MINHO@home

Fernando Ribeiro, Gil Lopes, Davide Oliveira, Fátima Gonçalves, Júlio Rodrigues

Grupo de Automação e Robótica, Departamento de Electrónica Industrial, Universidade do Minho, Campus de Azurém, 4800-058 Guimarães, Portugal
fernando@dei.uminho.pt, gil@dei.uminho.pt, dnoliveira@me.com, fatinha.gonc@gmail.com, juliocostarodrigues@gmail.com

Abstract. This paper briefly describes the development of a mobile robot to participate on RoboCup@Home. The focus of this project is to integrate robotic knowledge into home applications and human interaction. The robot has the ability to move in all directions due to its omnidirectional system with 3 Swedish wheels at 120º angle and can handle objects using an articulated arm with six degrees of freedom. It incorporates several vision systems allowing the robot to recognize faces and objects and to move autonomously on a domestic environment. Voice recognition and speech capabilities are also present.

1. Introduction

The group of Automation and Robotics of University of Minho has been participating on RoboCup for a long time [1]. The knowledge and experience gathered from our participation at RoboCup and other robotic events has served as a base to the developed system in the sense of becoming an innovative project. The robot was built from inside out in the University of Minho Robotics Laboratory (mechanics, electronics and software) with the purpose of optimising development costs and resources.

The Minho RoboCup Soccer Middle Size League (MSL) robots have helped us to create a solid and stable moving base and the principle was used in the same manner on this robot [2,3]. The initial concept was drawn in CAD software in order to test if all components would fit physically. The robot's bottom base is responsible for the movement of the robot where 3 omnidirectional Swedish wheels are used to drive and steer the robot. It also provides the space to house the batteries and all the electronics that control the robot. The second base is where the processing units are located. On the third base rest the structural elements of the articulated arm. On the top of the robot is the vision head. Fig. 1 shows a sequence with a MSL robot (left), followed by the robot in CAD 3D (centre) and then the real robot (right).

Fig. 1 – Design and implementation evolution from a MSL robot

This paper starts with the description of the structural implementation of the robot, followed by the chosen motor drivers and their control. The last part is dedicated to the software development in object-oriented programming.

2. Structure development

Each robot base is made of aluminum, which gives a solid and lighter structure to the robot. The robot arm is supported by two structured profiles with linear guides and ball rail systems in order to move the arm vertically (Fig. 2).

Fig. 2: Aluminium profile with linear guide and rail system

Three omnidirectional wheels are used in this platform and they were also developed using 3D CAD modeling and moulds were created by local industry for plastic injection. The overall dimensions of the wheels are 10 x 3 cm in two layers. Fig. 3 shows an image of the developed plastic wheels.

Fig. 3: MINHO@home developed omnidirectional Swedish wheels

The Minho MSL Team robots also use this type of wheels as they provide maneuverability in all directions. The robot incorporates three bottom bases with 48 cm of maximum diameter (Fig. 4) and three small bases to give support to the rest of the structure performing a total height of 1,80 m.

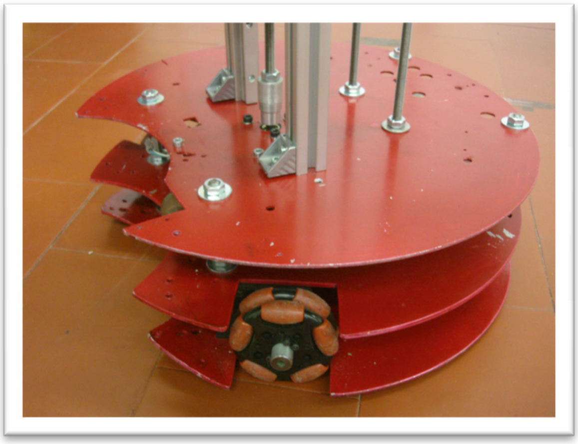

Fig. 4: Three bottom bases with 48cm of maximum diameter

The robotic arm has six degrees of freedom and it is also majorly made of aluminium for lightness. The movement in the joints is accomplished by the action of DC motors. Each joint rotation is obtained by the use of worm wheels/worm gears providing position fixing when power is not supplied and hence lower power consumption. The total weight of the arm is 2.5 Kg, with a maximum reach of 50 cm.

3. Motor drivers

Each omnidirectional wheel is moved by a DC motor with 33 W maximum output power and 5 N.m maximum torque. The interface between the controller and the motors is achieved by a LMD18200 microchip that is a H-Bridge with built-in diodes mounted in his typical circuit. Each LMD18200 microchip can deliver up to 3 A continuous output and a supply voltage of more than 55V and has a custom made PCB made on campus.

To control the wheels three AVR Butterfly evaluation kits are used, one per wheel, with an ATmega169 microprocessor and innumerous peripherals, like LCD, UART, USI and SPI communication interface, ADC and timers/counters with PWM, among others. A fourth AVR Butterfly works as a master and controls the other three AVR Butterfly using USI two-wire communication.

The encoders attached to each motor are the HEDS-5701 giving feedback rotary signals to its master controller that in turn sends it to the slaves as shown in Fig. 5.

Fig. 5: System feedback loop diagram for the motors of the wheels

The communication between the microcontrollers and the PC is made through a serial port. This PC calculates the distance to the target using the vision head and sends it to the master AVR Butterfly that calculates the exact motion values for each wheel. This is achieved by the equations 1, 2 and 3, obtained following Fig. 6.

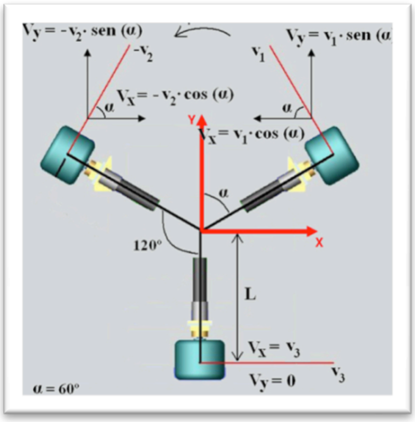

Fig. 6: Driving system

$$V_x = v_3 - v_1 \cdot \cos(\alpha) - v_2 \cdot \cos(\alpha) \quad \textbf{(Eq. 1)}$$

$$V_y = v_1 \cdot \sin(\alpha) - v_2 \cdot \sin(\alpha) \quad \textbf{(Eq. 2)}$$

$$\omega = L \cdot v_1 + L \cdot v_2 + L \cdot v_3 \quad \textbf{(Eq. 3)}$$

The arm motion controller follows the same working principle although with a slightly different hardware configuration due to less power needing. The arm DC motors are the *Transmotec* SD3039 with magnetic hall sensor encoders with 13 pulses per revolution at the motor and a 120:1 gear box reduction and 20:1 at the worm gear (Fig. 7). This gives us a 0.01º degrees of precision in each arm joint rotation. The motor driver used is the IC L298 which has two H-Bridges per chip.

Fig. 7: System feedback loop diagram for the motors of the robotic arm.

The AVR Butterfly working as a master receives the angles by serial port for the three different joints and hence sending the proper instructions to the MCU slaves.

4. Vision system

Two vision systems using four cameras are used in order to attain robot global positioning, robot fine positioning, object and face recognition and object handling. The global positioning system is achieved by a catadioptric system at the topmost part of the robot where a camera pointing upwards into the centre of a parabolic mirror captures a 360º image of the robot surroundings. This means that the mirror, camera and lens have to be selected in order to take the most out of the three devices by capturing as much as possible from the surrounding area.

Due to structure limitations that reduce the vision of the surrounding area a second catadioptric system is used positioned half way vertically of the robot. This second system covers the unreached spaces from the first system. These two sets will be used to globally positioning the robot and to avoid obstacles thus providing full autonomy on moving around the house.

To detect objects and faces and to allow object manipulation a stereovision system is used near the end of the robotic arm. It allows better close-ups for face recognition and object handling due to depth availability (3rd dimension). The three dimensional representations are important for determining the object position in the space. The use of inverse kinematics provides a correct movement of the robotic arm by determining the right angle of each joint.

5. Software

The robot software is written in C++ on Qt cross-platform application running on two *Linux Ubuntu* machines, one for the arm control and stereovision system and another to the robot locomotion and catadioptric systems. The computers used are low cost computers made in Portugal and were named after a famous Portuguese navigator called *Magalhães (Magellan)*. These computers are small, light and good battery life. Although limited on their power processing it demands better programming by using light and fast algorithms to achieve the intended tasks. A third computer is dedicated to voice control and recognition and speech with *Windows XP* and *Microsoft Speech SDK*.

The computer vision is developed using OpenCV 2.0 libraries along with GNU compiler and libraries and Nokia Qt framework providing real-time image processing. This entire system also provides for multiple tasks such as Human-Computer Interaction, object identification, face recognition, camera and motion tracking, stereo and multi-camera calibration and depth computation which are important in mobile robotics.

House navigation is attained by the first PC that has a virtual house map created in its memory. Global positioning then is achieved by mapping the acquired images to house positions in the virtual map [4,5]. Obstacles are detected and avoided should they be in the calculated path. This vision system is also able to detect small objects on the floor and collect them as it moves.

As an innovative application the commands exchanged between the PCs and the motion controllers are based in G-Code. This code is normally used on numeric control machines and in this case is applied to a mobile platform. The software that controls the motor drivers is written in C language on AVR Studio, which is a freeware version available to program and debug *ATmel* microcontrollers.

6. Voice control and recognition

A dedicated computer that uses Microsoft Speech Technologies SDK performs the voice control and recognition. Many RoboCup@Home teams have used this SDK as it is considered a stable and mature platform for the purpose.

7. Conclusions

The participation of the University of Minho on RoboCup events started a long time ago as Minho Team in MSL. The knowledge accumulated along the past years has opened a window to new researches and interests.

All the effort put in this project does not finish with it. The development and study of different areas can give the basic understandings to future applications. As examples of use of different technologies applied on this robot there is the Minho developed omnidirectional wheelchair [6] and the plans for future stock reposition robot for supermarkets. These implementations represent two new ways of exploring the advantages of robotics in real world challenges.

The application of several proposed technologies applied to RoboCup MSL such as an omnidirectional platform and the catadioptric vision system are important innovations that we intend to bring to the RoboCup@Home arena. Using low cost systems we intend to overcome the expensive all-in-one solutions hence providing accessibility and encouragement to new teams with lower budgeting.

Acknowledgements

The team would like to thank the Algoritmi Research Centre, Department of Industrial Electronics, School of Engineering and University of Minho for all support.

References

1. *New improvements of MINHO Team for RoboCup Middle Size League in 2003.* **F. Ribeiro, P. Braga, J. Monteiro, I. Moutinho, P. Silva, V. Silva.** Pádua, Itália : Robocup'2003 – Team Description Paper, Julho 2003.

2. **Ribeiro, F., Moutinho, I., Silva, P., Fraga, C., Pereira, N.,** "*Controlling Omni-directional Wheels of a MSL RoboCup Autonomous Mobile Robot*", Robotica'2004, April 2004, Porto, Portugal.

3. **Ribeiro, F., Moutinho, I., Silva, P., Fraga, C., Pereira, N.,** "*Three Omni-Directional Wheels Control On A Mobile Robot*", CONTROL'2004 - IMechE, IEE, University of BATH, Department of Mechanical Engineering, 6-9 September 2004, Bath, UK, ISBN 086197- 130-2.

4. **Ribeiro, F., Moutinho, I., Silva, P., Fraga, C., Pereira, N.,** "*Vision, Kinematics and Game strategy in Multi-Robot Systems like MSL RoboCup*", ROBOCUP'2004 – Team Description Paper, July 2004.

5. **Ribeiro, F., Tosini, L., Lopes, G.,** "*Localization of a Mobile Autonomous Robot Based on Image Analysis*", IEEE – The 7th Conference on mobile robots and competitions, Abril 2007, Paderne, Algarve, Portugal.

6. **"Omnidirectional Wheelchair"**, [Web] 2010 [cited 16/01/2010]; Available from: http://www.robotica.dei.uminho.pt/omniwheelchair.html.