Wheeled Mobile Autonomous Robot for Eurobot 2011

Raimund Edlinger[#1], Michael Zauner[*2], Walter Rokitansky[*3]

[#]*FH OOE Forschungs & Entwicklungs GmbH*
Stelzhamerstr. 23, 4600 Wels, Austria
[1]raimund.edlinger@fh-wels.at

[*]*FH OOE Studienbetriebs GmbH*
Stelzhamerstr. 23, 4600 Wels, Austria
[2]michael.zauner@fh-wels.at
[3]walter.rokitansky@fh-wels.at

***Abstract*— Vision and sensor systems and an efficient motion system are fundamental components in the process of designing and building autonomous robots.**
This paper describes the technologies behind a "chess robot", built to collect pawns, queens and kings and to separate them into on specified squares.
The robot, designed to participate to the International competition of robotics "Eurobot 2011", is able to distinguish the objects according to their shape and color.

***Keywords*— wheeled mobile robot, WMR, Eurobot, differential drive, computer vision**

I. Introduction

A self-navigating fully autonomous robot with the capabilities of element searching and collision avoidance would be an ideal platform for robotic researchers and students to develop robots for the competition EUROBOT. One of the important processes involved in the design of a robot is the evaluation of the concept of the robot because the Eurobot association defines a new theme each year. This paper describes the development of an autonomous robot for this contest. It describes the experience with the design, the evaluation of sensors and grasping systems and the implementation of a vision system which communicates via RS232 with the main board.

II. Eurobot Competition

A. Eurobot in general

Eurobot is an international robotics contest which involves students, researchers and amateurs from all over the world.
Created in 1998 as the "French Cup of Robotics", in 2006 350 teams from 26 countries took part in the competition. Organized in two phases (national qualifications and the international final), the competition consists of a real tournament in which the robots duel in "one-on-one challenges". At Eurobot finale, the first 16 teams from the qualifying phase are selected for the final round.

Every year, a different robotic challenge really with a newly defined set of playing rules is established. Robots must be absolutely autonomous and any kind of communication with the robots (either wired or wireless) during the matches is forbidden. Robots are limited, in size to an area of 120cm and a height of 43cm and they must implement an obstacle avoidance system.

B. Eurobot 2011

This year the Eurobot association decided to play a special kind of chess. The robots have to collect the pawns, queens and kings which are detected by a system of bar-codes. In the game it is allowed to stack a maximum of two pawns and a king or queen to have more points. The goal is to have more points on squares of our playing colour as the opponent after 90 seconds, see Fig. 1. A color (red or blue) and therefore a side of the playing area is allocated to the team before each match. When both teams and the referees indicate they are ready, the referee will determine the random positions for the playing elements to be placed on the table. This is done by drawing from a set of cards.

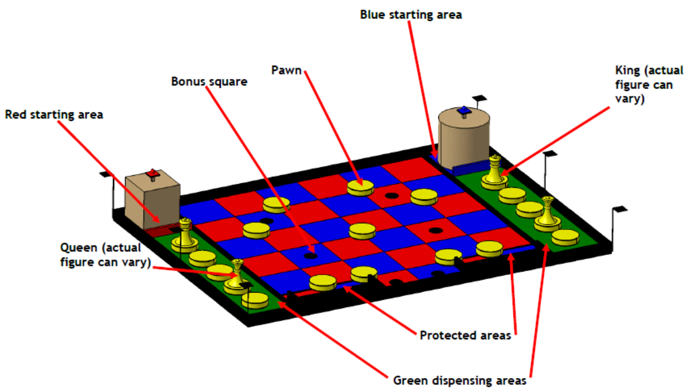

Fig. 1 Playing Area

III. ROBOT DEVELOPMENT AND EXPERIMENTS

A. Drive mechanism

The drive mechanism is in the base of the chassis and is equipped with a differential drive. Two brushed DC-motors with a planetary gear and a resistance R_A, machine constant k_m and gear ratio n are used to move the robot. The drive motors also contain a gearbox with a gear transmission ratio of 14:1 and a magnetic encoder for the speed and positioning control (shown in Fig. 2).

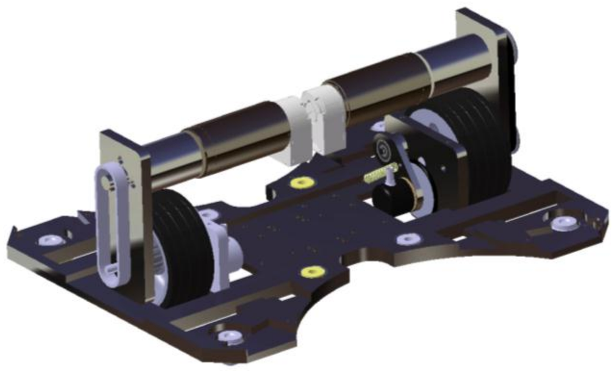

Fig. 2 Motion Control Unit

The posture $[x, y, \theta]$ of the wheeled mobile robot (WMR) is given with the centre of wheels axis *(CoA)* as reference point, see Fig. 3. The kinematic model of the unicycle type system is given by

$$\begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} \cos\theta & 0 \\ \sin\theta & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} v \\ \omega \end{bmatrix}$$

with control input $u^T = [v,\omega]$. We assume ideal velocity control of the inner loop and therefore the velocities may be considered as inputs [1].

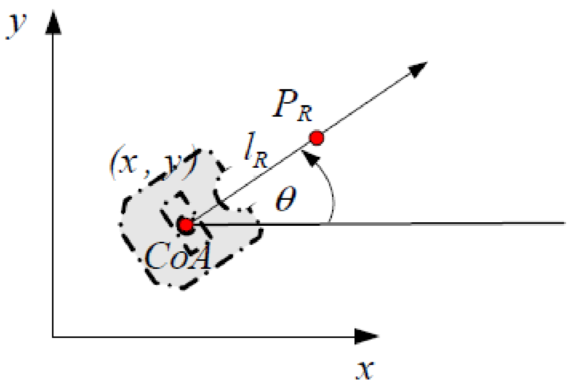

Fig. 3 The coordinate system

An Atmel ATxmega256 controller [7] on the main board is implemented to guarantee the exact execution of the movement and to calculate the trajectory.

B. Electronic and power supply

The power supply of the robot consists of two NiMH accumulators. These accumulators are connected to the supply-board which consists of 3.3V, 5V (logic), two 5.5V (power), 12V and 24V TRACO voltage converters. On the main board there are implemented three Xmega 256 microcontrollers from Atmel [2]. The main board, based on a modular electronic system [5], includes all of the intelligence needed for reading sensor information, controlling the movement of the robot and accessing the robots actuators (see Fig. 4). To reduce wiring complexity each input/output port has its own power supply for the sensor/actuator that is connected to it. The main processor distributes the tasks to the slave processors. It is the central unit which communicates with the slaves via serial interface (RS422). The main processor executes the main program which includes all the strategies, the timing, the route planning, etc.

The slave processors control three DC motors and four servos which control the speed, the position and the odometric navigation system.

A Human-Machine Interface (HMI board) is also connected to the main board. The HMI board allows the parameters to be easily changed and show error messages from the main board, moreover it provides easy access to the program and JTAG ports that are looped through to the main board.

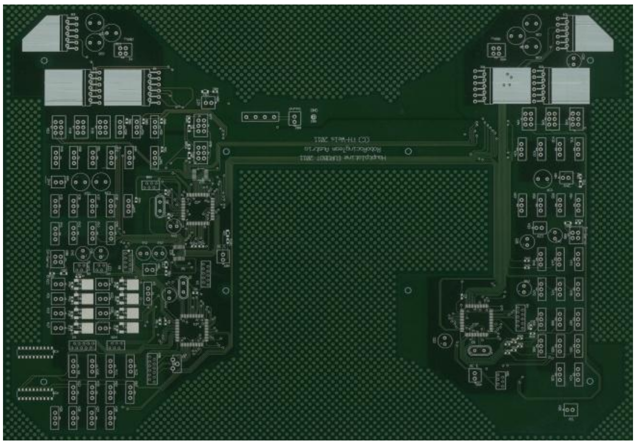

Fig. 4 Main board control

C. Element Management System

At the front and at the back of the robot are two grasping systems which are used to collect the royals and pawns (see Fig. 5). On each side of the robot there are two arms to collect pawns which have two infrared sensors for detecting the elements. Additionally on each arm there is a vacuum grasping system with an individual vacuum pump so that each arm can operate independently from the other. The elements are stored in special receptacles by the grasping system, enabling the transport of a maximum of six pawns and two royals (Fig. 5).

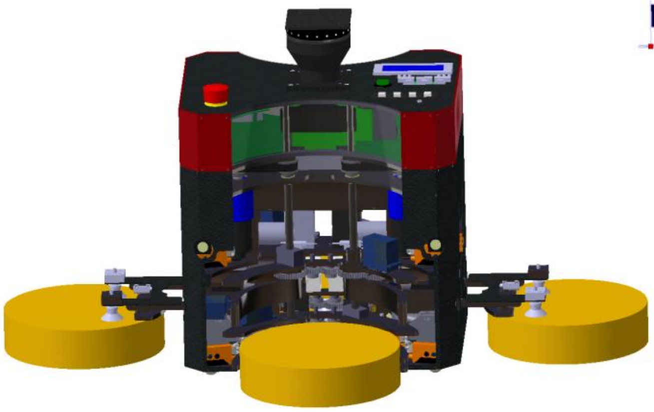

Fig. 5 Autonomous Robot for Eurobot 2011

D. *Avoidance System*

Eight ultrasonic sensors [3] are located around the robot and are required for the obstacle avoidance system. The sensors have a maximum operating distance of 100 cm. That way the robot can detect obstacles within a perimeter of over 2 m. Located on top of the robot is the opposing robot detection unit. This unit determines the location of the opponent robot. Due to this fact the robot can detect the position of the opposing robot at any time and thereby avoid collision. The robot tries to create a profile of the opposing robots' movement so that it is able to calculate the best way to go around it

E. *Vision System*

To plan an optimized path for the robot, there are two cameras which detect the playing elements. The cameras act as colour sensors and detect the mean colour of a predefined position. Fig. 6 shows the close range of the front camera. The classification of this section allows the determination of all royals and pawns. The information is transferred via serial interface to the main control board.

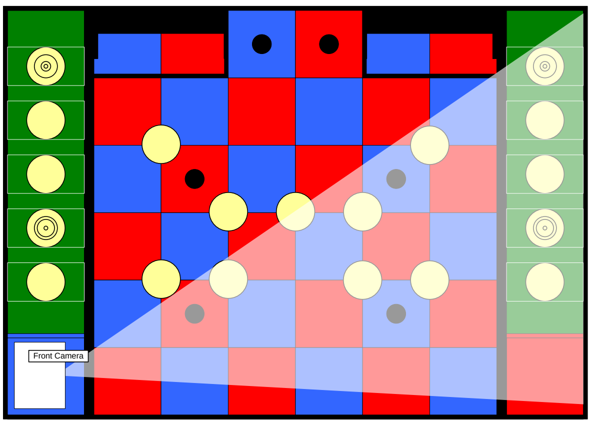

Fig. 6 Close range of the cameras

The way in which the vision system is set up depends on the imaging environment and the type of analysis and processing required. Based on the limitation of size of the robot the vision system consists of two webcams and a pico ITX to produce enough quality to extract information from the acquired images.

To ensure the full detection of the elements before starting the game the resolution of the camera have to change to 1024x576 pixels. At the beginning of the match, the robot must be placed fully with in the starting zones and it is important that the robot always has the same starting position *[x,y]* set to the reference position zero.

The positions of the front and back camera are fixed and acquire images of the objects from an angle with perspective errors. It is necessary to calibrate the system to assign real-world coordinates to pixel coordinates and compensate for perspective and nonlinear errors inherent in the imaging system.

To detect the yellow elements, region of interests (ROI) are used for pulling out the useful colour information in an image, see Fig. 7. The colour of a surface depends on the direction of illumination and the direction from which the surface of the objects is observed.

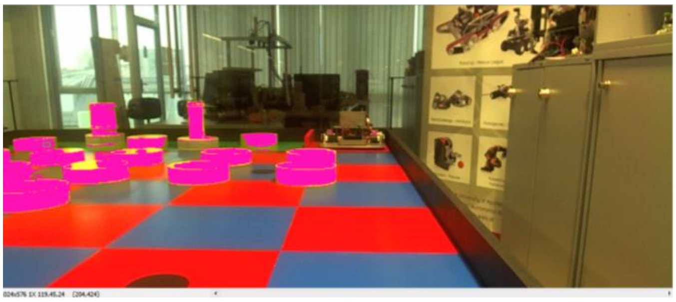

Fig. 7 Detection of the elements

The created ROIs are useful to focus the images analysis and to guarantee the full recognition of the constellation of pawns, queens and kings. After the start-up procedure the particle measurements of calibrated real-world units determine the location of particles and their shape features.

The measurements are based on characteristic features of the object represented in the image, the real-time detection of which is a processor-intensive task. Using 1GHz processor the performance of the machine vision system is limited to four frames/seconds. Nevertheless this limitation allows for scanning of the elements during the game.

Before and during the game the vision system sends and receives the following strings:

COMMUNICATION VIA SERIAL INTERFACE

Nr	Messages between main board and vision system		
	Read String	**Write string**	**Action**
0	#C*	#CB* #CR*	Playing Colour – Blue Playing Colour – Red
1	#A*	#APQPPKXPX PXXPPXX*	Constellation of the elements (see Fig. 6)
2	#M*	#Mxy*	Mapping the elements and send the x and y-coordinates
3	#Pxy*		Current position [x,y] of the robot on the table
3	#S*		Standby
4	#Z*		End

IV. CONCLUSIONS AND OUTLOOK

Our experiments demonstrate successfully that the management between vision and main board is very robust against unexpected faults in execution and the sensing of elements in the playing area. The generation of mapping the elements is dependent on the performance of the pico ITX and particle analysis in finding statistical information – such as the area, location and presence of particles. With this information we have performed many machine vision inspection tasks. The robustness of the measurement relies on the stability of the image acquisition conditions, sensor resolution, lighting, and vibration.

Future research will entail optimization of the machine vision and the implementation of the search and rescue system, which the robots will use to explore and navigate the generated map.

ACKNOWLEDGMENT

The authors are indebted to Gernot Grabmair for the support of the model-based nonlinear control for two-wheeled mobile robots (WMR). The authors grateful acknowledge the support of the Upper Austria University of Applied Sciences, National Instruments, IFM, IGUS and SMC for setting up the Robo Racing Team [4].

REFERENCES

[1] G. Grabmair, “Model-based Nonlinear Control of 2-WMR”, 4th International Conference on Research and Education in Robotics,: Springer-Verlag CCIS-series, 2011.

[2] AVR-XMega (2011) homepage ATMEL. [Online]. Available: http://www.atmel.com/dyn/products/devices.asp?category_id=163&family_id=607&subfamily_id=1965&source=left_nav

[3] UNDK 20 – Sonic Sensor (2011) homepage BAUMER. [Online]. Available: http://sensor.baumer.com/sensor/products/scripts/level2.php?cat=CONFUltraschall_Sensoren&psg=ulProduktgruppe|Distanz_messende_Sensoren,ulErfassungsdistanz_max|-188456959&pid=Ultraschall_Analogausgang_UNDK_20_Sd_200_mm&language=de&country=CH&header=Schweiz+%2F+Baumer+Electric+AG&ptk=

[4] RoboRacingTeam (2011) homepage [Online]. Available: http://rrt.fh-wels.at

[5] R. Edlinger and M. Zauner, “A Modular and Scalable Electronic System for Mobile and Autonomous Robots”, 4th International Conference on Research and Education in Robotics,: Springer-Verlag CCIS-Vol. 156, 2010.