Predicting the Robot Learning Curve based on Properties of Human Interaction

Sekou Remy, Dr. Ayanna M. Howard
Human-Automation Systems (HumAnS) Lab.
School of Electrical and Computer Engineering
Georgia Institute of Technology

Introduction

- Motivation Statement 1
  - Bullet 1
- Motivation Statement 2
  - Bullet 2

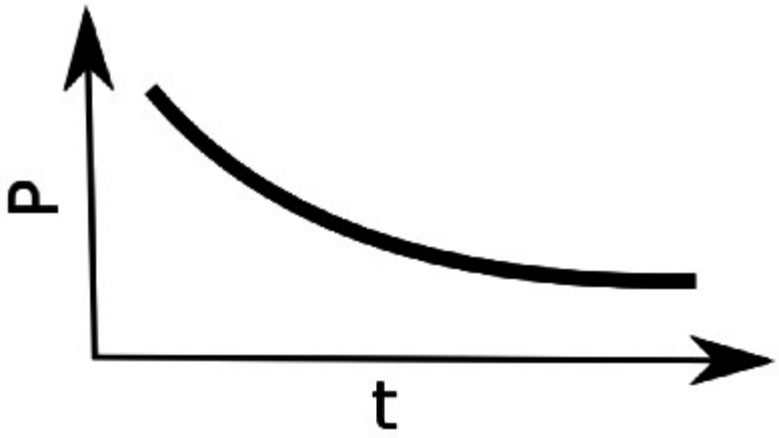
Purpose (1)

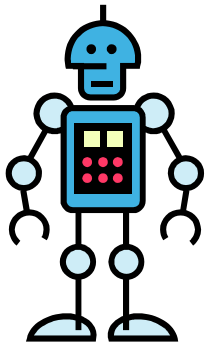
- To show that robotic students can demonstrate a learning curve, and that the properties of the curve are affected by the human teacher's capabilities in a measurable manner.

Purpose (2)

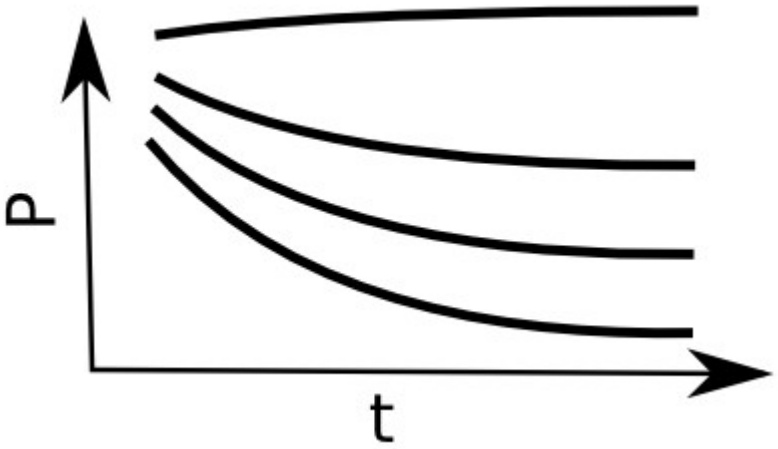
- To show that without a detailed model of the target behavior, or of the human teacher, it is possible to autonomously estimate learning progress by observing properties of the provided instruction.

Background





Background

- The learning curve will likely vary based on instruction.
  - 

Learning Curves

- Families of equations
  - Exponential:

$$P(N) = A + Be^{\beta(N+N_0)}$$

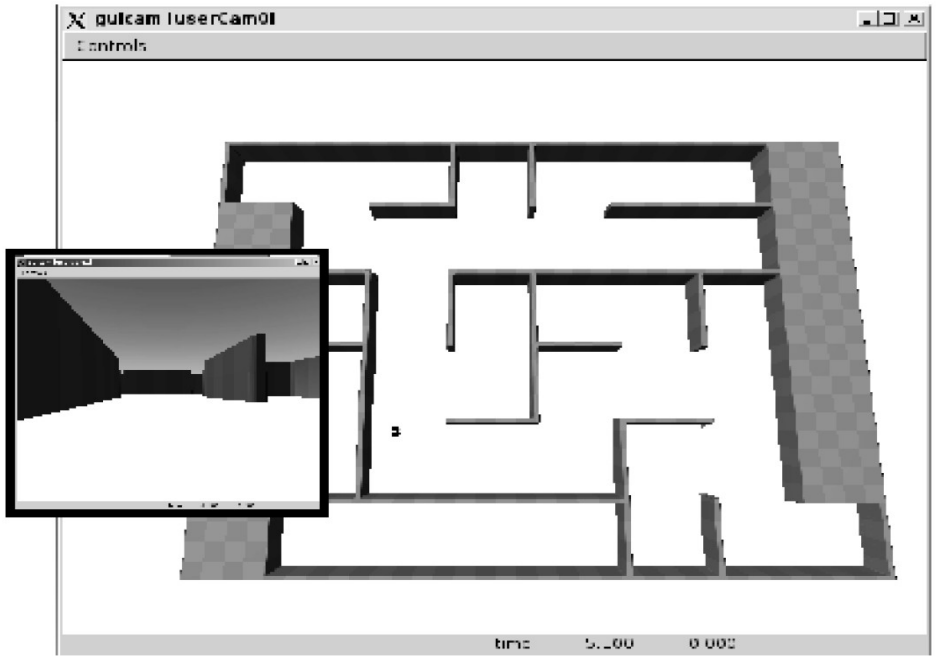
  - Power law:

$$P(N) = A + B(N + N_0)^{\beta}$$

- Applicability

Application Domain

- Mobility and navigation.



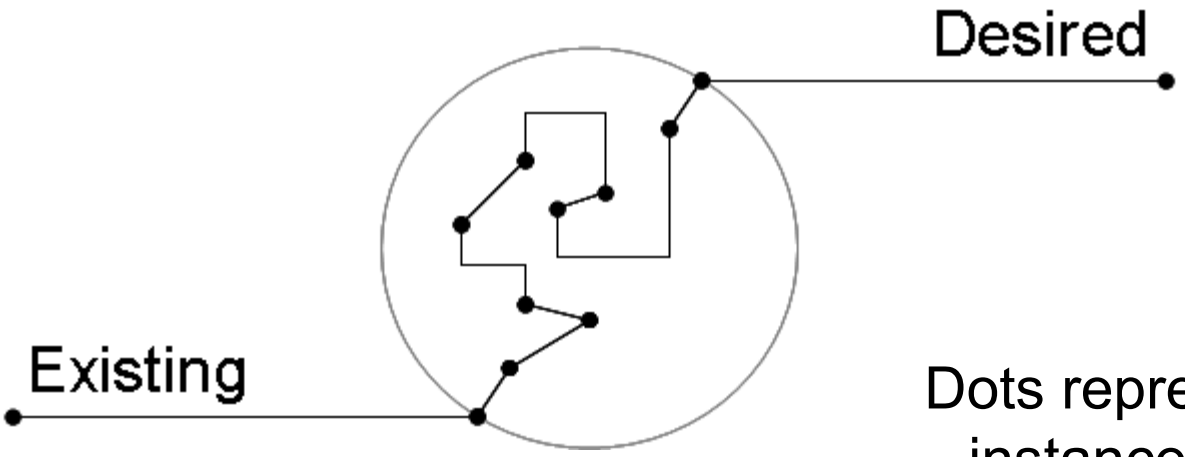
The Task

- Wall following.
  - Based on:
    - Proximity sensors.
    - Differential drive actuation.
  - Evaluation:

$$\text{performance} = \alpha_1 d + \alpha_2 t$$

Approach to Learning

- Interactive Learning with a robotic student and human teachers



Dots represent instances of teaching

Making Learning Easier

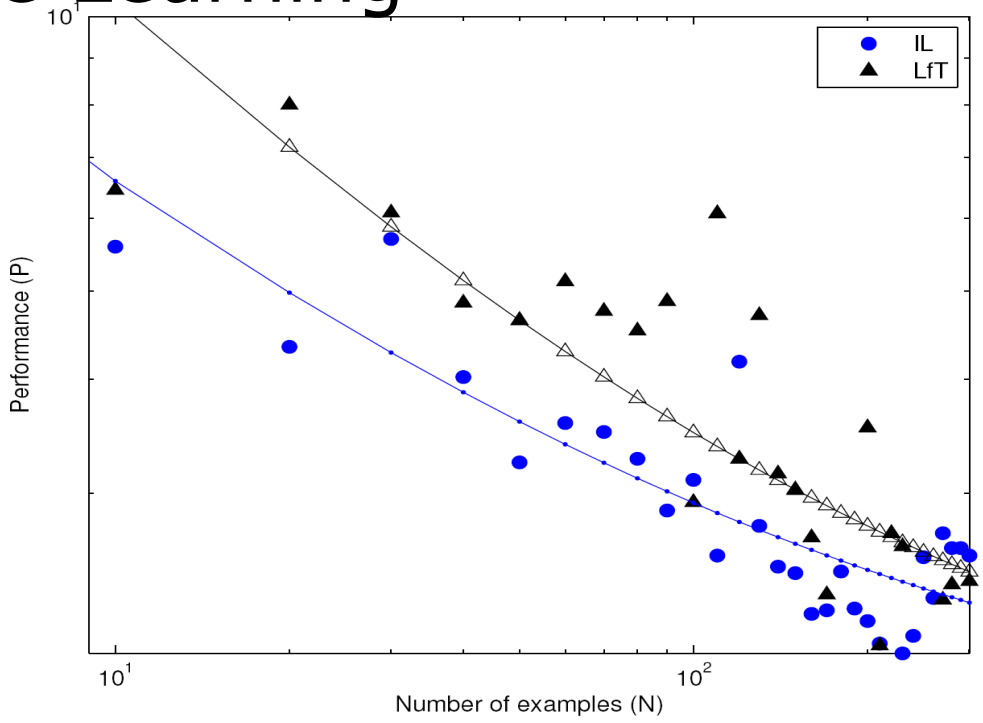
- How to make learning tractable problem.
  - Dimensionality reduction:
    - Principal Component Analysis.
    - Self organizing maps.
  - Requirements of reduction:
    - Local geometry preservation

Representing Behaviors

- Mapping from sensing to actuation.
  - F_N:X → Y
  - In the limit, F_N → F
    - in theory…
  - as N increases:
    - Over training.
    - User fatigue/discomfort.

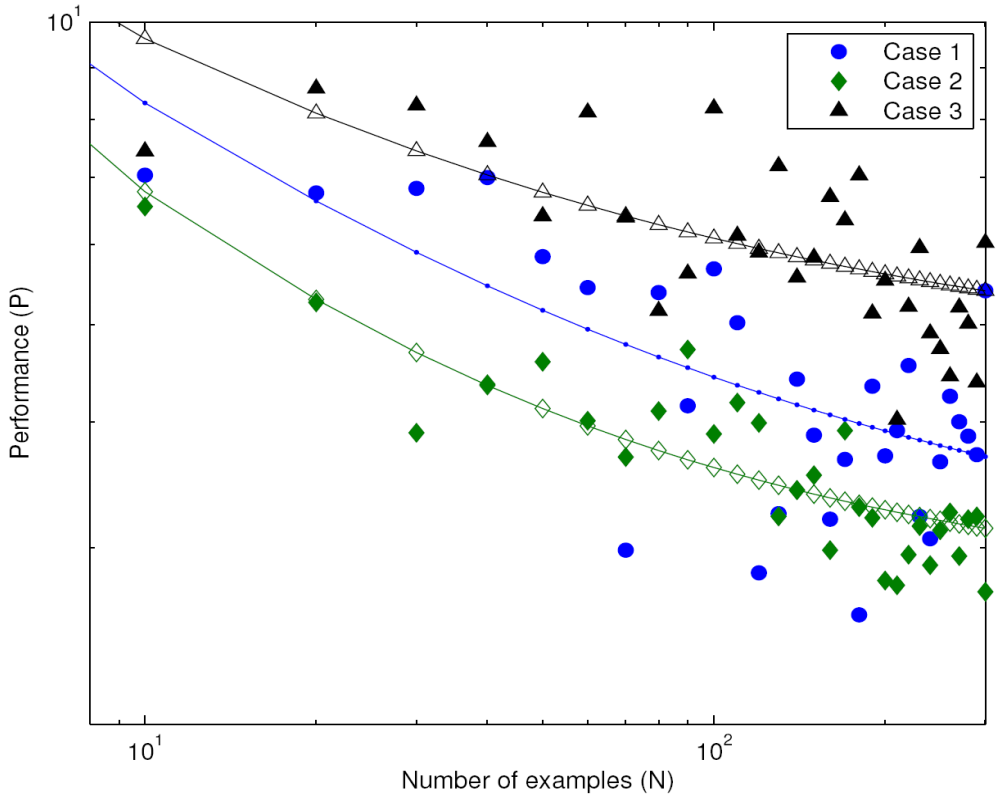
Results

- Learning from Teleoperation
- Interactive Learning



Results

- Cases 1,2,3.



Results

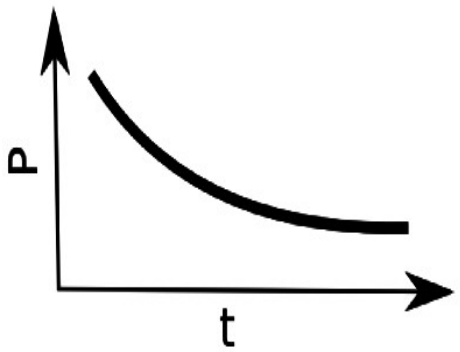
- Uncovering parameters based on data.

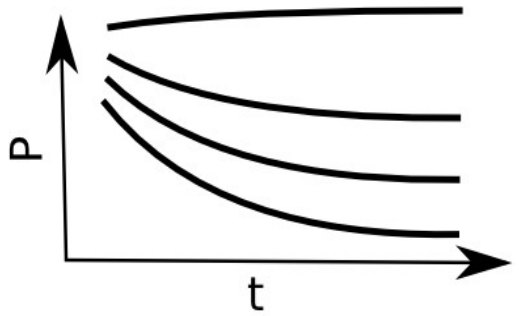
$$P(N) = A + B(N + N_0)^{\beta}$$

	IL	LfT	Case 1	Case 2	Case 3
β	-0.55	-0.64	-0.51	-0.65	-0.50
B	18.20	39.06	18.20	18.28	16.34
A	1.490	1.440	2.715	2.695	4.456

Summary (1)

- Purpose:
  - To show that robotic students can demonstrate a learning curve, and that the properties of the curve are affected by the human teacher's capabilities in a measurable manner.





Refocus

- Remember F_N:X → Y
  - Study how errors in X and Y change over time

$$MQE = \frac{1}{u}\sum_{k}\frac{1}{n}||m_i - a_k||$$

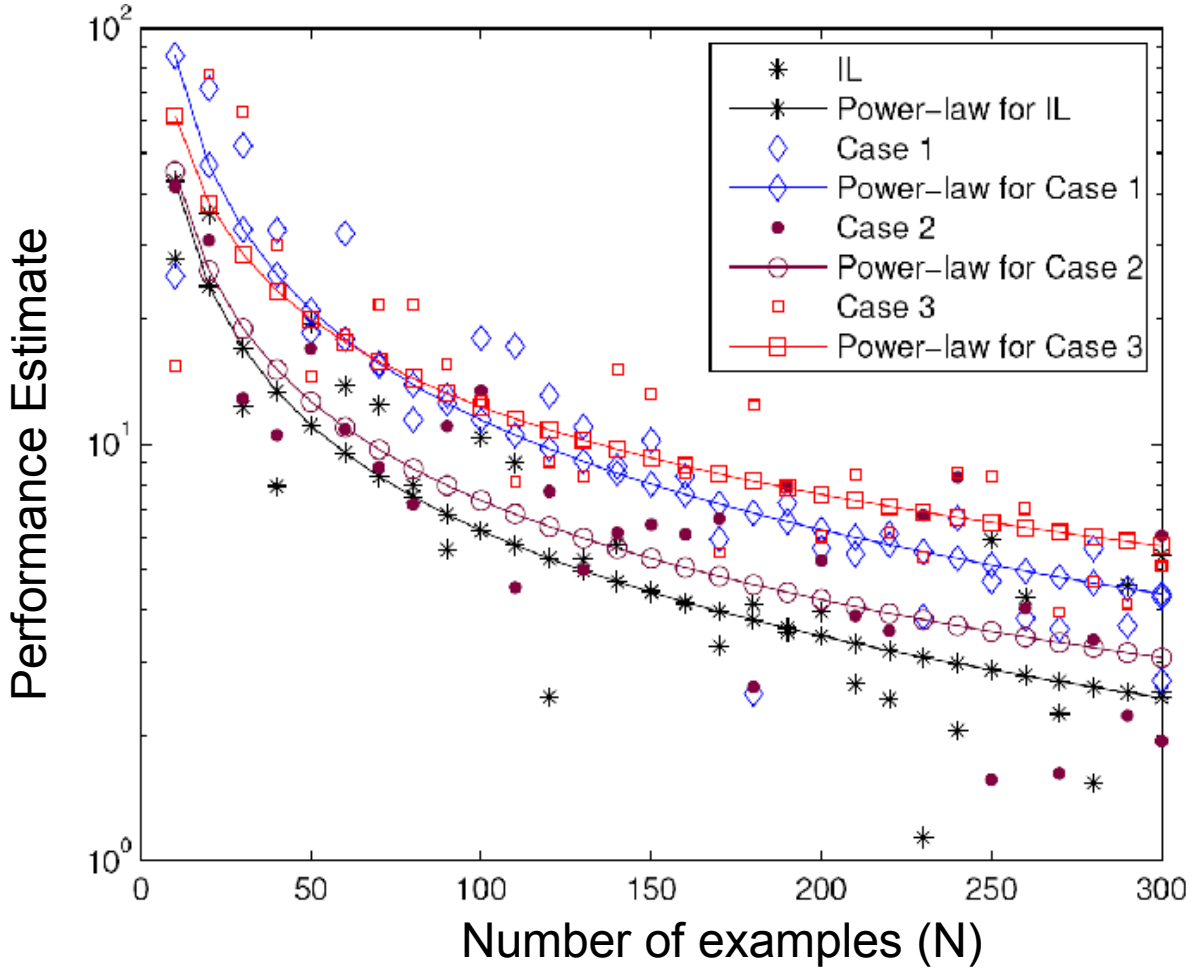
$$\frac{\delta MQE}{\delta i}\frac{\delta i}{\delta t}$$

  - Study how entropy of F_N changes over time

$$H = -\sum_{i=0}^{k} P_j(A = a_{j+i}) ln\left(P_j(A = a_{j+i})\right)$$

$$\frac{\delta H}{\delta i}\frac{\delta i}{\delta t}$$

Results

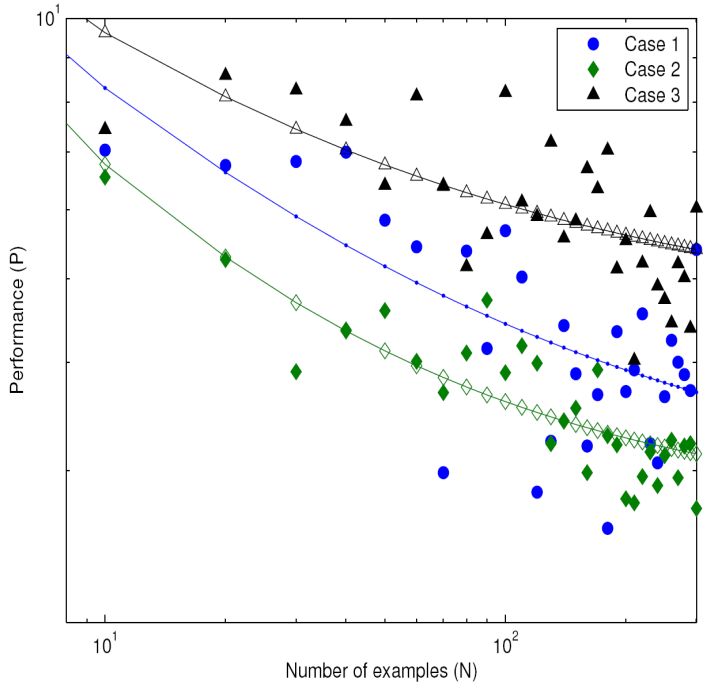

IL
Power–law for IL
Case 1
Power–law for Case 1
Case 2
Power–law for Case 2
Case 3
Power–law for Case 3
Performance Estimate
Number of examples (N)
10^2
10^1
10^0
0
50
100
150
200
250
300

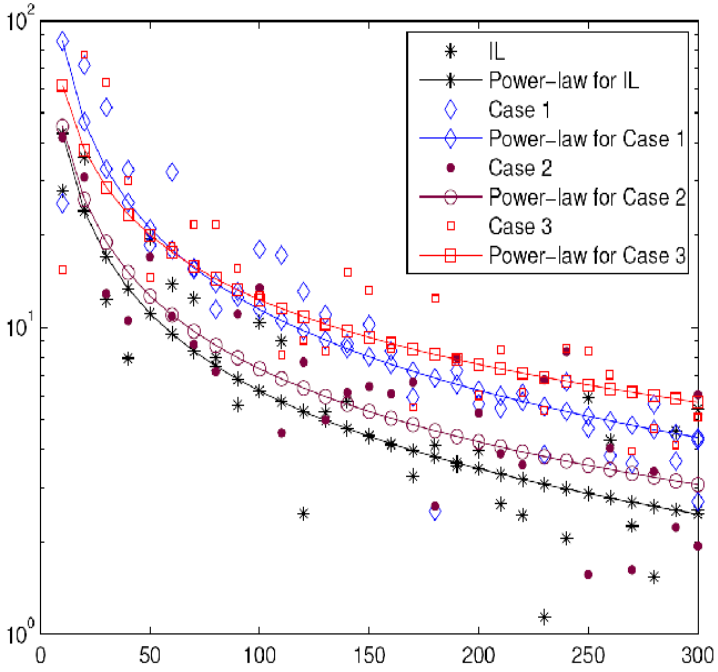
Results

- Unfortunately cannot compare apples to apples (Further work needed!)

	IL	Case 1	Case 2	Case 3
β	-0.8402	-0.8751	-0.7900	-.6993
B	297.24	643.85	278.6	308.4

Results


Case 1
Case 2
Case 3
Performance (P)
Number of examples (N)
10^1
10^2


IL
Power−law for IL
Case 1
Power−law for Case 1
Case 2
Power−law for Case 2
Case 3
Power−law for Case 3
10^2
10^1
10^0
0
50
100
150
200
250
300

Summary (2)

- Purpose:
  - To show that without a detailed model of the target behavior, or of the human teacher, it is possible to autonomously estimate learning progress by observing properties of the provided instruction.

Future work

- Mapping from estimate to actual performance
- Expanded user pool
- More complex instruction
  - Sensing
  - Action
  - Behavior

Questions

- ?