AALBORG UNIVERSITY
STUDENT REPORT

ED1 - P2 - H103

Unknown terrain mapping and navigation

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March 2, 2015

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STUDENT REPORT

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Title:
Unknown terrain mapping and navigation

Theme:
Scientific Theme

Project Period:
Spring Semester 2015

Project Group:
H103

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Copies: 1

Page Numbers: 15

Date of Completion:
March 2, 2015

Abstract:

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Preface

From hereby on, every mention of 'we' refers to the five co-authors listed below.

Aalborg University, March 2, 2015

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Chapter 1

Introduction

1.1 Initiating Problem

How to map unknown terrains in the absence of external technology, like GPS?

Chapter 2

Problem Analysis

Since the beginning of time, early human settlements were eager to explore their environment and surroundings. It did not take long, until the first humans started getting even further and become explorers. They started leaving marks and using landmarks to remember pathways and places. This primitive representation of prehistoric places and early history maps can be traced back to 24000-25000 BC [?]. Soon after, they started using maps which revolutionized the way we navigate and the way we travel, and therefore the field of Cartography become a reality. During the 19th century terra incognita disappeared from maps, since both the coastlines and the inner parts of the continents had been fully explored. Today, using technology and satellites, Earth is completely mapped, yet still not completely explored. Around 95 percent of our oceans are still remain unexplored, considering that they take up 70 percent of the planet's surface [?]. This is mostly due to extreme conditions and high depths, that humans can not be put up against. As technology advanced and matured, remotely operated underwater vehicles (ROVs) become a popular way of exploring the depths of our oceans, due to their accessibility to places where humans could not possible go before for a long period of time. In the meantime, interplanetary exploration took off during the mid-20th century with the start of the Cold War between the United States of America and the Soviet Union. This led to many great achievements, like the first successful interplanetary encounter, where the US Mariner 2 fly-by Venus [?] or when the Soviet Venera 3 made first impact on the surface of Venus [?]. The last successful program to date was the Mars rover CURIOSITY, which landed and still making progress in exploring and sending back scientific measures of the planet Mars. Exploring planets for future-settlements and first-contact is very important in order to quench out human curiosity but also for advancing the different fields in science and technology.

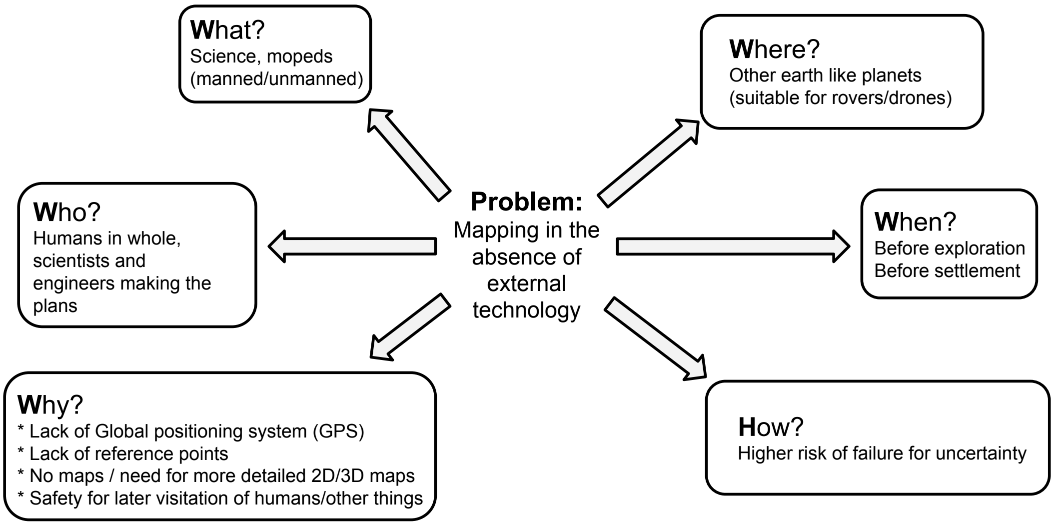

Figure 2.1: W-diagram

Mapping unknown terrains becomes a problem **when** new planets are discovered and mapping of the surface and it's atmosphere is required for further exploration and investigation. Scientists use the so-called Earth Similarity Index (ESI) for mapping extrasolar planets (also called exoplanets) for potentially habitable places in the Universe. [**?**] [**?**]. The ESI implies many factors, like surface temperature and other Earth-like properties.

Another scenario is underwater exploration, where trained divers are unable to explore and map the underwater terrain due to its depth and dangerous circumstances. In these cases robots and submarines, that can either autonomously or remote-controlled can take up the task of mapping the bottom of the ocean. It is also much faster and more reliable than sending down people to do the same task.

Besides exploration, the task of mapping unknown terrains is used in hostage situation and natural disasters as well, where people cannot enter a specific area without that being mapped upfront for various factors, like radiation leakage or armed terrorists. One example would be the Fukushima Nuclear Plant catastrophe in Fukushima, Japan on March, 2011. After the leakage in the reactor, rescue forces and scientist used autonomous drones to map the inside of the factory [**?**], which was put under quarantine for high levels or radiation and therefore no person was allowed inside of the building without proper precautions. Drones and autonomous robots are perfect for scenarios like this.

Unknown terrain can be defined as a terrain **where** no mapping has been done before.

The bottom of the ocean is mostly sand, mud, and water [citation needed.]. This make it difficult to navigate with a rover, but relatively simple to navigate with a submarine. In water, sensors that use sound need to be calibrated to work with the correct pressure of the water surrounding it, which varies with the depth of the water. If the water is murky, light based sensors may also not work, depending on the wavelength of the light they use. Light also refracts in water depending on the water density. It is possible to remote control vehicles in the bottom of the ocean.

Other planets can be much more complicated to navigate. The consistency of they atmosphere and terrain, may be not completely understood. This means that there is a higher chance of a rover being stuck on loose terrain, falling down sheer faces, and so on. It may also be the case that the planet has no atmosphere, so a drone would not be able to hover. One of the biggest issues with extraplanetary exploration is input lag. Other planets are very far away, this means that signals traveling to them can take several minutes at least and years at most to reach from the Earth. Therefore automation is better suited for this task. Other planets share the issues the bottom of the ocean has with sensors.

Disaster scenarios can also be said to be unknown terrain. Disaster scenarios means that the terrain might be loose or difficult to navigate, so a drone might be best suited for it. In most cases disaster scenarios happen in locations where the vehicle can be controlled manually

To answer the question **how** does this problem occur, we have to look into some possible scenarious discussed above. Exploration of unknown terrain and environments has been practised for many years. It originates from the human curiosity and the spirit to explore and gather information about the surroundings.

When dealing with unknown environments, unknown does not strictly refer to the environment itself but the persons state of knowledge about the physics and composition of the given environment. In a known environment, outcomes from every action can more or less be calculated or estimated. Where as in an unknown environment, it is a matter of investigation and figuring out what works and what does not. In the unknown environment it is important to gain knowledge of how everything work, so that in the future it possible for an individual make the best possible choice and decisions in the environment. [**?**] Even though most of the land has been explored and is being used for its vast amount of resources, the time will come where planetary and ocean exploration becomes a key factor for our technological advancements and our resources. Ocean exploration is important because it provides data from deep-sea areas, which in turn will reduce the amount of unknown environments left on our planet. Gathering data and intelligence from the ocean also helps with managing the resources that are available in the deep-sea areas, so that future generations can benefit from them. The ocean also provides information about future environmental conditions and can help predict earthquakes and tsunamis. Investigating the deep-sea also reveals new ecosystems and possible sources for medication, food and energy, which are all vital for scientific advancements. [**?**]

Humans have always had never-ending interest and need to push science and technology to its limits, and then desire to achieve something even further than what is possible. The many challenges humans have faced has led to many benefits for our society almost since its creation. Space exploration helps further our understanding about the history of our universe and solar system. [**?**]

Unknown terrain and environments pose a big issue for scientists and engineers **who** want to explore these areas. Designing vehicles and devices for the deep-sea ocean or planetary exploration is impossible, without any background information on what environmental factors they will be dealing with or encountering. Exploration is essential when in the future new resources are needed for scientific and technological advancements, that currently our of reach.

In the long run humans in general will be affected by the lack of exploration. Alternative resources and habitable areas for expansion will be necessary in the future, when earth's natural resource deposits become depleted and there are less habitable places.

Scientists are heavily hindered by society, because it is becoming too focused on risks. Only 5 percent of the ocean has has been explored, this leaves a large amount of areas untouched and mapped. Being concerned about taking risks is what will put the future development and science in jeopardy. [**?**]

Why we need to explore other unknown terrains is to help us better understand everything around us and to be able to go to other planets. If we are flying in the dark about the terrain underwater or on another planet and we are planning of settling there or use those resources then we have a bigger change of failure. If the trips are planned well and we make a good 3D map of the terrain we can come up with better plans on the next mission or if we want to use this location at all.

The problems with navigating a robot in an unknown terrain is the lack of reference points that are needed to make a 3D map and also reference point for the robot itself to being able to navigate. That makes two challenges for us. One is for the robot to being able to navigate through a completely unknown terrain and at the same time make sense of it and come up with reference point that will be use to make a 3D map.

If a robot is successful with that task and we get back a detailed 3D map then the next mission can rely on that information and have a easier way to navigate.

On earth we have the GPS (global positioning system) that is an space based satellites navigation system flying over the earth [**?**]. But putting up a system like that on another planet cost a lot of resources and the cost to start with would not be beneficial. GPS also does not penetrate water [**?**].

GPS theory

The Global Positioning System (GPS) is a space-based satellite navigation system that provides location and time information in all weather conditions, anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites.[1] The system provides critical capabilities to military, civil, and commercial users around the world. The United States government created the system, maintains it, and makes it freely accessible to anyone with a GPS receiver.

In addition to GPS, other systems are in use or under development. The Russian Global Navigation Satellite System (GLONASS) was developed contemporaneously with GPS, but suffered from incomplete coverage of the globe until the mid-2000s. There are also the planned European Union Galileo positioning system, India's

Indian Regional Navigation Satellite System, and the Chinese Beidou Navigation Satellite System.

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Photogrammetry theory

Photogrammetry is the science of making measurements from photographs, especially for recovering the exact positions of surface points. Moreover, it may be used to recover the motion pathways of designated reference points located on any moving object, on its components and in the immediately adjacent environment. Photogrammetry may employ high-speed imaging and remote sensing in order to detect, measure and record complex 2-D and 3-D motion fields (see also sonar, radar, lidar etc.). Photogrammetry feeds the measurements from remote sensing and the results of imagery analysis into computational models in an attempt to successively estimate, with increasing accuracy, the actual, 3-D relative motions within the researched field.

low altitude aerial photograph for use in Photogrammetry - Location Three Arch Bay, Laguna Beach CA. Its applications include satellite tracking of the relative positioning alterations in all Earth environments (e.g. tectonic motions etc.), the research on the swimming of fish, of bird or insect flight, other relative motion processes (International Society for Photogrammetry and Remote Sensing). The quantitative results of photogrammetry are then used to guide and match the results of computational models of the natural systems, thus helping to invalidate or confirm new theories, to design novel vehicles or new methods for predicting or/and controlling the consequences of earthquakes, tsunamis, any other weather types, or used to understand the flow of fluids next to solid structures and many other processes.

Photogrammetry is as old as modern photography, can be dated to the mid-nineteenth century, and its detection component has been emerging from radiolocation, multilateration and radiometry while its 3-D positioning estimative component (based on modeling) employs methods related to triangulation, trilateration and multidimensional scaling.

In the simplest example, the distance between two points that lie on a plane parallel to the photographic image plane can be determined by measuring their distance on the image, if the scale (s) of the image is known. This is done by multiplying the measured distance by

Algorithms for photogrammetry typically attempt to minimize the sum of the squares of errors over the coordinates and relative displacements of the reference points. This minimization is known as bundle adjustment and is often performed using the Levenberg–Marquardt algorithm.

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Stereophotogrammetry

Stereoscopy (also called stereoscopics or 3D imaging) is a technique for creating or enhancing the illusion of depth in an image by means of stereopsis for binocular vision. The word stereoscopy derives from Greek (stereos), meaning "firm, solid", and FIX HERE, meaning "to look, to see". Any stereoscopic image is called stereogram. Originally, stereogram referred to a pair of stereo images which could be viewed using a stereoscope.

Most stereoscopic methods present two offset images separately to the left and right eye of the viewer. These two-dimensional images are then combined in the brain to give the perception of 3D depth. This technique is distinguished from 3D displays that display an image in three full dimensions, allowing the observer to increase information about the 3-dimensional objects being displayed by head and eye movements.

2.1 Autonomous Vehicles and Robots

Autonomous robots or vehicles can work for an extended period of time gathering information from its surroundings to be able to work without human intervention. The robot or vehicles gathers different kinds of data, depending on what the goal of the robot it.Positional data can be utilized for navigation and path finding in a known and unknown environment. Intelligent autonomous devices are able to adapt to changes happening in its surroundings. Currently there are many robots on the market that are self-reliant, ranging from autonomous vacuum cleaner to drones and helicopters. [?]

Simple autonomous robots use ultrasonic sensors or infrared to manipulate itself if it detects obstacles. The is useful for obstacle avoidance and mapping of unknown areas, where the robot through a reference point can pin-point the obstacles it has encountered along the way. More advanced robots use vision to grant them the ability to see their surroundings, algorithms analyse the camera data and gives the robot depth perception, which grants the robot the ability to instantly identify objects and locate them immediately. [?]

There exists two kinds of autonomous robots, a single computer autonomous robot and insect robots. The single computer autonomous robot uses its own on-board computing unit to do its computations and decisions, whereas the the insect robots are a fleet a many robots who are controlled by a single separate computing unit. The advantage of having a single computer autonomous robot is that the tasks it performs can be done using more computer resources. It has the possibility of utilizing the computing power to its full potential, instead of relying on a separate unit that is also making decisions and calculations for many other robots. The individual robot in the insect family is simple, but the whole robot fleet can be advanced and possibly perform sophisticated tasks, that a require multiple simpler robots. [?]

2.2 Path finding

Chapter 3

Problem Definition

3.1 Hypothesis

Hypothesis

3.2 Problem Definition

Problem Definition

Chapter 4

Development

4.1 Description

Description and following chapters

Chapter 5

Discussion

Discussion

Chapter 6

Conclusion

Conclusion

Chapter 7

Perspective

perspective

Chapter 8

Appendix

appendix