, an application of our system in people recognition and patient monitoring to carry out assistance tasks by mean of robots is presented. Therefore, this paper is focussed on patient recognition and robot navigation in a collaborative way.

II. Architecture

The general objective of this work is to develop a robots´ fleet working together to make assistance tasks in a collaborative way (Fig.1). This way, we have placed cameras fixed on a building that permit recognize users and its position, then, the best placed robot in the environment make the assistance task. In this case, it is very important to know where is located each robot. For this reason, we have implemented a collaborative multi-robot mapping and localization system based on scan-matching (SM) and particles filters (PF) respectively.

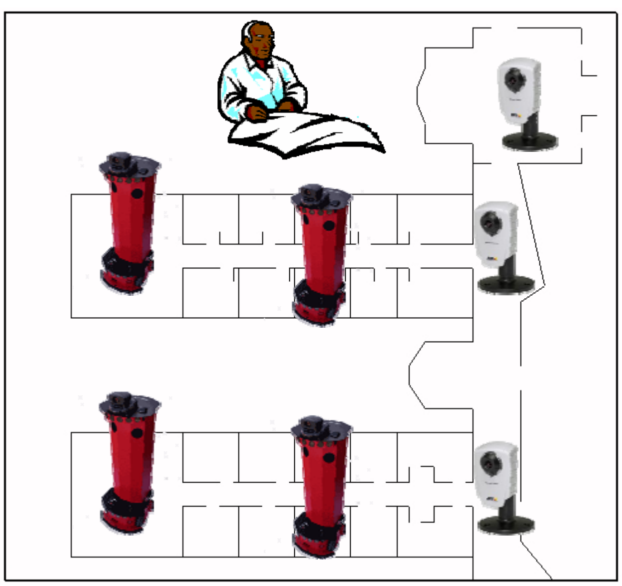

Fig. 1. Robot´s fleet working.

A. Robots

Four robotic platform have been developed (based on PeopleBot, pioneer DX and pioneer AT robots of ActivMedia Robotics [19]). Its architecture is composed of four large modules: environment perception, navigation, human-machine interface and high-level services as we show in Fig. 2. The perception module is endowed with encoders, bumpers, sonar ring, laser sensor and a vision system based on a PTZ (pan-tilt-zoom) color camera connected to a frame grabber. The human-machine interface is composed of loudspeakers, microphone, a tactile screen, the same PTZ camera used in the perception module, and wireless Ethernet link. The system architecture includes two human-machine interaction systems, such as voice (synthesis and recognition speech) and touch screen for simple command selection (for example, a destination room to which the robot must go to carry out a service task). The high-level services block controls the rest of the modules and includes several tasks of tele-assistance, tele-monitoring, providing reminding and social interaction [20].

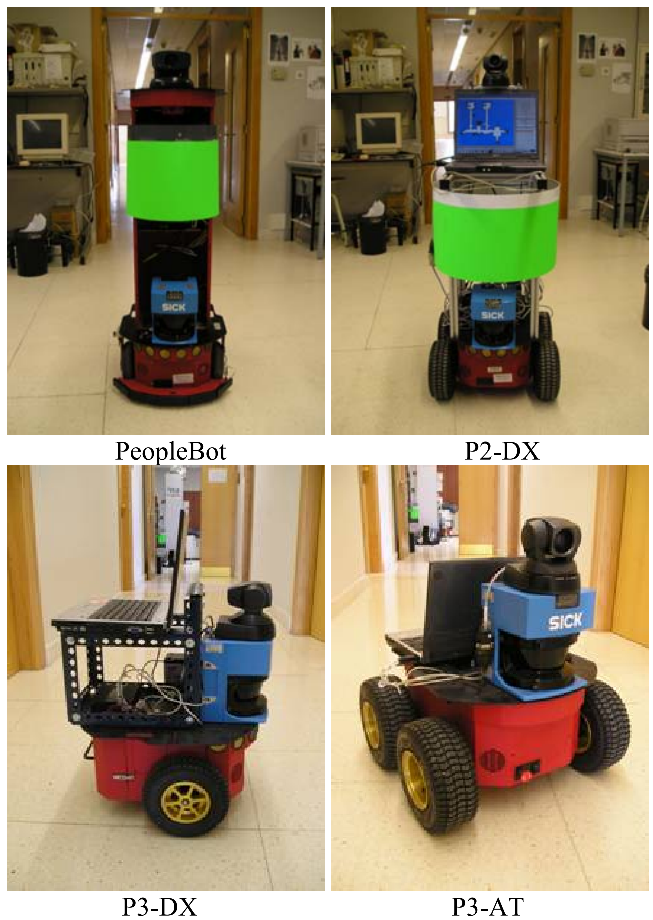

Fig. 2. . Robots.

III. Multirobot Map Merging

This section describes how to build a map from data obtained by multiple robots. In this work we have develop a multirobot map merging using scan-match technique [21].

To do it, we have modified some code and parameters in GMapping algorithm obtained from OpenSlam.org [22] which provides SLAM researchers a platform for publishing their algorithms. This code work with single robot and we have adapted it to multirobot system.

Next, a merging map example is commented working with scan-match technique (see figures 3 to 5). The goal is built the corridor 3 and 4 from Department of Electronics of University of Alcala. Figure 3 shows the trajectories followed for each robot. Robot 1 explores across corridor 4 and Robot 2 explores corridor 3, each robot built its partial map and calculates its pose any time (Fig. 4). When robot 1 meets robot 2, robot 2 send its map to robot 1. Robot 1 uses the partial robot 2 map and the detection model (robot 2´s pose detected) to generate the global map (Fig. 5).

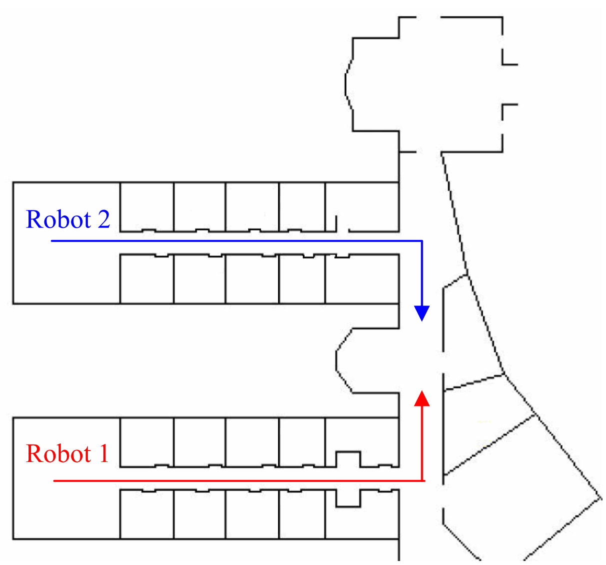

Fig. 3. Robots trajectories.

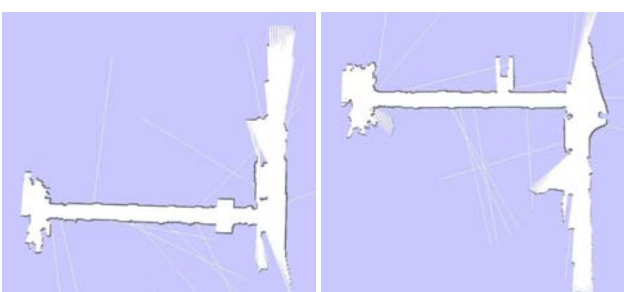

Fig. 4. Partial maps built by robots.

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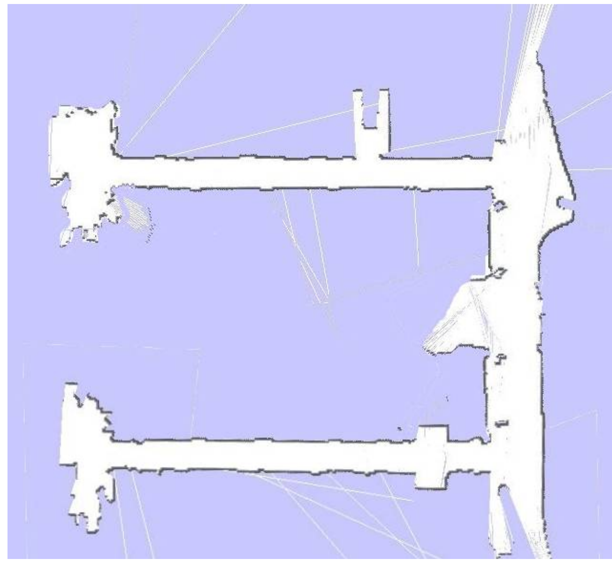


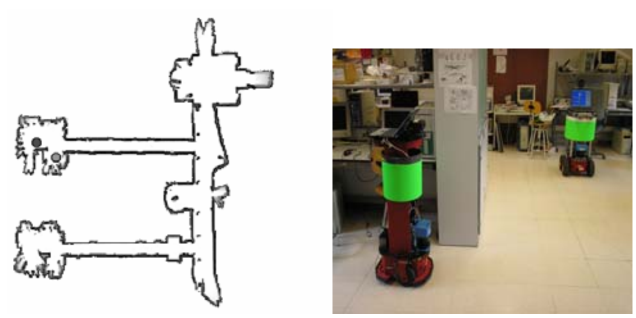
Fig. 5. Global map using scan-matching.

IV. Multi-robot Monte Carlo localization

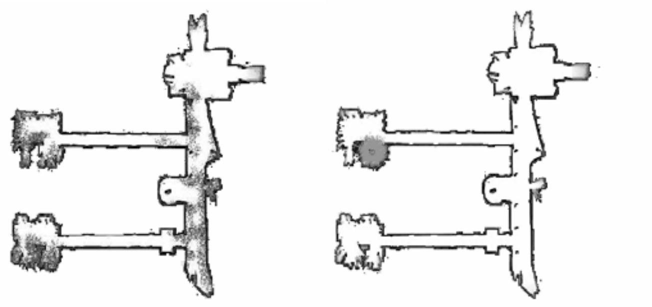
Monte Carlo Localization have been widely studied in [23]. MCL is a recursive Bayes filter that estimates the posterior distribution of robot poses conditioned on sensor data. The key idea of Bayes filtering is to estimate a probability density over the state x space conditioned on the data.

The key idea of multi-robot localization is to integrate measurements taken at different platforms, so that each robot can benefit from data gathered by robots other than itself. Therefore, when a robot n is detected by robot m it is necessary to introduce the detection model according with data obtained. In the absence of detections, the Markov localization works independently for each robot.

The following example shows how collaborative multi-robot Monte Carlo localization improves single localization [24]. Robot 1 is initialized with uniform belief and Robot 2 with gaussian belief. Figs. 6a.b show initial robots´ position and Figs. 6c.d show the initial distributions of particles.



a) b)



c) d)

Fig. 6. Initial distributions.

If Robot 1 wanders across top horizontal corridor (Fig. 7a.b), when Robot 2 detects Robot 1 (Fig. 7c.d), the detection model is sent and Robot 1 updates its belief distribution. This way Robot 1 is well-located before reaches the corridor (Fig. 7e.f).

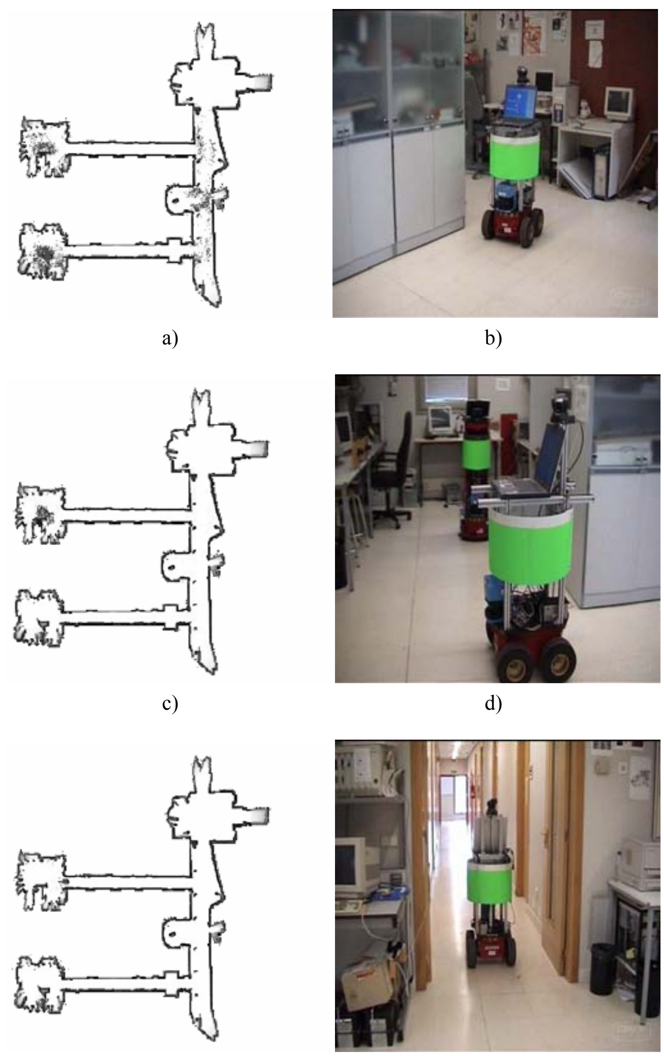


Fig .7. Collaborative multi-robot Monte Carlo localization.

V. Face Recognition

The problem of user identification consists of the following: a fixed camera acquires images of people in the work environment; an automated system extracts faces from these images and quickly identifies them using a database of known individuals. The system must easily adapt as people are added or removed from its database, and the system must be able to recognize individuals in the room. The face localization system is based on a detector of simple features called *Haar-like* and a classifier based on the learning algorithm *AdaBoost* [25]. This section focuses on the face recognition technology that is required to address this real-world task. Face recognition has been actively studied [26], in this domain, techniques based on Principal Components Analysis (PCA) popularly termed eigenfaces, have demonstrated excellent performance. In our case, we use a simple, memory-based PCA algorithm for face recognition.

A. Database and Preprocessing

The system uses human face images from a database composed by 20 tightly-cropped images of different individuals with only minor variations in pose (±20º) and facial expression. The faces are consistently positioned in the image frame, and very little background is visible. Fig. 8 shows several faces of a person and Fig. 9 shows faces of some individuals.

For detecting faces, the system acquires an image and detects where exits some faces. To do it we use a PCA algorithm as can be see in Fig. 10.

After that, using the previous database compares the face obtained with faces stored in database using PCA. With this information the user is recognized. If the system does not recognize the user, ask for his name and introduced a set of faces of him in the database and the database is trained again. This way, the system stores all users and the database is increased on-line.

Fig. 8. Different images of the same user.

Fig. 9. Images from different users.

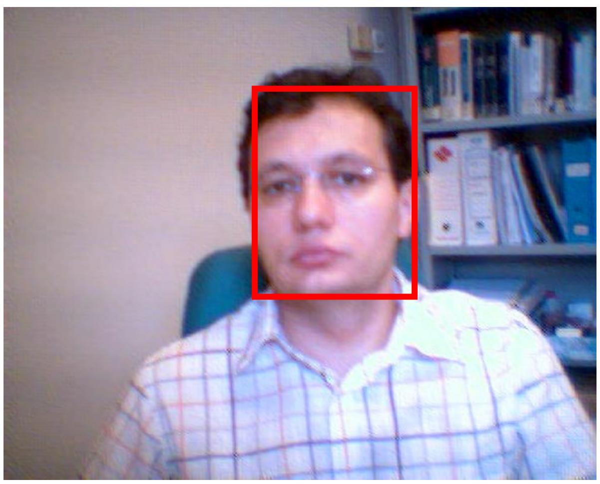


Fig. 10. Face detection.

VI. RESULTS. ASSISTANCE TASKS

Firstly, when robot team is placed is a new environment a map is generated using the multi-robot mapping system based on scan-matching. After that, the robots are auto-located using the multi-robot monte carlo localization. When robots are located in the environment they can navigate and make some assistance tasks.

Our objective is to design a fleet of robots to perform basic tasks such as transport medicines, taking messages or guiding visitors or patients to hospital beds or rooms.

The implemented system allows control a set of robots working together to carry out assistance tasks. A software application has been developed (Java) and allows to control the whole system from a remote computer or even from a mobile device (PDA). The system allows configure the position of the cameras and the number of robots. Robots can locate themselves in the environment and to navigate in a sure way. Fig. 11 shows a chart of this architecture and Fig. 12 the configuration window.

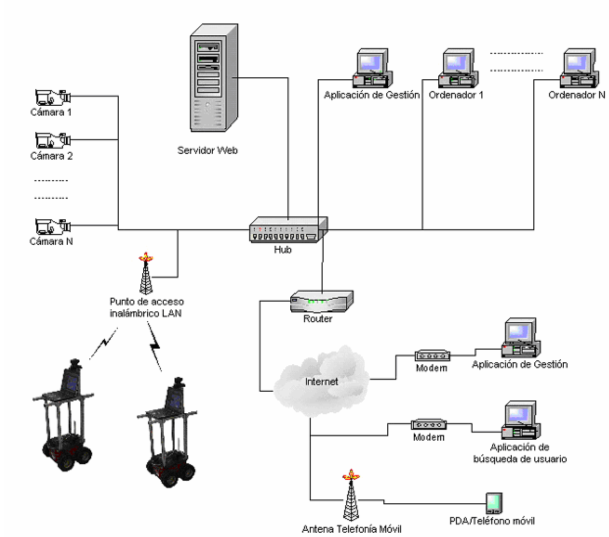


Fig. 11. Control scheme.

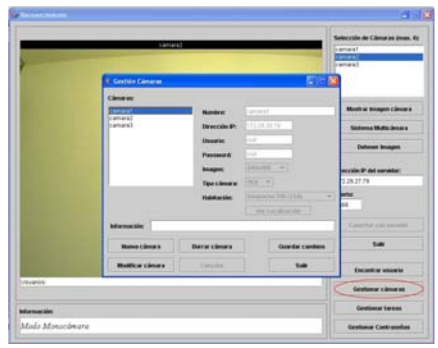
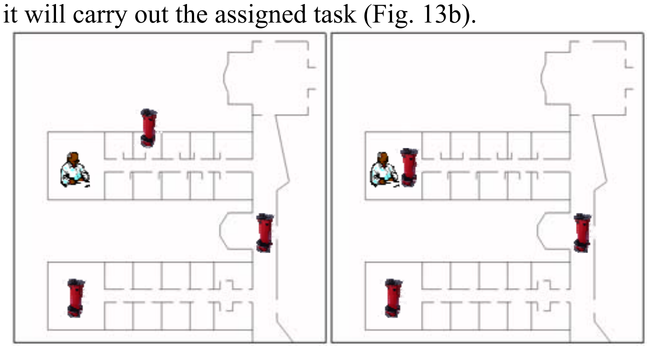


Fig. 12. Configuration window.

Once the system is configured, the tasks can be introduced, such as, taking messages to patients, e. g. "you have to take your medicine" or "you have to go sleep." Each task is assigned at a user and the hour and date of realization. The system continually is detecting patients or people in the images of the cameras and it takes a list from where they are. This way, when a task is executed it is looked for where the user is and the nearest robot is sending to carry out it.

For instance, if three robots are working in the environment (Fig. 13a) and the task activated is “going to the patient's room”, the system detects what robot is better located (Fig. 14) and sends the corresponding orders so that it will carry out the assigned task (Fig. 13b).



a) b)

Fig. 13. Assistance task in collaborative way.

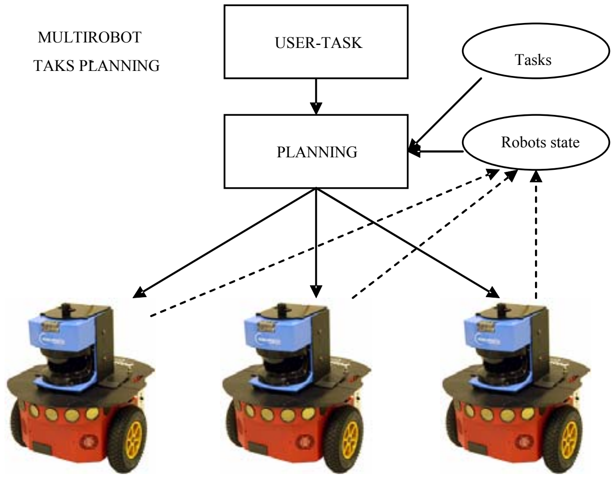


Fig. 14. Planning scheme.

VII. Conclusion

Teams of robots working together may be used to help on hospitals or geriatrics. These robots can carry out some easy or routine assistance task and free staff to spend more time with patients.

This paper reported the initial design and results of a robot´s fleet working together to make assistance tasks in a hospital, at home or in a geriatric in a collaborative way. Shortly, a multirobot scan-match mapping method has been showed. This allow to move robots to new working environment and to generate the new environment map in a quick and easy way. Besides, the multi-robot Monte Carlo localization algorithm applied to assistant robots has been studied and how the results obtained improves localization speed and accuracy when compared to conventional single-robot localization. This allows that the realization of collaborative tasks is more effective. On the other hand, an application for controlling and programming assistance tasks has been commented.

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