*EUROBOT$^{open}$ 2011*

# *Chess´ Up!*

## *Pilot Study RoboRacingTeam Austria*

## *“CheckMate 2011”*

Thomas Krösswang-Ridler
Christof Köchl
Edin Mujagic
Lukas Schlossinger
Markus Pfeifenberger
Stefan Meisinger

# *Contents*

# 1. QUESTIONNAIRE

Name of the team:

**ROBO RACING TEAM**

1. Is this the first participation to the contest for the team?

Yes **No**

2. Did some of the team members take part in the contest before?

**Yes** No

3. Did you wish the visit of the Eurobot volunteer to help/assist during the year?

Yes **No**

4. Provisional budget of the project: ***5.000 €*** for the robot
***1.500 €*** for the travel

5. What are your partnerships? (financial, material,…)
***ELRA*** – DC-Motors
***MAXON*** – actuator motor
***Beta Layout*** – PCBs
***SMC*** – pneumatic equipment
***IGUS*** – linear actuator
***IFM*** – sensors

# 2. GENERAL DESCRIPTION

## 2.1 THE ROBOT

The robot was constructed in the drawing program CATIA V5R18. The main objective in the design of the robot was to build a tower and to carry as many towers as possible.
**The robot dimensions are:**

| | |
|---|---|
| Starting configuration | 1197mm |
| Deployed configuration | 1399mm |
| Height | 350mm |

The robot can collect the kings, queens and pawns with the gripping system and stack them to a tower. The main task of the robot is to place the enemy's and its own towers on the fields of the selected color.

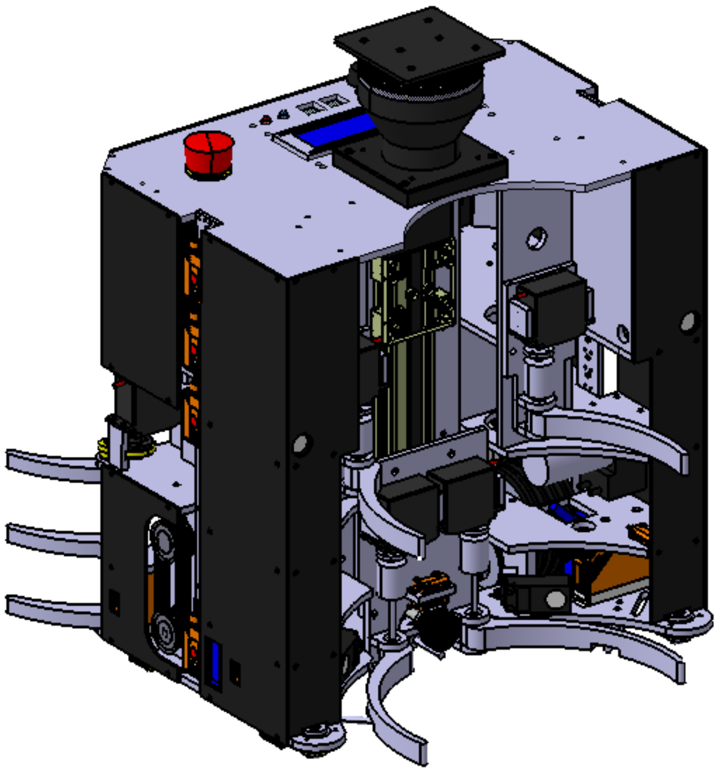


**Fig.1 The robot**

## 2.2 SIMPLE OUTLINE OF THE ROBOT

The robot is divided into three zones. At the front is a gripping system which is mounted on a linear actuator. The gripping system can grip a queen or a king and lift it up. In the middle of the robot is another gripping system mounted, which can hold a queen or a king. Then the robot is able to collect two pawns to build a “big” tower.
At the back of the robot there are two gripping systems which can also carry a “big” tower.
The robot has 20 infrared sensors to detect elements and to distinguish between pawns, queens and kings. The control unit is a modular electronic system, that is supplied with 18.5V. The opponent robot detection system, the programming interface and the emergency stop switch are located on top of the robot. Figure 2.2 and 2.3 show the robot in a top view and in a side view.

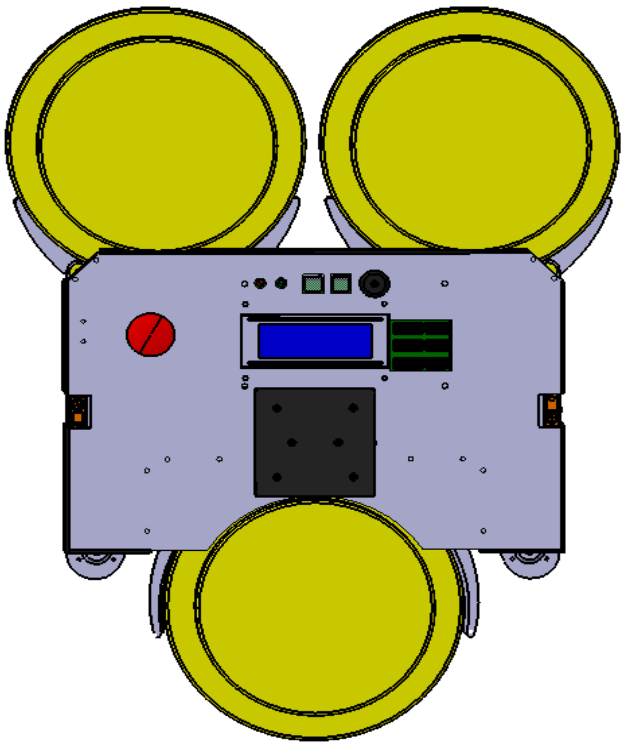


**Fig.2 The robot– top view**

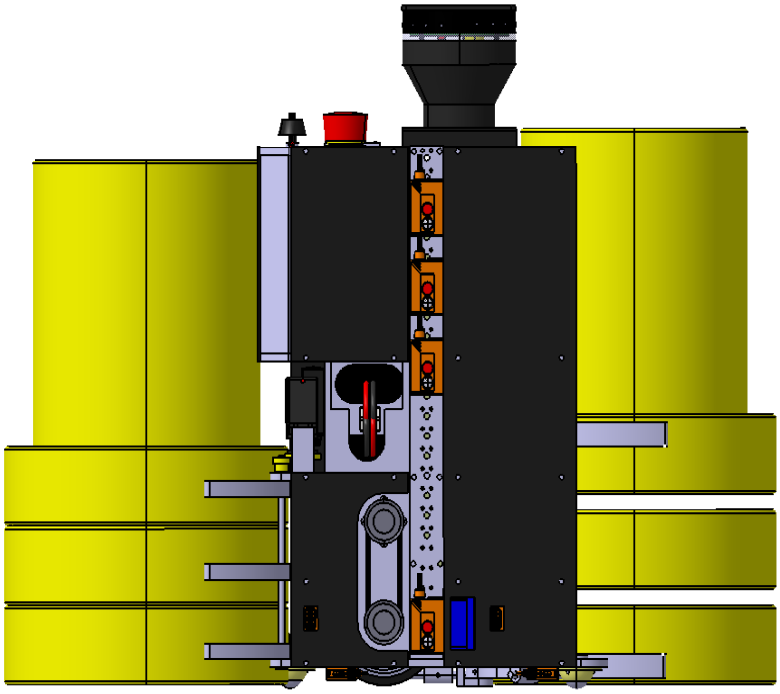


**Fig.3 The robot - side view**

# 3. TECHNICAL DESCRIPTION

## 3.1 ROBOT MOVEMENT

The drive mechanism is the base of the chassis and is equipped with a differential drive. A DC-motor with a planetary gear was used to power the robot's movement. The driving motors contain a planetary gear with a gear transmission ratio of 15:1 and a magnetic encoder for the speed and positioning control (shown in Fig.4).
A special motor board is implemented to guarantee the exact execution of the movement. This motor board is connected to the local positioning system on the top of the robot.

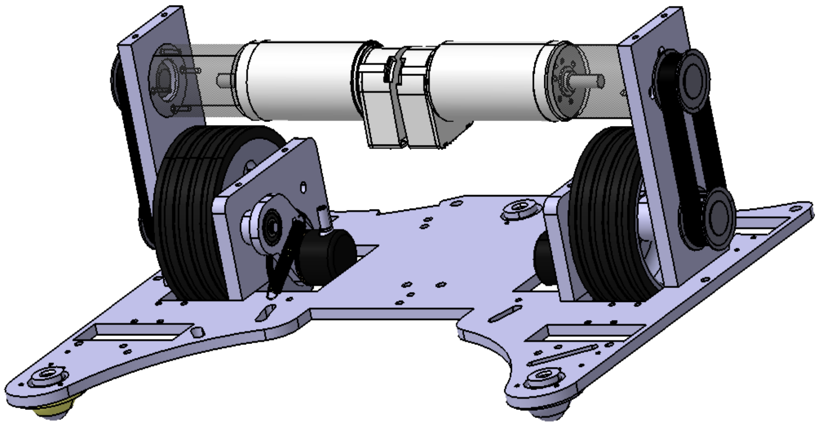


**Fig.4 Motion Control Unit**

**Calculation of the acceleration by a given torque:**

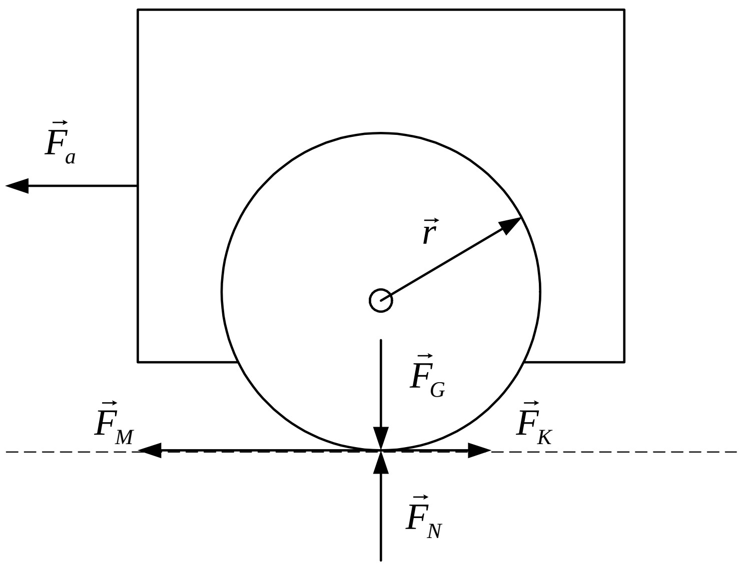



**Fig.5 Modeling of the occurring forces**

| ***Symbol*** | ***Description*** |
|---|---|
| r | radius |
| $F_G$ | weight |
| $F_N$ | normal force |
| $F_K$ | lose of force by rolling friction |
| $F_M$ | driving force |
| $F_a$ | acceleration force |
| M | motor torque |
| g | acceleration of gravity |
| $\mu_K$ | friction coefficient |
| m | mass of the robot |
| m´ | mass per motor |
| P | motor power |
| n | rotation per minutes |
| f | rotation per seconds |
| $v_{End}$ | final velocity |
| U | wheel circumference |
| $\omega$ | angular velocity |
| a | acceleration of the robot |

$$\vec{M} = \vec{r} \times \vec{F}_M \; ; \left|\vec{M}\right| = \left|\vec{r}\right| \cdot \left|\vec{F}_M\right| \cdot \sin\varphi \Rightarrow \left|\vec{F}_M\right| = \frac{\left|\vec{M}\right|}{\left|\vec{r}\right| \cdot \sin\varphi} \qquad (3.1)$$

$$M = \frac{P}{\omega} \qquad (3.2)$$

$$\omega = 2 \cdot \pi \cdot f \qquad (3.3)$$

$$f = \frac{n}{60} \qquad (3.4)$$

$$v_{End} = f \cdot U = \frac{n \cdot U}{60} = \frac{n \cdot 2 \cdot \pi \cdot r}{60} \qquad (3.5)$$

$$\vec{F}_K = \vec{F}_N \cdot \mu_K = m \cdot \vec{g} \cdot \mu_K \qquad (3.6)$$

$$\begin{aligned} \vec{F}_a &= \vec{F}_M - \vec{F}_K \\ F_a &= \frac{M}{r} - m´ g \cdot \mu_K \\ a &= \frac{M}{r \cdot m´} - g \cdot \mu_K \end{aligned} \qquad (3.7)$$

$$a = \frac{60 \cdot P}{r \cdot m \cdot 2 \cdot \pi \cdot n} - g \cdot \mu_K = \frac{60 \cdot P}{U \cdot m \cdot n} - g \cdot \mu_K$$
$$a = \frac{P}{m \cdot v_{End}} - g \cdot \mu_K \qquad (3.8)$$

**Excel-Calculation:**

| M [Nm] | r [m] | $\mu_K$ | planetary gear | motors | n [U/min] | m [kg] | a [m/s$^2$] | $v_{End}$ [m/s] |
|---|---|---|---|---|---|---|---|---|
| 0,0931 | 0,04 | 0,025 | 15 | 2 | 7670 | 10 | 6,74 | 2,14 |

## 3.2 POWER SUPPLY

The power supply of the robot is a LiPo accumulator (lithium polymer). This accumulator supplies the power board (see 3.11.2), which converts the battery voltage to lower voltages needed for different electronics.

**Technical data of the accumulator:**

| | |
|---|---|
| accumulator technology | NiMh |
| maximum output current | 30A |
| maximum loading current | 4.2A |
| Capacity | 4200mAh |
| dimension (l x w x h) | 218 x 45 x 22 mm |
| Weight | 787g |
| Voltage | 12V |

## 3.3 FRONT SIDE GRIPPER SYSTEM

The front side gripper which you can see in fig. 2.4 has to grip a obstacles and carry it up to the second gripper of the front side which is fixed about 15cm over the bottom . This is needed to build towers with the obstacles and to get a lots of points. The front gripper consists of the gripper itself, a linear drive by the company Igus, and a DC-Motor by the company Faulhaber. To make the delivery between the two front grippers possible, the dc motor has to be regulated to a special position, which is about 13cm over the ground. As a controller our team created a proportional plus integral controller. After the delivery the gripper moves upwards to wait for the next obstacles.

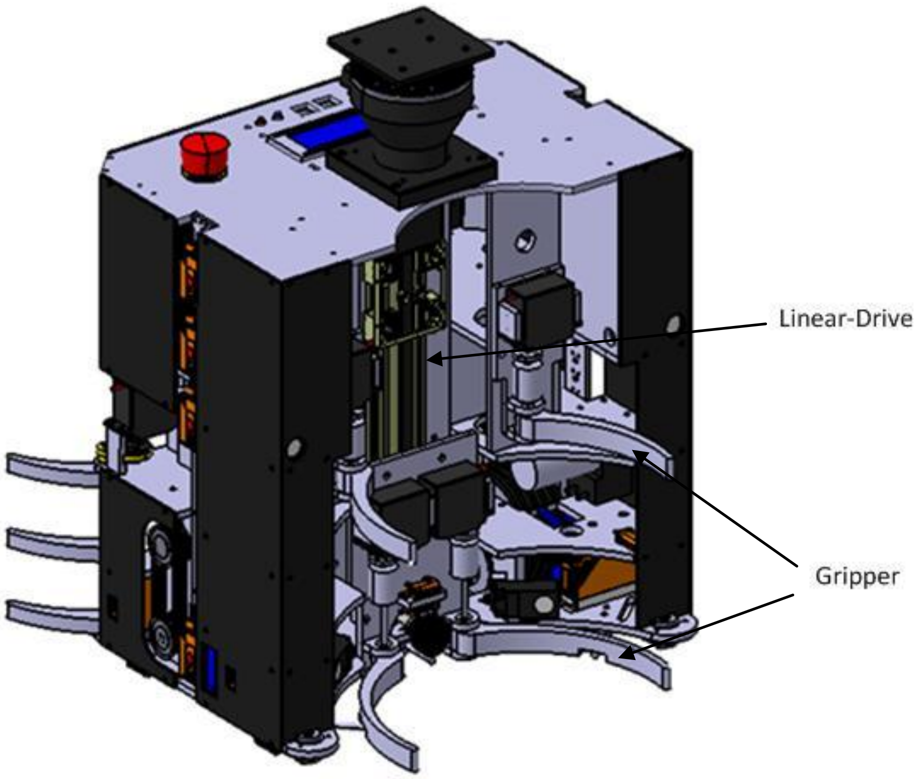



**Fig. 3.3 Front side gripper**

## 3.4 BACKSIDE GRIPPER SYSTEM

One of the big issues in this challenge is that the opponent is allowed to move your towers. So we have to take the most points with us. Therefore we have two grippers at the backside of the robot. On both sides of a gripper are three arms to handle each segment of a tower. The arms which are mounted to a shaft are moved by a servomotor. The grippers are not that big because of the robot dimensions which are fixed by the Eurobot. The perimeter of the robot at start configuration is <=1200mm due to that the position of the grippers are inside the robot which is shown in Fig. 3.4. After the start the grippers deploy to a maximum that the robot has a perimeter of nearly 1400mm in whole which is shown in Fig. 3.5.

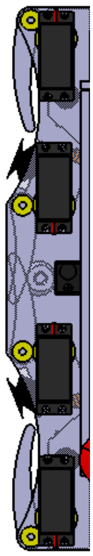


**Fig. 3.4 Gripper at Start**

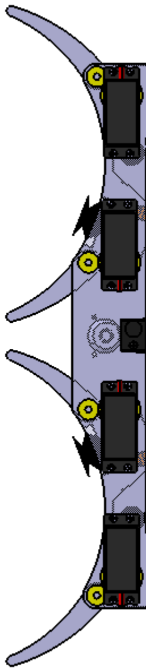


**Fig. 3.5 Gripper deployed**

The Problem of the short gripper is that it is not possible to grip the tower to drag it by. Therefore is a pneumatic sucker used which allows us to move the tower in every direction.

## 3.5 POSITION DETECTION

### 3.5.1 Odometric Navigation

The basic navigation is based on odometric navigation. As shown in Fig.3. the robot will measure the increments of the left and the right wheel cyclically and calculate the differential path *ds* and the angle $\varphi_R$. With these variables the exact x- and y-position can be calculated.
At the beginning the x and y coordinates and the starting angle must be known and these values are stored in the microcontroller.

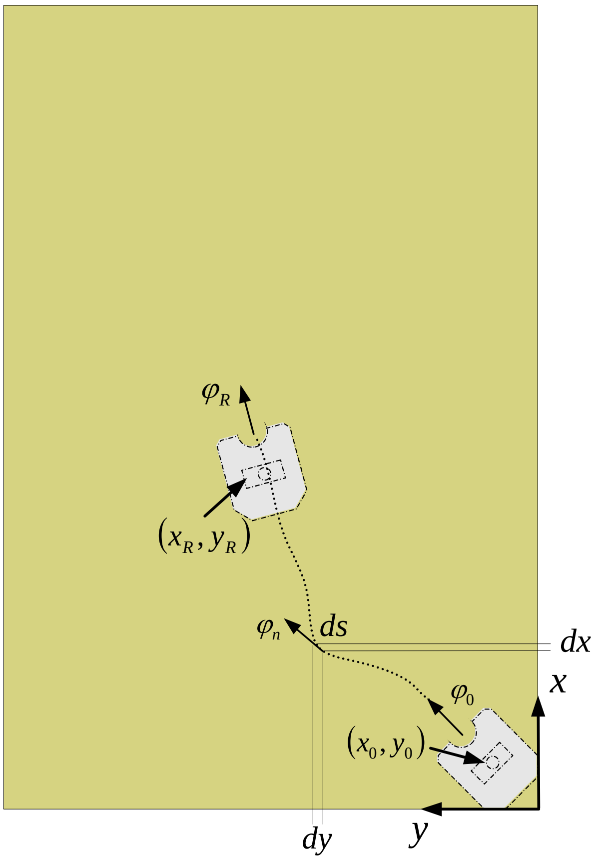



**Fig.3.6 Odometric navigation**

$$s_n = \frac{1}{2} \cdot (Increments\_Left + Increments\_Right) \quad (3.9)$$

$$\varphi_R = \varphi_0 + (Increments\_Right - Increments\_Left) \quad (3.10)$$

$$ds = s_n - s_{n-1} \quad (3.11)$$

$$x_R = x_{R-1} + ds \cdot \cos \varphi_R \quad (3.12)$$

$$y_R = y_{R-1} + ds \cdot \sin \varphi_R \quad (3.13)$$

### 3.5.2 Infrared Navigation

The basic navigation is based on infrared navigation system. As shown in Fig.3.6 the robot will measure the distances from the robot to the beacons. Three beacons are arranged on the sidelines of the field.
To locate the position of the robot infrared cameras are placed on the top of the robot. These cameras detect infrared signals (wavelengths between 870-950nm) which are sent by the beacons. The cameras in this system have a resolution of 1024 x 768 pixels. Furthermore the cameras can detect four different infrared LEDs in same time. When an infrared LED (Blob) is detected the cameras are able to calculate the X and Y coordinates of the Blob. This coordinates match Image coordinates of the camera.
To get the exact position of the robot an intercept point calculation is needed. For this task at least two beacons have to be analyzed.
The beacons include two rows of LEDs. Each row consists of four LEDs. The distance of the rows is variable. By using a calibration reference point (horizontal distance of the rows) the current position can be calculated by mathematic proportional computation.

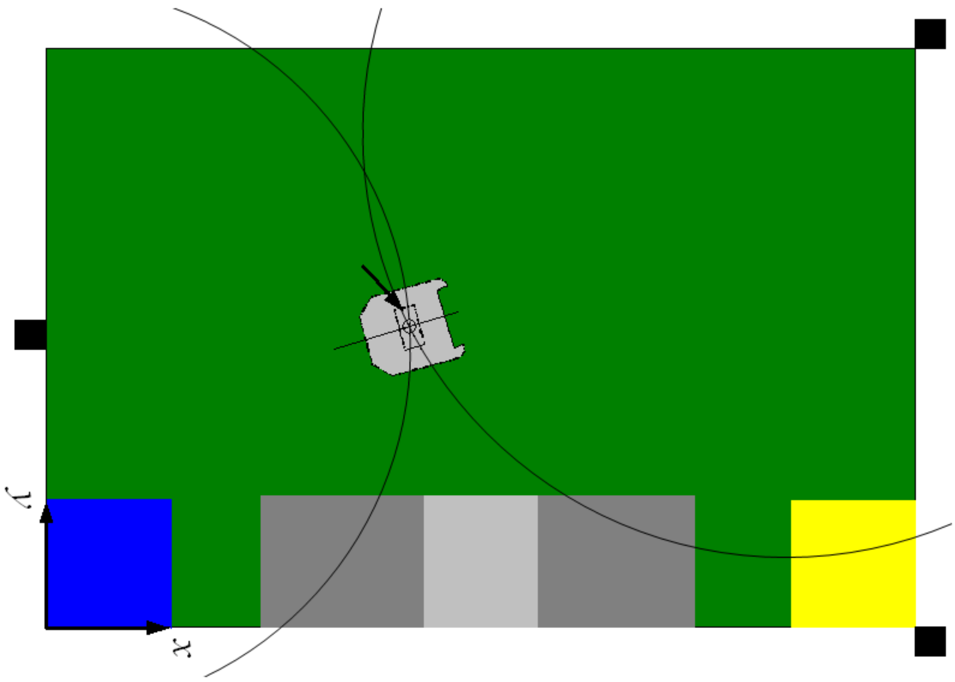



**Fig.3.7 Infrared-cameras Navigation**

The advantage of this system is that you don´t have to know any x and y coordinates at the beginning of the run. Ambiguities of this measurement system after the start could be shut out within using the previous position. All the calculations will be done by an ATMEGA microcontroller.

## 3.6 AVOIDANCE SYSTEM

The rival will be detected by a system which is generally speaking the same as the position detection system of the robo racing team robot. Therefore there are also infrared cameras on the top of the enemy robot and additional a radio module is included in this position detection module. The position of the rival will be sent to the FH-robot, there the original coordinates will be calculated.

Due to this fact the robot can detect the position of the opposing robot at any time and it is always in a position to avoid a collision. The robot tries to create a profile of the opposing robots' movements so that it is able to calculate the best way to go around it (as shown in Fig.3.7).

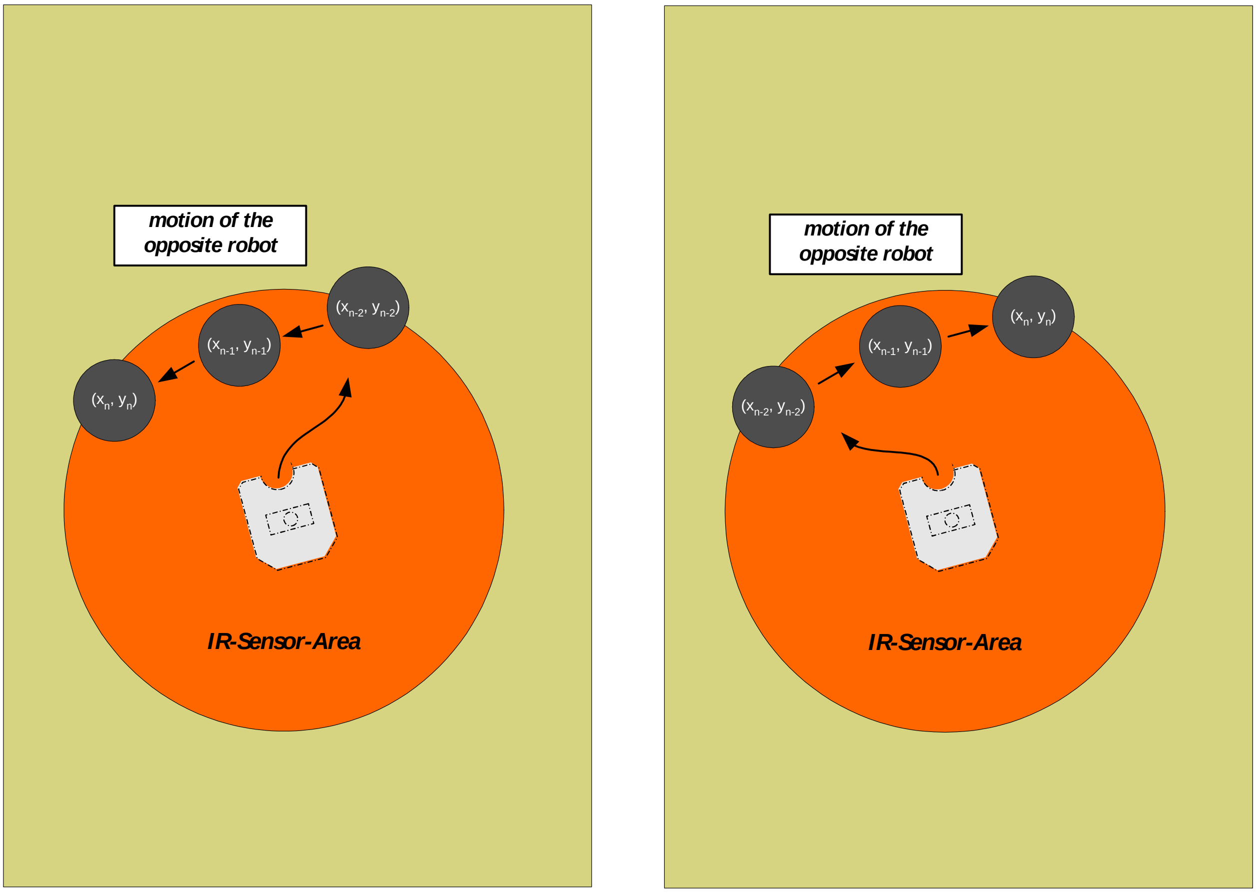



**Fig.3.8 The robots' path finding**

## 3.7 OPPONENT ROBOT DETECTION UNIT

On top of the enemy robot there is a sending module, and on the top of our robot there is the interacting receiving module and both together build the opponent robot detection unit. The device detects the direction in which the opponent robot is located and also the boarding can be determined. Additionally the robots own location is determined by analysis the measurement results.
Due to this fact the robot can detect the position of the opposing robot at any time and it is always in a position to avoid a 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. (The opponent robot detection unit and the measurement parameters are shown in Fig. 3.10).

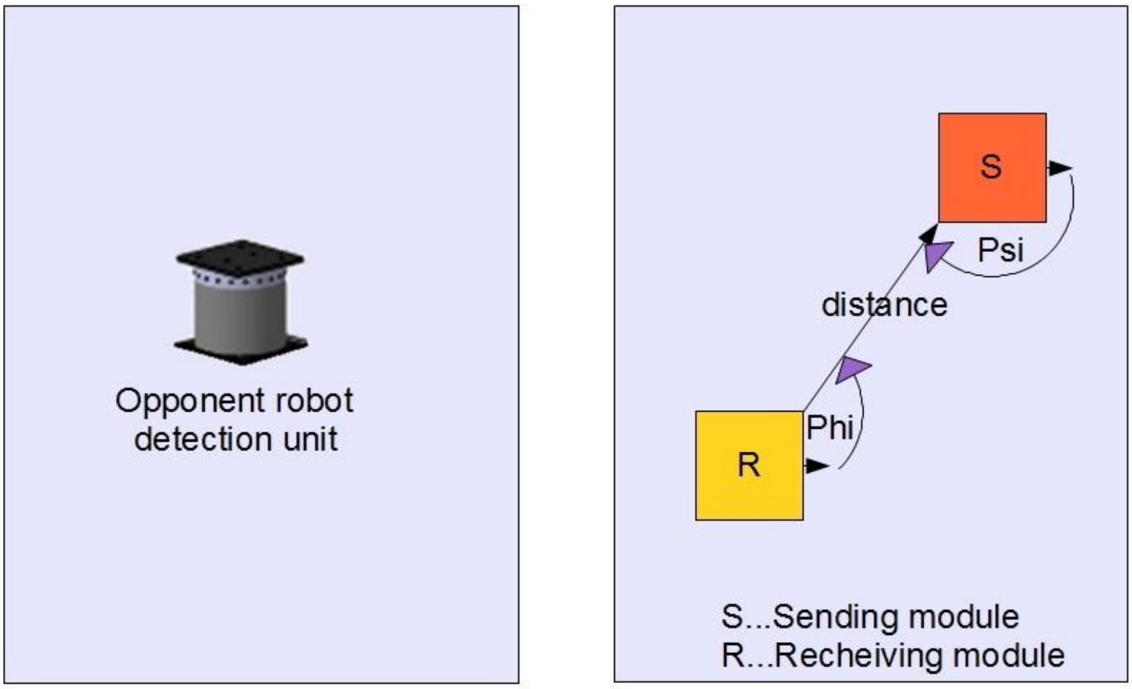



**Fig. 3.9 The opponent robot detection unit**

**Technical data of the opponent robot detection unit:**

| | |
|---|---|
| dimension (l x w x h) | 80 x 80 x 80 mm |
| accuracy of angle measurement | 9° |
| accuracy of distance measurement | 500 mm |
| operating distance | up to 1800 mm |

## 3.8 SENSORS

### 3.8.1 Ground Sensors

On the baseplate of the robot are four O5K500 contrast sensors from IFM which detect the color of the floor to be sure that the elements are moved on the right field. The sensors are located 20mm above the floor on the front and backside of the robot as shown in Fig. 3.11. It is possible to teach the sensor one contrast and if the contrast is detected the supply voltage is available at the output.

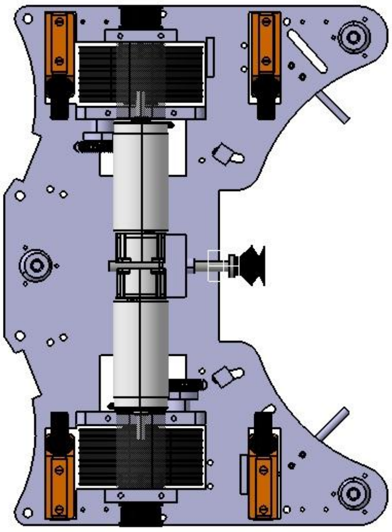


**Fig. 3.10 Baseplate with contrast sensors**

### 3.8.2 Front side Gripper Sensors

Two reflected light sensors are mounted on the front gripper plate to detect which element is handled. The O5H5008 has a range of 15mm and the O5H5004 a range between 20mm and 50mm. If a pawn is collected only one sensor is activated if it is a queen or king both sensors activate. (shown in Fig.3.12)

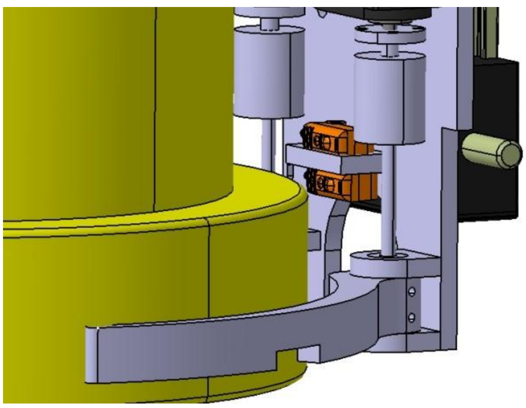


**Fig. 3.11 Sensors on the front gripper**

To detect elements which are in the driving direction or a little bit off the road are two ultra-sonic sensors from baumersensorics used. These two UNDK20U6903 analog sensors have a scope of max. 1000mm and a teach-in port for the range.

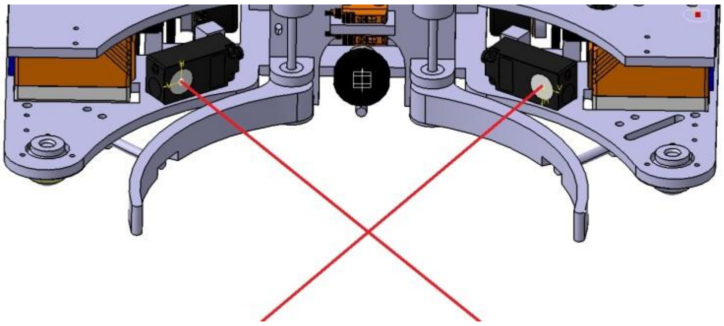


**Fig. 3.12 ultra-sonic sensors for detecting elements**

### 3.8.3 Lateral Sensors

To locate elements which are not in the driving direction of the robot there are four reflected light sensors fixed on the side as shown in Fig. 3.13. The sensor on the bottom is searching for pawns and the three sensors above are locating kings, queens, small towers and big towers. The sensors from IFM with the type designation OJ5002 have a range of max. 600mm but it’s possible to teach them a lower scope.

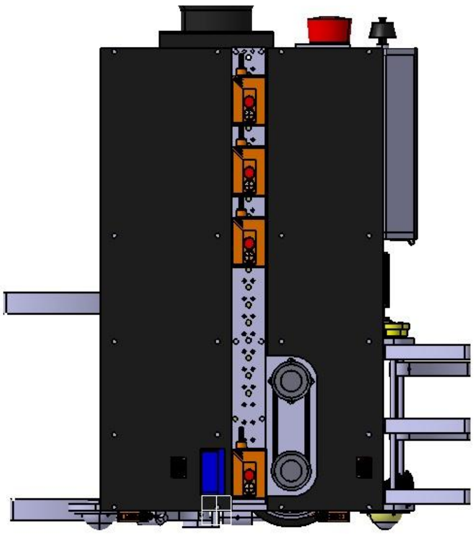


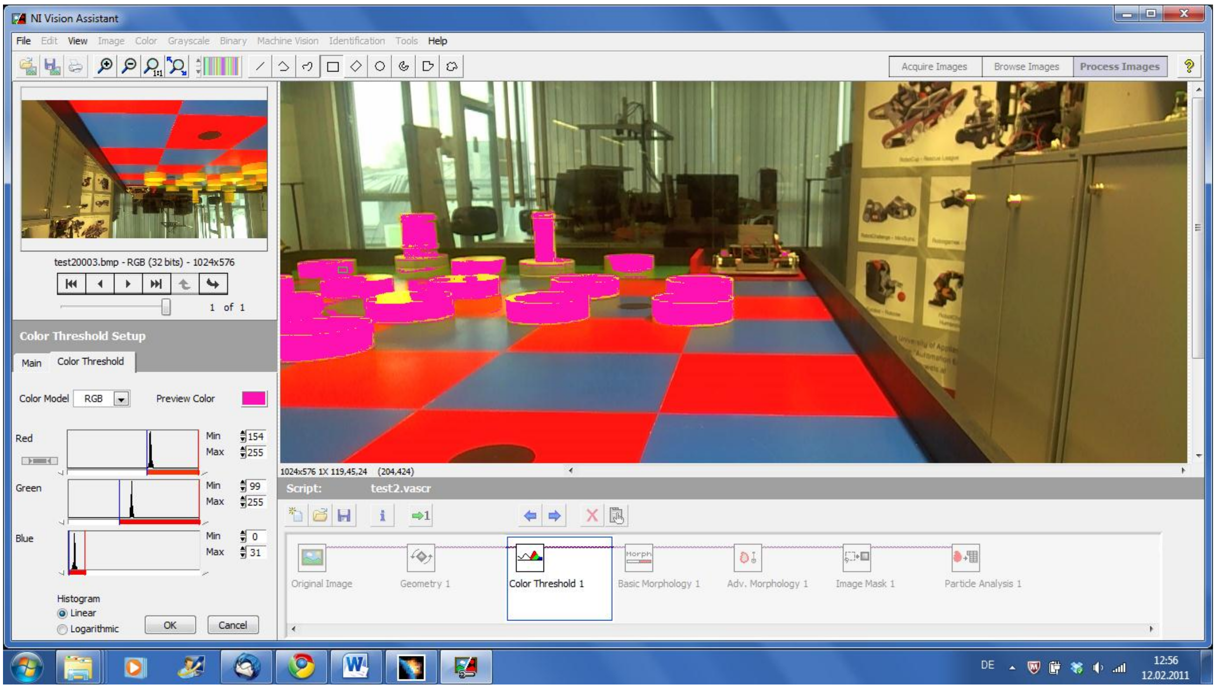
**Fig. 3.13 Lateral Sensors of the robot**

### 3.8.4 Barcode sensor

One of the biggest problems of the game is to locate the kings and queens. This is realized with two barcode readers from wenglor sensorics which read the barcode on the element.

### 3.8.5 Camera

A camera is used to get the starting configuration of the elements. The image taken by the camera is processed with NI Vision Assistant and is an alternative to the barcode readers. The quality of the measurements greatly depends on the table lighting.




## 3.9 REMOTE CONTROL

For the testing of the robot it is essential to control every single motion and sensor for themselves. Therefore a program for the remote control of the robot was written in C#. Furthermore this program allows us the commissioning of the robot and the camera the easy way. The familiar Windows – Interface allows the user to keep the setting – in period as short as possible.

Following points were the main tasks of the program:

- Simply entry of commands
- Adjustable maximum values of the commands
- Ability of multiple commands to a chain
- Show robot data
- Evaluation of the camera
- Fast programming of the camera
- Communication via XBee (RS232)

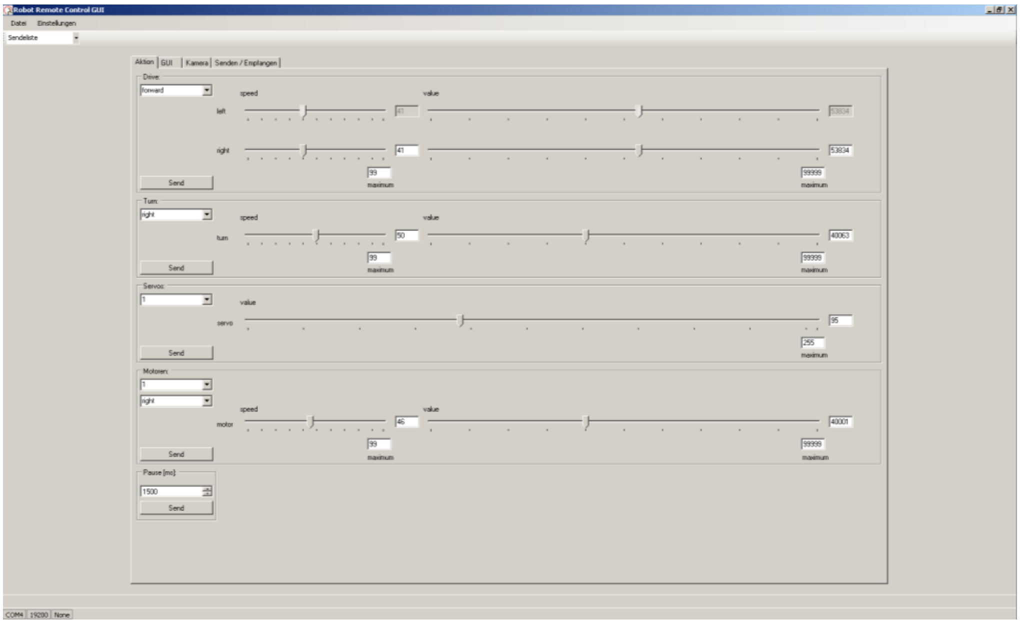



**Fig.3.14 Entry of commands**

## 3.10 WIRELESS COMMUNICATION SYSTEM – XBEE

To communicate with the robot without using wires, we decided to equip it with an XBee-PRO RF module. Over this connection we are able to send the robot commands or information from the enemy detection system. It will be also used to check the robot´s status or to transmit the actual sensor signals to a PC.


**XBee Pro RF module**

**Main Features:**

- Performance
  - Indoor/Urban: up to 100 m
  - Outdoor line-of-sight: up to 1500 m
  - Transmit Power: 100 mW (20 dBm) EIRP
  - Receiver Sensitivity: -100 dBm

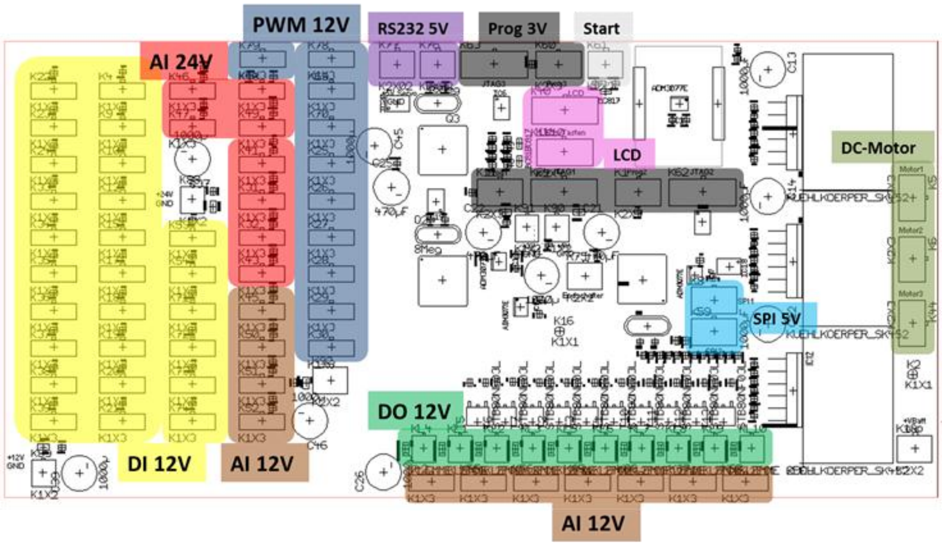
- Power
  - TX Current: 270 mA (@3.3 V)
  - RX Current: 55 mA (@3.3 V)
  - Power-down Current: < 10 µA

- Advanced Networking & Security
  - Point-to-point, point-to-multipoint and peer-to-peer topologies supported
  - 128-bit Encryption
  - Self-routing/Self-healing mesh networking

The module operates within the ISM 2.4 GHz frequency band. Through its serial port, the module can communicate with any logic and voltage compatible UART or through a level translator to any serial device (For example: RS-232/485/422 or USB interface board).

# 3.11 ROBOT INTELLIGENCE

## 3.11.1 Mainboard




The robot's mainboard includes all intelligence needed for reading sensor information, controlling the movement of the robot and accessing the robots actuators. To reduce wiring complexity each input/output port has its own power supply for the sensor/actuator that should be connected to it.

<u>Main Features:</u>

- 3 XMEGA256A3 as controllers
- 26 digital inputs, 10 digital outputs
- 19 analogue inputs
- 10 PWM-outputs for brushless DC-motors
- 3 Motor-Ports for DC-Motors (2 for robot movement, 1 for linear drive)
- 2 SPI-Ports for communication with the beagle-system
- 2 RS232-ports for barcode-scanner and camera
- communication ports for human-machine-interface
- programming- and JTAG-port for each microcontroller

### 3.11.2Power-Board and Human-MachineInterface(HMI)-Board


**HMI-Board**


**Power-Board**

The HMI-Board was designed for changing parameters and showing error messages from the mainboard, moreover it allows easy access to the program- and JTAG-ports that are looped through to the mainboard.

The power-board supplys the mainboard as well as all sensors, actuators and motors with a regulated DC-voltage:

- 24V / 410mA for ultrasonic sensors
- 12V / 5A  for infrared sensors, pneumatic pumps and valves
- 5V / 12A for brushless DC-motors
- 5V / 3A and 3.3V / 1200mA for the mainboard electronics

### 3.11.3 Software

All software is programmed with the programming tool CodeVisionAVR and is written in C.


The main board runs a self-developed cooperative multitasking system, so that more actions can be carried out at the same time. The 3 microcontrollers communicate with each other per UART.

# 4. ORGANISATION

## 4.1 MEMBERS' SKILLS

| | |
|---|---|
|  | ***Ing. Michael Zauner BSc***<br>Tel.: +43 (0)7242/72811-3520<br>E-Mail: michael.zauner@fh-wels.at<br>***Skills***<br>• Team leader |
|  | ***Mujagic Edin***<br>E-Mail: edin.mujagic@students.fh-wels.at<br>***Skills***<br>• Sensors<br>• Vision |
|  | ***Krößwang-Ridler Thomas***<br>E-Mail: thomas.kroesswang-ridler@students.fh-wels.at<br>***Skills***<br>• Electronics<br>• driver programming for hardware |
|  | ***Meisinger Stefan***<br>E-Mail: stefan.meisinger@students.fh-wels.at<br>***Skills***<br>• Mechanic<br>• Construction |
|  | ***Köchl Christof***<br>E-Mail: christof.koechl@students.fh-wels.at<br>***Skills***<br>• Electronics<br>• Wireless communication (XBee) |
|  | ***Pfeifenberger Markus***<br>E-Mail: markus.pfeifenberger@students.fh-wels.at<br>***Skills***<br>• Mechanic<br>• Construction |

| | |
|---|---|
|  | ***Schlossinger Lukas***<br>E-Mail: lukas.schlossinger@students.fh-wels.at<br>***Skills***<br>• Sensors<br>• Programming |

## 4.2 PROJECT SCHEDULE

| | |
|---|---|
| ***October*** | • conception<br>• building the EUROBOT-table<br>• constructing the mechanic components of the robot<br>• testing different sensors, pumps |
| ***November*** | • constructing the mechanic components of the robot<br>• testing different sensors |
| ***December*** | • ordering, assembling and testing first components<br>• designing a mainboard for the robot |
| ***January*** | • assembling and testing grippers, servos<br>• constructing the mechanic components of the robot<br>• testing different sensors<br>• designing a mainboard for the robot |
| ***February*** | • testing a camera system<br>• assembly of the main mechanical construction done<br>• assembly of the mainboard |
| ***March*** | • to develop different strategies |
| ***April*** | • to develop different strategies |
| ***May*** | |

## 4.3 PARTNERSHIP

| | |
|---|---|
| | ***UpperAustriaUniversity of Applied Sciences Campus Wels***<br><br>**FH OÖ Studienbetriebs GmbH**<br>Stelzhamerstraße 23<br>4600 Wels/Austria<br>Tel.: +43 (0)7242 72811-0<br>Fax: +43 (0)7242 72811-3166 |
| | ***Supplierof all DC motors***<br><br>**ELRA Antriebstechnik-Elektronik Vertriebs Ges.m.b.H.**<br>Schönngasse 15-17<br>A-1020 Wien<br>Tel.: +43(0)1 214 17 85-0<br>Fax: +43(0)1 216 38 34 |
| | ***Supplier of all PCBs***<br><br>**Beta LAYOUT GmbH**<br>Feldstraße 2<br>D-65326 Aarbergen<br>Telefon: ++49 (0)6120 907010<br>Telefax: ++49 (0)6120 907014 |
| | ***Creation of the CFC plates***<br><br>**Filiale WelsLand**<br>Zoblstr. 11 a<br>A-4650 Edt/Lambach<br>Tel.: +43 7245 20661<br>Fax: +43 7245 20661 40<br>Tel.: 0800 288 288 |
| | ***Grasping System***<br><br>**SMC Pneumatik GmbH (Austria)**<br>Girakstr. 8<br>A-2100 Korneuburg<br>Tel.: +43 2262 62280 0<br>Fax: +43 2262 62285 |