Aalto University
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ELEC-E8126: Robotic Manipulation Learning

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Learning goals

- Understand application areas of learning in robotics.
- Understand challenges of learning in robotics.

Applications of learning in robotics

- What can you think of?

Applications of learning in robotics

- Learn how world works
  - Robot and/or environment dynamics
- Learn what to do (and how)
  - Learn a control policy, skill, task
- Learn to understand environment / situation
  - Learn to perceive
- *Learn how to interact, ...*

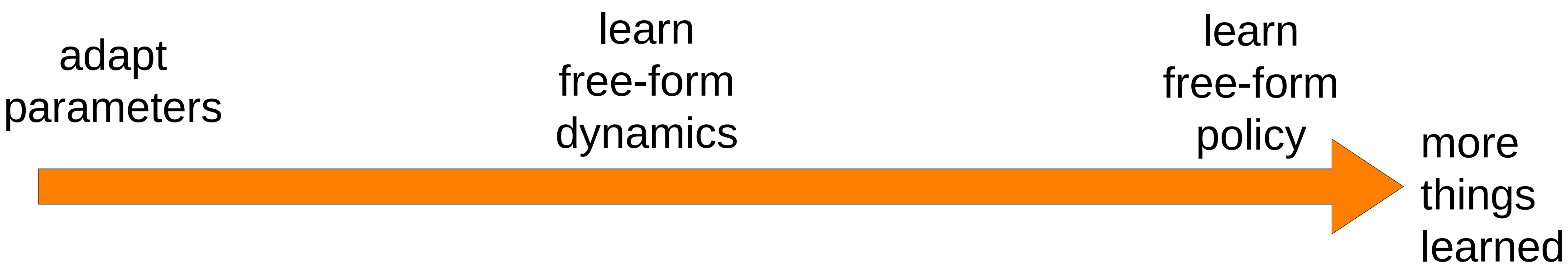
Types of machine learning

- Supervised learning
  - Learn input-output mappings from examples
  - Give some examples!
- Reinforcement learning
  - Learn by acting and observing rewards
  - Give some examples!
- Unsupervised learning
  - Cluster inputs without outputs
  - Give some examples!

Scope of learning

Scope can vary from e.g. adapting physical parameters to learning “everything”.

Example: Control



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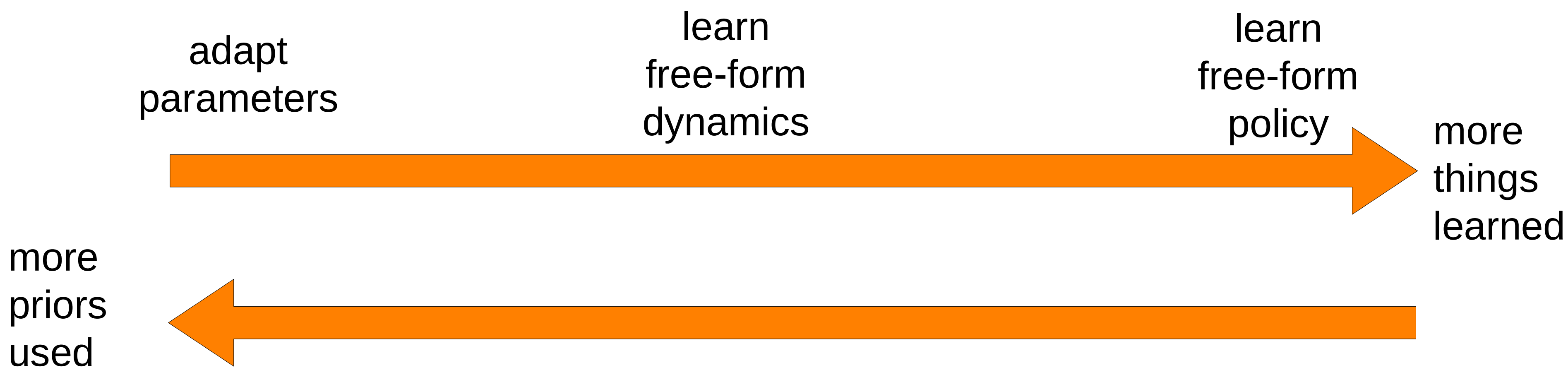


Are assumptions (“priors”) good to have?

Effect of priors

- When are priors useful?
- What's their meaning in learning?
- When are they harmful?

Challenges of learning in robotics

- Data cost is usually high.
  - Physical experiments time consuming and potentially unsafe.
- Desired operation not always easy to define.
  - For reinforcement learning.
- Safety and performance of learning difficult to guarantee.
  - Depends on data and method used.
  - Possibly weak transparency – internal operation often difficult to characterize.

Some solutions

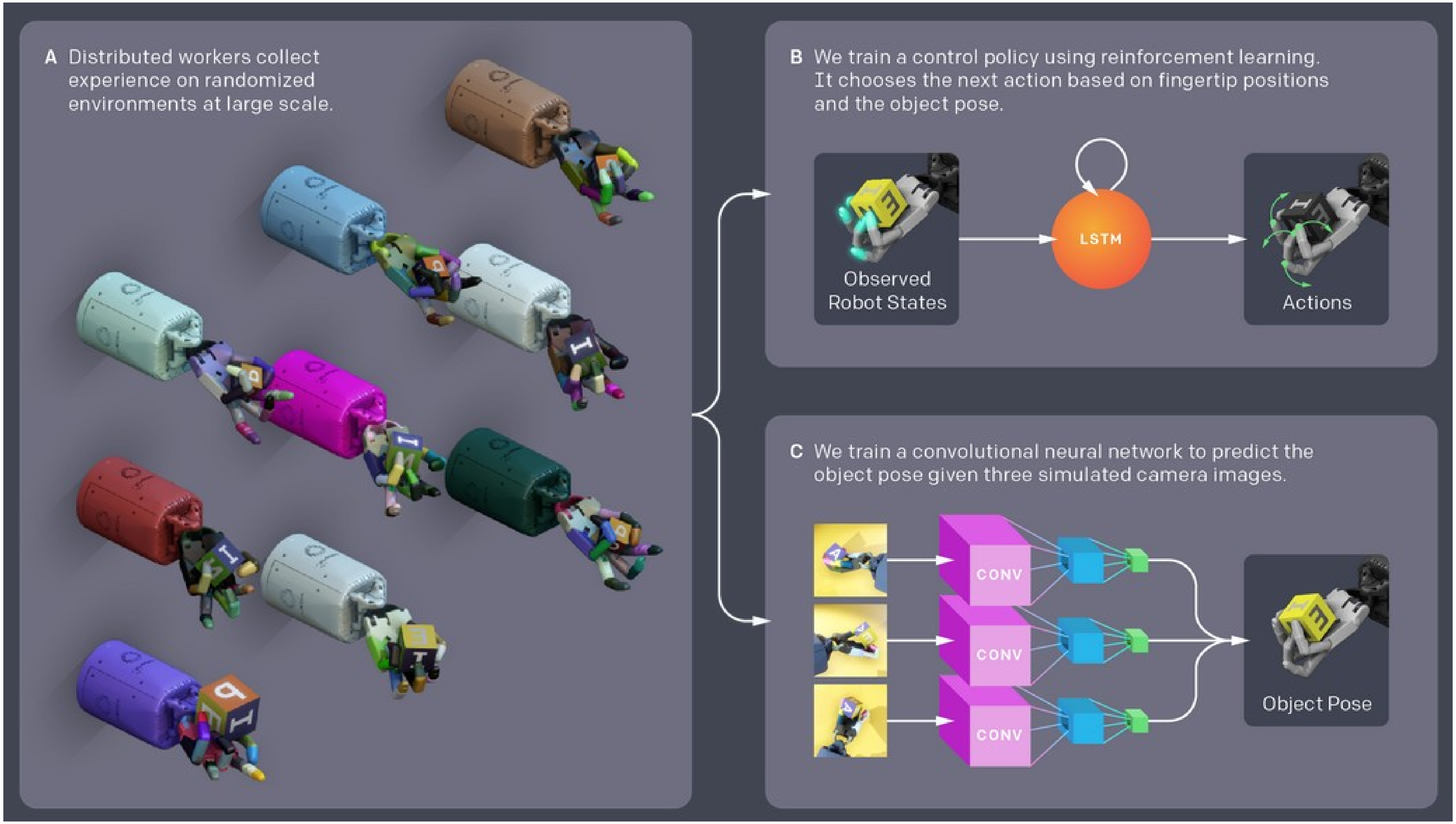
- Data cost
  - Simulation may provide training data.
    - Reality gap between simulation and real world a challenge.

- Safety and transparency
  - Explainable learning currently a topic of major interest.

Let’s watch a video

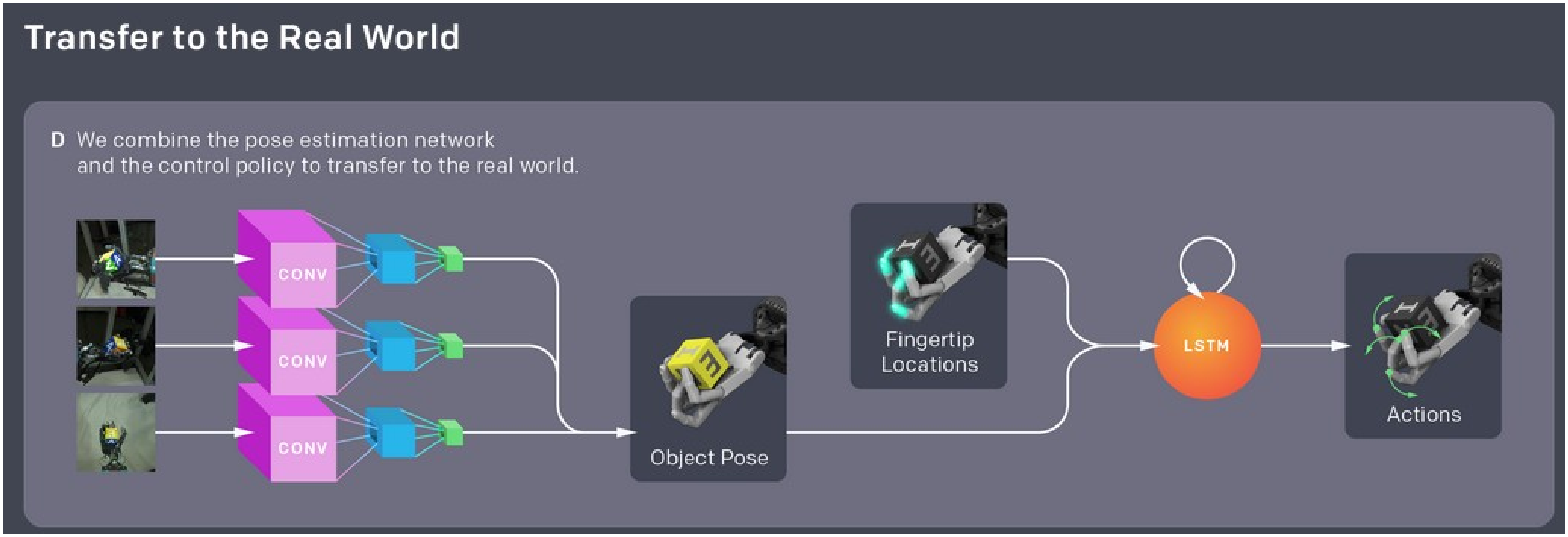
https://www.youtube.com/watch?v=jwSbzNHGflM

Example: Dextrous manipulation



OpenAI 2018

Example: Dextrous manipulation



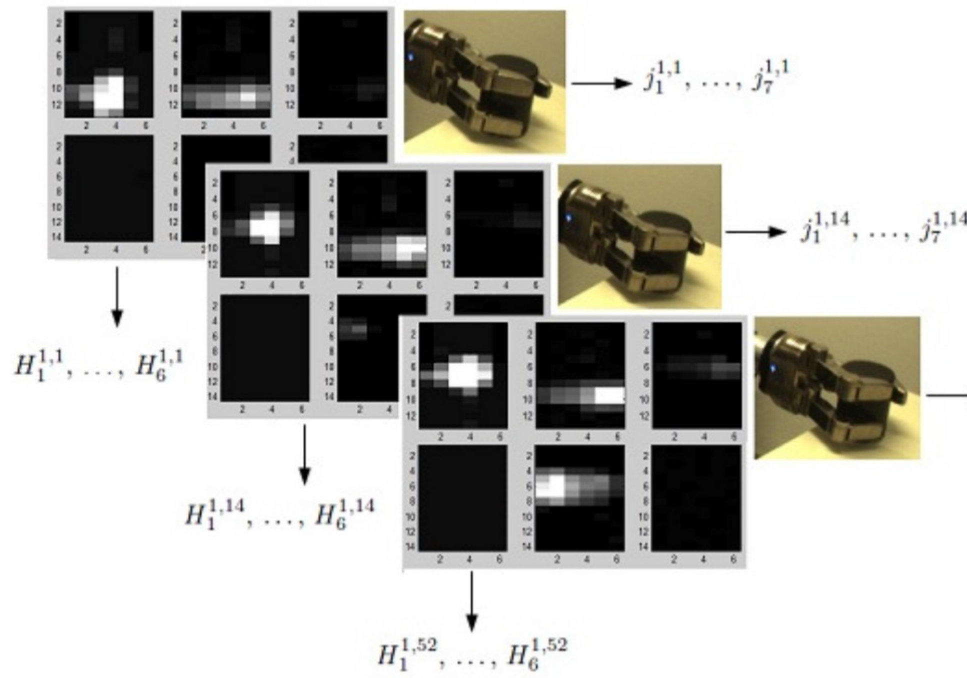
Example: Dextrous manipulation

Analyze!

- Could this approach be used in practice?
- In which cases?
- Why or why not? Which constraints are there for use?
- Any other notes?

Example: Learning grasp stability

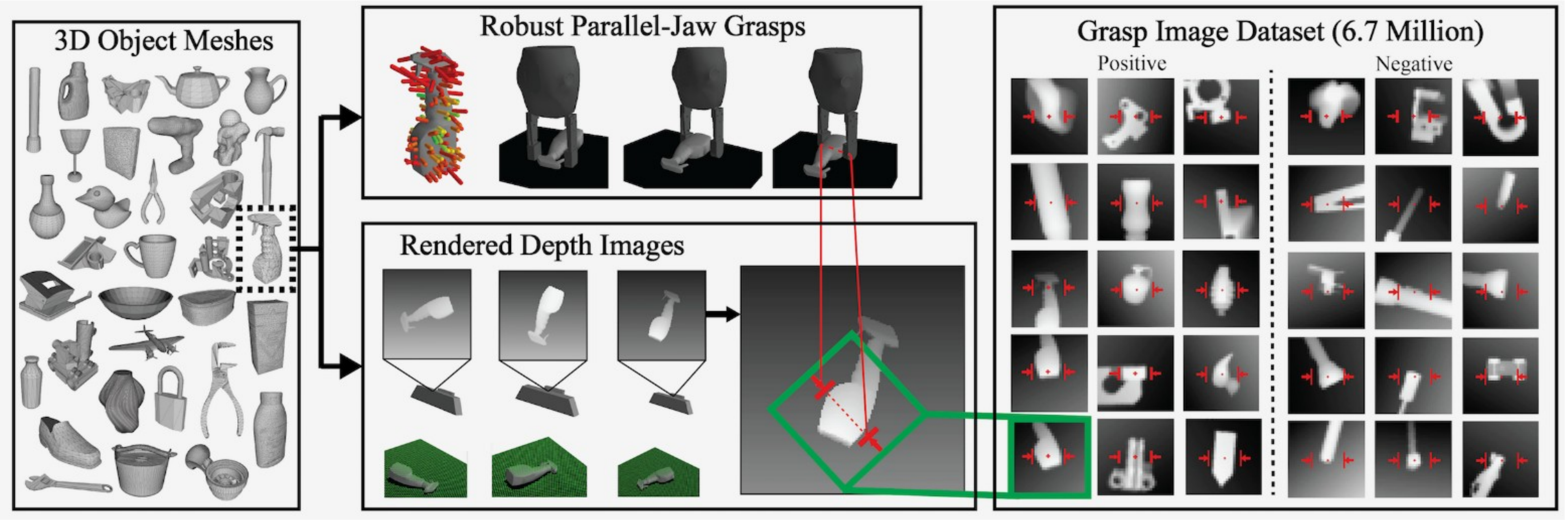
- Learn to predict if a grasp is stable based on tactile sensor measurements.
- Simple simulation and analytic grasp quality measures to generate training data.
- Statistical ML.



Bekiroglu et al. 2011

Example: Learning where to grasp Dex-Net 2.0

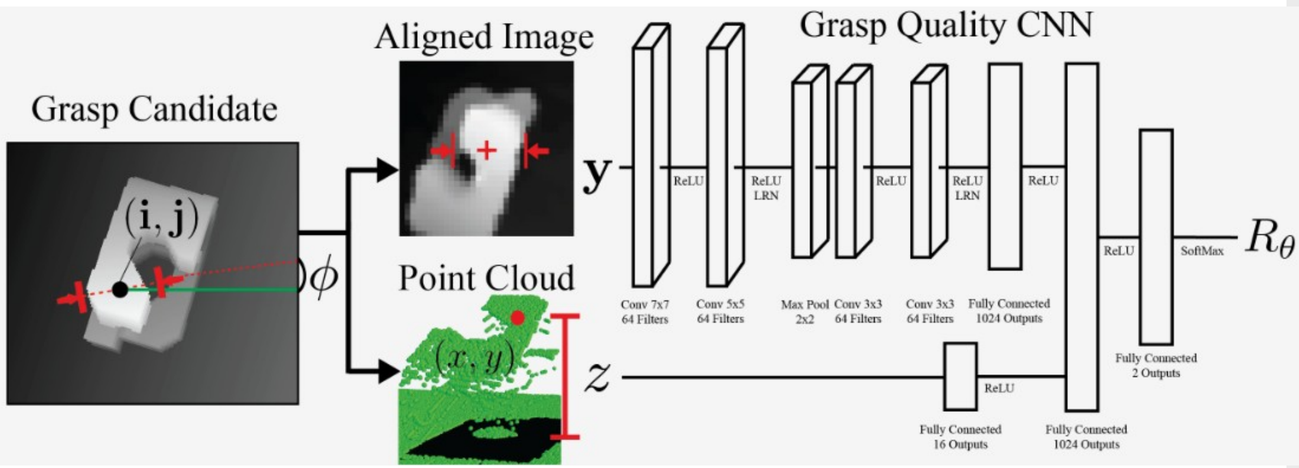
- Simulated pointcloud training data creation.

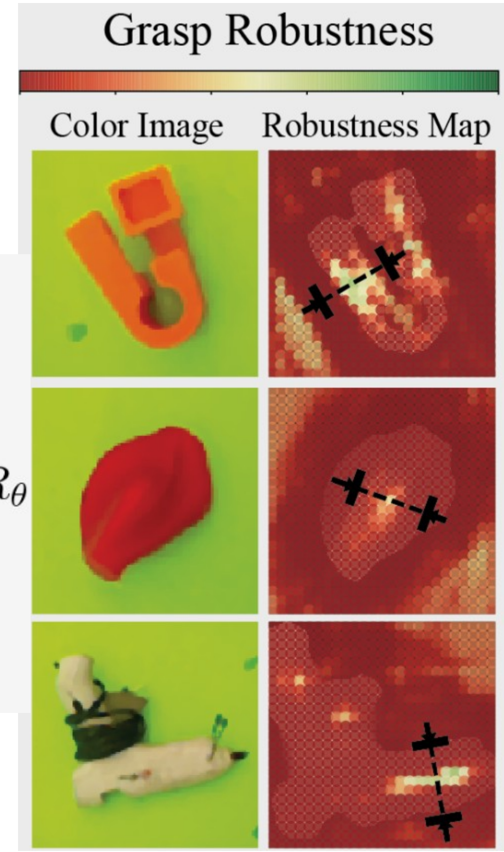


Mahler et al., 2017

Example: Learning where to grasp Dex-Net 2.0

- Learn to predict quality metric from image using convolutional NN.





Mahler et al., 2017

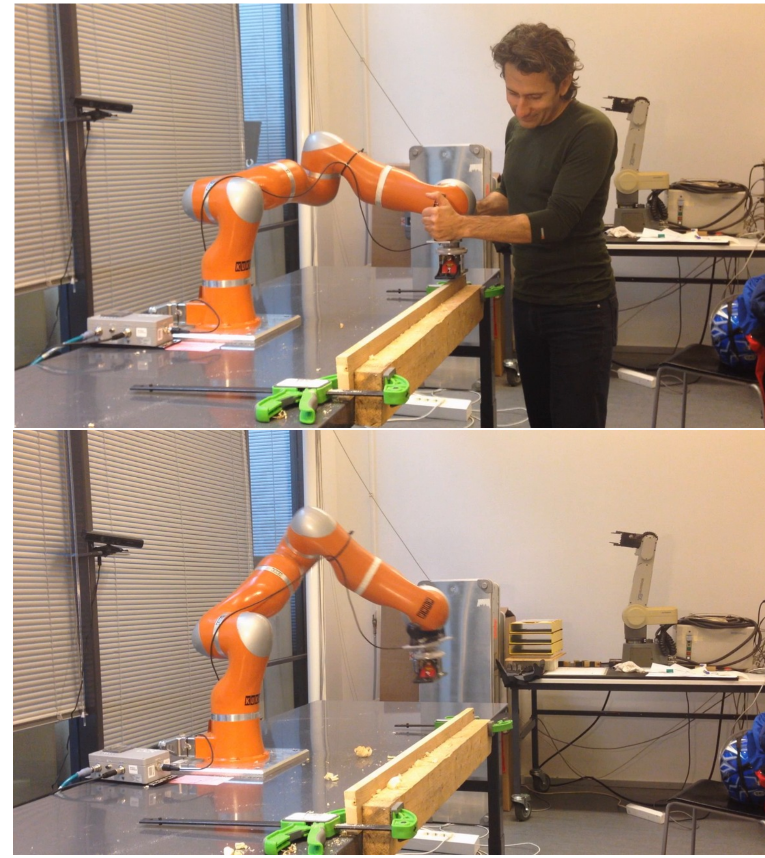
Example: Learning movements Movement primitives

- General idea: Learn trajectories (trajectory primitives).
  - Can be modulated, e.g. end-point or speed change.
  - Learned from e.g. human demonstration.
  - May be improved by reinforcement learning.
  - Sequencing can also be learned.

Muelling et al. 2013

Example: Learning in-contact skills

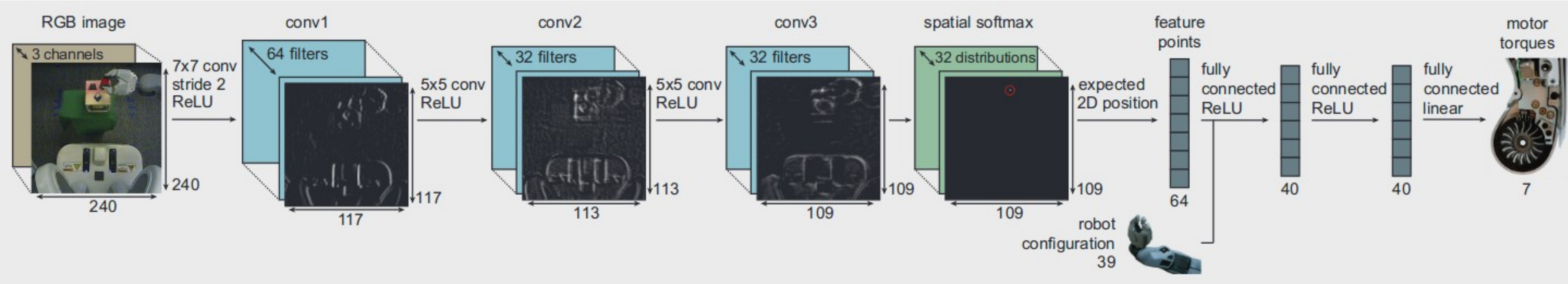
- Learn position and force trajectories from human demonstration.
- Impedance control with force feed-forward.
- Can be improved by reinforcement learning.



Montebelli et al. 2015

Example: End-to-end learning of deep visuomotor policies

- Learn a NN controller from vision to torques.
- Training: Learn first individual trajectories using reinforcement learning, train NN using supervised learning.



Levine et al. 2015

Summary

- Machine learning provides tools for subproblems in robotic manipulation.
- Data availability is often a challenge.
- At the moment, robot learning still primarily only in research labs because of lack of robustness.

Next time: Task level planning

- Readings:
  - Springer Handbook of Robotics, 2nd ed., secs. 14.3-14.3.2, 36.3-36.3.3
  - Handbook freely available through library webpage lib.aalto.fi. Log-in first and then search for “Springer Handbook of Robotics”.