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An investigation of deep imitation learning for mobile robot navigation

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Semester 5

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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	0
IV (2023/2024)			1	0	1	0

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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.	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 2022		
Fundamentals of informatics	Passed with 7/10				
Optimisation	Passed with 7/10				

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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 Summer School (Participated)	
Total:	0.35/3

Stages of research and dissertation preparation

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	Name of task	Duration	Notes
	2.2. Theoretical research: 2. Research on new reactive mobile robot navigation trajectory controller, based on learning from experience (e.g. imitation learning, reinforcement learning). 3. Research on hierarchical goal-directed visual navigation system for mobile robots, based on aforementioned reactive component.	March 2022 – May 2022	Theoretical methods studied
3.	**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	

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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

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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.

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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

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What has been carried out so far

- Participation in summer school (Deep Learn 2022)
- More literature study
- Implementation of baseline and a proposed method

Research

Learning to imitate

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- 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.

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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 NoCrash benchmark has been established.
- NoCrash 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.

Meta-learning

- In contrast to supervised learning where a dataset is seen as a whole, meta-learning posses the dataset as multiple smaller datasets containing one task each, holding a **context set** and **a target set**.
- Both context and target sets consist of input-output pairs of data.
- Meta-learning assumes that each of the tasks contain **some common statistical properties** which when modelled well, can improve the performance of the learning algorithm.
- Hence the goal of meta-learning is to train a model which can **adjust the performance to unseen data** from known tasks based on the provided context set.
- Which intuitively becomes the **concept of learning a learning algorithm**.
- Why meta-learning? **Data efficiency**.

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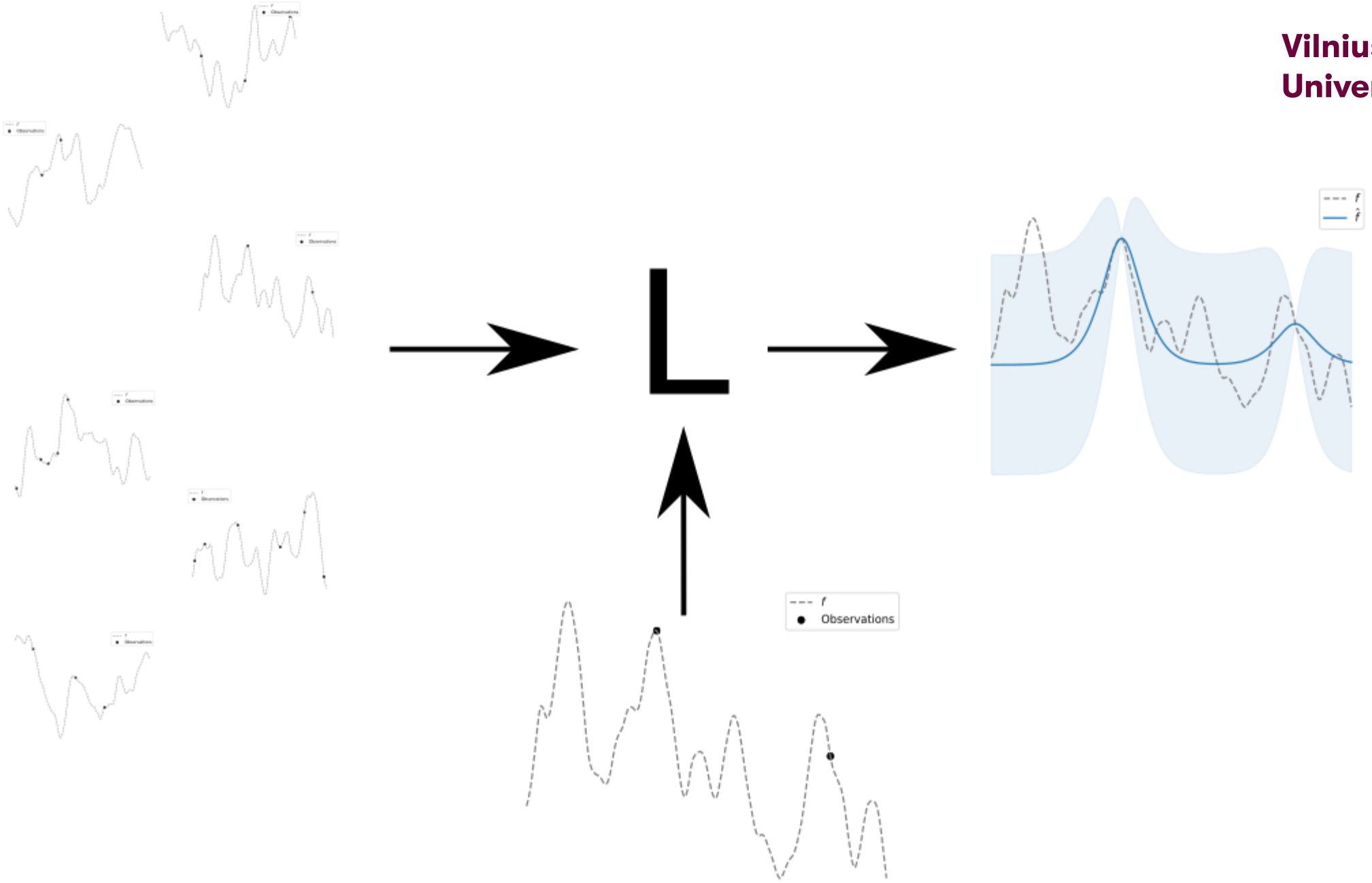

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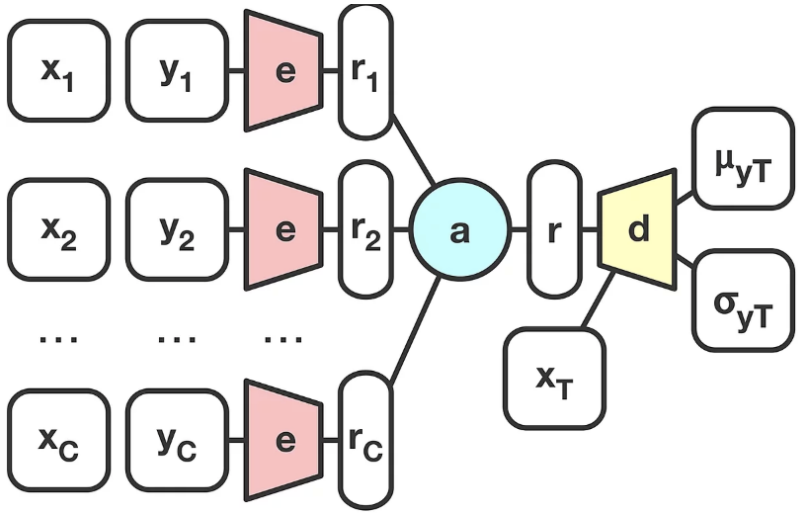
Conditional Neural Processes (CNPs)

- CNPs are simple deterministic variants of neural processes, and they leverage a series of input-output mappings to model the distribution at a given point, conditioned over on a context set.
- The architecture of the learner consists of an **encoder-decoder form**.
- The **encoder** takes a context set consisting of multiple input-output pairs and generates a summary feature vector.
- The summarised vector is then passed to the decoder.
- The **decoder** takes the summary feature vector along with a single input data point of interest, and generates predictions, or often probability distribution over the prediction variable.



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CNP in context of autonomous navigation (Proposed idea)

- Most of the current controllers are reactive to single input image.
- More information can be provided about recent history.
- Information can assist by holding information on environment conditions and decisions made in such conditions.
- Potential way of avoiding need of large datasets, as meta-learning is an attempt in the direction of few-shot learning.

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Implementation

- The proposed method was implemented on top of the state-of-the-art autonomous navigation method, which is called imitating a reinforcement learning coach (ROACH).
- For the implementation of the proposed idea, additional resnet was added to form an encoder of context data.
- Context data settings for **1 data point and 3 data points were implemented**.
- In total of 160 episodes of **driving data was collected** in the driving simulator.
- From each episode, around 15% of randomly selected data was kept aside as context set and rest was kept for observation training data (target set).
- The neural network implementation was done with the Pytorch framework.

Challenges

- As the selected baseline is a state-of-the-art method, it uses a **high resolution** of images and a very heavily parameterised neural network model.
- To train such a model it requires a **high amount of resources**, and as the proposed method with a context encoder adds another resnet model to the existing baseline, the demand for resources increase to an even higher number.
- Given the high resolution images to maintain the performance of the baseline and to compare the proposed method, the **disk access time** is also impacted resulting in slower training.
- Due to such complexities, train time for a single experiment run **requires 2 weeks of training with usage of two GPUs at once**.
- These complications bring down the speed of experimentation.

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Plan to overcome challenges

- Forming own baseline which is simple and uses PilotNet instead of resnet.
- Augmenting the simple baseline with the proposed methods such as CNPs.
- Having PilotNet will also help support a smaller image resolution, rightly impacting the disk access time during training.

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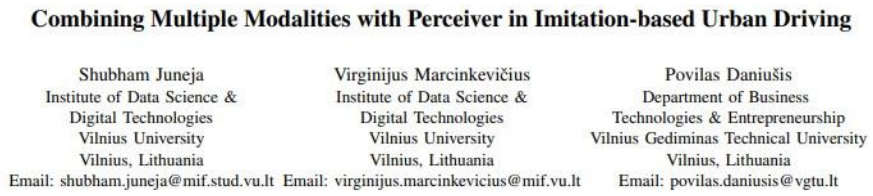
Published work

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

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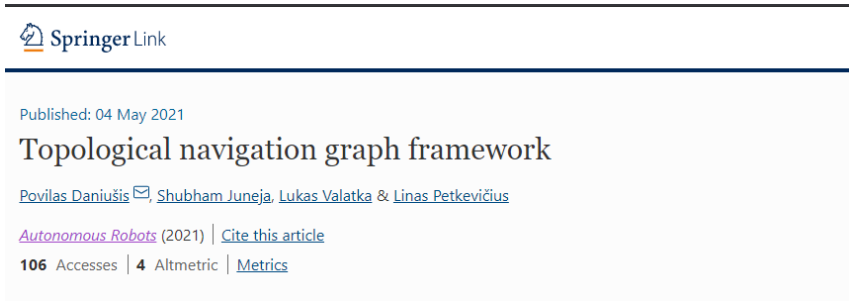

SpringerLink

Published: 04 May 2021

Topological navigation graph framework

Povilas Daniušis, Shubham Juneja, Lukas Valatka & Linas Petkevičius

Autonomous Robots (2021) | Cite this article

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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.

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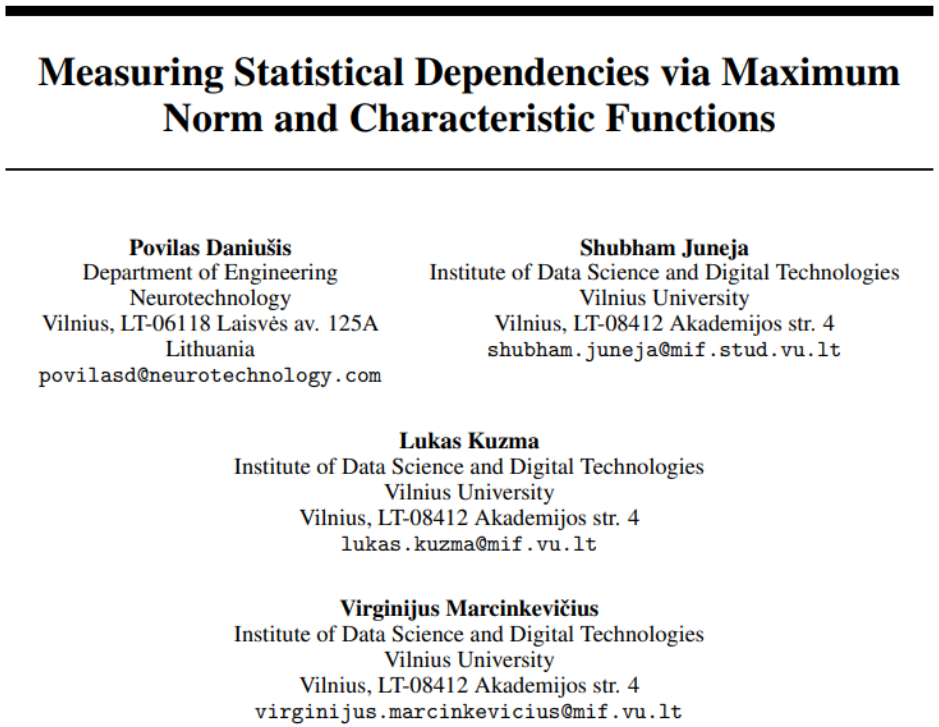
Publication work in progress:

- Rejected from NeurIPS 2022 conference, will be reworked for a Journal paper.



Measuring Statistical Dependencies via Maximum Norm and Characteristic Functions

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Work plan for semester 5

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Research:

- Implementation of proposed ideas and experimentation.

Conference Participation:

- Conference in Druskininkai, December 2022

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Thank you