



**Vilnius
University**

An investigation of deep imitation learning for mobile robot navigation

Shubham Juneja

Supervisor: Dr. Virginijus Marcinkevičius

Semester 7

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	Under Review
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 20 th 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 with a poster in conference at Druskininkai.	December 2023	Journal paper at IEEE Access Journal with title “Visual Place Recognition Pre-Training for End-to-End Trained Autonomous Driving Agent”	Under review
Fundamentals of informatics	Passed with 7/10				
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
2.	2.3. Empirical Research: 1. Implementation of results of 2.2.2 and 2.2.3 to improve the state-of-the-art trajectory controller and navigation methods.	May 2022 – August 2022	Implemented conditional neural processes for conditional imitation learning based trajectory following.
	2. Performing an experimental study of the developed algorithms to analyse their effectiveness and to compare with related alternate methods.	September 2022 - February 2023	Implemented and experimented with visual place recognition trained encoder over navigation. Analysis of the proposed method was also performed on benchmarks.
	2.4. Analysis of the obtained data, summary, preparation of conclusions: 1. Summary of theoretical research. 2. Summary of empirical research. 3. Summary of results and preparation of conclusions.	March 2023 – August 2023	Reported results of pre-training encoder on visual place recognition for navigation, into a scientific paper and submitted for review in IEEE Access journal for review.

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.



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.



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.



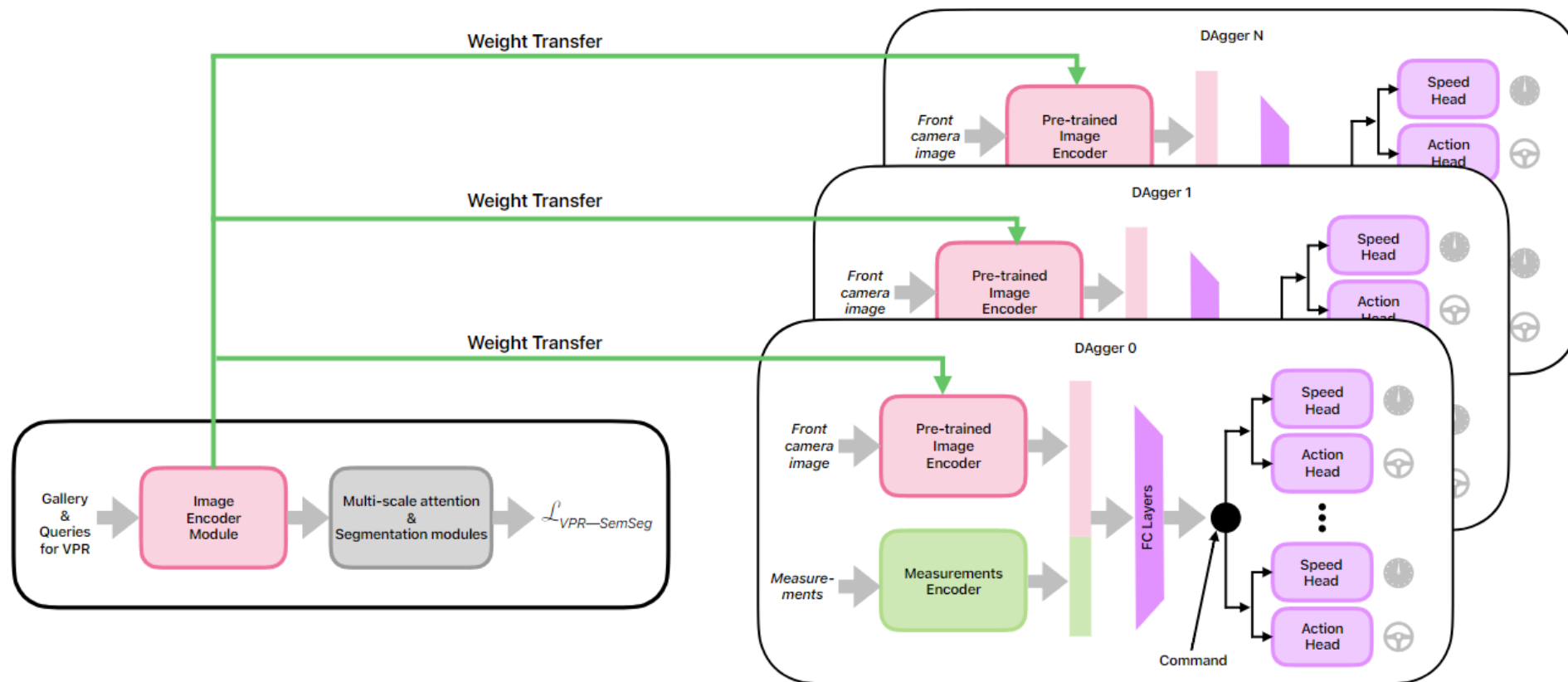
Visual Place Recognition Pre-Training for End-to-End Trained Autonomous Driving Agent

- All end-to-end driving benchmarks test under varying weather conditions.
- Performance in the state-of-the-art seem to generalise worse for previously unseen weather settings.
- Current algorithms train for different weather conditions during the imitation learning process, where it is implied but not explicit.

Proposed method

- Currently used encoders in end-to-end driving architectures are ImageNet pre-trained Resnet encoders.
- We propose, pretraining the encoder for the task of visual place recognition at first.
- Followed by carrying out imitation learning to learn the task of driving.
- This way we attempt to achieve weather invariance.

Proposed method



Visual Place Recognition

- Visual place recognition is an area which deals with making recognition of places invariant to weather and lighting conditions.
- Data is collected at different times of the day, with the help of GPS coordinates in order to be able to sample closer locations and further locations as per requirement.



(a) Wet noon



(b) Clear sunset



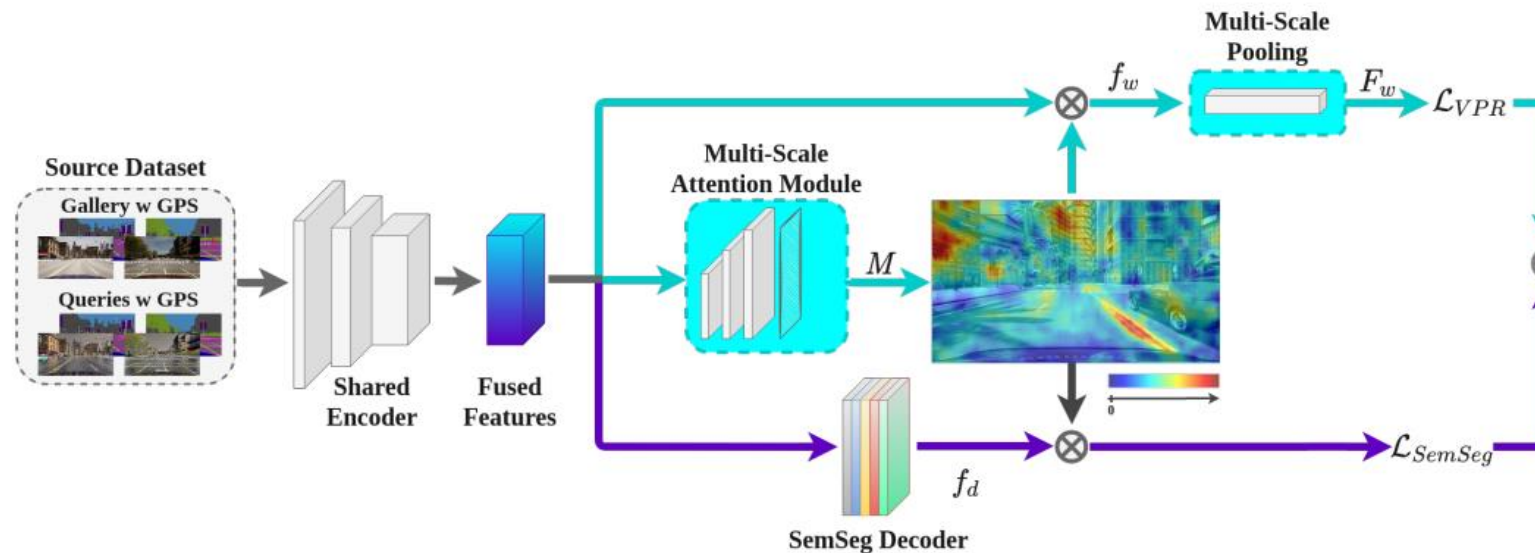
(c) Soft rain sunset



(d) Wet sunset

VPR Method used: SegVPR

- SegVPR learns global embeddings from visual and semantic context of data.
- It uses semantic segmentation to dynamically guide the task of recognising places.



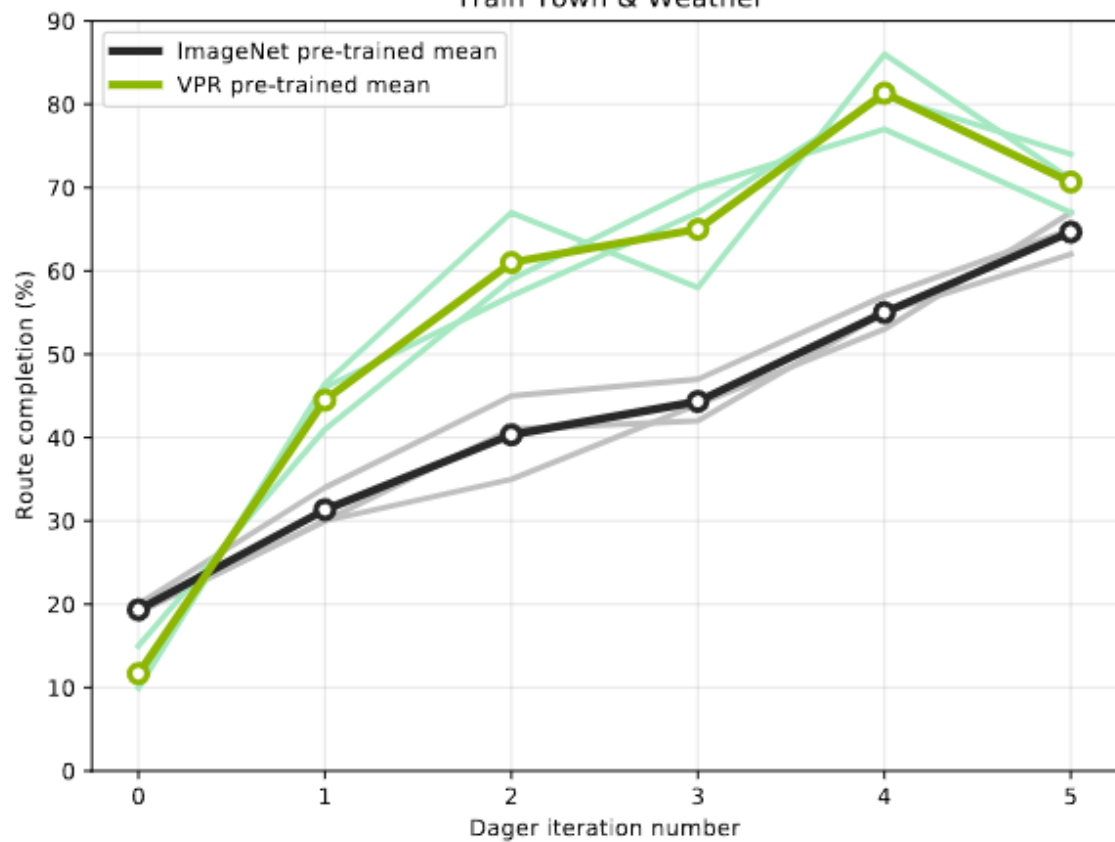


**Vilnius
University**

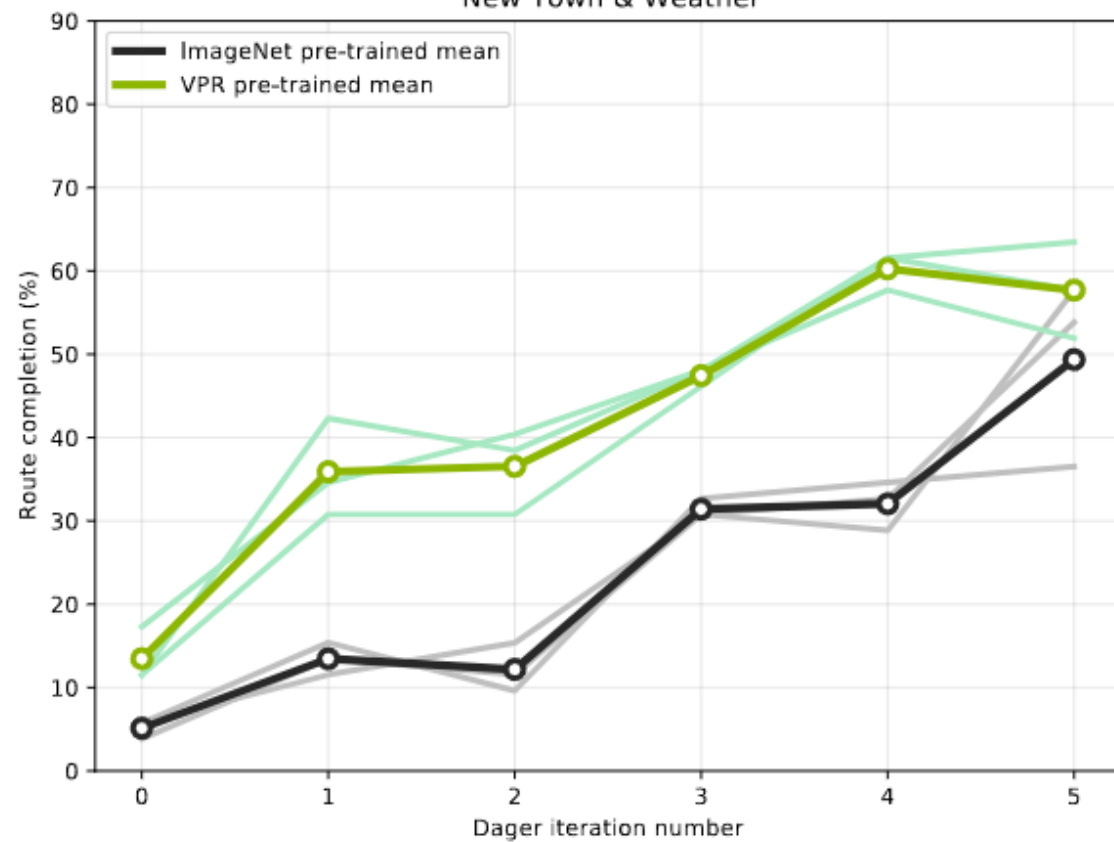


Results

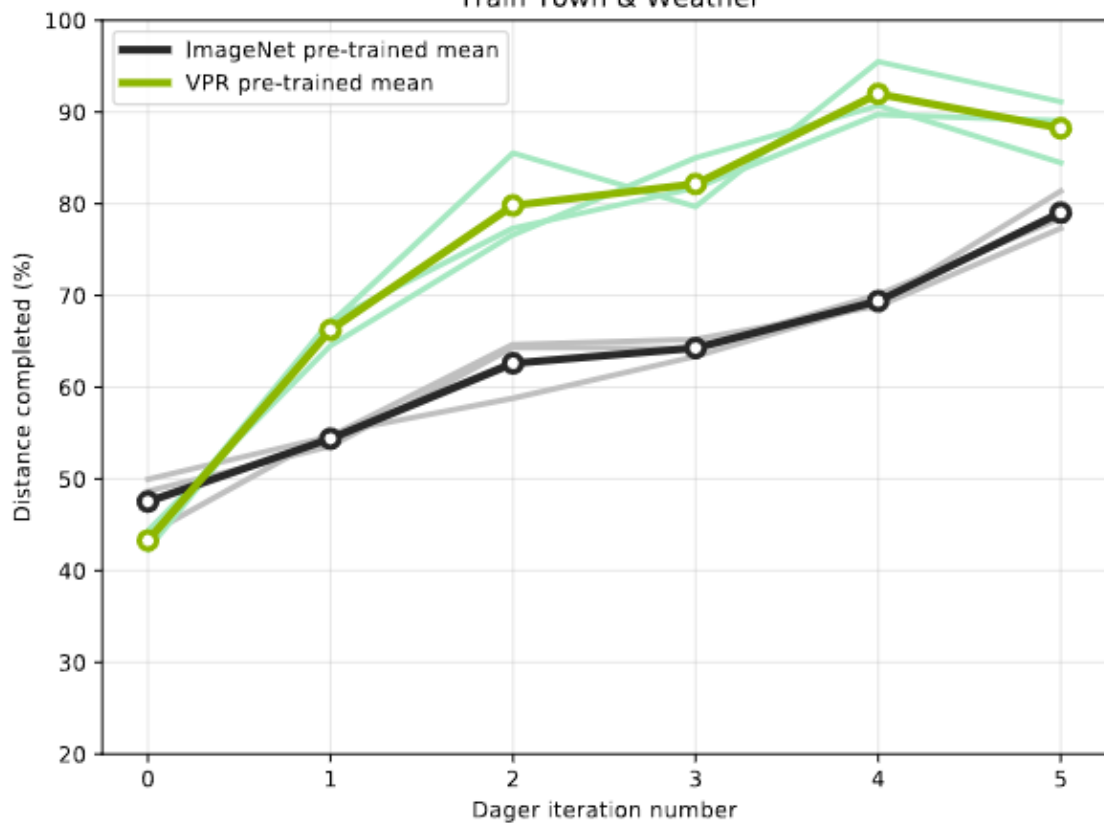
Train Town & Weather



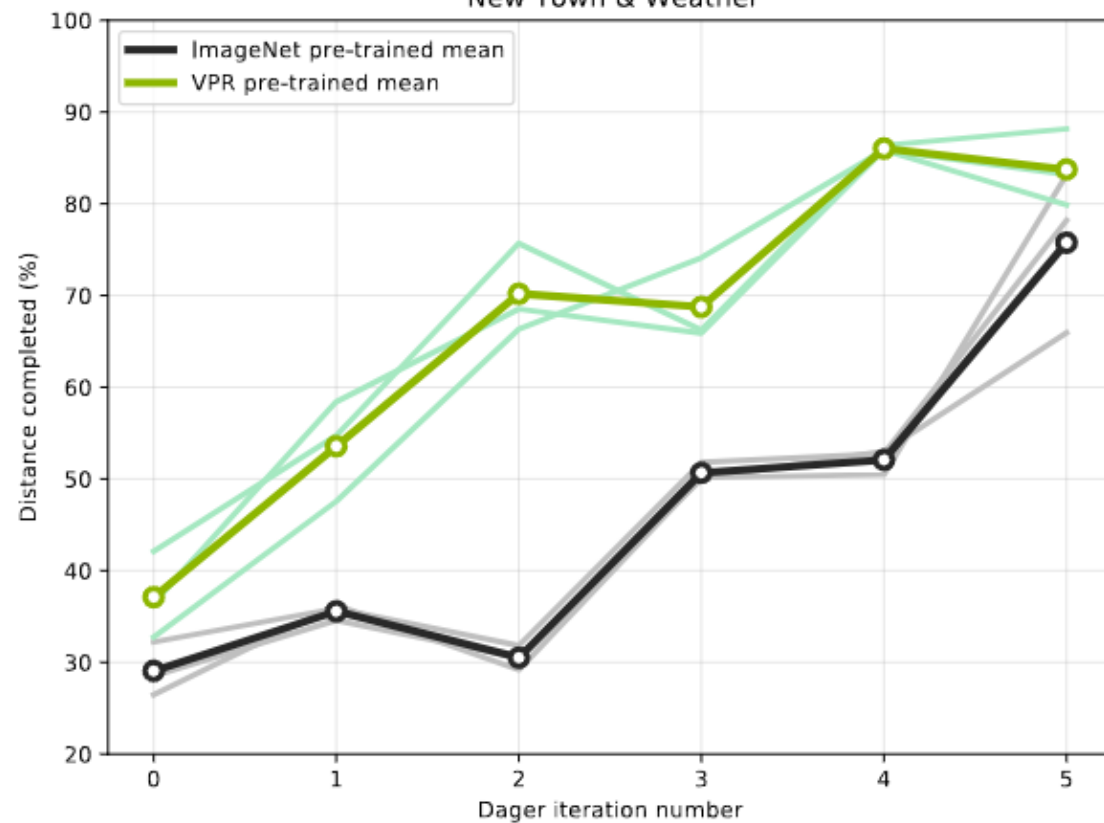
New Town & Weather



Train Town & Weather



New Town & Weather



Published work

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.

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

Publication work in progress:

- Under review in a journal

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

SHUBHAM JUNEJA¹, POVILAS DANIUŠIS², and VIRGINIJUS MARCINKEVIČIUS³,

¹Vilnius University Institute of Data Science and Digital Technologies, Vilnius, LT-08412 Lithuania (e-mail: shubham.juneja@mif.stud.vu.lt)

²Neurotechnology and Vytautas Magnus University, Lithuania (e-mail:povilasd@neurotechnology.com)

³Vilnius 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).

Work plan for semester 7

Research:

- Waiting for review of the recent paper.
- Conducting research for second journal paper.
- International conference participation.
- Registration for deep learn 2024 summer school.



**Vilnius
University**

Thank you