ACTIVE LEARNING EXPERIENCE IN SIMULATION CLASS USING A LEGO®-BASED MANUFACTURING SYSTEM

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Contents

HIGHLIGHTS:

- An educational project launched in a course of manufacturing systems for mechanical engineering.
- The main idea is to exploit the student's interaction with a LEGO® Manufacturing System.
- The experience shows that the teaching methodology is successful and can be replicated.

TABLE OF CONTENTS:

1. Educational Scenario

CONTEXT:

- Creating, building and validating a simulation model of a system that cannot be observed represent a real obstacle for student learning.
- Recently, the role of experience has gained attention in Higher Education.

"students use the game as an experimental setting just like one would a simulation"

Padilla et al. (2016)

"creativity doesn't come from laughter and fun: it comes from experimenting, taking risks, and testing the boundaries."

Resnick and Robinson (2017)

Padilla, J. J., C. J. Lynch, S. Y. Diallo, R. J. Gore, A. Barraco, H. Kavak, and B. Jenkins. 2016. "Using simulation games for teaching and learning discrete-event simulation". In 2016 Winter Simulation Conference (WSC), 3375–3384.
Resnick, M., and K. Robinson. 2017. Lifelong kindergarten: Cultivating creativity through projects, passion, peers, and play. MIT Press.

1. Integrated Manufacturing Systems Course

GOAL:
The course will allow students to analyze the performance of complex manufacturing systems using simulation models.

EXPECTED OUTCOMES:
A classwork module will be delivered in **Computer Lab** to allow students to use state-of-the-art software for simulation of manufacturing systems. In **Physical Lab** students will be required to make experiments oriented to accomplish problem solving activities in the **Project Work**.

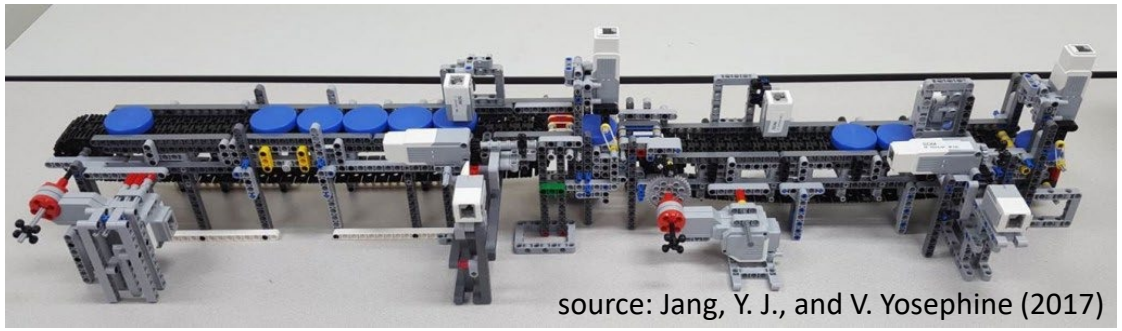
3. State of the Art

LEGO® BASED INDUSTRIAL ENGINEERING EDUCATION:

- Sanchez and Bucio (2012) based a course on a manufacturing system realized with LEGO® to teach the principles for controlling discrete event systems to postgraduate

- Syberfeldt (2010) described a practical exercise to teach simulation-optimization to students using a physical LEGO® factory simulating the refinement of raw materials. The main purpose was to make students understanding the benefits of performance evaluation.

- Jang and Yosephine (2017) developed a LEGO® MINDSTORMS® flow line consisting in one feeder and two machines with an intermediate buffer.



source: Jang, Y. J., and V. Yosephine (2017)

Sanchez, A., and J. Bucio. 2012. "Improving the teaching of discrete-event control systems using a LEGO manufacturing prototype". IEEE Transactions on Education 55(3):326–331.
Syberfeldt, A. 2010. "A LEGO factory for teaching simulation-based production optimization". In Industrial Simulation Conference, ISC'2010, June 7-9, 2010, Ramada Plaza Hotel, Budapest, Hungary, 89–94. EUROSIS-ETI.
Jang, Y. J., and V. Yosephine. 2017. "Teaching stochastic systems modeling using lego robotics based manufacturing systems".

3. State of the art

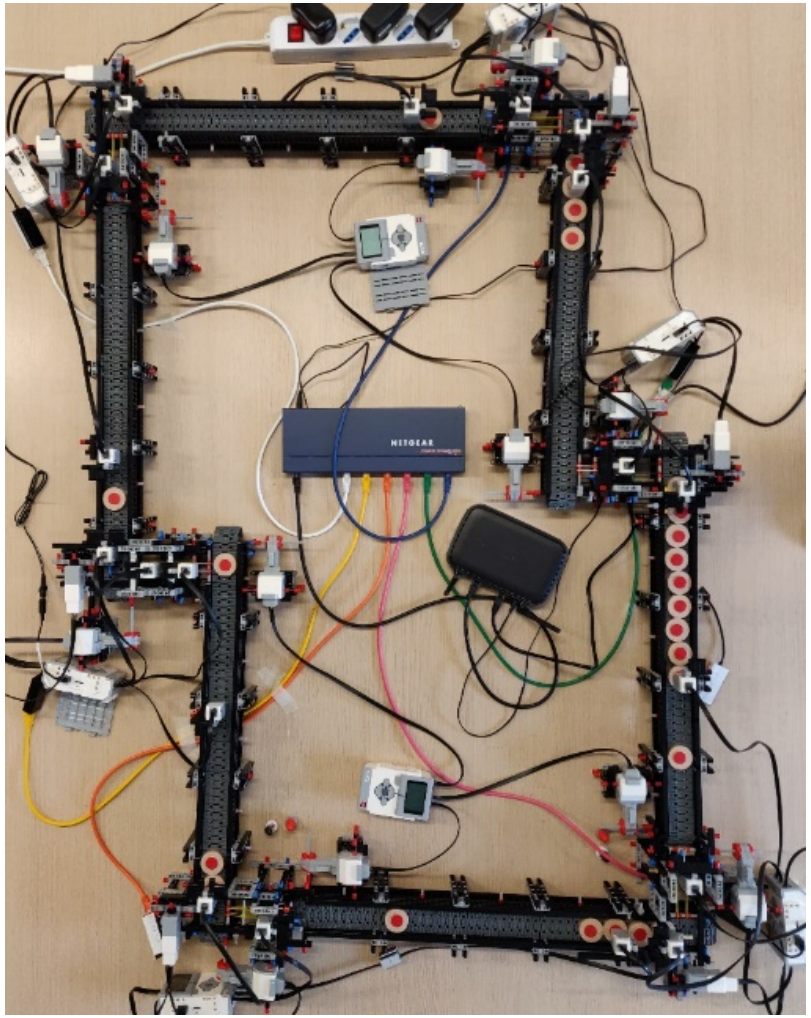
CONTRIBUTION

In this work, we target to teach students how to model a real manufacturing system and to use DES as performance evaluation method.

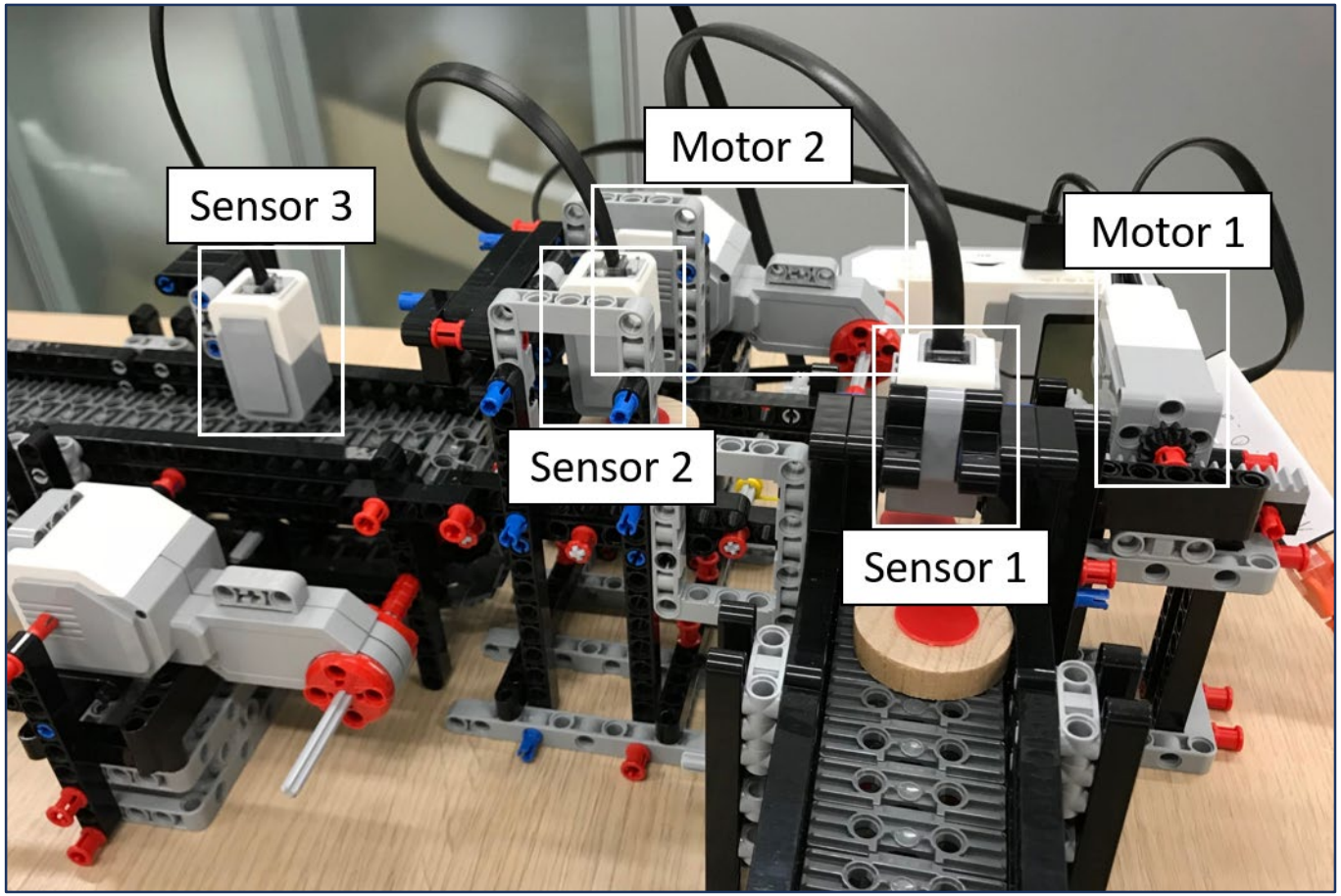
Table 1: Brief comparison of literature contributions where LEGO®-based manufacturing systems are used for teaching in IE.

	Sanchez and Bucio (2012)	**Syberfeldt (2010)**	**Jang and Yosephine (2017)**	**This Work**
Analyzed System	Closed-loop Line	Flow Line	Flow Line	Closed-loop Line
Processing Times	Deterministic	Stochastic	Stochastic	Stochastic
Failures	NO	NO	YES	YES
Data collection	NO	YES	YES	YES
Method used	*Not required*	ANN	Markov Chains	DES
Reconfiguration	NO	YES	YES	YES

4. LEGO® MANUFACTURING SYSTEMS



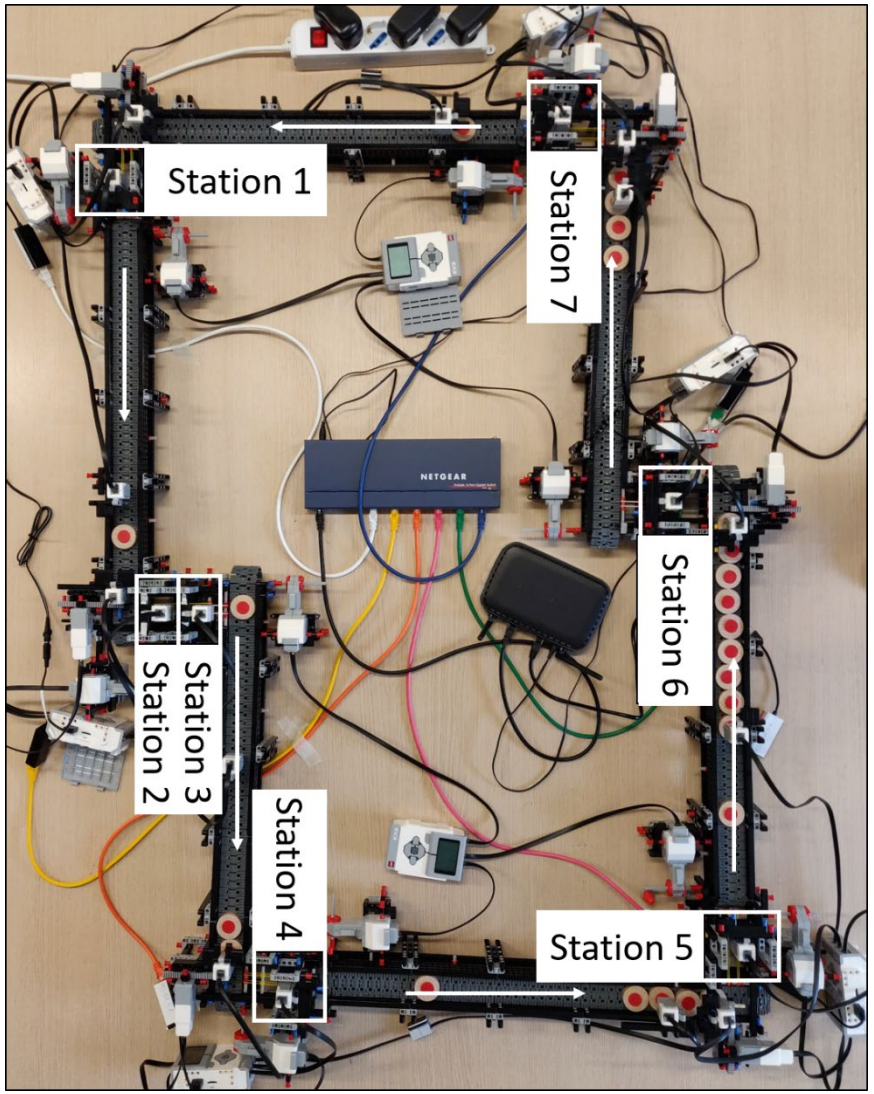
4. Physical Model



SYSTEM DETAILS:

- Sequential stations with intermediate conveyors that also operate as buffers.
- Each station is controlled by LEGO® EV3® bricks.
- Wooden circles tagged with red plates represent pallets that load the workpieces.
- Buffer capacities are defined by the position of a sensor on the downstream conveyor of each station.
- The total buffer capacity is limited and the blocking after service rule is applied.
- The processing times ($T_{W,A}$, $T_{W,B}$) are represented by a time that each piece must wait in a station before being released.

4. Physical Model



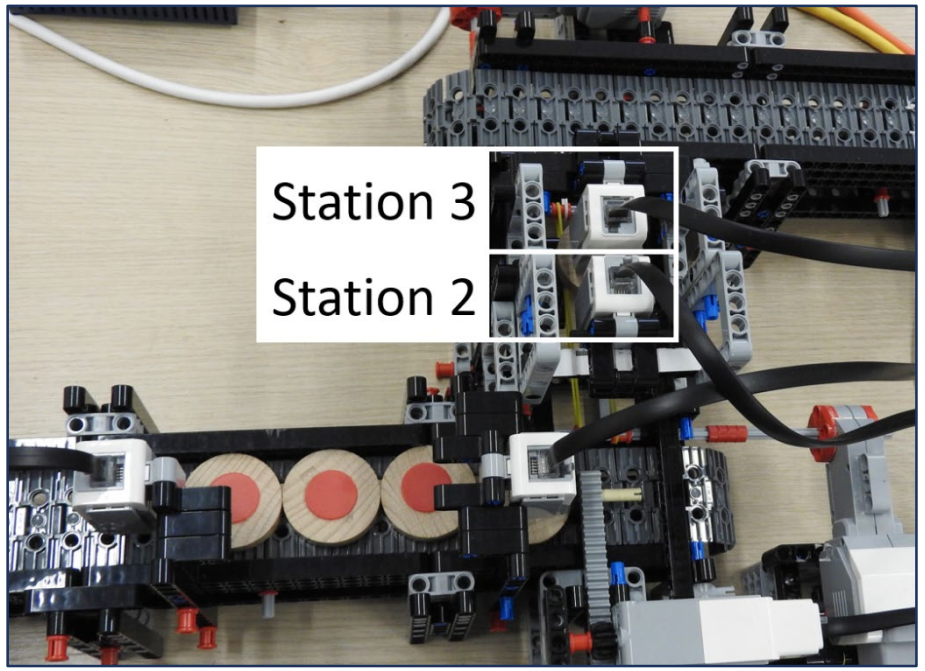


Table 2: System parameters: Triangular (TR), Weibull (WB), and Uniform (UN) distributions are used.

Station s	1	2	3	4	5	6	7
Processing Times [s]	TR(2,4,6)	2	2	WB(5,2)	WB(6,1.5)	2	2
Repairing Times [s]	-	-	-	-	-	TR(8,9.5,11)	UN(10,13)
Failure Probability	0	0	0	0	0	0.35	0.35
Buffer Capacity x_s	5	0	9	3	9	3	13

Course Details

LEARNING GOALS:

- The main elements of integrated manufacturing systems and their relationships;
- The basic principles of discrete event simulation;
- The basic analysis methodologies in the context of simulation.

ACTIVITIES IN CLASS:

- Modeling several integrated manufacturing systems using DES software
  (e.g., manufacturing lines, assembly lines, flexible manufacturing systems)
- Building DES models with data input analysis techniques;
- Understanding system behavior with data output analysis techniques;
- Ranking and comparing alternative manufacturing systems using simulation outputs.

Phases

IN LAB SIMULATION

Phase 1 → Phase 2 → Phase 3 → Phase 4

- Phase 1: FIRST VISIT; DATA COLLECTION
- Phase 2: AS-IS ANALYSIS; BOTTLENECK DETECTION; NR. OF PALLETS
- Phase 3: BAP
- Phase 4: SOLUTION IMPLEMENTATION

Data from the LMS

FILE FORMAT (*.TXT):

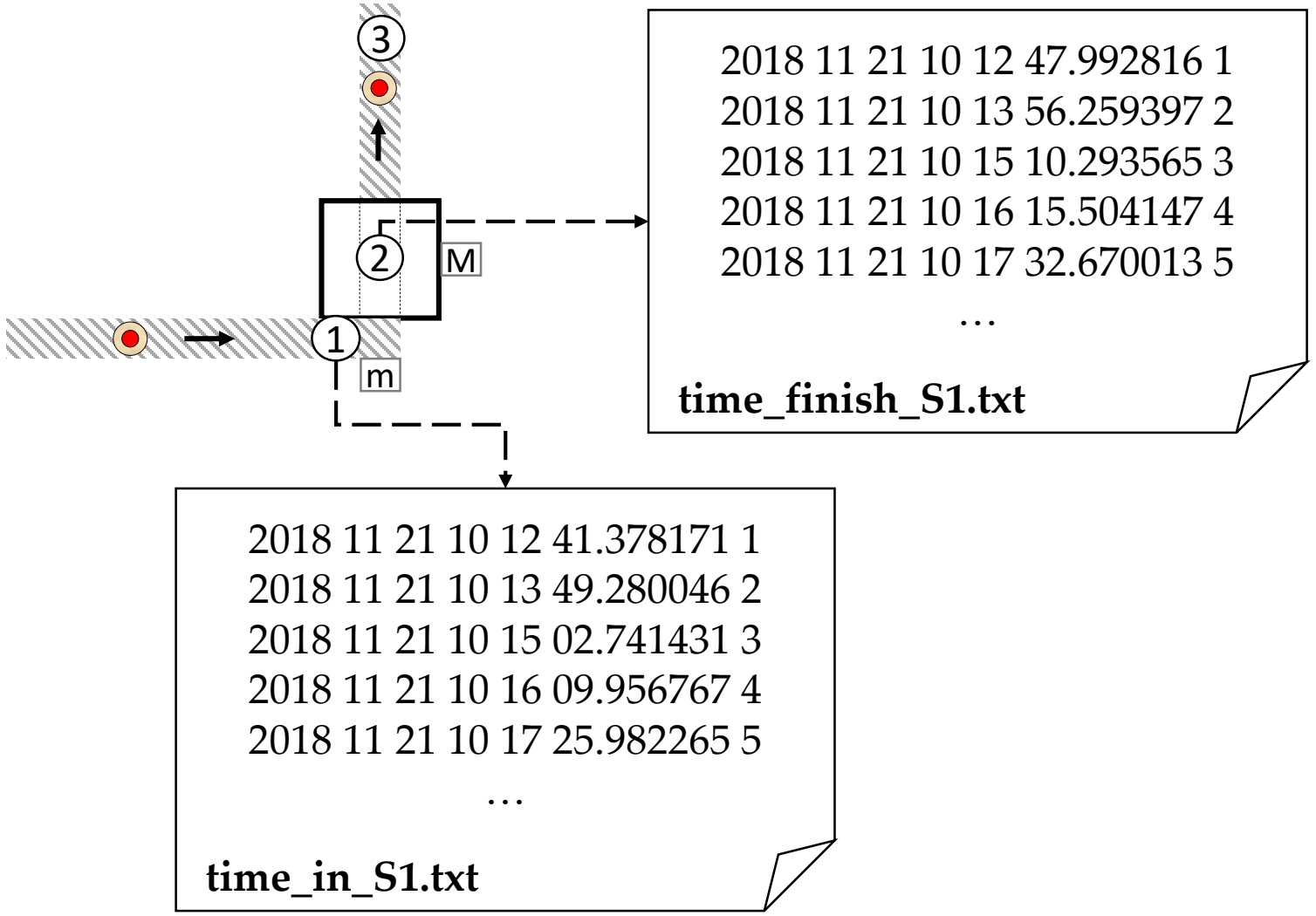
<datetime>	<part_counter>
…	…
…	…

1 = Sensor

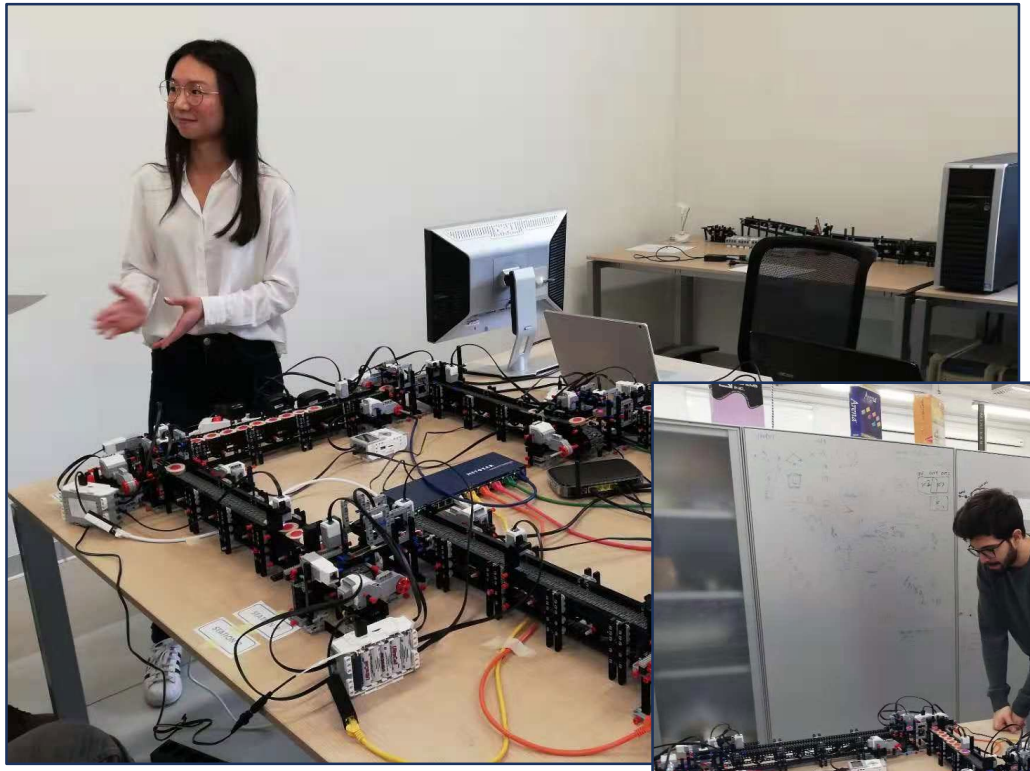
M = Motor

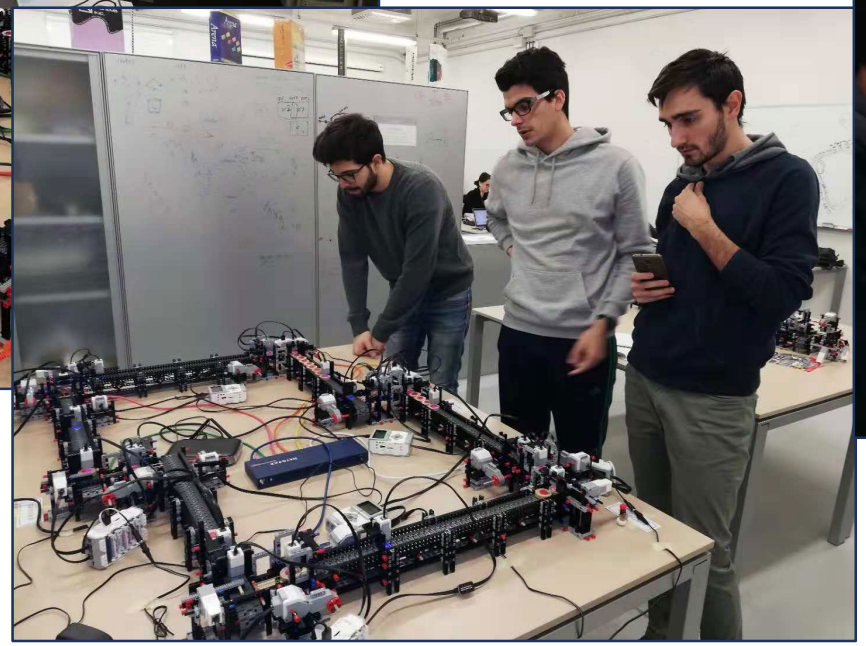
= Conveyor

= Pallet



Pictures





Developed Competences

- The ability to handle complexity of manufacturing systems.
- The skill to integrate knowledge acquired in other courses on productions systems and industrial plants.
- The competence to formulate judgement with incomplete and uncertain data.
- The capability to study in a manner that may be largely self-directed and/or autonomous.
- The ability to communicate their choices and conclusions to specialist audiences.

Conclusions

Achievements:

- A LEGO® -based learning system developed for the course of Integrated Manufacturing Systems in Politecnico di Milano.
- Students are facing real problems in model building and input analysis more effectively than with traditional lecture-based learning

Lessons Learned:

- High variability of approaches for system observation and modeling
- Students appreciate the possibility of collecting additional data (e.g., conveyor speed, blocking times)

Next Developments:

- This year edition:
  - First visit open to all the students;
  - Multiple visits to the physical system are possible
  - Introduction of a Quality Control Station: it is required to estimate the ratio of good/bad parts
- Next Edition:
  - Introduction of modelling complexity (e.g., shared resources)
  - Production systems where other decision-making problems can be experienced, e.g., machine loading rules, routing of pallets, scheduling.

THANK YOU

Suggested References

Padilla, J. J., C. J. Lynch, S. Y. Diallo, R. J. Gore, A. Barraco, H. Kavak, and B. Jenkins. 2016. "Using simulation games for teaching and learning discrete-event simulation". In 2016 Winter Simulation Conference (WSC), 3375–3384.

Resnick, M., and K. Robinson. 2017. Lifelong kindergarten: Cultivating creativity through projects, passion, peers, and play. MIT Press.

Lugaresi, G., D. Travaglini, and A. Matta. 2019. "A LEGO® Manufacturing System as Demonstrator for a Real-time Simulation Proof of Concept". In 2019 Winter Simulation Conference (WSC). IEEE.

Sanchez, A., and J. Bucio. 2012. "Improving the teaching of discrete-event control systems using a LEGO manufacturing prototype". IEEE Transactions on Education 55(3):326–331.

Syberfeldt, A. 2010. "A LEGO factory for teaching simulation-based production optimization". In Industrial Simulation Conference, ISC'2010, June 7-9, 2010, Ramada Plaza Hotel, Budapest, Hungary, 89–94. EUROSIS-ETI.

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