RoboCup Logistics League sponsored by Festo

Rules and Regulations 2013

The Technical Committee

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Contents

1 Introduction

Preamble

The future of Production Industry lies with smarter systems. With current developments pursuing the goal of more aware, more decentralized behaviors in factories, a scientific platform for applied research is required. The RoboCup Logistics League sponsored by Festo is determined to develop into a state-of-the-art platform for mobile robotics education. This industrial motivated league keeps the focus on challenges promoting precise actions, further encouraging external data supported autonomy.

This year's competition environment is laid out in the pages to come. It ensures the same and fair circumstances for all participants, it however is neither meant to dictate nor suggest the way how to fulfill the task, but is meant to develop the Logistics League further towards deploying Automated Guided Vehicles in industrial applications. This includes current challenges of developing industry-wide standards for Cyber Physical Systems for production processes like designing plug-and-produce capable systems.

After an exciting RoboCup in Mexico, we look forward to a new scale of competition that will emerge from initiatives around the globe. In 2012 we had our first Logistics League World Champion. In 2013 we introduce the Referee Box changing the competition at its core by introducing a flow of information. This allows for more dynamic games and the automatic tracking of scores, and to relax the hitherto existing regulations regarding additional computing power.

Finally, no rulebook is perfect. Feel obliged to inform us about issues you like to discuss or gaps that might have an impact on the competition, so we can keep the necessity for rule discussions at the RoboCup event to a minimum. We are open for all kinds of suggestions; the set of rules will be fixed at 01/01/2013 and revised in April 2013 after the German Open 2013 competition.

1.1 The task

Our aim is to simulate autonomous guided vehicles in industrial applications. In opposition to regular automatic guided vehicles teams shall complete the following task without human interference as successful as possible, competing with a second team against the clock.

The Logistics League's main challenge is a multistage production cycle of different product variants with self-crafted intermediate products and delivery of the final product. This genuine goal will be rewarded considerably higher than partial fulfillment of the task. Autonomous robots transport hockey pucks which act as a placeholder for (intermediate) products between the processing machines. A machine can basically be understood as a signal light with an attached RFID reader as described in Appendix A. Each puck carries an ID tag which will be read and processed according to the related machine's specification. If procurable this will lead to a new puck state: a new sub-assembly is produced or prepared. Complete work orders require all related subassemblies of product variants (cf. Section 6.3 for details). Such transformations can rely on more than one puck as input to be triggered.

This work flow is controlled by a referee box broadcasting information via wifi (see Section 5.2). The work flow itself is divided into three different phases: a short setup phase, an exploration phase (see Section 6.2.4) during which robots receive scores for correctly discovering and publishing the yet unknown types of the different machines on the field. After this phase the referee box will announce all machine types and designations. Succeeding into the second game phase the actual production tasks as described in detail in Section 6.2.5 is disclosed to the teams and their robots.

The whole factory area can be used as an intermediate storage. Finally successfully assembled products are to be delivered to the correct delivery gate and get unloaded into its delivery slot. The factory area has to be treated in the best possible way. Any possible damage to the field or the machines will be penalized by the referee.

1.2 Agreements & regulations

The Logistics League follows a certain design philosophy. All teams are obliged to use the Robotino robotic system from Festo Didactic GmbH & Co. KG with certain freedoms and limitations. The usage of all currently publicly available revisions is in order, see Section 4 and Appendix A for further details. All available sensor equipment that does neither exceed Robotino's diameter (see Appendix A.1.1) nor require external assistance (like Indoor GPS) is permitted.

2 League administration

2.1 Technical Committee 2013

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3 Competition Area

3.1 Field dimensions

The point of origin for each statement within this rulebook that uses relative coordinates is the bottom left corner of the competition area namely the corner near robot insertion area below the blue input storage area. All indicated sizes of mark-ups are to be considered outside dimensions.

The competition area is a 5.6 m × 5.6 m large arena with several RFID-mounted machines, mark-ups, a stock of raw-material and a delivery zone. It is surrounded by boards, 0.5 m of height to reduce object interference from outside the area. The default width for mark-ups is 19 mm, the default color is black.

The factory area spans across 4.8 m × 5.6 m. There are two boundaries, set by two mark-ups, 0.4 m from the left and right borders of the competition area. The factory area is joined by two opposing 0.4 m × 1.0 m zones at the left and right middle. The left zone is painted blue marking the *input storage area* with the *late order insertion point* to the top. The insertion area is 0.6 m of depth with the insertion slot in its middle. This spot is a 0.1 m × 0.1 m empty square that will be equipped with a pallet carrier for the late order challenge. The space below the input storage area is called *robot insertion area*.

The right zone is marked green and houses the three *delivery gates*. Each gate is of 0.3 m width with 0.1 m space to the next delivery gate separated by black mark-ups.

The delivery gates feature one signal per gate placed in the middle of each gate zone. The delivery slot resides besides a unit that is identical in construction to a production machine. Each of the three RFID devices within these gates feature a black centered square of 0.1 m × 0.1 m called delivery slot, which resides exactly below the RFID device.

Additionally to the delivery gates, 13 machines are placed within the competition area: 10 machines representing the multistaged production process, two machines to recycle consumed pallet carrier and one test station. The machines of the production process are placed within the factory area as stated in Figure 1. They are aligned in a 90° angle (the facing direction may change during the tournament). Each production machine resides in the center of a squared machine space spanned by standard mark-ups with 0.6 m each side.

The 3 additional machines are arranged in the corners of the competition area, and aligned at 45°, facing the center of the factory area. The lower left corner will remain empty. The competition area is shown in Figure 1.

3.2 Coordinates of the Machines and Field Slots

The coordinates of the machine centers and the centers of the different field slots are presented in Table 1.

3.3 The pallet carrier puck

The data-carrying RFID tag is attached on top of a hockey puck. Each pallet carrier can be identified by a unique number. The tournament puck features a diameter of 7.5 cm and is shown in Figure 2. Please consult Appendix A.2.5 for further information of the RFID tag.

3.4 Machines

3.4.1 General information

All machines are identical devices consisting of

- one plate housing the RFID read/write device and
- one signal unit according to Figure 3.

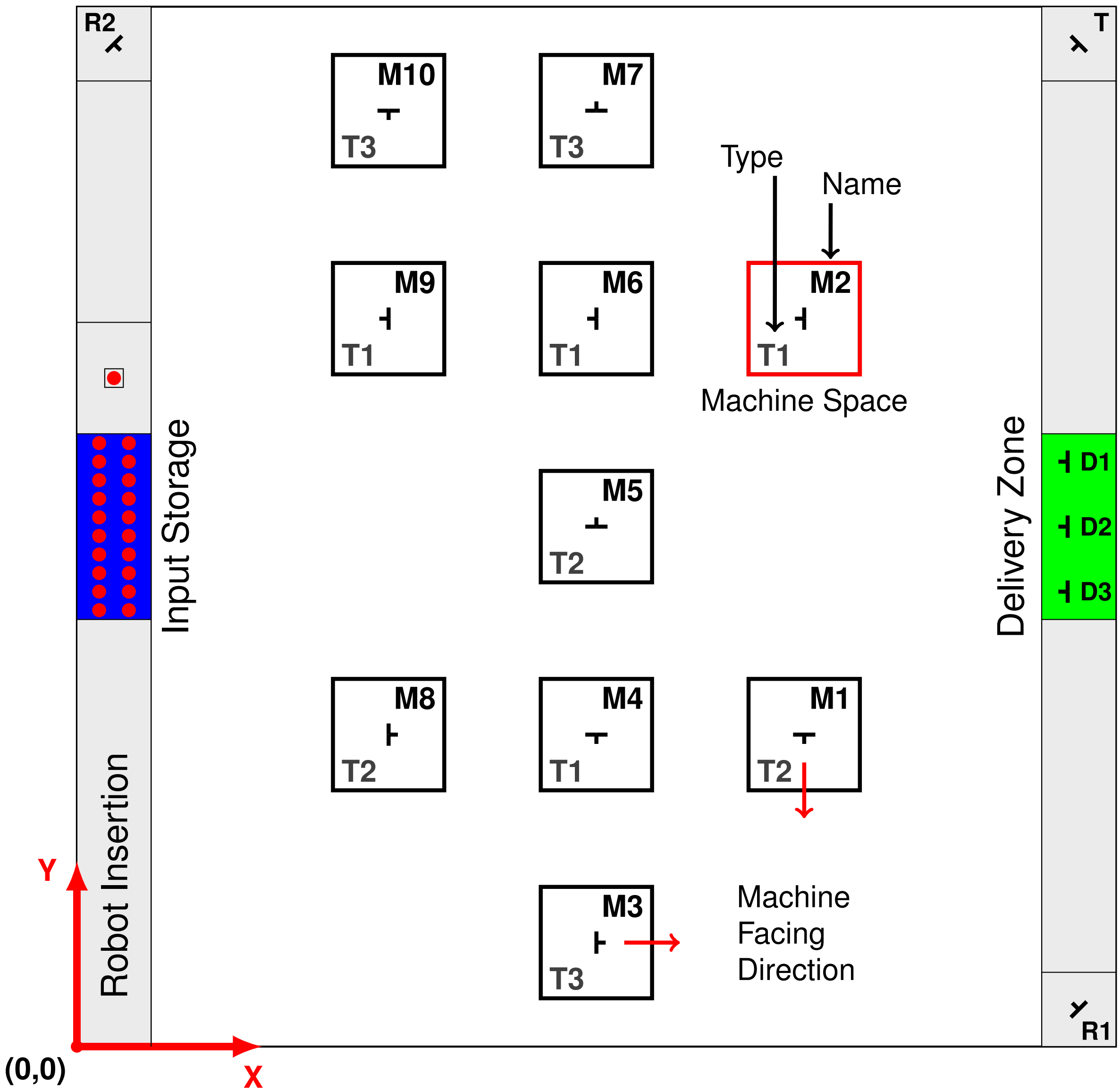


Figure 1: Competition Area

They share the same design and RFID device. The overall size is 280 mm × 160 mm × 100 mm (height × width × depth). Confer also Appendix A for further details. Machines can be in different states which are communicated by their signal lights.

3.4.2 Production machines — during exploration phase

During the exploration phase the robots have to explore the unknown factory environment and identify the types of the different machine in the competition area. The frequency of machine types is defined in Table 2. The machines will indicate their different types by individual light signals. In total there are seven light signals possible with at least one LED switched on (no flashing lights). The light signals and the corresponding machine types are initially unknown. The Referee Box will assign every machine type to a light signal and publish it to the robots. The exploration phase starts with the announcement of the exploration game phase by the Referee Box.

Abbr.	Unit	x [m]	y [m]
M1	Machine 1	3.92	1.68
M2	Machine 2	3.92	3.92
M3	Machine 3	2.80	0.56
M4	Machine 4	2.80	1.68
M5	Machine 5	2.80	2.80
M6	Machine 6	2.80	3.92
M7	Machine 7	2.80	5.04
M8	Machine 8	1.68	1.68
M9	Machine 9	1.68	3.92
M10	Machine 10	1.68	5.04
R1	Recycling unit 1	5.40	0.20
R2	Recycling unit 2	0.20	5.40
T	Test station	5.40	5.40
	Late order insertion point / slot	0.20	3.60
D1	Delivery slot 1	5.34	3.15
D2	Delivery slot 2	5.34	2.80
D3	Delivery slot 3	5.34	2.45

Table 1: Coordinates of machines and field slots

Figure 2: Puck

Figure 3: Machine

An exploration information message is sent which defines the light signals of the machine types, e.g., red and green LED switched on indicate machine type T_1. If a robot perceives the red and green LED light switched on at machine M_1, the robot has to announce that machine M_1 is of type T_1 to the Referee Box. Therefore, the robot has to send a *machine identified message* to the Referee Box. Please consult the RoboCup Logistics League Referee Box Integrator's Manual for a detailed definition of the message types.

3.4.3 Production machines — during production phase

The default operating mode of all machines implies that only the green LED is turned on. This signals that the machine is ready for input. To enable the production process it is necessary to transport the pallet carrier accurately to the RFID device.

If a (intermediate) product is fed into a machine, the machine reads the RFID tag and checks whether or not the product can be processed and indicates the result by its signal light. If an appropriate product is fed to the machine, the yellow LED turns on indicating that the machine is processing the product (green and yellow LED on). If the machine needs another sub-assembly to generate an output, the green LED turns off and the yellow light indicates that the machine is waiting for the next sub-assembly. A consumed pallet carrier has to stay within the machine space borders (no part of the puck being outside the mark-up, note that if the overhead camera system is used there might be a small tolerance, but the team may not rely on this) until the production cycle of that very machine has been completed. Products resulting from violating this requirement are considered junk and will not be rewarded.

If the yellow LED is turned off after processing, further input materials are fed to the machine, the green LED indicates that the machine has finished the work order and the last carrier is

Optical Feedback	Operating mode
All LEDs turned off	The machine is physically offline, caused by a real error which should not happen during the competition.
Red LED turned on	The machine is out of order.
Green LED turned on	The machine is idle and ready.
Green and yellow LED turned on	The machine is processing or consuming the current data carrier.
Yellow LED flashing (at 2 Hz)	The machine detects wrong material. This can be caused by data carriers that are already consumed, sub-assemblies that do not fit to this machine type's work order or corrupted data carriers.

(a) Optical Feedback during production phase

Type	Distribution	Input	Output	(Final)processing time[s]
T_1	4 times	S_0 (raw-material)	S_1	$t_1 = 3$ to 8 sec
T_2	3 times	S_0; S_1	S_2; one consumed container	$t_2 = 15$ to 25 sec
T_3	1 times	S_0; S_1; S_2	P_1; two consumed containers	$t_3 = 40$ to 60 sec
T_4	1 times	S_0; S_1; S_2	P_2; two consumed containers	$t_4 = 40$ to 60 sec
T_5	1 times	S_0	P_3	$t_5 = 20$ to 40 sec

(b) Machine Types

Table 2: Production Machines

transformed to its corresponding output.

If a product is fed to a machine which is not appropriate, the machine reacts with a yellow light flashing at 2 Hz. A red light indicates that the machine is in an error state. In this case no products can be processed on the machine (for details cf. Section 6.4.1. Table 2 summarizes the operating modes of the production machines and the corresponding signal lights.

The machine always processes the required pallet carrier delivered last, all prior components will be consumed. All machines will start processing the data carrier as soon as it enters the machine zone as stated in section 3.1. They will change their operating mode according to Tables 2 to 5.

In order to complete the machines' work order the input materials have to be delivered one-by-one into the RFID device's action range. The sequence of delivered input materials is irrelevant (e.g., S_0-S_1 or S_1-S_0). Multiple data carriers in range of the device will result in erroneous behavior of the device. Consumption of materials, such as S_0 used in the production of S_2, will take 2 seconds. Unloading the machine can be done immediately after the operating mode changes away from processing. As long as the machines are used properly, they will not produce any junk. The distribution describes how many machines of the respective types will be randomly placed resulting in a total of 10 court machines.

Optical Feedback	Operating mode
All LEDs turned off	The machine is physically offline, caused by a real error which should not happen during the competition.
Red LED turned on	The machine is out of order
Green LED turned on	The machine is idle and ready.
Green and yellow LED turned on	The machine is processing the current data carrier.

Table 3: Recycling Unit

Optical Feedback	Stored data on the data carrier
Red turned on	This delivery gate is inactive.
Green turned on	This gate is active, namely the designated gate.
Yellow blinking	False delivery to active gate.
Red on, Yellow flashing (at 2 Hz)	False delivery to inactive gate.
Red, Yellow, Green turned on	Successful delivery

Table 4: Delivery Gates

3.4.4 Recycling unit

During the staged production process raw-material is transformed or consumed by the machines. To use consumed raw-materials again, the robots can use one of the two recycling units placed in the corners of the competition area. The recycling unit processes all supplied loading carriers back to raw-material (S_0) within 2 seconds. The optical feedback provided by the recycling unit differs from production machines and is shown in Table 3.

3.4.5 Delivery gates

If a variant of a final product is finished, it has to be delivered to the customer through one of the three delivery gates. Only if the machine signal successful delivery (all lights steadily on) points are awarded. This state will last until the puck is removed by the referee. The puck may no longer be used in the game. There will be only one active gate at a time. A gate is active between 60 and 180 seconds. After the gate switches, there is a grace period of 3 seconds in which delivery will still be accepted to the formerly active delivery gate. False deliveries to an active gate will be indicated by a flashing yellow light (e.g. taking a S_0 puck to the active gate) and false deliveries to an inactive gate by a steady red and blinking yellow light. In both cases, the puck will be taken out by the referee and it may no longer be used in production or delivered. In case of a delivery to an active gate, the team will be awarded with the points for the delivery; if the gate was inactive, no points will be awarded. If, however, a pallet carrier was not successfully delivered, the pallet carrier will remain where it is. See Table 4 for the possible delivery gate signal states.

3.4.6 Test station

The type of a sub-assembly can be determined at the test station in the corresponding corner of the competition area. The test station reads the RFID of the pallet carrier and visualizes the product type with the light signal as shown in Table 5.

Optical Feedback	Stored data on the data carrier
Green LED turned on	The station is ready to read the next data carrier.
All LEDs turned off	Consumed pallet carrier.
Yellow LED turned on	Raw-material (S_0)
Red and yellow LEDs turned on	Sub-assembly 1 (S_1)
Red LED turned on	Sub-assembly 2 (S_2)
Green LED flashing (at 2 Hz)	Finished product variant 1 (P_1)
Yellow LED flashing (at 2 Hz)	Finished product variant 2 (P_2)
Red LED flashing (at 2 Hz)	Finished product variant 3 (P_3)
All LED flashing (at 2 Hz)	Puck is out of game after delivery to (in)active gate

Table 5: Test Station

4 The Robotino system

All participants have to design their competition Robotinos within the following specifications. For a detailed technical description of the basic hardware, refer to the Appendix A.

Any kind of sensors can be changed or added to the Robotino platform. However, it is not possible to implement sensors that require modifications outside the Robotino area (e.g. Northstar, indoor GPS). It is furthermore strictly forbidden to implement any kind of RFID device into the Robotino. There must be no changes to the controller or mechanical system. The pushing device is defined as a passive, non-mechanical load handling attachment. The robots peripherals must not exceed the maximum total height of 0.7 m. Additional hardware (sensors, computing equipment, etc.) must be within a diameter of 0.65 m centered at the robot's rotational center. Additional hardware may only occupy up to 25% of this additional 0.15 cm wide ring around the robot. The only additional actuator allowed is one pushing device for pucks which can be the original or a modified one. It however must not exceed the following outside dimensions (including possibly added sensors): 0.25 m × 0.15 m × 0.05 m (width × depth × height). The puck must be visible from above while inside the pushing device.

It is allowed to install additional computing power on the Robotino. This may either be in form of a notebook/laptop device or any other computing device that suits the size requirement of the Robotino competition system. Furthermore, it is allowed to communicate with an additional computing device off-field. This device may be used for team coordination and/or other purposes. However, communication among the robots and the off-field device is not guaranteed during the competition.

4.1 Markings

All field robots must be assigned a single unique number out of the set $\{1,2,3\}$. The number must be written on the robot in one or more places and clearly visible from all directions, e.g. printed adhesive labels placed on top or the sides of the robot. The number must be the same as is announced in the beacon signal to the referee box (cf. Section 5.2).

To allow identification by the overhead camera system of the referee box, all robots must wear unique colored labels on top of the robot. The labels will be provided by the organizing committee. Teams must provide appropriate mounting capabilities such that the labels are freely and completely visible from above. The marker in 2013 will be round labels of approximately 20 cm in diameter printed on paperboard.

5 Communication

Robots have to operate autonomously, that is, without any human interference during the game. Communication among robots and to off-board computing units is allowed only using wifi (cf. Section 5.7). Communication is not guaranteed and may be unavailable during parts of the game. Interruptions must be expected and are no reason to pause or abort a game, even if they endure for long periods of the game.

5.1 Bandwidth allocation

No minimum bandwidth is guaranteed. The amount of communicated data over the wifi connection shall not exceed 2 Mbit/s. Even though the lower layers could provide for more bandwidth, the overall available frequency spectrum and wifi channels have to be shared, not only within our own league. Generally, a conservative use of bandwidth resources is advised. Should a frequently or endured exceedance of the bandwidth limit become known, or if the overall bandwidth limit must be reduced due to outer circumstances, the TC can monitor the network traffic and demand reduction in communicated data as necessary.

5.2 Referee box

The referee box (refbox) is a software system that runs on a system provided by the Organization Committee. It controls the overall game, monitors feedback from the robots, and awards points. It is instructed by an assisting human referee and keeps a log of all relevant game events. The final game report will be produced by the referee box. While we strive for a maximum of automation of this control task, we rely on the human referee for final judgment, in particular for border or under-specified cases, and will provide the largest set of override abilities feasible.

The refbox is the single point of instruction for robots during the game. After game setup has finished, game state information and orders are announced by the refbox. Commands must be acknowledged. In certain situations (for example during the exploration phase) for successful and true communication with the refbox points are awarded. The aim is to reduce human interference year by year to a minimum as to exhibit the widest autonomy during the game possible. Ultimately, the refbox should be able to fully control the game by itself, transforming all participants, team members, and visitors alike into pure spectators of the game, sometimes providing maintenance and crisis intervention when necessary.

The communication from the refbox to the robot is a datagram-oriented broadcast protocol based on Google protocol buffers[1] (protobuf). The protocol definition and technical parameters are described in detail in the RoboCup Logistics League Referee Box Integrator's Manual.

[1] Available at `https://code.google.com/p/protobuf/`

5.3 Remote control

Remote operation or instruction of any kind of the robots is forbidden at all times during a game. The only allowed interaction is for the start-up (cf. Section 6.2.3). Any failure to comply with this rule will lead to immediate disqualification of the infringing team.

5.4 Monitoring

Passive monitoring, i.e. receive-only communication from a base station of the robots' performance is allowed. However, the overall bandwidth limit may not be exceeded. If the referee has any reason to belief that a monitoring application might be used for instruction, he can demand the shutdown of the monitoring software (also refer to previous section on Remote Control).

5.5 Inter-robot communication

Robots currently active on the field can freely exchange any information that supports a coordinated team play. Robots not actively participating in the game, for example because they have been irrevocably removed from the current game, may not communicate with the other robots. It is forbidden to communicate with any sensors that are not physically attached to the robot, including, for example, but not limited to a camera aside the field. Likewise any off-robot actuator is forbidden.

5.6 Communication eavesdropping and interference

Communication of another team may neither be eavesdropped on nor be interfered with. Teams not currently active shall disconnect from the field access points.

Monitoring of bandwidth used or of possible misbehavior may only be performed by members of the TC or an appointed delegate. Any indication of misbehavior will be discussed by the team leader convention and may result in penalties or disqualification from the tournament.

5.7 Wifi regulations

In order to provide the optimal possible solution for wireless communication during the event, all teams are required to use the 5 GHz wifi equipment. They are furthermore required to connect their Robotinos wifi unit to the access point provided. All teams can also rely on wifi clients supplied by Festo but are not required to. A detailed description concerning the infrastructure can be found in Appendix A.2.4.

6 Game play

A match is defined by two contesting teams competing at two separated identical competition areas. Each team consists of a maximum of 3 robots. Each match consists of 5 minutes of setup time, a 3 minute exploration phase, and a 15 minute production phase. The three phases of the game are detailed below.

6.1 Environment setup

The physical distribution of the production machines is fixed. Their alignment will be randomized during the tournament setup. The machine type of each production machine will be randomized prior to each match. The processing time of each machine type will be determined in the same way, so the waiting time during a match will be static for each machine of all machine types (e.g. all T1 could have 7 seconds processing time). The active delivery gate will also be randomized prior to each match but during a match the active gate can switch. At the beginning, 20 raw materials (pucks in S_0 state) will be placed in the input storage initially spread as shown in Figure 1. The pucks may only be touched by a robot after the game has started. In particular, they may not be re-positioned for better alignment if they have been pushed or moved by a robot during the game.

6.2 Game phases

6.2.1 Team setup

No team member is allowed to enter the competition area prior to or during a match. All robots which are to participate in the game, need to be in the game area during setup. All robots are allowed to roam through the entire area, autonomously or teleoperated. However, no robot is allowed to touch any pallet carried during setup; infringements will be punished as *misbehaving robot*. The referee box will control the setup period. When the game starts, all robots need to be in the insertion area; no robot is allowed to be in the factory area at start-up. If a robot is not able to move to the insertion area, the team has to call upon the referee for *robot maintenance*.

6.2.2 Interruptions and robot maintenance

During a match and while the robot is active on the field no manual interference or manipulation of the robot in hardware, software, configuration, instructions, or whatsoever, is allowed.

Each team is allowed to maintain each robot once per game. The team has to call upon the referee for *robot maintenance*. The referee should judge the game situation carefully and should allow the robot to be taken out for maintenance, if the neither the calling team nor another robot would have any advantage in the current game situation from the take-out. An advantage would be, for instance, to take out a robot, if two robots are hindering each other. It is up to the discretion of the referee when to allow the robot maintenance.

After a robot has been taken out for the first time, it is handed to the team. The team can perform any repairs to the robot and/or the robot's software. The repair time may take at most 120 seconds. If the robot is not returned to the field in time, it is disqualified from the ongoing game.

To return the robot into the game, the team asks the referee to place back the robot onto the field. After the referee accepts the motion, the robot is placed in the robot insertion area. The team has 15 seconds quick setup time, which is limited to basic instructions like initial localization or software start-up.

The referee can interrupt the game at any point in time, but should do so rarely as not to interfere with the overall game flow (also cf. Section 6.4).

If a robot needs to be taken out for the second time, either on request or as decided by the referee, it is disqualified from the current game. It may no longer communicate with the still active robots and must be taken out of the competition area.

Sub-assembly	Deployable	Prerequisites	Result
S_0	T_1, T_2, T_3, T_4, T_5	none	S_1, P_3 or `consumed`
S_1	T_2, T_3, T_4	S_0	S_2 or `consumed`
S_2	T_3, T_4	S_0, S_1	P_1, P_2
`Late Order`	T_5	none	`Processed Late Order`

Table 6: The production table

6.2.3 Game start

All matches will start at the exact time scheduled by the organization team. From this point on, all robots must be located within the robot insertion area and the teams involved are allowed to start their robots to work autonomously within one minute (the game time will already start during this time). This can be done by issuing one single distinct command via any kind of interface or pressing a single button on the robot.

6.2.4 Exploration phase

With the start of the game, the exploration phase begins. For three minutes all machines indicate their type using steady light signals. The signal light encoding of machine types will be published by the referee box as described in Section 3.4.2 and in detail in the RoboCup Logistics League Referee Box Integrator's Manual. The robots are to roam the environment and announce the detected types to the referee box. Each properly reported signal scores 4 points, each signal reported wrongly will give −3 points penalty. A minimum of zero points will be accounted for this exploration phase. Production or moving pucks is not allowed during the exploration phase.

6.2.5 Production phase

With the end of the exploration phase, the actual production begins, which lasts 15 minutes. The referee box publishes all information regarding products and machines. This includes position, orientation, and type of each machine, as well as the different product variants that can be produced and the time windows for production of each variant.

6.3 Production portfolio

The production portfolio is presented in Table 6 and in Fig. 4, which presents the same information as a production graph.

6.3.1 The production table

Table 6 shows the production table for the main challenge; the multistaged production processes as well as the Late Order Challenge. The main challenge can be repeated as long as enough pallet carriers can be provided to complete the cycle. The different machine types are specified in Sect. 3.4.

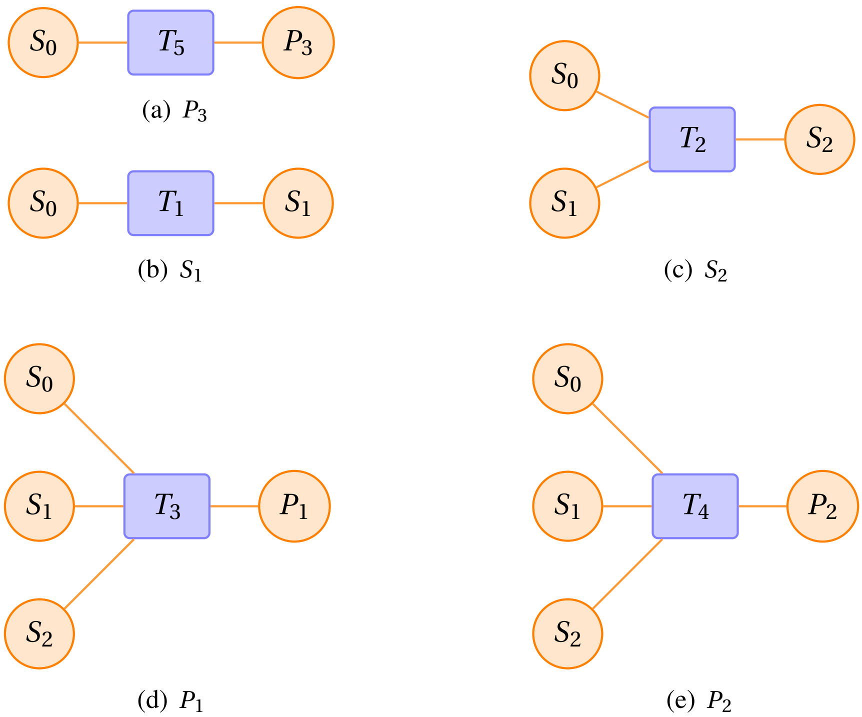


Figure 4: Production Chain Diagrams showing the machines and inputs relative to their outputs.

6.3.2 Late order

The late order challenge is derived from the former express good rule. It will be announced at a random time by the referee box in form of an updated order information message listing a new order for a P_3 product to be delivered within a specified time window of 120 sec length. The order will be added to the periodically order information message as soon as the delivery time window begins. The challenge requires a fast paced processing and delivery of the requested product in time. There will be two late orders per game at randomized times.

The P_3 product can be produced from any S_0 puck at a T5 machine at any time (it may be pre-produced). In order to allow visually triggered processing an S_0 will be placed in the late order insertion slot above the input storage as soon as a late order is announced. This S_0 puck will not be removed and can also be used for normal production. Note that, if the late order insertion slot already contains an S_0 when the next late order arrives an additional S_0 puck is placed in the input storage.

A robot may not be initially placed next to the insertion slot, but only in the robot insertion area (below the input storage).

6.4 During a match

Any referee can interrupt the match at any time. After the referee box is stopped, all robots have 5 seconds to stop all robot movement. Robots that do not stop within the time limit will be treated in the same way as misbehaving robots (cf. Section 6.2.2). The match time will be paused during the interruption.

Slot	Parameters	Demanded number of items
1	$N_{1,1}$, $N_{2,1}$, $N_{3,1}$	$N_{1,1}$ = Number of P_1 to produce in slot 1
		$N_{2,1}$ = Number of P_2 to produce in slot 1
		$N_{3,1}$ = Number of P_3 to produce in slot 1
2	$N_{1,2}$, $N_{2,2}$, $N_{3,2}$	$N_{1,2}$ = Number of P_1 to produce in slot 2
		$N_{2,2}$ = Number of P_2 to produce in slot 2
		$N_{3,2}$ = Number of P_3 to produce in slot 2
3	$N_{1,3}$, $N_{2,3}$, $N_{3,3}$	$N_{1,3}$ = Number of P_1 to produce in slot 3
		$N_{2,3}$ = Number of P_2 to produce in slot 3
		$N_{3,3}$ = Number of P_3 to produce in slot 3

Table 7: Production plan

6.4.1 Out-of-order

The downtime generator will take down machines randomly out of the pool containing production machines and recycling units. It will do so at random points of time. There will be 6 to 8 of such triggered events during a match. The machines affected will remain out of order for 30 to 120 seconds. Every machine can only be forced out of order once per match. If the machine turns offline during processing or consumption of mounted a pallet carrier, it will afterwards resume the process (extending the overall processing time by the down time). The refbox will adjust the down times of T5 machines not to collide with late orders to allow production and delivery within the late order time.

6.4.2 Production Plan

The referee box will announce a production plan. It will consist of the products to produce, the amount thereof, and delivery time slots for each product. There will be three time slots for the game, each lasting 5 minutes. Hence the first time slot will begin on game start and last until 4:59. The second slot starts at 5:00 and lasts until 9:59. The third time slots starts at 10:00 and lasts until 15:00. The later order is added to the production plan as soon as its delivery time slot starts (cf. Section 6.3.2).

Products which are delivered in the requested time slots score considerably higher than the ones delivered outside of the time slots. The production plan is shown in Table 7. The numbers indicate how many products of a certain type shall be produced in each time slot. Each number is in the range from 3 to 10.

In the round-robin phase (cf. Section 7.1) each team will get a randomized production plan. In the playi-off and final phases the production plan is the same for the two teams directly competing against each other but not for the other two competing teams. This is to avoid any potential influence on the result of prior knowledge of the later playing teams.

Sub-task	Main challenge	Points
Produce S_2	Finish the work order of a machine type 2	+4
Produce product variant P_1	Finish the work order of a machine type 3	+12
Produce product variant P_2	Finish the work order of a machine type 4	+12
Produce product variant P_3	Finish the work order of a machine type 5	+0
Delivery	Deliver one of the final product variants to the designated loading zone at the time specified in the order	+10
Wrong delivery	Deliver one of the final product variants to the designated loading zone out of the requested time range or after all products requested in the period have already been delivered	+1
False delivery	Deliver an intermediate product	0
Recycle	Taking a consumed material from a machine that completed its work cycle to the recycling machine	+5

(a) Scoring scheme for the main challenge

Sub-task	LOC - Late Order Challenge	Points
Delivery of LO	Deliver the processed late order (LO) to the active delivery gate in time.	+20

(b) Scoring scheme for the late order challenge

Reported	Exploration Phase	Points
Correctly	Correctly determine a machine type and report it successfully to the refbox	+4
Incorrectly	Wrongly reported machine type	-3
Round Total	A maximum of 40 points can be achieved by correctly reporting all ten field machines. A minimum of 0 points is awarded.	0 – 40

(c) Scoring scheme for the exploration phase

Table 8: Scoring Scheme

7 Tournament

7.1 Tournament Scoring Specifications

Round-Robin phase There will be three stages in the tournament. The first stage is a group phase and will be played as a round-robin. The best 4 teams of the round-robin stage will advance to a playoff round. The best 2 teams of this phase play the final game.

At the round-robin stage, the teams will receive the true points they scored by delivering and producing goods during the competition. The points will be accumulated in this phase and the teams will be ranked according to the accumulated points in descending order.

Playoffs At the playoff stage, the scoring scheme will be different. As each team in this phase directly competes with an opposing team, the team that scores more points as the direct opponent, will be announced as the winner and 3 points will be awarded to this team. A loss will be awarded with 0 points. Additionally, if both teams are unable to score any points during the match by delivering or producing goods, both teams will receive 0 points. In case of a draw within the playoffs, the game time will be extended by 5 minutes unless both teams scored zero points. This will be announced by the refbox instead of a game closed message. If this extension leads to a draw too the overall regular points of the teams will determine the match winner. If the overall points are equal too, a direct comparison between the teams in question will decide. If this fails to resolve the situation, the teams will approach a coin toss to determine the winner.

Finals. The best 2 teams of the playoff phase will advance to the finals. The two teams compete directly in concurrent games. The team that scores more points after the regular game time wins. If there is no winner after the regular time, the game continues for 5 more minutes. If after this time there is still no winner, a coin toss will decide.

The detailed seeding will be created at the event. Although the idea is to allow each participant to challenge each other team the league can be adjusted to meet time requirements.

7.2 Task fulfillment

Table 8 provides the itemized clearance of all task related processes and their scoring.

7.3 Penalties

The catalog in Table 9 represents the decision basis for the referees without being exhaustive or binding. The abidance of these rules will be monitored by at least two referees. One “field” referee will overlook the competition area. The field referee is allowed to enter the area at any time. Accidental moving of a puck or similar unintended tampering resulting from the referees presence on the field must be coped with. A second "station" referee operates the control station for the referee box to issue the initial start command and monitor the game flow and the correctness of the digital representation and automatic scoring.

Issue	Sanction
Premature movement	No robot is allowed to move until the referee announced the start of the match The faulty robot will be grounded for 2 minutes.
Damaging factory equipment	Theoretical damage to the real factory equipment as a result of collisions and negligent actions. This behavior will be punished as a minor rule break.
Not showing up	A team not showing up at all. The team will be removed from the tournament unless the team leader can provide a sincere explanation.
Manual Interference	A manual interference of a team, i.e. touching a robot without the referee's permission, during the game will be punished as a major rule break.
Breaking a minor rule	A rule infringement with minor impact on the team performance or competition mechanics. Upon decision of the referee, 25 % of the scored points of the team at the time of the infringement will be deducted, at least 1 point.
Breaking a major rule	A rule infringement with considerable impact on the team performance or competition mechanics. Upon decision of the referee, 50 % of the scored points of the team at the time of the infringement will be deducted, at least 5 points.
Arguing with the referee	There will be no discussions during a match. Each team can make a motion to protest a certain match and its result which will be dealt with after the match. There will be a warning. Continued disregard will result in a time punishment to the team's current or next match.
Disregarding rules of conduct	Following the rules of conduct should be self-explanatory Upon disregard, the referee will impose sanctions ranged from time punishments to the team's complete removal from the tournament.

Table 9: Infringements

7.4 Technical Challenge

Within the league, the technical advances should be documented from year to year. Therefore, the Technical Challenge is introduced. Each team should prepare for participating in any number of the following tasks. However, participation has no influence on the normal game results, but the winner will be awarded by a certificate.

Navigation and collision avoidance. The single robot is to show that it avoids other obstacles and robots while moving along specified points. Therefore the robot must drive from the robot insertion area to the delivery zone within 60 seconds. However, the paths between the robot insertion area and the delivery zone will be blocked randomly by static obstacles and the robot must not touch any of the obstacles. For touching an obstacle, the team receives a penalty. The fastest team with the fewest penalty points to reach the delivery zone wins this challenge. All other teams are ranked according to how fast they were and how many penalties they conceived. Initially, the robot will be placed by a team leader of a different team anywhere in the robot insertion area. The team has 15 seconds to perform a quick setup after the robot has been placed. The robot has completed the challenge as soon as it touches the delivery zone at any point. In 2013, the robotino transport cases will be used as static obstacles. The total number of obstacles will be the same for all teams. Possible distributions of the obstacles will be defined by the team leaders before the challenge starts (e.g. 6 possible distributions). A roll of dice will decide the actual distribution of obstacles.

Whack-a-Mole. A single robot is placed by a team leader of a different team anywhere in the robot insertion area. The team has 15 seconds to perform a quick setup after the robot has been placed. It then has to detect the single shining signal unit on the play field. The regarding unit will have all lights - green,yellow, and red - switched on. As soon as the robot enters the related machine area of that signal, the signal unit has been marked as whacked, is switched off and another random signal unit is switched on. A robot is inside a machine area if and only if its center is within the area. This is detected by the visual tracking system if available, or the human referee. Participating robots must therefore be equipped with the appropriate markers. The goal of the challenge is to switch off as many signal units as possible within a given time frame. Teams are ranked according to the number of turned-off signals.

Free challenge. Each team will be given 5 minutes to showcase their robot team, e.g. show some new robotics developments. This may involve any task as long as it is performed with at most three Robotino robots within the competition area. For the time of the free challenge, any software or hardware modification is allowed, even though otherwise disallowed in the regular competition. This may be used to showcase ideas for future developments of the league and to highlight particular advances in the system of the presenting team.

The team leaders of non-presenting team will judge the performance and rate it with points between 0–10. The team with the most sum of points will win this challenge. The other teams are ranked in decreasing point order.

Conducting the Challenges. The technical challenges are conducted in the following way. The team leader of each participating team agree on a date and time during the tournament for the

Technical Challenge in their first team leader Meeting. For each type of challenge, a time slot is assigned in which teams can participate once in the challenge. Each team can register for any of the challenges. All team leaders have to be present at the time of the challenge to judge the other teams. The OC is responsible to conduct the Technical Challenge and can appoint team leaders to support in conducting the challenges. Each challenge will have a separate ranking. In each ranking, the team on the last rank will receive 0 points, the last-but-one ranked team will receive 1 point etc. The points for each ranking will be added and the team with the most points accrued over all challenges will be awarded with the Logistic Leagues Technical Challenge Award.

A Engineering Reference

A.1 The Mobile Robot System

The mobile robot system Robotino is a platform with an open mechanical interface for the integration of additional mechanical devices and an open electrical interface to integrate easily additional sensors or motors of devices. Power is supplied via two 12 V lead gel batteries which permit a running time of up to two hours. The scope of delivery likewise includes a charging device. Robotino is driven by 3 independent, omni-directional drive units. They are mounted at an angle of 120° to each other. The three omni-directional drive units of Robotino, defines the robot as being holonomic, meaning that the controllable degrees of freedom equals the total degrees of freedom of the robot. The drive units are integrated in a sturdy, laser welded steel chassis. The chassis is protected by a rubber bumper with integrated switching sensor.

A.1.1 Robot Dimensions

Diameter: 370 mm

Height including housing: 210 mm

Overall weight: approx. 11 kg

Maximal payload: about 6 kg

A.1.2 Drive Unit

Each of the 3 drive units consists of the following components: DC Dunker motor with nominal speed of 3600 rpm and nominal torque of 3.8 N cm. Integrated planetary gear unit with a gear ratio of 4:1. Omni-directional wheels of diameter of 80 mm. Toothed belt with gear wheels providing a transmission ratio of 4:1. Altogether this provides a gear transmission ratio of 16:1. Incremental encoder with a resolution of 2048 increments per motor rotation. The motor and gear arrangement is shown in Figure 5.

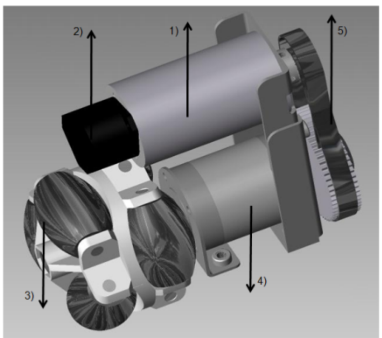


Figure 5: Drive unit with motor (1), encoder (2), omni-directional wheel (3)

The motor speed will be controlled via a PID controller implemented on a Atmel microprocessor of the controller board of Robotino.

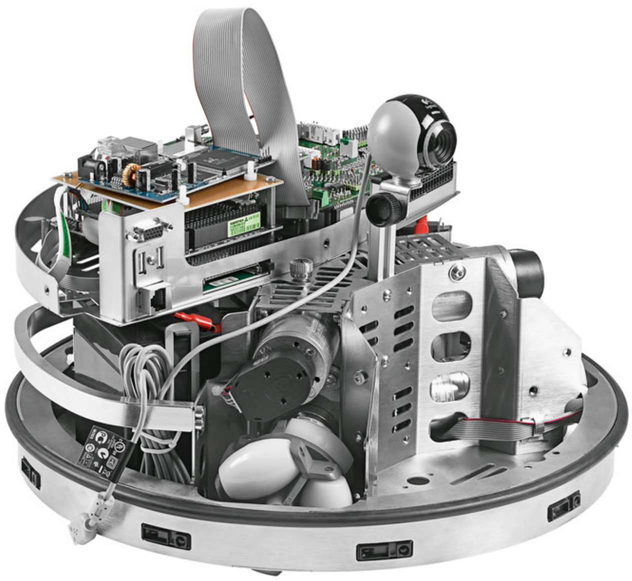
A.1.3 Sensors

Robotino is equipped with 9 infrared distance measuring sensors which are mounted in the chassis at an angle of 40° to one another. Robotino can scrutinize all surrounding areas for objects with these sensors. Each of the sensors can be queried individually via the controller board. Obstacles can thus be avoided, clearances can be maintained and bearings can be taken on a selected target. The sensors are capable of accurate or relative distance measurements to objects at distances of 4 cm to 30 cm. Sensor connection is especially simple including just one analogue output signal and supply power. The sensors' evaluation electronics determines distance and read it out as an analogue signal. The anti-collision sensor is comprised of a switching strip which is secured around the entire circumference of the chassis. A reliably recognizable signal is thus transmitted to the controller unit. Collisions with objects at any point on the housing are detected and, for example, Robotino is brought to a standstill. The inductive proximity sensor is supplied as an additional component. It serves to detect metallic objects on the floor.

The inductive proximity sensor must be attached to the mounting furnished for this purpose, and must be connected to the I/O interface. The output voltage is 0 V to 10 V. The sensing range is 0 mm to 6 mm. Path tracking can also be implemented with the two included diffuse sensors. Flexible fiber optic cables are connected to a fiber-optics unit which works with visible red light. Reflected light is detected. Different surfaces and colors produce different degrees of reflection. However, gradual differences in reflected light cannot be detected. The sensors must be attached to the mountings furnished for this purpose, and must be connected to the I/O interface.

Robotino is equipped with a color webcam. The webcam is equipped with a USB interface. Also, there will be integrated a digital Gyroscope providing a high accuracy of the odometry in the virtual factory.

A.1.4 Controller Board – 2010 Revision



The controller housing is connected to the wiring in the chassis via one plug-in. Thus you can easily take off the controller housing and you have direct access to the mechanical system. The controller system of Robotino is divided into two parts – an embedded PC and a micro-controller interface card: The Controller of Robotino consists of an embedded PC and a micro-controller interface board. The main controller is the embedded PC 104 plus controller with the 500 MHz processor AMD LX800. The PC has a SDRAM of 128 MB and is provided with a 1 GB flash card. There are numerous communication interfaces on board:

- 2 × 100 Mbit/s Ethernet
- 2 × external USB, 1 × on-board USB-connector
- 2 × RS232
- 1 × Parallel port and 1 × VGA port
- Wireless LAN Access Point following the standards 802.11/b/g.
- The access point can be switched into a client mode. As an option you may use WPA2-coding.

A.1.5 Software

Preinstalled is an Ubuntu Linux operating system with real time kernel running on the embedded PC 104. The main part of the controller is the Robotino server, a real time Linux application. It controls the drive units and provides interfaces to communicate with external PC applications via wifi. There is an API with libraries which allow you to create applications for Robotino in numerous programming languages:

- C++ and C
- C#
- .net and JAVA
- MatLab and Simulink
- Labview

You may find a lot of examples concerning using the different API's in the public forum "Open-robotino" at `http://www.openrobotino.org`.

Robotino View Robotino View is a graphical programming language with numerous prepared function blocks you can easily connect via input and output parameters to establish more complicated function diagrams. You can use these function diagrams as subprograms for more complex programming sequences. To build up general programming sequences Robotino View follows the international standard IEC 61131-3. You may run Robotino View on an external PC and Robotino View communicates directly with the Robotino Server on the PC 104 via wifi in order to control the robot system. The function blocks receive a direct feedback of the hardware components such that you can live interact with the robot system. On the other hand you can download Robotino View programs into the PC 104 in order to run the applications completely autonomously. There is a well defined interface to develop own function blocks in C++ or Lua.

Image Processing Depending on the Robotino version it might happen that the standard web camera only provides image data by JPEG compression. This is very useful if you run your image processing on the PC and exchange the data via wifi. However, if you would like to run your image processing algorithms on the Robotino controller then the processor is not powerful enough in order to pack and to unpack the image data in a reasonable time. Thus we recommend for running image processing algorithms on the Robotino controller to use a camera without JPEG compression, e.g. use the low cost Logitech web camera C250.

A.2 Machines

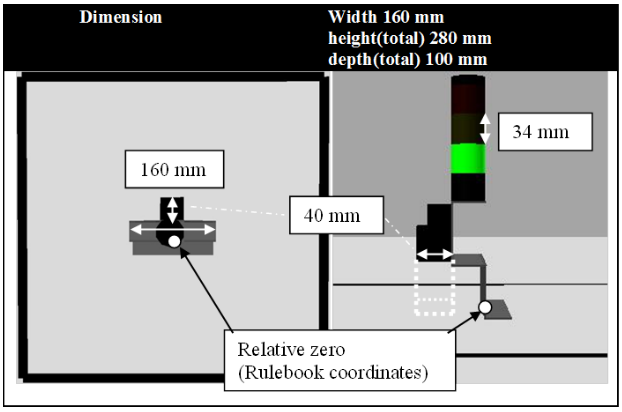


Figure 6: Ranges and dimensions of a signal

A.2.1 Brackets

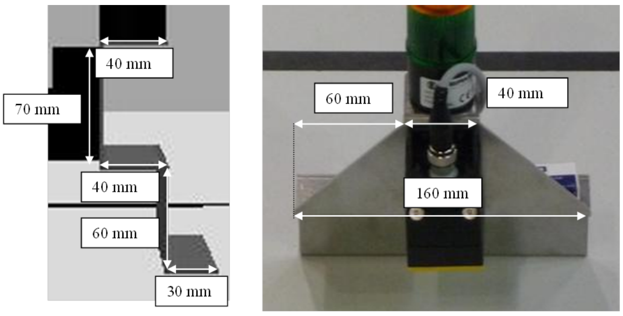


Figure 7: Ranges and dimensions of the supporting brackets

A.2.2 Signal

Dimension & diameter	36 mm
height(total)	147 mm
Segment height	34 mm, including 5 mm unlighted border
Lifespan	max. 50.000 h
Connector	Bottom, 2 m supplied Compatible to the I/O-Terminal of MPS(r) units.
Safety	IP65
Voltage	24 V
Current	3 × 40 mA
Kind of current	DC
Operating mode	−20 °C to 50 °C
Signal type	Static LED
Signal	Ultra-bright LED
Source	Festo # 549843

Table 10: Technical specification of the signal

A.2.3 RFID device

Technical data of the read/write head	Housing rectangular
Housing and working dimensions	40 mm × 40 mm with the centered RFID tag.
Housing height	65 mm
Operating voltage	DC
Housing material Plastic	PBT-GF30-V0, black
Material active face Plastic	PA6-GF30, yellow
Operating voltage	10 V DC to 30 V DC
DC rated operational current	≤ 80 mA
Data transfer	inductance coupling
Working frequency	13.56 MHz
Radio communication and protocol standards	ISO 15693
Read/write distance	max. 115 mm
Output function	4-wire, read/write
Electrical connection	Connectors M12 × 1
Vibration resistance	55 Hz (1 mm)
Shock resistance	30 g (11 ms)
Protection class	IP67
Operating voltage display	LED green

Table 11: Technical specification of the RFID device

A.2.4 Wifi equipment

Festo AP	LANCOM L-322agn
Transfer rate	Up to 108 Mbit s^{-1}
Data link protocol	802.11 a/g/n
Frequency	5.0 GHz
IP-distribution	172.26.200.xxx for LAN clients(DHCP) 172.26.101.xxx for the Robotino devices 172.26.1.xxx for Robotinos
Subnet Mask	255.255.0.0
Encryption	Unsecured
SSID	Separated for both teams: RobotinoEvent.1 RobotinoEvent.2
Festo Clients	3COM WL-560
Power Supply	Clients: 12 V, 1 A, Most Laptops cannot power them via USB!
Connector	Ethernet

Table 12: Technical specification of the wifi equipment

A.2.5 Data carrier

Dimension	⌀20 mm
Height	2.5 mm
Data transfer	inductance coupling
Working frequency	13.56 MHz
Memory	read/write
Memory type	EEPROM
Memory size	128 B
Freely usable memory	112 B
Number of read operations	unlimited
Number of write operations	105
Typical read time	2 ms B^{-1}
Typical write time	3 ms B^{-1}
Radio communication and protocol standards	ISO 15693

Table 13: Technical specification of the data carrier