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An investigation of deep imitation learning for mobile robot navigation

Shubham Juneja
Supervisor: Dr. Virginijus Marcinkevičius
Semester 1

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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	1				
II (2021/2022)	2	0				
III (2022/2023)			1	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 score of 9/10	Participation in conference in Lithuania	Planned to participate in ALLSENSORS 2021 conference https://www.iaria.org/conferences2021/ALLSENSORS21.html	Review of research on topic of the dissertation (In conference proceedings)	
Research methods and methodology of informatics and computer engineering	Planned to complete until September 2021				

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Workshops participated in

Workshop	ECTS
MOKSLINIŲ REZULTATŲ PUBLIKAVIMAS PAGAL FORMALAUS VERTINIMO REIKALAVIMUS	0.1
MOKSLINĖS INFORMACIJOS IŠTEKLIAI, PAIEŠKA, IR ĮRANKIAI	0.1
MENDELEY PRAKTINIS UŽSIĖMIMAS	0.15
Total:	0.35/3

Stages of research and dissertation preparation

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	Name of task	Duration	Notes
1.	Review and analysis of scientific research on the topic of the dissertation (in Lithuania and abroad): 1. Defining and describing the objectives of the dissertation research topic. 2. Overview of deep imitation learning and deep reinforcement learning for mobile robot navigation. 3. Summary of methods overview and presentation on the description of the analytical part of the dissertation. 4. Formation of research goal.	September 2020 – August 2021	Performed literature review on imitation learning and navigation methods, which is currently ongoing as planned.
2.	Carrying out research: **2.1. Development of research methodology:** 1. Identification and specification of problems arising in currently available methods. 2. Specification of tasks to conduct which address to identified problems. 3. Specification of navigation environments which will be analysed further. 4. Selection of appropriate research methodology. 5. Planning of theoretical and empirical research.	September 2021 – October 2021	
	2.2. Theoretical research: 1. Analysis of reactive imitation learning methods for sensorimotor control and strategy functions, which utilize deep neural networks, such as behaviour cloning, inverse reinforcement learning, generative adversarial imitation learning, etc. 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.	October 2021 – April 2022	

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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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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.

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What has been carried out so far

- Literature study from papers on imitation learning for mobile robot navigation
- Took courses on Machine learning (at VU) and Reinforcement learning (Online)
- Trying out Simulators (CARLA and OpenAI gym)
- Attempted to run state of the art methods in simulation

Takeaways

- Mobile robot navigation is being tried to solve in various ways, i.e. modular pipelines, end to end supervised learning, deep reinforcement learning, etc.
- Mainly mobile robots require following of trajectories to go from point A to B and avoid obstacles.
- The problem of urban driving seems to be solving a similar issue, but some research focusing on mobile robot navigation doesn't acknowledge the methods of urban driving, while some of the research acknowledges and utilizes them. And vice versa.
- As per imitation learning, there are methods in both areas of research which utilize imitation learning.
- CARLA seems to be a simulator common between trajectory following focused methods (which intersect with urban driving methods).
- Meanwhile some of the research prefers not to utilize simulators and preferring real world data to report results, leading to forming their own datasets.

Methods for Trajectory Following

- Conditional Imitation Learning **(CIL, 2018)** uses imitation learning with high level commands conditioned to the input to learn the skill of trajectory following.
- Conditional Affordance Learning **(CAL, 2018)** learns affordances in the form of low dimensional intermediate representations from videos, while conditioning with high level commands.
- Conditional Imitation learning with Resnet and speed branch **(CILRS, 2019)** is an extension of CIL with change in neural network architecture and using a separate branch to predict speed.
- Learning by Cheating **(LBC, 2019)** proposes training an agent in a two-step process, once with privileged information and once from a teacher network without privileged information.

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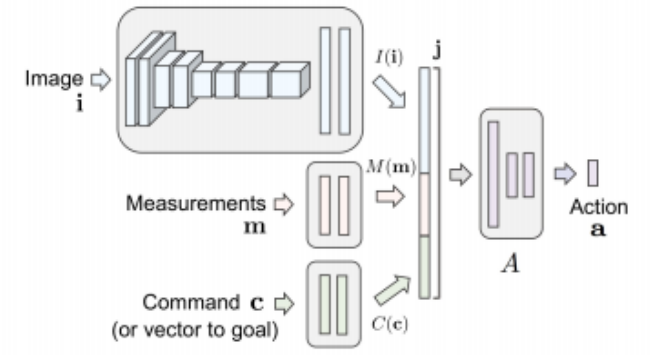
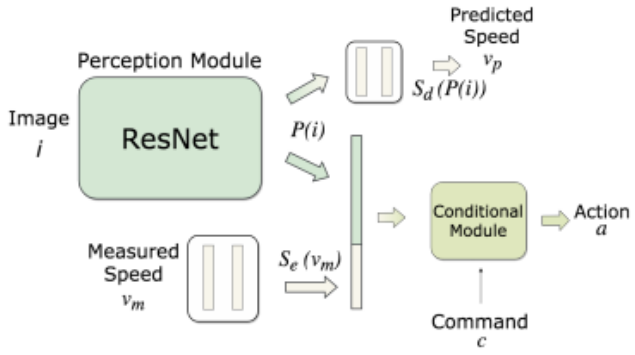
Methods for Trajectory Following

- Implicit Affordances **(IA, 2020)** uses a encoder to learn to predict affordances and then uses reinforcement learning to learn to navigate based on the affordances.
- Affordances based reinforcement learning **(IRL, 2021)** experiments with combining implicit and explicit affordances and training with reinforcement learning.





Comparison of report results

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Traffic levels	CIL	CAL	CILRS	LBC	IA	AT (Autopilot)	IRL
Empty	48 ± 3	36 ± 6	51 ± 1	100 ± 0	99	100 ± 0	100 ± 0
Regular	27 ± 1	26 ± 2	44 ± 5	94 ± 3	87	98 ± 1	98 ± 1
Dense	10 ± 2	9 ± 1	38 ± 2	51 ± 3	42	60 ± 3	91 ± 1

Table shows results reported by Agarwal, T., Arora, H., & Schneider, J. (2021). Affordance-based Reinforcement Learning for Urban Driving. *arXiv preprint arXiv:2101.05970*

Work plan for rest of the year

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Review and analysis of scientific research on the topic of the dissertation (in Lithuania and abroad):

- Defining and describing the objectives of the dissertation research topic.
- Overview of deep imitation learning and deep reinforcement learning for mobile robot navigation.
- Summary of methods overview and presentation on the description of the analytical part of the dissertation.
- Formation of research goal.

Passing exam:

- Research methods and methodology of informatics and computer engineering

Publication plan:

- Review of research on topic of the dissertation (in conference proceedings)

Conference Participation:

- Participation in ALLSENSORS conference.

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Thank you