Undergraduate Research Opportunity Program (UROC)

Human-Automation Study by Using a Smart Phone Controlled Inverted Pendulum Using Motorized Potentiometer

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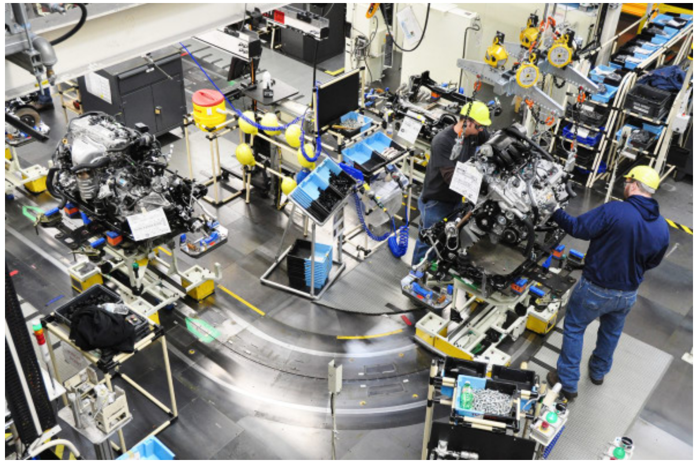
Introduction

Human in the Loop

- Many industrial processes involves human operators in the automated control loop to reach the desired operating points and manufacturing goals.

- Understanding and modelling the human behavior in the control loop is necessary to determine how the human response in the process affects the final result of the manufacturing process.



Introduction

Research goals

- Analyze the human behavior when it is inside the automation loop through a performance assessment doing a complex task

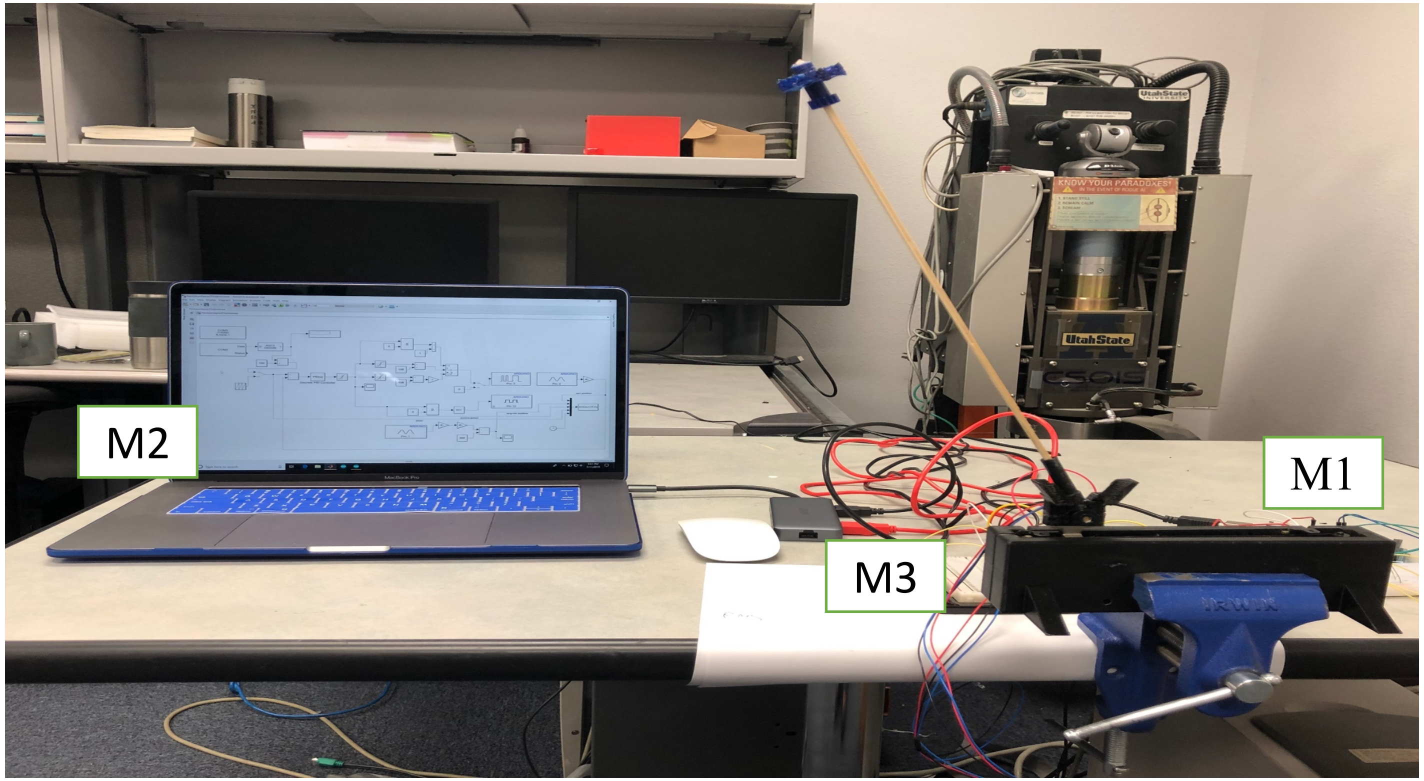
- Benchmark task: keep straight the inverted pendulum system

- System prototype built using:
  - Android application(Position Control Inverted Pendulum)
  - Bluetooth & Arduino
  - 3D printing for pendulum pieces
  - Matlab
- Task assessment for 20 test subjects

- Performance indices calculation to compare the automatic control vs Human in the loop approach

Inverted pendulum system

System prototype

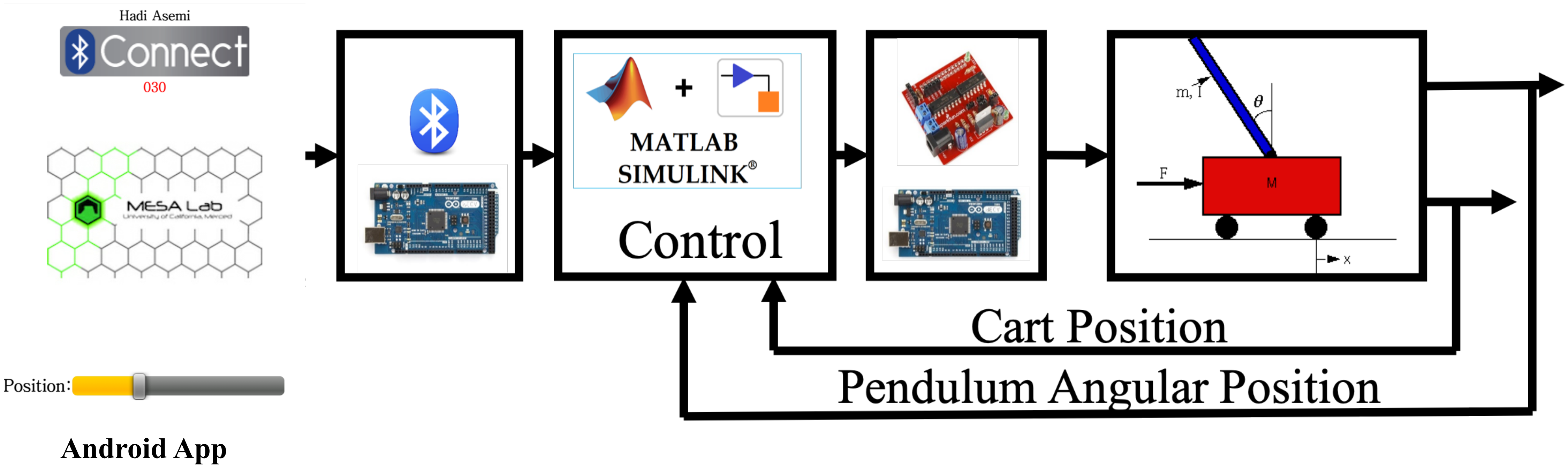


System components:

- M1: Inverted pendulum
- M2: Matlab Simulink
- M3: Arduino boards

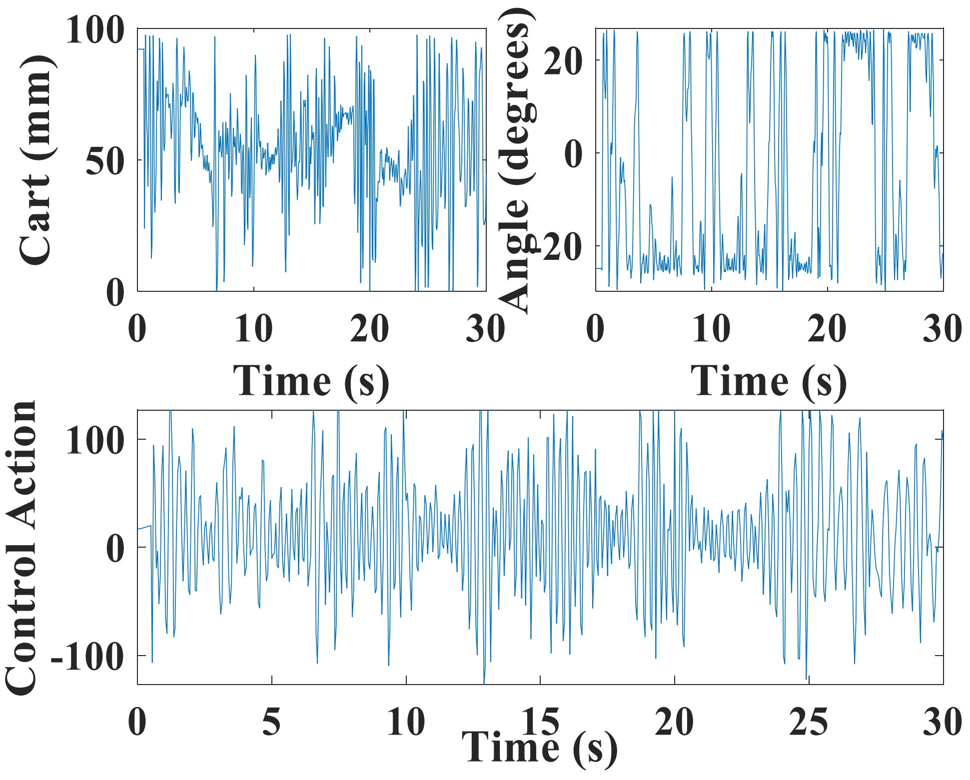
Inverted pendulum system

Human in the loop Control diagram

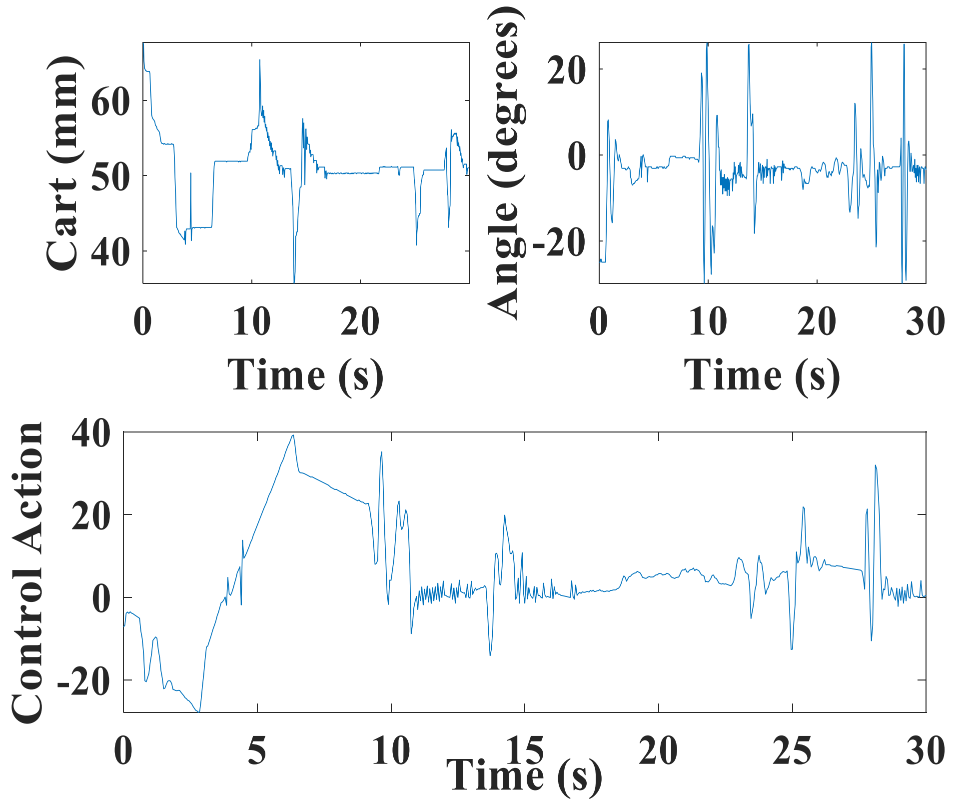


Obtained results

Human in the loop vs Automatic control response



Human in the Loop



Double PID control

Result analysis

Performance indices

Root mean square value(RMS):

$$RMS = \sqrt{\frac{1}{N}\sum_{i=1}^{N} x(i)}$$

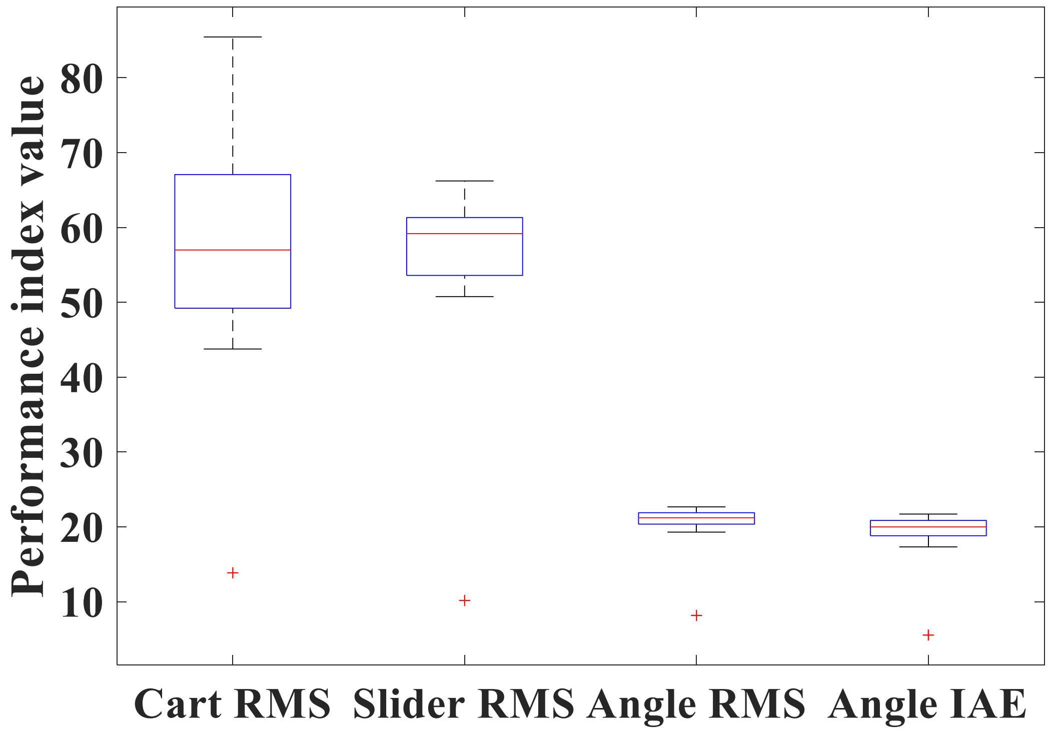
Integral of absolute error (IAE):

$$IAE = \frac{1}{N}\sum_{i=1}^{N} |e(i)|$$

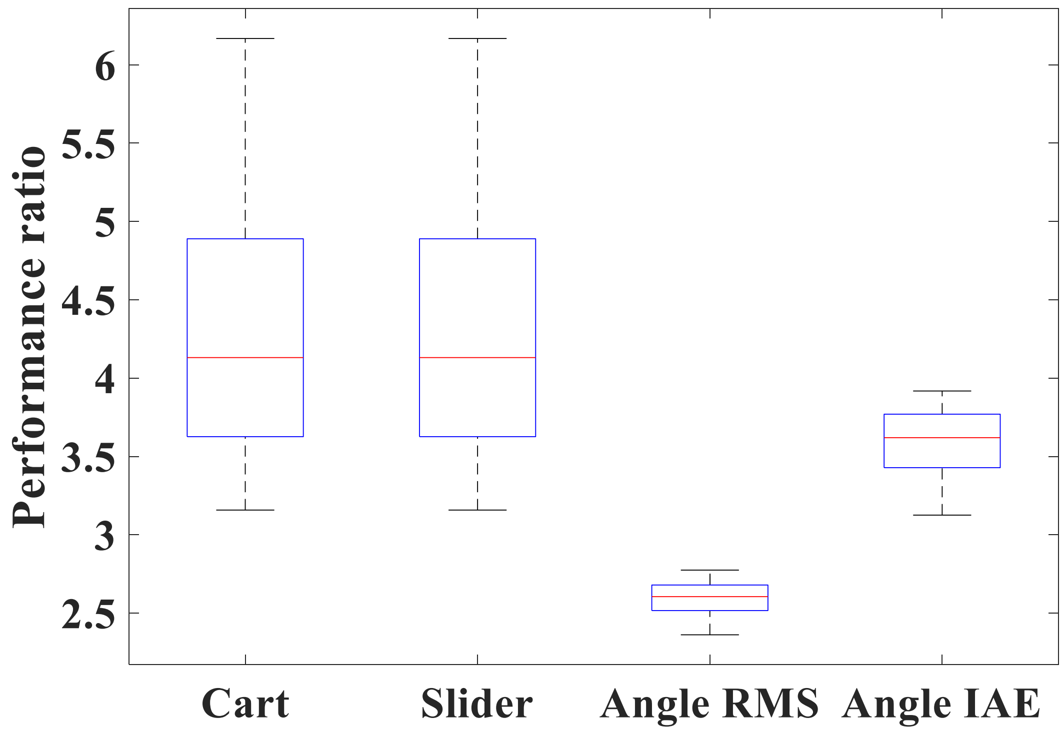
Subject	Cart RMS	Slider RMS	Angle RMS	IAE Angle
Automatic	13.855	10.166	8.167	5.539
1	57.240	53.784	19.293	17.316
2	51.920	63.662	20.991	19.497
3	65.699	60.221	21.142	19.923
4	71.985	66.214	20.890	19.495
5	68.428	62.319	21.726	20.631
6	49.688	57.585	22.537	21.704
7	61.253	52.503	22.468	21.639
8	62.658	59.102	21.282	20.135
9	61.705	63.418	20.444	18.829

Result analysis

Box plot comparison for 20 test subject



Human in the loop vs Automatic control



Human vs machine performance ratio

Conclusions and future works

- The human behavior is strictly related with the performance of the proposed task.
- Sudden and faster changes in the human operator command signal reduces the times of the pendulum reach the desired position and increase the RMS value of the command action
- Human interaction reduce the system performance if the operator is not well trained to perform the task
- As future works, the introduction of machine learning tools to assist and improve the human in the loop control is proposed as well as testing advanced control techniques for automatic control

Thanks for your attention

Space for questions