Testing of UWB Sensors For Use in Multi-robot Relative Localization Systems and Design of UWB Plugin for ROS/Gazebo Simulation Environment

P. Raichl[1], P. Marcon[1]

[1]Faculty of Electrical Engineering and Communication, Brno University of Technology, 61600 Brno, Czech Republic

E-mail: xraich02@vut.cz, marcon@vut.cz

Abstract—This paper studies the possibility of using UWB sensors DWM1000 as a part of relative localization systems and a part of local avoidance systems in multi-robot systems, especially UAV swarms. The first part of the paper presents the behavior of UWB sensors DWM1000 in real, various conditions/environments. The second part of this paper describes ROS/Gazebo UWB plugin for relative localization. This plugin was created based on the first part of this paper and it is integrated with an open-source platform for UAVs from the Multi-robot Systems (MRS) group at the Department of Cybernetics, Faculty of Electrical Engineering, Czech Technical University in Prague. A Simple simulation of a multi-robot system with the designed, integrated plugin is shown.

Keywords—UWB, DWM1000, UAV Swarms, ROS, Gazebo, UWB plugin, UWB simulation, relative localization

1. INTRODUCTION

The coordination of multi-robot systems is a quite challenging issue and it is much more challenging when these robots are UAVs(Unmanned Aerial Vehicles), because of the different heights in which these robots can operate. To create the best movement action, the more global knowledge about the near environment every robot in the swarm has, the easier the problem is. The knowledge about the near environment, especially own position and velocity and position and velocity of coordination's partners, can be created by different types of sensors, cameras [1], infra-red emitters and receivers in specific layout [2] or UV LED markers [3].

In recent years, UWB technology has started to be used in indoor localization systems. The goal of this technology was to achieve high localization accuracy on distances higher than other technologies which can be used for localization systems such as WiFi, Bluetooth, and lower interference of signals. The Typical configuration of localization systems based on UWB modules is shown in fig. 1. This configuration consists of several anchors, i. e. UWB modules whose position is known and static, i.e. these modules are not moving, and 1 or more tags, UWB modules which are placed on moving robots and we are calculating their position. The minimal number of used UWB modules is 4(3 anchors, 1 tag), so the location of robots in the environment can be calculated by trilateration[4].

We intend to use UWB modules as a part of a relative localization system or as a part of a local avoidance system in multi-robot systems, especially UAV swarms. In this configuration, every robot measures its distance from others. As most of the papers are aimed at the study of UWB systems in an indoor environment, this paper brings knowledge of how UWB modules perform in indoor and outdoor conditions in an environment without obstacles between UWB modules.

Because building and testing of a relative positioning system for multi-robot systems is a quite difficult task where collisions between robots can occur, it is important to test every new feature of this system in simulation. Because we are using *ctu mrs platform*[1] [5] for our robots which is programmed in ROS and uses Gazebo environment for simulation, we need to design and program UWB plugin for this ecosystem because UWB plugin which could be used for simulation of relative positioning system doesn't exist. This plugin is also described in this paper.

[1]Open source platform for UAVs from Multi-robot Systems (MRS) group at Department of Cybernetics, Faculty of Electrical Engineering, Czech Technical University in Prague

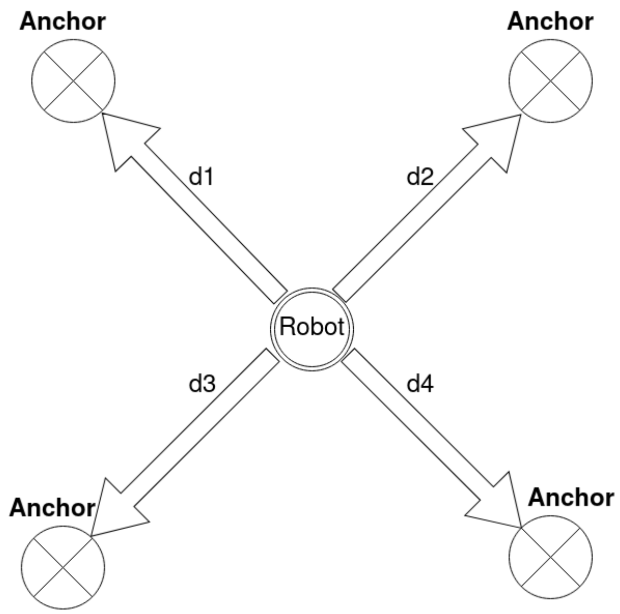

Figure 1: Classic UWB localization configuration

2. MATERIALS AND METHODS

Nowadays, several manufacturers offer UWB modules, for example, NXP, Apple, CEVA, Qorvo. For our experiments, Qorvo DWM1000 was chosen. It is a module that integrates the antenna and everything needed for using DW1000IC. This module uses the SPI bus for communication with a superior microcontroller, where the code is running. As a superior microcontroller we used ESP8266 on the WeMos D1 development kit.

UWB sensors were studied in 3 different environments: Anechoic laboratory, Classic laboratory, Outdoor open space without obstacles. Conditions of tests are described below for each environment.

Anechoic laboratory and Classic laboratory This is an indoor environment and it is used primarily to verify the function of used UWB sensors and to test the accuracy of sensors on short distances, i.e. from a few cm to a few m. The accuracy was determined by comparing the measured distances with known distances. Between UWB sensors there were no obstacles. The difference between these two kinds of laboratories is that the Anechoic laboratory has special material on the walls which prevents signal reflections. On the contrary, in the classic laboratory, there are a lot of equipment and walls which can cause signal reflections.

Outdoor open space This test was performed on the tennis court. The main purpose of this test was to find out if the accuracy from the laboratory can be achieved in outdoor space without obstacles. For this purpose, a tennis court was used.

UWB for relative positioning in multi-robot systems This approach is different from the typical configuration shown in fig. 1. In this approach every UWB module acts as a tag and anchor at the same time, i. e. every module calculates its distance from the others and this information can then be used for relative positioning in formation control or as a part of local collision avoidance system. This configuration is presented in fig. 2.

The information gained from measurements in different environments is used to design UWB Gazebo plugin. The plugin simulates the reception of UWB ranging measurements from different tags/anchors. The structure of the UWB plugin is shown in fig. 3. The plugin publishes into 2 topics: /uwb/tags - publishes its name. /uav/uwb - publishes distances to other UWB modules. The ranging message is similar to the output of UWB sensor DWM1000, see fig. 7. Every UWB module has to be paired with a robot by setting these parameters in *urdf file*[2]: model name, namespace..., see fig. 4.

[2]The Unified Robotic Description Format (URDF) is an XML file format used in ROS to describe all elements of a robot.

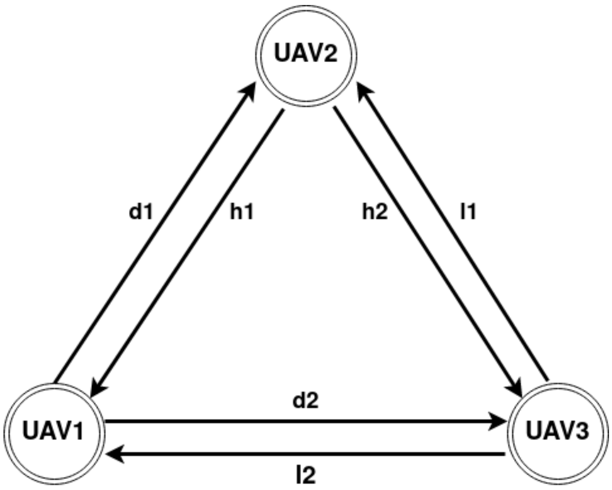

Figure 2: UWB Relative positioning approach

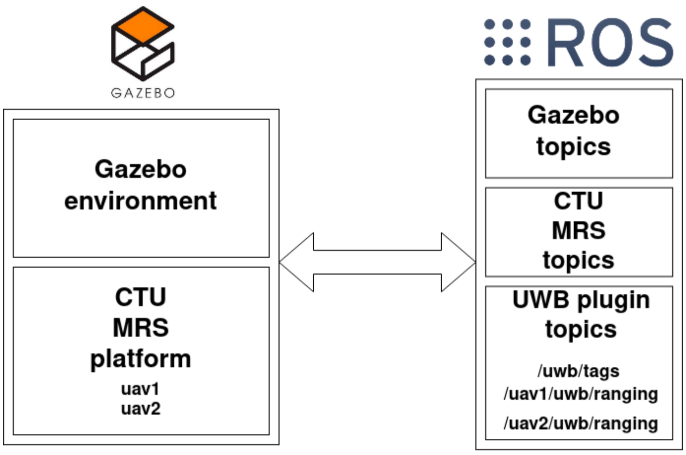

Figure 3: Structure of environment - topics

```
<gazebo>
  <plugin name='libuwb_plugin' filename='libuwb_plugin.so'>
    <update_rate>20</update_rate>
    <frequency>3.9936e9</frequency>
    <tag_link>right_tag</tag_link>
    <robot_namespace>${namespace}</robot_namespace>
  </plugin>
</gazebo>
```

Figure 4: Instalation of plugin - urdf file

3. RESULTS AND DISCUSSION

Figure 5 shows accuracy of UWB modules in Anechoic Lab and Classic lab. Accuracy in the graph is expressed as a relative error in the range of 30 to 220 cm. In the Anechoic laboratory, the accuracy agrees with datasheet information from the manufacturer, i. e. positioning accuracy is from 3 to 10 cm. In the Classic laboratory, the accuracy is worse, especially on short distances below 1m.

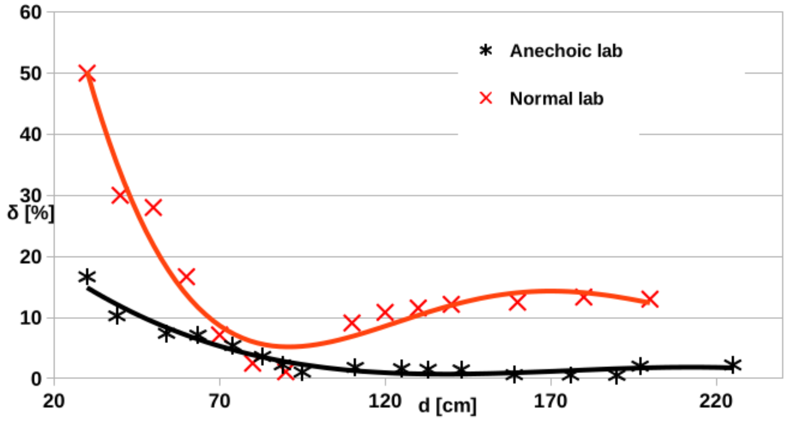

Figure 5: Measurement in the Anechoic Laboratory and the classic laboratory

In figure 6 relative error of UWB modules from outdoor measurement in the range of 100 cm to 10 m is shown. The relative error is about 4% which is relatively low when compared to measurement in Classic lab. It is probably due to limited signal reflections in the environment without obstacles. This approves that UWB modules could be used for relative positioning of UAVs in swarms in an outdoor environment at least when flying above obstacles or after fusion with information from other sensors, especially cameras and lidars.

It is important to note that rotation of antenna has significant effects on the accuracy of UWB modules when even small obstacles are around it, which could make our approach for relative positioning in UAVs swarms problematic as UAVs can have different tilts and headings and other parts of UAVs can play a role of obstacles.

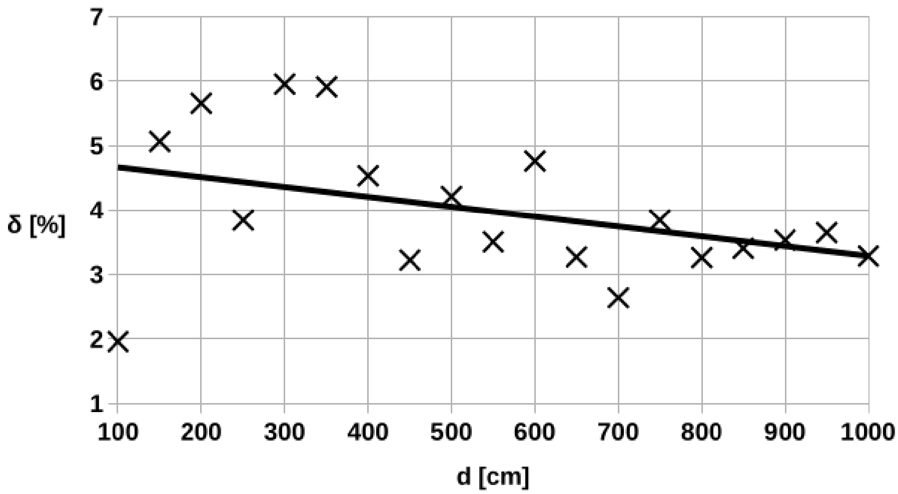

Figure 6: Measurement in the outdoor environment without obstacles

UWB plugin was integrated into ctu mrs architecture and simple simulation was done. In figure 7, there are 3 UAVs in simulation with integrated UWB plugin. Output from UWB topic was verified with ground true positions of robots. Verification was done for 3 different positions, see. tab. I. The positions match each other. The small difference between ground truth and UWB ranges is due to noise in UAV's movement and different timestamps of ground truth and UWB ranging.

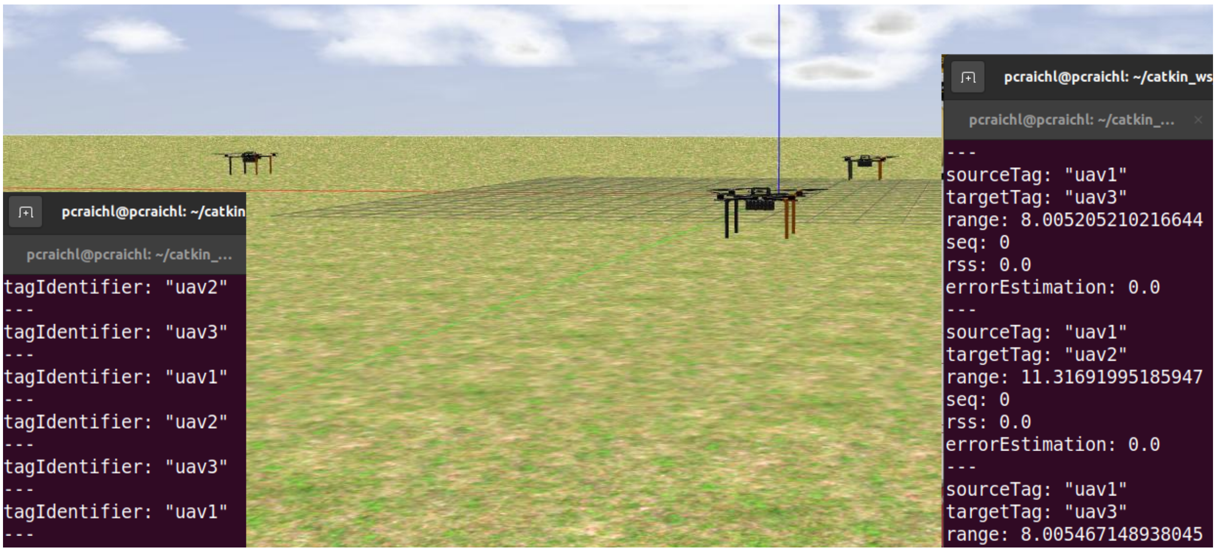

Figure 7: 3 UAVs simulation - ctu mrs platform

Table I: Ground truth distances vs distances produced by UWB plugin for uav1 and uav2

Ground truth distance	UWB plugin distance	Difference
4.3056	4.4156	0.11
7.2564	7.1689	-0.0875
11.6259	11.4169	-0.209

4. CONCLUSION

UWB modules DWM1000 from Decawave were tested in three different environments: Anechoic Laboratory, Classic Laboratory, and outdoor environment without obstacles. Accuracy of tested UWB modules represented by relative error is shown in fig. 5, 6. The results have shown that UWB modules could be used as a part of a relative positioning system in multi-robot systems, especially in the environment without obstacles or in heights above obstacles, where signal reflections are limited. ROS/Gazebo plugin of UWB modules was designed, integrated with ctu mrs platform, and tested in simple simulation with 3 UAVs, see fig. 7. In the future, the performance of UWB modules in an outdoor environment with obstacles could be tested.

ACKNOWLEDGMENT

This paper was funded from the general student development project at Brno University of Technology.

REFERENCES

[1] M Saska, J Vakula and L Preucil. Swarms of Micro Aerial Vehicles Stabilized Under a Visual Relative Localization. In ICRA2014: Proceedings of 2014 IEEE International Conference on Robotics and Automation. 2014, 3570–3575.

[2] J. Roberts and et al., ”3-d relative positioning sensor for indoor flying robots.” Autonomous Robots, vol. 33, no. 1-2, pp. 5-20, 2012

[3] A. Ahmad et al., ”Autonomous Aerial Swarming in GNSS-denied Environments with High Obstacle Density,” 2021 IEEE International Conference on Robotics and Automation (ICRA), 2021, pp. 570-576, doi: 10.1109/ICRA48506.2021.9561284.

[4] Liu, Liu, Bofeng Li, Ling Yang, and Tianxia Liu. 2020. ”Real-Time Indoor Positioning Approach Using iBeacons and Smartphone Sensors” Applied Sciences 10, no. 6: 2003. doi:10.3390/app10062003

[5] MRS UAV System - open source platform for UAV research. https://ctu-mrs.github.io/