

ARCHITECTURE OF MOBILE ROBOTICS PLATFORM PLANNED FOR INTELLIGENT ROBOTIC PORTER SYSTEM - IRPS PROJECT

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Abstract:

The aim of this paper is to present the Intelligent Robotic Porter System with respect to architecture of Mobile Robotic Platform. The set of requirements for Mobile Robotic Platform was defined and analysed. Main engineering problems that occurred during the development of Mobile Robotic Platform's architecture were specified and described. Problems were confronted with PIAP's proposed solutions for technical issues at this stage of the project.

Keywords: mobile robots, autonomous navigation, mobile platform, teleoperation

1. Project overview

The Intelligent Robotic Porter System (IRPS) is an international project within the 6th Framework Programme, 6th Call IST (Information Society Technologies). Project is scheduled for 01.01.2007 to 31.12.2009.

The purpose of the project is to provide mobile robotics platforms with advanced mapping and navigation systems based on a very accurate 3D-measurement technology. The purpose of the mobile platform will be to transport disabled persons within the area of public airport, which is structured, however variable environment. Implementation of navigation system, working in real time, able to define objects in the robot's workspace is essential to the project.

The 3D measurement technology, named LIMS (LIDAR Imaging and Measurement System, LIDAR - Light Detection and Ranging) based on three eye-safe laser systems originated in Israeli Aerospace Industries - Lahav Division meets application requirements. It was shown, in feasibility study, that highly accurate measurements could be achieved in real time, on the move and in presence of sparse objects and vibrations. LIMS will be used to recover the position of the robot related to the environment by using natural landmarks, through the comparison of the actual 3D map with previous 3D maps already stored in system memory. This operation will be complemented with reflectance and video data to increase information and robustness. Since the positioning and mapping will not rely on absolute positioning systems, the application can be used indoors as well as outdoors environments.

The main objective of the project is to develop and integrate an accurate 3D sensing system as a modular component for robotic platforms, enabling fast dense mapping of large areas, populated with sparse objects.

The IRPS project will demonstrate capabilities of the LIMS module integrated with the mobile platform on the move with nominal speed of 5 m/s.

This concept will be developed and implemented as a key component for robotic applications for quality and dimensional control, ambience monitoring inspection and advanced navigation. Applications will be deployed for operation in large areas and within congested human environments. Operation within a network of co-operative robots will be considered.

2. IRPS structure and modules

The IRPS will consist of three main modules (sub-systems). The LIMS will be hosted on the mobile platform. Both LIMS and MRP communicate with MCC, which receives data from LIMS and generates high-level commands for MRP. The high level commands received by MRP on-board PC are converted to low level commands (desired speed, desired wheel turning angle) for the low level controller and then executed. LIMS scans and maps the area of operation. Currently acquired maps are compared to 3D maps stored in system memory. The position of robot is calculated and appropriate commands are sent to MRP on-board PC.

LIMS operates in one of two modes: Data Acquisition Mode and Navigation Mode. In Data Acquisition Mode operator controls robot. LIMS maps the area and stores the 3D maps in system memory. These maps will be the reference used when operating in Navigation Mode. When in Navigation Mode, robot executes commands generated by MCC and compares current local 3D maps with those acquired in Data Acquisition Mode to determine its position.

MRP internal communication will be provided by CAN-bus. Communication with MCC will be *via* Radio-Ethernet or IP at the early stages of the project, and ultimately *via* Wi-Fi or Wi-max. The IRPS sub-systems are described below.

The Mobile Robotic Platform (MRP)

At the early stage of the project (prototype V1), a relatively small sized robot will host the LIMS and on-board hardware. The main objective of MRP V1 will be operation in laboratory conditions as the test platform for LIMS and other essential components. Ultimate prototype (V3) will be fully customized for the needs of disabled passengers and will be adapted to operate within the crowded area of public airport. The MRP mechanics will be based on electric cab.

The Mission Control Centre (MCC)

The MCC is in charge of collecting commands from handling agents or the user. The MCC operator uses the various applications available in the MCC to task the robot and plan the route based on the complexity of the environment. In general, the MCC oversees the operation of MRP and LIMS. At the early stages, the MCC will consist of an external PC wired with the MRP *via* IP. Also, the use of Radio-Ethernet is considered. Along with the project development, the MCC will be constantly improved, until it evolves into fully operational control station.

The LIDAR Imaging and Measuring System (LIMS)

LIMS is the 3D eye-safe laser scanner dedicated to the observation and detection of known structured environment changes, based on the accurate measurement of the platform position on the move. Systems relies on the previously acquired 3D maps stored in memory which are being dynamically compared to currently acquired maps, so that the robot position can be determined.

Fig.1 represents IRPS system structure, with three main sub-systems specified. Note communication between sub-systems *via* Radio-Ethernet or IP, because this is the diagram for the first IRPS prototype. Later prototypes will communicate with MCC via Wi-Fi or Wi-Max as stated in end-user requirements.

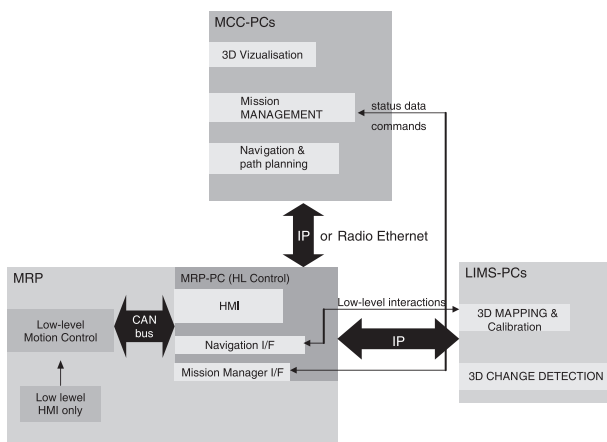


Fig. 1. IRPS structure [1].

3. Requirements for MRP

General requirements for IRPS have been stated basing on the analysis of environmental conditions, passenger needs and safety issues. The set of requirements was obtained during interaction with consortium partners and survey of end - user community. These requirements apply to the final demonstration prototype, adapted to operate within the crowded area of public airport. The preliminary requirements gathered during the first phase of system specification are listed in Table 1. Further, requirements that are more detailed are about to be developed during the project.

Table 1. General requirements for Mobile Robotic Platform.

Type of requirement	Description
number of seats	1 (2 in a row)
mass	max. 500kg per m
speed	less than 17km/h
range	not less than 30 km (2h of continuous drive)
turning radius	max. 2m
additional cargo space	only for hand luggage only and batteries
maximum dimensions: constraints: - dimension of the lift - metal detector gate dimensions:	the narrowest dim. 1m 71 cm
communication	wireless, allowed on the airport
warning system: horn, lights	horn, lights
additional requirements	no reconfiguration on board, only software update by control room operator

The IRPS will be safe for the passenger and environment thanks to the LIMS Change Detection function as well as a set of ultrasonic sensors operating as the redundancy for the LIMS. Passenger will be able to communicate with the system through user-friendly HMI. HMI will be also equipped with safety features such as joystick for emergency-manual steering, emergency stop button and passenger detection.

4. MRP technical problems

4.1 Communication:

Internal

The communication inside the MRP should be divided into two layers - communication between low level control system and actuators and communication between high level control system and low level control system. The communication protocol between high and low level control should be optimised for sending steering information.

External

The communication between MCC and MRP should be broadband because of the huge amount of data send between them. It should be wireless and use the band that is allowed on the airport. The protocol used should be universal as different applications will use it for sending data - information from sensors, steering commands, information dedicated to localization and map building as well as navigation and path planning.

4.2 Power supply

Demand of LIMS

It has not yet been stated if LIMS is equipped with its own power supply. Assuming that LIMS does not have it, the additional on-board set of batteries is required. The additional power supply has to be capable of supplying LIMS with up to 1 kW of peak power.

Other payload

Apart from LIMS and executive mechanisms, MRP host other modules that need to be supplied with power. On-board PC and ultrasonic sensors need to be provided with power.

Executive mechanism

Executive mechanism will consist of steering servo

and braking actuators that should be supplied with enough power to operate along the full range of MRP.

User requirements for range

Overall, power supply for MRP should meet user requirements concerning range. All the on-board modules should be constantly supplied with power during two hours of continuous drive.

4.3 Executive mechanics

Directional control

MRP motion system should be optimised for manoeuvrability, speed and quick reaction so that it would meet requirements of safe operation within the area of public airport.

Speed control

Main problem concerning speed control is the reduction of cab's velocity. The braking should be smooth enough not to disturb the passenger and fast enough to stop the cab before hitting the potential obstacle.

4.4 Physical requirements

Dimensions

As stated in point 3, requirements concerning physical properties of MRP strictly affect the selection of electric cab used as MRP. Due to the environmental conditions of public airport, the dimensional constraints for MRP may prove to be hard to meet.

Weight

Electric cab together with LIMS, on-board hardware, power supply, passenger and his hand baggage should not exceed the weight permissible for the airport structure and lifts. Additional power supply for on-board modules is the main factor increasing MRP overall weight.

Payload

MRP should withstand applied load. Again, the main problem is the additional power supply for the on-board modules that will significantly increase the load of the MRP. Also, the overall mass of LIMS has not yet been determined. Payload cannot exceed electric cab's structural strength.

Passenger seat and cargo space

Sufficient space for passenger and space for his hand baggage should be provided on the MRP. Passenger should feel comfortable while travelling on MRP and his hand baggage should be safely transported. The problem is to optimise MRP size so it would meet physical requirements (the more compact, the better) as well as it would satisfy the passenger.

5. Proposed solutions

5.1 Communication

The communication issues apply to MRP-MCC communication as well as internal MRP communication. After the analysis of available communication types was stated that IRPS would use Wi-Fi standard for remote communication with MCC. The use of Wi-max standard is taken into consideration. Both of the communication standards are allowed to use on the airport and the existing WiFi infrastructure can be applied for the system [2]. As all the applications responsible for path planning and naviga-

tion will have two instances - one in MCC and one on MRP, the communication between them will be done with the use of IP. This protocol will be used for communication between MCC and MRP.

The internal MRP communication between external and on-board instances of high-level control will be executed through Ethernet bus with IP. The communication between high-level and low-level controllers will be implemented by CAN-bus and CAN-open protocol. The CAN standard is widely used in automotive and mobile robots industry and is easy to implement.

5.2 Power supply

Electric cab's motor will use its own batteries provided by manufacturer. Depending on MRP modules power consumption, the power for on-board hardware will be supplied by electric cab's batteries or additional batteries. If the on-board modules are to be supplied from cab's batteries, PIAP team will provide power outputs (for example 24V) from cab's batteries to supply them. In case of installing additional power supply on MRP, its weight and dimensions are essential to platform mechanics. Therefore, the use of lithium polymer batteries is considered. Their price is high, comparing to gel batteries, however their small dimensions and light weight together with relatively large capacity makes them considerably the best choice for supplying MRP modules with power [3]. The lithium polymer batteries are compact, so that they can be grouped into sets dedicated to supply specified modules. The use of lithium polymer batteries would save space and mass of the MRP. Currently, all consortium partners are working on estimating the power consumption of their modules, so that the question of additional batteries could be resolved.

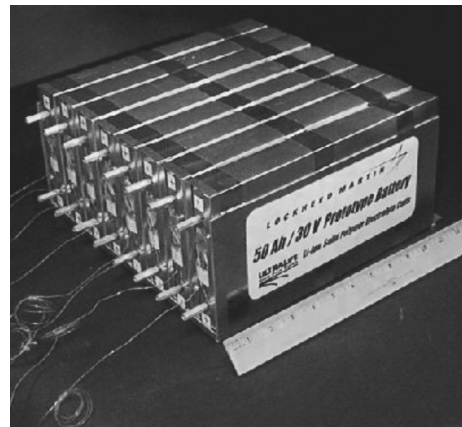


Fig. 2. Example of lithium polymer 50Ah/30V batteries [6].

5.3 Executive mechanism

Executive mechanism will consist of system responsible for turning the wheels of the cab to desired angle (directional control) and speed control system responsible for moving the cab with desired speed. Executive mechanics will be operated by low-level controller, which receives commands (desired wheel turning angle, desired speed) generated by high-level controller.

Servomotor will be implemented as wheel turning system. Current angular position of wheels from servo encoder will be dynamically compared to desired angular

position of wheels. Servomotor's shaft will be coaxial with steering column and geared with it. Steering wheel will be removed to provide the comfort of passenger.

Use of actuator-based braking system operating in speed-feedback loop is taken into consideration. The braking actuator either push the brake pedal or be built into cab's brake system, therefore it would directly operates jaw brake shoes.

5.4 Physical requirements

The structural strength of airport facilities is large enough to withstand the load of 500 kg per square meter. Anticipated overall weight of MRP with passenger and his hand luggage will not exceed 400 kg, so there is no risk to affect the airport facility structure. Additionally, if LiPo batteries will be used, the overall weight of MRP, as well as its payload, will be significantly reduced.

The narrowest dimension, resulting from detector gate width is the problematic issue affecting the selection of electric cab. Initially, before end-user requirements were formed, the use of Melex electric car was considered (see Fig. 3). Melex is the leading manufacturer of electric cabs in Poland. Melex cabs are suitable to operate within the public transport areas, however their dimensions are relatively large. Unfortunately, none of the Melex models will be able to pass through the detection gate with dimensions specified by end-user. After specifying the requirements, the selection of cab was verified and the Klingler electric cab model "bed pusher" was taken into consideration (see Fig. 4).



Fig. 3. Melex cab - first selection for MRP [7].



Fig. 4. Klingler "bed pusher" - alternative to Melex [8].

This model is more compact and more manoeuvrable compared to Melex; furthermore it maintains reasonable payload capacity. The on-board modules can be installed in front of the cab, and the cargo space will be on the rear side of the cab. After purchasing selected model compliant with IRPS requirements, PIAP will adapt the electric cab's construction with respect to passenger needs and physical properties of the modules provided by consortium partners. The cab's construction mechanical adaptation will consist of installing additional mountings for on-board modules, handles for passenger and baggage basket or box.

6. Proposed MRP architecture

After the analysis of main technical problems and confronting them with proposed solutions [4,5], the hardware structure block diagram was elaborated (Fig.5 see next page). The diagram represents main functional blocks of IRPS (hardware aspect). The area of diagram marked with EXECUTION annotation consists of main responsibilities of PIAP in the course of elaborating mobile robotic platform for IRPS.

7. Summary

In this article, the IRPS project and its main technical challenges were described. The survey made for end-users helped in definition of their requirements and translation it into the technical constraints that were shown within. The technical problems that were defined by the project team were listed and shortly described. The proposed solutions for the problems that had been developed were formulated and shown accordingly. Finally, the MRP architecture that fulfils the preliminary user requirements was proposed.

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References

- [1] IRPS community internal materials.
- [2] Telecommunications Act of 1996, Pub. LA. No. 104-104, 110 Stat. 56 (1996).
- [3] Oman H., "New battery types for space vehicles", *Aerospace and Electronic Systems Magazine*, IEEE, vol. 17, issue 4, April 2002, pages 34-40.
- [4] Bräunl T., *Embedded Robotics: Mobile Robot Design and Applications with Embedded Systems*, Springer 2006.
- [5] Nehmzow U., *Mobile Robotics: A Practical Introduction*, Springer 2006.
- [6] www.grc.nasa.gov
- [7] www.melex.com.pl
- [8] www.klingler-ag.ch

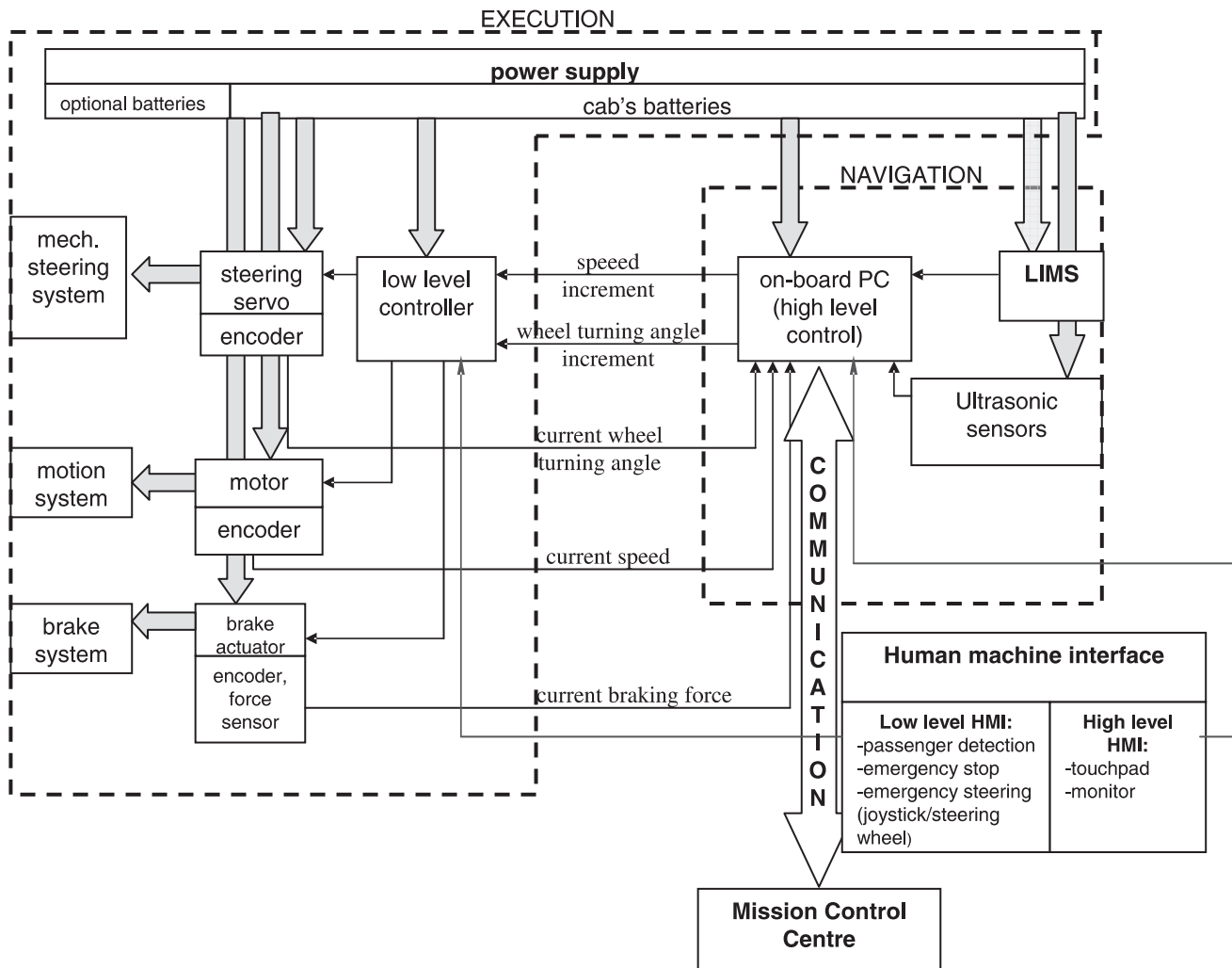


Fig. 5. IRPS hardware block diagram [1].