Master's thesis description
2016-2017

Sub-GHz Propagation Measurements using Drones
Michiel Aernouts

Supervisors: Ben Bellekens, Maarten Weyn
01/01/2017

Universiteit Antwerpen

Abstract

In order to improve localisation of wireless devices, wireless networks have to be optimised. This is attained by creating a wave propagation model of the environment. In order to create such a model, mapping approaches that use an octree data structure appear to be most suitable. Several SLAM algorithms that implement this structure are applicable. Also, the three-dimensional model has to be as complete as possible in order to be representative for the environment. Therefore, executing an efficient exploration algorithm and completing the occupancy grid map is of the essence. Since a propagation model requires measurements at specific locations, accurate drone navigation has to be carried out as well.

This thesis will focus on the complete three-dimensional mapping of an indoor environment in order to create a map that can be used as input for a wave propagation model. With an ErleCopter and an RGB-D camera, we will experiment with several SLAM algorithms and exploration approaches in order to achieve a realistic model.

Contents

1 Master's thesis description

1.1 Problem Description

Over the past few years, few research topics have generated as much interest as the Internet of Things. IoT is the idea of connecting all kinds of ordinary objects, such as refrigerators, thermostats, cars or even clothing, to the internet.

Although IoT opens up a wide range of possibilities, numerous challenges arise when implementing this idea [1]. Because of the increasing popularity of location-based services in IoT, localisation of wireless devices based on received signal strength has become a significant research topic [2]. The received signal strength is an indication for the magnitude of the electric field at the receivers' location. A wave propagation model can predict the attenuation of signal strength as it propagates through space. Such a model can then be used to diagnose and optimise network configurations [3], thus improving localisation accuracy and precision. In order to create a propagation model, three dependencies have to be taken into account: hardware configuration, location and environment. The receiver has to gather information about its location in the current environment.

Many different types of propagation models have been defined [4]. Previous research focussed on the validation of an indoor ray launching propagation model for sub-GHz frequencies [5, 6, 7, 8]. It is important to gather precise information about the environment in order to implement this type of model. In [5], the researchers used a sub-GHz measurement device that was programmed with an LPWAN protocol, such as DASH7, SigFox, LoRa, ZigBee, IEEE 802.11ah, etc. A robot was used to gather radio measurements, laser range measurements, and the odometry of a traveled trajectory. The robot drove around in a room that is equipped with multiple radio transmitters, which periodically transmit data. The collected measurements were inserted in a SLAM algorithm in order to model a map of the environment and the trajectory of the robot. SLAM made an estimation of the trajectory while creating an occupancy grid map. AMCL (Adaptive Monte Carlo Localisation) provided a solution for the global localisation problem by calculating the location probability using particle filters [9]. Consequently, a fluent trajectory was calculated. The resulting map and trajectory were then stored into a quadtree data structure.

However, in order to extend the validation to a three-dimensional space, a drone has to be utilised. When using a drone instead of a robot, some important differences have to be taken into account. In contrast to a driving robot, navigating a drone to a precise and accurate location has proved to be challenging. Due to the drift of a drone's inertial sensors, it is difficult to accurately determine its exact position [10].

Furthermore, the data structure for a three-dimensional map has to support a complete volumetric representation of the environment in order to generate a correct propagation model. Hence, a variety of 3D data structures has been developed, all of which have their pros and cons. For the grid map to be complete, exploration algorithms have to be researched in order to be assured that the complete environment will be mapped. After that, it has to be researched how the distorted 3D data can be completed, so that a realistic representation of the environment is achieved.

1.2 Research question / Thesis statement

What SLAM algorithms can be applied with an autonomously navigating quadcopter that collects an ideal amount of RF measurements and models the complete environment in an octomap, so that it can be used to evaluate an accurate and precise 3D wave propagation model which can be stored in an octree data structure?

1.3 Approach / Methods

In order to answer the research question, multiple suitable 3D SLAM algorithms will have to be researched. These algorithms can simultaneously map the environment while calculating the position of the quadcopter. Preferably, the algorithms natively support mapping to an octree data structure. That is why we will focus on RGB-D SLAM [11], 6DSLAM [12] and OctoSLAM [13].

These algorithms will result in an occupancy grid map, which has to be as complete as possible. The first step in order to achieve this is efficient exploration of the environment. We will research how and where the drone has to fly in order to attain an optimal map. Firstly, we will try to combine the Nearest Neighbour Next Best View (NN_NBV) algorithm presented by Quin et al [14]. Secondly, we will experiment with different trajectories that we define ourselves.

Another important aspect of our research is the completion of the occupancy grid map. The map has to be a complete volumetric representation of the environment where the measurements were collected. We will take the grid maps that resulted from the SLAM algorithms, and try to complete them using a method that was proposed by Turner et al [15].

For accurate navigation of the drone, we will research the PID controller from DroneSense that is proposed by Yu et al [16].

We will utilise an ErleCopter, a quadcopter that natively operates with ROS (Robotic Operating System). It is possible to connect peripherals, such as a camera or a measurement device, directly to the ErleCopter via its USB-interface, which is a main advantage over other quadcopters. We will attach an RGB-D camera to the quadcopter in order to collect data for the SLAM algorithm. A 3D printer will be used to shape a stable mount for the camera and protection against potential collisions.

1.4 Preliminary results and discussion

As only a literary study has been carried out for now, no results are available yet. We conducted research on different SLAM algorithms, and explored multiple ROS tutorials for robotic mapping.

2 Work plan including time table

In order to create a visual representation of the work plan, a One Page Project Manager sheet (OPPM) is added in appendix A.

3 Implications of research

This research will contribute to extending the validation of a two-dimensional propagation model to a three-dimensional model, by using a quadcopter. With this improved propagation model, communication systems can be optimised. This makes it possible to locate a wireless device more accurately and precisely.

4 Contacts

4.1 Internal supervisors

Ben Bellekens
Tel. +3232651682
ben.bellekens@uantwerpen.be

Maarten Weyn
Tel. +3232651865
maarten.weyn@uantwerpen.be

4.2 Student

Michiel Aernouts
Tel. +32472416322
michiel.aernouts@student.uantwerpen.be

References

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A Appendix

Project Manager: **Michiel Aernouts** **Project Name:** Sub-GHz Propagation Measurements using Drones Report Date: 1/01/2017

Project Objective: Create a complete 3D map of an indoor environment.

Hardware configuration	Autonomous exploration and navigation	Mapping the environment	3D completion	#	Major Tasks	November	December	January	February	March	April	May	June					Michiel Aernouts	Ben Bellekens	Maarten Weyn	
	O	O		1	Study of existing algorithms	O	O	O	O									A			
	O	O		2	Carry out ROS tutorials for robotic mapping		O	O	O									A			
O				3	Assembly of the ErleCopter				O									A	B	C	
O				4	Connect peripherals with the ErleCopter				O									A	B	C	
O				5	Modelling and printing protection for the ErleCopter				O									A	B	C	
	O			6	Testing NN_NBV exploration				O	O								A	B	C	
	O			7	Defining/Testing other exploration algorithms				O	O								A	B	C	
	O	O		8	Mapping with RGBD SLAM					O	O							A	B	C	
	O	O		9	Mapping with OctoSLAM					O	O							A	B	C	
	O	O		10	Mapping with 6D SLAM					O	O							A	B	C	
			O	11	3D data completion of the resulting maps					O	O	O	O					A	B	C	
	O	O	O	12	Comparison of the results						O	O	O					A	B	C	
				13																	
				14																	
				15																	
				16																	
				17																	
				18																	
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				21																	
				22																	
					Risks, Qualitatives, Other Metrics	Green=Adequate, Yellow=Worrisome, Red=Dangerous															
O				1	Hardware assembly													A	B	C	
	O			2	Exploration of the environment													A	B	C	
	O			3	Autonomous navigation													A	B	C	
		O	O	4	Complete mapping of the environment													A	B	C	
				5																	
					# Internal People assigned to the project:																

Major Tasks and Risks **Report Dates** **Sub-Objectives** **Costs and Metrics** **Summary & Forecast**

Metric 1	0
Metric 2	0
Metric 3	0

Expended Budgeted

OPPM_Michiel_Aernouts.xlsx Template 31/12/2016 16:23