The Coordination of Multiple Agents with Social Law

By Michael Wu (USA), Fiona Schlakman (USA) and Laura Eljarrat (ISR)

Mentored by PhD Student Ronen Nizri and Dr. Erez Karpas

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ABSTRACT

Designing a multiple robots system is difficult. One of the main challenges is maintaining coordination between the robots. One coordination method is to apply some restrictions on the robots' actions. The union of these restrictions is called Social Law. Our work aims to provide physical evidence that Social Laws are a safe and efficient coordination method. For that, we created a model with several robots, each robot is free to act in order to achieve its own goal. In order to avoid any conflicts we enacted a Social Law. We were able to supply substantial evidence that Social Laws are an efficient method for robot-to-robot interaction.

INTRODUCTION

Artificial Intelligence and Robotic System Architecture

Most modern robots are now able to reason and tend to use the three-step paradigm: Sense, think and act [1] (fig. 1).

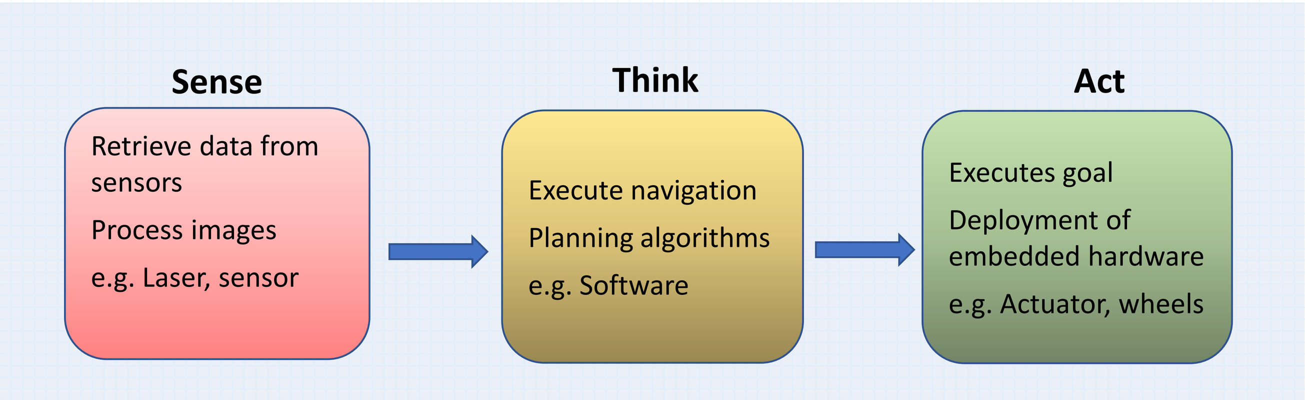

Figure 1: Autonomous systems simplified

Multiple Agent Systems

Multiple agent systems are any loosely coupled network of intelligent agents and are commonly used for transportation and industry. However, one of the main challenges when designing large environments of autonomous agents is **coordination** with each member.

Coordination Methods

Three most common ways robots coordinate are through:

- **A centralized system** for all agents
  - Issue: scales poorly within larger groups
- **Acting and planning independently** with established negotiation methods
  - Issue: Hard to design
- **Social Laws**: **Apply some restrictions** on the agents' actions

Social Laws

Social Laws is a method where some restrictions are applied on the robots' actions in order to maintain coordination between them. A system that is obliged to follow this law is called an "artificial social system" [2]. A social law is called robust [3] if it guarantees that each agent can choose any plan it wants to achieve its goal, and the plans of different agents will not interfere with each other.

Objective and Requirements

The objective of our project is to provide physical evidence that social laws are an efficient and safe method for coordinating multiple robots. This problem has two parts:

- Defining a planning instance with a robust social law
- Establishing a logically correct problem within a domain for a robot to solve independently successfully

To complete these sections, we used **ROS** (Robot Operating System) and **PDDL 2.1** (Project Domain Definition Language) in order to design this system (fig. 2).

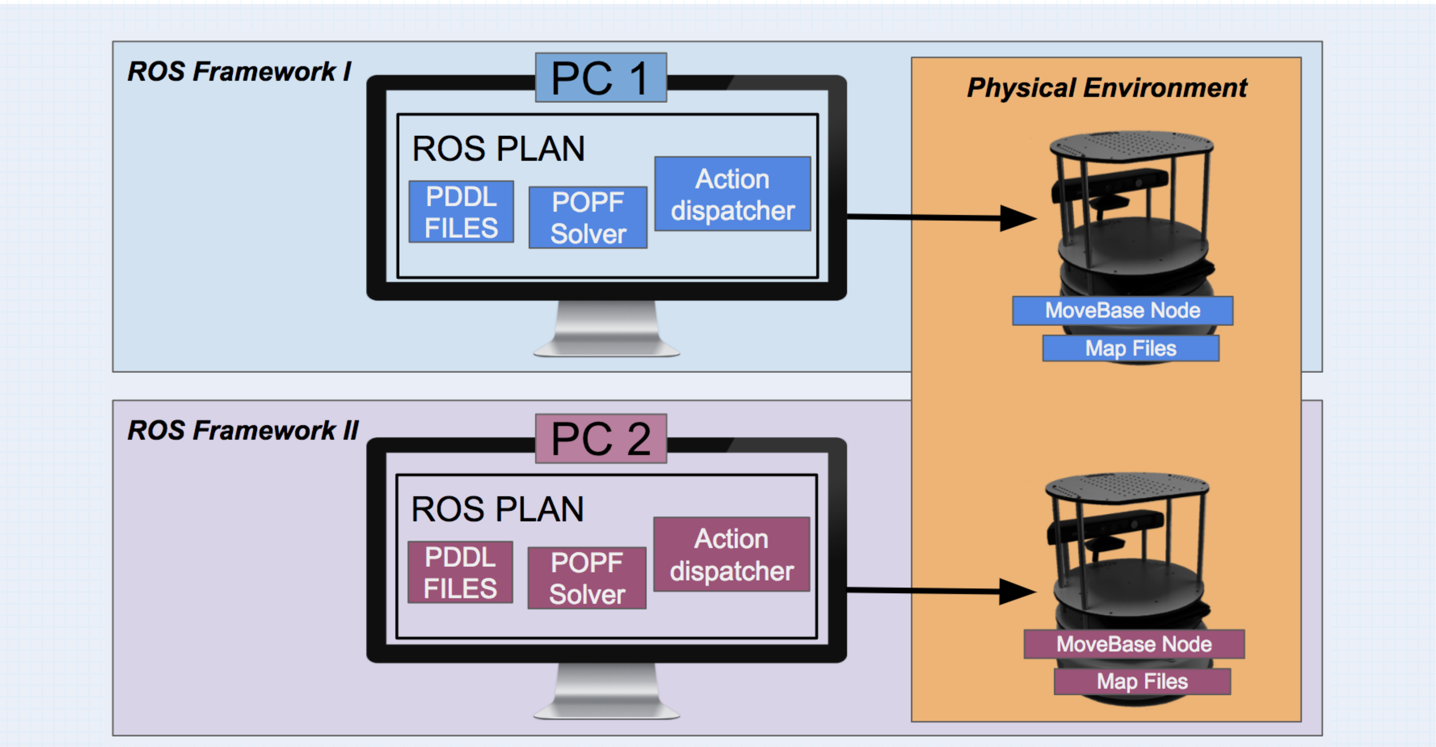

Figure 2: System setup

SETUP AND DOCUMENTION

Our physical domain was divided into 12 squares, each classified as either **dirty** or **clean**.

The Turtlebots are able to move and clean. The goal of each robot is to clean all of their assigned squares and return to its docking station.

Our setup can be divided to the following main components:

2 Turtlebots: The TurtleBot is a low-cost, personal robot kit with open-source software. (see fig. 3)

ROS Kinetic: The Robot Operating System (ROS) is a flexible framework for writing the robots' software.

ROSPlan: The ROSPlan Framework provides a generic method for task planning in a ROS system. Domain and problem files are written in the standard planning language PDDL 2.1. ROSPlan uses a temporal planner, POPF, to automate planning in ROS.

Turtlebot navigation package: A 2D navigation stack that takes in information from odometry, sensor streams, and a goal pose and outputs safe velocity commands that are sent to the Turtlebot mobile base.

World prepared map: We created a map by using a Turtlebot that scanned the environment (fig. 4).

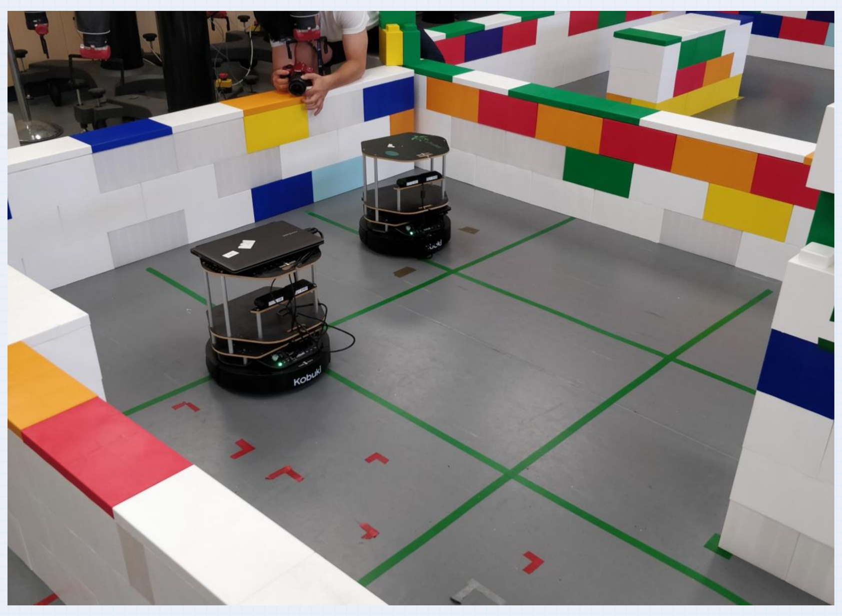

Figure 3: TurtleBots acting in the domain

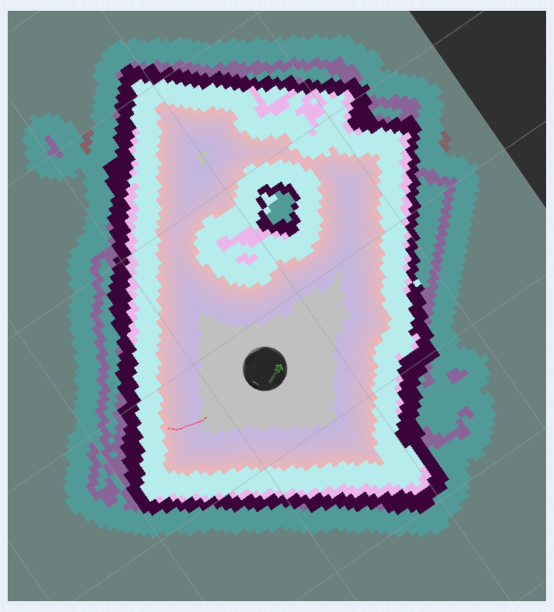

Figure 4: Visualization of the domain through the robot's eyes

RESULTS

We have created a multiple robot system with a Social Law that ensures each robot would be able to complete its goal without any interference. After several tests we concluded that **Social Law is a safe and effective way to maintain coordination in our system**. Furthermore, this coordination method doesn't require communication between the robots. This is a major advantage in larger systems, communication might be expensive or impossible. Also, this coordination method most likely has a better computational complexity then any of the other methods.

CONCLUSION AND FUTURE WORK

Social Laws are a safe and effective method to coordinate a multi agent system. This method doesn't require cross robot communication and has a better computational complexity.

In the future, we hope to expand our project and create new models where there are different social laws. We believe this would help us get a better understanding of this method. Finally, we would like to add in more Turtlebots into our system and see how the model is done on a larger scale.

REFERENCES

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2. Tennenholtz, 1991; Shoham and Tennenholtz, 1992a; 1992b; 1995; Moses and Tennenholtz, 1995.
3. Automated Verification of Social Law Robustness in STRIPS. ICAPS 2017: 163-171].

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