Evaluation of an Open Source Realtime-Kinematic GPS Software Library

Andreas Gschossmann
University of Applied Sciences
Regensburg
Email: andreas.gschossmann@hs-regensburg.de

Prof. Dr. rer. nat. Rudolf Bierl
University of Applied Sciences
Regensburg
Email: rudolf.bierl@hs-regensburg.de

***Abstract*—The accuracy of GPS in general is about 5 meters. One possibility to get more exact values for outdoor positioning solutions is Real-Time Kinematic GPS (RTK-GPS). There is an open source library, written in ANSI-C, which provides algorithms using this method, called RTKLIB. It was developed at the Tokyo University of Marine Science and Technology and was published under the BSD 2-clause license. This paper will test the provided functions. It shows how robust they work in certain situations and provides measurements of the localisation results for both, static and moving objects. The standard deviation is determined and the measurements will be discussed.**

I. Introduction

A. Aim of the project

The main intention of this paper is to examine wether RTK-GPS is suitable for navigation applications of Unmaned Aerial Vehicles (UAV), especially quadrocopters. For this purpose the RTK-GPS library RTKLIB [1] was tested in two experimental setups:

- navigation solution of a moving object
- navigation solution of a static object

B. Quadrocopter GPS applications

Quadrocopters are multi rotor flying robots. During the last two years the number of quadrocopter applications have increased dramatically. This development is a consequence of the increasing price of suitable MEMS sensors. Their

- ability of Vertical Take Off and Landing (VTOL),
- good controlability of their direction of flight
- and their steady flight qualities

makes them good carriers for cameras and sensors. Thus they are a cheap option to replace helicopters in inspection tasks. Also they can be used to automize inspection tasks, which, up to now, have been carried out by persons. Among these applications there are several that need positioning solutions with submeter precision. One example is the detection of defect panels by overflying a solar field with a thermal camera and searching for heated areas on the solar panels. Due to the limited resolution of thermal cameras, that are light enough to be carried, the UAV has to fly in a height of about three to five meters. To be able to autonomously filming the solar panels without getting out of the filming area of the thermal camera submeter precision in navigation is necessary.

C. Realtime Kinematic GPS

The general accuracy of GPS without any corrections is less than $\pm 2.5m$ [4]. One of the errors GPS suffers is the fact, that the GPS signals are refracted at the ionosphere and thus travel more time than expected. Using differential GPS this error is compensated by using two GPS modules. One module, is fixed to a certain position (base). It computes correction data from knowing its real position and the measured GPS position and sends it to the moving GPS module (rover). This is like shown in figure 1.

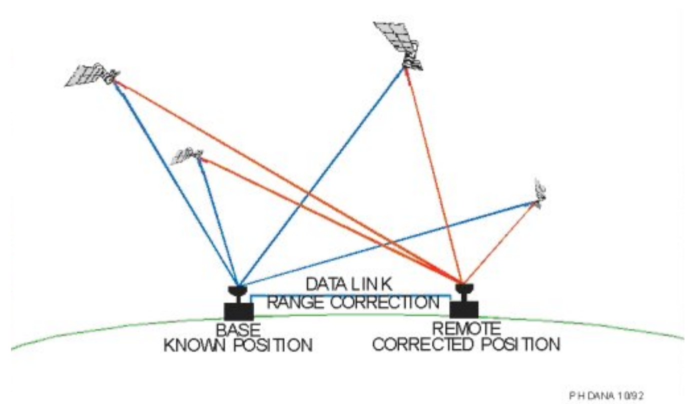

Fig. 1. Differential GPS [2]

RTK-GPS additionally measures the carrier phase information of the GPS/GLONAS/GALILEO signals. By this method also the L2 frequency, which is reserved mainly for military use, can be analyzed. Since only the raw data of the carrier phase is analyzed it is not dependent on the timestamp of transmitted modulated time information.

D. Result of the experiment

The measurements showed that the precision of RTKLIB is suitable for the expected navigation applications of Quadrocopters.

E. Structure of the paper

First it is explained how the experiment was set up and performed. After that an overview over the results of the experiment is given. In the end the results are being discussed and possible further steps are explained.

II. Experiment

A. Hardware configuration

For both, base and rover, uBlox LEA-6T GPS modules where used in combination with an active GPS antenna (ANN-MS-0-005). Since the base station may be placed at a hard-to-reach area, an arm based small computer is used in combination with an Li-ion battery. The GPS module is connected over USB to the base station. For the rover a laptop was used. Also the second GPS module connected by USB. To send the correction data the base station is connected to the rover by WLAN. Figure 2 is taken from the manual of RTKLIB. It shows the hardware configuration with the two PCs and also the software of RTKLIB running on the according platform.

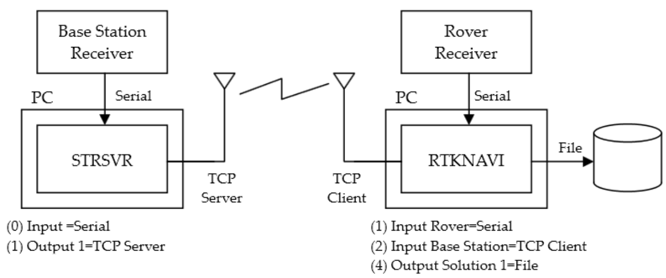

Fig. 2. Hardware mashup base and rover [2]

B. Software

RTKLIB in version 2.4.2 is used for the RTK-GPS computation. It runs on the base station and the rover. The operating system on the base station is a Debian based Linux. For this ARM-based platform RTKLIB had to be compiled. The operating system on the Rover is Windows 7. For Windows there already are compiled binaries of RTKLIB. To configure the GPS module on the base station a C++ driver was written for the uBlox module. On Windows u-center[5], a software provided by uBlox, is used for configuration of the gps module. The two computers where in the same WLAN network and communicating by TCP/IP. This is one of the features of RTKLIB.

RTKLIB accepts the uBlox protocol UBX, so the uBlox modules are configured to output UBX only. If NMEA is output as well, the RTKLIB looses track. Since RTKLIB analyses the barrier phase, RTKLIB needs the raw data of the uBlox gps module. It also needs the bare positioning solution. So the uBlox modules are configured to output these two messages. The update frequency of the uBlox module is set to 5 Hz and the baudrate is put to 115200 baud for both modules. The position of the base station was computed, by measuring the mean value of the GPS position over three hours. It is configured to *kinematic* mode. Only carrier phase L1 is being analysed, since it turned out, that RTKLIB becomes very slowly if it analyses more than one carrier phase.

C. Realisation

Figure 3 shows the locations of the base station and the rover for the first measurement on a map. The rover was kept on this position without moving. For 300 seconds, the corrected position solution of the rover was measured. The results of these measurments can be seen in figure 5 and figure 6.

Fig. 3. Base station and rover

For the second measurment, the base station was kept at the same place, as in the first measurment, but this time the target was moved for about 15 meters along the left border of the path. The yellow line in figure 4 shows the corrected position of the rover.

Fig. 4. Corrected position of the moving base

III. RESULTS

A. Measurement static target

Figure 5 and figure 6 show the first measurements, with the rover not moving. It shows the drift in meters of the longitude, latitude and height during 300 seconds.

The conditions for this measurment were very good, since the signal of 10 satalites was available. The longitude and the latitude are drifting several milimeters only. The drift of the height, with several centimeters is a bit higher. This fits perfectly with the results in [3].

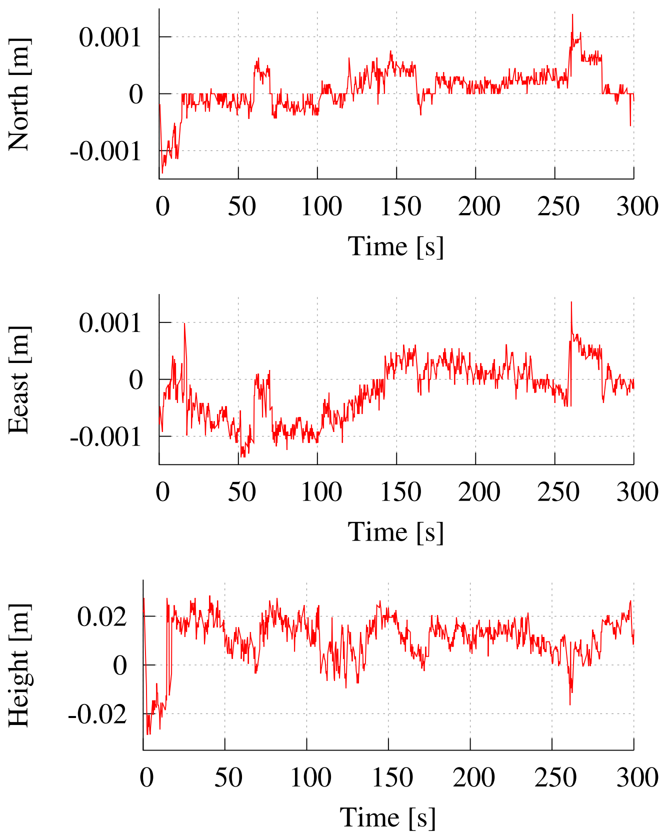

Fig. 5. Drifting of the longitude, latitude and height of a static target in 300 seconds

In figure 6 the longitude is plotted against the latitude. Also the 2σ circle is printed into this diagram. Just like figure 5, this clearly shows that results are even better, than the ones presented by [3]. This is on the one hand due to the many good signals of satellites, and on the other hand due to the fact, that the mean value of the position of the base station was computed over an exagerated long period of time, what leads to a more precise base position. Some of the measurements, not recorded, were not as good, but still had a precsion of several centimeters.

B. Measurement moving target

The results of the measurement of the moving target can be seen in figure 4. The only orientation for this measurement is

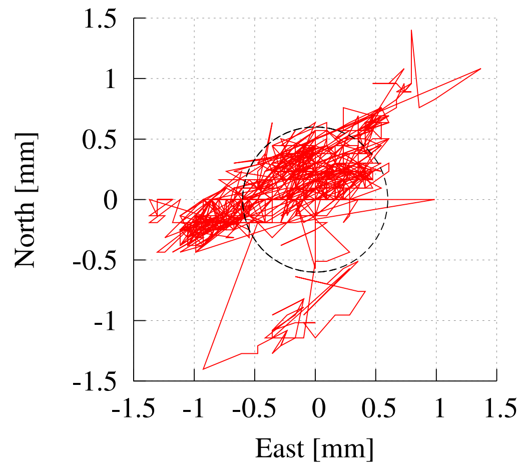

Fig. 6. 2D plot of the position of a static target

the left border of the path. It can be seen, that the border of the path is hit sufficiently with the requirement of submeter precision. The corrected position data during the movement never was older than 250 ms.

IV. DISCUSSION AND FURTHER STEPS

As the measurements show that the examined library is capable to supply a corrected GPS signal of centimeter precision under good conditions. The 2σ standard deviation for the 2D-plot in figure 6 is 0.6 mm only. The measurements of the moving objects showed precision of under one meter. For applications like the previously discribed inspection of solar panels this is sufficient. However there are still error sources for GPS, that cannot be prevented by RTKLIB. Using the quadrocopter near high building still causes obstructions of the signal. Further more all measurements were made with good weather conditions. Measurements with bad weather conditions have to be made too. Nevertheless, RTKLIB is a convincing solution for outdoor positioning of an UAV.

V. REFERENCES

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