CREATING COMMON PRESENCE FOR A MULTIENTITY RESCUE TEAM

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Abstract: The paper presents a multientity rescue/mapping team consisting of both human and robotic members that are in remotely connected to a coordinator. Both entities explore a common area and provide both verbal description (human) and accurate mapping data (both) from their local environment. This information is fused with a possible apriori map resulting an environmental model called common presence. Common presence is updated continuously with new information and it includes the latest available information from whole area where the entities are or have been. Both entities will get continuous updates of the common presence in the form they best understand. With this information entities can improve their navigation and feeling of presence and exchange environment dependent information. The system and all the developed sub-systems are described and the test results of the integrated system are evaluated. *Copyright © 2005 IFAC*

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1. INTRODUCTION

The traditional factory robots have already been followed by the new generation of robots – field and service robots. These robots can navigate freely among the humans and carry out more and more demanding tasks. The first field and service robots are already commercially available. The best knowns are the vacuum cleaners for home use (Trilobite and Roomba), but also industrial systems like Sandvik-Tamrocks robotic mining system Automine [Pulli] are available. However, these examples are single or few task robots, which carry out their tasks with minimised human effort, like vacuum cleaners. The automine concept utilises the operator in loading (teleoperation) and in exceptional situations.

In previous cases the interaction between robot and operator is quite minimal. The situation changes dramatically when the robot has to solve several more complicated tasks, including object/environment recognition and manipulation or it has to work in continuous cooperation with humans. Despite the continuously increasing computing power and development in "artificial intelligence", the autonomous abilities of robots remain very limited. In all the more complicated tasks, human help is needed. Human help can take the form of direct teleoperation or higher-level action like giving verbal advice, but in all cases it involves the human as part of the task execution control loop(s) of the robot [Fong 2002].

Field and service robots do physical work tasks with and among humans. Therefore the HRI must include effective tools to change spatial information between robot and operator. Spatial information has two features, which make it a crucial part of the HRI. Firstly, in all physical work tasks, navigation, perception and environmental awareness are the key issues; secondly, humans and robots process the position and map information in very different ways. For a robot, the environment and navigation is somehow bound to numerical coordinates, while a human relies on relative information based on perceived landmarks [Forsman].

Search and rescue robots are typical field and service robots. In a rescue task different levels controls and communications between the humans and robots are very typical. Difficult tasks can be executed only by direct teleoperation, while some simple mapping tasks can be done autonomously. Fig 1 shows the overall principle of the rescue operation considered in more detail later on in the paper. The rescue task is different comparing to many other tasks. There are exploring entities both human and robotic ones, which are moving either together or separately. Exploring entities – also humans - are controlled by one or several operators outside the explored area. Explorers are looking for special targets, like victims or explosive materials, and mapping the environment, thus the spatial information is even more important here than in human robot interaction in general.

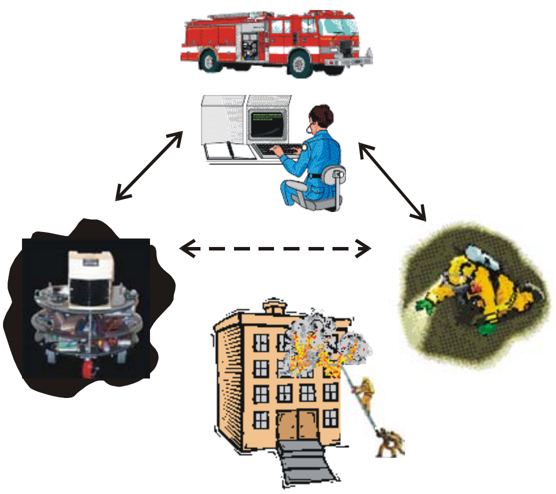

Fig. 1. Rescue scenario

2. PELOTE SCENARIO

Pelote-project (Building Presence through Localization for Hybrid Telematic Systems) is part of the IST programme of the European Community. The target of the project is to study how to map a totally or partially unknown area with group of human and robotic entities and form a common environment model (presence) from the mapped data produced by both entities. The model is updated in real-time and provide presence for both humans and robots. This type of scenario is typical in rescue, military and planetary exploration tasks.

The case example in Pelote is a rescue task where firemen and supporting robots are mapping a common area together with help of a remote operator Fig. 1. Both entities specialize to tasks, which are natural for them. Robots can perform accurate navigation and measurements from the environment even in hostile conditions. Humans can give fast verbal descriptions of the situation and conditions. Human senses are also more versatile than robot senses. Exploring entities are supported by a remote human operator in a mobile control room. He teleoperates robots and supervises the firemen. He also summarizes the information obtained from both entities to the common environment model.

3. COMMON PRESENCE

In all human – robot, like in human - human interaction the common understanding of the environment is a key issue in the communication. Especially important this is in the case of field and service robots doing position bound work tasks [Suomela].
The complicated work tasks of the field and service robots require more and more sophisticated user interfaces. The cognitive user interfaces are relatively new area of interest in robotics research. In one hand, the idea is to use the human cognition in order to overcome the lack of robot cognitive capabilities. On the other hand, the purpose is to reduce the cognitive load of human when "programming" the robot (e.g. teaching new tasks).

The common presence is an effort to build an interface that allows the use of both human and robot cognition to build up a better understanding of the current situation.

The term common presence means that all entities have some common space, which they can understand in a similar way and exchange information with symbolic meaning through it. The common presence can be understood as a virtual working environment for different types of entities. The objects in the virtual environment are understandable to all entities. This kind of virtual space does not represent all the components of the virtual environment for a human, only those with some important key features. All entities have a location, which puts them inside this virtual space. All entities have the capability to modify the environment, through mapping, inserting new objects etc.

In traditional user interfaces, the user interface provides an access to the robot and its sensors through it. This is a simple control loop, where the robot provides all information to human and human controls the robot accordingly. The common presence can also be understood as an enhanced user interface, where the (perception) information and commands are exchanged between robot, human explorer and human operator. In a sense, the model is an interpreter, which translates the environmental information perceived (or created) by an entity to be easily understood by the others Fig 3.

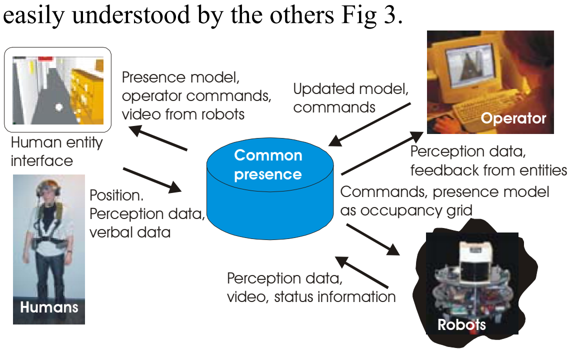

Fig. 3. Common presence in PeLoTe

The base of the common presence is the robot's geometrical environment model. The presence is formed by augmenting model by conceptual information and ability to interpret the augmented model. The model is common for all entities and the outcome is similar to all of them, but the interpretation is different for human and robot.

The environment models of the robots are called maps. In most cases the maps are 2D projections, representing the objects in the environment. For the humans this kind of representation is also very understandable. The common objects (doors, corridors etc.) and the objects that have significant meaning from the mission point of view (dangerous area, victims, temperature etc.) can be identified by both humans and robots. The position and status of all the entities are also shown in the model. It also gives information for the global operations such as path planning.

To maintain the model, it is required that all the entities are operating under the same coordinate system. This simple requirement turns out to be the key of building the common presence. If every entity has the same coordinate system (and thus have a position inside the model), the tasks like adding common objects or using the environment model are easy. On the other hand without consistent position other entities have no idea where e.g. the common objects are placed and the information cannot be shared.

The concept of position is very different for different entities. Humans navigate relatively to the environment and they don't know their numerical coordinates without additional navigation equipment i.e. a human cannot tell his position to a robot. Due to this a separate localisation system must be set up for humans in order to bind the human and the information he provides into the model.

Common presence includes the basic model or map of the environment enhanced with objects and other position bound information. The aim is to include all environmental information in symbolic form. Thus the common presence provides possibility to change spatial information between humans and robots and it includes the "presence" that is common to all entities i.e. an entity specific presence can be filtered out from the common presence.

In practise it is obvious that there is no model that would give "perfect presence" to all of these entities. This is, however, not the point. The key idea is to build a model that supports all the entities in the system in their work and can be used as the information integration platform trough which communication between entities can be set up.

4. COMMON PRESENCE IN PELOTE

4.1 Standard Rescue Map

In PeLoTe the common presence is based on the possible apriori map of the explored area called Standard Rescue Map (SRM). The future objective is that SRMs of all buildings with straight connection to public alarm center will be in the database of rescue officials. After an alarm the firemen could already during their transfer to rescue place make planning with the help of standard form maps.
Physically SRM is a 2D polygon map and an object database, which can be updated with any kind of object information. SRM shows the navigable area and important objects like sprinklers, fire alarm areas, flammable or poisonous chemicals etc. are stored in the database. Objects are divided to different dynamic layers based on their type and importance. In the case of human only important/needed layers are visualised in order to avoid excessive amount of information. A good example of similar type approach is the ECDIS used in ship navigation [Ecdis].

4.2 Planner

Planner helps the operator to control robots. When operator has chosen an area to be explored, the planner plans a route in order to cover the whole area with the robot's sensors [Kulich]. The route is send to the robot, which will autonomously drive the planned route.

4.3 The operator

The operator is sitting in the operator room controlling and supervising both the human and robotic entities in the target area. To perform his task well the operator should be as present in the target area as possible. The way to do this is by telepresence, which is limited to the map (Fig. 4), images and video from both entities and verbal comments from human entities.

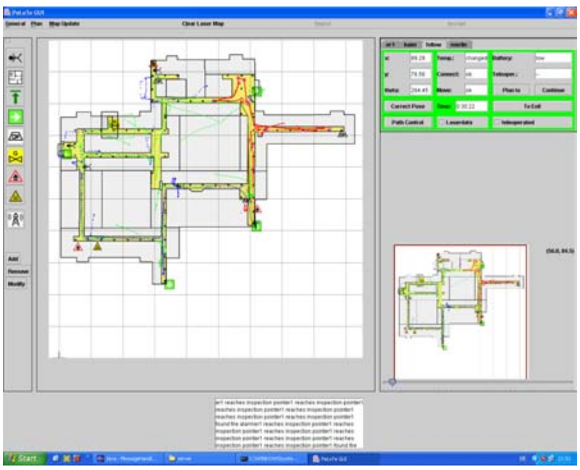

Fig. 4. Operator GUI, map view

He has the common-presence model, mapping data, video and images sent by the entities and the verbal information from the human entities [Driewer]. The operator organizes this information and tries to get the best possible information from the target area.

Operator fuses the data from human explorer into the common presence model. During the task human inside doesn't have time to use computer or any other additional devices. Thus, most of the information he provides consists of verbal information describing wholeness instead of details in the following way: "The roof of the 1st floor lecture hall has collapsed, at least two victims". The operator imports the information into the common presence, which is shown as a topographic map in the display of the human entity.

Augmenting the map by specified information is done by adding drag-and-drop objects based on location. If for example human (or robot sensors) observes inaccessible area, this can be added to model by placing an object into this location. Adding this kind object into the model triggers path planning for all entities. The path planner then takes into account that into this specific area no paths are planned.

4.4 Human Entity

In PeLoTe scenario the human entity – a fire fighter, for example – is moving in a more or less hostile environment in order to map the area and search for possible victims. The situation is always new and very challenging. He has to be aware of fire, hot gases and even collapsing structures. Most probably, he is very present in the ongoing situation. He is not thinking what he will eat for the dinner or dream about a sunny beach etc. In certain situations – heavy smoke, for example – the fire fighter is again very present but the sensor information is very limited. In the worst case, he doesn't see anything. The only way to perceive the environment is to explore the walls and floor with fingers. While exploring in the total darkness, e.g. the sense of direction will be lost rapidly. In this kind of situation, the extended environmental model – common presence – provides additional information from the near environment and broadens the fire fighter's feeling of presence, allowing him to execute his task more efficiently. In a way, the situation can also be described as augmented reality or "local telepresence" (Fig. 5).

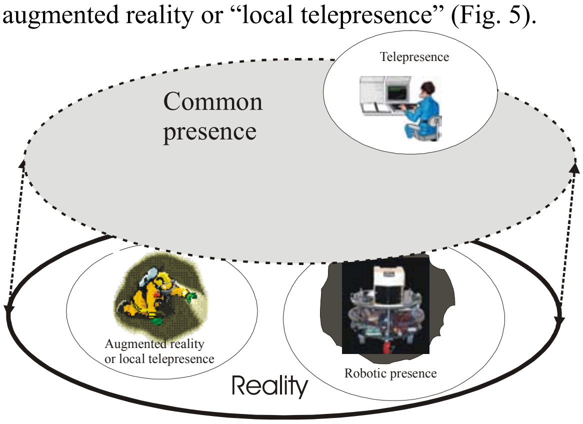

Fig. 5. Different presences of the PeLoTe entities

Therefore, the location information is also extremely crucial. It is impossible to create "tele"presence for an entity without knowing his position. The virtual world and the real world have to match.

As mentioned humans only rarely know their accurate position. Therefore an automatic, infrastructure free, navigation system – personal navigation (PeNa) was developed (fig. 6).

Fig. 6. PeNa hardware

PeNa improves the usability of the verbal mapping information and makes it possible to generate automatic mapping data. The core of the PeNa is so called human dead reckoning based on gyro, compass and continuous ankle distance measurements. Dead reckoning is supported by a laser scanner, which provides laser odometry and map based localisation. In Fig. 7 is an example of navigation accuracy.

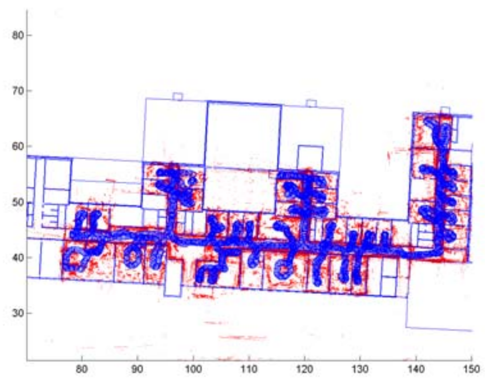

Fig. 7 Human localisation using a priori map

4.5 Robotic Entity

Robots (Fig. 8) are used to support and help the human explorers. At the moment there are two types of robots: Mappers and followers. Mappers have the capabilities to do automatic route following and mapping, whereas followers can be used as teleoperators to explore hazardous areas under the continuous control of the operator or to follow and support the human explorers. In general robots – especially mappers - are in the same situation as fire fighters. The difference is their cognition, which is very limited compared to what human entities have. The cognition of the robot in this case limits to the knowledge of the position, path to be travelled and input information from sensors.

Mapper's task is to follow the given path and make measurements from the environment. One important task is to update the map physical map of the environment. The mapped data is pre-processed on the robot and sent to the operator to be added into the common presence.

In addition mappers can carry (and drop) US-beacons, which support the personal navigation of human entities.

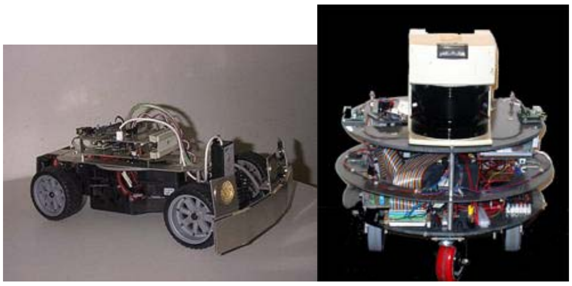

Fig. 8. PeLoTe Robots, follower and mapper

As in the case of human, the operator can assist in the fusion of information to the common presence. In complicated situations, the operator teleoperates or commands the robots, i.e., the functions are based on the operator's telepresence.

5. BUILDING AND SHARING THE PRESENCE

5.1 Forming the presence

To fulfil the demands of common presence the SRM has to be enhanced with additional information. The map geometrical data has to be symbolized and object names stored in the object database. The real time positions of all the entities are updated continuously. Additional information like video clips and verbal comments for humans and visual model information of the objects for the robots can also be included. Common presence is finalized with presence filters, which form the common presence information into an understandable form for each entity. For humans this means a zoomable map with important objects (Fig. 10) and other entities and for robots it means a geometric polygon map included with visible objects. Both entities can refer the environment with symbolic names of the areas and objects.
The common presence is formed from three main parts: Possible apriori map of the explored area, human mapping data and robotic mapping data. The continuously updated common presence is formed by the human operator.

The operator can afterwards include or correct "constant wall – type" objects as part of the model. In the database all objects have at least size, position, type, additional information and layer group. Additional information can be anything, even a photo or verbal description, which can be seen/hear by clicking the object. The layer group information is used visualise only needed information in order to avoid the information flood on the model.

5.2 System telematics

In a real rescue situation a functioning communication will be perhaps the most central issue. The existing communication channels like WLAN and cellular phones and other radio networks cannot be trusted in an emergency situation. In modern buildings the steel and concrete structures will also effectively damp the traditional point-to-point radio communication like VHF walkie-talkies.

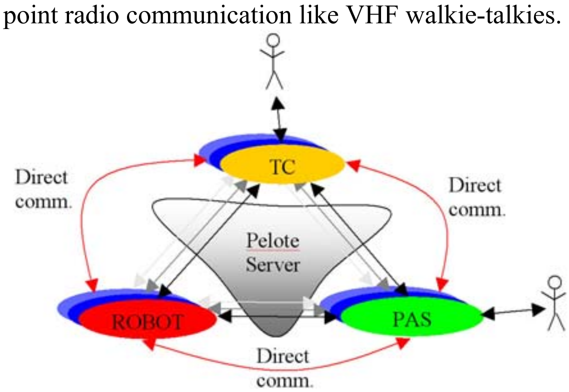

Fig. 9. Pelote communication, TC means the operator and PAS is the personal assistance system meaning the support system of the exploring humans.

In PeLoTe-project the communication channels were not in the focus, thus the communication was built on TCP/IP based client server architecture. In the experiments a WLAN network was used. Communication is based on a PeLoTe server, which is physically located in the operator station. Additionally to the server communication entities can have straight contacts based on radio modems between humans and robots and walkie-talkies between humans. Verbal communication can also be done with the VoIP. Communication is illustrated in fig. 9.

6. FINAL EXPERIMENT AND RESULTS

The PeLoTe system was tested during the final experiment in Würzburg between 20-21.11.2004. The experiment was organized to prove the functionality of the complete system and to make the presence evaluations. Six teams, consisting of operator, fire fighter and two robots, carried out the experiments. For presence research there was also six "traditional" fire-fighting teams. The mission was to search and map a large office type of area and rescue all found victims to a safe exits. The rescue area was assumed to be mostly dark because of the smoke, which was simulated by using a blanket.

The tests were carried out as user tests. The users had never used the system before and they had 20 min training before the mission. Half of the users were university students with strong computer background. The other halves were voluntary fire fighters with little or no experience with computers.

The evaluation of presence is rather complicated. The evaluation is usually carried out with questionnaires. From this paper point of view, the interesting is the "measure" of the common presence. We are not even interested about the "amount", just if there was common presence or not. One clear indication of this is that the system is functional i.e. the robots, humans and the operator are able to understand each other. First of all it has to be mentioned that it shows high usability of the system, if people that has never used it, can use it with 20 minutes training.

The functionality was clearly showed: the operator was able to track the situation, command the robots, guide the human in the building, and map the situation as the mission was running. The PeNa users were able to report victims, stay away from the dangerous areas reported by robots, follow the instructions from the operator and use the system for navigation. One indication of the "local telepresence" or augmented reality was the very different behaviour of traditional fire fighters and PeNa users. In complete darkness the traditional teams were exploring the area by walking along the walls, where as the PeNa users used the information provided by PeNa and stayed off the walls using the free space. All users found this feature useful.

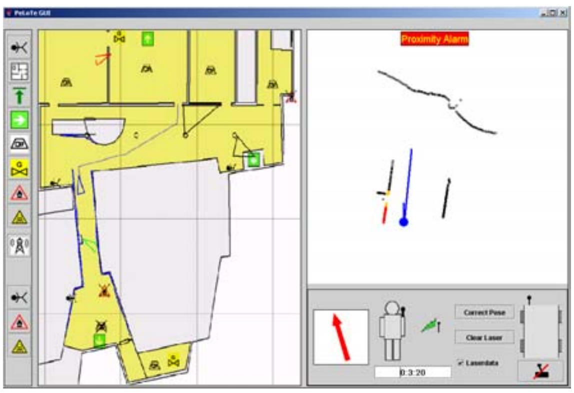

Fig. 9. Human interface with map including the navigated route (left) and real-time scanner data with proximity alarm (right).

Another indirect evidence of the presence (or situational awareness) of the operator and PeNa user was the stress level that the teams had during the mission. The traditional teams with only voice communication and map in hand had much higher stress level than the PeLoTe teams. This was evident from the conversations that went through during the mission. Another evidence found was that after the mission the PeLoTe teams were able to remember better what happened during the mission.

7. CONCLUSIONS

Co-European research project PeLoTe has constructed a human-robotic rescue team, which is capable to search and map buildings and areas in rescue situations. The change of information is based on similar understanding of the environment, which is modelled as a general map called "common presence". Common presence is continuously updated by both types of rescue entities – human and robotic. The updated presence is transferred back to the entities in the form each entity can best utilise.
Human mapping and exploring capabilities have been improved with innovative personal navigation system, which provides beacon free localization of a human in all conditions. Navigation system was further improved and completed to a simultaneous navigation and mapping system by adding a laser scanner on the human entity. The system has been integrated and tested with good results in the end of the year 2004.

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