Politecnico di Torino | ScuDo
Scuola di Dottorato ~ Doctoral School
WHAT YOU ARE, TAKES YOU FAR

Doctoral Dissertation

Doctoral Program in Electrical, Electronics and Communications Engineering ($36^{th}$cycle)

# Human-centered robotics: challenges in socially-aware navigation and mission planning

**Giada Galati**

******

**Supervisor:**
Prof. Alessandro Rizzo

**Doctoral Examination Committee:**
Prof. Mattia Frasca, Università di Catania, Italy
Prof. Marina Indri, Politecnico di Torino, Italy
Prof. David Naso, Referee, Politecnico di Bari, Italy
Prof. Domenico Prattichizzo, Referee, Università di Siena
Prof. Kimon Valavanis, University of Denver, USA

Politecnico di Torino
2024

# Abstract

Over the past decade, remarkable advances in science, engineering, and technology have catalyzed the expansion of robotics. This transformative progress has given rise to a surge in the widespread integration of robots that interact directly with humans. In the scope of this dissertation, emphasis is placed on the examination of human interaction with robots. Specifically, the study delves into two distinct categories of interaction: firstly, the *bystander*, i.e. a human who assumes a non-interactive role with the robot but coexists in the same physical space, and secondly, the *supervisor*, i.e. a human who oversees robots and makes decisions related to critical situations.

Some examples of *bystander-robot* interaction are the offices, hospital and hotel. In such context, the main aim of the human is the avoidance, instead, the main aim of the robot is to guarantee not only physical safety but also consider the psychological safety associated with coexisting in an environment with humans. To achieve an optimal integration of both types of safety, it is necessary that robot moves intending to minimize any disturbance to pedestrians, thus seeking to ensure its social acceptability. This goal is achieved through the concept of socially-aware navigation. Thus, in this thesis *two* socially-aware navigation algorithms are developed: the first is based on game-theory (GT), and the second is based on the social force model and the game theory (GTSFM). Each algorithm underwent rigorous evaluation, using state-of-the-art *quantitative* metrics and collecting *qualitative* information through participant-administered questionnaires.

Compared to the current state-of-the-art method, the GT algorithm achieved better performance according to both types of evaluation.

Regarding the *quantitative* evaluation, GTSFM exhibited a smoother path compared to the two state-of-the-art algorithms, resulting in a more natural motion. The *qualitative* analysis, performed with a real-world experiment, did not identify any algorithm that showed significant superiority over the others. This lack of distinction

can be attributed to unaccounted factors. The robot's appearance could have obscured the distinction between the algorithms. Additionally, the limited velocity of the real robot may have limited the range of conditions tested among the different algorithms and, consequently, obscured the distinction between them.

These results represent a significant milestone in advancing the integration of robots into social environments also leaving important hints for future research development.

On the other hand, some instances of *supervisor-robots* interaction are evident in scenarios characterized by complex and critical tasks such as rescue operations. In such context, a multi-robot autonomous system is involved to handle the mission. Instead, the human is responsible for crucial decision-making, particularly assessing the mission's overall success, ensuring the safety of human lives, and managing unforeseen situations. Within this context, coordinating a multi-robot system with human supervision is crucial. Thus, in this dissertation, a task allocation in a dynamic environment is proposed obtaining promising results.