ROBCO 11 - Intelligent Modular Service Mobile Robot for Elderly Care

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Abstract:
The article focuses on the development, research and prototyping of the "Intelligent Modular Service Mobile Robot which will work in Elderly home for providing Elderly Care". Prognoses of the European Commission show that the tendency in Europe and especially in Bulgaria is of a continuously growing ageing of the population. Most of the elderly people want to live in their own houses for as long as possible and the proposed Intelligent Modular Service Mobile Robot can help them with the tasks such as "stand up" or "seat down", preparing or warming food, serve and clear the table, bringing water, books, medicines etc., it can fetch and carry difficult and heavy objects, video and audio programs selection contact with physician or with family members, day and night monitoring and fall preventing.

Keywords: *Service Robots, Mobile Robots, Modular Robots, Intelligent Robots*

1. Introduction

The key concept of the proposed Intelligent Modular Service Mobile Robot (Fig.1) is its easy adaptability in order to achieve services for a wide range of Elderly needs by performing different tasks for supporting Elderly care.

Fig.1 ROBCO 11 - Intelligent Modular Service Mobile Robot for Elderly Care

The Intelligent Modular Service Mobile Robot for Elderly Care consists of the following components:

- Intelligent onboard multilevel control system and ROS based software for the control of the different modules of the Intelligent Modular Service Mobile Robot;
- Modular remote control User Interfaces Teleoperation UI – Joystick based; Tactile UI – Touch screen based; Voice UI – Speech recognition based; Gesture UI – Gesture recognizing device; Brain control UI - Brain control devices;
- Electro-actuating systems, batteries and automatic recharging systems (docking stations) allowing 24 hours Service;
- Mobile Robot Platform - 4 wheels/2 powered wheels Intelligent fully autonomously vehicle with all its systems built on a modular principle able to carry peripheral systems or tools;
- Manipulating Articulated Robot Arm System including a proper gripper, which will allow different tasks to be performed like fetch an carry, bringing and manipulating difficult objects etc.;
- Sensor Systems – including Tactile sensors, Infrared sensors, Ultrasound Sensors, Artificial vision system and Voice generation and recognition systems, which help performing all functions related to environment and user interactions – monitoring of spatial location and orientation of the robot, maintaining proper course, obstacles detection, safety of the people and robot itself, object visualization and recognition, robot control and communication between a family member or physician and the Elderly for supporting the Robo-Care.

Movement of the robot in the range of service is one of the basic functions which determine the operational characteristics and abilities. Parameters as carrying capacity, positioning accuracy, speed, range of operation depends on area of applications of the robotic system.
A typical mobile platform consists of mechanic base, motors, gear, wheels, motor controller and power stage.
The control subsystem is very important for the operation and integration in the robot. The presented concept of mobile base control introduces an IP based approach, which allows easy integration in many environments including ROS (Robot Operating System).
The control board is based on modern 32-bit MCU equipped with many ready to use features in hardware and allows high level programming in C or C++.

2. Components

2.1. Drive systems

There are many construction designs for wheel based drive. Every of them has own positives and drawbacks so the choice should be based on application area of the system.
Here is presented a brief look of some of the used drive systems in robotics:

Differential (tank) drive – fig.2

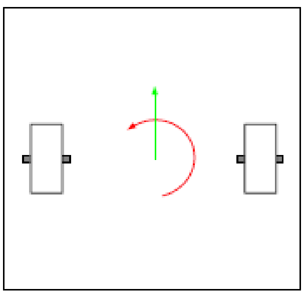

Fig. 2

Omnidirectional drive -fig.3

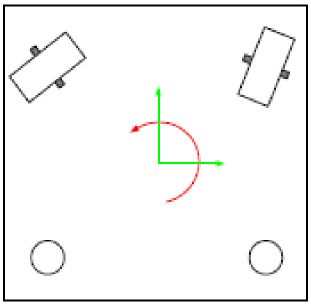

Fig.3

Mecanum Drive (Sweddish wheel) – fig.4

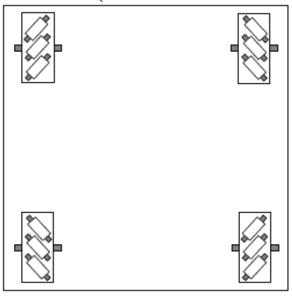

Fig.4

The presented control concept can be used in all types of the drive systems but for experimental purposes we have chosen a differential drive mobile base.

2.2. Motors

The choice of the driving motors depends on the construction and power requirements of the mobile platform.

The most commonly used are:

- Brushed DC motors
- Brushless motors
- AC induction motors
- Steeping motors
- Direct drive motors.

In our construction we use a brushed DC motors, which have good power characteristics and linear correlation between the applied current and motor torque, which makes the control more straight-forward and deterministic.

2.3. The control board

The control system – Pixeye NetIO (fig.5) is based on the modern 32 bit MCU.

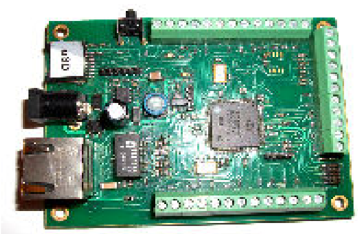

Fig.5: The Net IO control board

The board features 6 PWM Outputs 10 Digital I/O and 4 ADC, 2 quadrature encoder inputs and a 100Mbps Ethernet interface.
The internal block diagram of the TI Stellaris LM3S6965 is presented on fig.6.

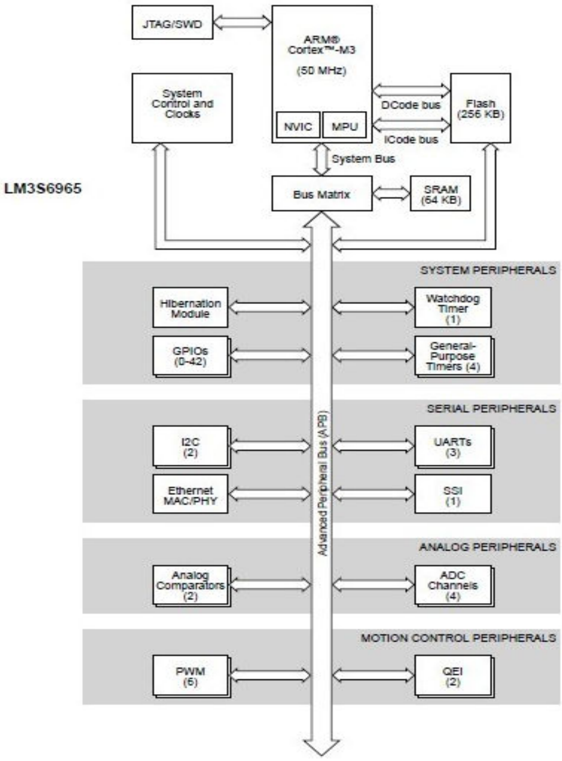

Fig.6: Internal structure of LM3S6965

For the current mobile platform drive two of the available PWM outputs are used and two of digital outputs as a motor direction switching.
All of the inputs and outputs of the board is accessible via the Ethernet interface from any IP based network.
The protocol is HTTP based on the API of the board, provided by the manufacturer.
The typical PWM output of the board is presented on fig.7**.**

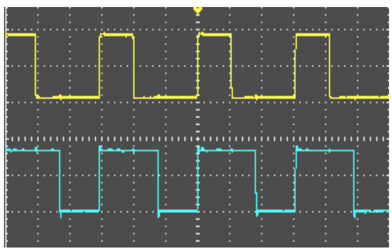

Fig.7 Typical PWM output

The power stage and the control of the DC motors is discussed in details in the next chapter.
Two types of feedback are implemented using integrated features of the board:

- Motor current, which gives direct information of the torque sampled via the ADC of the board. The current is measured by current sensors integrated on the H-bridge boards.
- Motor coupled encoders, sampled by the quadrature inputs provided by the board. Readout of the encoders gives full details for the velocity and position.

The leftover I/O pins and ADC inputs can be used for various sensors.

2.3. The power stage

A very common circuit in robotics for driving DC motors is used between the control board and the motors. It's called H-bridge because looks like the capital letter 'H' when viewed on a discrete schematic. The H-Bridge is the link between digital circuitry and mechanical action.
The great ability of an H-bridge circuit is that the motor can be driven forward or backward at any speed, optionally using a completely independent power source.
On figures 8, 9 and 10 respectively are presented the current flows in a typical H-bridge when the motor is driven in forward and reverse direction.

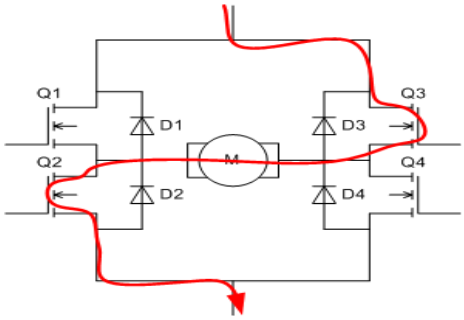

Fig.8: Current flow in forward direction

The switches are turned on in pairs, either high left and lower right, or lower left and high right, but never both switches on the same "side" of the bridge.
The speed control is done via changing of the duty cycle of the PWM from the control board.

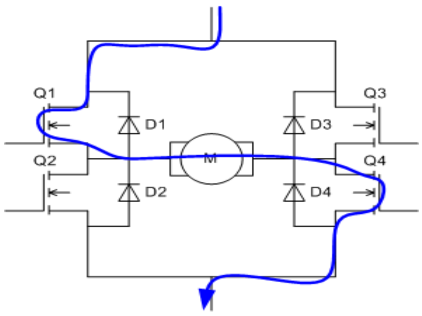

Fig. 9: Current flow in reverse direction

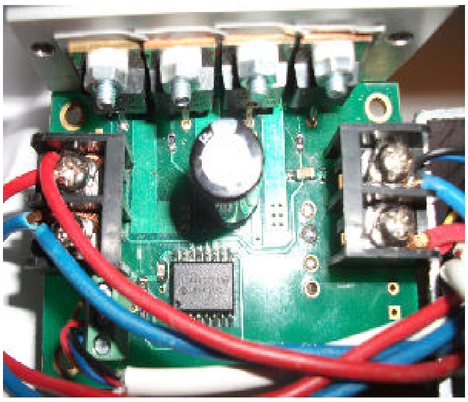

Fig.10. H-Bridge used in the system

2.4. System Structure

On figure 11 is presented the full structure of the control system. It consists of the control board, dual H-bridges, DC brushed motors, current sensors and optical relative encoders for feedback.

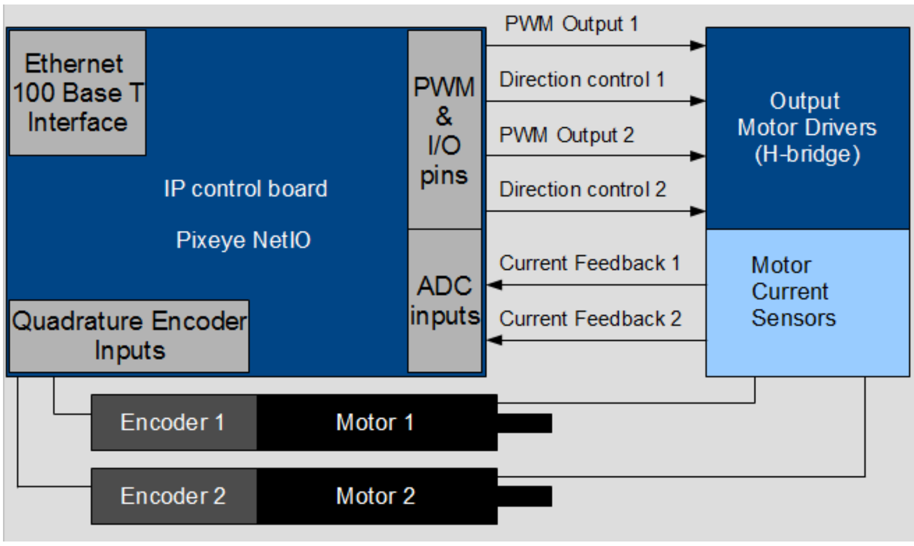

Fig.11: Control system for differential drive mobile platform

3. Intelligent Modular Service Mobile Robot Software Systems

Robot Operating System (ROS) is an open-source meta-operating system. It is a platform for applications in the field of robotics. For the moment Linux distribution Ubuntu is the operating system that supports fully ROS. That distribution has a great future related to porting and integration into embedded world. That gives ROS an excellent perspective for development and use of robot-related applications in systems varying greatly in scale and complexity. The following graphic is generated using the *rxgraph* tool of the ROS system. It displays the node architecture of the application (Figure 12):

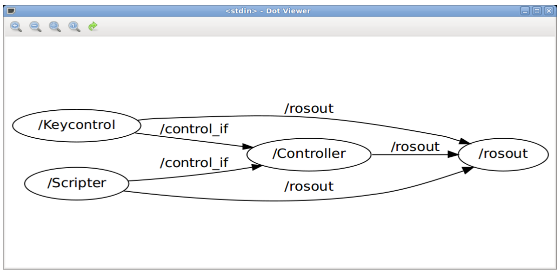

Figure 12. Node architecture of the application

A basic software is called *roscore* and it is a part of every standard ROS application. It can be started from a shell console using command *roscore*. The node *rosout* is a standard node for almost every application under ROS and it implements visualization of various system messages – information and error logs and other changes of the state of application. It takes messages from all of the rest of nodes that belong to the application and displays them in the console. The application itself consists of the nodes:

- *Controller*
- *Keycontrol*
- *Scripter.*

The *Controller* node (takes commands from the other two modules and implements their validation, formatting and transmitting through the serial link to the embedded controller of the robot. It is accomplished by registering for receiving messages on the topic *control_if.*
The other two nodes transmit commands for the manual and automatic mode of operation correspondingly.
The *Keycontrol* node reads commands from user input (terminal console), generates appropriate commands, formats them into messages and publishes them on *control_if* topic.
The *Scripter* node reads commands from a given script file (a text file, containing commands to the robot embedded controller), filters and formats them and publishes them on the topic *control_if.*
In this application the flexibility of the ROS platform is clearly visible. Such a system becomes very scalable and easily extendable. New nodes can easily be added, for example a node for receiving commands from a remote terminal and many others. All these nodes can publish on the same topic *control_if* without changing the Controller node, as there is no need for any node to be aware of the number and functions of the others that publish on the same topic.

4. Intelligent Modular Service Mobile Robot Sensor Systems

Sensor systems are essential part of every intelligent mobile robot. They help performing all functions related to the environment and user interactions – monitoring of spatial location and orientation of the robot, maintaining proper course, obstacles detection, safety of people and the robot itself. Depending on its primary function sensors can be divided into several groups:

- <u>Tactile sensors</u>

These sensors react on a physical collision with hard obstacles. They are usually attached to the mechanical bumpers surrounding the mobile robot. The most common implementation of these anti-collision sensors is by mechanical micro-switches, reacting on pressure. Other possible implementations will be considered, such as using materials for which the electrical resistance depends on mechanical pressure, as well as electromagnetic-based sensors.

- <u>Proximity sensors</u>

They react on presence of an object that is closely located but not colliding with the robot. Their implementation can be based on infrared transmitters/receivers, ultrasonic echolocators, laser distance meters, etc. In all cases the proximity of the object is evaluated by parameters of the echoed signal. The effectiveness of different proximity sensor types will be evaluated and compared with respect to detecting different types of objects, possibilities of precise distance measurement, limitations of range and viewing angle and other parameters.

- <u>Acceleration sensors</u>

They can be used both for tracking velocity changes of the mobile robot and for detecting the direction of the earth gravity (when the robot is not moving) thus detecting the spatial orientation of the robot itself. *Different types of accelerometers will be examined* and their parameters will be evaluated – resolution, number of axes etc.

- <u>Vision system</u>

The growing demands on improved interactivity of the robot as well as performing different types of specific tasks lead to the necessity of introducing robot vision capabilities. The possibilities of application of commonly used cameras today will be considered, as well as usage of special cameras with higher speed and/or resolution and other relevant parameters. Today’s trends in the field of robot vision will be analyzed such as *color* spots discovery, contour extraction, object recognition using different types of classifiers (i.e. ANN - Artificial Neural Networks and others).

- Voice interaction system

The need for verbal interaction with the mobile robot is none less necessary than Robot Vision for improving interactivity. This feature consists of two different types of functions – speech recognition and speech synthesis. The task for speech synthesis has always been basically simpler but the challenge today is synthesis of natural human speech with proper intonation, pauses, and other parameters of natural human speech, that leads to significantly improved interaction between the robot and users. For the task of speech recognition different advanced systems will be considered and their parameters – evaluated.

5. Intelligent Modular Service Mobile Robot Control System

The Intelligent Modular Service Mobile Robot for Elderly care has three main modes:

- Manual Mode for manual control of the robot - Depending from the necessity of the Elderly, the Intelligent Modular Service Mobile Robot will be controlled either by Joystick – Teleoperation UI; Touch screen - Tactile UI; Speech recognition - Voice UI; Gesture recognition- Gesture UI; Brain control - Brain control UI.;
- Semi-Autonomous mode use Control System by executing high level tasks like warm food or bring glass of water;
- Autonomous mode use Control System for Elderly day and night monitoring, fall preventing and for emergency cases.

The Intelligent Modular Service Mobile Robot will have the ability to learn from its own experience (already executed tasks) as well as to interpret human behaviors

Since the Intelligent Modular Service Mobile Robot will stay in the Elderly home and will perform a real interaction with the Elderly, the robot motion must ensure Elderly and robot's safety.

6. Conclusion

Prognoses of the European Commission show that the tendency in Europe and especially in Bulgaria is continuously growing ageing of the population. Most of the elderly people want to live in their own houses for as long as possible and the proposed Intelligent Modular Service Mobile Robot for Elderly Care can help them with tasks such as stand up or seat down assistance, preparing or warming food, serve and clear table, bring water, book, medicine etc., fetch and carry difficult and heavy objects, video and audio contact with medical physician or with family members, day and night monitoring and fall preventing.

Since Bulgaria is on the one of the first places in Europe for the number of disabled persons (According to the Bulgarian Government Statistics), the proposed Intelligent Modular Service Mobile Robot will be able even to provide Care for disabled persons as well.

ROBCO 11 can „live" at the home of the disabled person and helps him throughout the day. Robot will be able to remind him to take medications, it will serve food and drinks, will turn on electronic devices, will alert when his health is getting worse and will connect with his physician, relatives or in emergency ambulance.

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