Roadmap-based Planning in Human-Robot Collaboration Environments

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Short bio

Zahid has completed his undergraduate studies in Pakistan at GIK Institute and master studies at Chalmers University, Sweden. He completed his PhD at FEUP in May 2018. At Chalmers, his major was Dependable Computer Systems that focused on security, reliability and timeliness of computer systems. Following which, he has spent time working as a research assistant in the area of wireless sensor networks at CISTER research unit Portugal, in the area of formal safety analysis and natural language processing at Linköping University, Sweden and in real-time communications at Distributed and Real-Time Embedded Systems Laboratory (DaRTES), FEUP. At DaRTES, his work is on reservation-based scheduling techniques over Switched Ethernet using a real-time Ethernet protocol, FTT-SE. Currently, he is a post-doctoral researcher at Digital & Intelligent Industry Lab (DIGI2) at FEUP working in the área of path planning for industrial robots. His research interests include collaborative robots, real-time communications, resource reservation techniques, and distributed embedded systems.

Introduction & motivation

- Increased **automation** supported by **industrial robots**
  - Pre-programmed to perform **repetitive** or dangerous tasks
    - offer better precision, accuracy, **reduce** production time, labour cost ...
  - Typically, **static** scenario(s)
    - task set or environment do not change

- **Motion planning** is **central** to the operation of the robots
  - Drive from start to the **goal** position while **avoiding collision** with obstacles

PRM
RRT
RRTConnect ….

Introduction & motivation

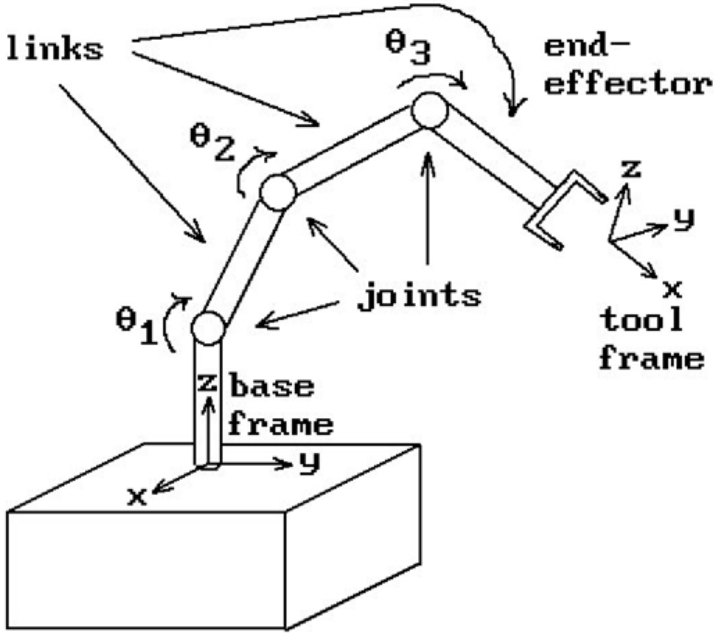
- **Collaborative** robots
  - allow humans to work **side-by-side** robots
  - cost savings and workplace **efficiency**.

– **Dynamic** scenario(s)
  - **run-time changes** in tasks and / or environment
    – ability to **replan** trajectory **online**
  - robot must be able to **perceive** human actions

EBMP
Dynamic PRM
Incremental path planning ….

Some concepts

- Robotic arm with **n+1** **links** connected with **n** revolute **joints**
- **Forward** kinematics
  - Calculate the end-effector pose given the position of joints
- **Inverse** kinematics
  - Given the position of the end-effector work out the joint angles to reach that position
- **Configuration** is any possible placement of the robotic arm
  - Determined with independent parameters (joint-angles)
  - Collision-free configuration C_{free}, occupied space C_{obs}
- Configuration space denoted **C** is the set of all possible configurations



This work

- **Path planning** with **obstacle avoidance** in **dynamic** collaborative scenarios

Intelligent monitoring solution

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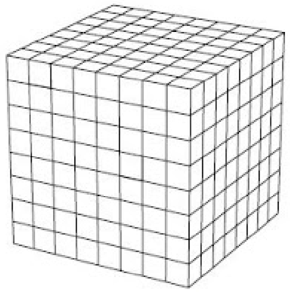
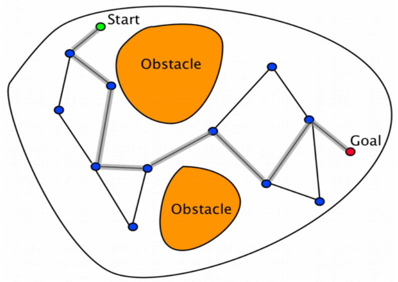
Random sampling approach



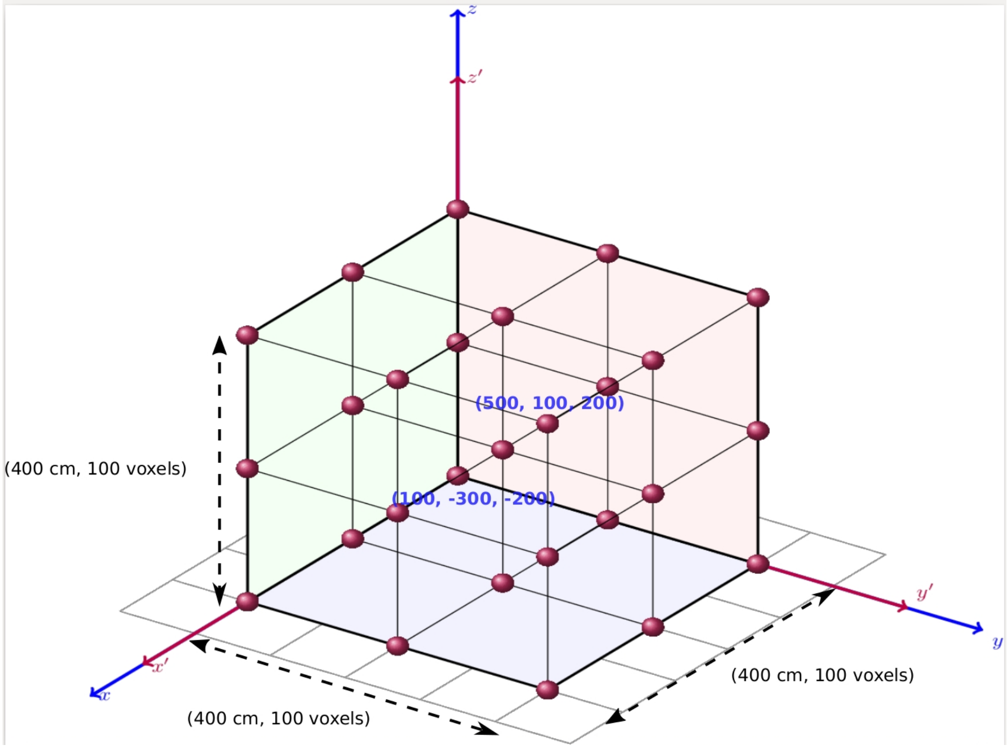
Voxel grid



Probabilistic roadmaps

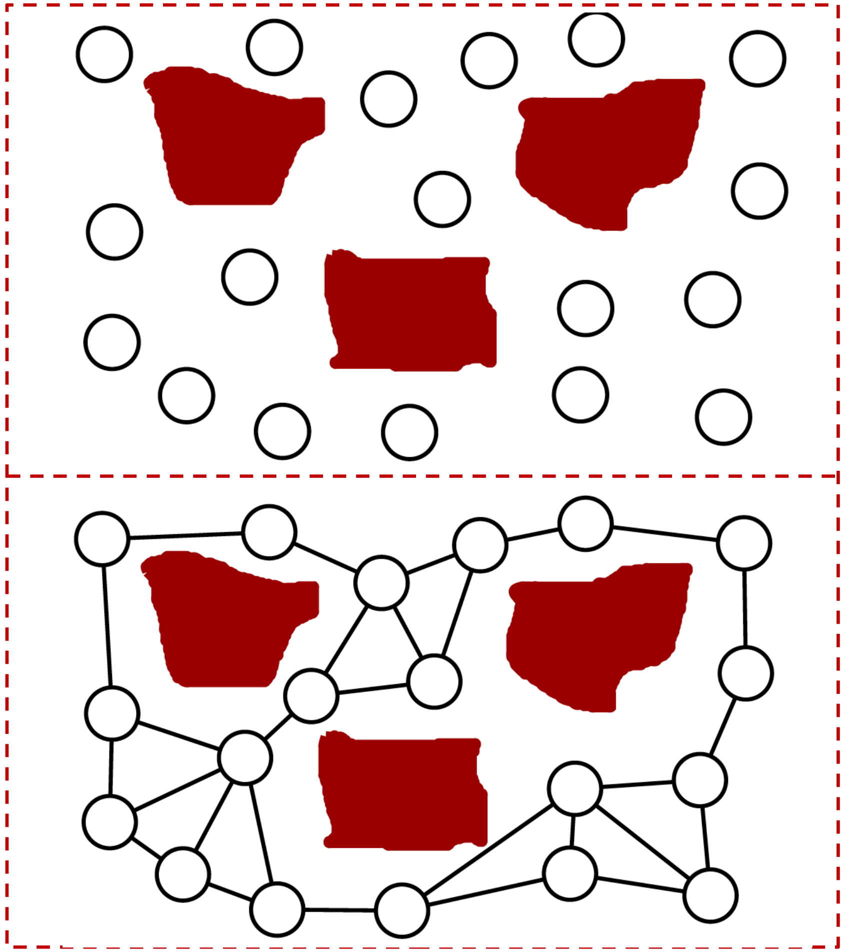
Proposed approach

- Grid *G* and roadmap *R* correspondence
  - c: cells in *G*
  - configuration q: nodes of *R*
- *G* aids roadmap computation
  - Each c stores how many q with end-effector (ee) in c
    - Sampling stops when most cells in *G* reach a limit
    - uniform distribution of ee positions over workspace



Proposed approach

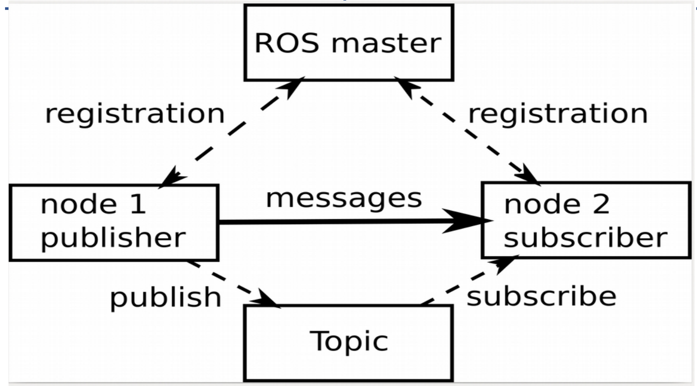
- Standard **PRM** to form edges between sampled nodes
- An occupied cell c invalidates respective configurations q_i
- At **runtime** track environment changes, obstacles appearing or disappearing
  - The grid *G* can inform when cell gets occupied or free and respective node or edge in *R* increments a counter
  - Nodes / edges with +ve counters discounted at query time



Tool support (ROS)

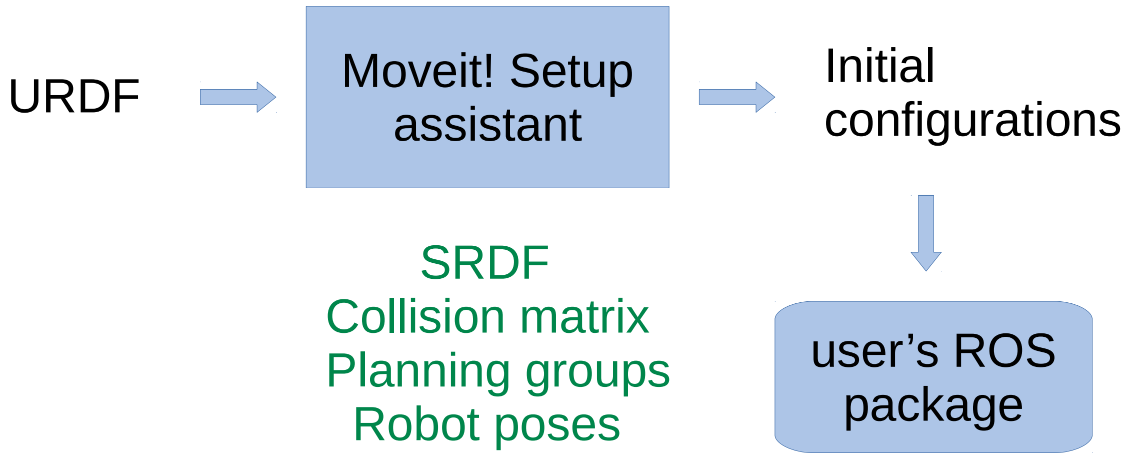
- **ROS** provides a framework to develop / test robot software
- **Package management** system
  - Various useful packages, hw drivers, perception, navigation, transforms and simulations … rapid prototyping
- Supports several languages
  - C/C++, Python, Java
- **Inter-process** communication

- **Package** contains nodes, configurations etc
- **Master** registers topics and services
- **Node** is an executable unit of code that implements a specific functionality
- **Topic** is bus with a name to share messages (publish/subscribe)
- **Parameter server** central parameter location

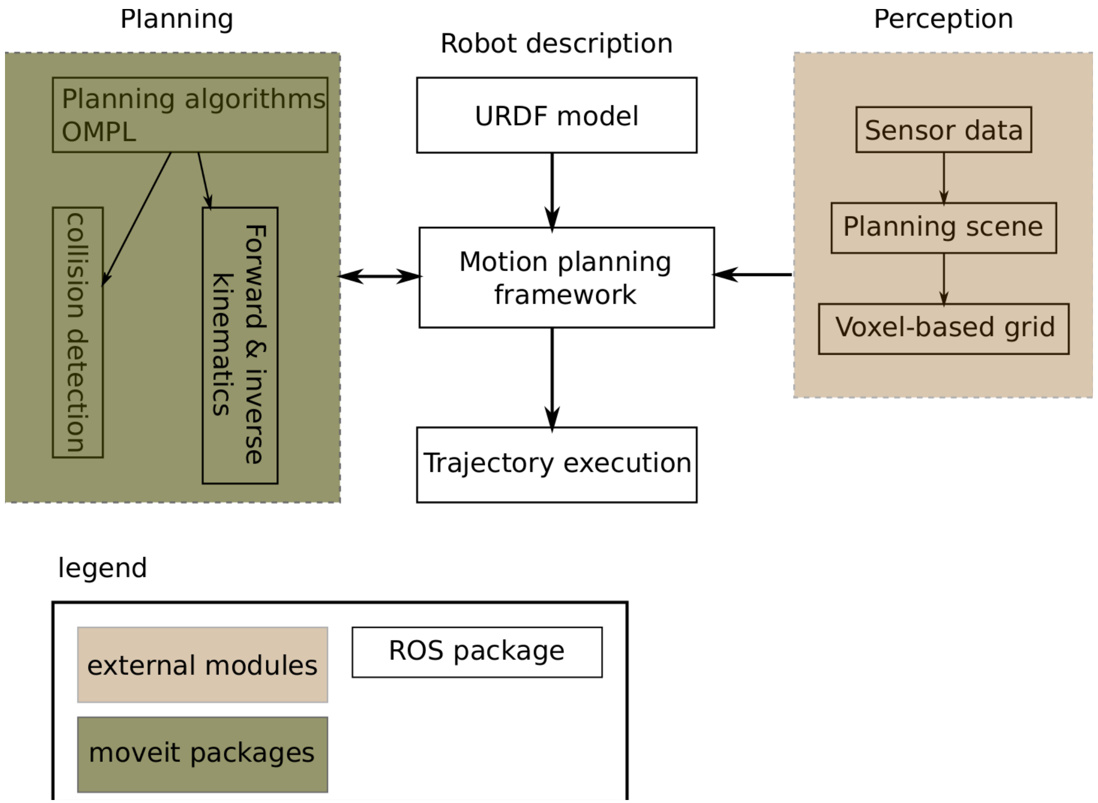


Tool support (Moveit!)

- Mobile manipulation software in ROS
  - **Motion planning** & environment integration
  - Many robots supported
    - manipulators, mobile robots, humanoids
- Moveit uses plugins
  - **Kinematics**
    - KDL, track_ik, UR5KinematicsPlugin
  - **Path planning**
    - OMPL (sampling probabilistic motion planning)
- Moveit **setup assistant**



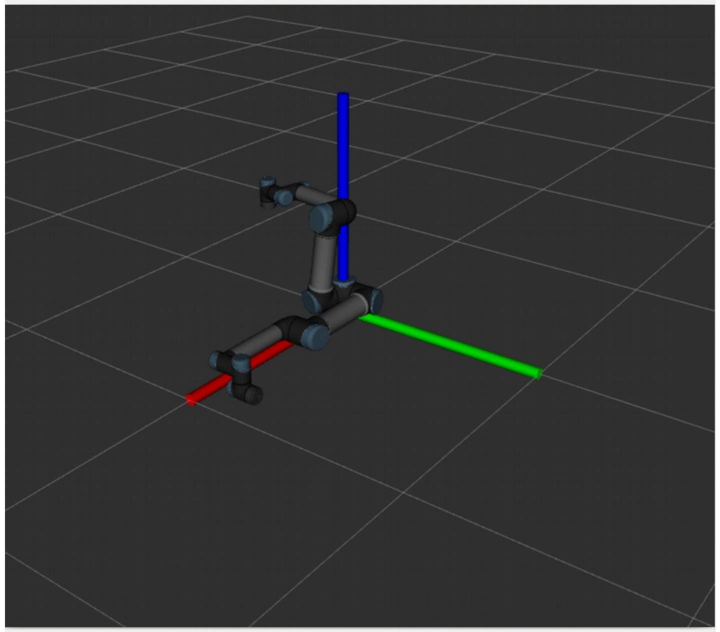
Proposed solution architecture

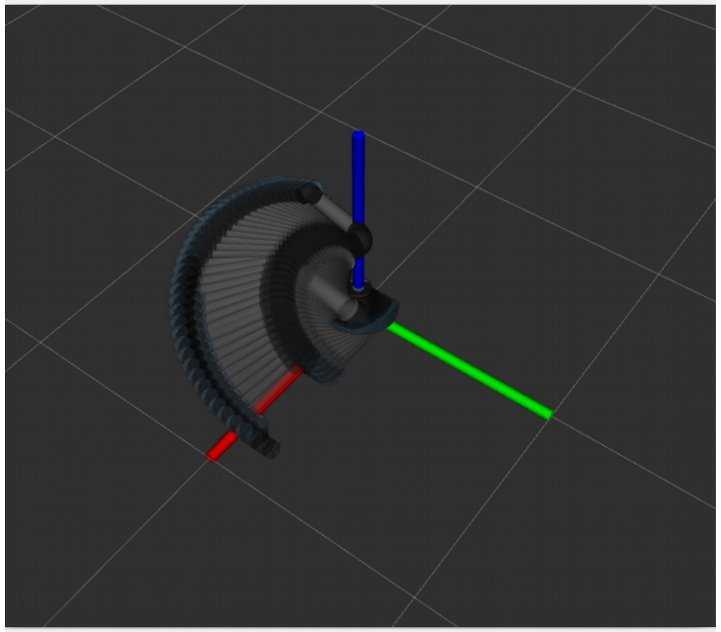


Preliminary test

- We perform a simple test with regards to chosen tools
  - We test trajectory planning of a **Universal Robot** UR5
  - We test the **path planning component** of the solution independent of the voxel grid
  - We use **PRMStar** algorithm
- We consider the following **joint-space goal** given by the configuration vector
  - {−1.83, −1.732, 1.8, −1.634, −1.57, 2.88} ~ {-105, -99, 103, -93, -90, 165}
- Motion is tested in the absence of collision object(s)

Preliminary test





Conclusions & future work

- We proposed to combine a **voxel-based grid** with a **roadmap-based** approach, for its simplicity and efficiency.
- Tools such as **ROS** and **MoveIt** with available functional packages improve software development time for robots.
- We presented a simulation architecture based on these tools.
  - We successfully tested planning to simple **pose** and **joint-space goals** in simulation environment
  - **Independently** of the voxel grid component

- To efficiently handle **dynamic** scenarios,
  - We can input fresh voxel grids to the planning program, with a certain frequency.
  - The **refresh rate** of the voxel grid depends on the response time of previous planning query.
  - Currently, we are looking into solutions to address these issues.