RESCUER Technology for Incident Area Mapping

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Abstract. *This paper presents a technology for dangerous areas mapping based on a remote controlled mobile robot with stereo vision and sensors for different hazard sources detection. The main goal is to build a map of the incident area, which is conformable to the specific rescue specialists' requirements. The main steps of the developed technology include robot localization, analysis of data from SH and sensors/detectors for different objects identification, extracting depth information from SH about the identified objects and incident area map building. The procedure for mobile robot, hazard sources and survivors localization is based on information from a stereo head and 3D compass. Information from the stereo head, different sensors and specialized information systems is used for risk sources identification. Image processing techniques are used for incident area map building.*

1. Introduction

A robotic system RESCUER, which is designed to carry out different missions in incident areas, caused by terrorist acts, natural disasters and industrial incidents, is developed in the frame of the RESCUER project (IST-2003-511492, RESCUER). One of the RESCUER main functions is to investigate incident areas, to find different hazard sources, to assess their characteristics and to form a local map of this area. The incident area mapping is an essential part of RESCUER, as the map contains very important information for rescue teams. The map of the incident area has to meet to the specific rescue specialists' requirements, which are related to the following:

- the map has to be a simplified 2D map with 3D representation of some area objects, like hazard sources and survivors;
- different object zones of type obstacles (destructions, collapses, etc.) must be presented in different ways and their visible boundaries have to be marked;
- the position of hazard sources (dangerous gas sources, spills of dangerous liquids, dangerous substances, explosive materials, radiation sources, improvised explosive devices, unexploded ordnances, etc) must be presented using 3D coordinates and standard placards;
- the survivors location must be presented using 3D coordinates;
- the robot observation positions have to be presented on the map.

The mapping technology corresponds to different preconditions, which is related to the incident area characteristics and to the RESCUER system ability. These preconditions include the following:

- the incident area is usually unstructured;
- different hazard sources can be found in the area: destructions, collapses, CBRNE (chemical, biological, radioactive, nuclear and explosive dangerous agents), IED (improvised explosive devices), local fires, etc., as well as survivors;
- the mobile robot (MR) is remotely controlled by an operator located in a Mobile Control Centre (MCC);
- different specialized CBRNE sensors/detectors, like a detector for IED, radiation monitor, gas monitor, life detector, as well as a stereo vision system mounted on the robot are used to obtain information about the area;
- the duration of the search mission is extremely important for the SAR mission efficiency.

Robot mapping is a complex task that involves localization and exploration. Most of the work in the robotic map building is based on two technologies: occupancy/certainty grids, and feature-based methods.

Occupancy grid mapping, pioneered by Moravec and Elfes [1,2], is the most widely used technique. This technique gives very good results even with imprecise range sensors like sonar rangefinders [3,4,5,6], but it can be applied to any kind of sensor if a suitable sensor model is available [7,8,9].

In the occupancy grid method the environment is divided into a discrete grid. Each grid location is assigned a related to the probability that the location is occupied by an obstacle. Initially, all grid values are set to a 50% probability („unknown" case). Sensor readings supply uncertainty regions within which an obstacle is expected to be. The grid locations that fall within these regions of uncertainty have their values increase, while the grids in the sensing path between the robot and the obstacle have probabilities decreased.

Many SAR systems use this method as a fast and robust way to build a map [10,11]. The limitation of the classic method is that the map is 2D.

Feature-based methods [12,13] work by locating features in the environment, localizing them, and then using them as known landmarks by which to localize the robot as it searches for the next landmarks. This method is more favourable towards using stereo vision [14].

There are some combinations of the two methods [15] that use 2D occupancy map with sparse 3D landmarks for robot localization.

The goal of this paper is to present the RESCUER technology for incident area mapping, which is based on a remote controlled search and rescue robot (SAR) with a stereo head (SH) and specialized sensors for different hazard sources detection. The developed mapping technology uses some ideas of the approaches described above and new procedures, which give a possibility to build a map of the incident area in conformity with the specific rescue specialists' requirements.

2. Mapping Technology

The RESCUER technology for local map building includes the following main steps:

- robot localization;
- analysis of data from SH and sensors/detectors for different objects identification;
- extracting depth information from SH about the identified objects;
- incident area map building.

2.1. Robot Localization

Feature based procedures are used for MR localization. The robot localization is not autonomous. The following procedure is used for the mobile robot localization:

- The operator navigates remotely the MR and locates it in the first (initial) position P_1 (*figure 1*).
- The operator chooses the coordinate system, in which the map will be presented. The first MR position is accepted as a local map coordinate system origin. It is foreseen the local map to be presented in three different coordinate systems, which have one and the same origin and different orientations: initial coordinate system – its axes coincide with the robot local coordinate system in the first position P_1; base coordinate system – its X and Y axes are horizontal and the Y axes is orientated towards the movement direction; absolute coordinate system - its X and Y axes are horizontal and the Y axes is orientated to the north direction.
- The procedure for MR localization is based on the information obtained from SH and 3D compass only. Two landmarks (reference points) are used for MR localization. These are objects in the investigated area, which are visible from two neighbouring MR observation positions. The landmarks position is determined in the following manner. The operator orientates consecutively the SH towards the two chosen landmarks. He marks a small area in the landmark image. Depth information from the marked area is extracted and the coordinates of points from the latter are determined in the base coordinate system using two consecutive transformation: from the coordinate system of the stereo head (where they are initially extracted) to the robot coordinate system; and from the robot coordinate system to the base coordinate system. The centre of 3D point set is used as a reference point.

Only one reference point R12 is selected from the first observation position (*figure 1*) Two reference points Ri,1 and Ri,2, (where Ri,1= Ri-1,2) are selected from any one observation position.

- MR localization in any observation position (for example P_2) is done using the following steps. The coordinates of the first chosen reference points (R_{21}) are determined in the SH coordinate system. After that these coordinates are recalculated in the MR coordinate system. The coordinates of the same reference points (R_{12}) are already determined in the local map coordinate system during the previous observation (position P_1). The current MR observation position in the local map coordinate system can be calculated on the basis of this data.
- The operator moves the robot to a new observation position after the completion of the procedure described above.

2.2. Identifying the Objects in the Area

The needed information about the obstacles is obtained from the SH only. The choice of the objects, which have to be presented on the map, is done by the operator, located in the MCC.

The netted information about the risk sources is obtained from the SH and from the sensors/detectors mounted on the MR. An assessment of the degree of hazard, caused by the respective risk source under specific environment condition is automatically made on the base of the sensor data, as well as the date from the specialized information systems (CAMEO, ERGO, EOD IS-OP) built in the RESCUER system. If the degree of hazard exceeds a definite threshold value, then the risk source is represented on the map. If the information about some risk sources can not be obtained from the sensor/detector, then there is a possibility their characteristics to be evaluated using data from SH. On this stage of the work this valuation is made by the operator, but now the research team works on the problem concerning the automatic recognition of the placards, which is used for risk sources marking.

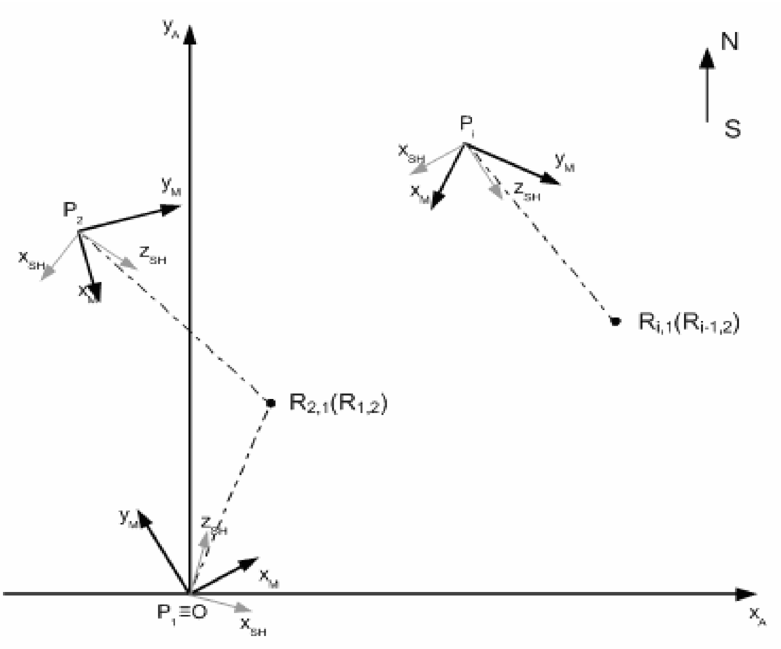

Figure 1. Determination of the robot observation position

The information about the survivors can be obtained both from the life detector mounted on the MR, and the investigated area image (SH).

2.3. Extracting Depth Information about the Identified Objects

The different object zones (obstacles, risk sources, survivors, etc.) are chosen by the operator using environment im-

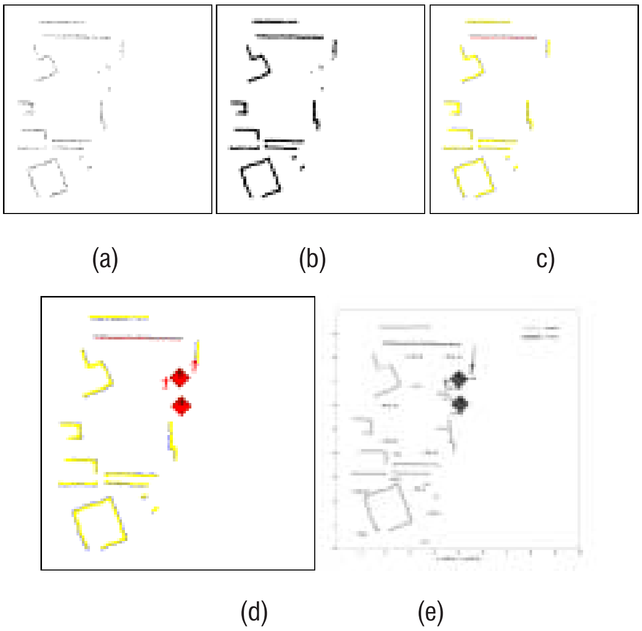

Figure 2. Local map building steps

ages. The coordinates of the observation position have already been determined. The operator orientates remotely the SH to the chosen object and marks a part of the object in the image. He sets manually the type of the object zones. A set of 3D points from the marked object area is extracted using stereo image analysis. These points are calculated in the SH coordinate system. After that these coordinates are consecutively recalculated in the MR coordinate system and the local map coordinate system. Different object zones can be marked from one observation position.

The data about the visible object zones contours, the object height or depth, as well as other object characteristics are obtained after the analysis of the data about the obstacles object zones.

2.4. Incident Area Map Building

As a result of the previous procedures we have 3D points extracted from the two images of the SH and transformed in the local map coordinate system. These points are divided in separate layers of data depending on the object type. The following procedure is developed for the local map building:

- each set of points about the corresponding object type is presented as a binary image (*figure 2a*). A raster with appropriate cell dimensions is used for that purpose. The raster cell size is conformable to the MR dimensions. The raster cell value is set to 1 if this cell contains object points or to 0 if it does not;
- to improve the quality of the binary images we use some image processing techniques. At first compact objects zones (*figure 2b*) are formed from the initial binary image (*figure 2a*) using the morphological transformations dilation and erosion. After that we use a filtration to eliminate separate isolated pixels and zones with small dimensions;
- the binary images of object zones like obstacles, collapses and spills of dangerous liquids are analyzed to determine visible contours of the objects and to mark these contours (*figure 2c*). The visible contours of different object types are represented on the map through different colours;
- the data about risk sources object zones is analyzed to determine the mass centre of the respective object. These objects are presented on the map using specialized placards, which are associated to the mass centres. The survivors object zones are shown in the same manner. The two types of objects are added to the map, which already contains the obstacle object zones (*figure 2d*);
- finally the MR observation positions Pi are added to the map. A coordinate frame is depicted on the map (*figure 2e*) too. The dimensions of the coordinate axes are automatically determined.

3. Mapping User Interface

The developed graphical user interface (GUI) for RESCUER local mapping is presented in *figure 3*. It consists of a set of panels:

- a panel with the environment image, formed by one of the stereo head's cameras;
- a panel with an image of the last marked reference area by the operator;
- a panel for visualization of the local map of the interested area;
- a panel with command buttons.

The developed RESCUER local mapping GUI allows the operator to participate in the mapping procedure by:

- setting new observation position, using „New Position" button;
- selecting consecutively the two reference areas („Select R1" and „Select R2");

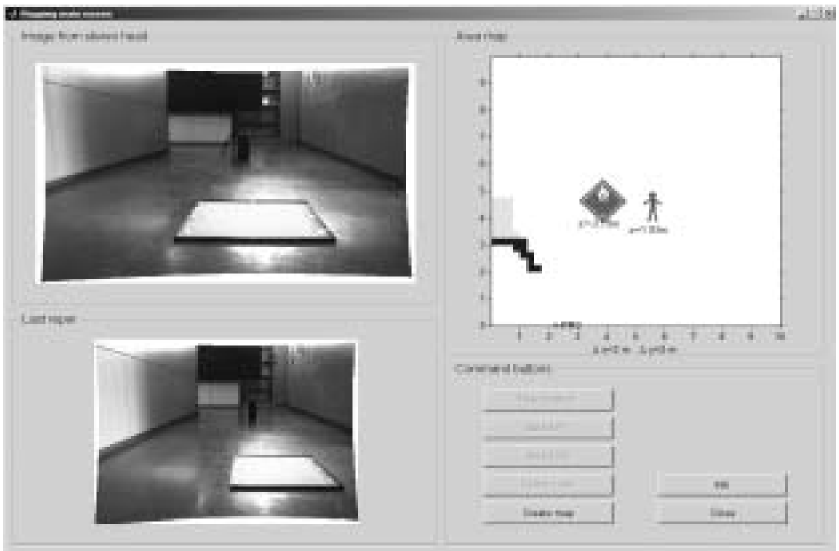

Figure 3. RESCUER mapping interface

• selecting new object to be presented on the map (button „Select zone");

• building and visualizing the map (button „Create map").

Besides, the interface presents video information from one of the SH cameras, the frame taken from the video data showing the last selected reference zone, as well as the incident area map. The map is refreshed after each observation position.

4. Conclusion

The developed RESCUER technology for incident area mapping uses information gathered by a remote controlled search and rescue robot with a stereo head and specialized sensors/ detectors. The local map of the investigated area is designed for the rescue specialists, who will work in the area after the robot mission completion. In comparison with the well known SAR robot mapping technologies the RESCUER technology has some new characteristics, like:

• the mapping is conformable to the RESCUER missions, as well as the specific rescue specialists' requirements;

• different object zones of type obstacles (destructions, collapses, etc.) are presented in different ways and their visible boundaries are marked;

• the map is a simplified 2D map with 3D representation of some area objects like hazard sources and survivors. These objects are presented on the map using specialized placards and symbols;

• image processing techniques are used for local map building.

The RESCUER research team is developing new procedures, which are meant to reduce the operator role in the mapping process, as: automatic association of the appropriate placards and symbols with the risk sources and survivors positions, automatic recognition of the risk sources on the bases of placards images, etc.

References

1. Elfes, A. Using Occupancy Grids for Mobile Robot Perception and Navigation. – *Computer*, 22 (6), June 1989, 46-57.

2. Moravec, H. and A. Elfes. High-resolution Maps from Wideangle Sonar. In Proc. IEEE Int'l Conf. on Robotics and Automation, St. Louis, Missouri, March 1985.

3. Huang, G. Q., A. B. Rad and Y. K. Wong. A New Solution to Map Dynamic Indoor Environments. – *In International Journal of Advanced Robotic Systems*, 3, 2006.

4. Wei, S., Y. Yagi, M. Yachda. Building Local Floor Map by Use of Ultrasonic and Omni-directional Vision Sensor. IEEE Int. Conf. On Robotics and Automation, 1998, 2548-2553.

5. Noykov, Sv., Ch. Roumenin. Occupancy Grids Building by Sonar and Mobile Robot. – *Robotics and Autonomous Systems*, 55, No. 2, 2007, 162-175.

6. Schiele, B., J. L. Crowley. A Comparison of Position Estimation Techniques Using Occupancy Grids. Proceedings 1994 IEEE International Conference on Robotics and Automation, 2, 1994, 1628-1634.

7. Matthies, L., P. Grandjean. Stochastic Performance Modeling and Evaluation of Obstacle Detectability with Imaging Range Sensors. – *RA*, 10 (6), 1987.

8. Murray, D., J. J. Little. Using Real-Time Stereo Vision for Mobile Robot Navigation. – *Autonomous Robots*, 8, April 2000, No. 2, 161-171.

9. Murray, D., C. Jennings. Stereo Vision Based Mapping and Navigation for Mobile Robots. Proceedings 1997 IEEE International Conference on Robotics and Automation, 2, 1997, 1694-1699.

10. Yanco, H. A., M. Baker, R. Casey, B. Keyes, P. Thoren, J. L. Drury, D. A. Few, C. Nielsen and D. J. Bruemmer. Analysis of Human-Robot Interaction for Urban Search and Rescue. In Proceedings of the IEEE International Workshop on Safety, Security, and Rescue Robotics, Gaithersburg, MD. 22-24, August 2006.

11. Baker, M., R. Casey, B. Keyes, H. A. Yanco. Improved Interfaces for Human-Robot Interaction in Urban Search and Rescue. Proceedings of the IEEE Conference on Systems, Man and Cybernetics, October 2004.

12. Fazli, S., L. Kleeman. Simultaneous Landmark Classification, Localization and Map Building for an Advanced Sonar Ring. – *Robotica*, 25, August 2006, No. 3, 283-296.

13. Rencken, W. Autonomous Sonar Navigation in Indoor, Unknown and Unstructured Environments. In Proc. IEEE Int'l Conf. on Intelligent Robots and Systems, Munich, Germany, September 1994, 431-438.

14. Se, St., D. Lowe, J. Little. Vision-based Mobile Robot Localization And Mapping Using Scale-Invariant Features. In Proceedings of the IEEE International Conference on Robotics and Automation, 2001, 2051-2058.

15. Little, J. J., J. Lu, D. R. Murray. Selecting Stable Image Features for Robot Localization Using Stereo. In Proceedings of IEEE/RSJ International Conference on Intelligent Robotic Systems (IROS'98), Victoria, B.C., Canada, October 1998.

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