THESIS
DESIGN OF AN AUTONOMOUS DREDGE BOT CONTROLLER

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THESIS

Design of an autonoumous dredge bot controller

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December 19, 2019

Client	Royal IHC
External reference	mk-4.55
Internal reference	MED01
Version	0
Status	concept
Classification	none

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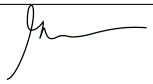
WRITTEN BY	Jelle Spijker	December 19, 2019	
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CHAPTER SUMMARY

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CHAPTER CONTENTS

CHAPTER 1 INTRODUCTION

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This chapter will first specify three use-cases, specified in the project assignment, in which an AOD must operate. It then describes basic principles, applications and tools relevant for these use cases.

1.1 USE CASES

The use case below are determined by ir. F. Hofstra, these cases are expected to be valid and realistic. Keeping in mind their marketability. These cases will determine the needed functionality for an AOD and stand at the basis for the controller design.

1.1.1 ARBITRARY SHAPED SPACE

An AOD is placed in a predefined arbitrary shaped space, not too complex, with an area of $3500\mathrm{m}^2$. The shape of this space is set, but the movement pattern is unrestricted. The AOD has to remove a layer with a depth of $5\mathrm{cm}$. The controller has to determine an optimal path with the least amount of time or the shortest path. This can be coupled with learning capabilities and an analyze capacity. At a later time additional constrains can be added which keep in mind the deployment location of a flexible dredgeline and an umbilical.

1.1.2 MARINA AQUA DELTA

The AOD operates in a predefined space with obstacles, not every obstacles is known. The actual location is marina Aqua Delta located in Bruinisse, the Netherlands. The shape of this location is set but the movement pattern is unrestricted. An AOD has to remove a layer with a depth of $5\mathrm{cm}$. The controller has to determine an optimal path with the least amount of time or the shortest path. This can be coupled with learning capabilities and an analyze capacity. The marina has enough depth for the AOD to move underneath the scaffolding. No consideration has to be made for a flexible dredgeline and a umbilical. These conditions are introduced at a later stage.

1.1.3 THREE GORGES DAM

An AOD operates in a predefined space with obstacles, not every location of those obstacles is known. The predefined space is located at the foot of three Gorges dam. Silt is deposited at the foot of this dam, due to natural occurring erosion and sedimentation. The accumulation of silt can be controlled by dredging localized pits. Which in turn create locations with a lower density. This induces a gravity driven density current towards those locations. The AOD has to maintain an average nominal depth with a certain silt deposit rate.

2 CHAPTER
DREDGING PRINCIPLES AND APPLICATIONS

This chapter describes the dredging task in some detail. Readers familiar with dredging and commonly used terminology can skip this chapter, since no new information will be provided. It first describes basic principles, applications and tools relevant for the previous described use cases, see section 1.1.

2.1 BASIC DREDGING APPLICATION

Training Institute for Dredging [2] defines dredging as the underwater removal of soil and its transport from one place to another for the purpose of deepening or making profitable use of the removed soil. They make an distinction between nine types of operations: dredging for prosperity, dredging in ports an d channels, exploitation of agricultural resources, mineral dredging, coastal protection, land reclamation, infrastructural projects, improvement of the environment and trenches for cables and pipelines.

All three of the described use-cases are of the maintenance type. Schrieck [5] states that the issue in maintain existing waterways and harbors is to preserve the depth of the bed by regular removing silt. In canals and ports basins, where currents are low, the sediment is mostly fine-grained silt and sludge. Where currents are stronger, as in access channels in tidal zones, or rivers, the sediment is sand. He further describes that a characteristics of this kind of work is the weak cohesion of the soil to be removed, since it consist of recently deposited sediment and no significant consolidation has taken place yet.

A special kind of maintenance dredging is sanitation dredging which is a process specially designed for contaminated sediment. Just in the way, sediment settles in rivers, harbours and deltas so does heavy metal, inorganic and aromatic compounds. Especially downstream of industrial areas. When these contaminated sediments become a risk towards public health and environment it needs to be removed with care and precision.

2.2 COMMONLY USED VESSELS AND EQUIPMENT

Common dredge tools used during maintenance work are listed below, of this list backhoes and suction dredgers are mostly used during port maintenance. Vlasblom [6] states that dredgers can be divided in mechanical dredgers and hydraulic dredgers. Where the difference lies in the way the soil is excavated; either mechanical or hydraulic.

2.2.1 MECHANICAL DREDGERS

Work by removing soil and sediment from the submerged soil bed by mechanically excavating it and transporting it to a storage location, such as a hopper which, is a storage container or compartment,.

BUCKET DREDGER

The bucket dredger consist of a pontoon with a well and six anchors. The buckets are connected on a uninterrupted chain that moves over a ladder on rotating disks. The ladder goes down from a high support construction to the bottom underwater [2]. Removing sediment in this motion and transporting it to the storage location. This type of dredger is moved on its anchors.

GRAB DREDGER

These types of dredgers excel in hard to reach places, such as corners or near constructions in ports and rivers. They work by lowering a grab or clamshells into the sediment and hoisting it up, releasing it captured content in a storage location.

BACKHOE

The backhoe consist of a hydraulic crane with a heavy bucket, mounted on a spud pontoon or self-elevating platform [2]. These types of dredgers are especially designed for heavy-duty purposes.

2.2.2 HYDRAULIC DREDGER

Work by removing and transporting soil from the seabed, using suction, provided by a dredge pump. The soil is stored in a storage location such as a hopper.

PLAIN SUCTION DREDGER

Vlasblom [6] describes a plain suction dredger as an stationary dredger, consisting of a pontoon anchored by one or more wires an with at least one sand pump, that is connected to a suction pipe. The discharge of the dredged material can take place via a pipeline or via a barge-loading installation. During sand dredging the dredger is moved slowly forwards by a set of winches.

TRAILING SUCTION HOPPER DREDGER

The Trailing Suction Hopper Dredger (TSHD) is a seagoing ship equipped with one or two suction tubes, a pump installation and a hopper with multiple bottom doors and one or more overflows. A draghead attached to each suction tube and is trailed across the sea bed to loosen the soil before it is pumped up [5]. This soil is stored in a hopper which is periodically discharged, at an designated location, through dumping or pumping out.

AUGER SUCTION DREDGER

According to VBKO Vereniging van waterbouwers in bagger-, kust- en oeverwerken [1] an Auger Suction Dredger (ASD) consists of a double symmetrical Archimedes screw, also called an auger, surrounded with a steel protective cover and a flexible rubber curtain. This auger is lowered on a rigid arm and positioned on the soil bed, where it cuts the material and actively transports in to the centre, where it is sucked away by a dredge pump. Because the complete dredging process takes place behind a flexible rubber curtain and the auger guides all material towards the suction mouth, this types of dredgers are well suited for sanitation maintenance.

CUTTER SUCTION DREDGER

According to Vlasblom [6] a Cutter Suction Dredger (CSD) is a stationary dredger equipped with a cutter device (cutter head) which excavate the soil before it is sucked up by the flow dredge-pump(s). During this operation the dredger moves around a spud pole by pulling and slacking on the two fore sideline wires. This type of dredger is accurate and can cut almost all types of sediment.

2.3 HYDRAULIC DREDGING PRINCIPALS

According to Van Den Berg [4] the de-facto industry of transportation of dredged sedimented, or slurry, are pipelines and combined with centrifugal pumps. The section below shortly describe the workings of a dredge-pump when it is used during slurry transport, the workings of an auger draghead and the shore pipeline.

NOTE 2.1: EXCLUDING MECHANICAL DREDGERS

Because a dredge bot perform it operation via a hydraulic suction action, excavation and cutter suction dredgers won't be discussed in this thesis.

FIGURE 2.1: AUGER SUCTION DREDGER [1]

2.3.1 DREDGEPUMP

In order to transport slurry with a particular density and velocity through a pipeline, a pressure, equal to the sum of all the resistances and geodetic head must be generated. A pump supplies this pressure [4]. Assuming a steady flow, the pump basically increases the Bernoulli head of the flow between point 1, the eye and point 2, the exit [3], which is illustrated in figure 2.2 and equation 2.1. Where the viscous work and heat transfer are neglected. Here H_2 which is net head of a flow at point 2 given in $[\mathrm{m}]$, p_1 which is pressure at point 1 given in $[\mathrm{Pa}]$ and p_2 which is pressure at point 2 given in $[\mathrm{Pa}]$ and $v_{f,1}$ which is speed of a fluid at point 1 given in $[\mathrm{m/s}]$ and $v_{f,2}$ which is speed of a fluid at point 2 given in $[\mathrm{m/s}]$. Coupled with ρ_s which is density of a slurry given in $\left[\mathrm{kg/m^3}\right]$ and g which is standard gravity model given in $\left[\mathrm{m^2/s}\right]$, describe Δp which is pressureloss given in $[\mathrm{Pa}]$.

$$H_2 = \left(\frac{p_2}{\rho_s g} + \frac{v_{f,2}}{2g} + z_2\right) - \left(\frac{p_1}{\rho_s g} + \frac{v_{f,1}}{2g} + z_1\right) \approx \frac{\Delta p}{\rho_s g} \tag{2.1}$$

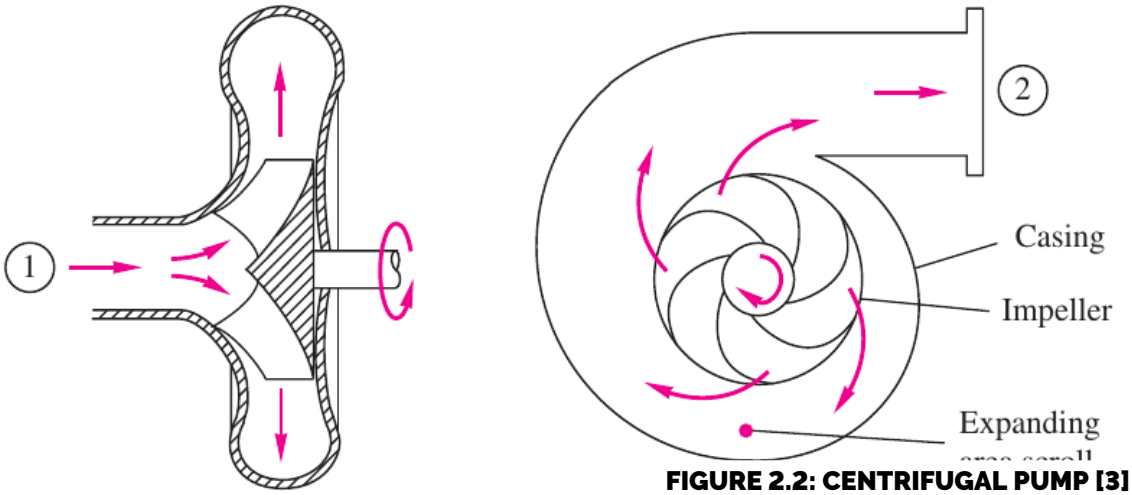

FIGURE 2.2: CENTRIFUGAL PUMP [3]

$$P_w = \rho_s g \dot{V}_s H_2 \approx \dot{V}_s \Delta p \tag{2.2}$$

The needed drive power P_w given in kW for $\dot{V}_s$ which is volumetric fluid flow given in $\left[\mathrm{m}^3/\mathrm{s}\right]$ can be calculated with equation 2.2. Where a efficiency factor should be applied to compensate for the losses. It is relevant to know how much power the pump uses, to transport a certain amount of slurry because it taps from the same source as that of a dredge bot propulsion system. The bot will use an **IHC 37.5-9.5-15** from which the characteristics are well known and documented in appendix .

point to c
pendix

NOTE 2.2: OUT-OFF SCOPE

Control of the dredge-pump during dredging operations is left out of the scope. It is assumed through out this paper that the pump is operated at a maximum capacity.

2.3.2 AUGER DREDGE HEAD

An auger umbilical which, is a electronic cable connecting an underwater vehicle, This method ensures an extremely quit cutting and mixing process with little spillage and turbidity in the surroundings. The large working width of the auger makes it extremely suited to dredge thin possible polluted, layers at a relatively high production rate [5].

CHAPTER 3
SYMBOLS LIST

SIGN	DESCRIPTION	UNIT	PAGE
ρ_s	density of a slurry	$\mathrm{kg/m^3}$	4, 5
g	standard gravity model	$\mathrm{m^2/s}$	4, 5
H_2	net head of a flow at point 2	m	4, 5
Δp	pressureloss	Pa	4, 5
p_1	pressure at point 1	Pa	4
p_2	pressure at point 2	Pa	4
P_w	drive power	kW	5
$v_{f,1}$	speed of a fluid at point 1	$\mathrm{m/s}$	4
$v_{f,2}$	speed of a fluid at point 2	$\mathrm{m/s}$	4
$\dot{V}_s$	volumetric fluid flow	$\mathrm{m^3/s}$	5
z_1	height at point 1	m	4
z_2	height at point 2	m	4

4 CHAPTER GLOSSARY

KEY	DESCRIPTION	PAGE
draghead	a suction mouth which is dragged across a water body	3
dredgeline	a pipeline which transports excavated slurry	1
erosion	an action of surface processes (such as water flow or wind) that removes soil	1
hopper	a storage container or compartment	2, 3
sedimentation	"the opposite of erosion	1
silt	a granular material of a size between sand and clay	1
slurry	describe a mixture that consist of both solid and fluid phases	3, 4
umbilical	a electronic cable connecting an underwater vehicle	1, 5

CHAPTER 5 ACRONYMS

KEY	DESCRIPTION	PAGE
AOD	Autonomous Operating Dredgebot	1
ASD	Auger Suction Dredger	3
CSD	Cutter Suction Dredger	3
TSHD	Trailing Suction Hopper Dredger	3

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APPENDICES

A APPENDIX FOLDER STRUCTURE