ATRVJr – mobile robot for Fire Fighter Services

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Abstract

Following paper shows the result of the development mobile robot ATRVJr for Fire Fighter Services dedicated to the risky intervention tasks. The concept of the hybrid software architecture based on Player and CORBA is shown. The basic functionalities such as SLAM, autonomous navigation and 3D map building are described. The HMI equipped with 3D visualization module is demonstrated. The experiment of ATRVJr assistance during Fire Fighters demo action is described.

Introduction

The software architecture is improved for ViewFinder Application[1][2]. The improvement is based on the investigation of the State of the Art hardware drivers for ATRV Jr functionality and its implementation. The need of research is motivated by the incompatibility between ATRV Jr Mobility software and ViewFinder System components.

The main goal of increased performance is achieved by combining State of the Art Player/Stage driver for the RFLEX–ATRV Jr on-board real time controller with ViewFinder system based on CORBA/CoRoBa/Mailman[3][4] communication technologies. The usage of player's driver determines independence of the ViewFinder System from indoor autonomous mobile platform. It means the robot is seen by the ViewFinder System as a set of functionalities, therefore another robot with similar functionalities can be used.

1 Developed ATRVJr

For purposes of the ViewFinder project ATRV–Jr (fig. 1) has been adapted to host several devices from the partners. The modifications of the construction were needed, because on the top of the robot there was no space for additional equipment.

Figure 1: ATRV–Jr robot.

The special chassis was designed and built to create desired space. It consists of several aluminum profiles, connected with T screw joints. Due to the flexibility of chassis components it is possible to configure several equipment configurations.

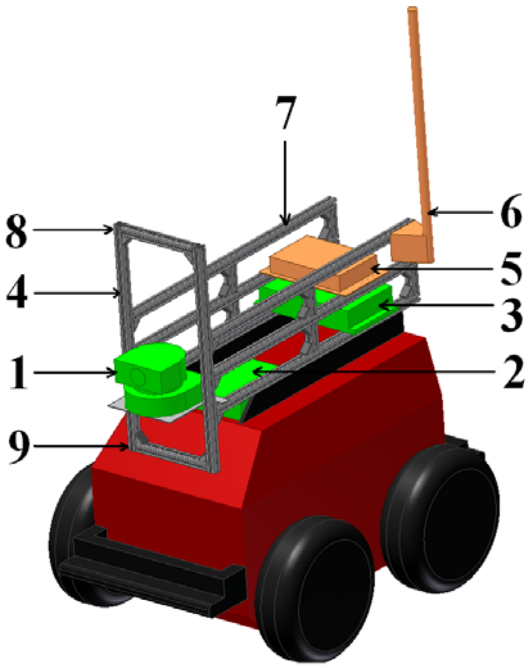

Figure 2: Design of the new ATRVJr chassis with additional devices.

In green there are marked basic devices which have been added for the improvement robot functionality. These devices are: Sony pan/tilt camera(1), Wi-Fi router(2), Digital Video System(3), aluminum chassis(4), wireless communication device(5) with antenna(6), PCU (7), chemical sensor(8), 3D laser range finder. The construction of the chassis is very flexible and it can be modified in order to provide desired space for other devices or relocate existing equipment.

Figure 3: ATRVJr equipped with 3D sensors.

2 Software architecture

The main advantage is the compatibility between several communication techniques such as Corba/CoRoBa, Player/Stage, Mailman. It was done by usage of CORBA middleware as the core of the architecture. The main advantage of proposed approach is that the architecture provide several communication models such as client – server (peer to peer), producer – consumer, mixed: client/server – server/client. For this reason it is possible to implement complex control software with flexible communication scheme.

The comparison between Player, Corba and Mailman was performed during several robot trials with different software configurations. It is important to emphasize, that the architecture of the system allows to define different configurations, that can be switched on the fly.

2.1 Player characteristic:

The Player provides almost full set of needed hardware drivers, therefore it is very useful software that supports mobile robot development. The limitation is determined by client-server communication between components. For this reason we are forced to request the server each time we would like to have a new information. Therefore, the local LAN of mobile robot can be potentially overload by the amount of data exchange between components. Another disadvantage is related to the video acquisition, compression and sending via wireless network. We observed that Player was not robust enough to send video in satisfied time (10 fps), even sometimes the communication was lost with no clear reason.

2.2 CORBA characteristic:

The CORBA provides several communication models (client – server, producer – consumer, mixed: client/server – server/client) that can be useful in development the flexible software architecture of the mobile robot. The main difference between client - server and producer - consumer is related to the separation between consumer and producer done by event channel. This solves the problem with handling the exceptions during data exchange. It is important to realize that event (producer - consumer) is more robust than request (client - server) in real – time applications, essentially because of the prioritization.

2.3 Mailman characteristic:

Mailman was designed for data exchange between 2 subnets via wireless communication with low bandwidth. The prioritization mechanism allows to design real time application. The concept is based on the usage of UDP protocol. Additional software mechanisms solve the problem of acknowledgement of the requests. Because Mailman is only communication channel it is needed to develop the hardware drivers using another communication techniques.

Several experiments where performed for Player/CORBA/Mailman comparison. The important observation is that Player provides robust hardware drivers of on the shelf ATRVJr mobile robot. Unfortunately the system based only on Player can not fulfill V-F requirements. The video from existing hardware can not be send in real time. The additional components based on CORBA such as VideoCorbaServer and HighLevelController improved the software architecture, therefore it satisfies the V-F requirements. The VideoCorbaServer with built in compression method provides video stream, that can be visualized (real time) in CorbaClient installed on the another PC located in Base Station. The HighLevelController receives the control data from BaseStation and executes it via Player components. The architecture based on the Player/CORBA components fully satisfy the V-F requirement, where additional CORBA components solve the problems related to the well known Player disadvantages. The improvement based on the replacement CORBA wireless communication by Mailman communication should boost the performance of data exchange, because of the two reasons: usage of UDP protocol and prioritization. The main advantage of the usage of the Mailman is the possibility of the fast robotic system reboot (the service discovery method in Mailman is faster in the comparison to service discovery method in CORBA). The main achievement is the knowledge how to combine the existing techniques to improve the robotic system with the reduction of the effort needed to reinvent existing solutions.

3 Robot functionalities

3.1 Robot navigation

Robot navigation means its ability to determine its own position in its frame of reference and then to plan a path towards some goal location. In order to navigate, the mobile robot requires representation of its environment i.e. a map of the environment and the ability to interpret that representation. The art of navigation consists of smaller robot competences like:

1. Ability to self-localizing in the environment, which requires
2. Map-Building and Map-Interpretation
3. Ability to path plan
4. And local obstacle avoidance

Localization denotes the robot's ability to establish its own position and orientation within the frame of reference. Path planning is effectively an extension of localization, in that it requires the determination of the robot's current position and a position of a goal location, both within the same frame of reference or coordinates. Map building can be in the shape of a metric map or any notation describing locations in the robot frame of reference. In this study we will present the most popular approaches to global path planning using A* and Dijkstra’s algorithms and two approaches to local obstacle avoidance using VFH (Vector Field Histogram) and Fuzzy ARTMAP.

It is worth to mention main advantages of two algorithms to global path planning. A* algorithm is preferred when searching the shortest path from the position point of the robot to the target point. It is experimentally proved to get the shortest path in reasonably short time using this algorithm. On the other hand Dijkstra's algorithm is preferred when the robot needs to search shortest paths to many targets and choose one on this basis.

3.2 SLAM

The experiment was performed using adapted and integrated SoA SLAM[5] algorithm in the building of „MECA" Royal Military Academy, Brussels, Belgium. The new system was configured to use several devices such as motor drives of ATRV Jr, laser measurement system SICK LMS 200, ring of front sonars and video camera. To this experiment SLAM based on the particle filter was used. Because of the bounded memory of the robot on-board computer the maximum number of particles was set to 250. The generated map was of the size 50 [m] x 50 [m] with resolution of 10 [cm]. The SLAM algorithm performs online and its results are presented on the following figures.

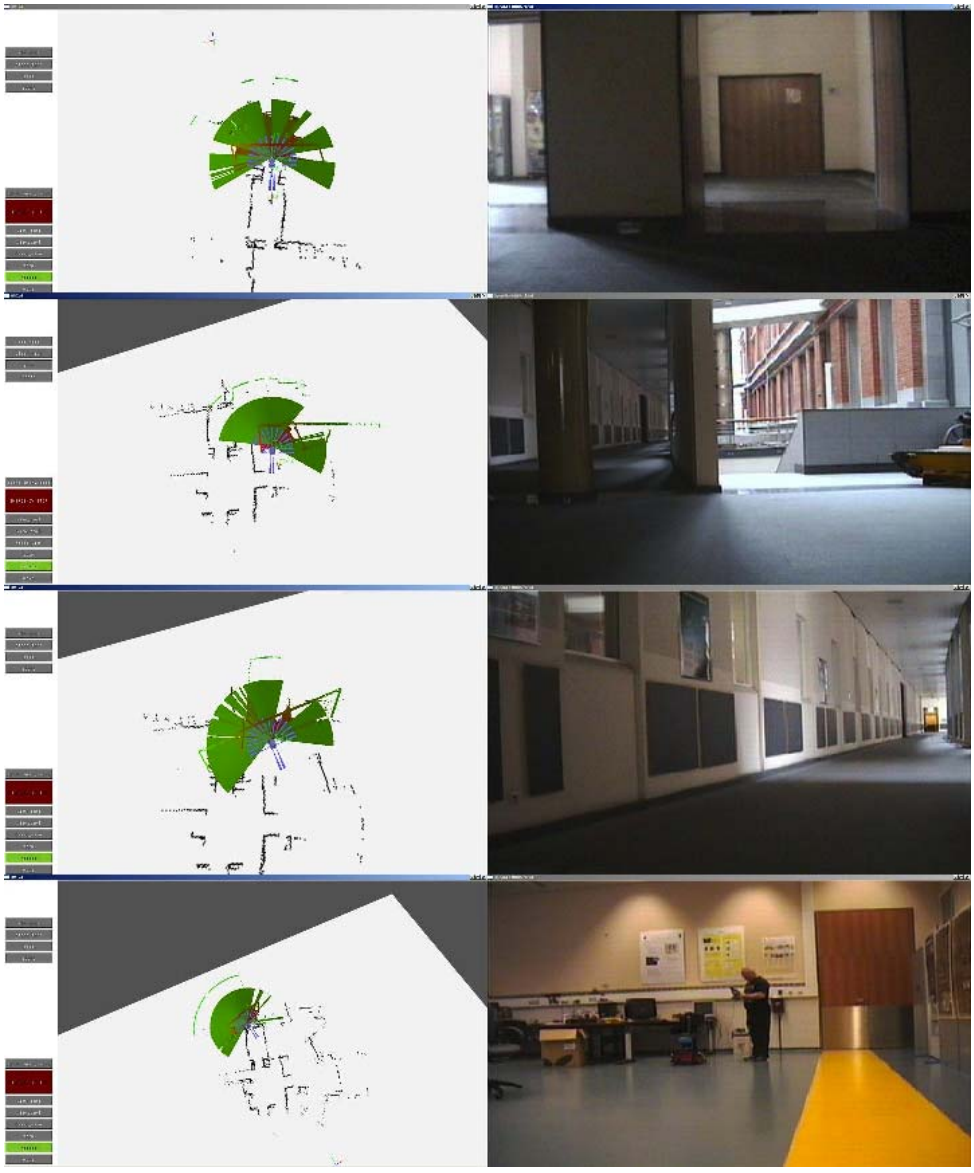

Figure 4: Left - 2D map view and sensors visualization of the robot. Right – camera view.

Chosen SLAM algorithm working online satisfies the needs for localization of the robot and 2D map building.

3.3 3D Map Building

The ATRVJr is equipped with sensors for building 2D and 3D maps. The 2D map is delivered to the HigLevelController as occupancy grid map where obstacles are denoted as +1, free space 0, unknown -1. The idea of summarizing the maps (laser/obstacle, temperature, chemical concentration) was introduced. The new concept is related to adding the projection of the 3D map onto 2D sum of maps. Therefore additional information concerning 3D obstacle can be used for navigation purpose.

The main achievement is the method of high accurate 3D model acquisition and reconstruction that can help Fire Fighter services during risky intervention. Following figures shows the results of performed experiments:

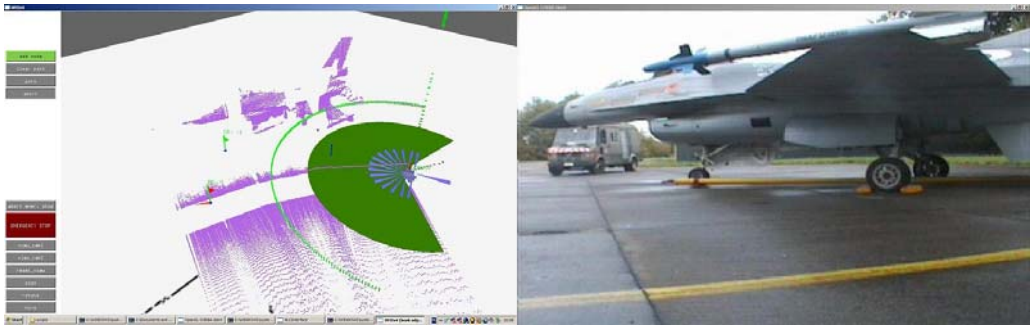

Figure 5: Visualization of the 3D reconstruction of aircraft.

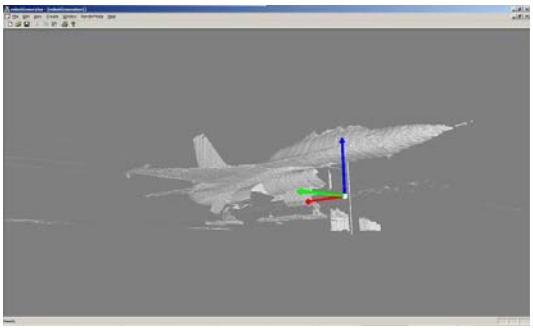

Figure 6: Model 3D – reconstructed aircraft.

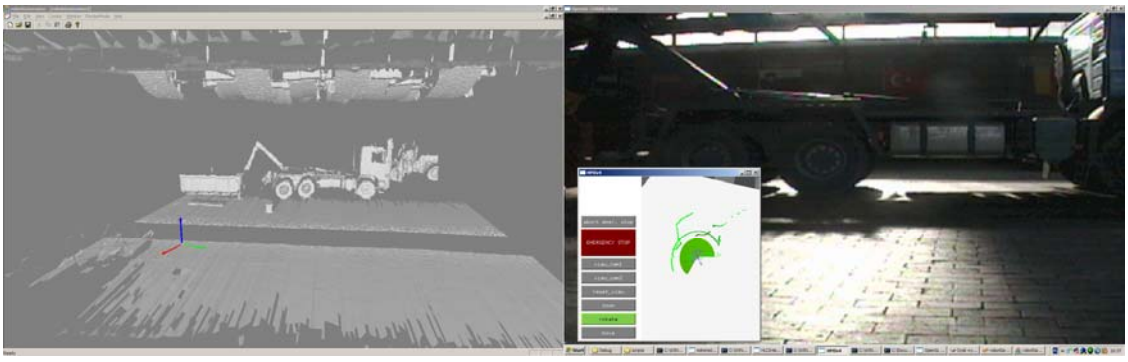

Figure 7: Model 3D – reconstructed vehicle.

3.4 HMI

a) Autonomous robot action

Robot ATRV Jr has been taken near the AIR-SHED SHxx (around 250 m from the location of the base station).

Figure 8: Robot ATRVJr near the AIR-SHED SHxx.

Subsequently ATRV Jr. performed autonomous action of gathering measurements inside the AIR-SHED on the distance of 20 meters.

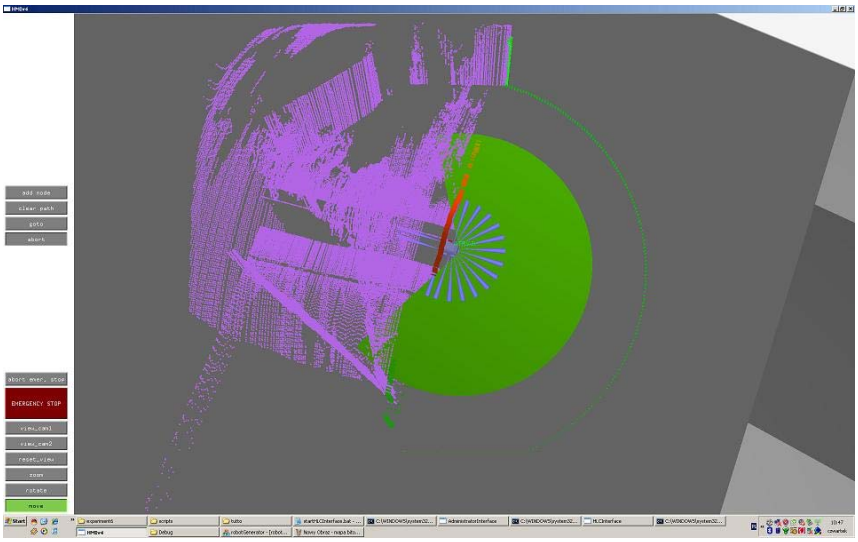

Figure 9: Sample 3D measurement of the robot ATRVJr taken remotely from the distance of 20 meters in the base station. The measurement was performed inside the AIR-SHED SHxx.

On the basis of collected data base station rendered the 3D model of the AIR-SHED which was visible to the head of the fire fighters team and is presented on the fig. 10.

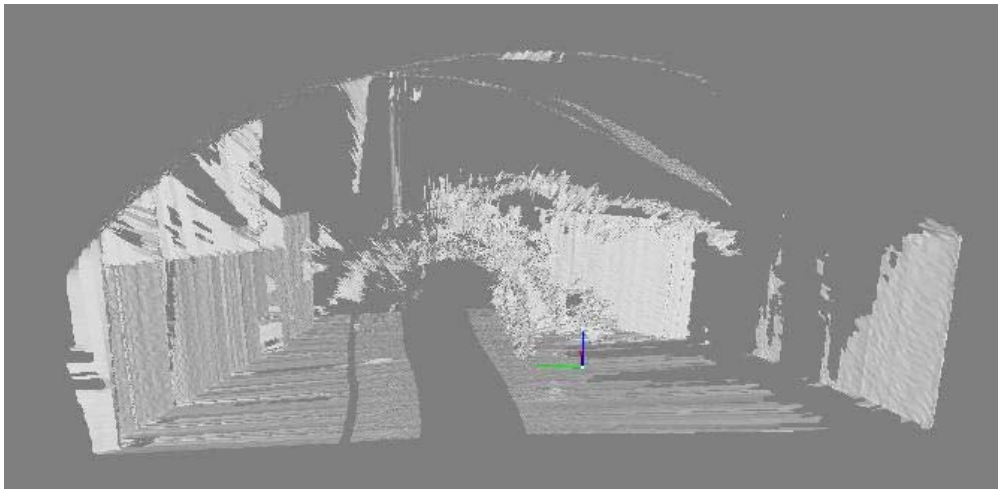

Figure 10: 3D Model of the environment inside the AIR-SHED SHxx rendered on the base station display.

4 Conclusion

The development of the autonomous mobile robot ATRVJr has been shown in the paper. The robot is equipped with sensor dedicated to support Fire Fighter Services during hazardous tasks such as inspection of crisis area. The concept of the hybrid software architecture based on Player and CORBA is shown. The new architecture allows to combine several devices from different vendors without high effort of integration. The basic functionalities of the system such as SLAM, autonomous navigation, 3D map building and visualization in the HMI has been demonstrated. It is important to emphasize that the software is scalable, so it is possible to build multi robotic system based on the ATRVJr – nodes that communicate each other to acquire more information from the environment.

5 References

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