ETH
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Autonomous Systems Lab
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Bachelor Thesis

Path Generation for a Mobile Drawing Robot

Spring Term 2014

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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

ϕ, θ, ψ	roll, pitch and yaw angle
b	gyroscope bias
Ω_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

Contents

Chapter 1

Introduction

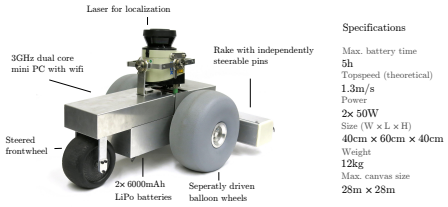
1.1 The BeachBot Project

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.



Specifications

Max. battery time
5h
Topspeed (theoretical)
1.3m/s
Power
2× 50W
Size (W × L × H)
40cm × 60cm × 40cm
Weight
12kg
Max. canvas size
28m × 28m

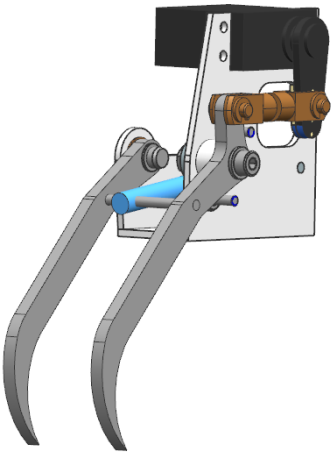


Figure 1.1: Various images of the BeachBot

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

Bezir Splines

Spiro Splines

Chapter 4

Implementation

Chapter 5

Conclusion

Appendix A

Appendix