Preface

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Abstract

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1 Introduction

Placeholder text. this is a placeholder citation to remove an error: Eriksen and Breivik 2017.

1.1 Motivation

- Mye samme som på fordypningsoppgaven.

1.2 Previous Work

- Mer å lese.
- Skrive om.
- Fortsatt mye likt som på fordypningsoppgaven.

1.3 Problem Description

- COLREGs-awareness.
- Trajecory planning.
- Target Ship prediction.
- NLP runtime optimization

1.4 Contributions

- Analyse av fordeler med å ha bedre / avansert prediksjon av TS.

1.5 Outline

- Samma stil som på fordypningsoppgaven.

1.6 Abbreviations

- Tenkte det kunne vært lurt å ha en handy liste over alle forkortelser
- Selv med denne listen vil jeg fortsatt skrive forkortelser fullstendig ut første gang de brukes.

2 Background

- Skal prøve å skrive med litt bedre rød tråd denne gangen

Before diving into the main matter of this thesis, some groundwork is neccessary to explain the fundamental theories that the thesis is built upon. This section will provide a structured overview of the concepts and terminology that will be used later.

2.1 Vessel Model

- Kinetikk.
- Kinematikk.
- hvorfor denne modellen.
- Hvordan brukes modellen.

In this thesis, the terms *vessel*, *ship*, and *boat* will all be used interchangably to refer to the same thing: a hollow structure that floats on water for the purpose of navigation. Exactly how the vessel behaves as it floats depends on a multitude of factors which can be modelled mathematically. There are many ways to model a vessel, but not every model is useful for every purpose. Just like how not every tool is fit as a hammer. To create a useful model for navigation and control specifically, we separate the modelling problem into two categories: Kinematics and Kinetics.

2.1.1 Kinematics

Kinematics is the aspect of the problem concerned only with the geometrical aspect of motion. When modelling our hollow structure is not enough to simply describe the velocity which with it floats. If the vessel has it's own actuator to generate thrust we must know which direction the force generated is pointing, and if there are external forces acting upon the vessel we must know which direction those forces are pointing. But what is the reference point for these directions? and where even is our vessel floating? *...Dette er ikke hvordan jeg ønsker å skrive dette avsnittet, men jeg lar det stå slik som det for nå...*

What we need is a reference frame, in fact we need multiple reference frames. A reference frame is simply a origin point and some defined direction or axis that together

come to define a coordinate system. One such frame is called Earth Centered Inetrial (ECI), this is an inertial frame where the z-axis is aligned with the axis which Earth rotates around while the x and y axis are fixed in space. An observer using this reference frame would see the Earth spinning around the z-axis, the solar system would appear to rotate around Earth, and objects which would be considered stationary on Earth's surface would have an angular velocity. Another useful frame is called Earth Centered Earth Fixed (ECEF) and is very similar to ECI except that the x and y axis now rotate with Earth's rotation. Objects which are considered to be stationary on the surface of Earth are also considered to be stationary to an observer using ECEF. EFEC is the frame in which Longitude, Latitude and Altitude are used to describe a position and heigh, and this frame is widely used in satellite based global navigation systems such as Global Positioning System (GPS).
There are two more reference frames which are very useful for modelling our vessel:

- **NED** or North-East-Down is a flat plane projection of some area on Earth. The origin point for a NED frame is generally some Longitude-Latitude position from ECEF with the x-axis poiting towards true North, y-axis pointing east and the z-axis ponting down towards the center of the Earth. NED will be denoted as n from here on.
- **BODY** is a frame affixed to the body of the vessel with the x-axis aligned with the longitudal axis of the vessel from aft to fore, the y-axis is the transversal axis pointing towards starboard, and the z-axis is the normal axis from top to bottom. BODY will be denoted as b from here on.

The reason for all these frames is that motion described by one frame can be transformed to be expressed in another, meaning that we can define the forces of our vessels actuators in b and transform this to motion in n. Consider that the z-axis for b and n are parallel, rotating from b to n becomes a principal rotation about the z-axis:

$$J_\Theta(\eta) = R_{z,\psi} = \begin{bmatrix} cos(\psi) & -sin(\psi) & 0 \\ sin(\psi) & cos(\psi) & 0 \\ 0 & 0 & 1 \end{bmatrix} \tag{2.1}$$

This rotation is the relationship between body velocities and positional change:

$$\dot{\eta} = R(\psi)\nu \tag{2.2}$$

where $R(\psi) := R_{z,\psi}$, $\nu = [u, v, r]'$ are the surge, sway and heave velocities of our vessel. And $\eta = [N, E, \psi]'$ is the north east position and heading orientation of our vessel.

2.1.2 Kinetics

- Kinetics is the model for turning forces into motion.
- Degrees of Freedom explained
- 3DOF rigid body kinetics from Fossen 2011
- Explain added mass, coriolis, dampening.
- explain thrust?

Kinetics is the aspect of the modelling problem that is concerned with converting forces to motion. something something 3DOF. something something mass, corriolis, dampening, thrust matrices.

2.2 Collision Avoidance

- liten introsnutt om hva jeg mener går under paraplyen ”Collision avoidance”.
- Denne blir vel egentlig ganske lik som i fordypningsoppgaven.

2.2.1 COLREGs

- COLREGs.

2.2.2 Situation Assessment

- Samme som i fordypningsoppgaven.

2.2.3 Target Ship Prediction / Situation Anticipation

- Vanlig metode (tCPA, dCPA).
- Avansert metode (hypotetisk, maskin lærings problem?).
- henger sammen med Situation assessment.
- Her kommer delen om trafikk pattern data for prediksjon.

2.3 Trajectory planning algorithm

- Litt tekst om hvordan modellen og collision avoidance knyttes inn i trajectory planning.

2.3.1 Line of Sight Guidance

- Hva er det.
- Hvordan gjøres det.
- Hva skal det brukes til.

2.3.2 Optimal Control problem

- matematikk.
- Hvordan brukes alt vi har skrevet om tidligere i dette kapittelet.
- Hva får vi ut som svar.

2.3.3 Model Predictive Control

- MPC kommer til å nevnes en god del, bør ha sitt eget lille kapittel.
- hva er det.
- Hvordan funker det.
- Hvorfor bruke MPC.

2.4 Robot Operating System

- Skrive litt om ROS?
- importering av MATLAB kode.
- Dette delkapittelet kan muligens gå under metode.

3 Method

3.1 Preliminaries

- Kommer alltid til å være begrensninger.

3.2 Algorithm Implementation

- CasADi.
- dataflyt.
- databehandling.
- output.

3.3 Robot Operating System?

- se 2.4

4 Simulation and Fullscale Results

- Simulation Results
- Fullscale test Results
- Discussion som tar for seg både simulator of fullskalatest i ett delkapittel.
- ALTERNATIVT: Et kapittel for simulator, et kapittel for fullskalatest, Diskusjon som eget kapittel etter begge som samler og diskuterer all resultatene.

4.1 Situation overview

- Flere situasjoner denne gangen.
- Forklar bedre nøyaktig hva situasjonene går ut på.
- Forklar bedre hvorfor jeg har designet situasjonen slik som den er.
- Hva er det jeg håper situasjonen vil vise oss.

4.2 Simulation Results

- Samme stil som fordypningsoppgaven.
- Lagre bilder som vektordiagram denne gangen.

4.3 Fullscale Testing

- Hvorfor fullskalatester.
- Hva Skal testes.
- Hva er det jeg håper fullskalatest vil vise oss.
- Hvis jeg ikke skriver om hvordan jeg implementerer kode og gjennomfører testene i metode kapittelet så må det beskrives her.
- Kriterier som skal testes?

4.4 Fullscale Test Results

- Skriv om hvordan det gikk.

4.5 Discussion

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5 Conclusion and Future Work

- Er alltid mer future work å ta for seg.
- Ellers lik struktur som i fordypningsoppgaven.

References

Eriksen, H. Bjørn-Olav and Morten Breivik (2017). 'MPC-based mid-level collision avoidance for ASVs using nonlinear programming'. In: *2017 IEEE Conference on Control Technology and Applications (CCTA)* (Mauna Lani Bay Hotel). IEEE. Hawaii, USA, pp. 766–772.