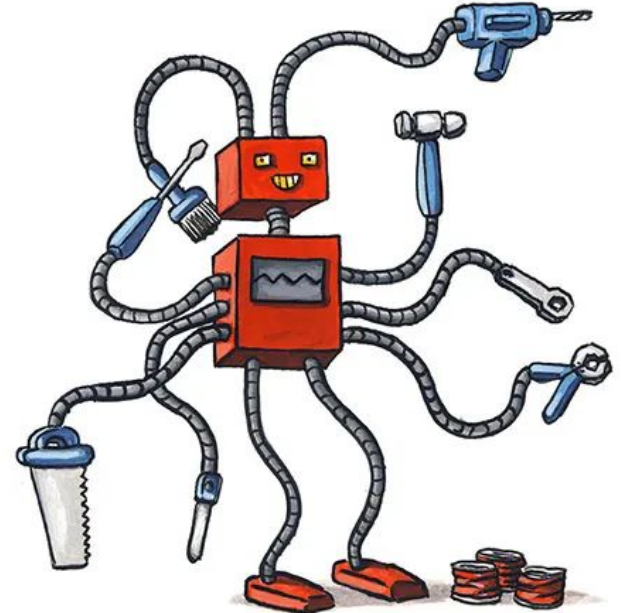# Machine Learning & Probabilistic Modelling

Dr. Svetlin Penkov

Fall 2019
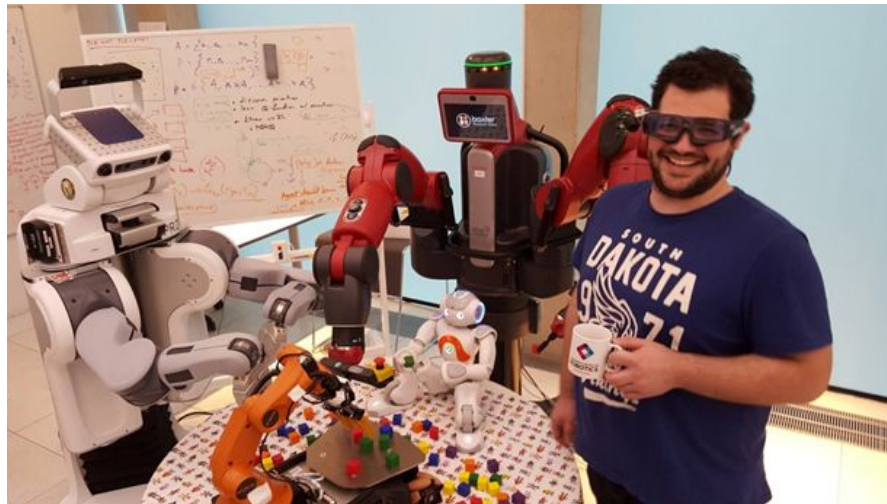
# About me

Dreaming about building intelligent robots since the age of 6...

# About me



FIVE AI

Research Scientist & Team Lead



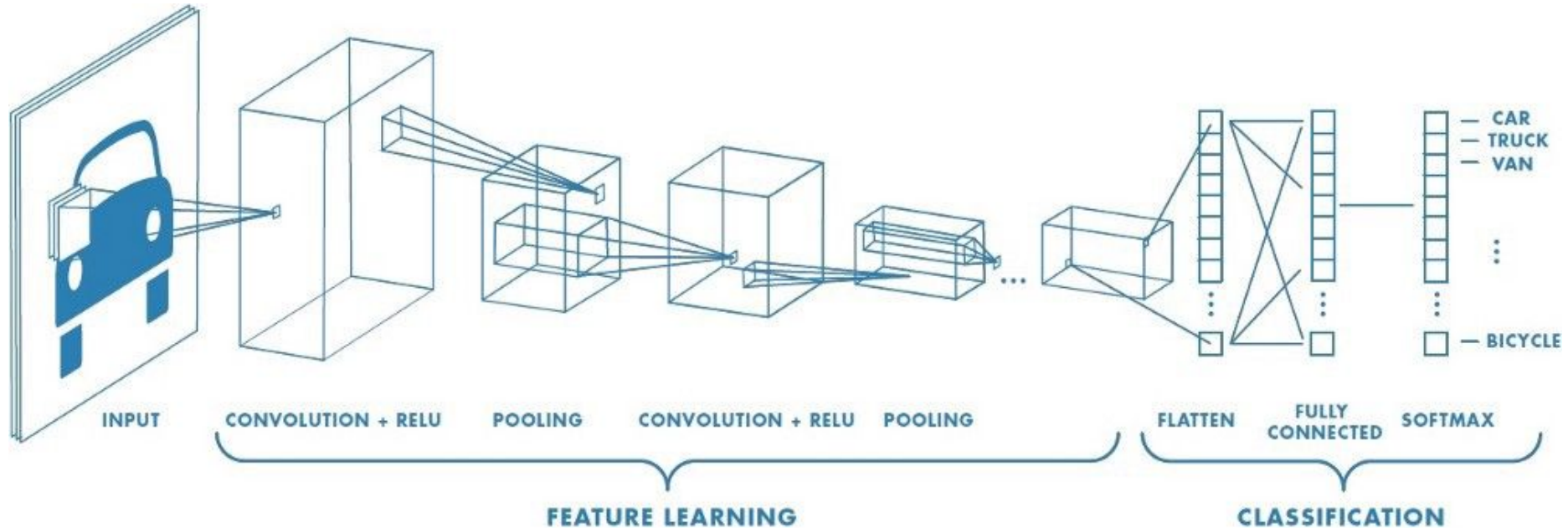PhD in Robotics & AI

THE UNIVERSITY of EDINBURGH

# About me

Robots should learn to program themselves…



- Team of world experts in AI and robotics
- Design, develop and deploy AI based solutions in **challenging domains**
- Research new **state-of-the-art AI methods**

# Why Machine Learning & Probabilistic Modelling?

# Deep Neural Networks



INPUT    CONVOLUTION + RELU    POOLING    CONVOLUTION + RELU    POOLING    FLATTEN    FULLY CONNECTED    SOFTMAX

CAR / TRUCK / VAN / BICYCLE

FEATURE LEARNING      CLASSIFICATION

# Probabilistic Machine Learning

- Deep neural networks sit within a more general framework for probabilistic machine learning

- All modern machine learning algorithms have a probabilistic formulation
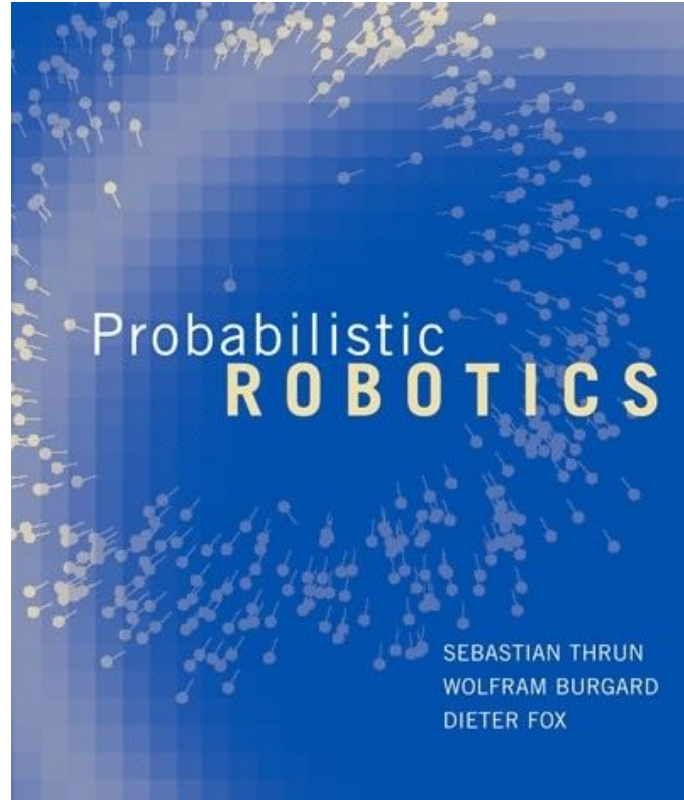
# Autonomous Agents



Lee Sedol resigning to AlphaGo.

Opening a valve at DARPA Rescue Challenge.

# Probabilistic Robotics

# Uncertainty

- Parameter uncertainty

- Structural uncertainty

- Algorithmic uncertainty

- Experimental uncertainty

- Interpolation uncertainty

Aleatory vs. epistemic uncertainty

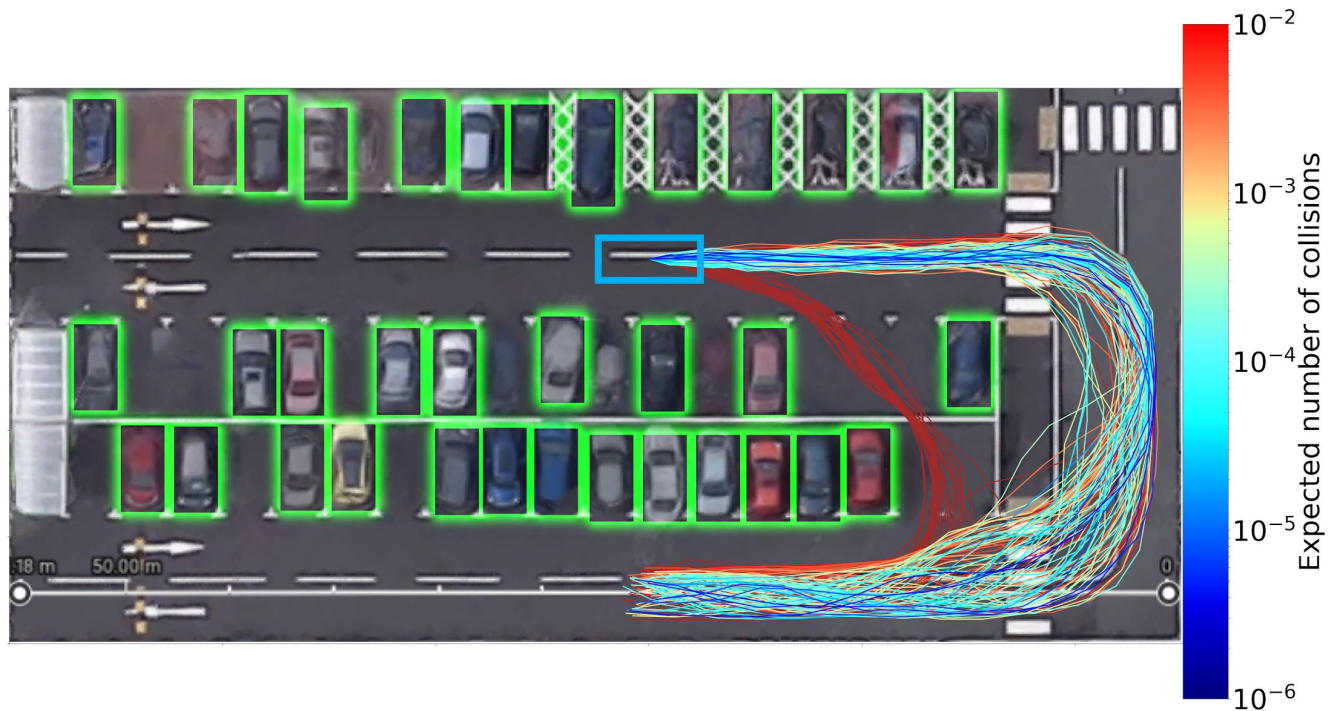# Uncertainty is Present in Any Real Data

1. I have written down the word '*uncertainty*' on a sheet of paper

2. Write down the word '*uncertainty*' on the same sheet

3. Pass the sheet to the next person

4. If you are the last person give me back the sheet

# Autonomous Driving

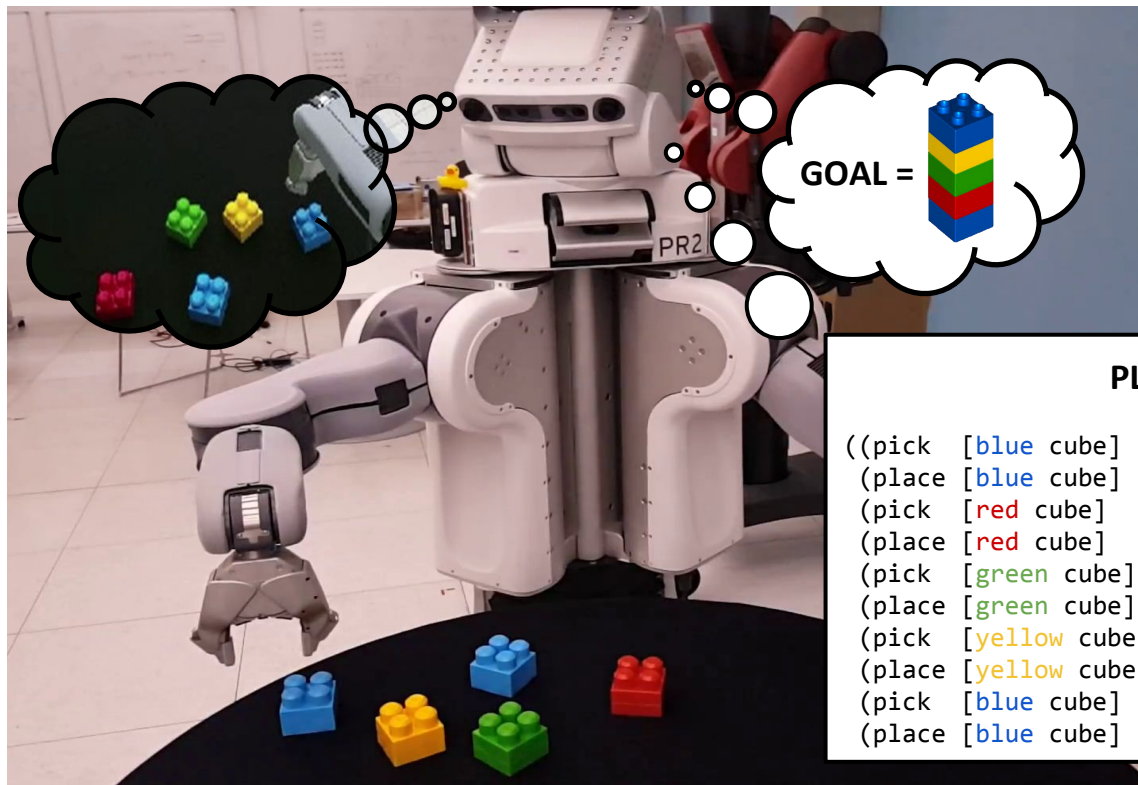# Simultaneous Localisation and Mapping (SLAM)



http://mitdbg.github.io/nedbday/2017/talks/leonard.pdf
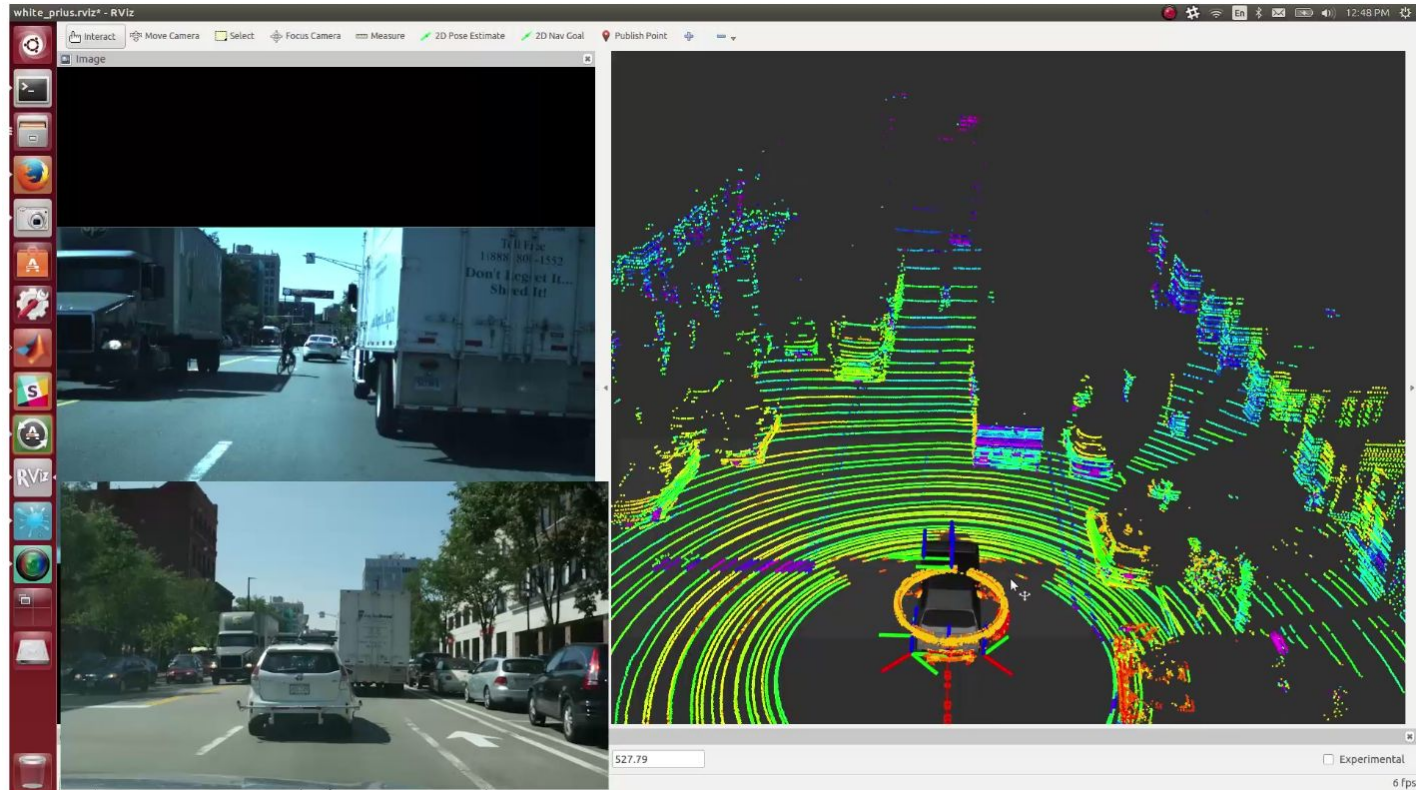
# Risk Estimation Under Uncertainty



Blake et al., *arXiv:1804.05384,* 2018

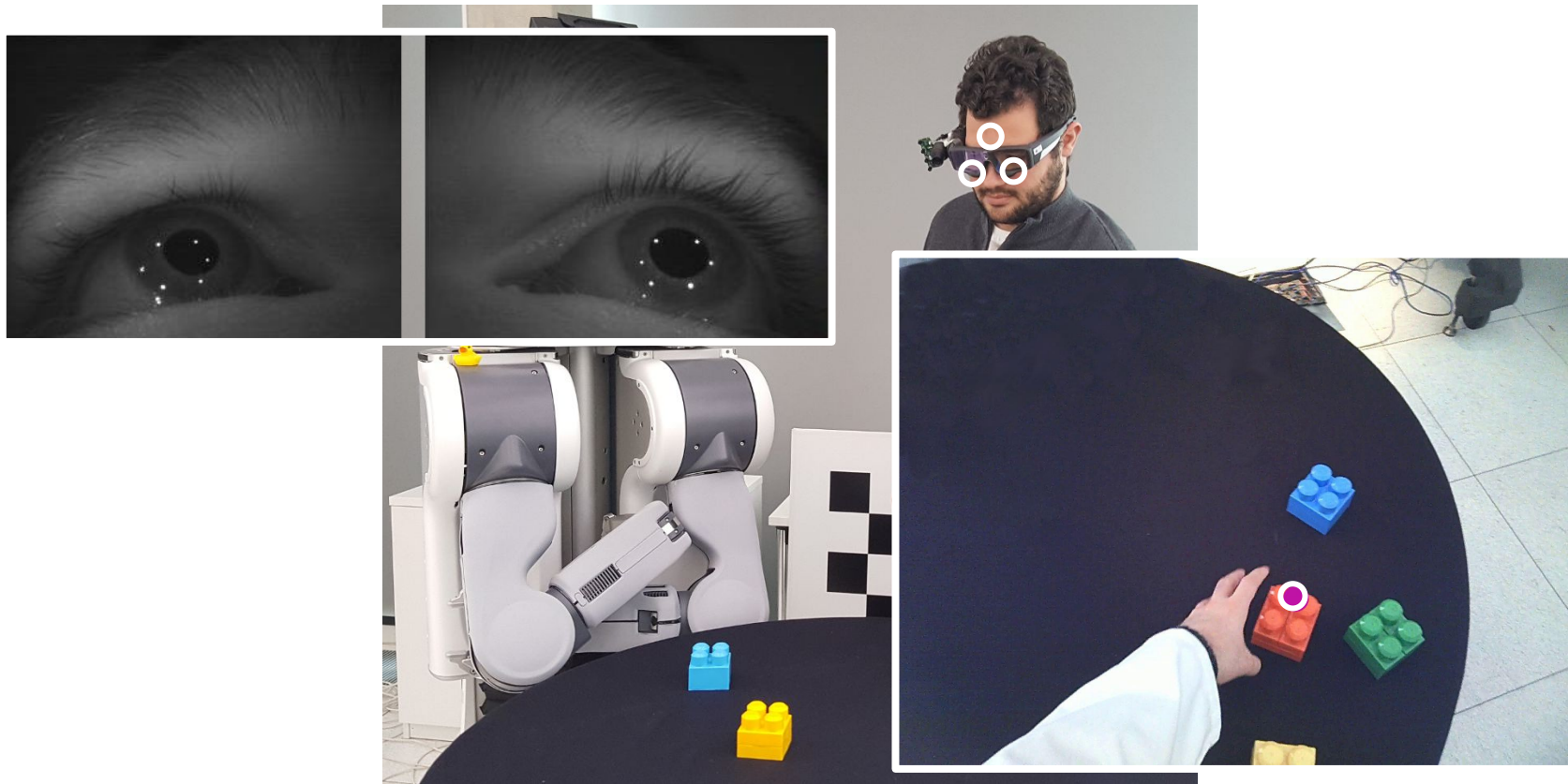# Learning From Demonstration

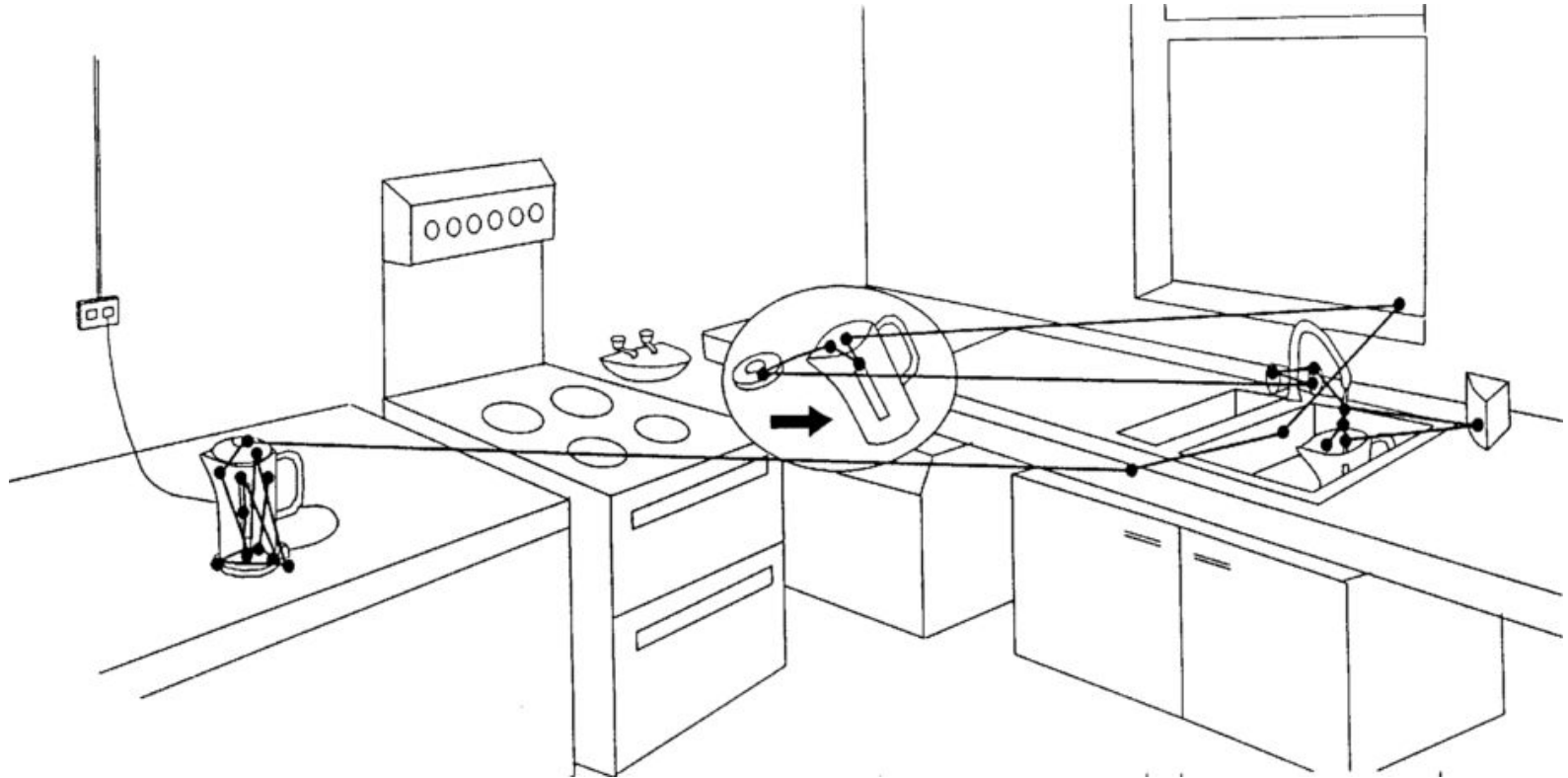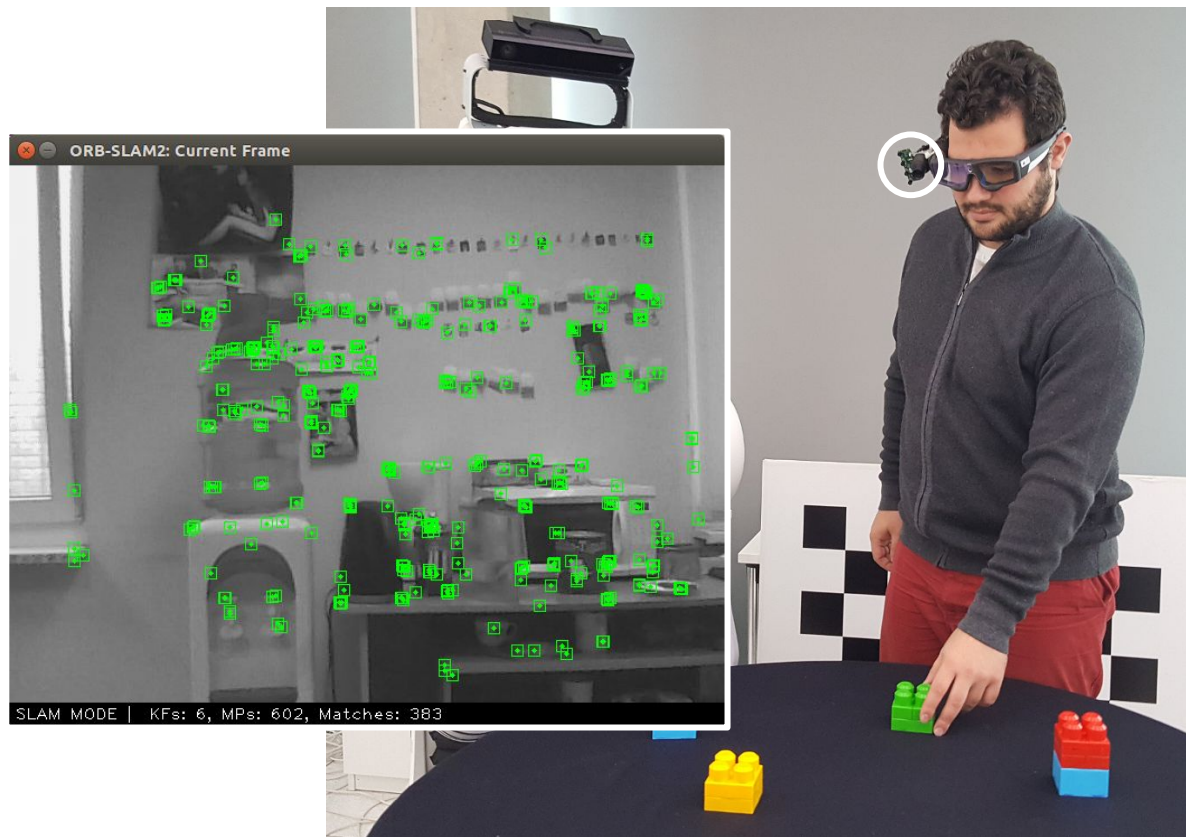# The Physical Symbol Grounding Problem (Penkov et al., ICRA 2017)

# Learning from Demonstration

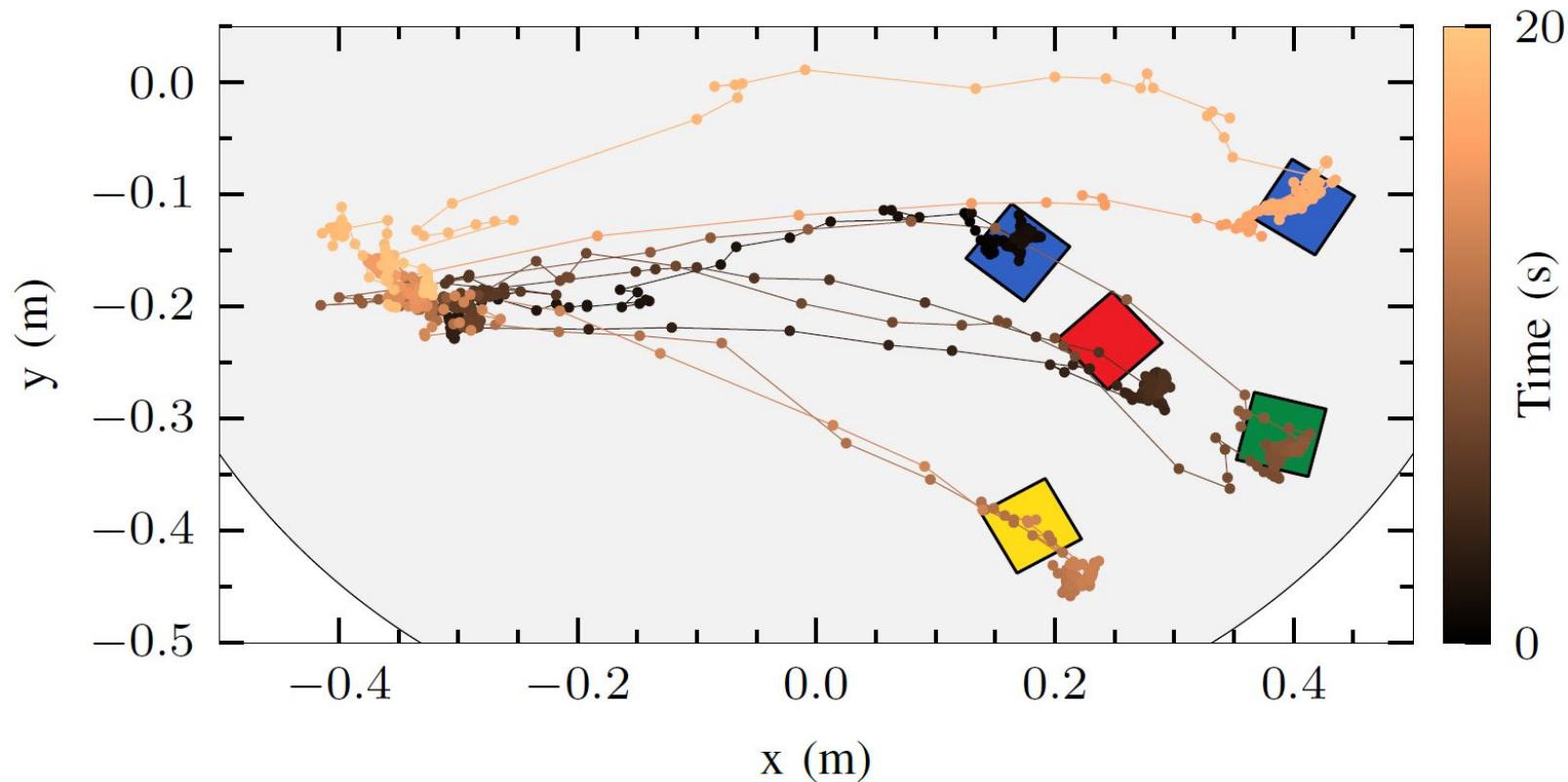# Eye Tracking & Task Execution
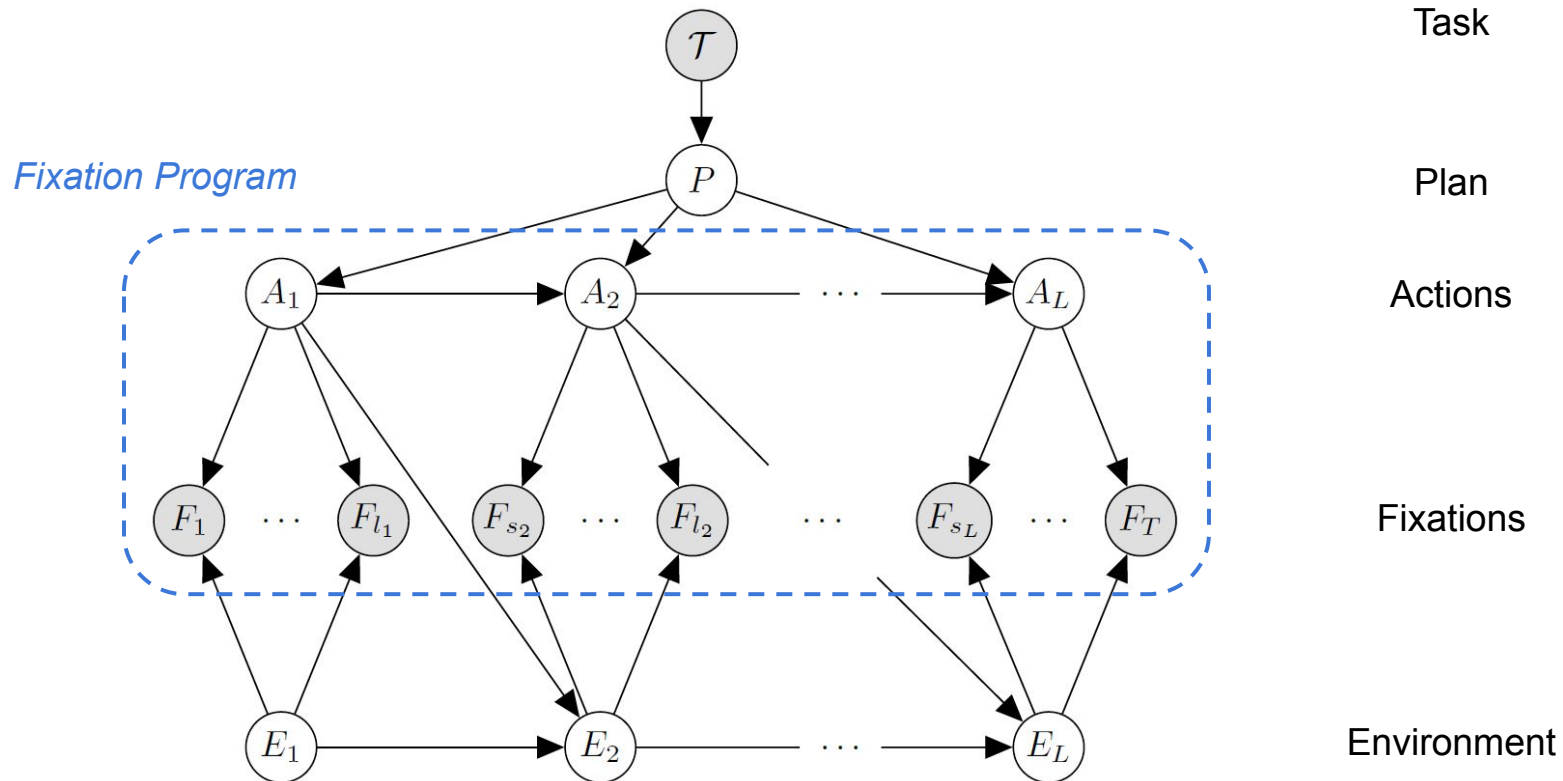
# 3D Eye Tracking with ORBSLAM

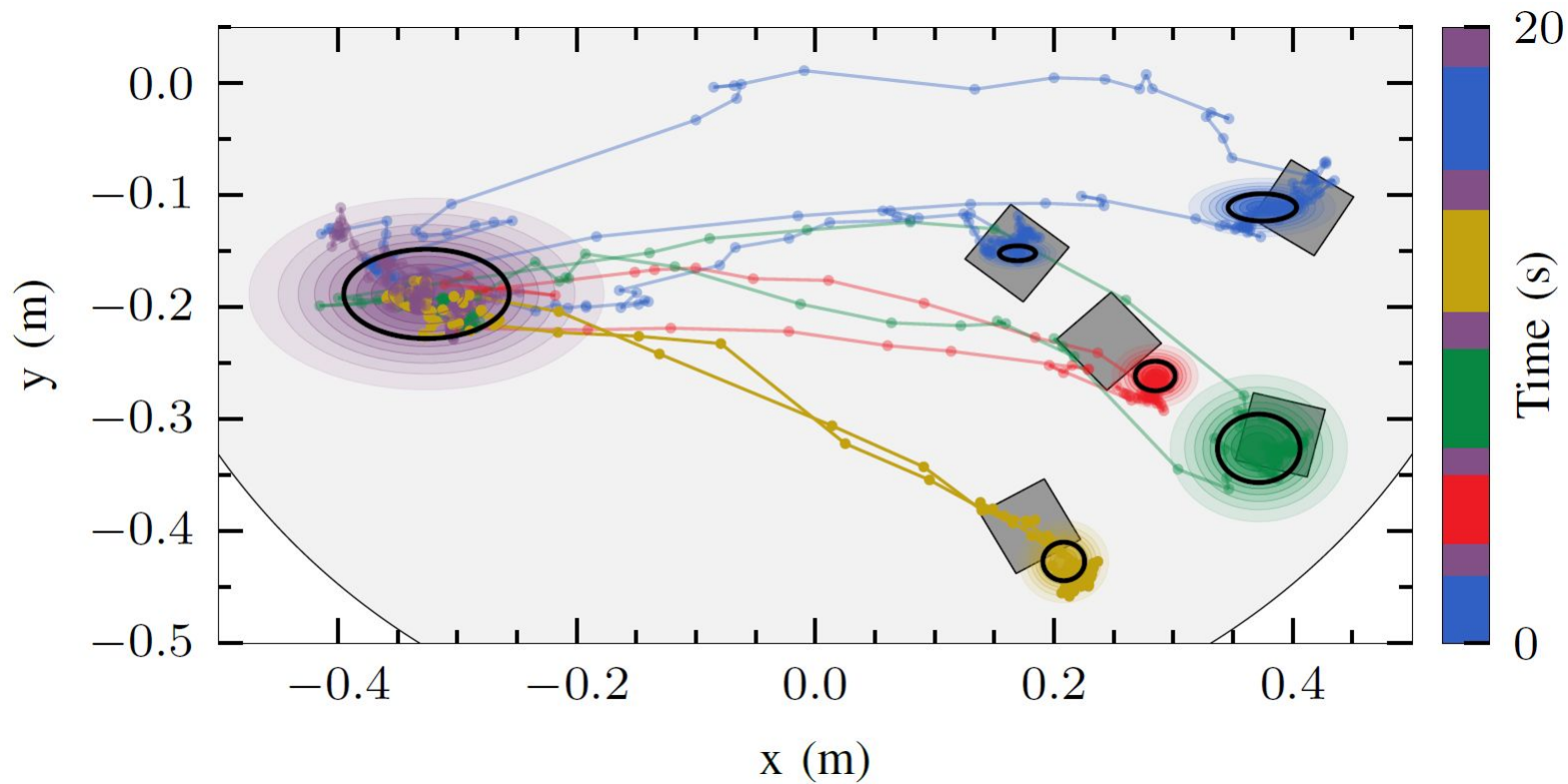# 3D Eye Tracking & Demonstration

# 3D Eye Tracking & Demonstration

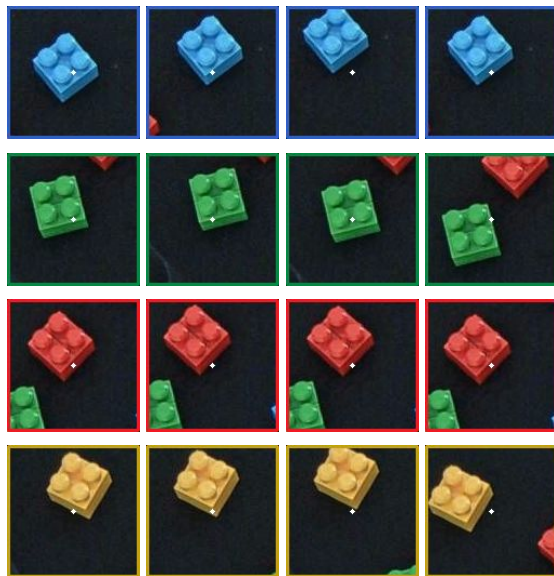# Probabilistic Graphical Model
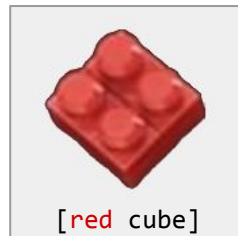
# Inference Results

# Instance Learning



Learnt Symbol Instances:

[red cube]

[yellow cube]

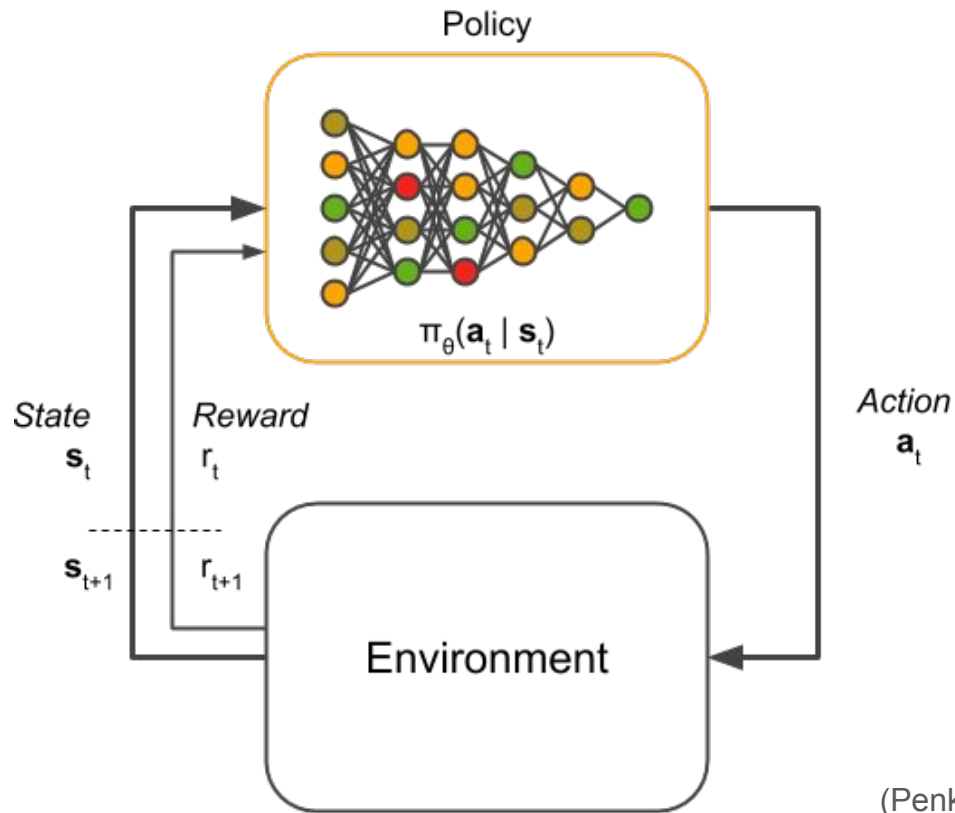[green cube]

[blue cube]

Learnt Goal:

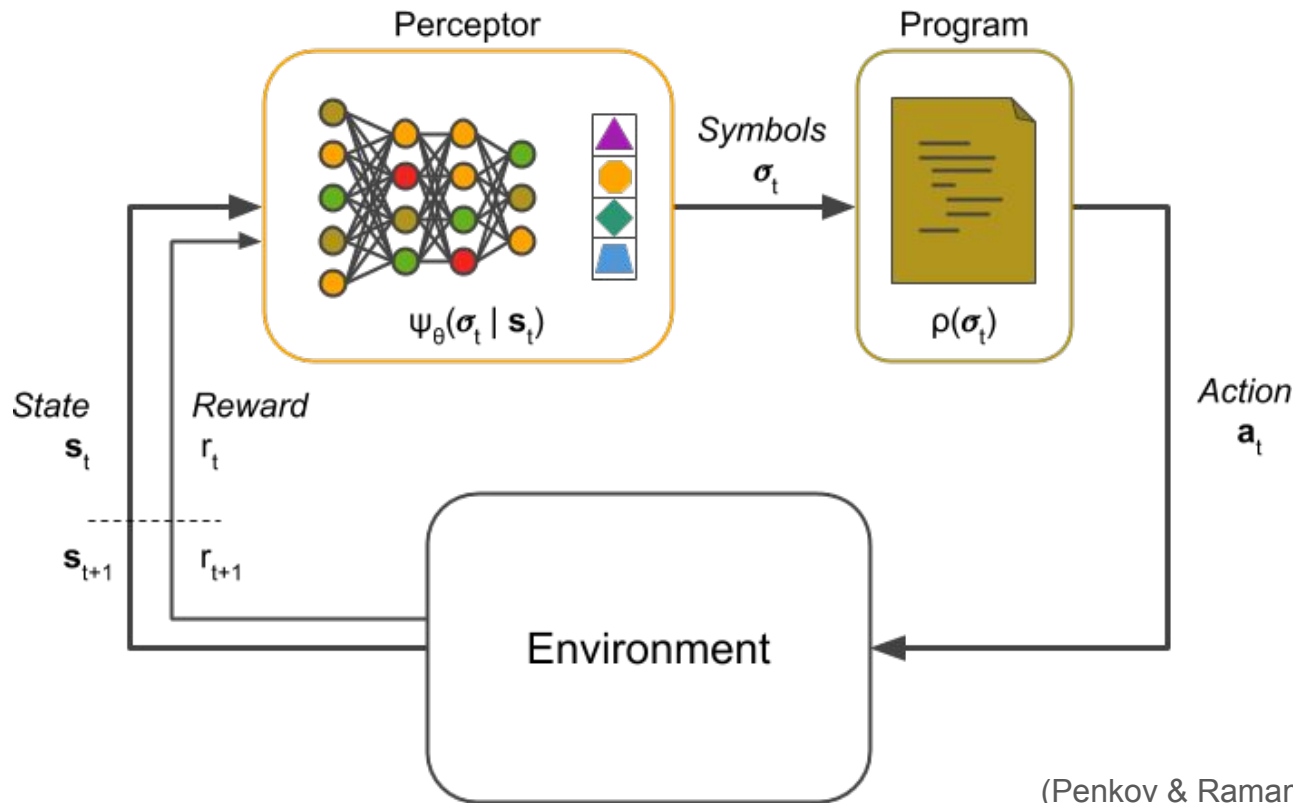# PR2 Tower Building

# HRI Collaboration



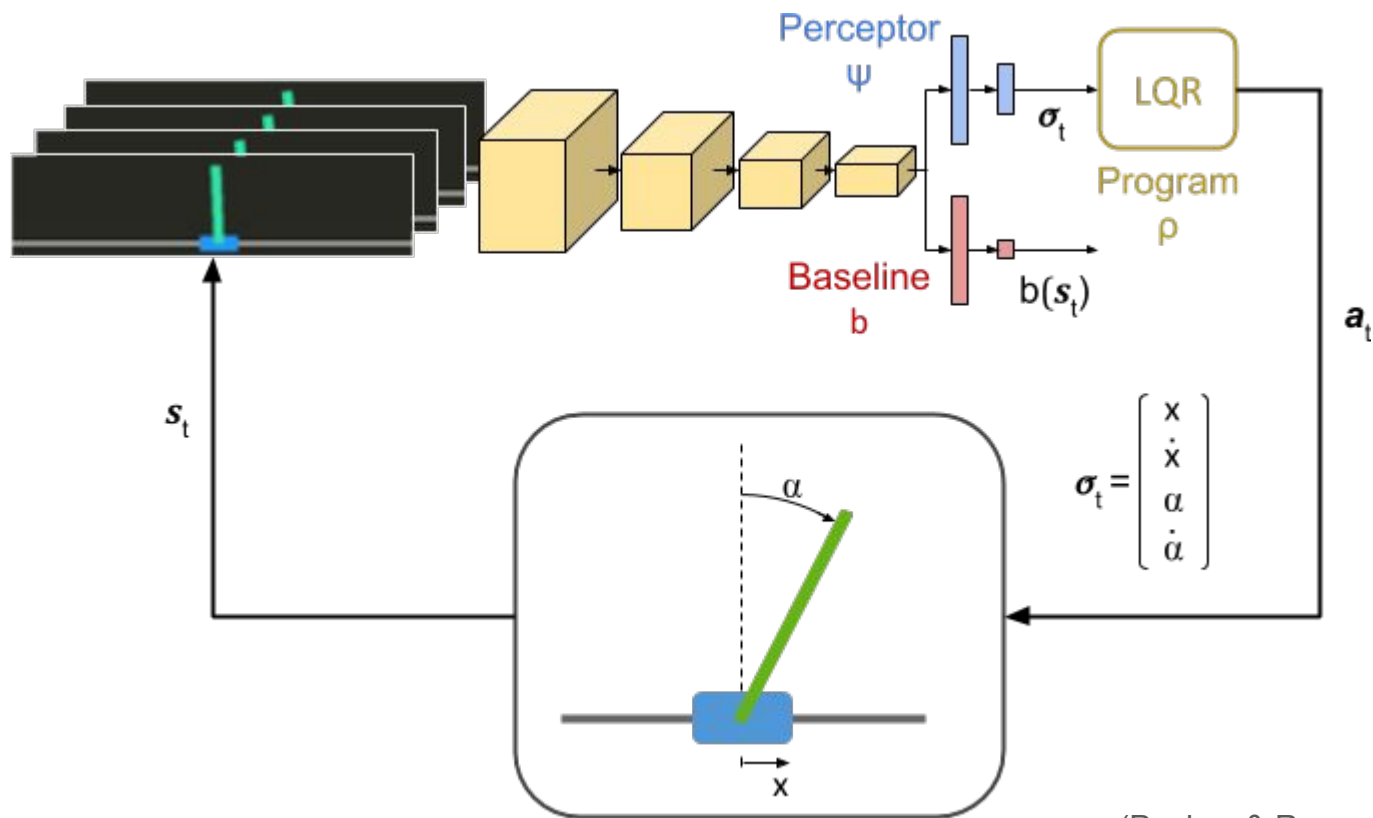Compliant joint manipulation improves task performance

# Reinforcement Learning

# Policy Gradients Setup



(Penkov & Ramamoorthy, ICLR 2019)

# Perceptor Gradients Setup



(Penkov & Ramamoorthy, ICLR 2019)

# Cart-Pole Balancing



(Penkov & Ramamoorthy, ICLR 2019)
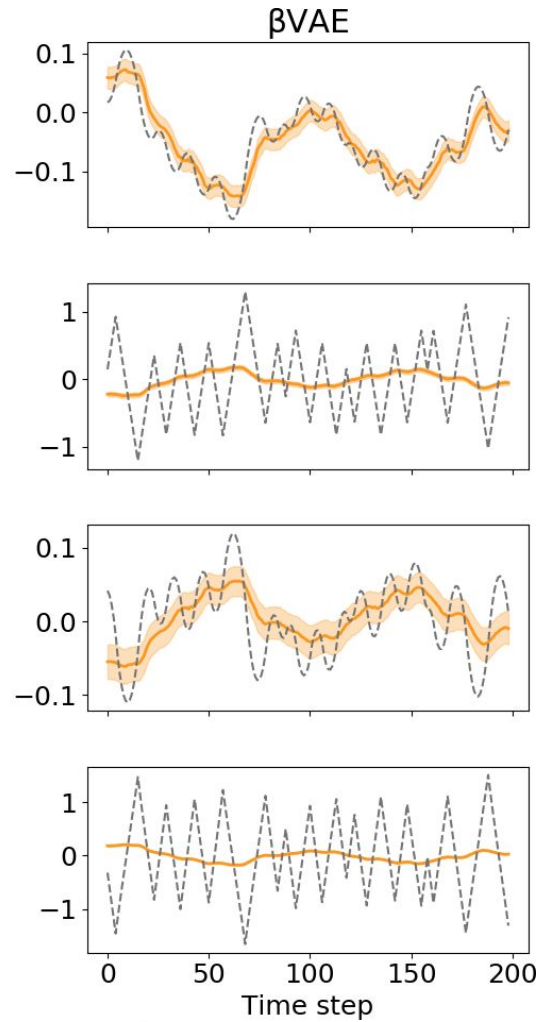
# Cart-Pole Balancing
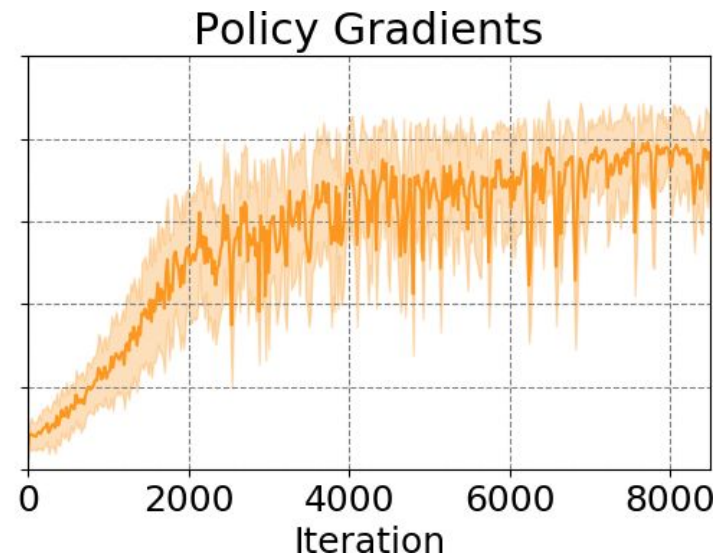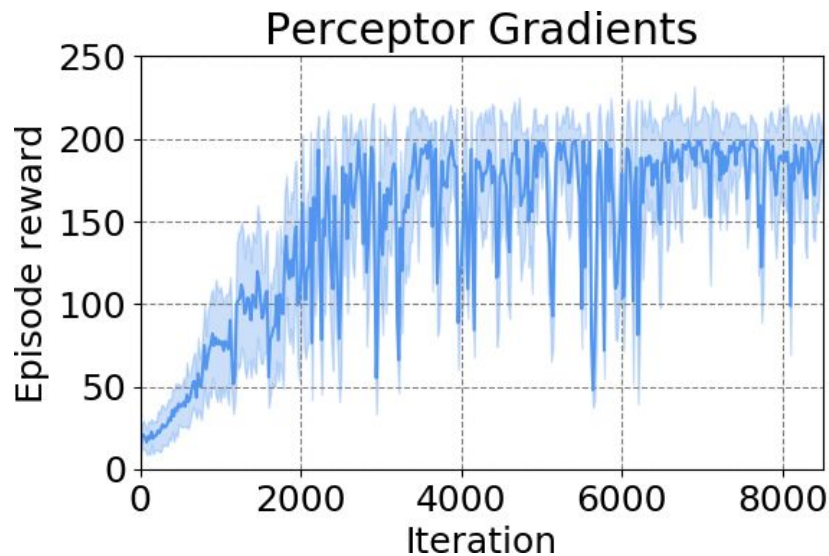
# Representation Learning



(Penkov & Ramamoorthy, ICLR 2019)
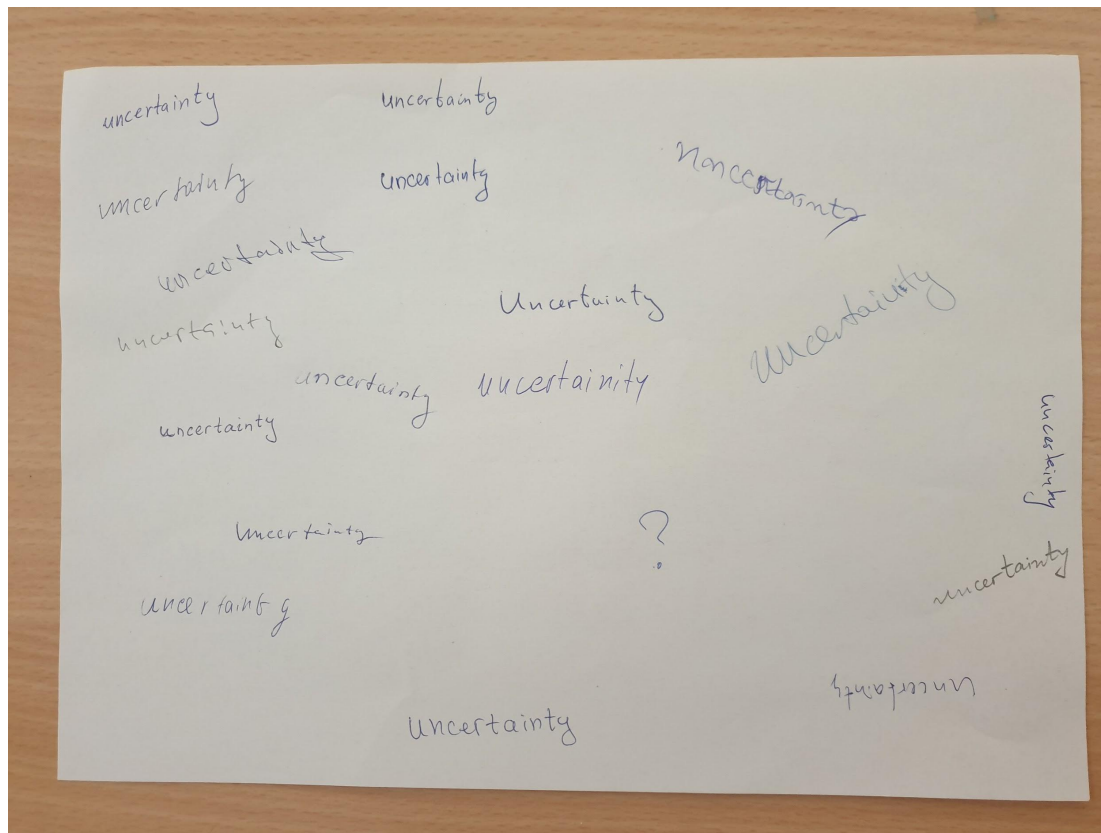
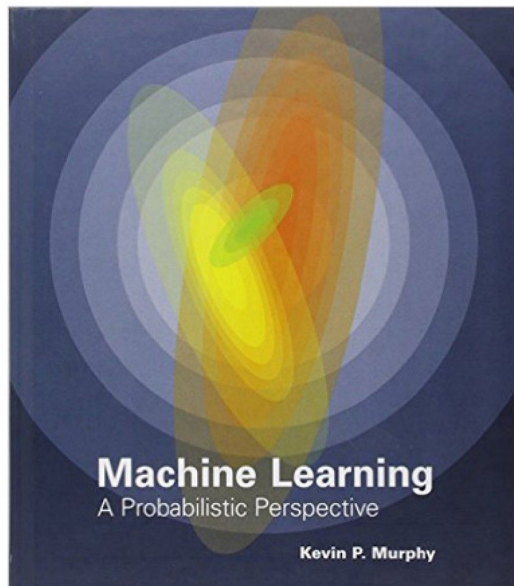| | Perceptor | βVAE |
|---|---|---|
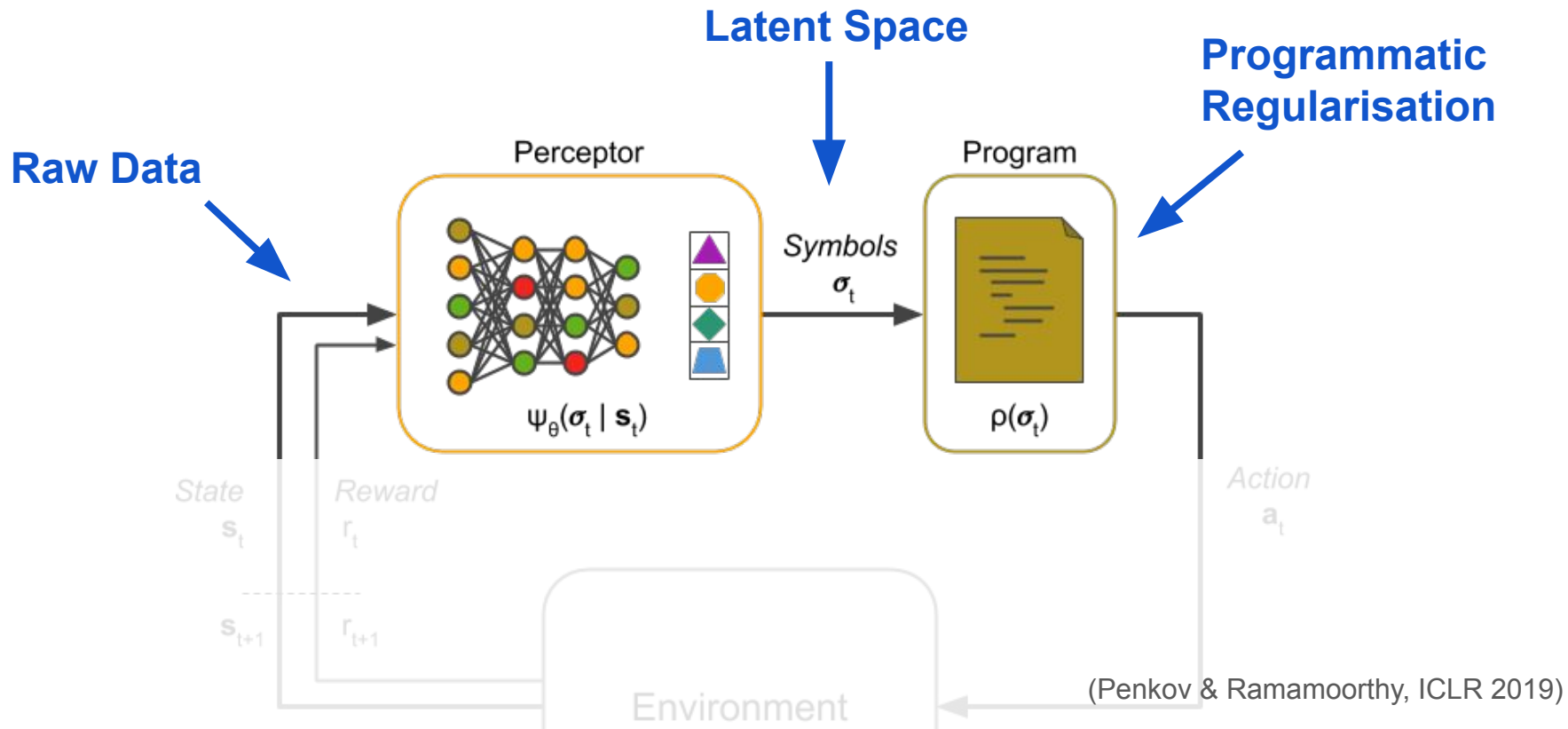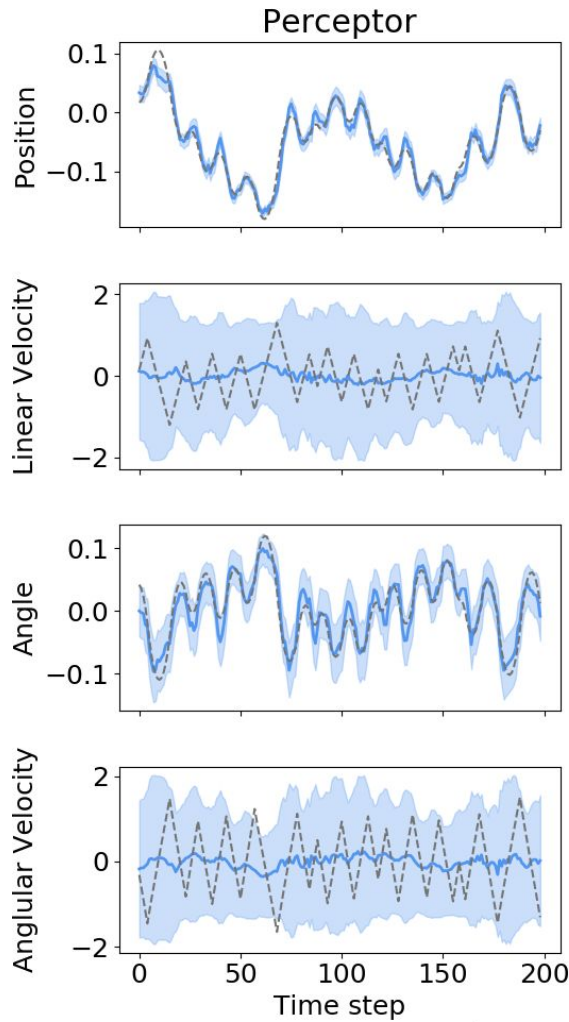
(Penkov & Ramamoorthy, ICLR 2019)

- - - Ground Truth

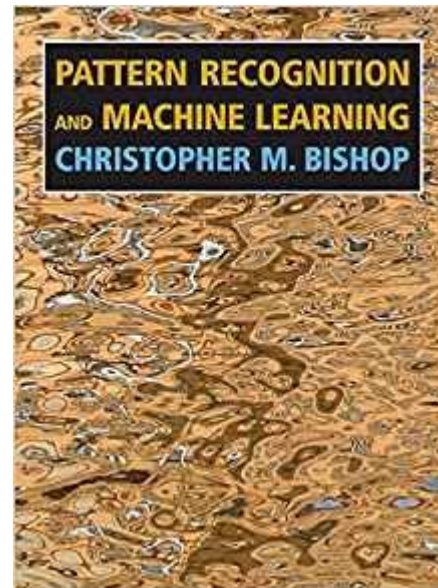# Is the sheet of paper ready?

# Course Logistics

- 15 lectures + seminars
- Every **Tuesday 17:00-21:00**
  - 17:00 - 19:00 seminars
  - 19:00 - 21:00 lectures
- Lecture Theatre 500
- Slides in english
- One coursework
  - out ~6th Nov, due ~1st Dec
- One project
  - out ~10 Dec, due ~1st Feb



Main textbook



Supplementary reading

# Course Logistics

- Course webpage
  - https://svepe.github.io/mlpm/

- Piazza group
  - Fill in MLPM enrollment form on the webpage to get an invitation
  - I will do my best to follow the group and respond to personal messages

# Final Note

- I hope you find the course hard, but meaningful
  - This means you will learn a lot
- There is a **solid theoretical thread** in the course
- There will be **hands on programming** involved

  - The project will involve programming (most likely Python)
- There will be lots of **state of the art examples and applications**
- I am teaching for the first time in Bulgaria, so any feedback is more than welcome

SEE YOU
NEXT TUESDAY AT 19:00 HERE!