

## Bachelor Thesis

# Path Generation for a Mobile Drawing Robot

Spring Term 2014



# Preface



# Abstract

The BeachBot is a mobile, autonomous drawing robot for large scale sand art. Its primary purpose is the entertainment of beachgoers. The goal of this thesis was to develop and evaluate algorithms to automatically generate suitable trajectories to draw arbitrary images on the canvas. Main challenges have been to find a trajectory that reduces the drawing time and to make watching the drawing process appealing.



# Symbols

## Symbols

|                      |                              |
|----------------------|------------------------------|
| $\phi, \theta, \psi$ | roll, pitch and yaw angle    |
| $b$                  | gyroscope bias               |
| $\Omega_m$           | 3-axis gyroscope measurement |

## Indices

|     |        |
|-----|--------|
| $x$ | x axis |
| $y$ | y axis |

## Acronyms and Abbreviations

|     |                                      |
|-----|--------------------------------------|
| ETH | Eidgenössische Technische Hochschule |
| EKF | Extended Kalman Filter               |
| IMU | Inertial Measurement Unit            |
| UAV | Unmanned Aerial Vehicle              |
| UKF | Unscented Kalman Filter              |



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# Chapter 1

## Introduction

### 1.1 The BeachBot Project

The BeachBot project was a “focus project” at ETH Zurich. During the last two semesters of the bachelor studies the team had the opportunity to develop a mobile and autonomous robot for creating sand drawings on beaches. In total 7 mechanical engineering students, one electrical engineering student and two industrial design students (from the Zuercher Hochschule der Kuenste) where working on the project. The result of the project is a 3 wheeled mobile robot. The key features are:

**Localization** The robot is able to reliably localize itself on the beach, using a laser range finder and 3 or more reflective poles. An localization accuracy of about 3 centimetres was achieved.

**Driving speed and turning radius** The top speed of the robot is about 0.4 metres per second and it can turn on the spot. Both back wheels are independently steerable. The front wheel is also actuated. This is done to reduce the risk of getting stuck in sand.

**Rake** The main drawing tool of the robot is a rake. The rake consists of seven pin-pairs which are individually movable.



Figure 1.1: Various images of the BeachBot

## **Chapter 2**

# **Requirements and Inspiration**

The BeachBot project itself was inspired by the images of sand artists like Peter Donnelly and Andres Amador, who create large scale sand art on beaches using a rake. Some of the imagery that we found online can be seen in Figure 2.1.



(a) Sand drawing by Peter Donnelly. Source: <http://becky-garrett.blogspot.ch/2009/03/sand-dancer-peter-donnelly.html>



(b) Sand drawing by Andres Amador. Source: <http://sftimes.co/?id=25>



(c) Sand drawing by Andres Amador. Source: <http://sftimes.co/?id=25>

Figure 2.1: Various beach drawings by artists

## **Chapter 3**

# **Path Planning Algorithms**

### **3.1 Algorithm Overview**

### **3.2 Image Structure**

### **3.3 Polygon Filling**

#### **3.3.1 Related Work**

#### **3.3.2 Straight Skeleton Filling**

#### **3.3.3 Back and Forth Filling**

### **3.4 Path Generation**

#### **3.4.1 Traveling Salesman Problem**

#### **3.4.2 Adaptation of Traveling Salesman Problem for the Algorithm**

### **3.5 Smooth line connections**

Beziér Splines

Spiro Splines

# **Chapter 4**

# **Implementation**

- 4.1 Input**
- 4.2 SVG Parser**
- 4.3 Tree Container**
- 4.4 Preprocessing**
- 4.5 Implementation of the Algorithms**
- 4.6 Postprocessing**
- 4.7 User Interface**

# **Chapter 5**

## **Conclusion**

## **Appendix A**

## **Appendix**

