UNIVERSIDAD POLITÉCNICA DE MADRID

Thesis Title

by

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UNIVERSIDAD POLITÉCNICA DE MADRID

Abstract

Escuela Técnica Superior de Ingenieros Informáticos
Departamento de Inteligencia Artificial

Master Degree in Artificial Intelligence

by Guillermo Echegoyen Blanco

The Thesis Abstract is written here (and usually kept to just this page). The page is kept centered vertically so can expand into the blank space above the title too...

Acknowledgements

The acknowledgements and the people to thank go here, don't forget to include your project advisor...

Contents

List of Figures

List of Tables

For/Dedicated to/To my…

Chapter 1

Introduction

[ToDo := Refs & Links]

In the following work an integration of a navigation system onto the Aerostack platform is presented.

1.1 Context

Aerostack is a framework for aerial robots, aimed at giving flight autonomy to some extent. It features a modular approach for the construction of behaviors that can be used to develop complex flights and automatic handling for certain situations such battery level or hardware conditions. It is the frame for the following work, which adds more autonomy through the integration of a octomap-based navigation system and a global planner. This provides a novel localization technique for the framework.

1.2 Motivation

So far, there exists only one simple geometry planner and an Aruco-based localization technique. In indoor environments, this system compels the need for environment preparation, the Arucos must be placed beforehand in well known localizations that must be hardcoded in the robot map. In this sense, there exists a need for a more robust, preparation-free localization system and accompanying planner. This work provides such an improvement with the introduction of a octomap-based navigation system and a global planner.

1.3 General Objective

This work aims at adding a novel navigation system to the Aerostack framework.

1.4 Specific Objectives

This section enumerates a comprehensive list of objectives.

1. Enrich the current navigation and localization systems.
2. Test and validate the new navigation and localization systems through simulated environments.

To achieve the first objective, the following additions to the framework are proposed:

- Add a robust planner based on a new navigation technique.
- Add a robust navigation technique through the use of octomaps.
- Add a robust localization technique based on octomaps.
- Add octomaps construction support through lidar.

1.5 Overview

[**ToDo := Review when everything is finished**]

This dissertation is organized as follows: ...

Chapter 2

Problem Description

In the present chapter the problem is presented, along with an introduction to the previous work. It is structured as follows: Section 2.1 introduces the Aerostack framework, Section 2.2 presents the context of the problem and the requirements a replacement should have. Section 2.3 describes deeply the improvements presented and the decisions taken to end in Section 2.4 with the description of the previous system.

2.1 The Aerostack Framework

Aerostack is an agnostic framework to build and design control architectures for aerial robotic systems. It provides some low level components as well as coordination processes and some planners. Figure 2.1 shows the general architecture of the framework.

2.2 Requirements

As of the second version of Aerostack, the only localization technique available is based on the recognition of a special type of marker called Aruco, first used for augmented reality applications. It is a fast and reliable technique to estimate the pose of the camera capturing the image. Altough this system works fine for many applications, it imposes the need of preparing the environment, placing this markers in a very precise way and annotating it's exact position before the experiments. While this might not be a problem in an augmented reality like scenario, when it comes to live localization in unknown environment it becomes useless. Hence, a new system for localization is required.

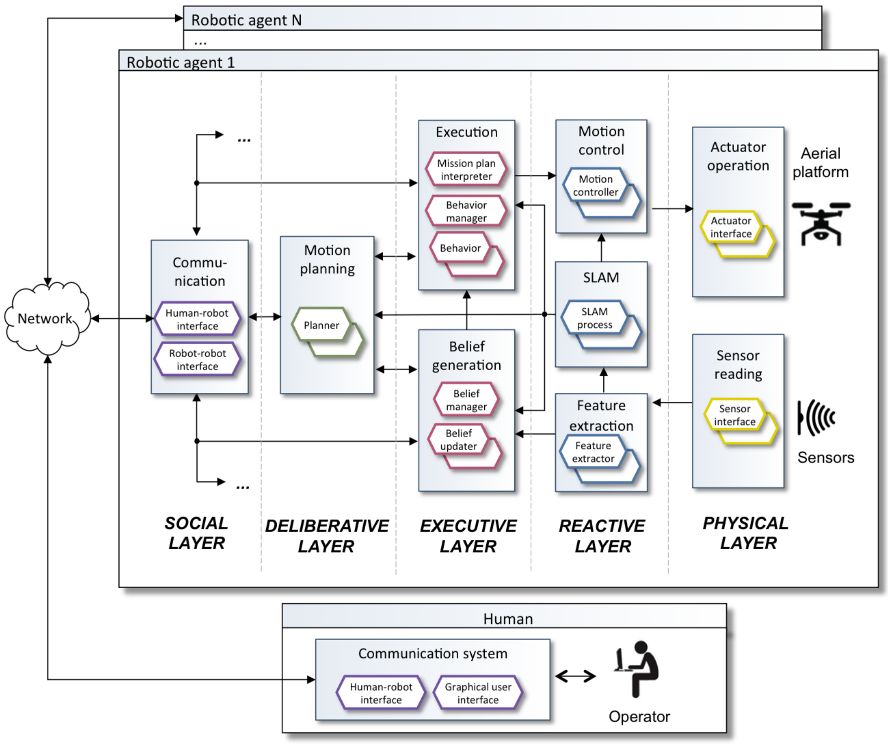

FIGURE 2.1: The Aerostack architecture

Along with the aforementioned localization technique comes the navigator which coordinates with a 2D geometric planner to accomplish the mission at hand. As the localization technique is to be changed, leading to a new way to perceive the environment, a new navigator and planner will be necessary.

2.3 Details of the New Features

A lidar is going to be used as the main source for localization. The module in charge of this part is already present in the Aerostack framework, but it is not being used. Based on lidar input an octomap is built. This octomap is then used by the navigator, along with the planner instructions to build a motion plan to execute.

The lidar + octomap functionality is provided by a module called hector_slam, developed at the Darmstadt University [1]. Taking the lidar's cloud of points it is able to reconstruct an octomap and then localize inside it (SLAM). The output of this module can be used to create a plan avoiding obstacles to reach a target point.

[ToDo := Review, NavStack & Global Planner]

2.4 Previous Work

By now, there is a process responsible for doing recognition of Aruco markers, it is connected to the robot camera and fetches data every n milliseconds, where n is a user defined constant. When an aruco is recognized, the pose of the robot can be estimated. Knowing the exact position of the marker enables the process to estimate the absolute position of the robot, leading to a high precision coordinates localization. While this approach has many advantages, it fails when the environment is not prepared beforehand.

To create a plan, a target position and the used Aruco markers are specified, then the motion planner creates a 2D plan to follow, using the Arucos to localize in the process.

Chapter 3

Review of the Methods

The following chapter reviews the techniques used

3.1 Raw Summary

3.1.1 Sensor Technologies

Technologies based on range sensing are primarily divided into two groups, the ones that use *Triangulation* techniques and the ones using *Time of Flight*.

In this section a survey of the current technical methods is presented. First, the technologies using triangulation are presented (subsection 3.1.1.1), as well as the problems that arise from this technique. Subsection 3.1.1.2 proceeds with time of flight based techniques to finish with a comparison in subsubsection 3.1.1.3.

3.1.1.1 Triangulation

Technologies based on triangulation usually involves various sensors which emmit a ray and measure it's reflection. To estimate the depth between the measuring device and a certain point of the world the following procedure can be used: Using the angle formed between two consecutive sensors to a certain point of the world and knowing the base distance b between those sensors gives a triangle, for the shake of simplicity let us assume that one of the rays form a right angle with the base of the sensors. Then, the angle θ of the other ray is related to the depth Z perpendicular to the base of the sensors by

$$\tan\theta = \frac{Z}{b} \tag{3.1}$$

3.1.1.2 Time of Flight

3.1.1.3 Comparison

Chapter 4

State of the Art

This chapter will review the classic methods used for localization and mapping, which is the core for any navigation technique, it starts describing the problems that arise both in localization and mapping. Continue with some of the most prolific solutions found to these problems to finish exposing the techniques and algorithms used by the Aerostack framework.

Localization is referred to all the techniques used to find the position in coordinates of an agent or object inside the world, relative to a reference frame. As far as it's absolute coordinates are known, anything can be used as reference frame, it is used as the coordinates system's centre. In an outdoors environment, the Earth could be the reference frame and the robot's coordinates can be acquired with a GPS, giving an absolute point inside the three dimensional space. It is desirable for these coordinates to be in a way that a computer can handle efficiently, tipically as two or three floating point numbers (although integer numbers are used sometimes too), depending on the number of dimensions used to represent the space. To save computational effort, the y axis could be unused in a wheeled robot.

Moving a robot avoiding possible obstacles through the space is tricky in itself, obstacles must be detected and handled correctly, moving objects can appear in the way, and so on. This alone does not provide any intelligence nor it helps planning, to aid in planning and moving smartly in the space, a map can be constructed while the localization is happening. The term mapping covers all the algorithms used to construct a map combining the data acquired from the many input sources a robot can have. Mapping opens the door for smart planning, along with many more advantages. A classic example is finding cycles in planned paths.

4.1 Localization

Localization techniques are divided into two groups: Outdoor and indoor techniques. The distinction comes from the fact that GPS signal cannot go through walls. This fact has led to a whole new set of technologies and techniques that are able to localize in environments without an absolute reference to the world.

This section is organized as follows:

4.1.1 Outdoor localization

Appendix A

Bibliography

[1] S. Kohlbrecher et al. “A Flexible and Scalable SLAM System with Full 3D Motion Estimation”. In: *Proc. IEEE International Symposium on Safety, Security and Rescue Robotics (SSRR)*. IEEE. Nov. 2011.