Vilnius University

An investigation of deep imitation learning for mobile robot navigation

Shubham Juneja
Supervisor: Dr. Virginijus Marcinkevičius
Semester 7

Vilnius University

Plan of studies & implementation summary

Study year	Exams		Conference participations		Publications	
	Planned	Completed	Planned	Completed	Planned	Completed
I (2020/2021)	2	2	1	1		
II (2021/2022)	2	2				
III (2022/2023)			0	0	1	1
IV (2023/2024)			1	0	1	0

Report of activity plan

Exams		Conference Participation		Publications	
Planned	**Status**	**Planned**	**Status**	**Planned**	**Status**
Machine Learning	Passed with 9/10	All Sensors 2021, Nice, France	Paper accepted and presented at All sensors 2021 conference at Nice, France. On the 20th of July, 2021.	Idea paper with the title "Combining Multiple Modalities with Perceiver in Imitation-based Urban Driving"	Published
Research methods and methodology of informatics and computer engineering	Passed with 9/10	Planned participation in AIEEE'24, Riga, Latvia.	In progress	Journal paper at IEEE Access Journal with title "Visual Place Recognition Pre-Training for End-to-End Trained Autonomous Driving Agent"	Accepted
Fundamentals of informatics	Passed with 7/10			Journal paper for Baltic Journal of Moden Computing.	In progress
Optimisation	Passed with 7/10				

Workshops

Workshop	ECTS
MOKSLINIŲ REZULTATŲ PUBLIKAVIMAS PAGAL FORMALAUS VERTINIMO REIKALAVIMUS	0.1
MOKSLINĖS INFORMACIJOS IŠTEKLIAI, PAIEŠKA, IR ĮRANKIAI	0.1
MENDELEY PRAKTINIS UŽSIĖMIMAS	0.15
DeepLearn 2022 Summer School (Participated)	
Total:	0.35/3

Stages of research and dissertation preparation

	Name of task	Duration	Notes
3.	Preparation of separate parts of the doctoral dissertation (research methodology, results, defended statements, conclusions, etc.): 1. Clarification of goals, objectives, research methodology, statements to be defended. 2. Preparation of the analytical part of the dissertation. 3. Preparation of the theoretical part of the dissertation. 4. Preparation of the experimental part of the dissertation. 5. Formulation of general conclusions.	September 2023 – April 2024	Journal paper accepted, calculating results for next journal and conference participation. Research on use of foundation models for pre-training.

Research Object and Aim

Research object:

- Deep imitation learning methods.
- Application of deep imitation learning methods for mobile robot navigation.

Research aim:

- To develop, implement and research an autonomous navigation system for mobile robots based on imitation learning and deep neural networks

Objectives of Research

1. To **develop and investigate** new sensorimotor reflex algorithms based on deep neural networks and various simulation learning paradigms (e.g. behaviour cloning, generative adversarial imitation learning) (e.g. trajectory following, obstacle avoidance, approach to a recognized object).

2. To **compose and implement** a new navigation system for mobile robots from the obtained sensorimotor reflexes.

3. To **compare** the obtained navigation system with alternative robot navigation algorithms.

4. To **prepare publicly available datasets** for the research of autonomous robot navigation algorithms based on the principles of deep neural networks and imitation training.

What has been carried out so far

- Literature study from papers on imitation learning for mobile robot navigation
- Took courses:
    - Machine learning (at VU)
    - Research methodology (at VU)
    - Fundamentals of Informatics (at VU)
    - Optimisation (at VU)
    - Reinforcement learning (Online)
- Trying out Simulators (CARLA and OpenAI gym)
- Attempted to run state of the art methods in simulation
- Participation in an international conference

What has been carried out so far

- Participation in summer school (Deep Learn 2022)

- More literature study

- Implementation of baseline and a proposed methods

- Experimentation

- Benchmarking (evaluation)

- Reported research and results into a journal paper for IEEE Access and submitted and accepted.

- Extended research on pre-training in the area of autonomous driving.

Research

Learning to imitate

- In imitation learning:
  - Given: Demonstrations
  - Goal: Train a policy (model) to mimic demonstrations
- Being a form of machine learning, data is collected, models are optimized, accuracies are evaluated.

Expert Demonstrations → State/Action Pairs → Learning

About the problem to solve

- Learning sensorimotor skills to drive and navigate based on visual input.

- It can be done with traditional methods such as SLAM, but it would require expensive sensors and extensive programming.

- The idea of imitation learning promises to solve this problem by learning from human demonstrations.

- Yet, it remains unsolved due the unpredictability of the real world causing the problem of covariate shift.

- To compare the ability between methods Leaderboard benchmark has been established.

- Leaderboard benchmark uses CARLA simulator to seed vehicles in different parts of a map and tests the ability of reaching from point A to B, under different sets of conditions.

Going further towards pre-training

- Pre-training has brought in a revolution to the area of language modelling.

- Recent work from this research showed the use of pre-training to be beneficial.

- Only a handful of methods have explored pre-training in autonomous driving so far.

Going further towards pre-training

- While pre-training can be expensive in terms of data and infrastructure, that is where foundation models come into picture.

- Foundation models are trained on a largescale dataset

- This scale is enabled by the data being unlabelled

- With use of self-supervised learning the models learn not just a single concept with regards to the image, but they explicitly learn:
  - semantic segmentation of an image
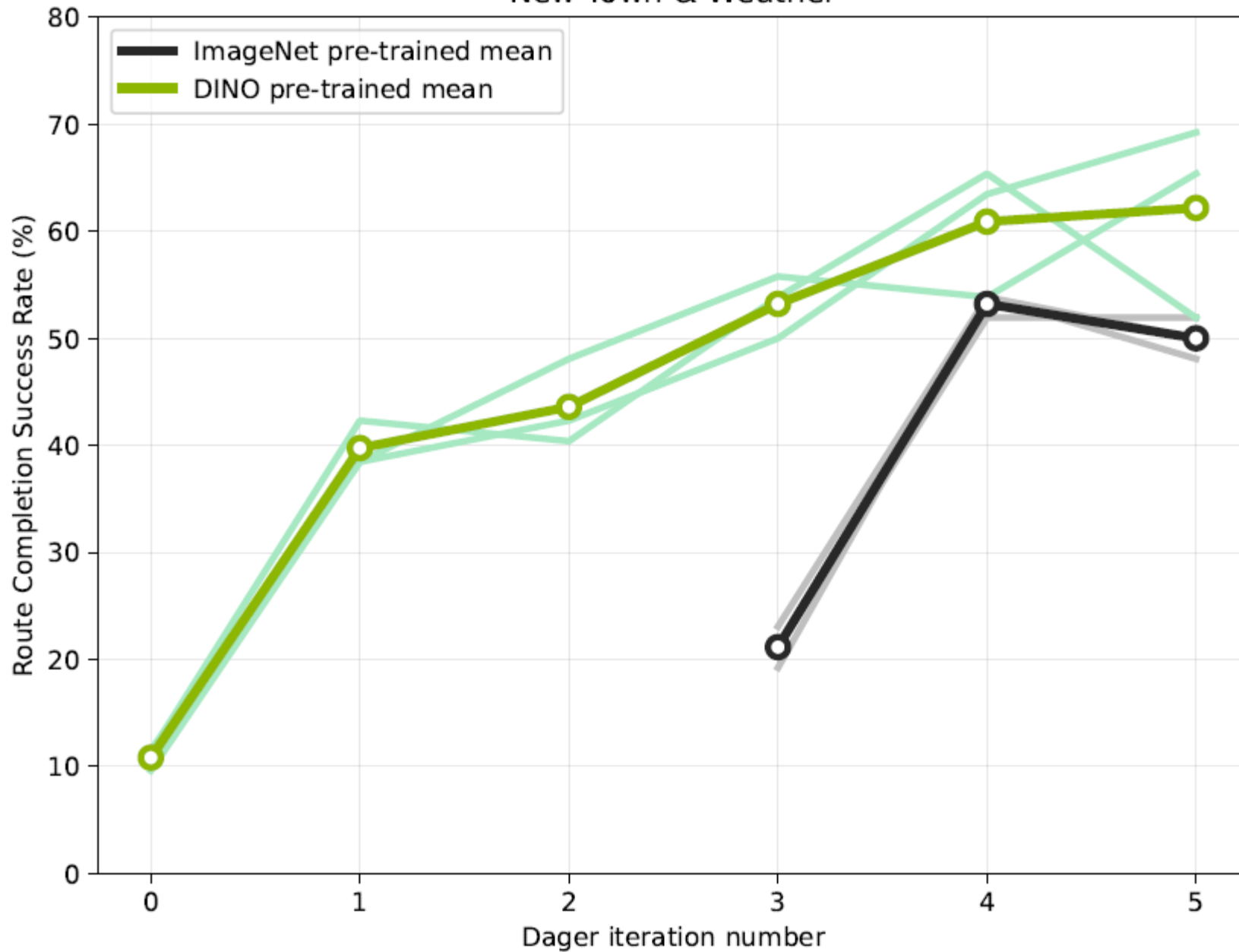 - scene layout
  - object boundaries

Results

Vilnius University

New Town & Weather

- ImageNet pre-trained mean
- DINO pre-trained mean

Previously published works

On record:

- Conference: All sensors 2021

- Participation type: Idea paper

Off record:

- Journal "Springer: Autonomous Robots"

- Impact factor: 3.6

Combining Multiple Modalities with Perceiver in Imitation-based Urban Driving

Shubham Juneja
Institute of Data Science & Digital Technologies
Vilnius University
Vilnius, Lithuania
Email: shubham.juneja@mif.stud.vu.lt

Virginijus Marcinkevičius
Institute of Data Science & Digital Technologies
Vilnius University
Vilnius, Lithuania
Email: virginijus.marcinkevicius@mif.vu.lt

Povilas Daniušis
Department of Business Technologies & Entrepreneurship
Vilnius Gediminas Technical University
Vilnius, Lithuania
Email: povilas.daniusis@vgtu.lt

Springer Link

Published: 04 May 2021

Topological navigation graph framework

Povilas Daniušis ✉, Shubham Juneja, Lukas Valatka & Linas Petkevičius

Autonomous Robots (2021) | Cite this article

106 Accesses | **4** Altmetric | Metrics

Combining multiple modalities with Perceiver in IL based learning

- We present a study pointing out how end-to-end methods rely on a single modality while lacking the performance compared to traditional autonomous driving methods which take a modular approach.

- Therefore, we propose a method to enrol more than one modality in the learner.

- We propose the use of a perceiver architecture in the learner as this architecture shows capability of learning with varying number and types of modalities as input data.

- Since the published paper is a idea paper, no experiments were presented.

Published Journal Paper

- Accepted at IEEE Access

Visual Place Recognition Pre-Training for End-to-End Trained Autonomous Driving Agent

SHUBHAM JUNEJA[1]**, POVILAS DANIUŠIS**[2]**, and VIRGINIJUS MARCINKEVIČIUS**[3]**,**

[1]Vilnius University Institute of Data Science and Digital Technologies, Vilnius, LT-08412 Lithuania (e-mail: shubham.juneja@mif.stud.vu.lt)
[2]Neurotechnology and Vytautas Magnus University, Lithuania (e-mail:povilasd@neurotechnology.com)
[3]Vilnius University Institute of Data Science and Digital Technologies, Vilnius, LT-08412 Lithuania (e-mail: virginijus.marcinkevicius@mif.vu.lt)

Corresponding author: S. Juneja (e-mail: shubham.juneja@mif.stud.vu.lt).

Publication work in progress:

- Under review in a journal

Measuring Statistical Dependencies via Maximum Norm and Characteristic Functions

Povilas Daniušis
Department of Engineering
Neurotechnology
Vilnius, LT-06118 Laisvės av. 125A
Lithuania
povilasd@neurotechnology.com

Shubham Juneja
Institute of Data Science and Digital Technologies
Vilnius University
Vilnius, LT-08412 Akademijos str. 4
shubham.juneja@mif.stud.vu.lt

Lukas Kuzma
Institute of Data Science and Digital Technologies
Vilnius University
Vilnius, LT-08412 Akademijos str. 4
lukas.kuzma@mif.vu.lt

Virginijus Marcinkevičius
Institute of Data Science and Digital Technologies
Vilnius University
Vilnius, LT-08412 Akademijos str. 4
virginijus.marcinkevicius@mif.vu.lt

Work plan for semester 8

Research:

- Conference participation at AIEEE'2024

- Journal publication on use of foundation models in the case of autonomous driving

- Writing thesis