RoboCup Logistics League (RCLL)

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History

Engagement of Festo

Festo Didactic

- Member of the Festo Group
- Training and Consulting for all sectors of industrial production related on industrial standards and customer needs
- Offers perfect training solutions in all technologies of Mechatronics since 50 years
- Over 500,000 hours of Technical Training and Seminars in 26 languages – worldwide
Engagement of Festo

- **Sponsor** since 2006
- **Gold Sponsor RoboCup 2009** in Graz with organization of demo challenge: Festo Hockey Challenge (6 teams)
- **Global Sponsor RoboCup 2010** in Singapore with organization of Demonstration Competition FLC: Festo Logistics Competition with 9 teams from: EG, DE, HU, KR, SG, TW
- **Global Sponsor RoboCup 2011** in Istanbul with organization of Demonstration Competition: FLC Festo Logistics Competition with 15 teams from: BR, EG, DE, HU, KR, MX, UAE
History

Logistics League – Localization in RoboCup

**Soccer**
No humans, highly dynamic, cooperative and adversary, very attractive

**@Rescue**
No Humans, Robot navigation in difficult terrain, variable tasks

**RCLL**
Industrial production logistics

**Service @Home**
Human-Robot Interaction, variable tasks

**Industry**
Environment adapted production, semi-structured
Two separate fields – one per team

Fixed product workflows for two types of products

Determine machine function while producing
Introduction of the Logistics League Referee Box

- Allow (virtually) unlimited computing power
- Separate exploration and production phases
- Three product types, static orders (always open)
History

RoboCup Logistics League 2014

- Fully dynamic and randomized order schedules
- Merged both fields into a single shared workspace
- Randomized assignment of the machines to the teams
History

RoboCup Logistics League 2015

- Physical processing machines based on Festo MPS
- Introduce small amounts of manipulation/handling
- Increase from 3 to almost 250 product variants
- Use existing slightly uneven floor (no special lab floor as before)
Machines no longer at fixed positions

Navigational challenge: still align precisely

Vision challenge: recognize MPS-based machines

Task planning: more product variants, strict time windows
RoboCup Logistics League 2016

- In-factory manufacturing logistics in Smart Factory
- Maintain and optimize material flow in production
- Multi-Robot planning/scheduling and coordination

RCLL provides a complex benchmark domain focusing on efficient planning/scheduling in a Smart Factory
Game Basics

Task: In-factory production logistics
Goal: variant production
Two teams playing on common field
Each team has 3 robots
Multi-robot coordination task

Game Phases

Exploration phase: 4 minutes
Task: detect and report machines
Production phase: 15 minutes
Task: produce and deliver goods
Logistics League 2016

Competition Environment
The competition field is divided into 24 zones.
Size of the field: **5.9 m x 12 m**
The right hand side is assigned to team 1 and the left hand side to team 2.

For each game the machines are randomly placed into zones such that the machines are symmetric to the y-axis.

The machines assigned to the teams might be randomly swapped to the other side.
Product Components

- **Base Elements**

- **Ring elements**

- **Caps**

Almost 250 product variants

Product type is determined by
- base element
- number and sequence of rings
- colour of cap
Production Machines

**Common**
- Based on Festo MPS®
- Marker to identify machine (type and side)
- Conveyor with input and output area
- Signal light to indicate state
- Internal power and air supply
- W-LAN communication to robots and Referee Box

**Add-on**
- Improvement of the input and output area
- Barcode Reader to identify product components
Production Machines – Base Station (BS)

... acts as a dispenser of base elements.

The application module consists of three magazines yielding the base elements. There is a single BS per team.

The base elements might have colour stripes to improve visual identification.
Production Machines – Ring Station (RS)

... mounts one or two coloured rings on an intermediate product.

The application module consists of two vacuum pick & place units with separate unique colours.

There is an additional slide which must be fed by one or two base elements to simulate the adjustment of machines.

There are two RS stations per team.
Production Machines – Cap Station (CS)

... mounts a cap as the final step in production on an intermediate product.

The application module consists of a vacuum pick & place module.

There are two CS stations per team.

Procedure:
- The shelf is filled with arbitrary base elements with a cap by a team member. One of them must be taken by the robot to the machine and is then disassembled and the cap is buffered in the machine.
- The cap is then mounted on the next intermediate product taken to the machine.
Production Machines – Delivery Station (DS)

... accepts only completed products.

The application module consists of three slides.

The robot has to choose the proper one (specified by the Ref-Box) for a specific order.

The delivered products are verified by either the referees or an automated external vision system.

There is one DS per team.
Exemplary Production Chain

**C0 Production**

- Retrieve base with cap from shelf at CS
- Prepare CS to retrieve cap
- Feed base into CS
- Discard cap-less base
- Prepare BS to provide black base
- Retrieve base from BS
- Prepare CS to mount cap
- Feed black base to CS
- Retrieve black base with cap from CS
- Prepare DS for slide specified in order
- Deliver to DS
Exemplary Production Chain

**C0 Production**

- Retrieve base with cap from shelf at CS
- Prepare CS to retrieve cap
- Feed base into CS
- Discard cap-less base
- Prepare BS to provide black base
- Retrieve base from BS
- Prepare CS to mount cap
- Feed black base to CS
- Retrieve black base with cap from CS
- Prepare DS for slide specified in order
- Deliver to DS
**Exemplary Production Chain**

**CO Production**

- Retrieve base with cap from shelf at CS
- Prepare CS to retrieve cap
- Feed base into CS
- **Discard cap-less base**
- Prepare BS to provide black base
- Retrieve base from BS
- Prepare CS to mount cap
- Feed black base to CS
- Retrieve black base with cap from CS
- Prepare DS for slide specified in order
- Deliver to DS
Exemplary Production Chain

**CO Production**

- Retrieve base with cap from shelf at CS
- Prepare CS to retrieve cap
- Feed base into CS
- Discard cap-less base
- Prepare BS to provide black base
- Retrieve base from BS
- Prepare CS to mount cap
- Feed black base to CS
- Retrieve black base with cap from CS
- Prepare DS for slide specified in order
- Deliver to DS
Exemplary Production Chain

**CO Production**
- Retrieve base with cap from shelf at CS
- Prepare CS to retrieve cap
- Feed base into CS
- Discard cap-less base
- Prepare BS to provide black base
- Retrieve base from BS
- Prepare CS to mount cap
- Feed black base to CS
- Retrieve black base with cap from CS
- Prepare DS for slide specified in order
- Deliver to DS
Exemplary Production Chain

**C0 Production**
- Retrieve base with cap from shelf at CS
- Prepare CS to retrieve cap
- Feed base into CS
- Discard cap-less base
- Prepare BS to provide black base
- Retrieve base from BS
- Prepare CS to mount cap
- Feed black base to CS
- **Retrieve black base with cap from CS**
- Prepare DS for slide specified in order
- Deliver to DS
Exemplary Production Chain

**CO Production**
- Retrieve base with cap from shelf at CS
- Prepare CS to retrieve cap
- Feed base into CS
- Discard cap-less base
- Prepare BS to provide black base
- Retrieve base from BS
- Prepare CS to mount cap
- Feed black base to CS
- Retrieve black base with cap from CS
- Prepare DS for slide specified in order
- Deliver to DS
Exemplary Robot Platform

- Custom Gripper
- Signal Camera
- Additional Laptop
- Conveyor Camera
- Marker Camera
- Wifi
- Internal Computer
- Laser Scanner
- Common Platform Festo Robotino 3
Semi-autonomous Referee Box – MES System for Production

Game Control
- Maintain game state/score

Communication
- Publish production plans

Data Recording
- Collect benchmarking data

Visualization and Instruction
- Referee/visitor monitoring

Machinery Control
- Instruct field machines
Rulebook 2016

Game Phases - Exploration

Setup (5 Minutes)
- Final preparation time for the teams.

Game Start with Exploration Phase (max. 4 minutes)
- All robots must be in the insertion area at start of this phase
- All robots must be connected to the Ref-Box.
- Robots have to explore their machines: zone ID, machine ID (marker), light pattern, type string
- Each properly reported machine type scores: 8 points
- Wrongly reported machine types will cause: -6 points
- Minimum will be 0 points after the exploration phase
- After exploration phase robots receive above information for all machines
Production Phase (15 minutes)

- The Ref-Box will announce orders throughout this game phase:
  Product type, amount, time slot for delivery

- For delivery the Ref-Box will announce the delivery gate which has to be used.

- Communication Robot → BS station: Colour of base element and side of delivery.

- CS and RS stations must be at first adjusted:
  - CS station requires an arbitrary base element with the assigned cap.
  - The RS station requires for some colour (defined by the Ref-Box) one or two base elements.
# Game Phases – Production: Status of Machines

<table>
<thead>
<tr>
<th>Optical Feedback</th>
<th>Operating mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>All LEDs turned off</td>
<td>The machine is physically offline, caused by a real error.</td>
</tr>
<tr>
<td>Red LED turned on</td>
<td>The machine is out of order</td>
</tr>
<tr>
<td>Green LED turned on</td>
<td>The machine is in idle and ready status.</td>
</tr>
<tr>
<td>Green LED flashing</td>
<td>The machine has accepted the setup command (flashes for up to 3 seconds).</td>
</tr>
<tr>
<td>Yellow LED turned on</td>
<td>The machine is currently busy.</td>
</tr>
<tr>
<td>Red and yellow LED flashing (2Hz)</td>
<td>Operation error, for example because a product was fed without proper setup of the machine.</td>
</tr>
</tbody>
</table>
## Game Phases – Production: Scoring

<table>
<thead>
<tr>
<th>Sub-Task</th>
<th>Production Phase</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finish CC₁ step</td>
<td>Finish the work order for a colour requiring one additional base</td>
<td>+ 5</td>
</tr>
<tr>
<td>Finish CC₂ step</td>
<td>Finish the work order for a colour requiring two additional bases</td>
<td>+10</td>
</tr>
<tr>
<td>Finish C₁ pre-cap</td>
<td>Mount the last ring of a $C₁$ product</td>
<td>+10</td>
</tr>
<tr>
<td>Finish C₂ pre-cap</td>
<td>Mount the last ring of a $C₂$ product</td>
<td>+30</td>
</tr>
<tr>
<td>Finish C₃ pre-cap</td>
<td>Mount the last ring of a $C₃$ product</td>
<td>+80</td>
</tr>
<tr>
<td>Mount Cap</td>
<td>Mount the cap on a product</td>
<td>+ 2</td>
</tr>
<tr>
<td>Delivery</td>
<td>Deliver a final product to the designated gate at the given time</td>
<td>+ 20</td>
</tr>
<tr>
<td>Late delivery</td>
<td>An order delivered within 10 seconds after an order is awarded a reduced score. For delivery time slot end $T_e$ and actual delivery time $T_d$ in seconds the reduced score is given by $20 - T_d + T_e$,</td>
<td>[10,..,20]</td>
</tr>
</tbody>
</table>
## Game Phases – Production: Scoring

<table>
<thead>
<tr>
<th>Sub-Task</th>
<th>Production Phase</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wrong delivery</td>
<td>Deliver one of the ordered final product variants to the designated loading zone out of the requested time range</td>
<td>+6</td>
</tr>
<tr>
<td></td>
<td>Deliver one of the ordered final product variants to a wrong designated loading zone at the time specified in the order</td>
<td>+4</td>
</tr>
<tr>
<td></td>
<td>Deliver one of the ordered final product variants to a wrong designated loading zone out of the requested time range</td>
<td>+2</td>
</tr>
<tr>
<td>False delivery</td>
<td>Deliver an intermediate product</td>
<td>0</td>
</tr>
<tr>
<td>Obstruction Penalty</td>
<td>Deliver a workpiece to a machine, which belongs to the opposing team</td>
<td>-2</td>
</tr>
</tbody>
</table>
Game Phases – Production: Filling Magazines and Shelf

- Each team must define one member being responsible for refilling the magazines and the shelf of the Cap station
Maintenance of Robots

- During a game a robot may be taken out for maintenance. Maximum time = 2 minutes. Referee must confirm. Otherwise, the team gets a minor penalty.

- Setup time after replacing the robot ≤ 15 seconds

- Referee may take out a robot if it is not moving at all for more than 2 minutes.

- If a robot must be taken out a second time then the robot is disqualified for the current game.
Pushing of Robots

- When a **pushing foul** is detected the responsible team has to restart their involved robot at the insertion zone again. A **penalty restart** counts like a maintenance time out. The other team can decide within 10 seconds to restart their involved robot in the insertion zone without it counting as a penalty restart.

- Pushing occurs only between robots of different teams.

- During driving robots must try to avoid physical contact with robots from the opposing team.

- Whenever a robot produces direct physical contact with another robot while moving, it must immediately stop movement in that direction (and choose a new direction for movement). Otherwise a **pushing foul** will be called.

- All robots are allowed to enter the input- and output area of any MPS station, but **robots must not obstruct opposing robots which intend to approach their assigned station**. If a robot cannot follow this rule, a **pushing foul** will be called.
Referees

Each participating team of the tournament must provide at least two team members which act as referees. These referees must be announced at the beginning of the tournament and are fixed throughout the whole tournament (unless the participant drops out of the tournament, e.g. because of illness).

Each game requires 3 referees. One referee will operate and oversee the referee box. Two field referees observe the field, announce rule violations, and communicate with the teams and Ref-Box referee. Each field referee is assigned to a particular field half.

Field referees are responsible for calling a pushing foul and for making decision whether a team is allowed to take out a robot for maintenance. Field referees are also responsible for removing fallen products from the playing-ground.

Rule issues are not to be discussed during a game. Referee decisions are binding for the game. After the game a team may protest following a well defined procedure.
RCLL Organization

www.RoboCup-Logistics.org

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