LEARNING ROBOTS LAB

MASTER THESIS TOPICS – 2026-2027

http://parallel.vub.ac.be/learningrobots/

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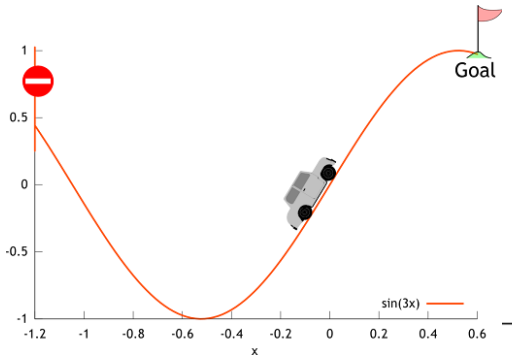
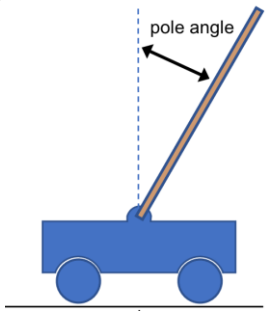
Learn a Robot to Tackle a Gymnasium Robotic Challenge with Qualitative models.

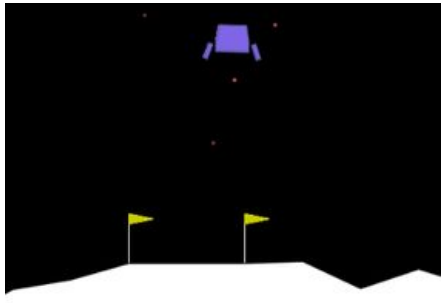
Autonomous robots must be able to solve problems on their own. For this purpose, OpenAI has standardized a set of challenges in a benchmark: https://gymnasium.farama.org/. Below you can see three of them: the car must reach the top of the mountain (by “swinging”), the cart must keep the pole upright, and the lunar lander must land between the flags. To solve such a challenge, a learning model is used. This model uses information from the task environment— in the second case, the angle of the pole— to then propose an action: changing the speed. The model must then learn a strategy to move the cart in such a way that it can keep the pole upright for as long as possible. This can be tested in simulation via Gymnasium.

The default approach is reinforcement learning, which trains a neural network by trial-and-error. This , however, has several drawbacks: a lot of training, no explanation is given (a neural network is a black box), and it just works in the environment it was trained in (no generalization or abstraction).

We propose an alternative method based on qualitative models describing relationships in a more abstract and general form:
“Turning the steering wheel clockwise makes the car turn right.”
“Pressing the gas pedal increases the car’s speed.”
“Picking up an object allows it to be moved elsewhere.”
These models can be learned with fewer interactions than traditional reinforcement learning techniques and are typically more transferable across tasks and domains.







Objective of the thesis:
Study and implement our qualitative-model-based learning approach.
Get acquainted with gymnasium and the challenges.
Work with our existing codebase and adapt it to a new setting.
Let the robot learn a qualitative model and apply it to beat the chosen challenges.
Perform experiments and compare to the state-of-the-art.
A solid programming background and basic understanding of machine learning are recommended.

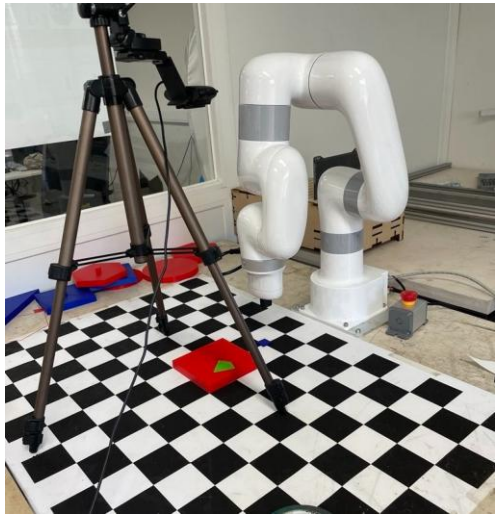
Supervision - Jan Lemeire, Ruben Spolmink

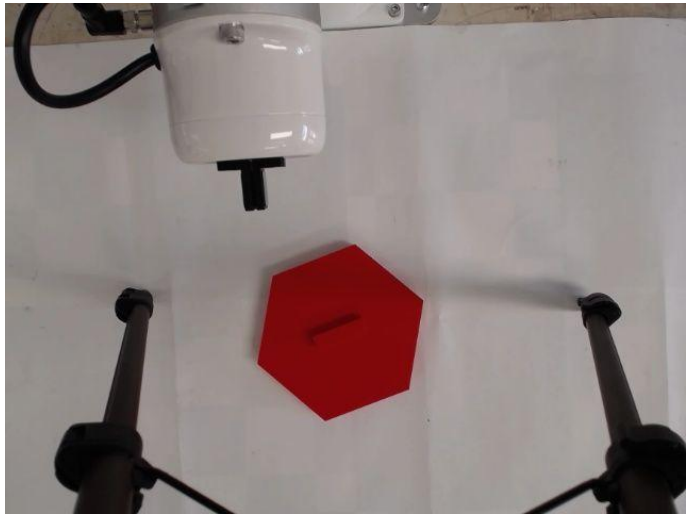
Learn a Robot Arm to Manipulate Objects through Qualitative Modeling.

We can program robots perfectly to perform tasks, but only in known environments. Pre-programmed robots struggle to handle new situations. To enable robots to operate in uncontrolled environments, they must be capable of learning. This is where the scientific field of self-learning robots comes into play. In this master's thesis, you will apply this concept to a robotic arm that must learn to manipulate objects: moving, stacking, cleaning up, and more. Our innovative approach, based on qualitative models, will lead to improved manipulation compared to the current state of the art.

The robotic arm (see figure) will be controlled based on camera images. The objects are identified and analyzed within these images, from which the important properties are extracted. During the exploration phase, the robot will try out various actions ("play"), using the observed data to learn a qualitative model that it can then use to perform tasks (the exploitation phase).

Qualitative models describe relationships in an abstract and general form:
"Turning the steering wheel clockwise makes the car turn right."
"Pressing the gas pedal increases the car's speed."
"Picking up an object allows it to be moved elsewhere."
These models can be learned with fewer interactions than traditional reinforcement learning techniques and are typically more transferable across tasks and domains.





Objective of the thesis:
Study and implement our qualitative-model-based learning approach.
Get acquainted with the robot arm.
Work with our existing codebase and adapt it to a new setting.
Let the robot learn a qualitative model and apply it to beat the chosen challenges.
Perform experiments and compare to the state-of-the-art.
A solid programming background and basic understanding of machine learning are recommended.

Supervision - Jan Lemeire, Ruben Spolmink