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Title

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Abstract

Preface

Contents

List of Figures

List of Tables

List of Algorithms

Chapter 1

Introduction

This chapter the background and motivation to why this project thesis has been written. Also reference to privios work, the goal of the thesis and the layout.

1.1 Background and motivation

Why is the project thesis relevant: Installing better GPS to enable better hight estimation

What have I done? Integrated new GPS with DUNE

What is next? Land the UAV. Test algorthm to Frølich, better state estimation

Unmanned aerial vehicles have in seen an increase usage in the civilian sector on land, where they can be used at a cheaper price then manned aircraft. However this has not yet been the case in the civil maritime sector, due to a harsher environment and smaller landing areas.

A UAV can increase performance in many maritime operation where today only other manned aircraft or satellites are the only solution. In the maritime sector they can be used in iceberg management, monitoring of oil spills, search and rescue and maritime traffic monitoring. To enable a safe UAV operation at sea there must be a system in place to ensure a safe landing.

There exist landing system that can guide the UAV towards a net, but they are expensive and restricted to a few UAVs. A pilot could always land the UAV, but it would be better if the UAV could hit the net by it self. In order to make the UAV able to perform a automatic landing the minimum requirement is that it know where it is at all time. This put a requirement of the position sensor. The position system need to combine low cost with high position accuracy. This thesis will test a new generation of GNSS receiver, and use GPS to find the position to the UAV. The demand on the accuracy is that the error must be in decimetres to ensure safe landing in the net.

A automatic landing system must include a path planner, guidance system and a accurate position estimation system, in addition to the low level control system in the UAV. A path planner and guidance system were created in a master thesis at the uavlab by Marcus Frølich. The gudiance system is currently under further development in two project thesis. A position system was created by Bjørn Spockeli, but it concluded that the GNSS receiver used were insufficient to perform automatic landing. This thesis will continue the research done by Spockeli, and introduce a new GNSS receiver that will be used with the open source program, rtklib. The motivation is to have a system with accurate local position estimate, such that in the future a landing can be performed automatic. The automatic landing system will use RTK GPS for position estimation. Motivation for work: Autonomos landing. Required accurate posisioning system, a feasable path, tuned guidence system, robust lav nivå kontroll. Include a system figure can give the reader information on how the autolanding system should work, and why this thesis is relevant.

1.2 Previous work

Work done in the UAVLab on automatic landing. The other master thesis on landing using visual assist. Other method that has been applied.

Work done in the rtk gps field conserning automatic systems.

Previous work in the field of ambiguity resolution, rtk gnss, auto landing with fixed wing drone without ground assist.

The work done by Frølich on simulation of a net landing. Work done by Spockeli. Need other research field. GPS navigation is a well researched field. Relevant to this task is landing with gps, or high accurate position estimation.

Other master thesis, paper on visual aid landing system. Frølich did the same research, using reasearch from Spocli.

1.3 Goal of thesis

Table 1.3 summaries the goal with this project thesis.

– Install the Ublox Lea M8T on the base station and x8

– Configure rtklib to calculate the relative position of the x8 in relation to the base station

– Make Dune able to receive the output stream from rtklib, and support a new imc message that contain the relative position of the x8

– Test and compare the Ublox receiver against the pixi(TRENGER MODEL NAVN) receiver

Install new GPS receiver on the x8 and base station. Test and compare to the pixi gps that is the standard solution i the uavlab. Evaluate if the new gps is good enough to enable automatic landing Install new GPS reciver with higher accuracy to enable automatic landing

1.4 System layout

How the landing can be performed. A operator send a landing request from Neptus to dune. The path generation task generate waypoints in both local and global frame. The global waypoints are return to Neptus to show the operator were the planed path is. The local waypoints are given to a guidance system. The guidance system only requrier the local position, which it will receive from a rtk GNSS task. The rtk GNSS task is required to send both the local position and the global. The global position will be calculated as an offset from the base station location. The local position is the relative position of the UAV with respect to the base station.

1.5 Layout of thesis

Chapter 1 Intro Chapter 2 Theory about coordinate system Chapter 3 Theory about GNSS system with focus on the GPS Chapter 4 Hardware and software Chapter 5 Test and result Chapter 6 Conclusion, discussion and further work

Chapter 2

Coordinate systems

This chapter will give an overview over different coordinate system and the relationship between them. A coordinate system is used to define a position relative to a origin. The choice of coordinate system is critical when describing the equation of motion. Newtons first law only apply when the origin is viewed as an inertial frame. When navigating on/or close to the surface there are two convension used; ENU and NED. Both the ENU and NED system is defines relative to the center of the Earth.

Write about the long lat system and the WGS 84, the ellipsoid and geosomething

2.1 ECEF

The Earth Centered, Earth Fixed coordinate system is defined in the center of the Earth with it's x-axis point toward the intersection between the Greenwich meridian and Equator (0 deg longitude, 0 deg latitude). The z-axis points along the Earth's rotational axis, and the y-axis complete the right handed orthogonal coordinate system. The ECEF system can be represented in either Cartesian coordinates (xyz) or ellipsoidal coordinates (longitude, latitude and height).

2.2 Ellipsoid

How the the Earth ellipsoid defined. Advantages and disadvantages. What most be considered when estimating altitude. The difference between the ellipsoid and geoid. The geoid follows the curvature of the Earth. When flying perpenticular to the geoid there will be an angle between the normal from the geoid and the normal from the ellipsoid.

2.3 NED and ENU

The North East Down frame and East North Up frame. See at lab assignment in gps. Defined tangential to the Earth ellipsoid. The ellipsoid that is currently used is the WGS-84 ellipsoid. The WGS-84 ellipsoid ... how it's defined, why used then refer Different orientation

Chapter 3

Real time kinematic GNSS

This chapter outline the basic of the GPS signal. how RTKGPS works. It's assumed that the reader is familiar with how a single GPS receiver works. The first section give a brief summary on what differential GPS is, and how that principle is applied in RTK-GPS. The two following sections is directly used in RKT-GPS(maybe write some more). The last section give a quick overview over the error sources that effect the measurement.

A short description of GPS signals and error sources. How to find the Ambiguity resolution and why it's important. What is differential gps, and why use RTK-GPS.

3.1 GNSS constelations

The two main GNSS constelation is operation today is GPS and Glonass.

3.2 GPS signals

GPS uses the signals L1 and L2 to calculate the receiver position, with the L5 signal soon fully available. More detailed information about the GPS signals can be found in (ref her)

The position is calculated from the pseudorange to each satellite that the receiver is tracking. The two basic ways to measure the psedurange is code and phase measurement. Phase measurement is the most accurate of the two, bu also least reliable.

The receiver needs at least four satellite to be able to estimate the receiver position. Three of the satellite is used for the position, and the fourth if used to calculate the receiver clock bias.

What is needed:

Carrier frequencies?

Code and phase measurements: Phase measurement is a must due to the ambiguity resolution

For position estimation purpose there are two signals mainly available, $L1$ and $L2$. A third signal,$L5$, has recently been introduce, but since the service is not fully operational it will not be covered in this thesis. The signal structure form GPS is written:

$$
\begin{aligned}
L_1(t) &= A_1 p(t) d(t) \cos(f_1 t) + A_1 c(t) d(t) \sin(f_1 t) \\
L_2(t) &= A_2 p(t) d(t) \cos(f_2 t)
\end{aligned}
$$

The carrier frequencies for the L_1 and L_2 signal are

$$
\begin{aligned}
f_1 &= 1575.42 MHz \\
f_2 &= 1227.60 MHz
\end{aligned}
$$

A_1 and A_2 are the signal amplitude, and $c(t)$ and $p(t)$ are the Pseudo Random Noise, where $c(t)$ is sequences modulated into the L_1 signal and $p(t)$ into both the L_1 and L_2 signals.

Could tell what c(t) and p(t) is, and what is known about them. Also the strength of A1 and A2. How the psudorange is not important for this thesis.

What is important:

Have done: Setting up the new GPS in the base station and in x8. Need to explain how rtklib work, and what is RTKGPS. Also need to talk about Ublox LEA M8T. It's here the talk about L1 becomes relevant. Maybe talk about the coordinate frame. Why use NED/ENU with base-station as fixed frame. The configuration of the GPS (elvation mask, kalman filter, search algortihm). Think I must remove the path theory chapter. Insert a theory chapter about coordinate frames. Maybe a chapter about Kalman filtering.

3.3 Error sources

In order to get high accuracy in the position estimation the different error sources must be identified and removed if possible. This section will identify some of the larger error souces that can affect the gps signal, and how to remove them in the estimation. Link the error source to where they originate

3.3.1 Clock error

There is drift in both the satellite clock and the receiver clock. The atomic in the satellites makes the clock drift neglable from the user perspective. The receiver clock tend to drift, and if not taken into account will cause large deviations in the position estimate from the true position. This error is remove by including a fourth satellite in the position computation. The satellite clock drift is smaller, because the clock is an atomic clock. The receiver clock error can be relative large. The satellite clock error given in the satellite message.

Relative time different

3.3.2 Ionospheric and Trophospheric Delays

Effect of signals travelling through the atmosphere. Free electrons from ultraviolet rays ionize a portion of gas molecules. These influence electromagnetic wave propagation.

Ionospheric delay

Upper layer of the atmos

Troposheric delay

Tropshospheric: clody weather, rain or sun. Local effect. Is removed with DGPS

3.3.3 Ephemeris Errors (maa leses om; se foiler?)

Error from satellites out of position. Cannot be corrected locally, but are maintained by someone.

3.3.4 Multipath

Before the satellite signal reach the gnss antenna there is a chance that it has allready been reflected from a nearby surface. This is called multipath and cause a time delay in the gnss signal. Main source of error in DGPS. Cannot be removed.

3.4 Differential GPS

Differential GPS consist of at least two receivers, where one is called a base station and the rest rovers. The two receivers are within range of a communication channel over which they are communicating. There are two basic ways to implement DGPS. There is the position-space method and the range-space method. Only the latter will be covered in this thesis.

3.4.1 Interger Ambiguity Resolution

Fixed and Float Interger Amiguity is used to calculate the carrier phase

$$\phi(t) = \phi_u(t) - \phi^s(t - \tau) + N \tag{3.1}$$

Counting the periods from

Write about how the different strategies work

3.4.2 Error mitigation in DGPS

The advantage with DGPS is that two or more recivers can share the same error sources. This enable the solution system almost completely remove them.

3.4.3 RTK GPS

RTK GPS scarifies correctness in order to give a position estimate in real-time. ADD HERE RESEARCH IN THE RTK FIELD. Real time position is critical for a autonomous system to navigate to a given position.

PASS PÅ FOR Å GÅ INNOM SYSTEM SPEC. KUN TEORI OM RTK GPS Dynamic system can be solved in kinematic mode, or with a moving baseline. In kinematic mode the rover is allowed to move, but the base station is assumed stationary with a known position. In the case of a moving baseline both the rover and base station is allowed to move. The position of the base station is calculated in single mode. Without a known position of the base station the global position of the rover can never be better then if calculated in single mode. However the relative position of the rover from the base station is calculate accurately. There for from a local control systems per Need to write about baseline restrictions. In the case of this thesis is a moving baseline relevant.

Trade off between getting the position fast, and getting it right

Moving baseline restrictions. The base stations position is calculated with in single mode. The error in position to the base station is inherit by the rover. Source of error.

3.5 Interger Ambiguity Resolution

3.5.1 Search space minimization strategies

There are several search techniques that can be applied to resolve the integer ambiguity, but this section will only cover the "Least Square Ambiguity Decorrelation Adjustment" (LAMBDA) method which is the technique used in rtklib.

Chapter 4

System Components

This chapter contains a brief description of the system that has been used.

4.1 Software

This section contain the different software that is used in the x8 system. The control and guidance system is runs on Dune, and the missionplaner on Neptus. The x8 operation system is GLUED. The system is connected to the rtklib which is in communication with DUNE. The internal communication in DUNE is based on IMC messages

4.1.1 GLUED

Glued is a minimal Linux distribution that contain only the necessary packages to run an embedded system. Write why it's used, what is the advantage

4.1.2 Dune

Dune is a runtime environment for unmanned systems on-board software created by LSTS (Underwater Systems and Technology Laboratory) in Porto, Portugal. The environment type is called a middleware, which is seeing increase usage in unmanned systems. Can refer to ROS or MOOS middleware.

Dune works by setting up individual task that can dispatch and subscribe to different IMC messages. The IMC messages will be explained in 4.1.3 A type of middleware. write how to link rtklib with dune Refer to the dune wiki page

4.1.3 IMC

Write about the message structure and how it's connected to DUNE. Include how to make new messages.

4.1.4 Netpus

4.1.5 RTKLIB

Rtklib is open source program that can estimate the receiver position based on raw GPS data. It can be used both with a single receiver or differential gps in real time. The setup is based on a base station and a rover. The base station use the str2str app to create a tcp connection with the rovers rtkrcv app.

rtkrcv

Rtkrcv is the app program that calculate the position of the rovers antenna. Rtkrcv is configured with a moving baseline in order to get a fixed solution of the position estimate. Write about other design choices that affect the position output.

Rtkrcv can be configured to have two output streams. The structure of the output stream is given the rtklib manual (Site it correctly). The solution body is given is table Rtkrcv uses the LAMDA search strategy for finding the ambiguity for the

Header	**Content**
1 Time	a1
2 Receiver Position	The rover receive antenna position
3 Quality flag (Q)	The flag which indicates the solution quality. 1:Fixed 2:Float 5:Single
4 Number of valid satellites (ns)	The number of valid satellites for solution estimation.
5 Standard deviation	The estimated standard deviation of the solution assuming a priori error model and error parameters by the positioning options
6 Age of differential	The time difference between the observation data epochs of the rover receiver and base station in second.
7 Ratio factor	The ratio factor of "ratio-test" for standard integer ambiguity validation strategy

Table 4.1: Table 1.

solution.

str2str

Str2str is the app program that retrieve the ublox signal from the gps and sends over tcp to the rtkrcv app. The str2str is setup to either send RMTC 3 messages, or whatever is send in from the GPS. Since the str2str do not support to send ublox signal directly. How to write that the user should not specify the input format or the output format.

4.2 Physical system

This section outline the physical components in the x8 and the base station.

4.2.1 Beaglebone

The system runs on a Beaglebone. A beaglebone were prepared for mounting in a x8

4.2.2 The GPS receiver

Write about the Ublox LEA M8T gnss receiver. Also include that it support sending GPS and GLONASS data at the same time. Need to be configured. A receiver were prepare and mounted in the x8.

Chapter 5

Experimental testing

This chapter contain the result from the test that were performed. The goal with these test was to evaulate the ublox receiver againgst the pixi receiver, and to get a impresion on the accuracy to the rtklib solution with ublox. The comparison test was performed with the pixi and ublox connected to the same antenna at both the rover and the base station. Then the deviation in the position estimate can only come from the receivers. The accuracy test of the ublox was tested by performing the same manoeuvre several times.

5.1 Physical testing

5.1.1 Fly test

5.1.2 GPS test

Chapter 6

Conclusion and Discussion

6.1 Further work

Setup the reciver to use both gps and glonass raw data.

References