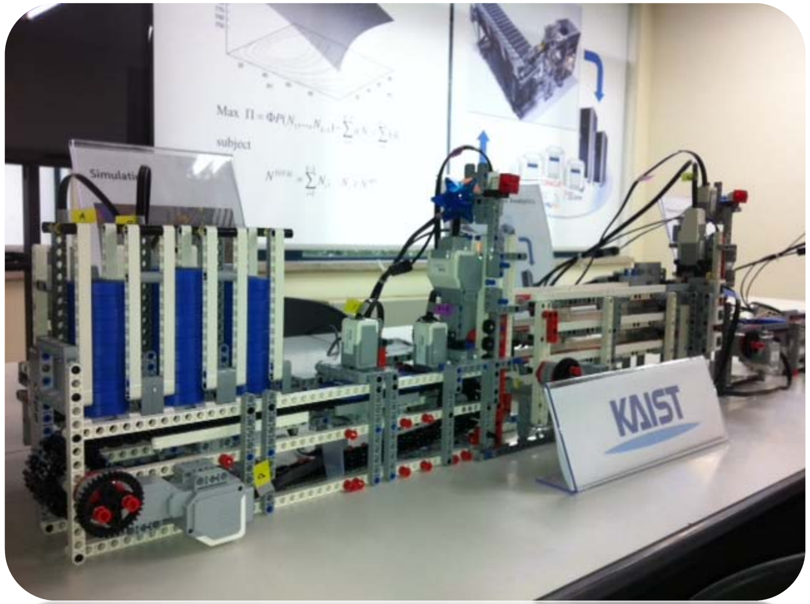
Teaching Stochastic Systems Modeling using LEGO Robotics-based Manufacturing Systems



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KAIST

Goal of the Talk

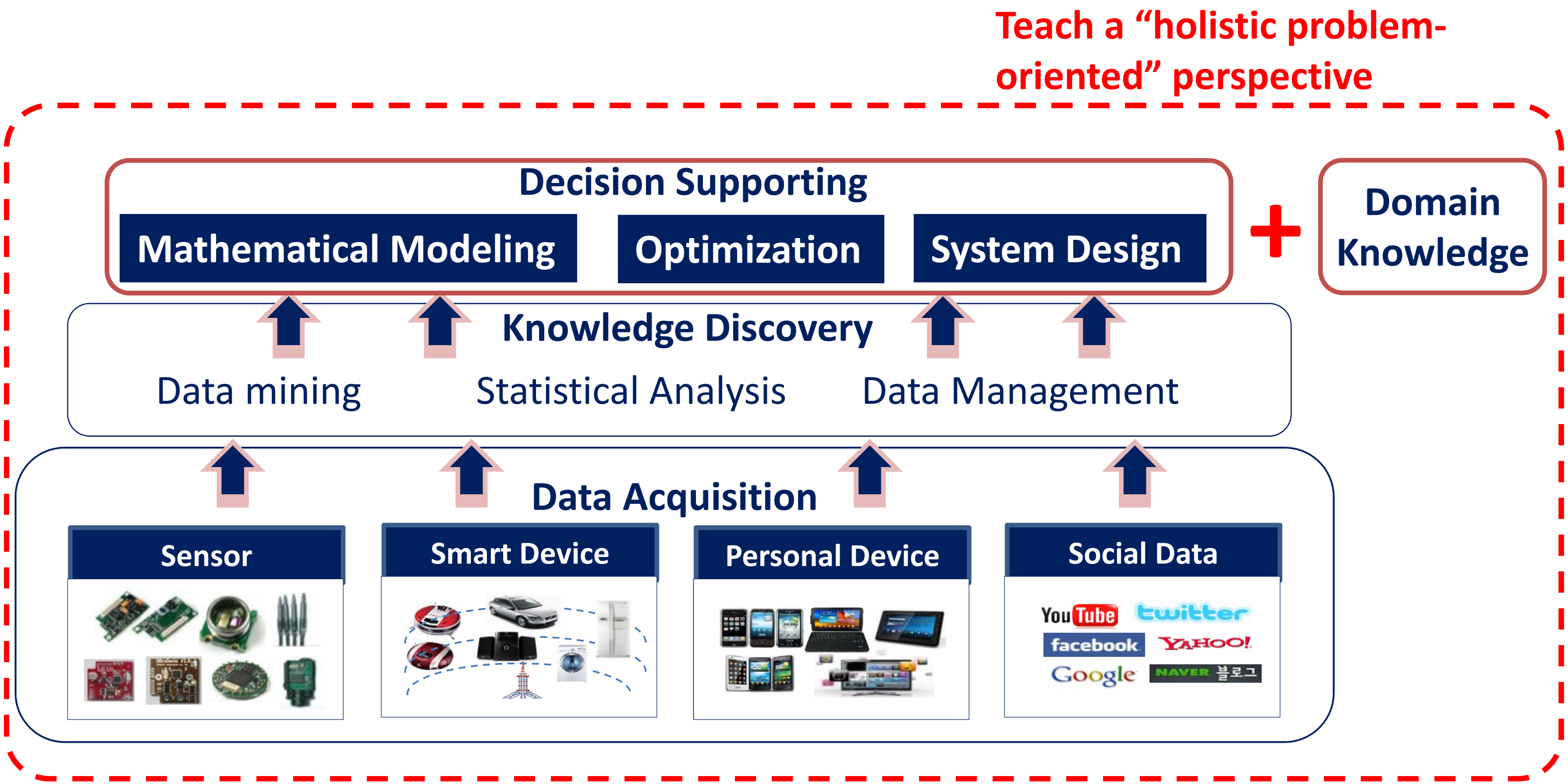
- **Introduce a new teaching method using LEGO Robotics**
  - Emphasize why this new teaching approach is needed

Role of Industrial/Systems Engineers in the Era of Industry 4.0

- **System integrator**
  - Integrating between technologies
  - Integrating between processes and technologies

- **Problem solver**
  - Problem oriented solution provider
  - Choose the “right” solution

Role of IE/Sys Eng for Industry 4.0



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LEGO EDUCATION

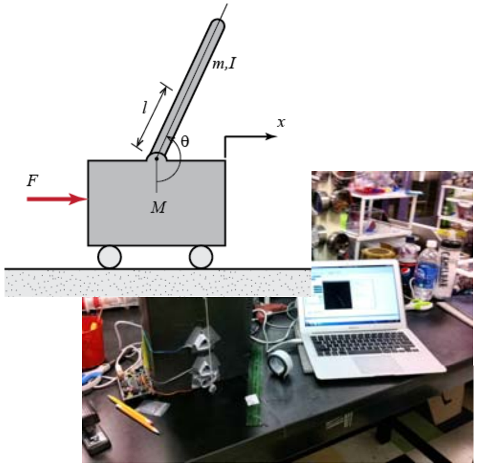
Topics

- Education issues
- LEGO System
- Future direction
- Conclusion

Educational Issues

- **Lack of providing system level "experience"**

Wind turner experiment at KAIST (Fluid Dynamics)



Control System Design Experiment (Control Theory)

Main Domain Areas in IE

Manufacturing Systems
SCM
Logistics & Transportation

Experiment?

Simulation

- **Computer simulation is often used in class to provide a virtual domain system; however, the pedagogical benefits are limited**

A. Landata, P. L. Morgado, J. M. Munoz-Guijosa, J. Sanz, J. Otero, J. Garcia, E. Tanarro, and W. Ochoa, Towards successful project-based teaching-learning experiences in engineering education, *International Journal of Engineering Education*, **29**(2), 2013, pp. 476-490.

Educational Issues in the Era of Industry 4.0

- **Hands-on experience is crucial in education**
- **Creativity comes from hands-on experience**

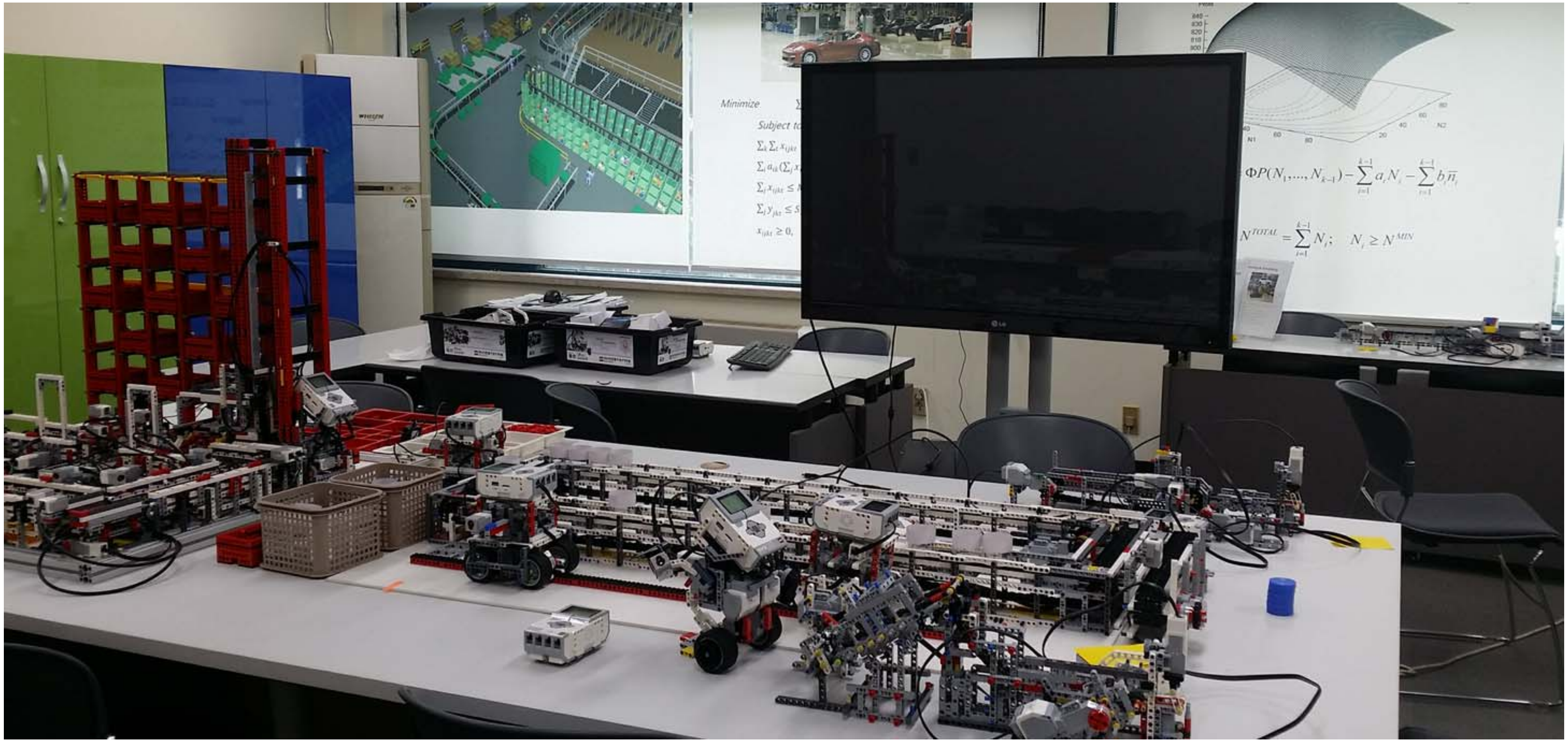
“No matter how many concepts you teach, no matter how deep you go, no matter how tough your exams are, the only lessons that will remain in the students’ minds are those that touch them”
- Saint-Nom and Jacoby

R. Saint-Nom and D. Jacoby, “Building the first steps into SP Research,” in *Proc. IEEE ICASSP*, 2005, vol. 5, pp. 545–548.

Topics

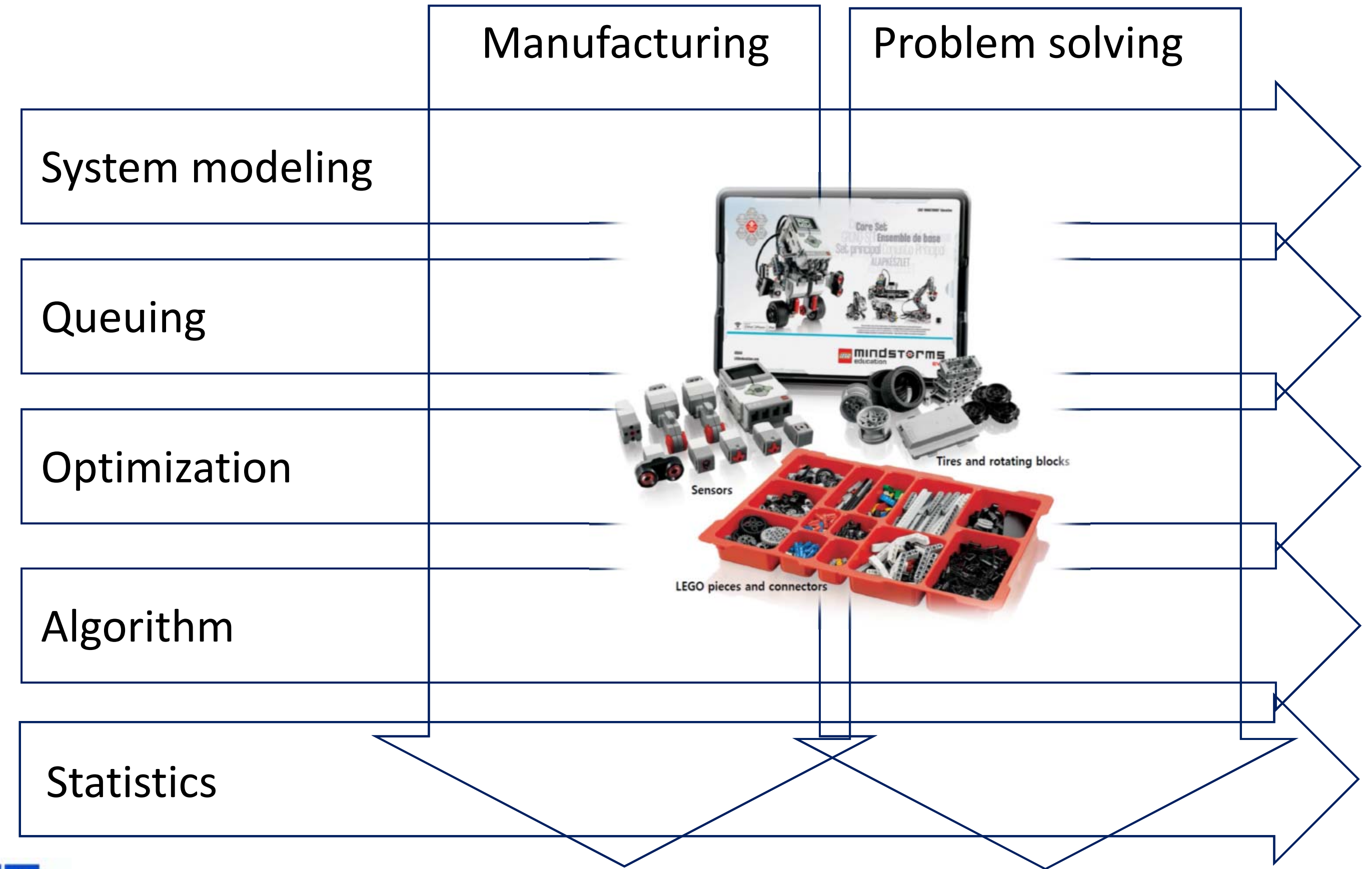
- Education issues
- LEGO System
- Future direction
- Conclusion

KAIST LEGO Manufacturing System (KLMS)



KAIST LEGO Manufacturing System

- **Dept. of Industrial and Systems Engineering at KAIST recently developed the KAIST-LEGO Manufacturing System (KLMS)**

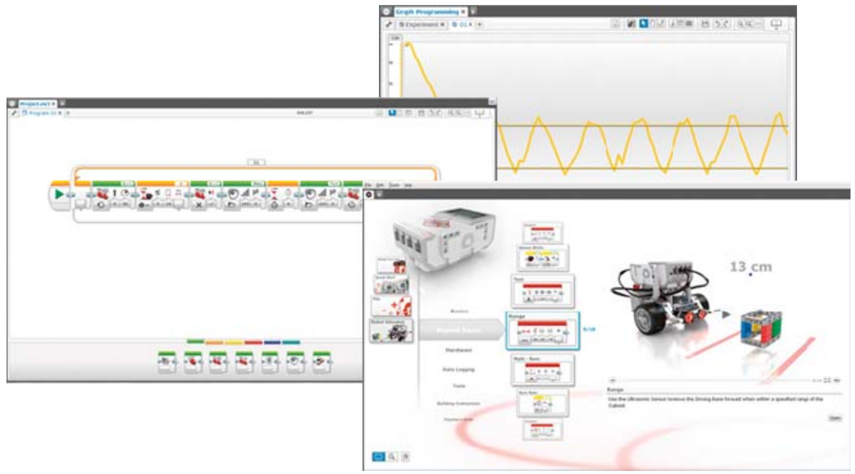


LEGO Mindstorms

- **Lego Robotics Kits**
  - *LEGO Mindstorms* EV3, the third generation of LEGO educational technology designed for classroom use

LEGO Mindstorms

- **Lego Robotics Kits**
  - Widely used in a robotics educations
  - Hardware/Software combined kit
  - Control with Matlab/LabView



Using LEGO in Education

- **Robotics**
  - Jes´us M G´omez-de Gabriel, Anthony Mandow, Jes´us Fern´andez-Lozano, and Alfonso Garc´ıa-Cerezo. Using lego nxt mobile robots with labview for undergraduate courses on mechatronics. Education, IEEE Transactions on, 54(1):41–47, 2011
  - Frank Klassner and Scott D Anderson. Lego Mindstorms: Not just for k-12 anymore. IEEE Robotics & Automation Magazine, 10(2):12–18, 2003
- **Control Theory**
  - A Cruz-Mart´ın, JA Fern´andez-Madrigal, Cipriano Galindo, J Gonz´alez- Jim´enez, C Stockmans-Daou, and Jos´e-Luis Blanco-Claraco. A Lego Mindstorms NXT approach for teaching at data acquisition, control systems engineering and real-time systems undergraduate courses. Computers & Education, 59(3):974–988, 2012
  - Yoonsoo Kim. Control systems lab using a Lego Mindstorms NXT motor system. Education, IEEE Transactions on, 54(3):452–461, 2011
- **Engineering Programming**
  - Alexander Behrens, Linus Atorf, Robert Schwann, Bernd Neumann, Rainer Schnitzler, Johannes Balle, Thomas Herold, Aulis Telle, Tobias G Noll, Kay Hameyer, et al. Matlab meets Lego Mindstorms freshman introduction course into practical engineering. Education, IEEE Transactions on, 53(2):306–317, 2010
  - Jan Moons and Carlos De Backer. The design and pilot evaluation of an interactive learning environment for introductory programming influenced by cognitive load theory and constructivism. Computers & Education, 60(1):368–384, 2013
- **Automated Systems**
  - Arturo Sanchez and Jorge Bucio. Improving the teaching of discrete event control systems using a lego manufacturing prototype. Education, IEEE Transactions on, 55(3):326–331, 2012.

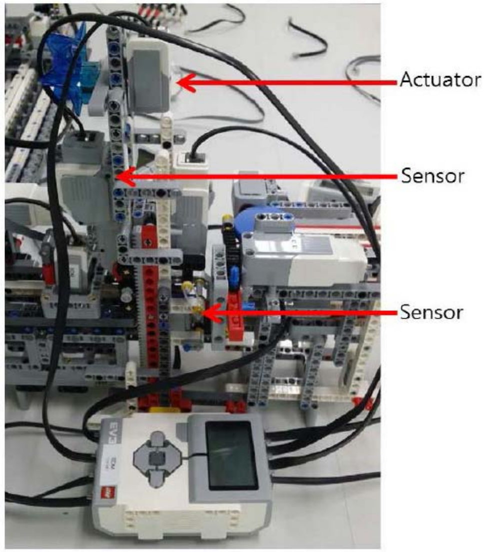
Class Projects with KLMS

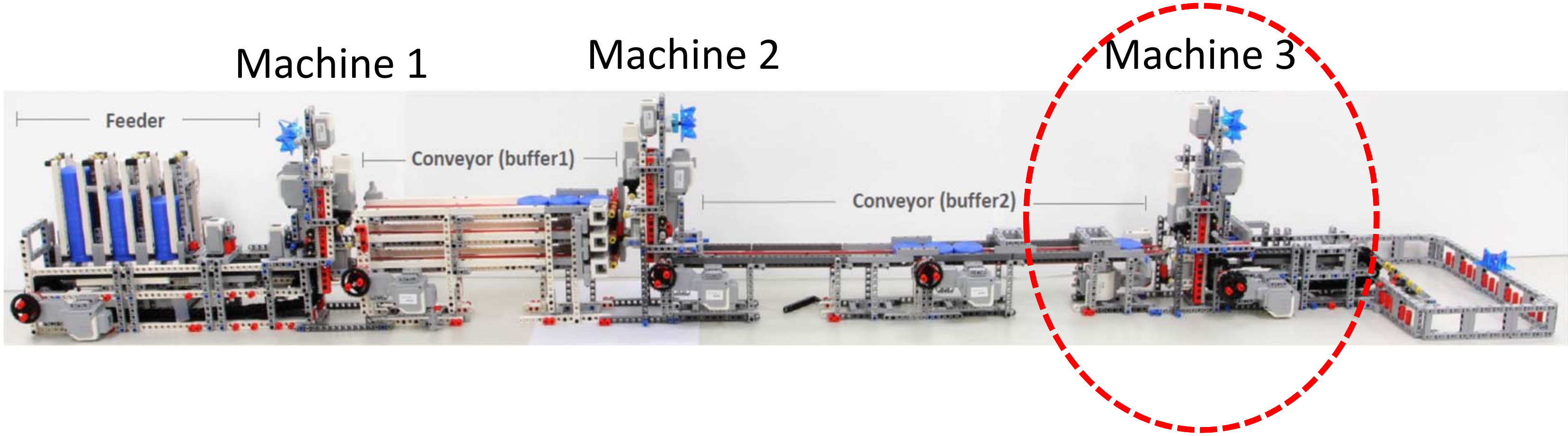
- **Project 1: System Analysis and Optimization**
  - Physical system to modeling
  - Statistical methods
  - Optimization concept

- **Project 2: System Design**
  - System hardware/software issue
  - Good system vs. bad system

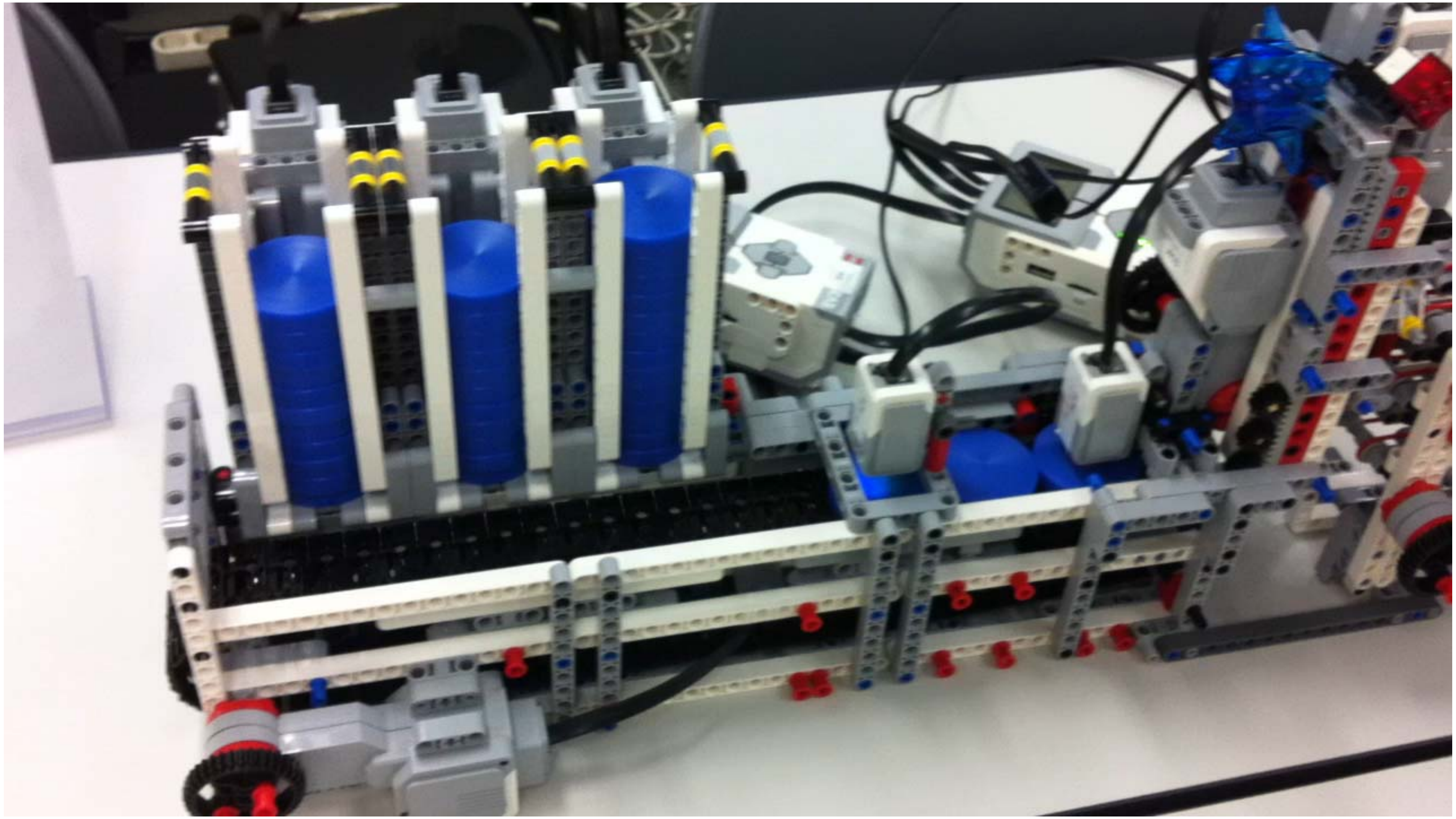
Project 1:System Analysis and Optimization

- **Machines**
  - Unreliable and constant processing time
- **Automated Material Handling System (AMHS)**
  - Conveyors and robots
- **Parts**
- **Feeders**
- **Software**
  - Matlab



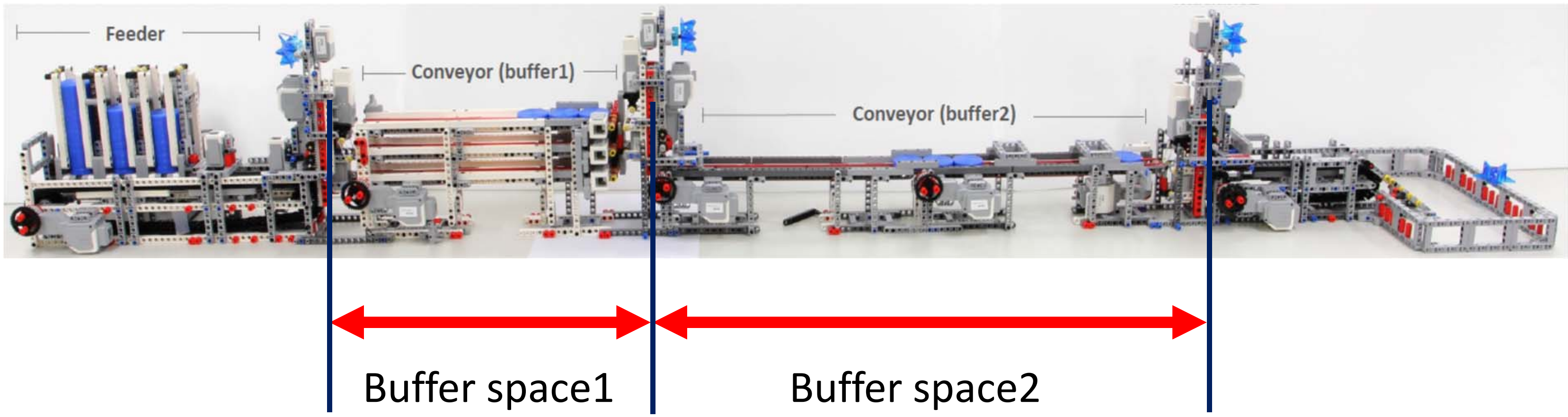


Project 1: System Analysis and Optimization



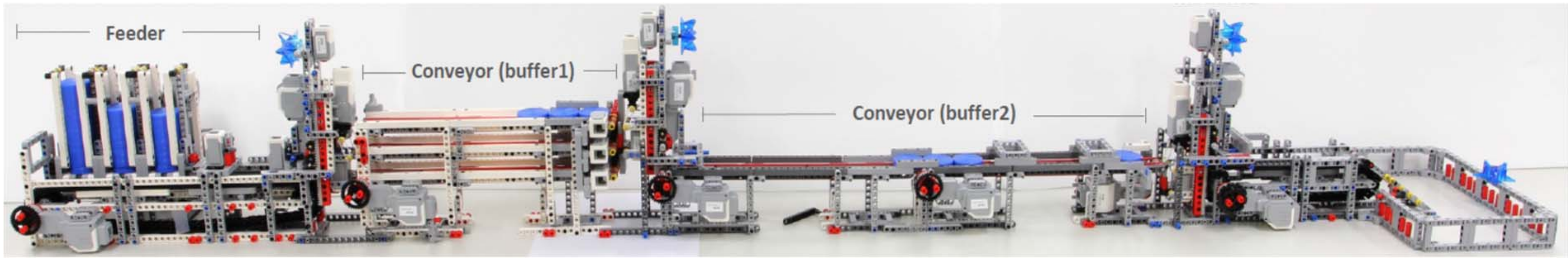
Project 1: System Analysis and Optimization

- **Goal of the Project**
  - Understand the process of modeling a physical system
  - Learn how optimization techniques can solve actual problems
  - Experience the actual issues of manufacturing operations



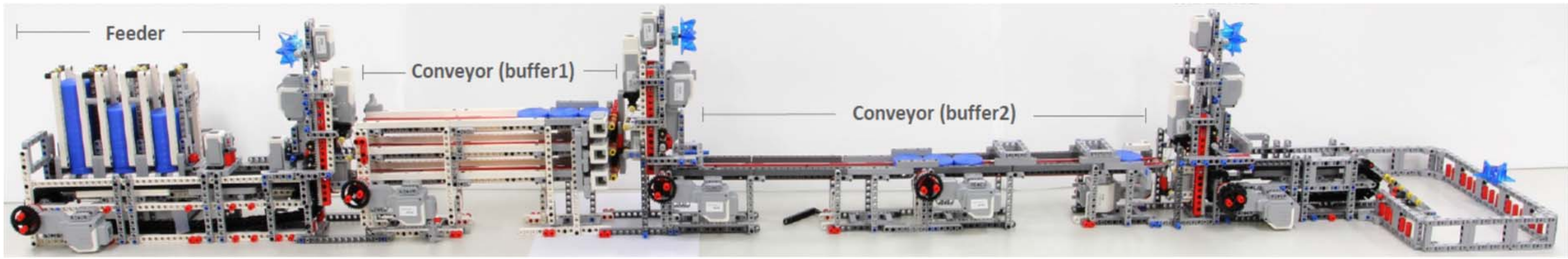
Problem Statement

- What is the role of the buffer space?
- What is the optimal allocation of the buffer space?
- What is the minimum buffer space to achieve a given production rate?



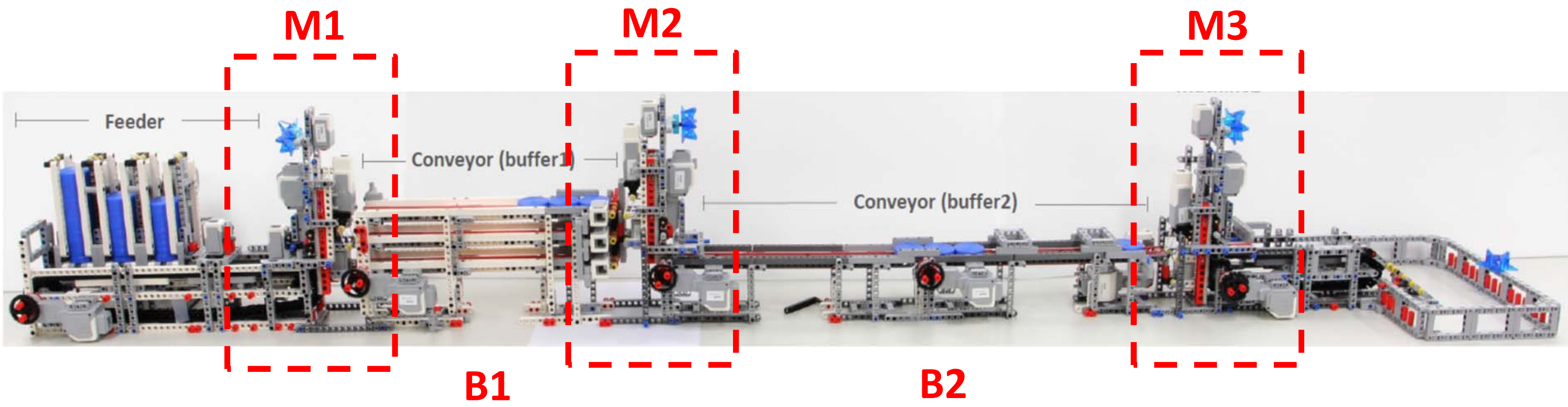
Unreliable machines

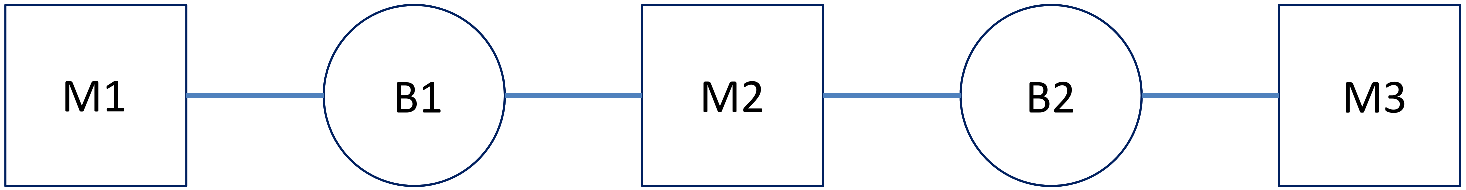
- **Stochastic model of unreliable machines**
- **MTTF and MTTR**
  - The probabilities of machine failure and repair are coded into the machine
  - However, students do not know the values
  - They need to find out the parameters



Stochastic System Modeling

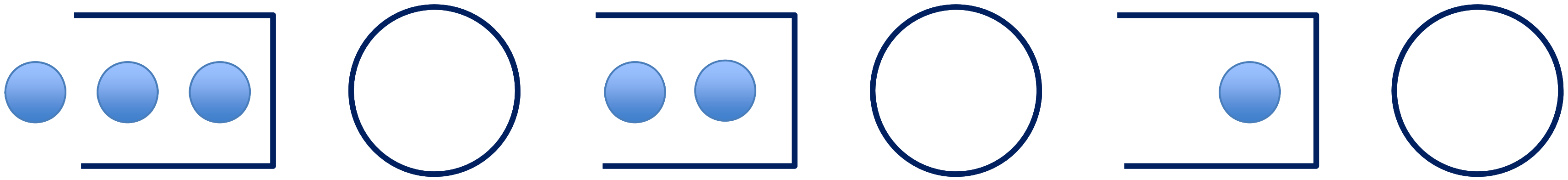
- **Modeling**

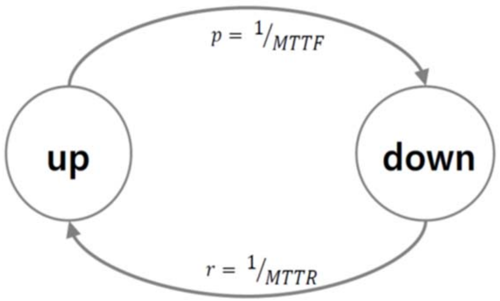




Stochastic Queueing Model

- **Multiple tandem line with finite buffers**

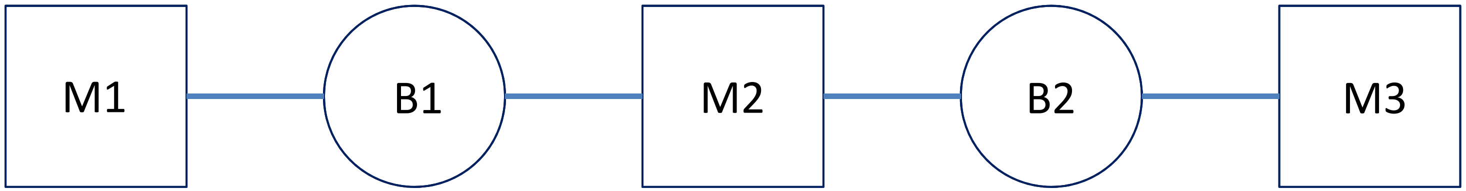




Optimization Problem

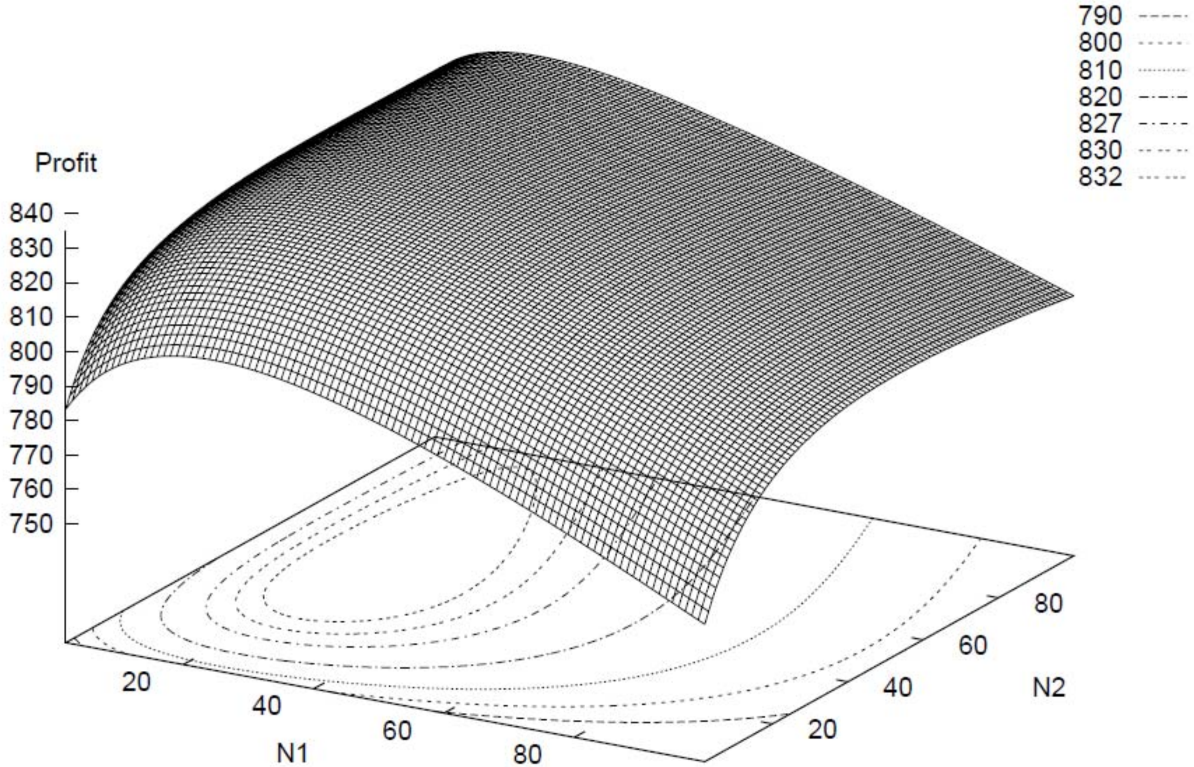
- **Optimization problem**

$$\begin{aligned}
\text{Maximize} \quad & P(N_1, \ldots, N_{k-1}) \\
\text{subject to} \quad & N^{\text{TOTAL}} = \sum_{i=1}^{k-1} N_i; \quad N^{\text{TOTAL}} \text{ specified}, \\
& N_i \geqslant N^{\text{MIN}}, \quad i = 1, \ldots, k-1.
\end{aligned}$$



Solution Algorithm

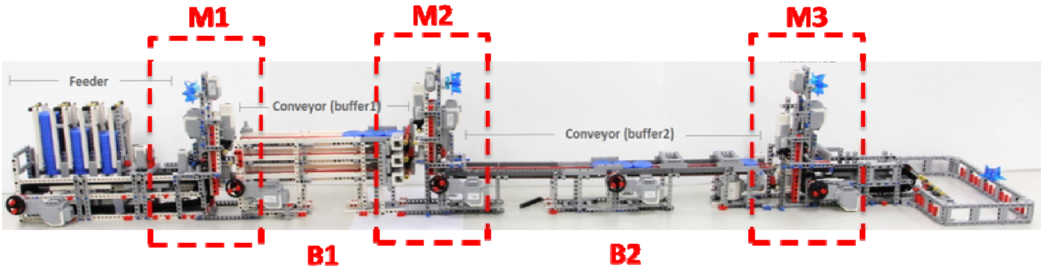
- **Optimization**



Gershwin and Schor. "Efficient algorithms for buffer space allocation." *Annals of Operations research* 93.1-4 (2000): 117-144.

Project 1: System Analysis and Optimization

- **System modeling**
- **Queueig modeling**
- **Optimization**

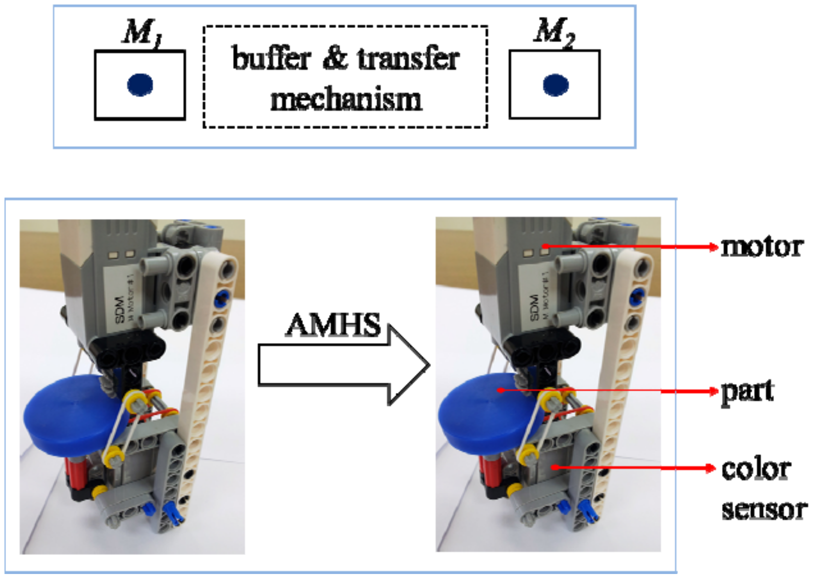


$$\begin{aligned} &\text{Maximize} \quad P(N_1, \ldots, N_{k-1}) \\ &\text{subject to} \quad N^{\text{TOTAL}} = \sum_{i=1}^{k-1} N_i; \quad N^{\text{TOTAL}} \text{ specified}, \\ &\qquad\qquad N_i \geqslant N^{\text{MIN}}, \quad i = 1, \ldots, k-1. \end{aligned}$$

Problem solving technique

Project 2: System Design

- **Automated Material Handling System (AMHS) Design**

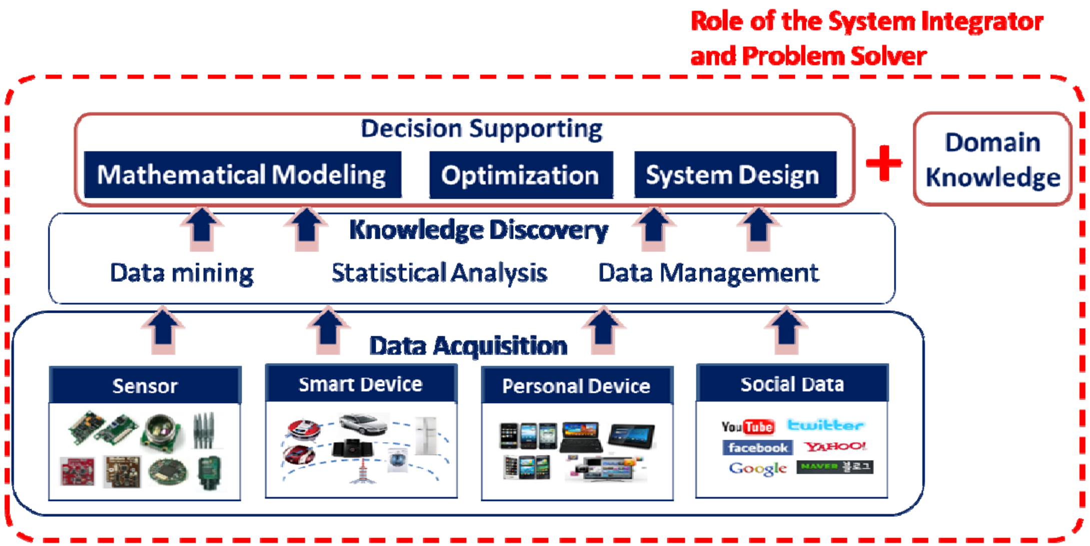


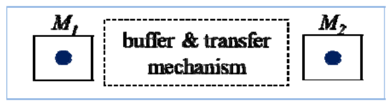
- Build a production line comprising two machines with an AMHS that connects the machines

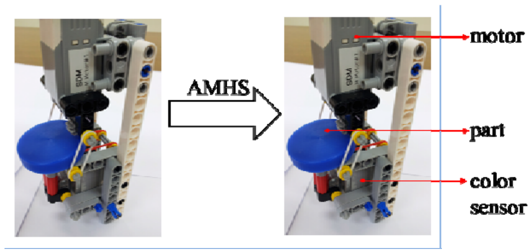
- The processing machines are pre-assembled and provided for the students

Project 2: System Design

- **Students should perform**
  - Signal processing
  - Statistical analysis
  - Building database
  - Mathematical modeling
  - Optimization



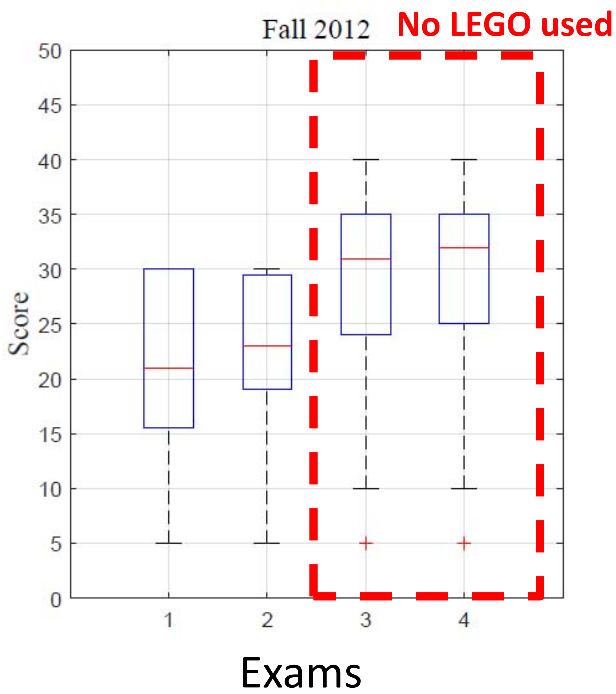


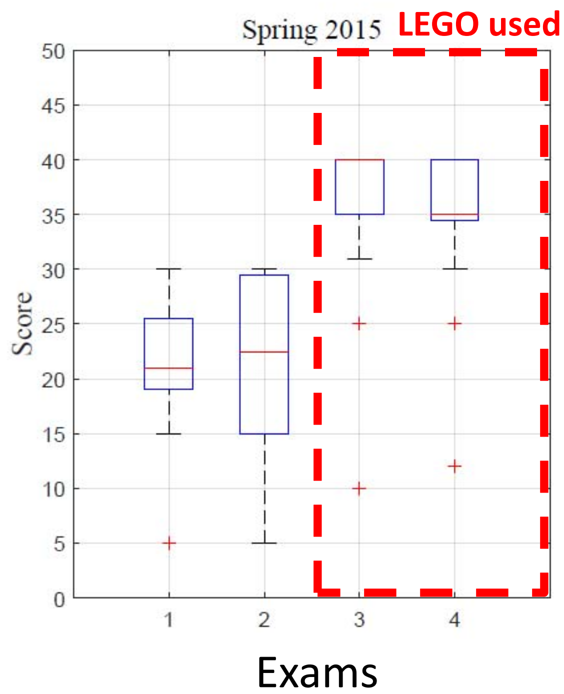


Systems Built by Students

Class Assessment

- No significant differences between the results for the Fall 2012 and the Spring 2015 classes are seen for the non-project-related quizzes (Quiz No. 1 and 2)
- However, a significant improvement is evident for the project-related quizzes (Quiz No. 3 and 4)





Class Assessment

- **Students comments:**
  - *I could learn from other students*
  - *5 weeks were too short and more time is needed*
  - *I now understand why the methodologies are needed*
  - *Team interaction and leadership training are needed*
  - *It was interesting to know how the randomness can be reduced with a good buffer design*

	Fall 2012			
	Undergraduate enrollment	Respondent	Average score	Std. dev.
Overall	32286	27351	4.19	0.83
Department	934	795	4.12	0.89
Course	68	64	3.99	0.84

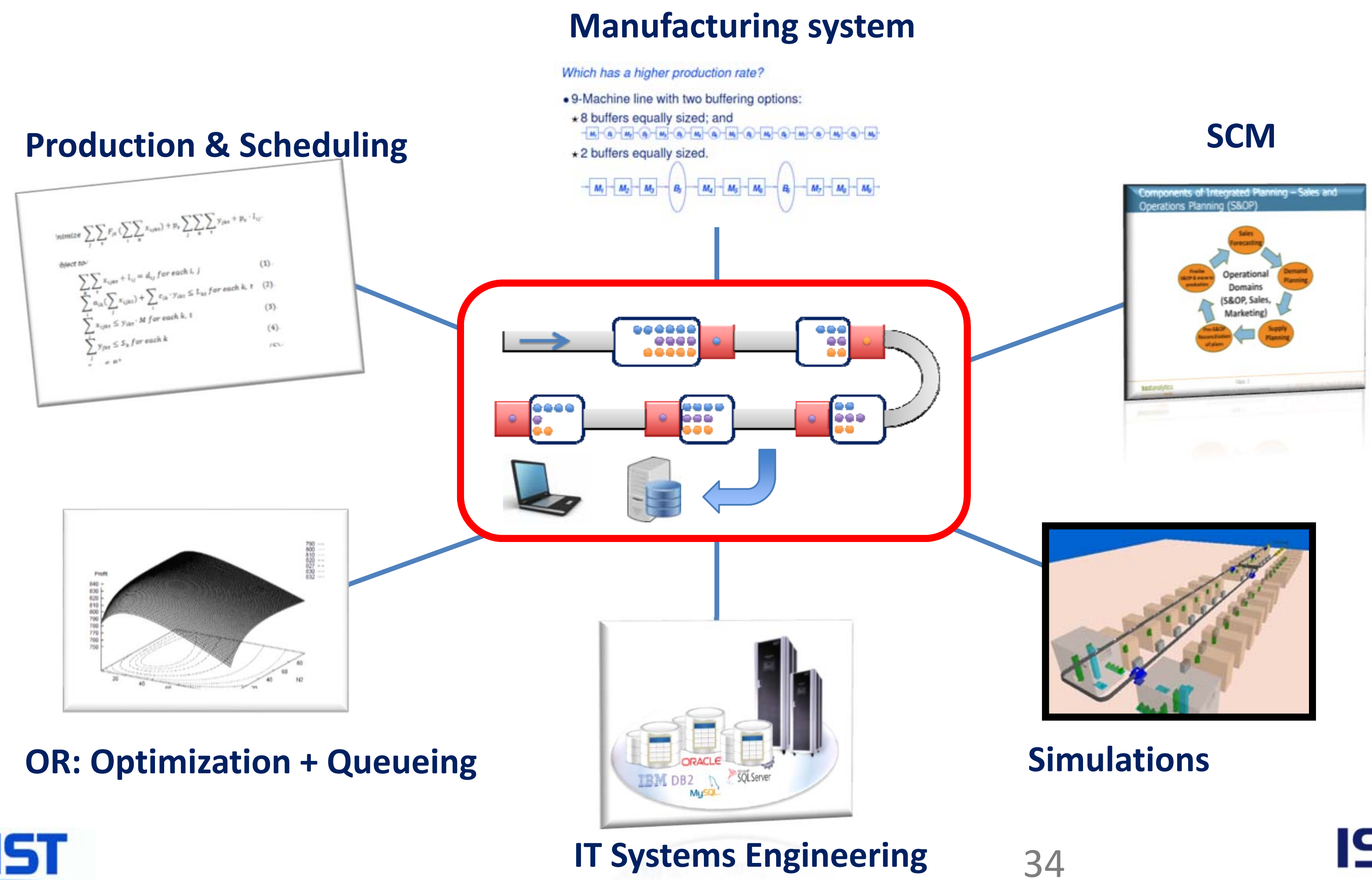
	Spring 2015			
	Undergraduate enrollment	Respondent	Average score	Std. dev.
Overall	32137	25948	4.18	0.82
Department	777	633	4.24	0.83
Course	32	30	4.41	0.79

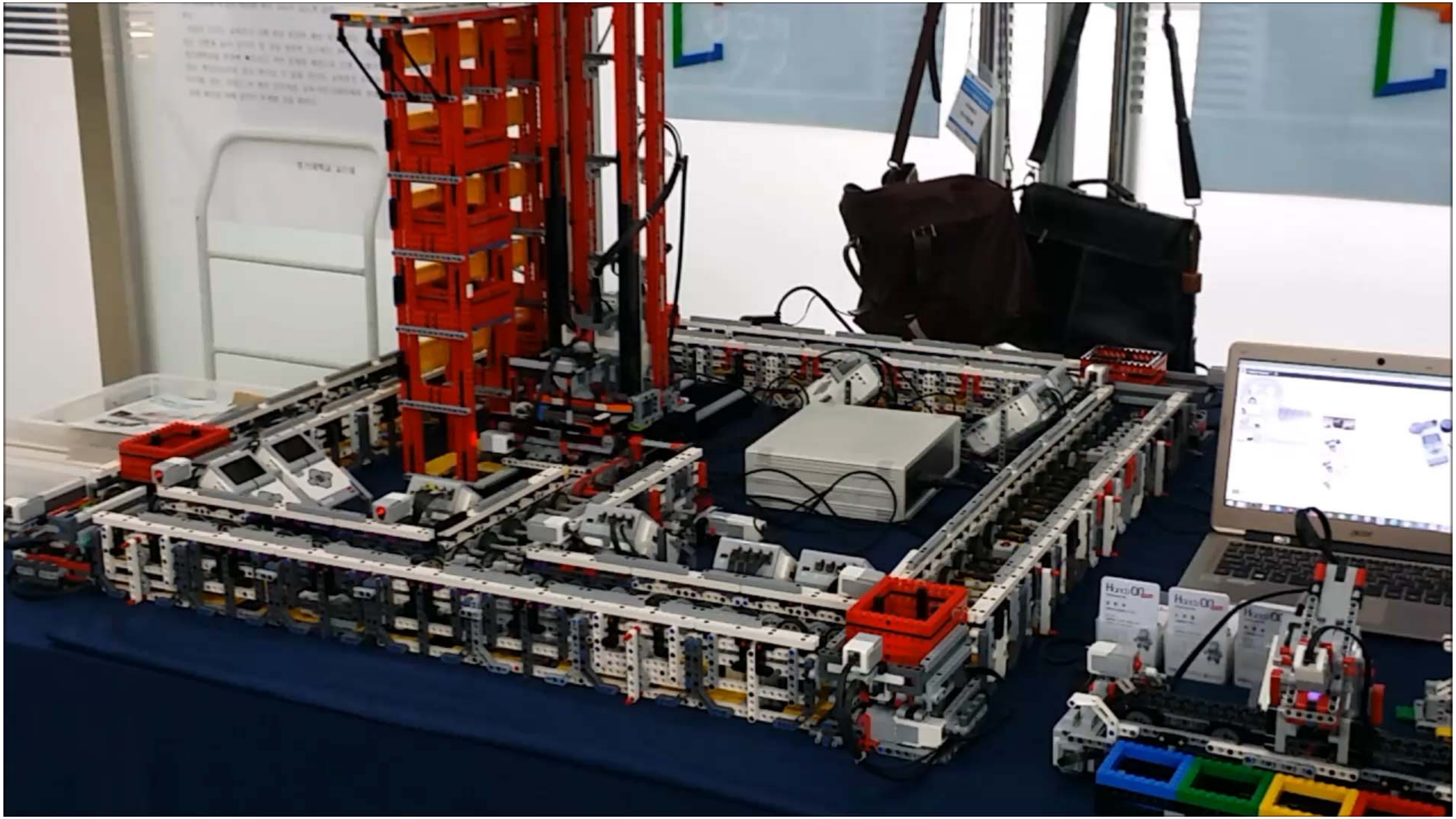
Topics

- Education issues
- LEGO System
- <u>Future direction</u>
- Conclusion

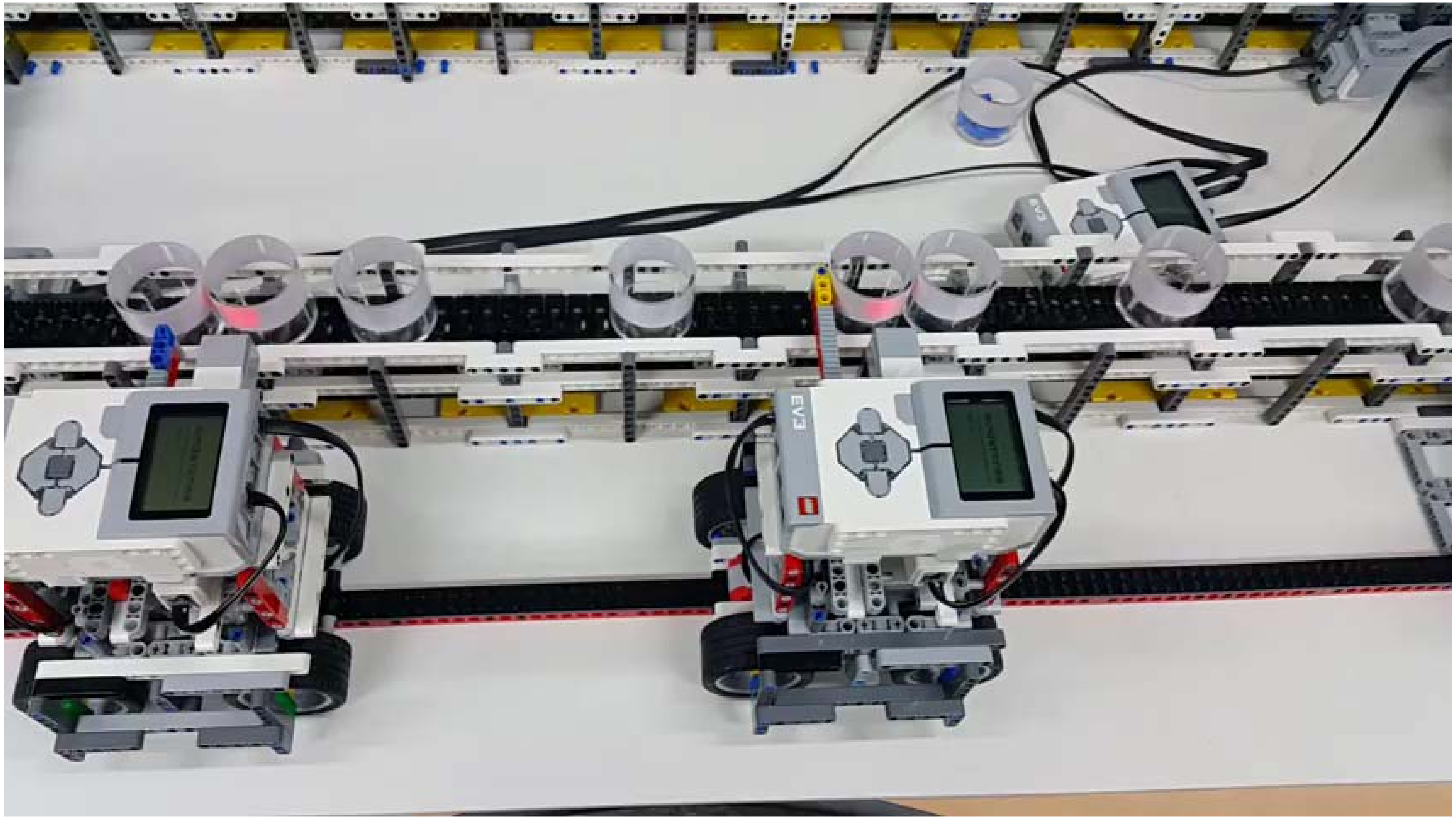
Class Integration

- **Integrate the class with the KLMS**





Graduate Study



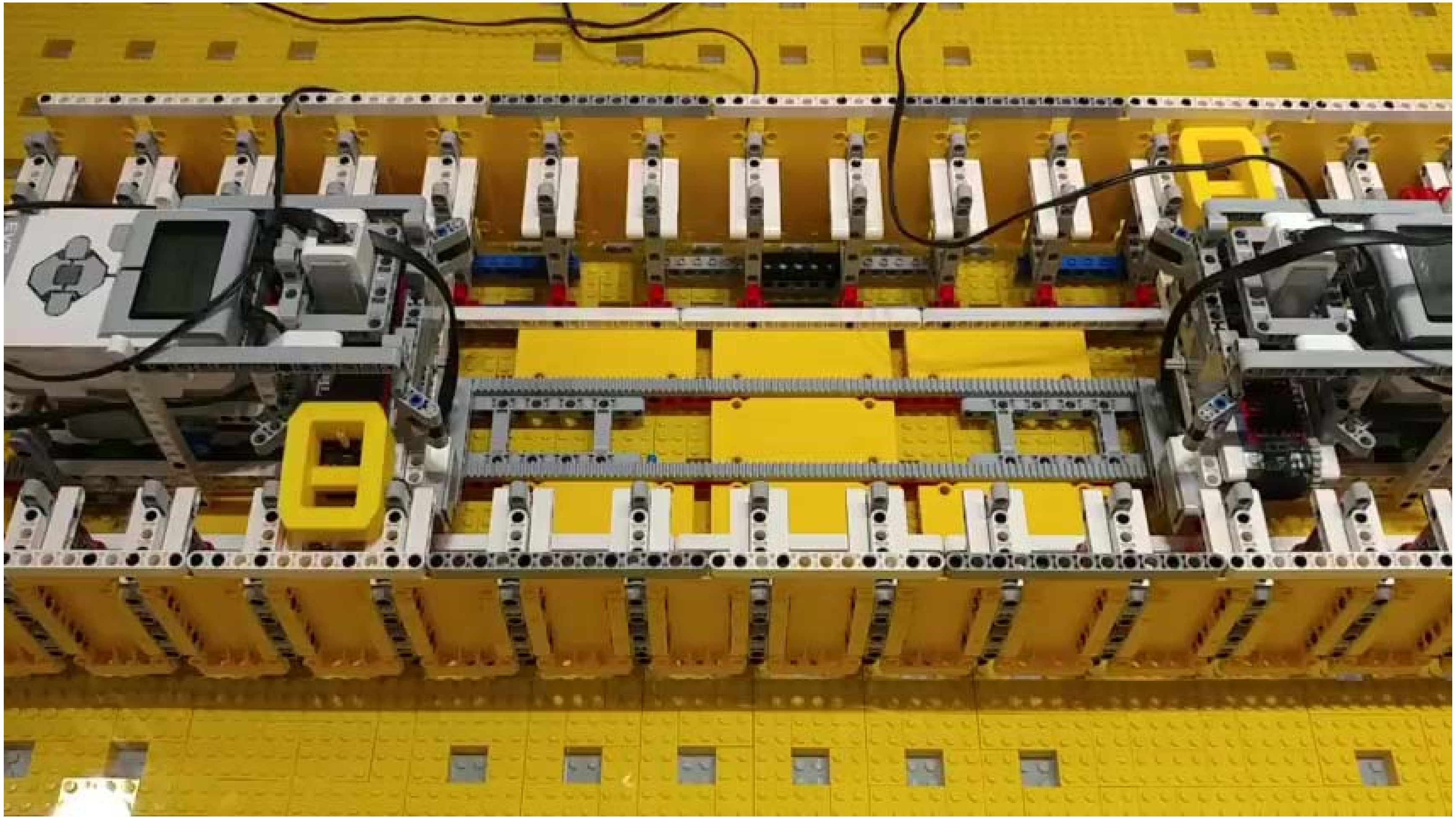
Hewlett-Packard Uses Operations Research to Improve the Design of a Printer Production Line

MITCHELL BURMAN
Analytics, Inc.
101 Rogers Street, Suite 216
Cambridge, Massachusetts 02142

STANLEY B. GERSHWIN
Massachusetts Institute of Technology
77 Massachusetts Avenue, Room 35-331
Cambridge, Massachusetts 02139

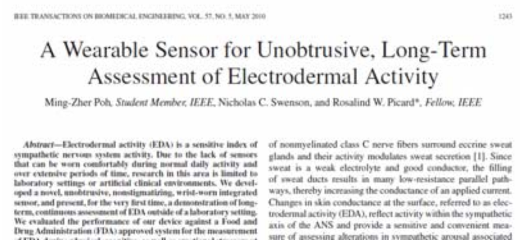
CURTIS SUYEMATSU
Hewlett-Packard Company
PO Box 8906
Vancouver, Washington 98668-8906

MDP & Reinforcement Learning



“Flipped Class”

Poh, Ming-Zher, Nicholas C. Swenson, and Rosalind W. Picard. "A wearable sensor for unobtrusive, long-term assessment of electrodermal activity." *IEEE transactions on Biomedical engineering* 57.5 (2010): 1243-1252.

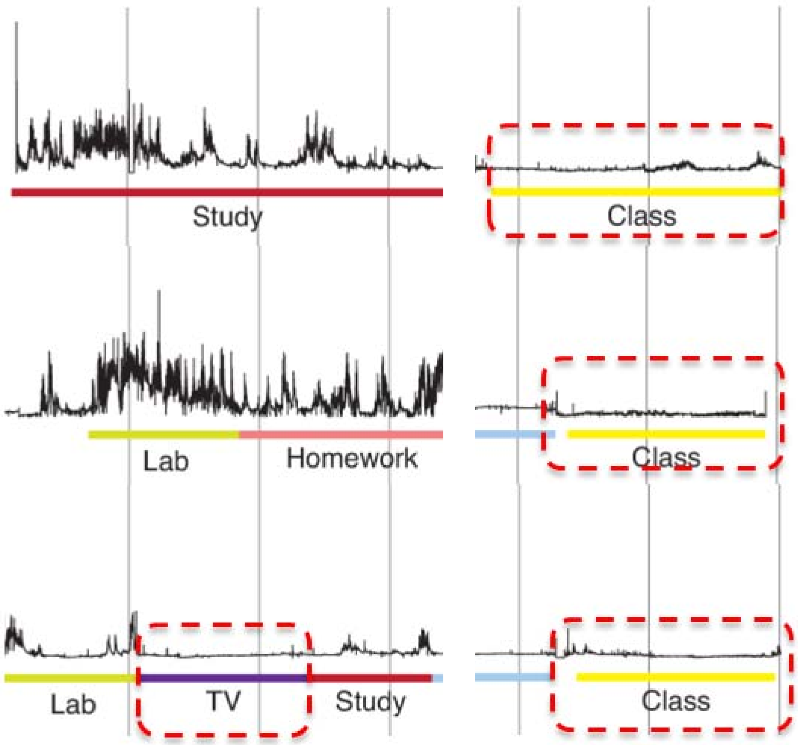

IEEE TRANSACTIONS ON BIOMEDICAL ENGINEERING, VOL. 57, NO. 5, MAY 2010 1243

A Wearable Sensor for Unobtrusive, Long-Term Assessment of Electrodermal Activity

Ming-Zher Poh, *Student Member, IEEE*, Nicholas C. Swenson, and Rosalind W. Picard*, *Fellow, IEEE*

Abstract—Electrodermal activity (EDA) is a sensitive index of sympathetic nervous system activity. Due to the lack of sensors that can be worn comfortably during normal daily activity and over extensive periods of time, research in this area is limited to laboratory settings or artificial clinical environments. We developed a novel, unobtrusive, nonstigmatizing, wrist-worn integrated sensor, and present, for the very first time, a demonstration of long-term, continuous assessment of EDA outside of a laboratory setting. We evaluated the performance of our device against a Food and Drug Administration (FDA) approved system for the measurement

of nonmyelinated class C nerve fibers surround eccrine sweat glands and their activity modulates sweat secretion [1]. Since sweat is a weak electrolyte and good conductor, the filling of sweat ducts results in many low-resistance parallel pathways, thereby increasing the conductance of an applied current. Changes in skin conductance at the surface, referred to as electrodermal activity (EDA), reflect activity within the sympathetic axis of the ANS and provide a sensitive and convenient measure of assessing alterations in sympathetic arousal associated



- **Nerve system activity (electrodermal activity - EDA) is measured**
- **Nerve activity while in the classroom is similar to that in watching TV!**
- **Many students are not stimulated in the classroom**
- **However, more activity is observed while studying and working for lab or HW**

“Flipped Class”

- **Provides a new teaching method**
- **Create a content for a “Flipped Class” format**

“Tae-Eog Lee has a simple philosophy about what academics should do in lectures: anything but lecture. **“Usually, in a conventional classroom, students don't think,”** he says. **“They just follow the professor's teaching.”**

Forbes

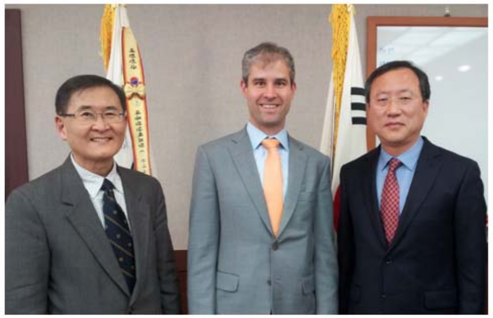
MAR 17, 2014 @ 08:50 AM 2,278 VIEWS

KAIST Doesn't Wait For Change In Korea, Pioneers 'Education 3.0'

As South Korea struggles to escape the downsides of centuries of a Confucian emphasis on rote learning while retaining the positives from that Confucian legacy, at least a couple institutions in the country aren't waiting for permission to move forward.

KAIST, the Korean Advanced Institute of Science and Technology, a top public research university located 150 km south of Seoul in the city of Daejeon, is trying not only to spark innovation in research and the creation of new products, services, and companies, but also in how it educates.

In my meetings with several on the campus—including the president of KAIST, Steve Kang; Tae-Eog Lee, a professor and the director of the Center for Excellence in Learning and Teaching at KAIST; and Woontack Woo, a professor in the KAIST Graduate School of Culture Technology with a specialty in ubiquitous virtual reality, I heard about a range of initiatives designed to bring KAIST to the forefront of innovation in a variety of fields, including the move beyond mass education to mass-customized education through blended learning, or what KAIST calls Education 3.0.



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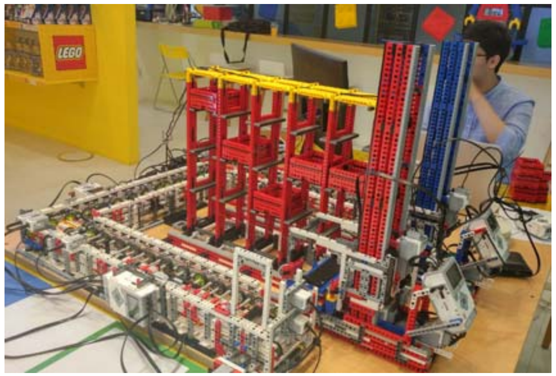
Future Direction

- **Create a platform for "Flipped Class"**
- **Convert information to knowledge**

- **Watch lecture videos**
- **Acquire the information**



- **Perform experiments**
- **Understand the actual issues**

- **Discuss with teammates and Instructors**
- **Convert information to knowledge**

KAIST

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Topics

- Education issues
- LEGO System
- Future direction
- Conclusion

Contribution

- **Spread to industry - Deloitte Consulting & LG Electronics**

KAIST 학생이 레고로 수업한다고?

■ 활용도 높은 레고과학 2題

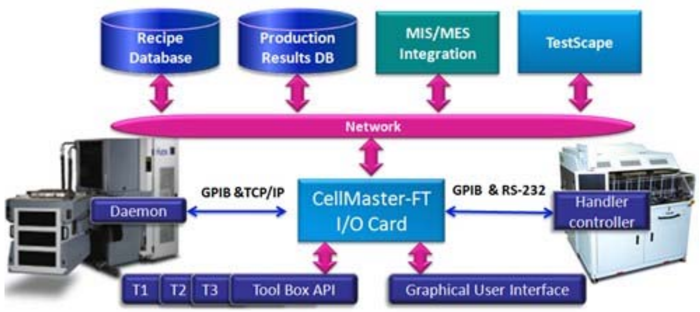
우리가 상상할 수 있는 모든 것을 만들어 낼 수 있는 창의적 장난감 레고. 1932년 선보인 이후 80여 년 동안 꾸준히 아이들은 물론이고 성인까지 마니아층을 만들어냈다.

'그들만의 새로운 세상을 창조하던' 레고가 장난감이라는 틀에서 벗어나 현실과의 접점을 넓히고 있다. 레고 블록의 조립기법을 응용한 기술이 산업·교육·건설현장에서 활용되고 있는 것은 레고가 더 이상 테이블 위의 장난감이 아닌, 실제 우리 생활에 도움을 주는 과학기술로 거듭나고 있음을 증명한다.

● 레고로 생산현장 문제 수학적 해결

3일 대전 KAIST 산업 및 시스템공학과 대학원 연구원들은 '공급사슬망관리'라는 수업에서 사용할 레고 공장 모형을 만드는 데 열을 올리고 있었다. 장영재 교수가 담당하고 있는 공급사슬망관리 수업에서는 공장에서 상품을 생산하고 소비자에

컴퓨터 프로그램으로 자유롭게 작동방식을 설계할 수 있는 레고로 만든 2m 길이의 공장 모형. 웅진케미칼의 정수용 마이크로필터 생산라인을 재현한 것으로, 실제로 모형 원자재가 컨베이어벨트를 따라 이동하면서 세 가지 제조 공정을 지나도록 설계돼 있다. 최영준 기자 jxabbey@donga.com



Conclusion

- **New teaching method is needed in the new era of Industry 4.0**
- **System-level & holistic-perspective can be effectively taught with LEGO**
- **Provide a direction for new teaching concept ("flipped class")**

Thank you

- **Acknowledgement**
  - Industry & academic sponsors of the LEGO projects
  - Undergraduate & graduate students in the department