ROS-based Integration of Task and Motion Planning for Adaptive Social Navigation

Phani Teja Singamaneni[1], Alessandro Umbrico[2], Andrea Orlandini[2] and Rachid Alami[1,3]
[1] LAAS-CNRS
Toulouse, France

[2] CNR – Institute of Cognitive Sciences and Technologies (ISTC-CNR)
Rome, Italy

[3]ANITI, Université de Toulouse
Toulouse, France

Abstract

Robots acting in real-world environments usually interact with humans. Interactions may occur at different levels of abstraction (e.g., process, task, physical), entailing different research challenges (e.g., task allocation, human-robot joint actions, robot navigation). When acting in social situations, robots should recognize the context and behave in different manners, so as to act and interact in a correct and acceptable way. We propose the integration of task and motion planning to contextualize robot behaviors for social navigation. The main idea is to leverage the contextual knowledge of a task planner to dynamically adapt the navigation behaviors of a robot to different social. The proposed control approach is implemented in ROS and tested in a simulated assistive scenario.

Introduction

Robots acting in situations requiring direct or indirect interactions with humans should realize behaviors that take into account a social dimension. In Human-Robot Interaction (HRI), it is necessary to reason about *how* tasks are carried out by a robot in order to do the *right action* in the *right way* and comply with the so-called *social norms* (Triebel et al. 2016; Bruno et al. 2019; Awaad, Kraetzschmar, and Hertzberg 2015). Implementing intelligent behaviors requires investigating the integration of Robotics and Artificial Intelligence (AI) (Lemaignan et al. 2017; Ingrand and Ghallab 2017). To this aim, it is paramount to endow the robot with *contextual knowledge* about humans, social environments, and (social) tasks to be performed.

In this work, we integrate Task And Motion Planning (TAMP) to enhance the awareness of the social navigation skills of robots. This approach relies on a motion planning framework, called CoHAN (Singamaneni, Favier, and Alami 2021; 2022), which allows the tuning of human-aware navigation behaviors. It exposes a number of motion parameters that are used by a task planner, called PLATINUm (Umbrico et al. 2017), to dynamically adapt motion behaviors to the expected social context. We present a ROS-based System implementing goal-oriented control through the combination of task and motion planning nodes.

Human-Aware Task and Motion Planning

The proposed TAMP approach supports reasoning on different perspectives: (i) the *domain perspective* characterizing technical requirements of a task; (ii) the *human perspective* characterizing the interacting skills of involved humans; (iii) the *robot perspective* characterizing acting skills of the robot; (iv) the *environment perspective* characterizing the physical space where tasks are executed. Fig. 1 shows the TAMP architecture.

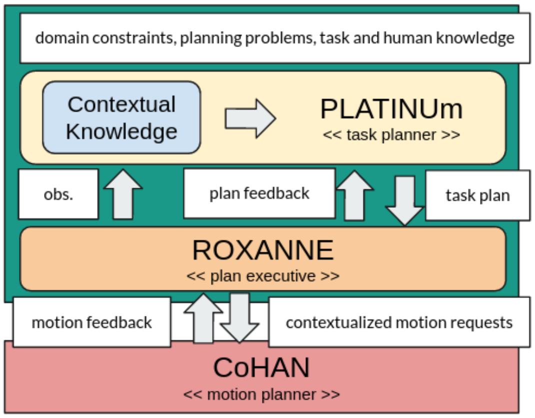

Figure 1: Integrated Task and Motion planning architecture.

At the task planning level, the physical and interacting features of humans are considered in order to estimate his/her reliability when directly/indirectly interacting with a robot. We define three categories of humans (i.e., fragile, average, and reliable) that implicitly measure the *uncertainty* of the interactions (i.e., respectively high, medium, low). Intuitively, the greater the uncertainty the greater the caution of robot behaviors. We define also three categories of tasks (i.e., technical, interaction, and social) in order to estimate the necessary trade-off between the social and technical requirements of each task. This contextual knowledge is then used at the motion planning level to dynamically configure the generation of robot trajectories. The different categories of humans and tasks are indeed mapped to patterns of values of the motion parameters exposed by CoHAN.

ROS-based Implementation

The approach has been implemented in ROS Melodic using: (i) PLATINUm (Umbrico et al. 2017) as a timeline-based task planning engine; (ii) ROXANNE as ROS-compliant executive for timeline-based plans, and; (iii) CoHAN (Singamaneni, Favier, and Alami 2021) as a motion planner implementing the navigation skills of the robot. ROXANNE is a ROS package supporting the development of goal-oriented plan-based controllers. It encapsulates PLATINUm as a timeline-based planning engine and provides a ROS-compliant executive. ROXANNE interacts with other ROS nodes through a set of topics exchanging custom messages.

The actual set of topics used by ROXANNE can be set through a dedicated configuration file. We configure ROXANNE with a single goal topic and a single pair of dispatching and feedback topics. The dispatching and feedback topics allow PLATINUm/ROXANNE to respectively send (contextualized) motion requests to, and receive information about their execution from CoHAN.

Simulated In-Hospital Assistance

The integrated approach is applied to a simulated hospital environment [1] considering three assistive scenarios: (i) A *drug delivery scenario* requires the robot to reach the pharmacy to pick up some drugs and deliver them to a particular patient located in a known room; (ii) A *patrolling scenario* requires the robot to move inside the different rooms of the floor to monitor the general health conditions of patients; (iii) An *emergency scenario* requires the robot to quickly reach the room hosting the patient asking for help.

These scenarios entail a variety of *social situations* e.g., approaching fragile users, navigating inside crowded corridors, or entering rooms populated by (fragile) patients. We briefly report the comparison of two configurations: (i) *cohan* showing the behavior without the use of contextual information from the task planner; (ii) *cohan+platinum* showing the behavior of the proposed TAMP approach.

Patrolling Scenario Fig. 2 compares the velocity profiles of the two configurations *cohan* (the top) and *cohan+platinum* (the bottom). They clearly show that, unlike *cohan*, the configuration *cohan+platinum* allows the robot to dynamically adapt its velocity to different social situations. The robot moves at a rather high speed when moving in the corridor (e.g., P1, P5, P9) where no significant interactions are expected. The robot instead moves at a low velocity when inside rooms and approaching patients (e.g., P2, P3, P4) where more human awareness is expected.

Emergency Scenario Unlike the previous scenario, the robot moves at a larger speed to rush to the patient in the *cohan+platinum* setting compared to the *cohan* setting. This clearly shows that the integrated approach takes lesser time to reach the patient in an emergency even with a larger overhead.

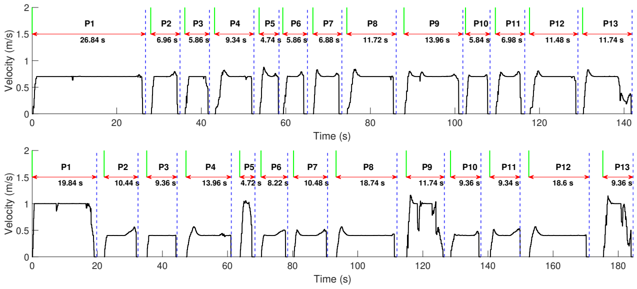

Figure 2: Velocity profiles and times for each navigation phase in the patrolling scenario. Top: *cohan*, Bottom: *cohan+platinum*.

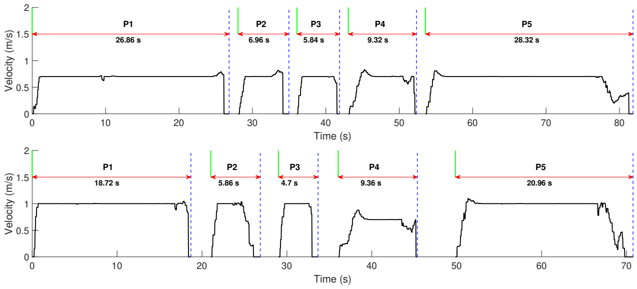

Figure 3: Velocity profiles and times for each navigation phase in the emergency scenario. Top: *cohan*, Bottom: *cohan+platinum*

Drug Delivery Scenario Fig. 4 shows the velocity profiles and the times of the two configurations in each phase of the scenario. P1, P5, and P9 are corridor navigation phases where the robot with *cohan+platinum* moves faster than *cohan*. P2, P3, and P4 phases see the robot interacting with the pharmacist to take the drugs. P6, P7, and P8 phases see instead the robot interacting with the patient to deliver the drugs. Unlike *cohan*, comparing the velocity of these phases within *cohan+platinum* it can be noticed the different behavior of the robot in the two social situations. Interestingly, the robot moves at a higher velocity when interacting with the pharmacist (reliable humans) while it moves at a lower velocity when interacting with patients (fragile humans).

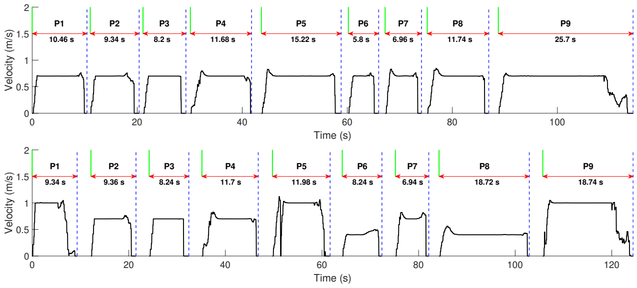

Figure 4: Velocity profiles and times for each navigation phase in the drug delivery scenario. Top: *cohan*, Bottom: *cohan+platinum*.

Link to the Video of the Demo

`https://www.dropbox.com/s/xj5cxkp6nivd6tx/icaps23_demo.mp4`

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[1] Simulator based on the stage_ros package - `http://wiki.ros.org/stage_ros`.

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