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POSITION CONTROL FOR AUTOMATIC LANDING OF UAV IN A NET ON SHIP

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Abstract

Automatic landing of a fixed wing Unmanned Aerial Vehicle (UAV) in a net on a ship require an accurate positioning system. There exist today high-end systems with such capability for special applications, e.g military systems and costly commercial systems, which restrict the availability of such systems. To increase the general availability these systems must consist of low-cost components. Here, an alternative is the use of low-cost Global Navigation Satellite System (GNSS) receivers and apply Real Time Kinematic GPS (RTK-GPS), which can provide centimeter level position accuracy. However the processing time for the RTK-GPS system results in degraded accuracy when exposed to highly dynamical behaviour.

This work present two alternative software and hardware position systems suitable for use in navigation system which apply RTK-GPS, namely Real-Time Kinematic Library (RTKLIB) with a Ublox Lea M8T receiver and a Piksi system. Both the Piksi and the Ublox receiver are single-frequency GNSS receivers. These systems will in this work be compared and their individual capability to provide accurate position estimate will be evaluated.

The RTK-GPS system is implemented in DUNE (DUNE:Unified Navigation Environment) framework running on an embedded payload computer on-board an Unmanned Aerial Vehicle (UAV).

The performance of these position systems are in this work investigated by experimental testing. The testing showed that the RTKLIB performed better than the Piski alternative, and further showed the tested navigation system provide sufficient quality for integration into a control and guidance system, allowing for automatic landing of an UAV in a net.

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Chapter 1

Introduction

1.1 Background and motivation

Recent development of flying UAVs has been recognized to provide an attractive alternative to work previously performed by manned operations. Typical work which has attracted attention includes inspection, aerial photography, environmental surveillance and search and rescue. Today UAVs are mostly operated over land, however in the future this will include over sea as well. This will give some challenges which must be overcome. One of these challenges is that the UAV need to be able to perform a automatic landing.

An UAV can provide an attractive alternative for many maritime operation where today manned aircraft or satellites is the only solution. In the maritime sector UAV can be used in iceberg management, monitoring of oil spills, search and rescue and maritime traffic monitoring.

An important premise for successful and safe UAV operation, in particular at sea, is the provision of a robust system for safe landing of the UAV on a vessel following completed operations. In order to perform an automatic landing a path planner, a guidance system, and an accurate position estimation system is required, in addition to the low level control system in the UAV.

Existing landing system can guide the UAV towards a net, but they are expensive and restricted to a few UAVs. A pilot can land the UAV, however a better alternative would be if the UAV could land it self by the use of a net. In order to make the UAV able to perform an automatic landing a minimum requirement is that it knows its position at any time. This will require a real time accurate position estimate. A highly accurate position sensor is expensive, however it's possible to achieve accurate solution with low cost sensors. This can be done by combining two GNSS receivers to estimate the relative position of one of the receivers in respect of the other receiver highly accurately. Then one of the receivers can be placed in the UAV, while the other on the vessel.

Automatic landing in a net has privously been successful performed in the NTNU MSc thesis [?].The thesis proposed a design that managed to land a UAV in a stationary net using RTK-GPS. However only 50% of the landing attempt was successful. An other successful automatic landing was done in the Stellenbosch University MSc thesis [?] using Differential GPS (DGPS). This MSc thesis gives a description on the control system required to perform an automatic landing, however the system in the thesis require a runway in order to land.

1.2 Literature review

Real Time Kinematic GPS (RTK-GPS) is a precise positioning technology that can obtain centimetre level accuracy by processing carrier phase measurement in the Global Positioning System (GPS) signal. A open source program, RTKLIB was presented in [?], which can be used in combination with low cost RTK-GPS able receivers. RTKLIB is used in this project work in combination with a Ublox LEA M8T receiver.

The use of RTK-GPS for accurate position estimation has been studied in [?]. The paper proposed how to create a low-cost RTK-GPS system that can accurate measure the position in 3D. They used raw GNSS data from the GNSS receiver and the program library Real-Time Kinematic Library (RTKLIB) to estimate the position of a trolley in real time.

Real Time Kinematic GPS (RTK-GPS) apply carrier phase measurement of the GNSS signal for position estimation. In order to get a accurate position estimate the integer ambiguity must be resolved. An integer ambiguity resolution strategy was proposed in [?], and demonstrated centimeter level accuracy for a baseline up to $2000km$. Further studies on integer ambiguity resolution strategies resolved in the Least-squares AMBiguity Decorrelation Adjustment (LAMBDA) strategy, which was proposed in [?], and further disused in [??]. The LAMBDA method has been wildly used, and has proven a quick strategy to resolve the integer ambiguity, which makes it ideal for RTK-GPS systems.

In the paper [?] it was studied high precision positioning of micro-sized UAV using RTK-GPS. The system used a GNSS receiver together with a ground based augmentation system as a base station. The use of a ground based augmentation system us advantageous if the UAV can communicate with the ground station. For UAV operations where information from a ground based augmentation system is not available a local reference station must be considered for RTK-GPS systems.

An alternative low-cost system that can be used for automatic landing is vision based landing system. In the paper [**?**] a vision based landing system, which would detect the recovery net, and plan a landing path is proposed. The system was successfully tested and is a valid alternative for a low-cost autonomous landing system. An other vision based landing system was proposed in [**?**]. This paper describes an intelligent vision aided landing system that can detect and generate landing waypoints for a unsurveyed airfield. The drawback with a vision based landing system is that it require much computational power. In addition the visual line of sight can quickly decrease during a operation.

1.3 Scope of work

The scope of this work is to validate the performance of suitable positioning systems by study and testing, and to identify gaps required to be closed for successful implementation for a integrated autonomous Guidance, Navigation and Control system which will allow for automatic landing of a UAV in a net on a ship.

An integrated system required for automatic landing will typically consist of four sub-systems as shown in figure **??**. Today these systems are individually available or in development; however not integrated into a proven working system allowing for automatic landing of UAVs. The four main systems comprises of the navigation part, the guidance part, the control part and the user interface.

The path planer and the guidance system used as basis for this work were developed as previous master thesis work [**?**]. A key component in the guidance system is the position estimation system, which was developed in the NTNU MSc thesis [**?**]. However, this system has been concluded to be in-sufficient with respect to provide means required for automatic landing.

The control and guidance system has currently only been tested in Software In the Loop (SIL) simulations with Ardupilot, which shows promising result likely to be sufficient for automatic landing applications. However this module has not yet been implemented to support the use of RTK-GPS as required for performing automatic landing.

This project work will continue the research done by Spockeli [**?**], and use a new GNSS receiver, namely the Ublox LEA M8T, that will be used together with the open source program, RTKLIB. The RTKLIB system is compared to the Piksi system from Swift Navigation. The real time position estimate from both systems are compared to a post-processed solution. The goal is to establish a system with accurate local position estimate, such that in the future a UAV net landing can be performed automatic. The navigation system must be accurate enough to correctly estimate if the UAV is following the generated landing path or if the deviation from the path is large enough such that an evasion manoeuvre is required. The position evasion criteria used in [?] is $\pm 1m$ cross-track error and $\pm 1m$ altitude error. The automatic net landing system will use RTK-GPS for relative position estimation. The main goal for this work is to describe the gaps of the available position system sufficient to scope further work required for closure of such gaps ultimately providing means for position estimating sufficient for completion of automatic landing.

This work will be done at the UAV-Lab, which is a research lab at NTNU. The UAV-Lab is a test facility for software and hardware, which include inertial navigations system,global satellite navigation systems and unmanned aerial systems.

1.4 Layout

This project work contain five chapters and one appendix. The chapter are indexed 1-5, and the appendix are indexed A. A short description of the chapters and appendix are given below.

– Chapter 2 UAV navigation system: Contains a general description of the Global Positioning System (GPS), in addition to how GPS is used in the navigation system.

– Chapter 3 System components and implementation: Describes the software and hardware components used in the navigation system, in addition to the implementation into the navigation system.

– Chapter 4 Experimental testing: Present the experimental results.

– Chapter 5 Closing discussion and conclusion: Summarize the conclusions draw from the result and provide recommendation for further work.

– Appendix A RTKLIB configuration: Present the configuration file for RTKLIB

References