INSTITUTO DE SISTEMAS E ROBÓTICA
UNIVERSIDADE DE COIMBRA

1st Open day & Workshop @ISR-UC

Motion Planning Supported by Reinforcement Learning in an Assisted Mobility Context

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Introduction

Demographic statistics show an accelerated ageing tendency, resulting in increasingly older societies. With the progress of age, several health complications arise. Mobility decay is for instance, one of the most recurrent disorders, mainly due to muscular, neurological, and osteoarticular decay.

Technological approaches that focus on helping sufferers of such disorders have been emerging. Which leads to the importance of researching novel Human-machine collaborative (HMC) navigation strategies that can improve user safety and navigational efficiency.

Problems: Difficult to model the user's intent and state to train models offline and gathering large datasets online can be strenuous to already debilitated users; Imitation or curriculum learning for behavior learning and domain transfer in assistive contexts has only recently been a focus of research.

Goals:

- Ensure a high-level of safety and reliability for indoor and semi-structured environments, taking into account context and social cues.
- Security and safety, when considering assistive platforms and human populated environments. Hazardous scenarios can lead to collisions, hardware damage or even human casualties.
- Environment representation for assistive contexts - e.g., Represent non-trivial obstacles such as gutters or downway stairs can be critical as they are not commonly detected as obstacles.
- Motion planning strategies must perform fine adjustments (e.g., docking a user to a table) which requires robust 3D representations.
- When considering assistive contexts, ensure the platform's safety, the user's safety and navigational efficiency.

Research Areas

3D environment representation (with mapping, localization, and SLAM)

New local motion planning strategies for mobile robots with particular application in the context of assistive robots

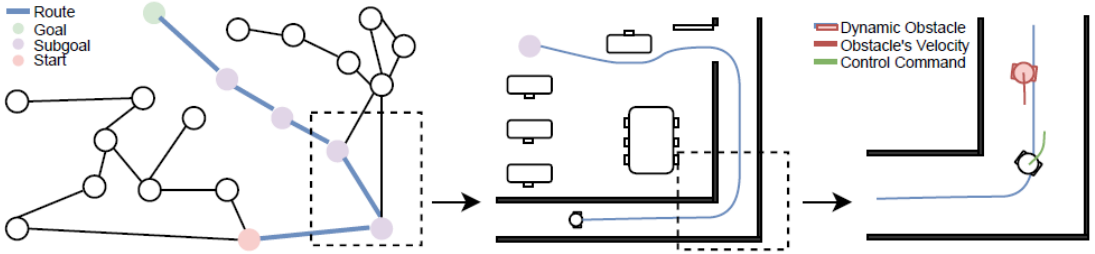
To avoid critical scenarios when validating local motion planning strategies in assistive contexts, simulation environments were used to simulate hazardous scenarios were datasets are not available, their occurrence is rare/sporadic, and real-world data gathering is complex/risky, as a way to minimize user strain and avoid hindering humans in the early stages of research and development of new algorithms.

Localization and Simultaneous Localization and Mapping (SLAM):

- Multimodal 2D localization and map maintenance – Multimodal sensor fusion to obtain accurate pose estimates and address the problem of maintaining a 2D representation over long periods of time.
- 3D simultaneous localization and mapping - the HMAPs representation is addressed and pipelines for localization and SLAM are presented. The goal was to provide reliable representations and accurate pose estimates.

Motion Planning:

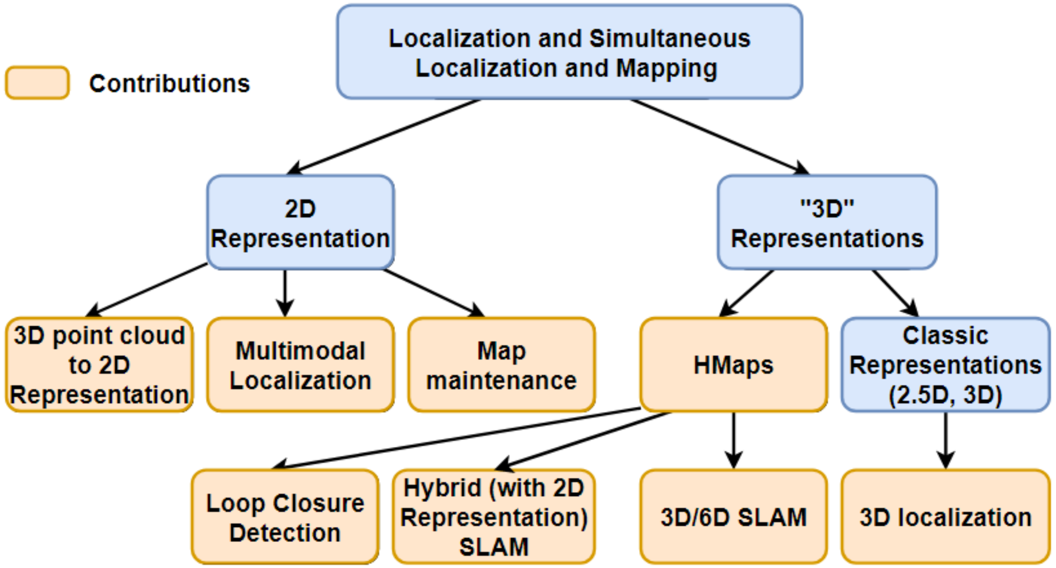
- Global Motion and Path Planning – methodologies focusing on mission planning over hazardous areas and in path planning considering dynamic obstacles.
- Local motion planning and user assistance – methodologies focusing on assisted mobility considering the user's intent and general approaches for local motion planning. The goals were intuitive and accurate translation of the user's intent as well as safe obstacle avoidance behaviors.



Mission Planning Path/Motion Planning Local Motion Planning

Contributions

Set of general frameworks for environment representation (with localization or SLAM applications) and motion planning with applications in assistive robots such as walkers and wheelchairs. The main contributions of this work are:



🟧 Contributions

Localization and Simultaneous Localization and Mapping

2D Representation

"3D" Representations

3D point cloud to 2D Representation

Multimodal Localization

Map maintenance

HMaps

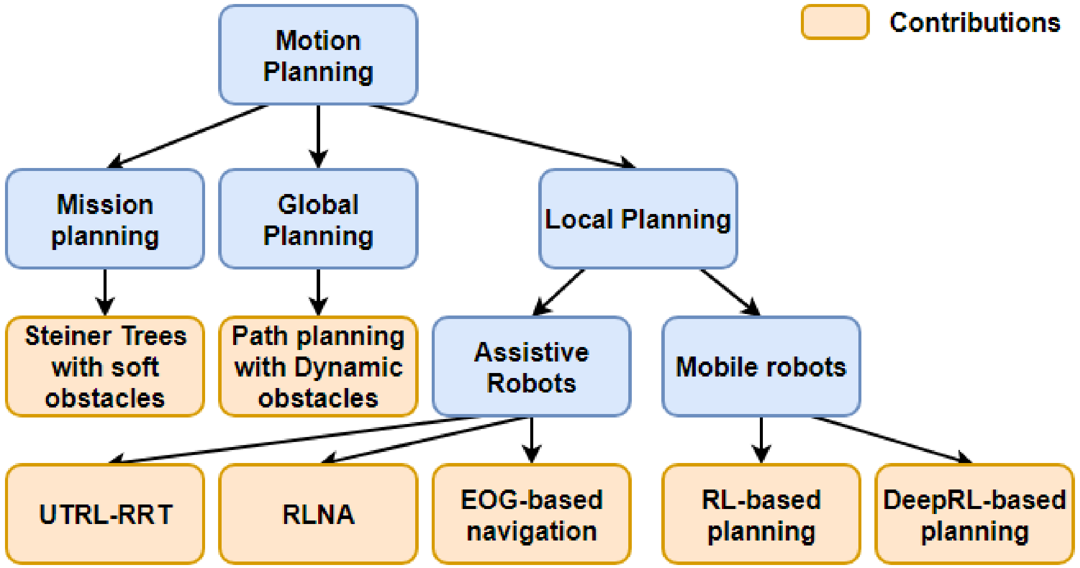
Classic Representations (2.5D, 3D)

Loop Closure Detection

Hybrid (with 2D Representation) SLAM

3D/6D SLAM

3D localization



🟧 Contributions

Motion Planning

Mission planning

Global Planning

Local Planning

Steiner Trees with soft obstacles

Path planning with Dynamic obstacles

Assistive Robots

Mobile robots

UTRL-RRT

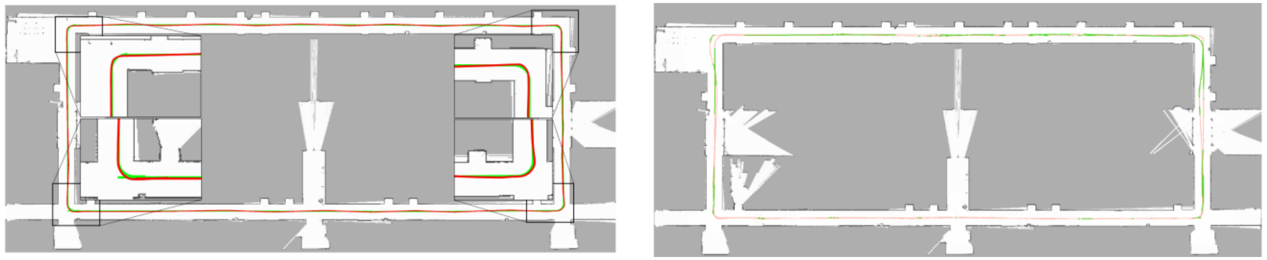
RLNA

EOG-based navigation

RL-based planning

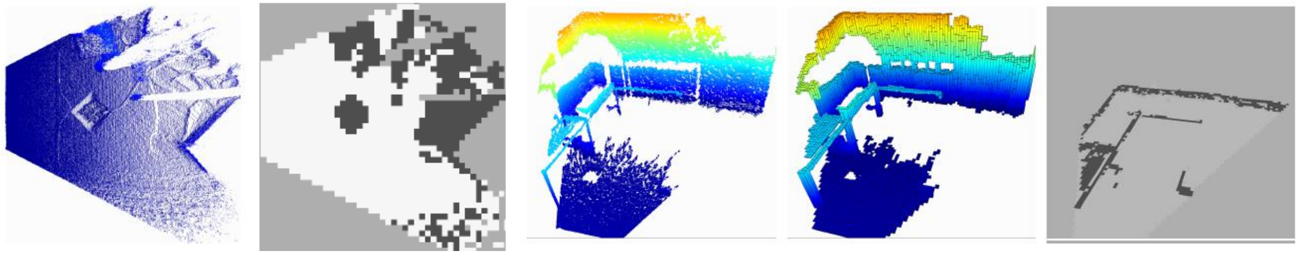
DeepRL-based planning

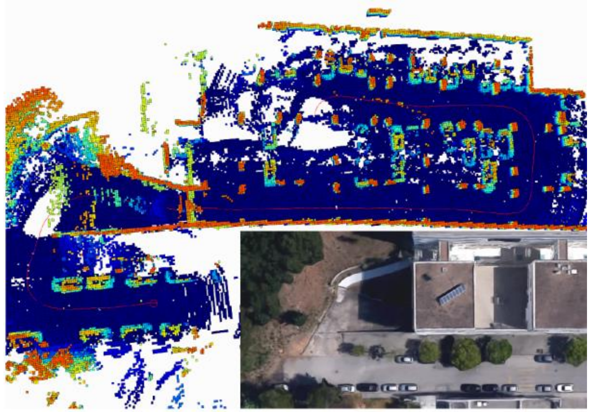
Localization and SLAM



- Particle Filter based 2D Localization using A-IPS, 2D LiDAR and odometry data.
- Map maintenance using Reinforcement Learning.
- 3D Point Cloud to 2D Occupancy Grid Map Using an Intermediary
- 2.5D Representation
- Particle Filter Localization and SLAM with 2.5D and 3D representations

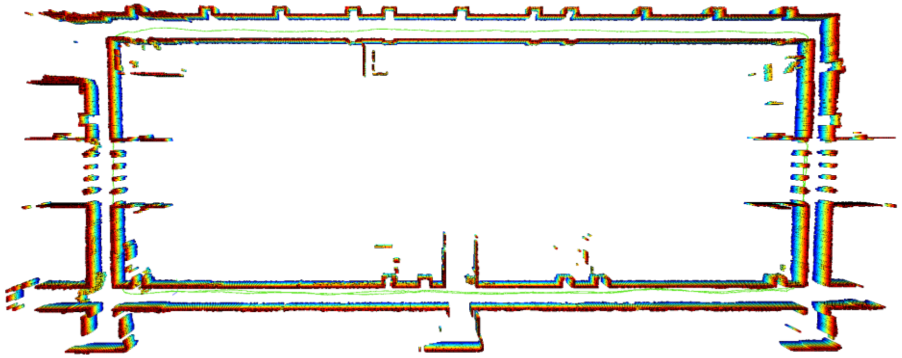
- **HMap representation**



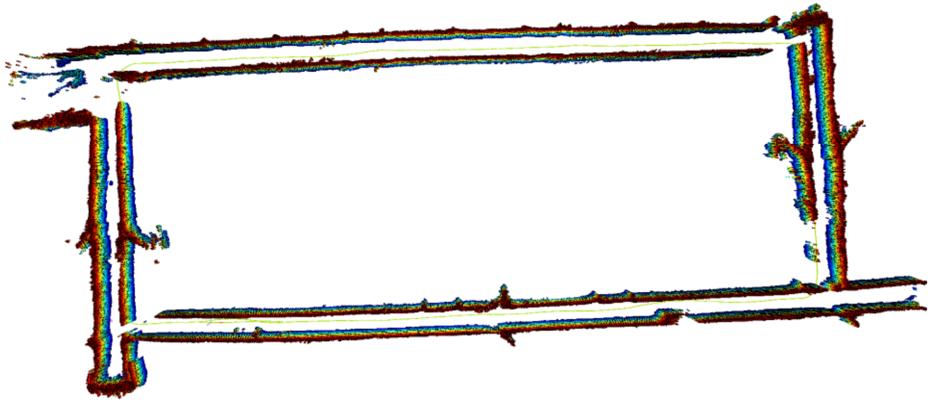


The electric vehicle drives from an underground parking lot (Department of Electrical and Computer Engineering) to the outside (near the entrance of the Department of Chemical Engineering)

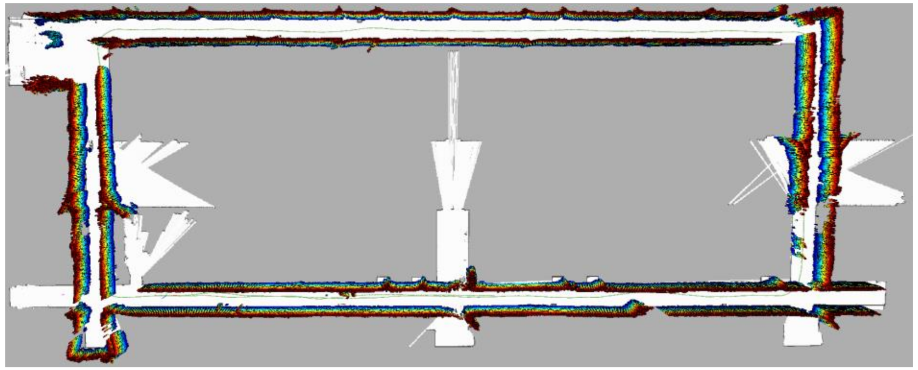
- Indoor HMaps-based SLAM



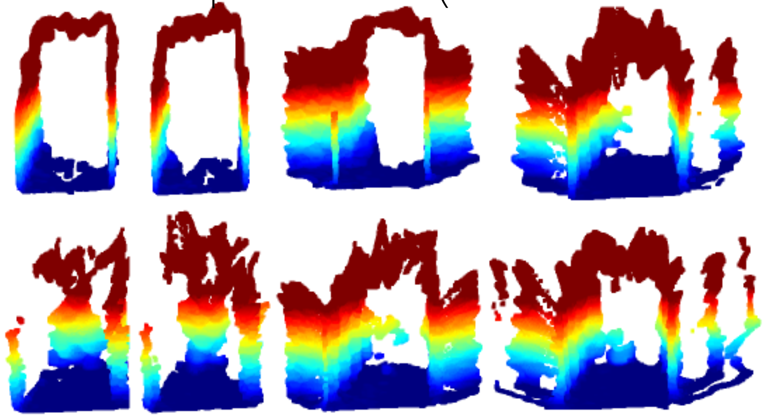
Velodyne point cloud



Realsense point cloud (from RGB-D camera)

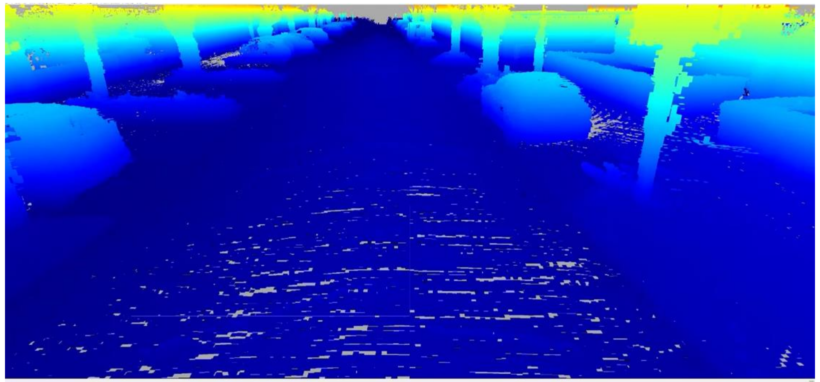


Hybrid 2D-3D HMap-based SLAM

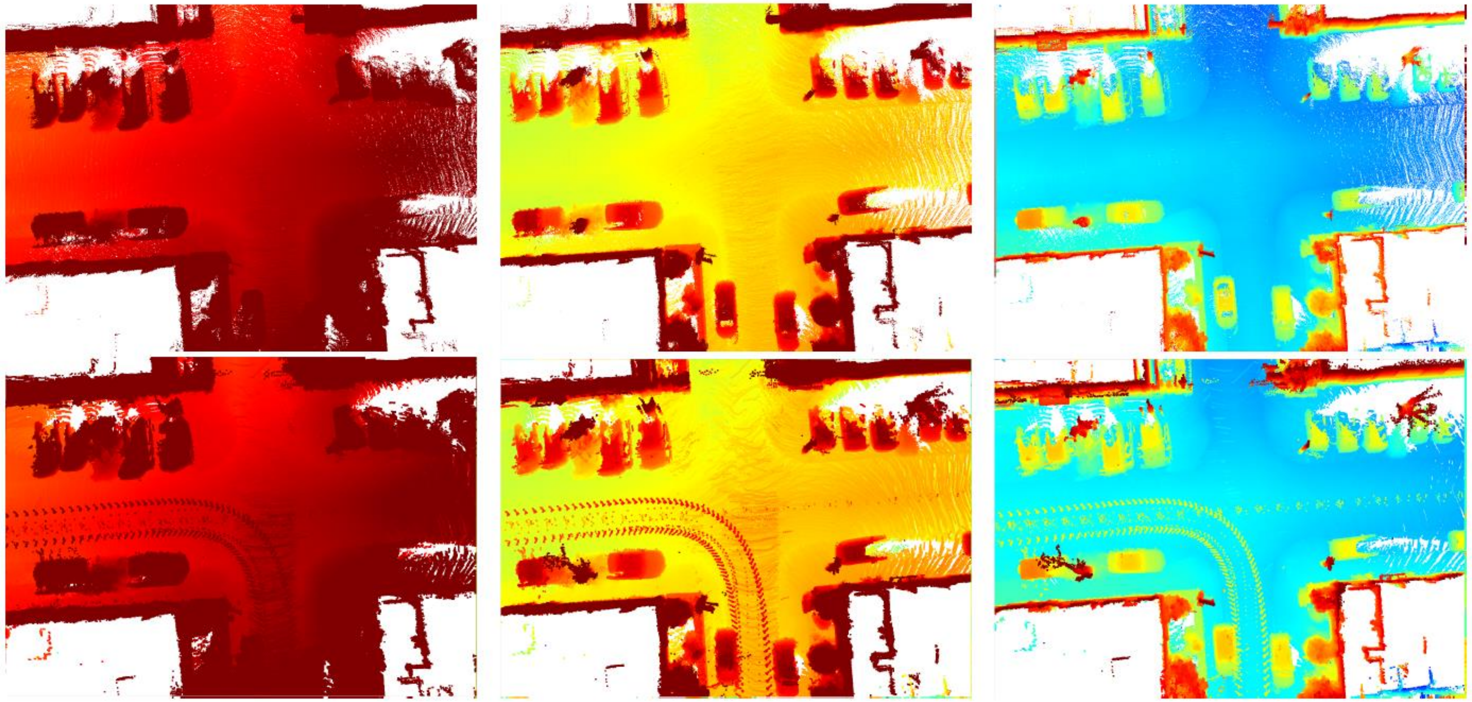


Raw Realsense point cloud (from RGB-D camera)

- Outdoor HMaps-based SLAM



KITTI Sequence 00 (odometry)

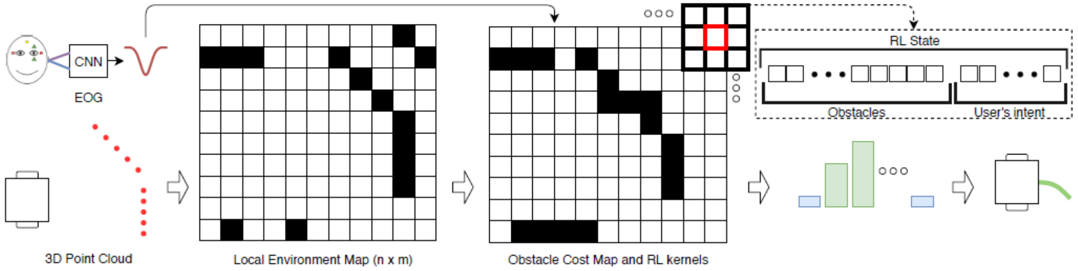


Top row contains the HMaps while bottom row the raw 3D point clouds. Artifacts visible in the ground-truth data (deformed car and trees) are less visible in the remaining methods and unrealistic ground and wall thickness is less pronounced for the HMaps 6D.

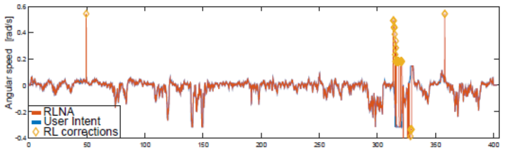
[1] Jens Behley and Cyrill Stachniss. Efficient surfel-based slam using 3d laser range data in urban environments. In Proceedings of Robotics: Science and Systems (RSS),2018

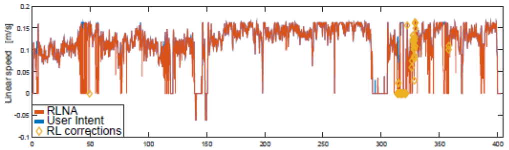
Motion Planning - Assistive contexts

EOG-based User Intent Driven Wheelchair Platform



User Intent Assistance for Robot-Assisted Navigation in a Walker platform

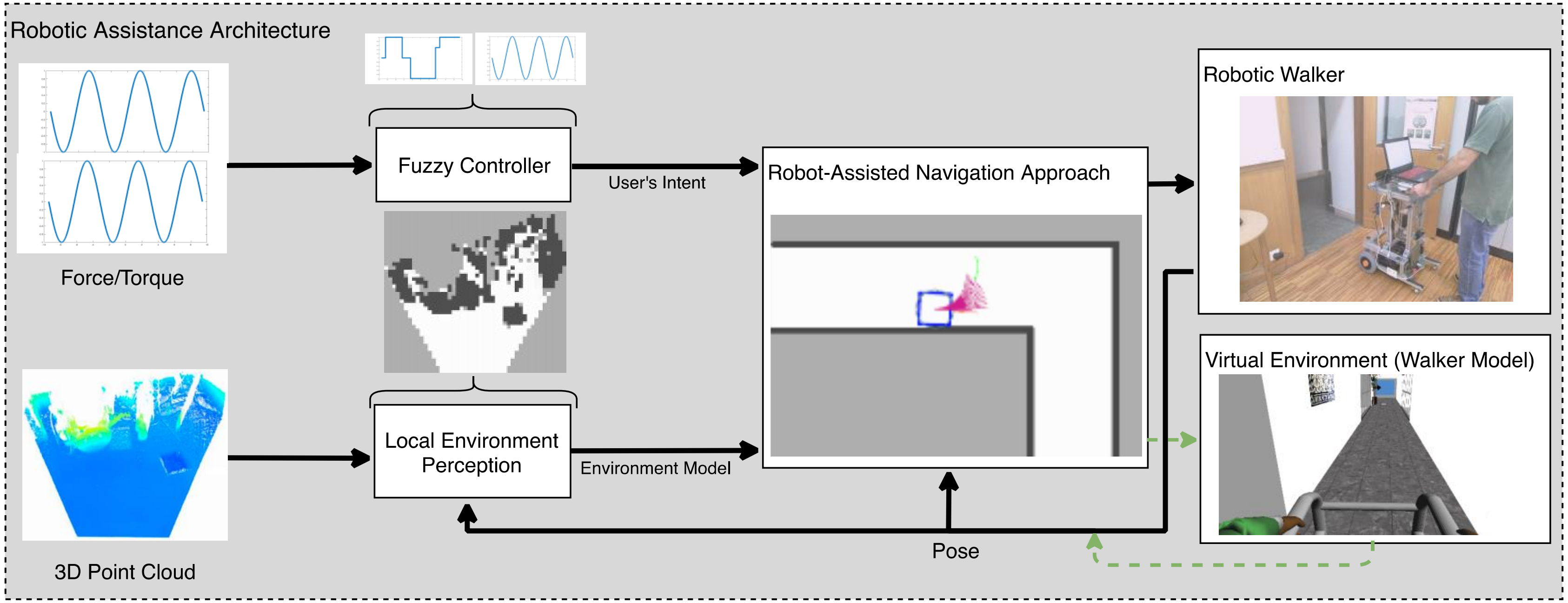




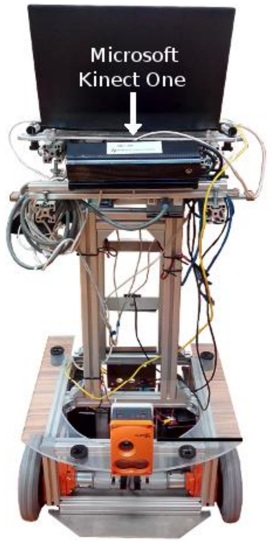
Two-stage Utility Theory Aided by RL and RRT for Robot-Assisted Navigation in a Walker platform

Motion Planning - Assistive contexts

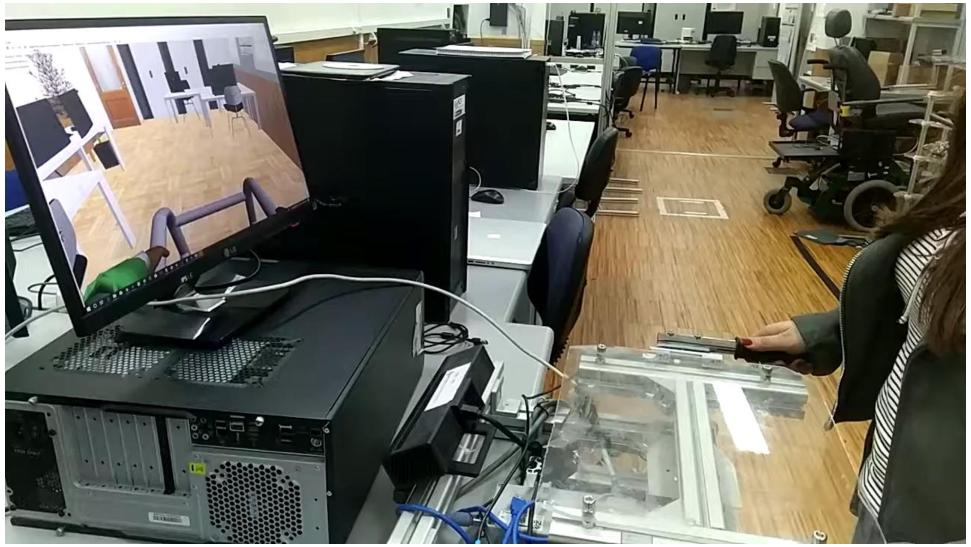
- Direct user control and the shared control categories of motion planning.
- Assistance without requiring a global map or a global plan of the user's actions
- Using a local map of the environment, the user can make local decisions and influence the walker's motion, but when a possible collision in the user's pathway is detected, the motion of the walker is adapted.



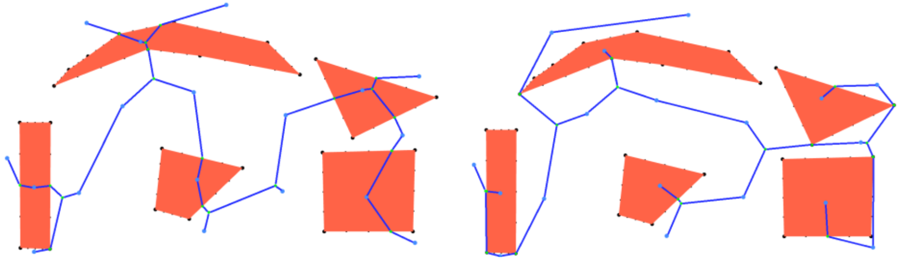
Problems …



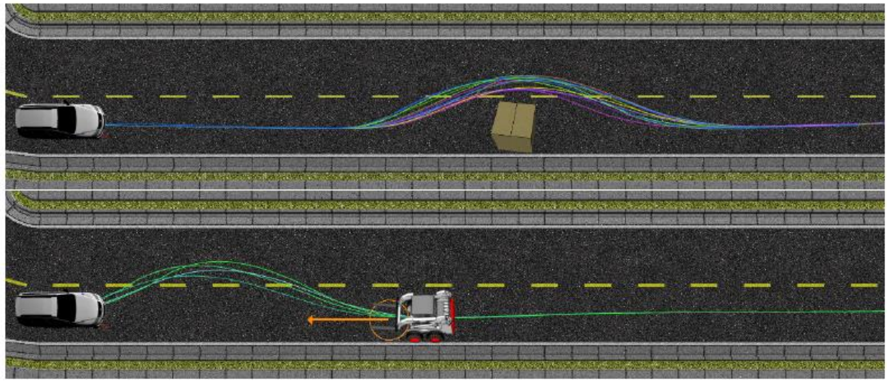
- Validation is not trivial, each user has different requirements.
- Training the models online can lead to collisions.
- Simulation environments can bridge this gap and allow for validation and online training in possible hazardous scenarios. Transfering models from simulation to real settings is not trivial

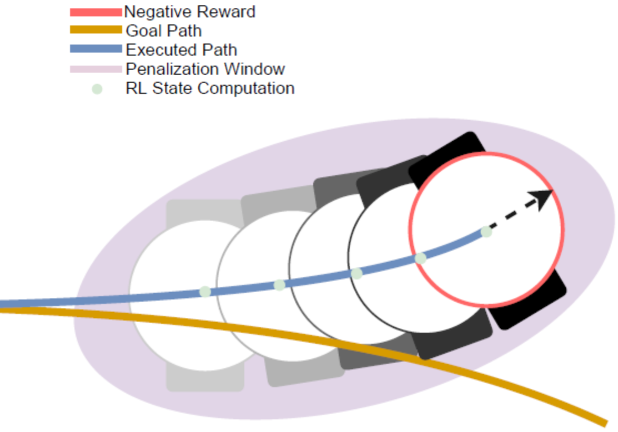


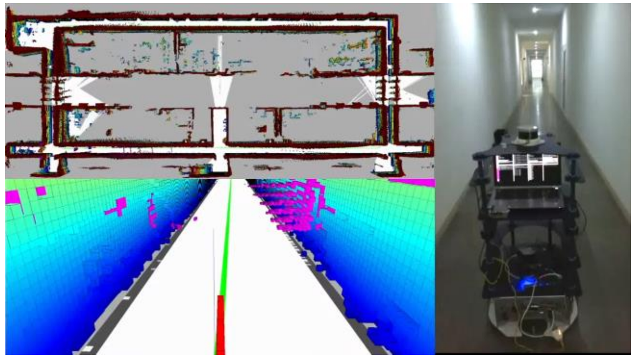
Motion Planning

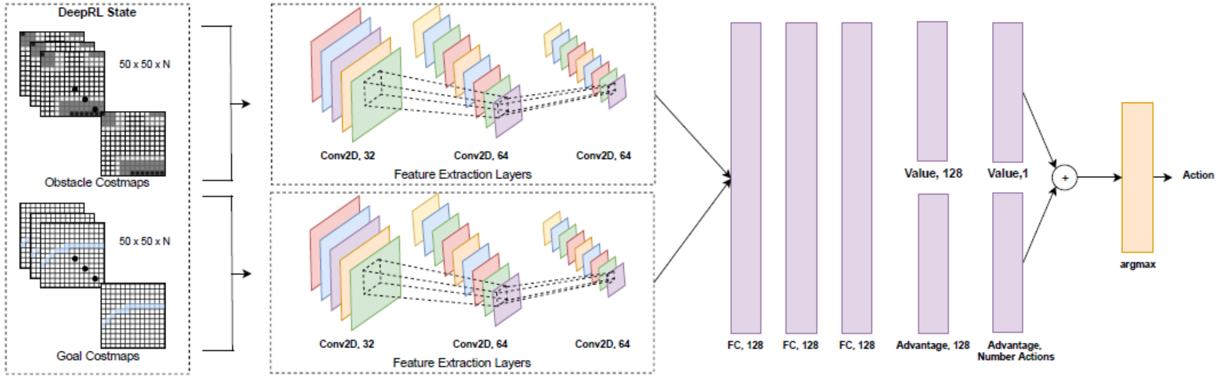


- Planning over hazardous areas represented with homogeneous obstacles using Steiner trees
- RRT-based Dynamic Path Planning
- Hybrid local motion planning using DWA inspired cost functions and RL
- Deep Reinforcement Learning based Local Motion Planning



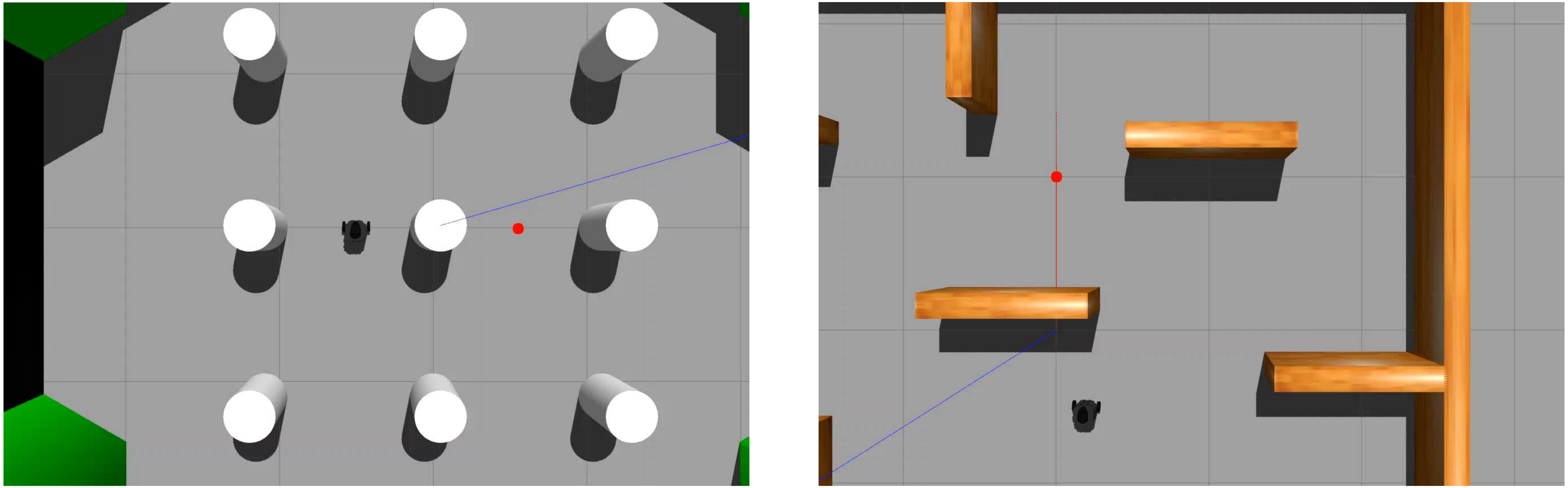






Motion Planning

- Deep Reinforcement Learning based Local Motion Planning

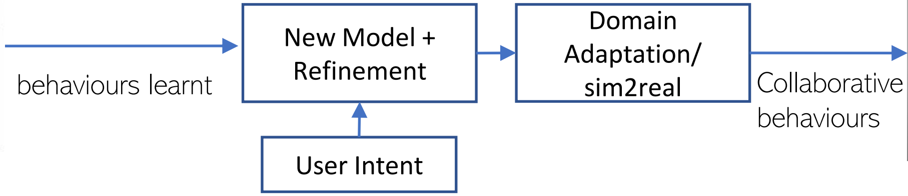


Problems: Catastrofic forgettiing between training scenarios, generalization and delayed rewards.

Current Research Axes

- Context-aware and social-aware motion planning (without a human in the loop), identification of critical scenarios, desirable behaviors, and data representation models.
- Imitate social constructs such as tending to one side of the pathway, waiting for a human conversation to end before interacting or waiting for a human to traverse a doorway before executing its task
- Aiming for better domain adaptation and generalization, for a robot to make decisions considering context, dynamic obstacles, social cues and safety, representations for sensor-agnostic models will be proposed using classic approaches such as 2D/3D costmaps and on Contrastive Representation Learning.
- Reward models generated from expert drawn affordances or, Inverse RL. The synergy between Deep RL and Inverse RL will allow for more robust models, with human-based expectations for long-term and short-term rewards, corresponding to global and local motion planning goals.

Context-aware, social-aware, ...



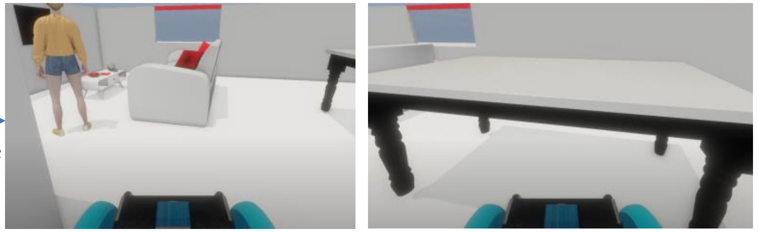
behaviours learnt

New Model + Refinement

User Intent

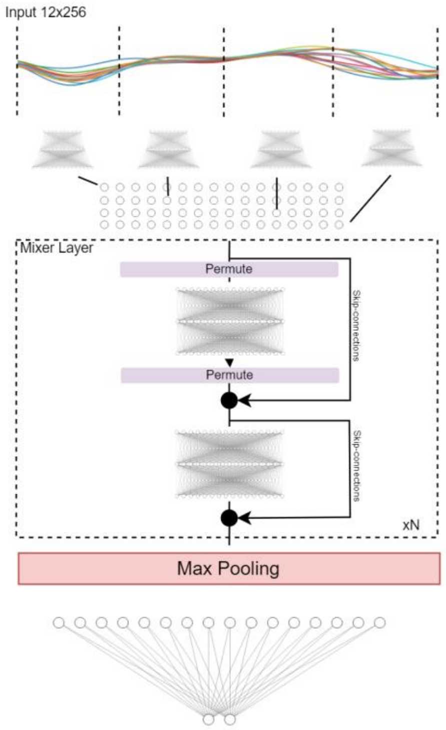
Domain Adaptation/ sim2real

Collaborative behaviours



Current Research Axes

- Behavior transference, considering the user's intent, an assistive platform and user-centered behaviors.
- Deep RL models considering now the user's intent, with a focus on the user's safety and comfort. New methods will be proposed to transfer important behaviors considering now the assistive context. Curriculum and imitation learning strategies will be employed for behavior transfer and domain adaptation strategies will be used to retrain/refine models due to the human in the loop.
- The user's intent, state of mind and emotions will be integrated and used to monitor user behavior and assess the user's level of comfort. By integrating not only the user's intent, but also biosignals (e.g., EEG, EOG, EMG) to model the user's state, new Deep RL methods will be able to generate more user-suited behaviors.
- Recent research has been focused on BCI Error Potentials (ErrPs) - The goal will be to assess how the robot's behavior is perceived as part of an online learning strategy that adapts to the user's condition.



ErrP Classification Net

Thank you