L1: Introduction
Perception in Robotics, Term 3, 2020

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Presentation: Who are we?

Instructor:	Prof. Ferrer (Gonzalo)
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Mobile Robotics Lab: Research group inside CDISE, it is focused on robot navigation, particularly our interests are within Path Planning and Perception and how to combine both into new solutions for robotics.

What is this course about?

Why are you here? What are your expectations?

Definition of *Perception*:
"Awareness of something through the senses"

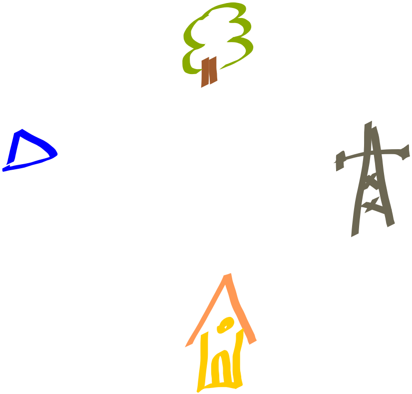
- Representation/Structure of the world: **State**
- Senses or **Observations** obtained from sensors: {Camera, Lidar, IMU, etc }
- Both representation must be meaningful for algorithms.

$$x \in X, \text{ (State)}$$
$$z \in Z, \text{ (Observation)}$$

Examples of state variables: Sensor poses, landmarks positions, map, room temperature, etc.

Problem Statement

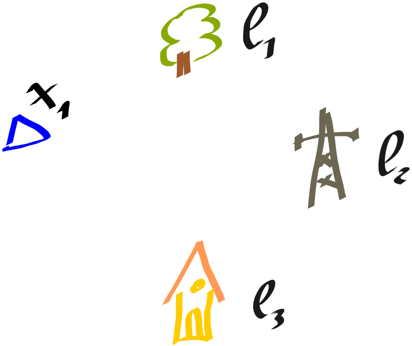
Robot (blue triangle) perceives the world, but *where it is??*



The solution is a distribution of the state variables $P(x)$
All methods described in this course are derived following a probabilistic approach. The world is uncertain.

Problem statement: Localization

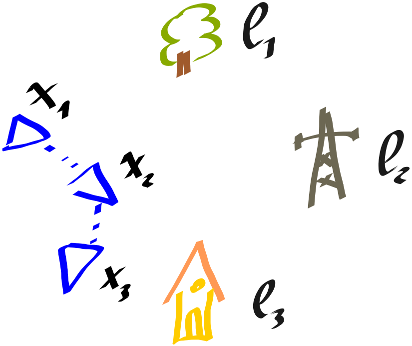
$P(x_1 | l_1, l_2, l_3)$



State x_1 is a 2D pose (in this example) we want to estimate. Landmarks $\{l_1, l_2, l_3\}$ are **known** positions corresponding to relevant features.

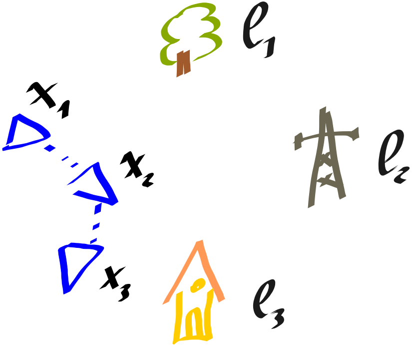
Problem statement: Mapping

$P(l_1, l_2, l_3 | x_1, x_2, x_3)$



The opposite problem: States $\{x_1, x_2, x_3\}$ are known and landmarks $\{l_1, l_2, l_3\}$ are estimated from these known positions.

Simultaneous Localization and Mapping



$P(l_1, l_2, l_3, x_1, x_2, x_3)$

The egg and the chicken problem!!

Course Goals

- Mastering ($\neq$ surveying) a set of core algorithms.
- Development of new technologies around modern state estimation techniques.
- Research in any field requiring precise state estimation.

Prerequisites

- Basic programming skills (Python)
- Probability: there is a document in canvas, L1.5
- Lin. Algebra: familiar with Geometry, $Ax = b$, Spectral decomp.

Class structure

16 lectures (B2-3007)	Monday 16:00-19:00 Tuesday 16:00-19:00 Thursday 16:00-19:00
40% Problem Sets	PS1: Probability PS2: Localization PS3: SLAM PS4: 3D Poses
25% Midterm exam	(3-March-2020)
25% Final Group Project	
10% Attendance	

Lectures Overview

- Block I: Introduction to Probabilistic Robotics (L1-5)
- Block II: Localization (L6-7)
- Block III: SLAM (L8-12)
- Block IV: Advanced topics in 3D perception (L13-16)

Midterm (3-3-2020) will include Blocks I, II and III. The exam will consist of a mixture of theory questions, theory-based problems and practical problems, requiring simple calculus. No laptops, calculators, phones, etc. are allowed. We allow one page double-sided, hand-written formula sheet during the exam.

Course Material

- Your class notes.
- Prof. handwritten lecture notes (uploaded before classes).
- Book: *Probabilistic Robotics*. S. Thurn, W. Burgard, and D. Fox, 2010, Third Printing (correct erratas)
- Canvas, selected papers for each lecture.
- Github `https://github.com/Kichkun/perception_course`
- Telegram `t.me/perc_rob`
- YouTube `https://www.youtube.com/playlist?list=PLRXYrdEUvBoCwKsQHJzafQYb7Nut0S2bn`

Problem Sets

- 4 Problem Sets (PS) during the term, due at approximately ten days intervals.
- PSs will be written in Python.
- PSs are substantial and should be worked on during the full allotted time period (each is a 10% of your grade).
- There will be a penalty of 15%/day. We will allow for 1 late submission without penalty (max 1 week).
- We will consider a late submission based on the last update on canvas.
- Students are encouraged to discuss on PS. Copying code is forbidden. On every PS there will be a section dedicated to Acknowledgments, if any.

Course Policies

Attendance
We will allow up to 3 missing classes and from there grade will decrease proportional to the number of absences.

PS Regrade Policy
If you believe we graded a problem-set or an exam of yours incorrectly, you can submit a regrade request no later than one week after the graded work is originally returned.

Academic Integrity
Reference to Skoltech's policy (see canvas)

Final Group Project

- Topic (related to the course): Extend a state of the art algorithm, or paper reproduction or implementation on your own settings.
- 3-5 Students / group
- Proposal: 1 page doc. Viability of the project.
- Progress (Optional) 3 page doc. Milestone.
- Presentation: 12' + 3' questions
- Paper: final project document, on a IEEE template.

Past projects

Ultrasound - IMU Sensors Fusion Algorithm Implementation *

Marsel Faizullin[1], Grigory Yashin[2], Ruslan Agishev[3] and Yakov Vasiliev[4]

Abstract— Accurate indoor localization is a challenging problem. It is worth noting that the use of one type of sensors does not allow performing either precise positioning or robust object tracking for this goal. This is especially true for unmanned aerial vehicles. In this article, we propose a Sensor Fusion algorithm based on processing data from two sensor systems: the MarvelMind ultrasound system and the IMU sensor mounted on the robot. Verif cation of developed algorithm is performed using motion capture Vicon Vantage 5.

Fig. 1. Experimental setup

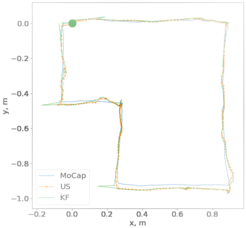


Fig. 5. Data fusion with pref ltered acceleration data

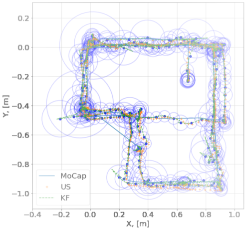


Fig. 6. Data fusion with pref ltered acceleration data

Past projects

1

Ego-motion, depth and mapping with monocular camera

Sergey Divakov, Artem Filatov, and Kirill Mazur

Abstract—The paper [2], which is a development of [1], proposed an unsupervised learning algorithm which can estimate the depth and ego-motion by the monocular video. The presented approach uses 3D geometrical constraints to correctly estimate those values. The algorithm is of great interest because it doesn't use any supervision datasets with the depth and ego-motion and achieves the state-of-the-art results on the both problems. In this project, we implement the proposed architecture in Pytorch. We also conduct experiments with the dataset collected on the Moscow roads. The architecture is able to correctly predict the depth on the Moscow roads, although it was trained on the KITTI dataset. Using the depth information and information from gps and gyroscope and magnetic f eld sensor, we reconstruct the map of the road.

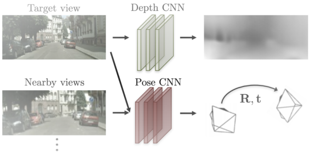


Fig. 1: High-level model overview

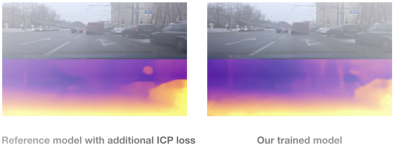


Fig. 5: Comparison of the depth prediction results

Past projects

SEGMENT-BASED LOCALIZATION ON 3D POINT CLOUDS

Anastasia Kiskun[1*], Konstantin Pakulev[1], Stanislav Tsepa[1], Olga Sutyrina[1]

Abstract—this article presents a model-based segmentation method applied to 3D data acquired on urban area. The purpose of the project is to implement technology for fast and accurate place recognition for localization on known maps, by identifying previously visited scenes and running an alignment with those. It has a necessity of robust place recognition for effective smoothing and mapping.

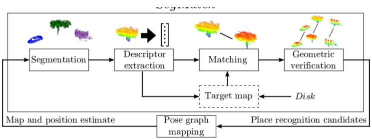


Fig. 1. SegMatch algorithm.

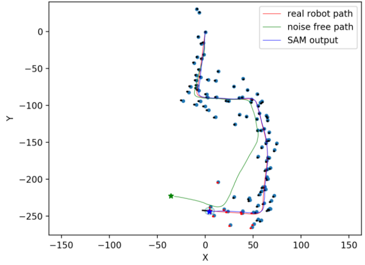


Fig. 11. : A set of landmarks and real, predicted and smoothed trajectories.

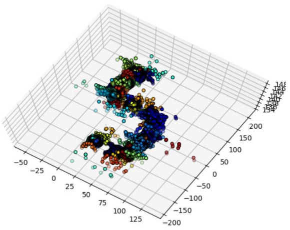


Fig. 8. Example of segmentation.