LATVIJAS UNIVERSITĀTE

ELEKTRONIKAS UN DATORZINĀTŅU INSTITŪTS
INSTITUTE OF ELECTRONICS AND COMPUTER SCIENCE

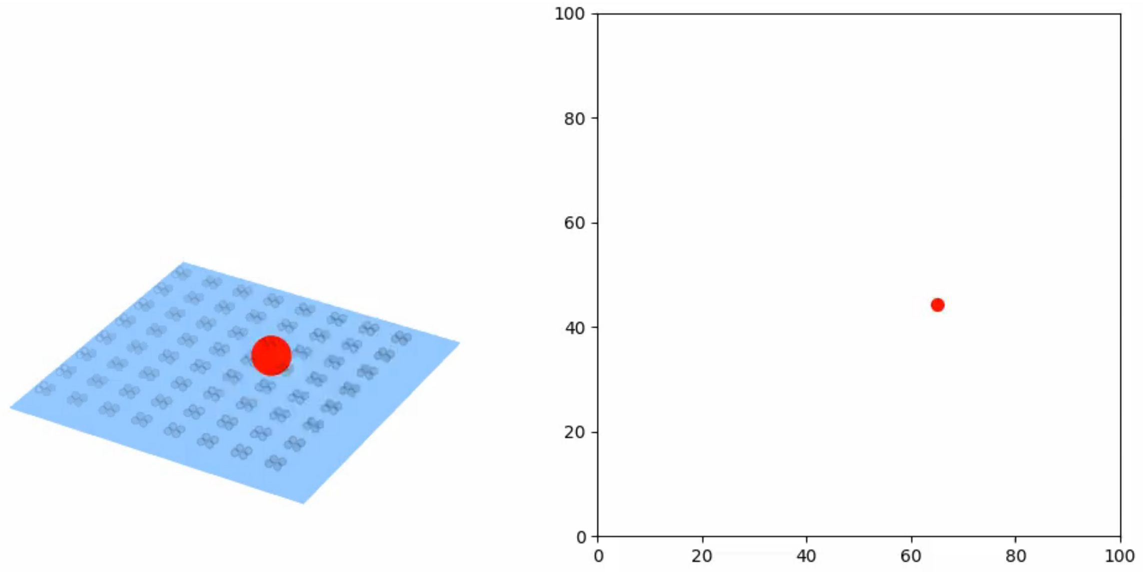
My progress so far

Oskars Teikmanis

7th semester

Recap of last time

- Current status:
  Researcher at the Institute of Electronics and Computer Science (EDI) and 4th year doctoral student at the University of Latvia
- Presented last time:
  - Work within 5G-ROUTES project: **self-driving vehicle publication**
  - Work within VPP-MOTE project: **differentiable physics for fluid manipulation**
  - Plans with quadrupedal robots

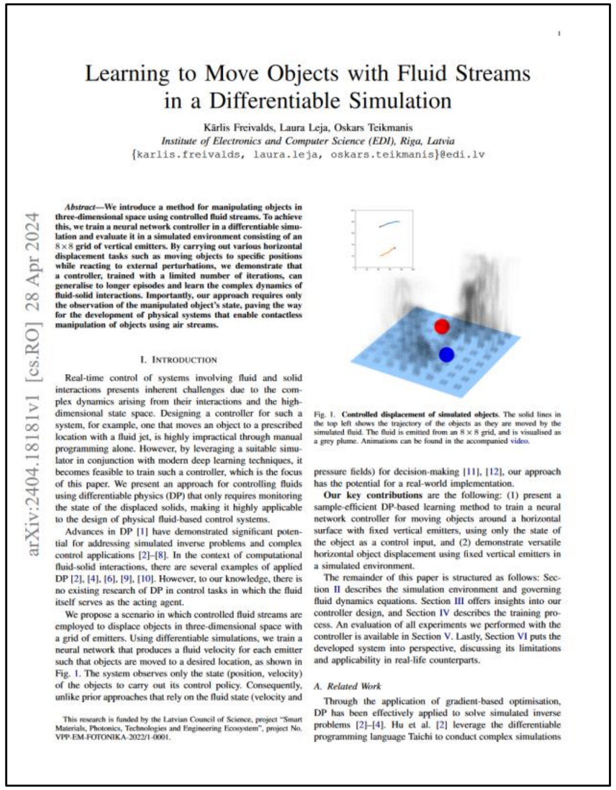


5G-ROUTES

- Summer tests for communication between vehicles via 5G.

- Video for project closure, featuring platooning and lane-change.

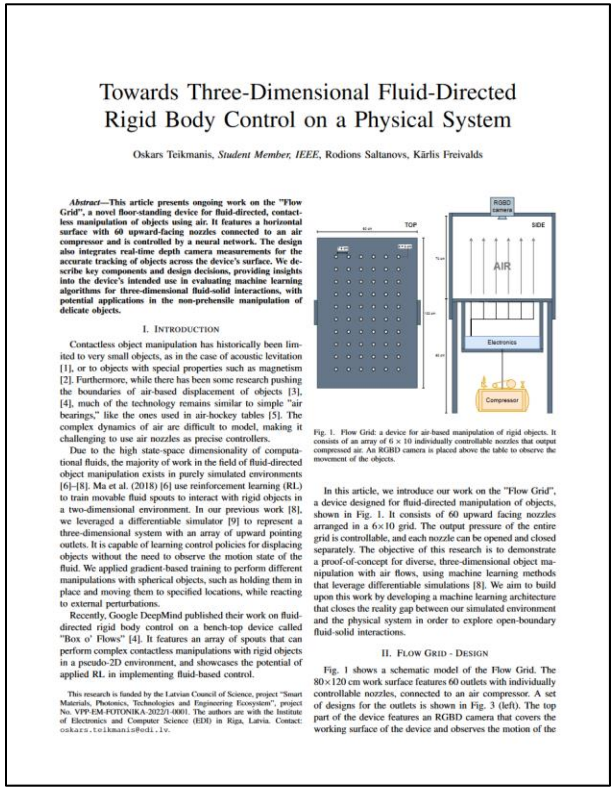
MOTE (VPP-EM-FOTONIKA)


Learning to Move Objects with Fluid Streams in a Differentiable Simulation

Kārlis Freivalds, Laura Leja, Oskars Teikmanis
Institute of Electronics and Computer Science (EDI), Riga, Latvia

arXiv:2404.18181v1 [cs.RO] 28 Apr 2024

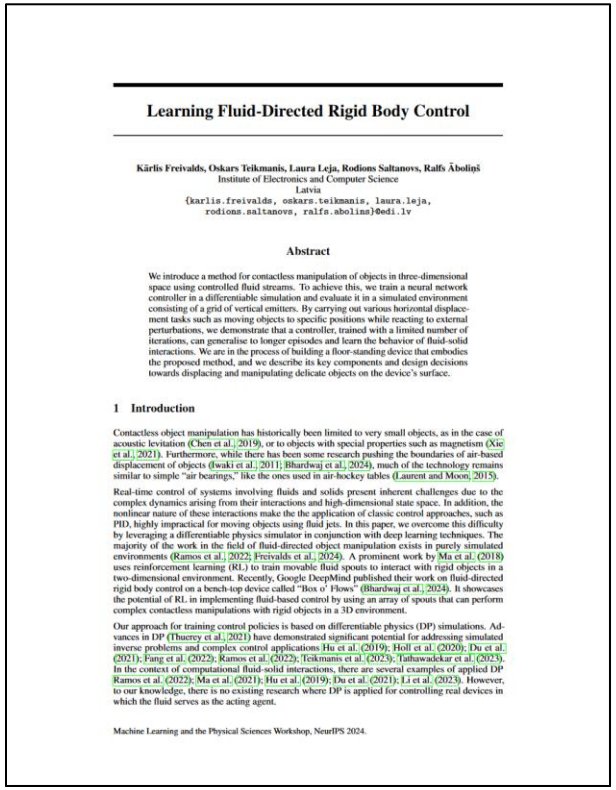
I. Introduction


Towards Three-Dimensional Fluid-Directed Rigid Body Control on a Physical System

Oskars Teikmanis, Student Member, IEEE, Rodions Saltanovs, Kārlis Freivalds

I. Introduction

II. Flow Grid - Design

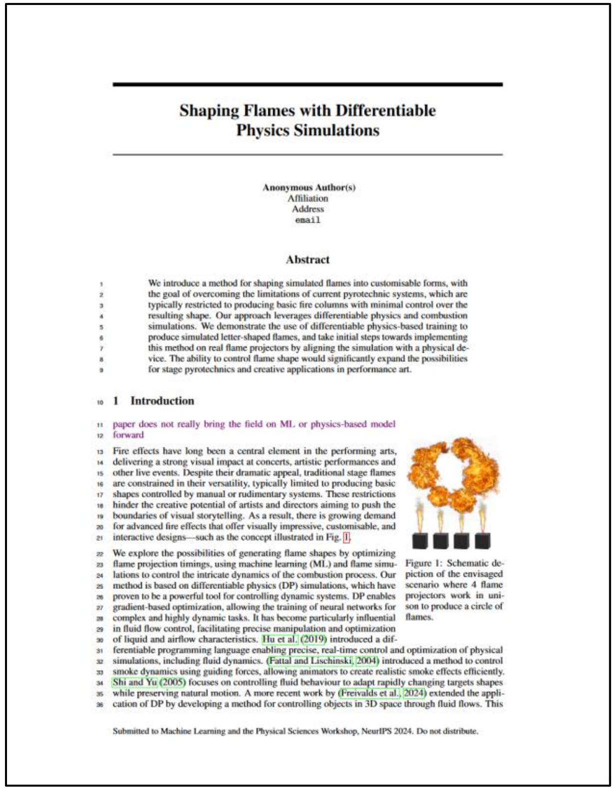

Learning Fluid-Directed Rigid Body Control

Kārlis Freivalds, Oskars Teikmanis, Laura Leja, Rodions Saltanovs, Ralfs Āboliņš
Institute of Electronics and Computer Science
Latvia

Abstract

1 Introduction

Machine Learning and the Physical Sciences Workshop, NeurIPS 2024.


Shaping Flames with Differentiable Physics Simulations

Anonymous Author(s)
Affiliation
Address
email

Abstract

1 Introduction

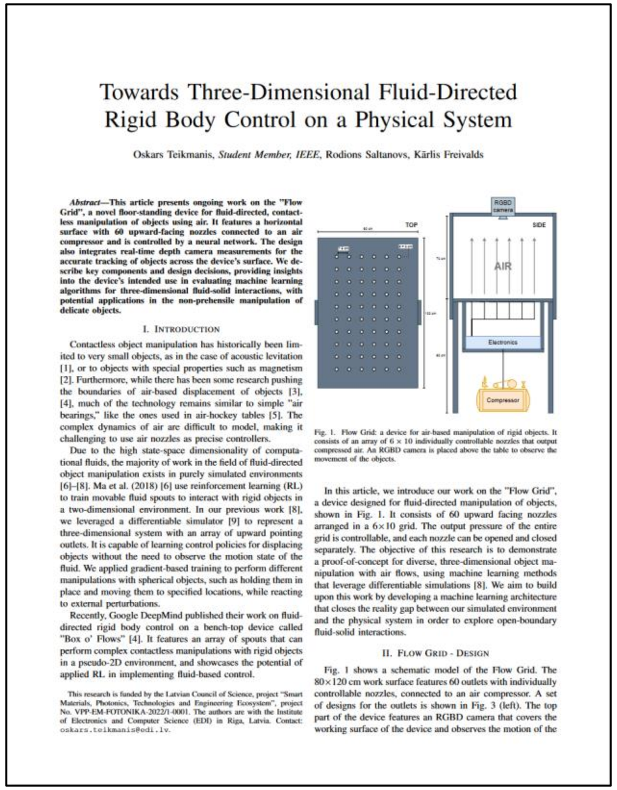
Submitted to Machine Learning and the Physical Sciences Workshop, NeurIPS 2024. Do not distribute.

ROBOT 2024, Madrid

ICRA@40, Rotterdam

NeurIPS 2024, Vancouver

MOTE (VPP-EM-FOTONIKA)


Towards Three-Dimensional Fluid-Directed Rigid Body Control on a Physical System

Oskars Teikmanis, *Student Member, IEEE*, Rodions Saltanovs, Kārlis Freivalds

***Abstract*—This article presents ongoing work on the "Flow Grid", a novel floor-standing device for fluid-directed, contactless manipulation of objects using air. It features a horizontal surface with 60 upward-facing nozzles connected to an air compressor and is controlled by a neural network. The design also integrates real-time depth camera measurements for the accurate tracking of objects across the device's surface. We describe key components and design decisions, providing insights into the device's intended use in evaluating machine learning algorithms for three-dimensional fluid-solid interactions, with potential applications in the non-prehensile manipulation of delicate objects.**

I. Introduction

Contactless object manipulation has historically been limited to very small objects, as in the case of acoustic levitation [1], or to objects with special properties such as magnetism [2]. Furthermore, while there has been some research pushing the boundaries of air-based displacement of objects [3], [4], much of the technology remains similar to simple "air bearings," like the ones used in air-hockey tables [5]. The complex dynamics of air are difficult to model, making it challenging to use air nozzles as precise controllers.

Due to the high state-space dimensionality of computational fluids, the majority of work in the field of fluid-directed object manipulation exists in purely simulated environments [6]–[8]. Ma et al. (2018) [6] use reinforcement learning (RL) to train movable fluid spouts to interact with rigid objects in a two-dimensional environment. In our previous work [8], we leveraged a differentiable simulator [9] to represent a three-dimensional system with an array of upward pointing outlets. It is capable of learning control policies for displacing objects without the need to observe the motion state of the fluid. We applied gradient-based training to perform different manipulations with spherical objects, such as holding them in place and moving them to specified locations, while reacting to external perturbations.

Recently, Google DeepMind published their work on fluid-directed rigid body control on a bench-top device called "Box o' Flows" [4]. It features an array of spouts that can perform complex contactless manipulations with rigid objects in a pseudo-2D environment, and showcases the potential of applied RL in implementing fluid-based control.

This research is funded by the Latvian Council of Science, project "Smart Materials, Photonics, Technologies and Engineering Ecosystem", project No. VPP-EM-FOTONIKA-2022/1-0001. The authors are with the Institute of Electronics and Computer Science (EDI) in Riga, Latvia. Contact: oskars.teikmanis@edi.lv.

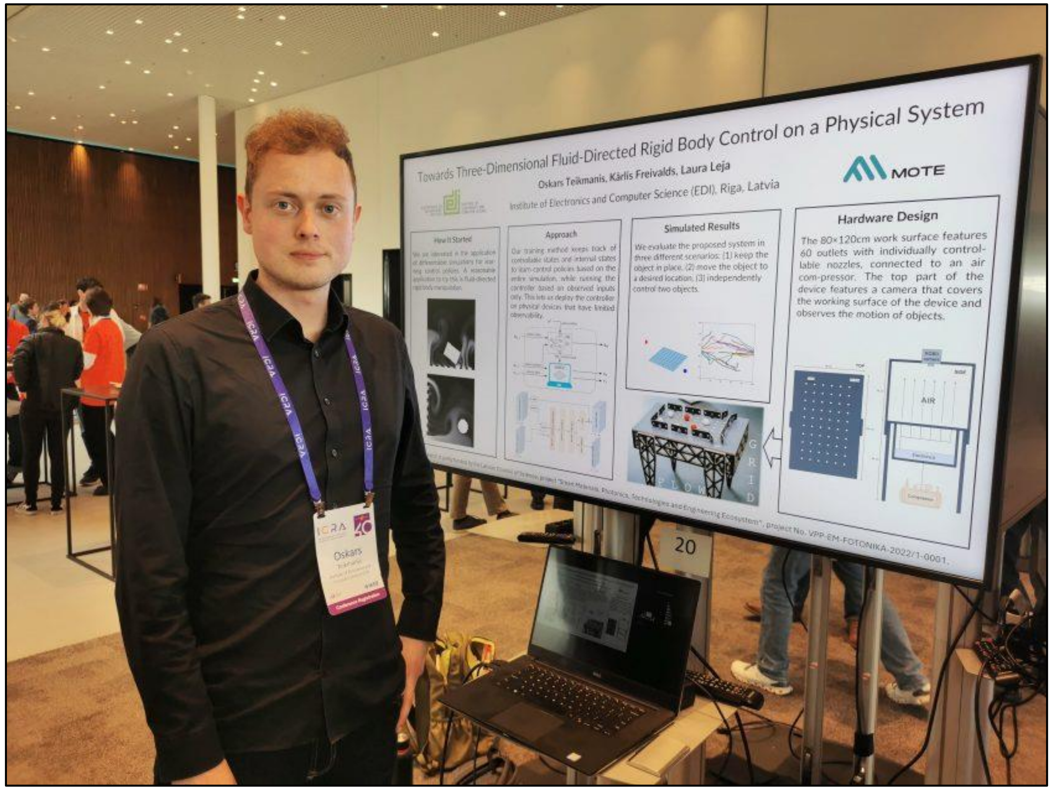
TOP
SIDE
RGBD camera
AIR
Electronics
Compressor

Fig. 1. Flow Grid: a device for air-based manipulation of rigid objects. It consists of an array of 6 × 10 individually controllable nozzles that output compressed air. An RGBD camera is placed above the table to observe the movement of the objects.

In this article, we introduce our work on the "Flow Grid", a device designed for fluid-directed manipulation of objects, shown in Fig. 1. It consists of 60 upward facing nozzles arranged in a 6×10 grid. The output pressure of the entire grid is controllable, and each nozzle can be opened and closed separately. The objective of this research is to demonstrate a proof-of-concept for diverse, three-dimensional object manipulation with air flows, using machine learning methods that leverage differentiable simulations [8]. We aim to build upon this work by developing a machine learning architecture that closes the reality gap between our simulated environment and the physical system in order to explore open-boundary fluid-solid interactions.

II. Flow Grid - Design

Fig. 1 shows a schematic model of the Flow Grid. The 80×120 cm work surface features 60 outlets with individually controllable nozzles, connected to an air compressor. A set of designs for the outlets is shown in Fig. 3 (left). The top part of the device features an RGBD camera that covers the working surface of the device and observes the motion of the



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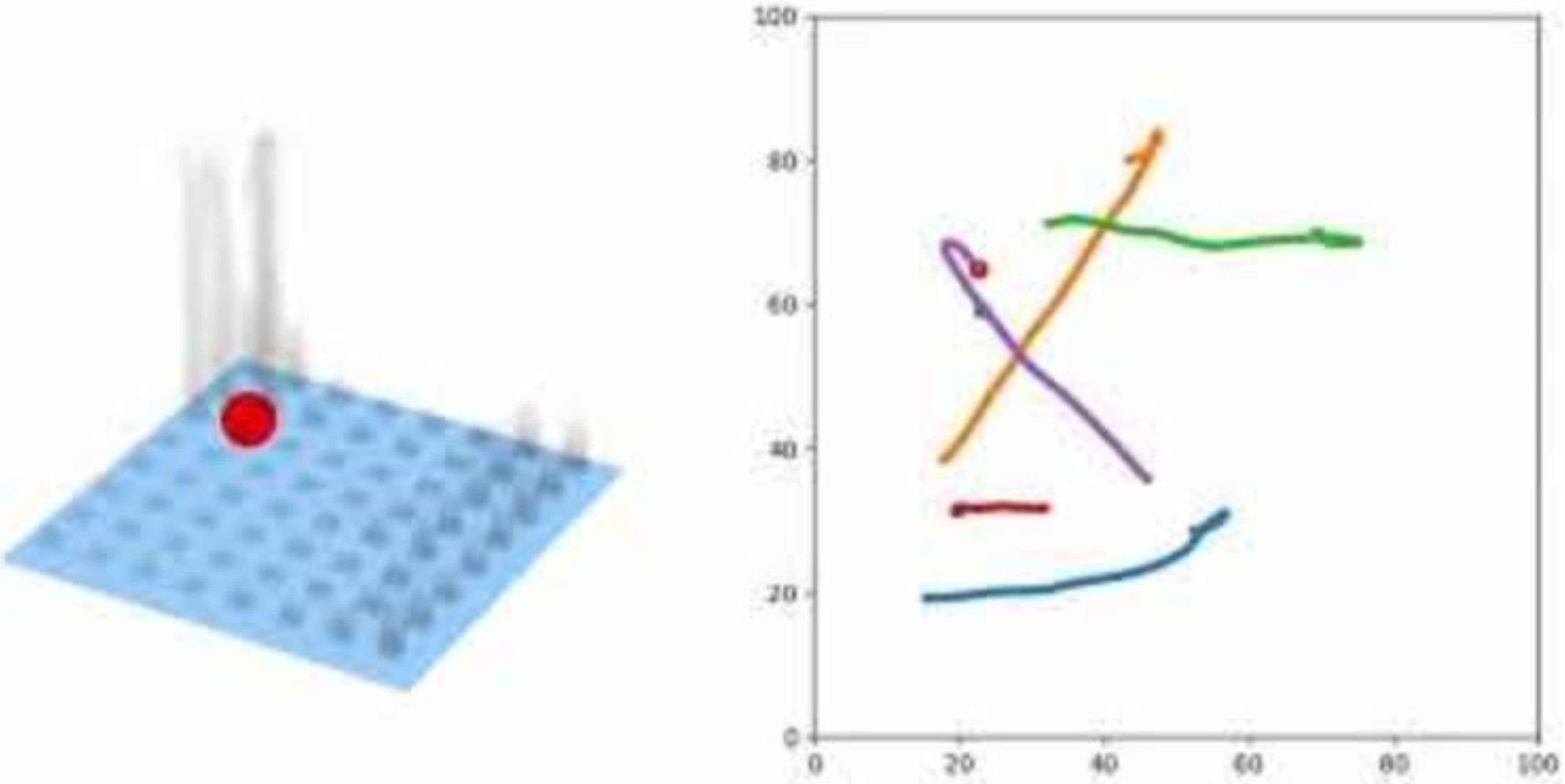
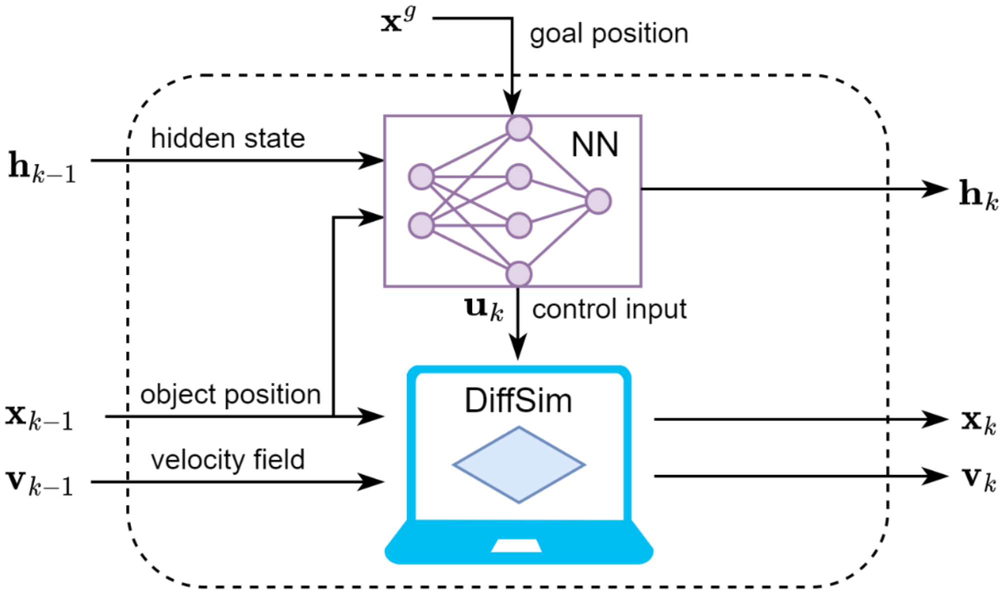
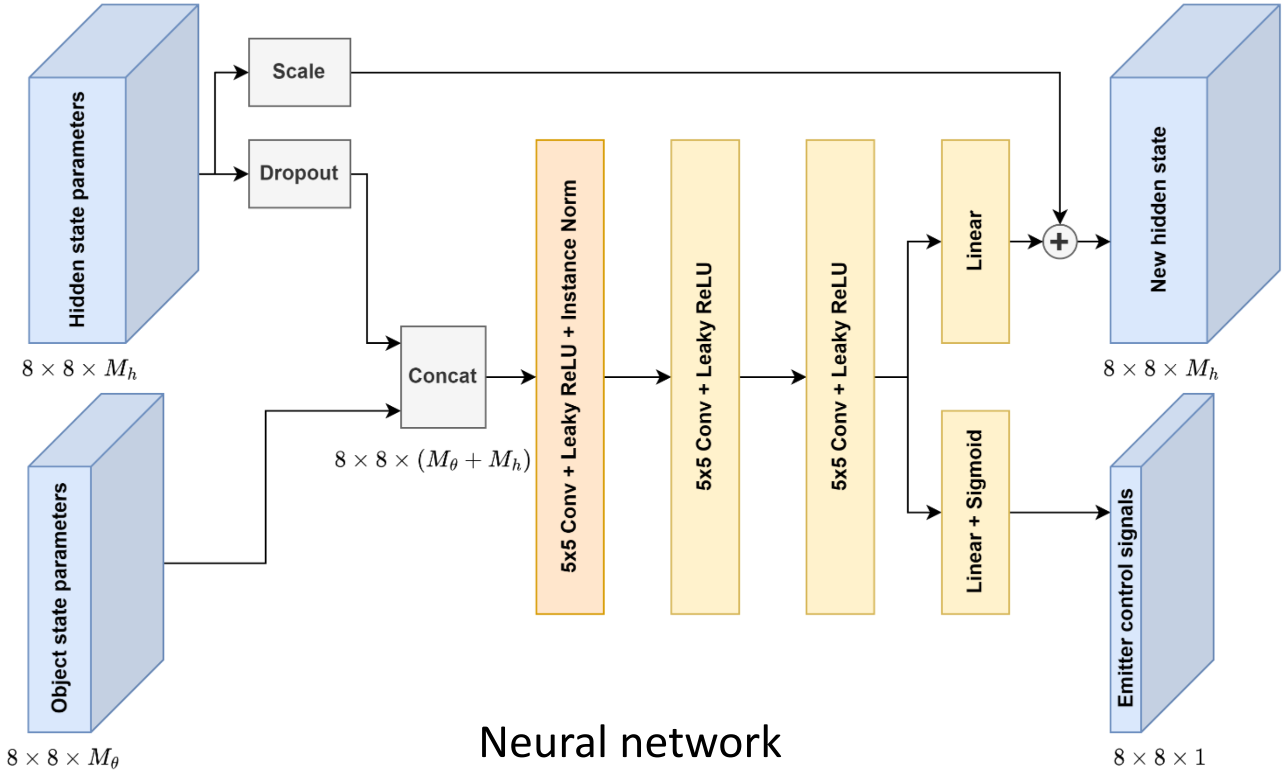

100
80
60
40
20
0
0
20
40
60
80
100

System architecture

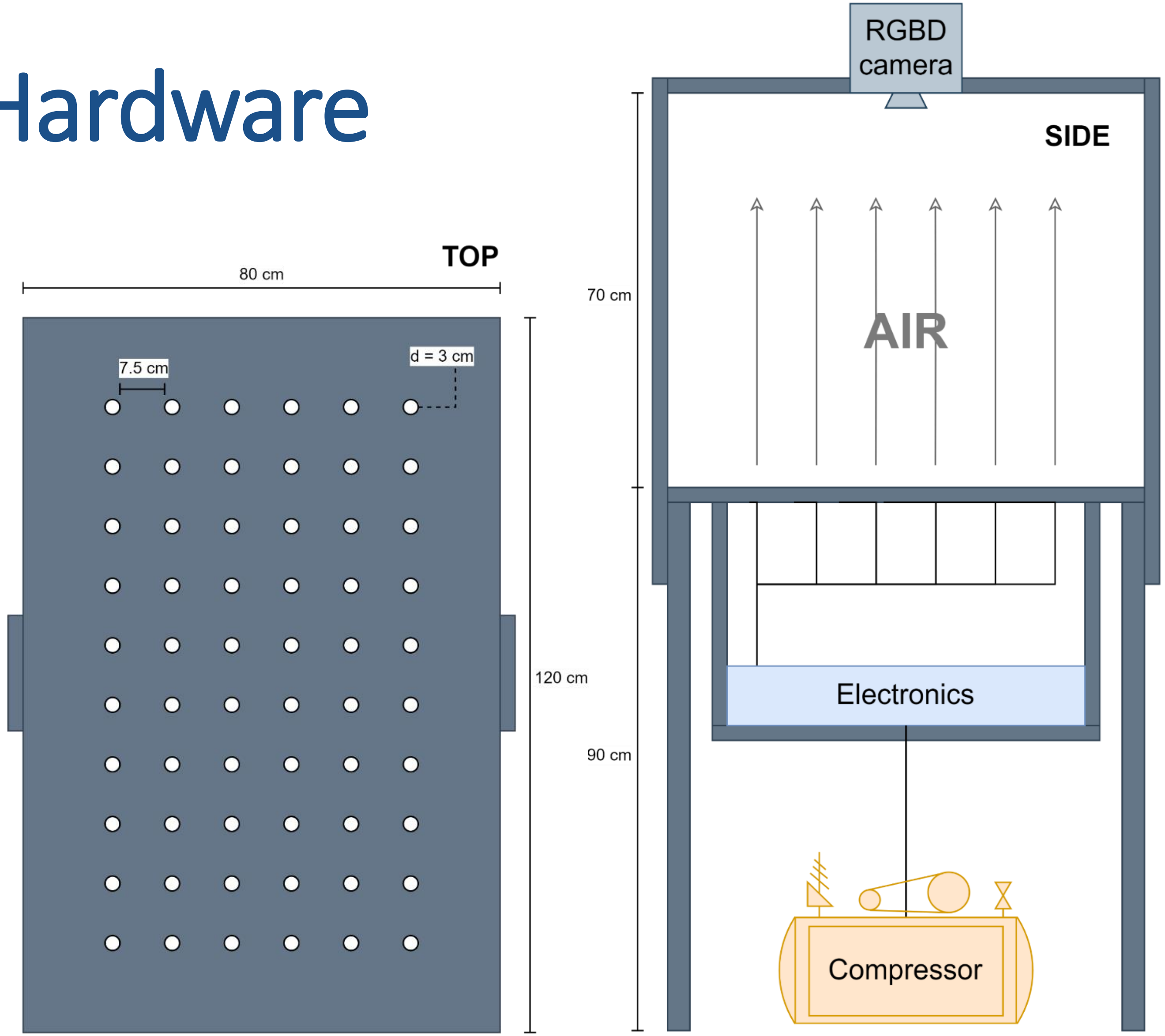


Simulation and training

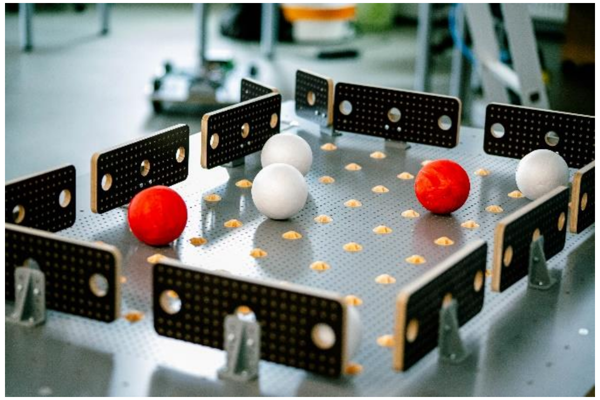


Neural network

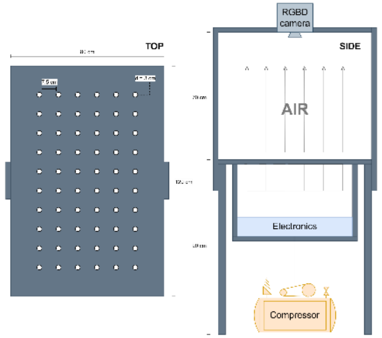
Hardware

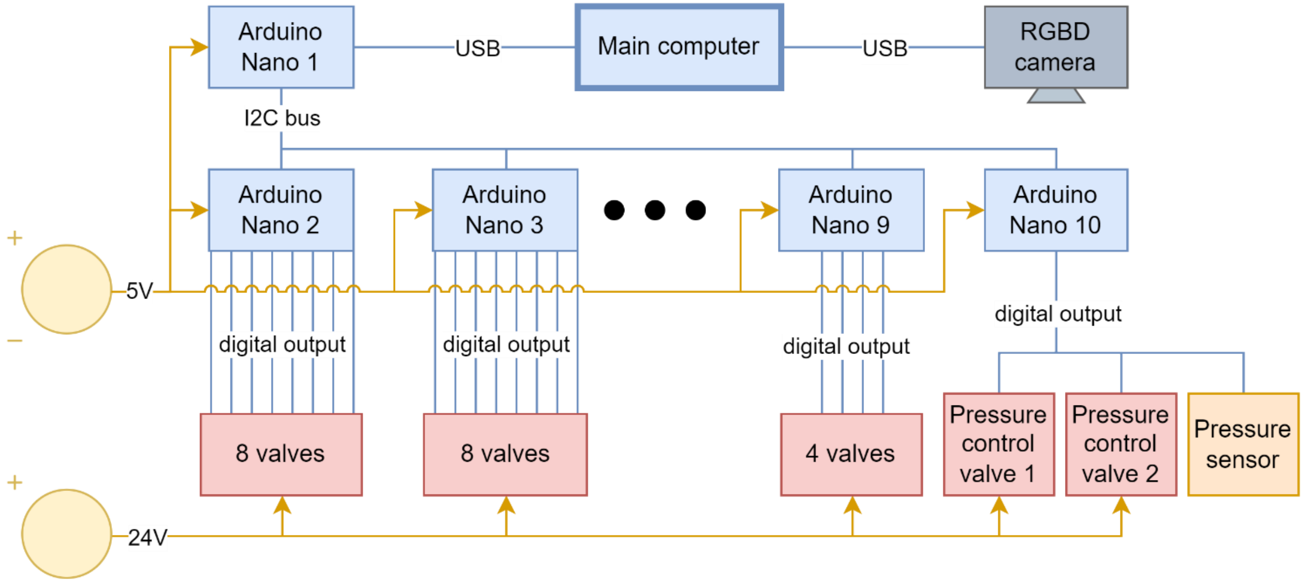


TOP
80 cm
7.5 cm
d = 3 cm
120 cm
RGBD camera
SIDE
AIR
70 cm
90 cm
Electronics
Compressor

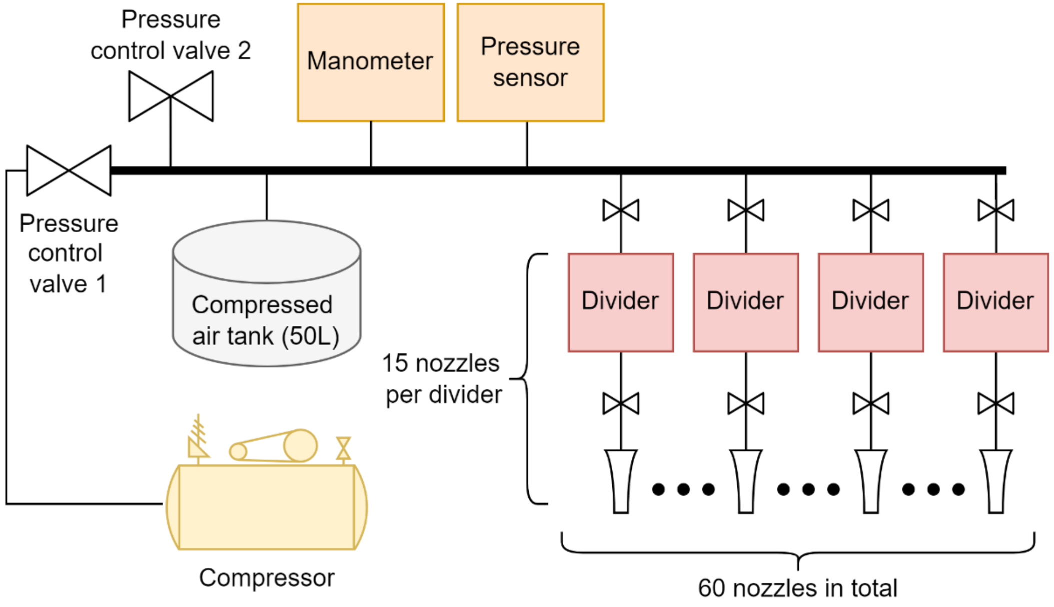


Hardware architecture

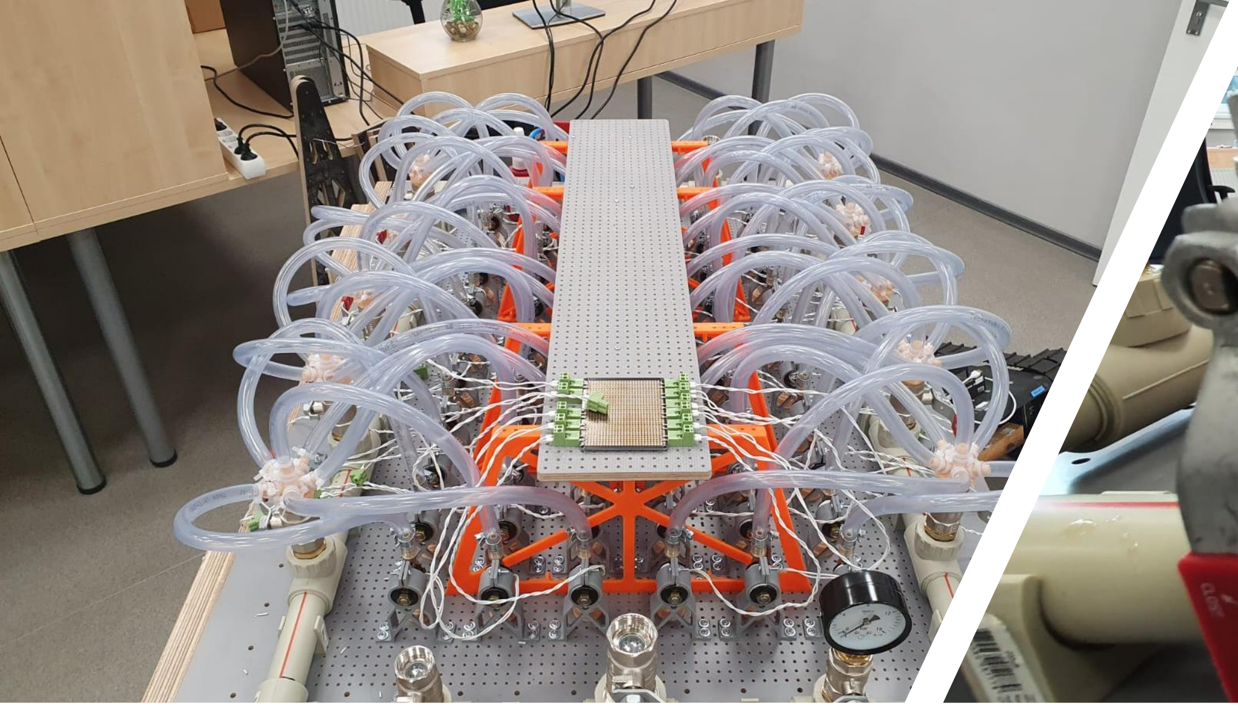
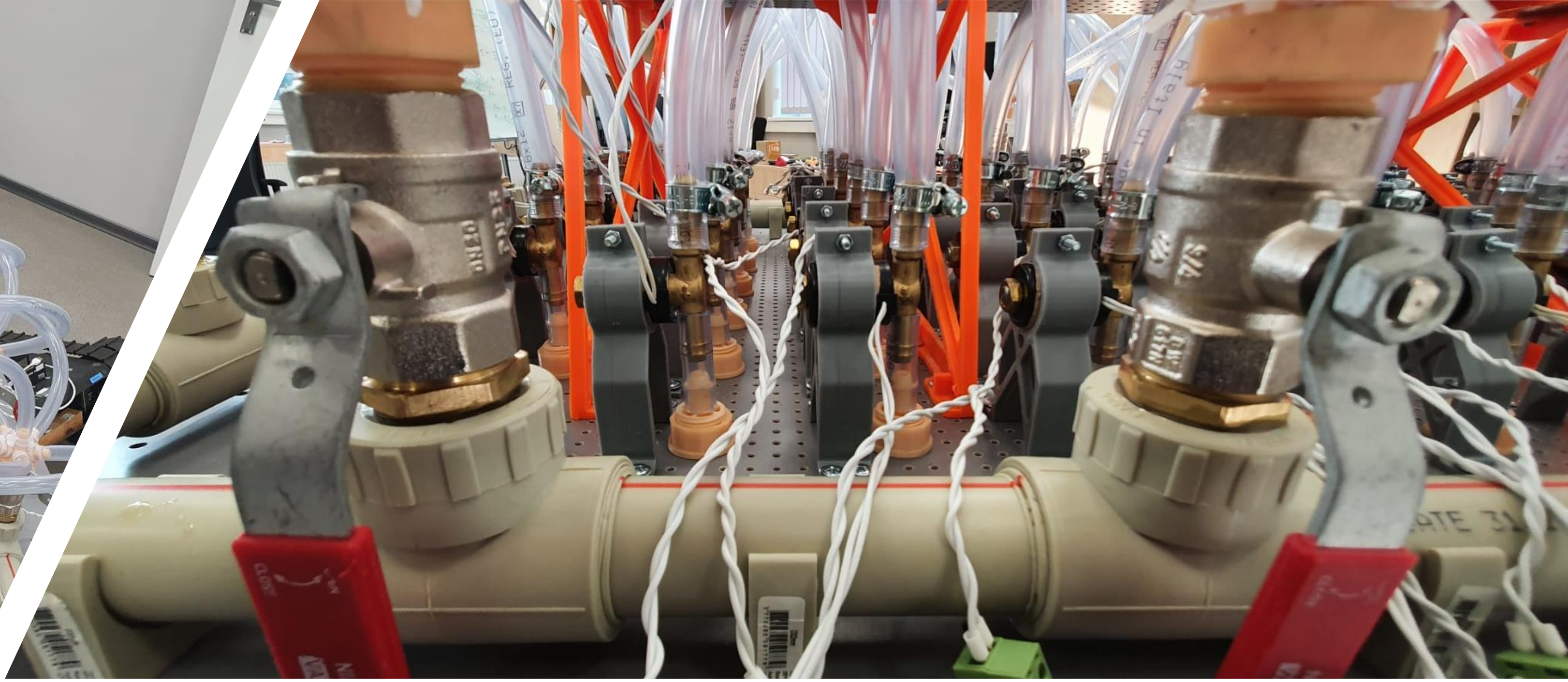
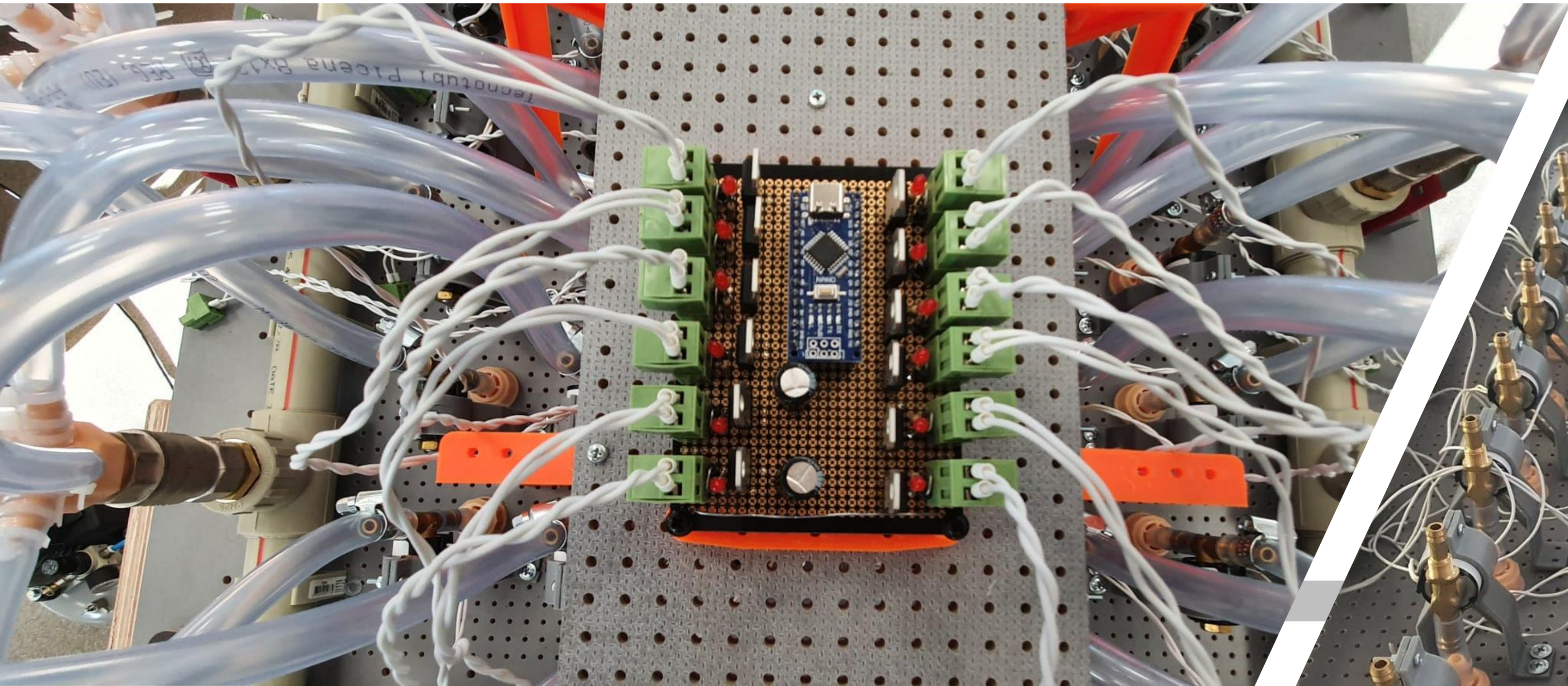
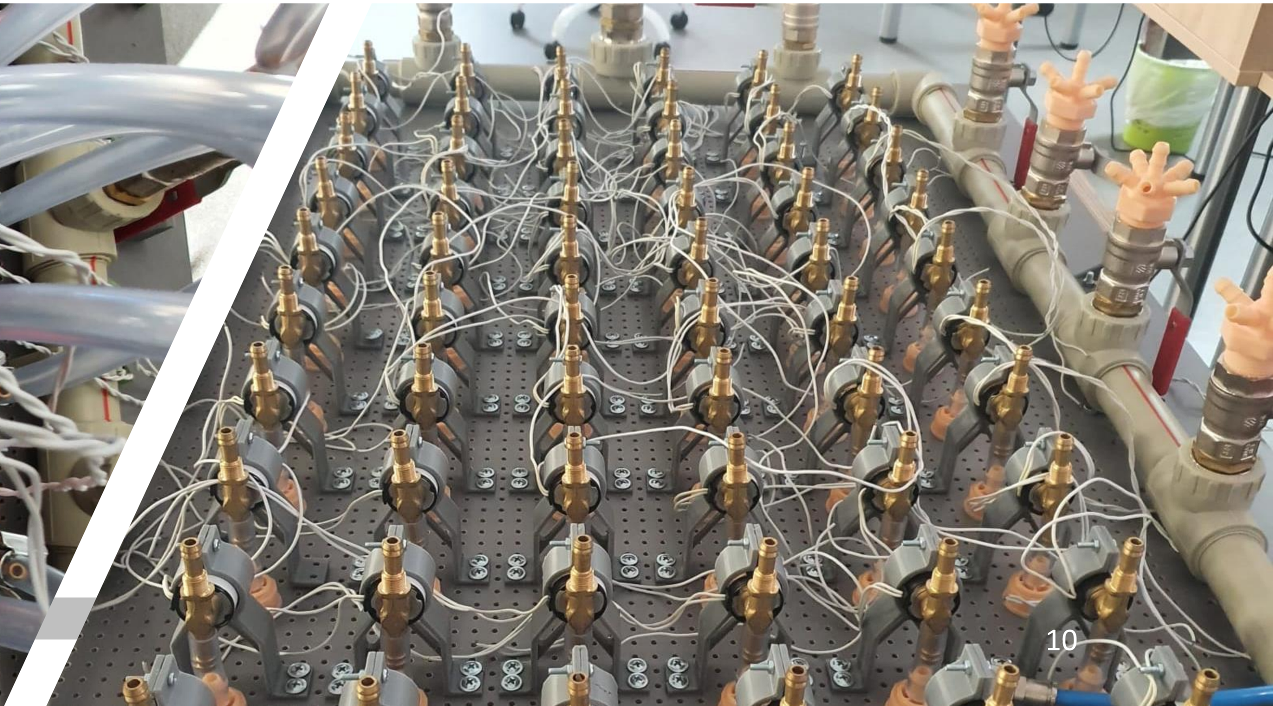




Electronics layout



Pneumatics layout

First prototype

MOTE

VPP
Valsts pētījumu programma

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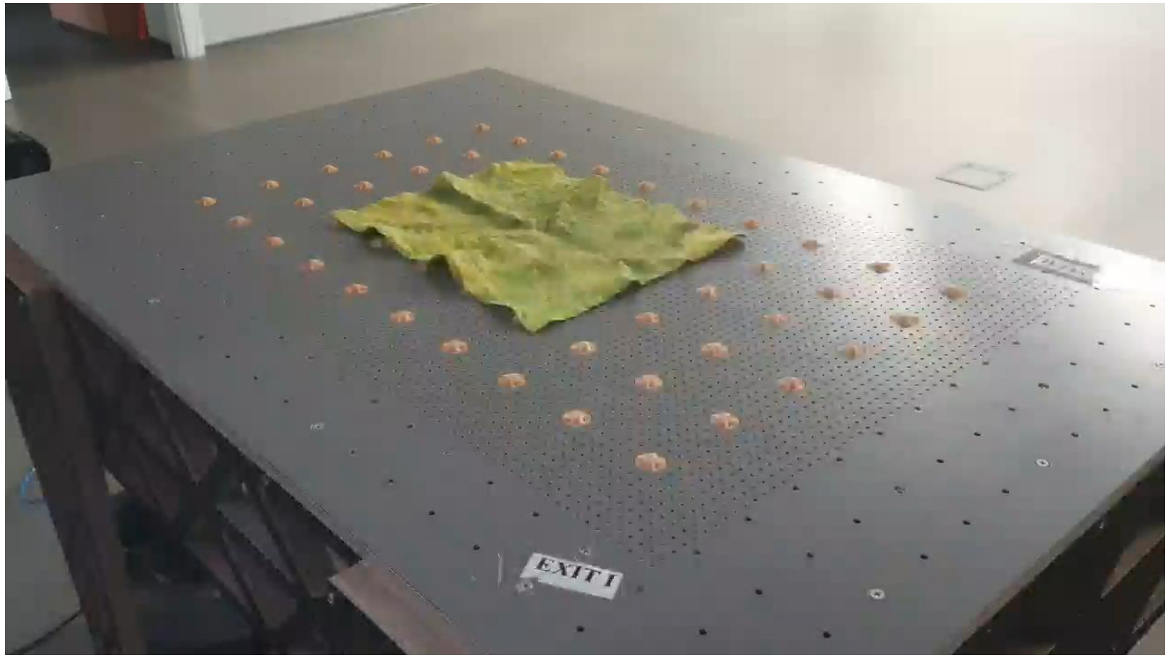
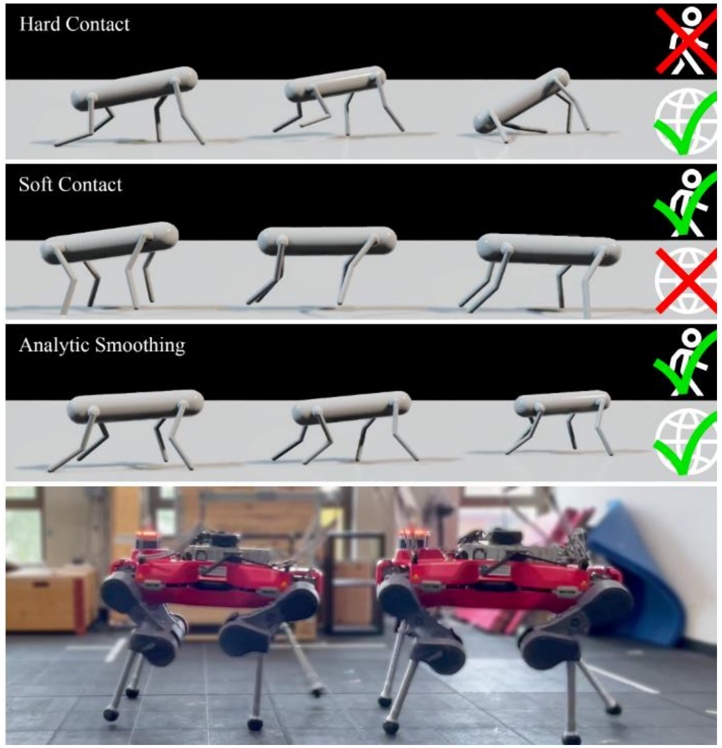
Current iteration



Further work: quadrupedal robots

Unitree Go2 quadruped



Bagajo *et al.*, CoRL 2024

Q&A