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Wireless Ranging in Swarm Robotics

Some Department

Bachelor Thesis

Wireless Ranging in Swarm Robotics

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Finken
Ranging
Evaluation
Result

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1 Prior Art

1.1 The FINken Robot Platform

The FINken project aims to create a swarm of autonomously flying quadcopters to research swarm intelligence beheaviour on robots. Many algorithms in swarm intelligence are based on distance values. On this occasion it is important to find a sensor that is capable to measure distances and to integrate it into the FINken robots.

source

1.1.1 Robot Description

The FINken 3 robots are quadcopters controlled by the LisaMX 2.1 autopilot-board[1] using the opensource autopilot firmware Paparazzi[2]. The robots are propelled by four rotors that are directly attached to a brushless motor. In combination the motors can be controlled to change the direction of the thrustvector (pitch and roll), to change the overall amount of lift generated (thrust) and to change the orientation of the airframe (yaw). The airframe contains all the actuators, processors and batteries needed for flight. Additionally it carries a multitude of sensors used for operating autonomsly.

1.1.2 Environment

Creating a swarm of flying robots is a rather difficult task. The environment for the FINken robots is created to protect the robots from mechanical damage and to function well with the sensors the robot uses.

The FINken robots fly in an area of 2 m by 3 m that can be expanded to about 3 m by 4 m. The flight area is enclosed by netting and ultrasound-reflecting foil those barriers act the same way a wall would without damaging the robots if they fail to elude them. Usually the altitude of operation is between 0.5 m to 1 m. To prevent damage when the quadcopters crash the floor is coverd with mats that work well with ultrasound and infrared sensors. It is possible to create virtual environmental factors by using a projector and an rgb-sensor mounted on top of the robots. This virtual environment can be used assign a certain task to the robot, e.g. finding the brightest spot.

foto

1.1.3 Dynamic Beheavior

put this subchapter into introduction

The robots are highly dynamic-the robots have enough acceleration to leave the operating environment in any possible direction. This is mainly because the robots need lots of payload capacity to carry different sensors and computing power, with enough headroom to make changes in the future. Even if the high power of the motors is not utilized stability is a problem. If the copter is angled by only 6° and it's height is kept stable it is accelerating at about $1\,\mathrm{m\,s^{-2}}$

1.1.4 Sensor Concept

The sensors used by the FINken robots serve two purposes: To enable the robots to fly autonomsly and to interact with other robots and the environment.

Autonomous Flying

To form a swarm the robots need to function as single individuals first-that means not crashing into walls, ceiling, floor or other robots. Of course the sensors needed for autonoms flight must not be disturbed by anything else.

The flight dynamics of the FINken robots shall be as simple as possible. The robots shall be able to fly at a given height and navigate in x-y-direction to perform their given tasks. Highly dynamic maneuvers are possible for the airframe, but are not realizable with the sensor data we currently get.

ref to christophs ba

For flying autonomously two major problems have to be solved: Height control and navigation. For controlling the height of the copters either the ultrasound distance measurement of the optical flow sensors are used, alternativly the height is measured by an infrared sensor that must be equipped when the optical flow sensors are not.

Navigating the x-y-plane is a much harder task. Because sensors are not perfect the copter will drift in any given direction and precise speed and position measurements are hard to get by. As a consequence implementing a position hold mode is quite a challenge. Assuming that a stable position can not be kept there is still something that can be done to fly for longer time periods. With an ultrasound distance sensor in each direction the robot can sense its surroundings and avoid any obstacles in its vicinity. An essential precondition for navigating around obstacles that way is a certian level of stability and avoiding highly dynamic maneuvers.

wording

Interaction

The FINken robots shall be able to do more than simply not crashing. Of course sensor values needed for autonomous flight can also be used to interact with the robots environment, but there are also senors that are exclusively used for interaction.

To interact with an environment a solution is necessary that works well in the laboratry. The environment of the robots shall be changed without changing the physical layout of the lab. An environmental factor that can be easily changed is the lighting of the flying area. In the swarmlab a projector can be used to affect the quadcopters. To measure the current lighting situation an rgb color sensor is mounted on top of the copter.

The range-sensor is also mainly used for interaction. Ranging values enable the FINken robots to implement attraction-repulsion-beheaviour.

1.1.5 Hardware interfering with ranging

There are different ranging technologies that might be used in a FINken quadcopter. However there are different components that can interfere with the new sensor that shall be integrated e.g. by disturbing the measurments made by the new sensor.

Sonar Sensors Sonar sensors to measure distances of the nearest object in four directions (front, back, left, right)

Motors Four brushless motors that may cause RF-interfercene and noise

Telemetry BTLE-/Zigbee modules to exchange data with the ground station

RC-Control 2.4GHz based Radio Control to manually control the robots

fink3?

Supply Lithium polymer batteries with nominally 6.6V output voltage that is converted to 5V and 3.3V by the power distribution hardware

weight

payload

Payload The overall weight of the copter in the current configuration is about g with about g headroom for additional equipment

Size The copter has a rotor to rotor distance of 10cm, and a sensor tower that is about 4cm by 4cm wide to use the existing mounting holes would be favourable

1.2 Evaluation of Existing Ranging Solutions

mehr fokus auf andere copter projekte

There are some technologies that can be used for ranging, however the usual application for most of those technologies in research is positioning. For that reason it is interesting to search for positioning applications that use range measurements, however many of those positioning technologies are base on other principles than multilateration[1]. [3]

The usual technologies used for ranging are based on time of flight measurments, signal strength, optical tracking, and phase diffence measurments in signals.

1.2.1 Indor Time of Flight

The obvious approach for replacing the GPS signal is to use a simmilar approach indoors.

wording

The problem is that very short timespans have to be measured accuratly, because radio waves are so damn fast. [12] states, that standard errors of

[1]The usual methods for positioning are: *multilateral*—which is what we are interested in because only ranging measurments are used, *multiangular*—which is no use to us, because angle measurements are used and by *orientating in a map* with different factors like beacon-positions–which is also no use to us.

$2.6\,\mathrm{m_{RMS}}$ and $1.8\,\mathrm{m_{RMS}}$ was measured in different indoor scenarios. With an operating area only 3 m wide this approach is not suited for our robots.

A project that looks more promising is decaWave. According to [11] the measurement error is generally under 1 m and with filtering can be brought to below 15 cm. The proposed method of filtering needs 27 measurements to compute one range value.However the decaWave project was unkown to us when we started looking for ranging possibilities so

wording

blabla

1.2.2 Cricket / Active Bat

A very clever approach to ranging is used by ranging solutions like cricket[16] and active bat[20]. RF-Signals travel at the speed of light and therefore you need to be able to measure very short timings in time of flight scenarios. Sound however travels at a speed much slower than radio waves. The same principle can be applied when you measuring the distance of a lightning strike by measuring the time between thunder and lightning. Cricket and Active Bat also measure the time difference an RF-signal and an ultrasound pulse need to travel from transmitter to reciever to calculate the range between two sensor nodes.

A bad side effect of using sound as medium to the ranging method is that there is an upper bound to the update frequency for all nodes sharing the medium (i.e. close enough to sense each other). [20] claims that one ranging measurement can be done in a 20 ms slot. That means we can have 50 range updates per second. Assuming we have a swarm of five robots that form a fully connected graph we would need at least ten range measurements to get all swarm distances. So the upper boundary for ranging update frequency in a swarm of five robots is 5 Hz. Considering that this is the upper limit this is a solid disadvantage of this method. Furthermore the FINken robots currently use sonar based distance sensor to measure the distance to the nearest object in some direction so either the update frequency would be diminished much further or the sonar sensors needed to be replaced

accuracy / price, moving objects

Ultrasonic ranging on quadcopters is done by [8]

Another problem is the noise created by motors and propellers. The sound made by the quadcopters is not ending in the hearable spectrum but also extends to the ultrasound range. In conclusion ultrasound based ranging is a very neat approach that could be integrated into the FINken robots, but the current setup that already includes sonar sensors make this approach impractical.

1.2.3 RSSI-based ranging

A property that can be used to do RF-based ranging is signal strength. The further the source of the signal is away the weaker the signal gets. RSSI-based ranging is done for serveral different technologies: Bluetooth, WLAN, RFID– There are even approaches using maps created of different RSSI-ranging sources. http://www.gnss.com.au/JoGPS/v9n2/JoGPS_v9n2p122-130.pdf

quelle

quelle

quelle

quellify

The main factor that rules out RSSI-based ranging is that radio-waves are not propageted equally in every direction. Antenna-orientation might have a much bigger impact on signal strength than distance. Additionally radio waves might be weakend when travelling through the FINken robots and by doing so passing wires and electronic components.

typical propagation pattern picture

1.2.4 External Tracking

Most projects use external tracking to measure the position and orientation of the quadcopters. The most common optical tracking systems are very costly in comparison to the other ranging methods described here. This price is justified by the superior performance of this method.

refs

This means tracking accuracy as well as the possibility to measure orientation. All that at a high update frequency.

research performance statistics for ranging solutions

ETH, tracking, sensorik foo

A huge drawback to this method is that many components are used that need to be integrated into the environment and cannot be carried by the robots themselves. For swarm robotics this is not an ideal solution as using external tracking would mean communicating with some kind of centralized tracking interface-destroying the scalability and the priciple of local interaction leading to global beheaviour.

price

1.2.5 Atmel RTB, Dresden Elektronik, Meterionic

Another thing that can be measured phase shift. This is a principle that is used by some of the ultrasonic methods. However the phase difference can also be measured in radio waves. This is utilized by the ranging hardware from the Atmel Ranging Toolbox. Multiple frequencys are used to measure a phase difference. Because the wave length changes with different frequencys you can take all of the measured phase differences and compute a distance. Similar hardware using the same software stack is also sold by *Dresden Elektronik* and *Meterionic*.

quelle

Using phase differences in RF discards the medium access problems of ultrasonic methods as well as the wave propagation problems of RSSI-based methods. Therefore it seems like a feasible approach for the FINken robots.

2 Concept

2.1 Hardware

2.1.1 Ranging Hardware

There are several different possible hardware plattforms for the Atmel ranging software. At the time this thesis started however we only had a precompiled libary for the Atmel ranging modules . For the evaluation scenario those modules are quite useable, but there are better options available with the binaries for other hardware plattforms. On the copters we want to use $Module from dresden elektronik which is already integrated into the new hardware revision of the FINken robots.

exact name

The disadvantage of the Atmel sensors is that they are not designed for production use but as development plattforms and therefore are quite big and heavy and not really suited to be used on the FINken quadcopters. It is possible however to build a simmilar hardware setup that is much smaller by using smaller packages of the same chips, leaving lots of unused PCB area and unused connectors.

2.1.2 Autopilot

The FINken robots use the LISA/MX autopilot board in hardware revision 2.1. This board is used for higher level auto pilot functions as well as pure stabilization–unlike other UAV projects where there are different units for stabilization control and higher levelfunctions like pathfinding. This means that all sensors are connected to this board; every computation from evaluation of sensor input to the output of PWM signals to the motors controllers is done on this board.

2.2 Interconnect

There are diffrent solutions to connecting the ranging board to the Paparazzi autopilot. All of the following methods of connecting hardware are supported by the LISA/MX board and one has to be chosen for the new ranging sensors.

2.2.1 Pulse width modulation / Analog value

Using a single GPIO pin or analog value is completely impractical, but a good example to explain the problems the honest solutions need to address.

First of all there is a limited number of GPIO or ADC-pins on both boards. On the autopilot board those pins are quite rare, especially because they cannot be shared easily between components. The second problem is that we do not only need to read a range value from the sensor but we also need to tell the sensor which value to fetch. Therefore some kind of bidirectional communication between autopilot and sensor need to take place. The big advantage of using a GPIO pin would be that only one single wire[1] would be needed to connect autopilot and sensor.

2.2.2 UART

The "Universal Asynchronous Receiver/Transmitter"-Protocol uses two wires to establish communication between devices. [19]

The Disadvantage of UART-style Protocols is that it is a bidirectional connection. That two pins are needed on sender and reciever side and if another device should be connected two new pins are needed. On the Lisa/MX autopilot there are four dedicated UART connections that might be used, but already three of them are used.

[1]Plus two wires for voltage supply

2.2.3 SPI

2.2.4 CAN bus

2.2.5 I2C

I2C is a two wired bus protocol that can be used to connect multiple slave devices to one master device. There already are multiple sensors connected to the autopilot via I2C. All of the ultrasound-sensors and also the optionalcolorsensor use I2C to communicate with the autopilot. The autopilot board also supports to have two independent i2c-networks.

Especially the fact that there already is a sensor network on the FINken makes it the best choice as a communication protocol for the new sensor.

problem: slaves can block the bus

3 Implementation

Somehow the sensordata needs to find its way into the control loops of the autopilot. We have established that i2c is the hardware solution to transmit the data.

Now it is important to pin down in which way the measurements get triggert and when and how the result is transmitted back.

3.1 Communication Protocol

There are two possible ways to talk to the sensor. You can define independent commands to start a measurement and retrieve data. The obvious disatvantage of this method is, that there is a bit of communication overhead and the master device won't read the data from the sensor as soon as it is possible—the master might event start a new measurement without even reading the result at all.

The other way to do things is that the slave device writes the data onto the bus as soon as it is arriving. This way of sending results however has disatvantages that ar e far worse then reading measurements a bit later and even missing some measurements. Those disatvantages are caused by the way i2c handles slave writes.

The sensor has different functions described by i2c-registers that can be written to by the master device. The registers and the format of the range response are described by *i2c_interface.h*.

Another design decision that has to be made is how the data structure for ranging results should look like. Obviously the measured distance needs to be included in the message, but instead of the original 32-Bit value only a 16-Bit value is used, as distances up to more than 60 m can be expressed that way.

status, dqf, range, addresses, message id

Byte	Name	Description
0x0	ECHO	return payload byte
0x1	START_RANGING	trigger range measurement
0x3	START_REMOTE_RANGING	trigger remote measurement
0x2	READ_LAST_RANGING	read measured distance
0xFE	SET_I2C_ADDRESS	set new i2c address
0xFD	SET_SHORT_ADDRESS	set new ranging short address
0xFC	SET_REFLECTOR_ADDRESS	set reflector address
0xFB	SET_INITIATOR_ADDRESS	set initiator address
0xED	GET_SHORT_ADDRESS	get ranging address
0xEC	GET_REFLECTOR_ADDRESS	get reflector address
0xEB	GET_INITIATOR_ADDRESS	get initiator address
0xFF	CLEAR_BUFFER	clear i2c write buffer
0xCA	SET_FREQ_START	set lower ranging frequency
0xCB	SET_FREQ_STEP	set ranging frequency spacing
0xCC	I2C_SET_FREQ_STOP	set upper frequency
0xCD	SET_DIVERSITY	turn on/off antenna bdiversity

Table 3.1: Implemented I2C-Commands and Description

The dqf value also needs to be transmitted, as the sensor node can not decide in wich way the values should be used by the master device, i.e. making application dependent filtering more accurate[1]. In secenarios with multiple ranging nodes or remote ranging the addresses of both nodes taking part in the range measurement also need to be included into the message. This information enables the master device to assign the range values to the right pair of devices, even if one of the messages gets lost or the order of measurements changes.

Depending on the setup the sensor nodes do not communicate measurement failures, but retransmit the old values again. As a consequence two more values should be transmitted: The status of the measurement and a message id. Those values enable the client to discard erroneous measurements and duplicate readings.

"TWI", "Phillips-I2C", "..."

[1] An application were the dqf-value is of much use is a Kalman-State-Filter, which could gain accuracy by using the dqf value to estimate the reliability of the range values.

3.2 Paparazzi Module for Ranging

Treiber für Ranging

(optional)Treibe für Pseudo GPS

Addressing is done using the unique aircraft id of the indivdual robots. Because the short addresses for the ranging nodes are 16 bit long and the aircraft ids are 8 bit values it is feasable to use a fixed prefix together with the ac-id as node addresses.

3.3 Python Scripts

For testing the sensor nodes and also for aquiering the data for evaluating the sensors I set up a RapsberryPi minicomputer as i2c master. Using this setup for testing has proven really effective even before integrating attaching the sensor nodes to one of the finken robots. Python might also be a very powerfull tool to prototype mathematical processing of the sensor inputs like filtering and fusion of different ranging results.

i2cranging.py contains functions for the master side of I2C communication. Those can either be used from the python PEPL or by other scripts. *poll_range.py* contains a convenient method to take continous range readings from the unix shell and is mainly used to generate csv-files with ranging values.

4 Evaluation

4.1 Robustness of Implementation

For use in the FINken robots not only the quality of the measurements is relevant. The sensor also needs to be well integrated into the autopilot framework.

With the current hardware this integration can not be done completly, because the current hardware plattform is simply to big to fly. This step of integration will be done with the . de-modules

4.1.1 Bus hangup

I2C is an easy to implement and use bus protocol. One of the drawbacks of I2C is that misbehaving clients are able to block the whole bus. As a consequence a malfunctioning sensor might render the others sensors useless, in worst case crashing the copter.

At the moment the ranging sensors cause bus hangups, when rangings are requested to often. measure

4.1.2 i2c errors per time

Another problem that may occure is that i2c data packets can get lost. This would mean the autopilot has to rely on expired data and it might break any kind of derivate computed from the range value . jaja, als ob man da was sinvolles ausrechnen könnte :(measure

4.1.3 Integration Test for Quadcopter

4.2 Ranging Accuracy

The most important question for the FINken project is: "Can the ranging values be used by the FINken robots". To answer this question some understanding of the magnitude and distribution of the ranging error is needed.

Finding out how accurate the range values actually are proves rather diffucult, because there are lots of interdependend variables that influence ranging accuracy.

4.2.1 Frequency Selection

move to implementation?

The frequencys used by the ranging can be chosen by the user of the ranging nodes, however frequency selection greatly influences the quality of the measurements. This is especially because normal 2.4 GHz wifi and serveral other technologies are using the same frequencys as the ranging modules the selection of a well working one is crucial to ranging performance. In section 4.2.1 there is an analysis on the frequency utilization on wifi channel 6. A download was started and then ended which is noticable in the waterfall plot.

Comparing the utilization on this channel with the frequency range shown in Figure 4.2.1 which is right next to the first frequency used by the ranging modules several things can be noticed. The noise in the frequency range for ranging is much lower then on frequencys with used for wifi—about 15 dB in average and 20 dB in peak. You can also see the peak generated by the ranging modules. The line at the center frequency 2.4831 GHz is an artifact created by the SDR that was used, but the line at 2.483 GHz is created by the ranging modules (which is exactly why the center frequency was chosen right next to the actual frequency). You can already see that the peak can still be lost in noise like it is shown in the FFT plot but is very stable over time as you can see in the waterfall plot.

Because of the lower utilization of those frequencys a range of 2.480 GHz to 2.500 GHz has been chosen. All the frequencys in this range look quite simmilar to the sample taken at Figure 4.2.1. This values have to be taken with a grain of salt. It is really hard to reproduce what kind of RF-noise interfering with the nodes is currently generated in the swarmlab.

There are other factors that impact ranging quality that can not be measured that easily – at least the quality of the antennas for different frequencies and the impact of the number of aviable channels in the frequency range and channel spacing are variables that can not be directly measured in our lab[1]. In the end this means finding the right parameters for ranging frequency settings is a really hard problem, especially because measuring the ranging error over many frequencys takes lots of labtime. It is not viable to measure all aviable combinations for those parameters.

Find out antanna measurements / calibrated antennas

wording

labtime + lab utilization ... ? or is this to mimimi

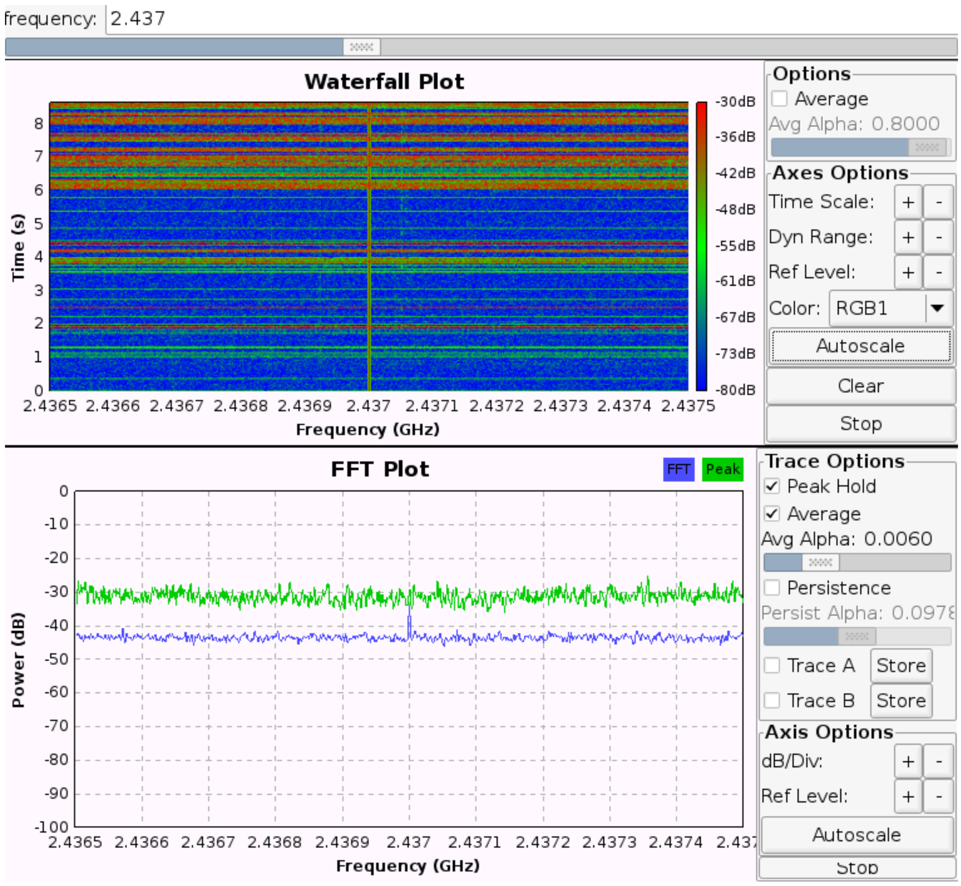

Figure 4.1: RF-Spectrum on 2.437 GHz

[1]The sourcecode and algorithms used by the modules is closed source, so we are not able to infere the effect of channel spacing and number of channels from that.

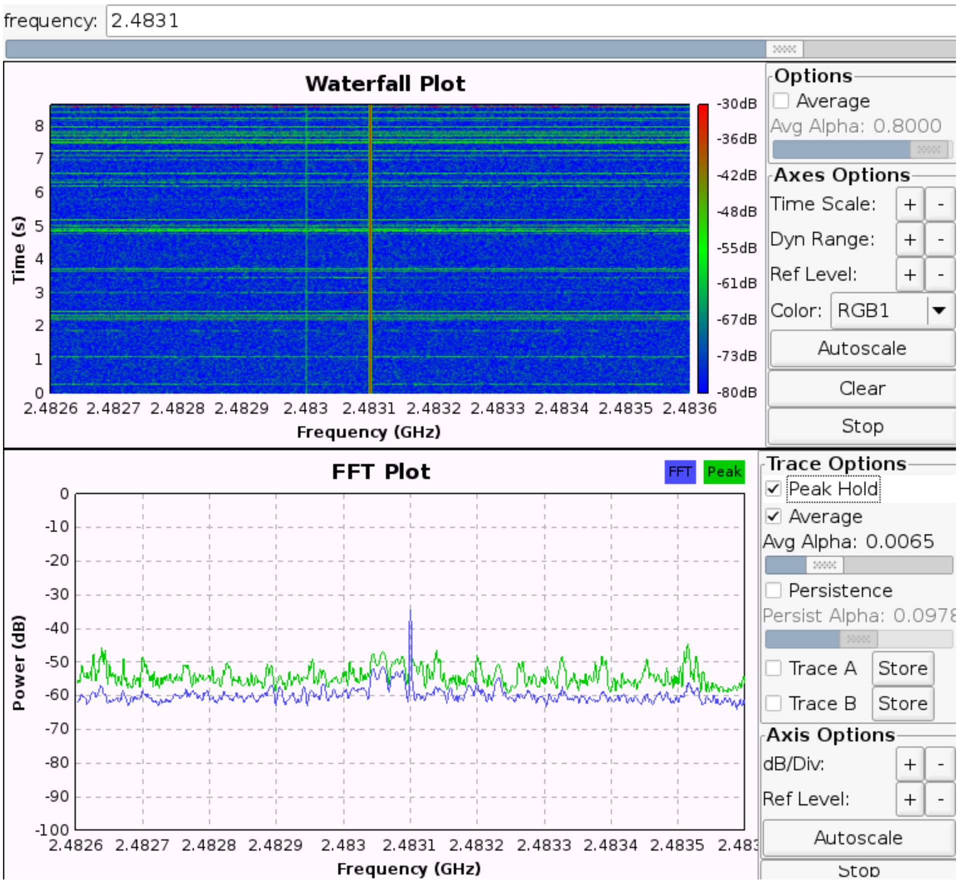

Figure 4.2: RF-Spectrum on 2.483 GHz

4.2.2 Influence of DQF on Range Values

One value the ranging api provides is the DQF[2]-value. It is reasonable to expect a huge amount of scatter for lower DQF values. As Figure 4.3 shows this is not how the range value behaves.

For the values measured with 1 m real distance we can see that the values meassered with lower quality do not have the same mean value as those with higher quality. Also values measured with lower quality are closer to each other than those with higher signal quality. As long as we only look at the values taken at 1 m real distance it seams like we could be able to improve the range estimate by including the dqf value into the computation of the distance. To

[2]Data Quality Factor

do that this behaviour would need to be stable accross different distances, i.e. no matter if the measurement is taken at 1 m or 3 m distance the when the dqf is low the measured range is lower and if dqf is high the measured range is higher.

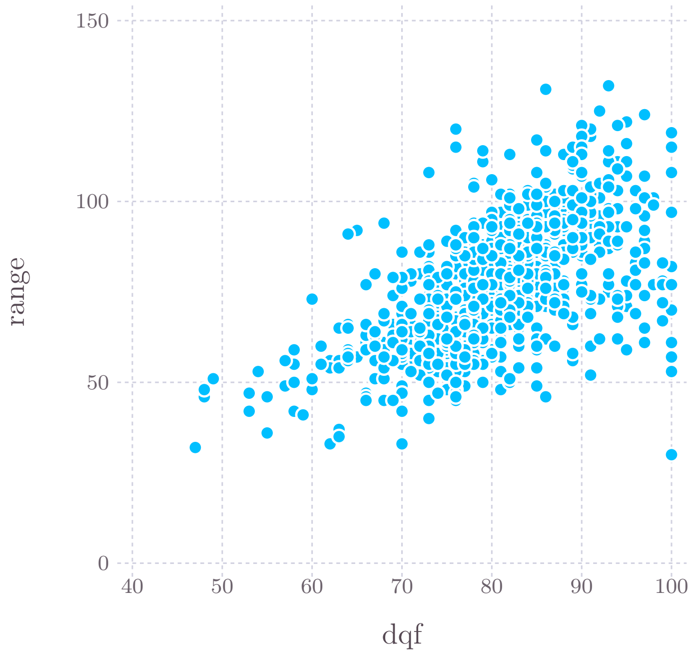

Figure 4.3: 1000 values measured at 1 m distance

Figure 4.4 shows measurements taken at different distances. The values for further distances have far more noise than values for lower distances. This leads to bad consequences.

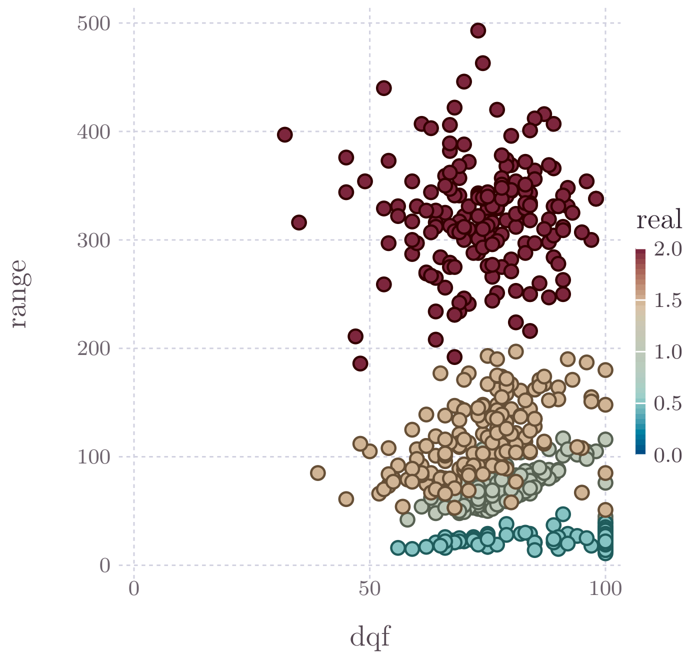

Figure 4.4: values measured at 0.5 m to 2 m real distance

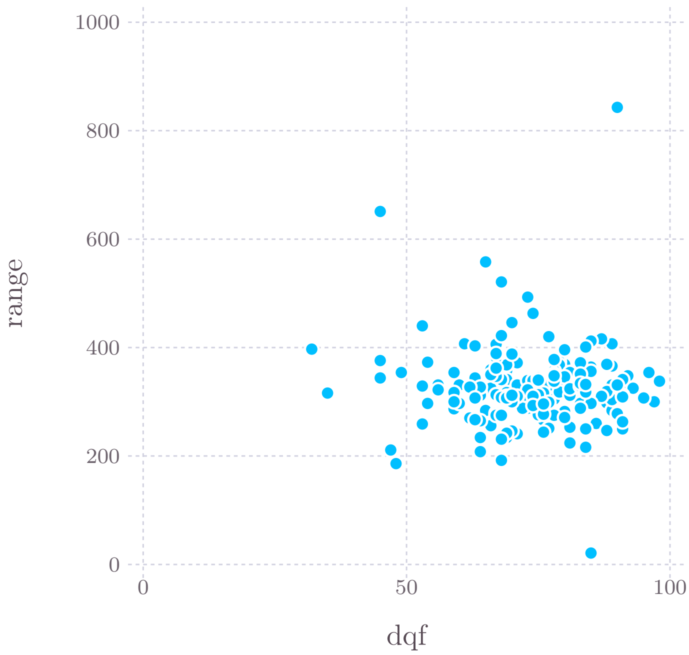

Figure 4.5: 100 values measured at 2 m distance

4.2.3 Influence of Distance

It is important to know how the ranging nodes behave at different distances. In Figure 4.6 this relationship is shown. The results are not what was hoped for when the hardware was selected. As you can see in Figure 4.6 the lower values yielded for any given distance might be in the intervall yielded for pretty much all distances. Additionaly the mean values are not even nearly monotone, there are some irregularities in the values where a higher distance leads to lower range values.

prettify

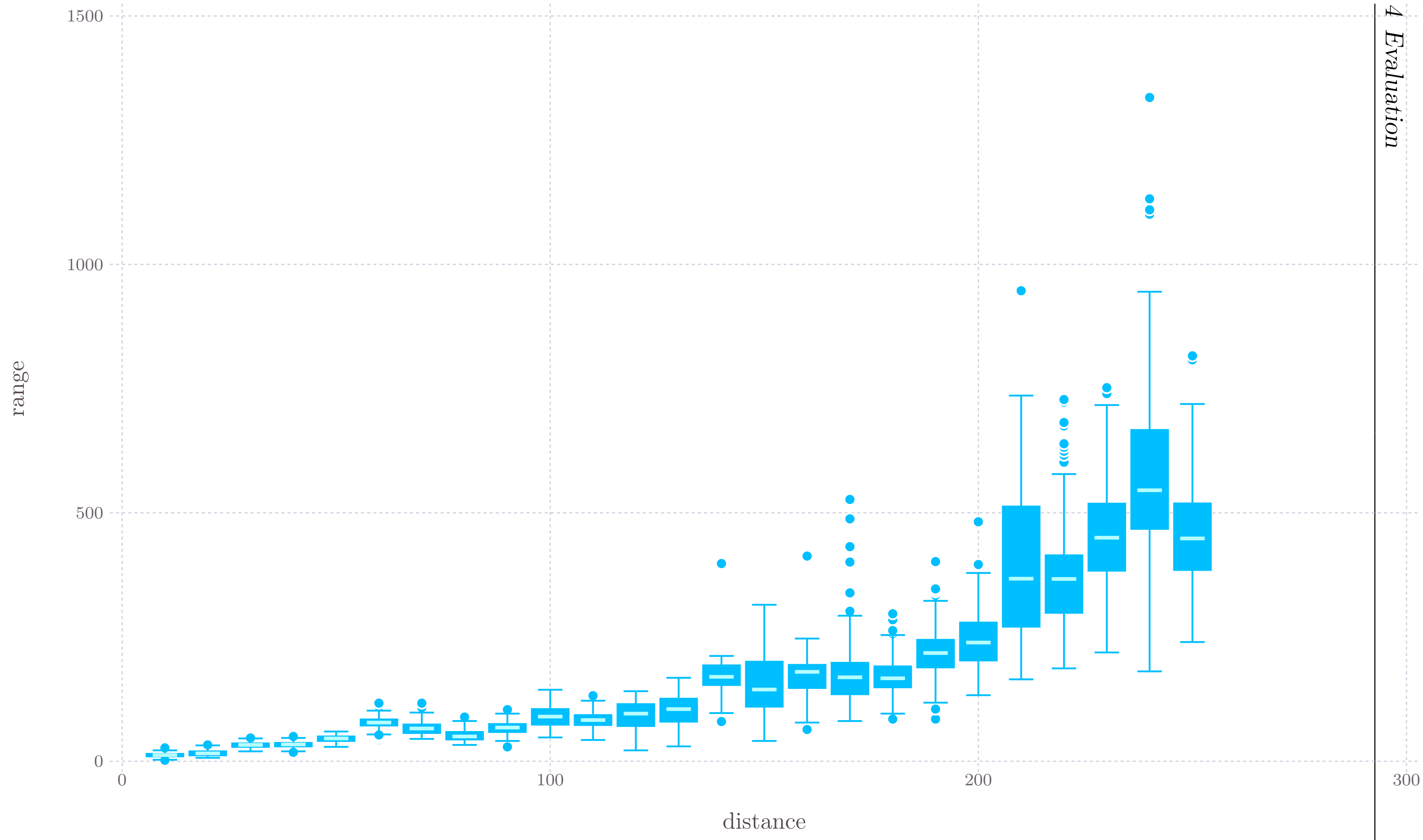

Figure 4.6: range values and real distance

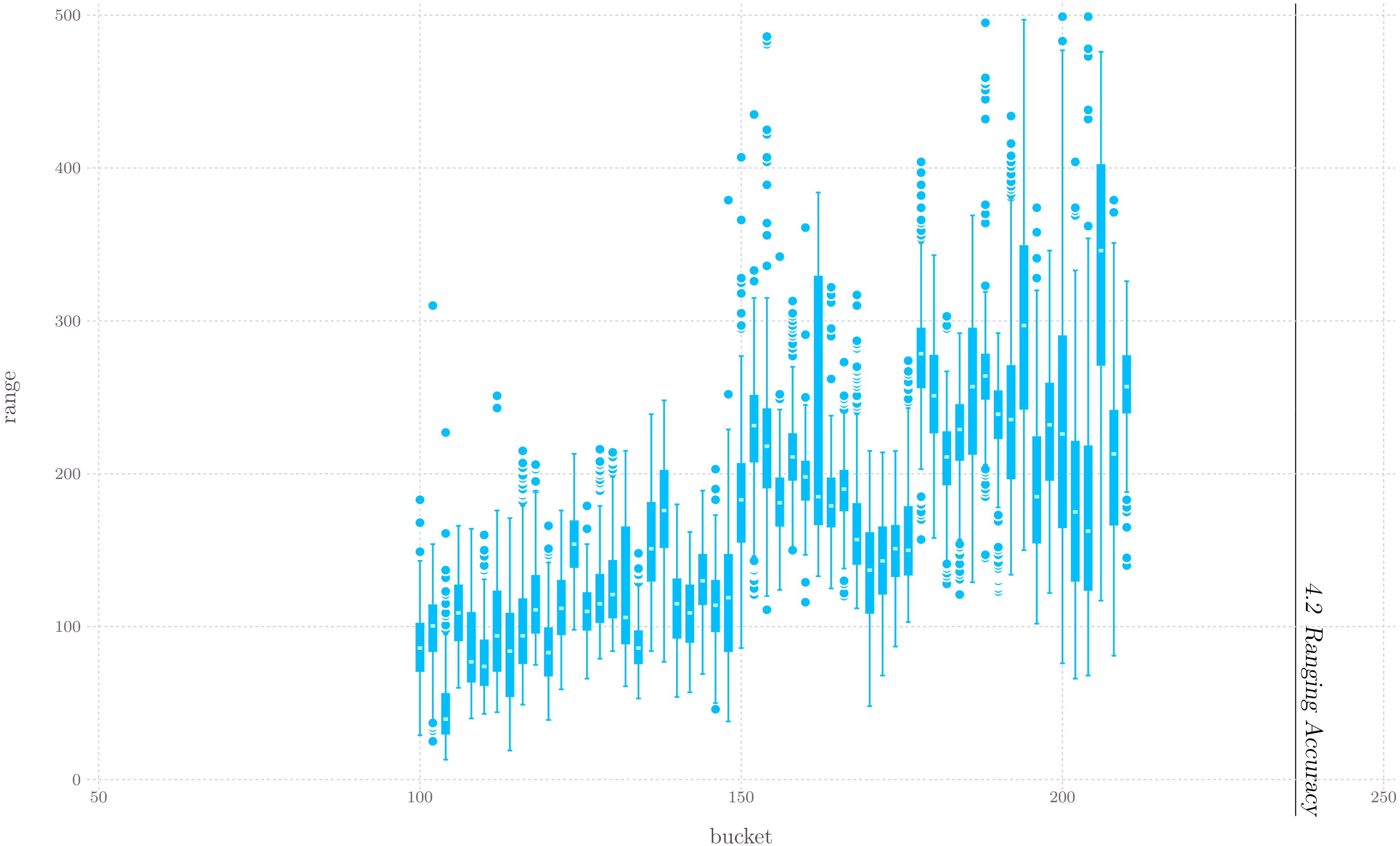

Figure 4.7: Range values with 1 cm resolution

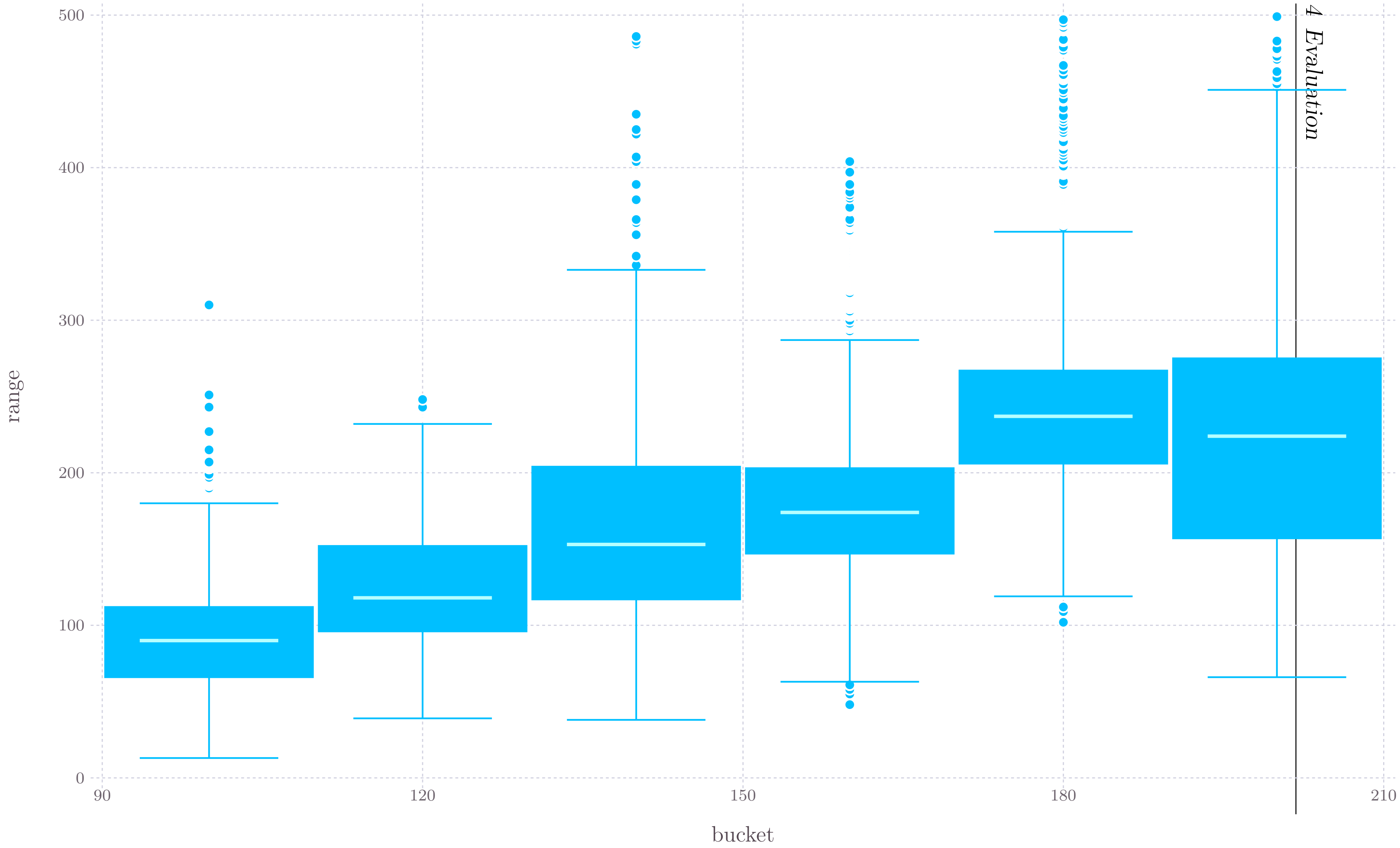

Figure 4.8: Range values with 1 cm resolution, with bucket size of 20 cm

Looking at a smaller resolution of distance values you can see exactly the same thing. This seems very bad at first glance. However the values look much better when multiple readings are combined. The result of this approach is shown in Figure 4.8.

A filter needs to be implemented to compute the right range value if a usable range estimate should be given. However we can not simply measure 20 values to compute a filtered value at once, especially as the values must not be measured at the same distance. As long as the quadcopter is moving measurements could be taken continuously. This would diminish introduce a time delay into the measurement which is not desireable.

wording, move to conclusions?

4.2.4 Antenna Orientation

(diversity, no diversity) * (parallel, perpendicular)

4.2.5 Orientation of Devices

4.2.6 Moving Nodes

Movement has an influence on the quality of the range values depending on the ranging method used. For the phase different measurements a moving node could mess up the range value if the phase differces measured at multiple frequencys don't match the same distance because the node moved in between.

wording

However moving the node in a defined way and taking a measurement at a fixed distance is a sophisticated task.

4.2.7 Ranging on FINken Robots

4.3 Properties of a Distance Function

The ranging sensor on the FINken robot shall be used to provide a distance between two quadcopters, similar to a distance measure used in swarm intelligence algorithms. In the pure mathematical sense a distance function has to fullfill certian properties.

If $f(x, y)$ is a distance function it has to have the following properties.

$$f(x, y) \geq 0 \tag{4.1}$$

$$f(x, y) = 0 \iff x = y \tag{4.2}$$

$$f(x, y) = f(y, x) \tag{4.3}$$

$$f(x, z) \leq f(x, y) + f(y, z) \tag{4.4}$$

Of course the value measured by any real sensor will not completly accomplish to satisfy those conditions. For use in swarm robotics it is therefore very interesting to know in which way the range values break the pattern of a mathematical distance function.

4.3.1 Non-negativity and Coincidence

The first property of a mathematical distance measure to look at is non-negativity. This is quite easy: The values yielded by the ranging modules are clearly positiv. Also the property of coincidence is always given. Each module has a unique address and is therefore able to check, if it is ranging itself. Having two modules occupy the same physical spot is obviosly not possible so there cannot be two different modules that are equvivalent in a mathematical sense.

4.3.2 Symmetry

In this section the following notation will be used: $A \rightarrow B$ means a range reading is taken from node A with B as reflector node.

Symmetry is a property that can not be achieved by the ranging sensors because of noise. A range reading $A \rightarrow B$ will not be equal to the reading for $B \rightarrow A$ just because the two readings will be altered by noise. The question that remains is: Do we have the same error for both directions.

measure, plot, evaluate

4.3.3 Triangle Inequality

The Triangle Inequality will also be broken by noise. I.e. if we measure $d(A, B) + X + d(B, C) + X$ and $d(A, C) + X$ the measurement error X might as well break the condition of the Triangle Inequality.

4.4 Conclusion

5 Future Work

5.1 Misc

find better caption

5.1.1 Improve Range Values

Of course the range values can also be improved mathematically. In this work no filtering of valid measurements was performed. However the results might be improved by computing range values based on multiple measurements. A good way of dooing this would be to find a “clever” way of filtering, that takes into consideration the distribution of the values. To exploit the distribution of the values a better theoretical model for this distribution would be needed.

filtering -> papers

5.1.2 Further Integration

integration testing, optitrack

5.1.3 Flying with Pseudo-GPS

One of the things that can be done with ranging is position estimation via multilateration. Even if the FINken project is mainly interested in gaining a viable distance measure between individuals in a swarm a position estimate would be beneficial for the performance of the autopilot-especially as the normal use case for the Paparazzi autopilot is outdoors and with a GPS reciever attatched.

To integrate positional data into the FINken two steps are needed: Implementing the multilateration algorithm on the sensors and writing a new GPS module that uses the data from the sensor. An aditional benefit of using anchor nodes to compute a position estimate is that we can find out our current heading and the direction of other swarm entities much easier

5.1.4 Distance Based Bounding Box

Currently nets and ultrasound reflecting foil are used to enclose the flight area. Those could be replaced by ranging beacons that enclose the operating area, either by computing a position and defining coordinates which should not be left or by placing ranging nodes in the area and defining a minmum distance to the nearest node. This could be a nice setup for mobile deployment of the FINken robots.

5.2 Applications in Swarm Robotics

5.2.1 Direction

A value that the ranging sensors don't yield is the direction of the other sensor it is ranging with. For use in swarm algorithms this is a problem: Normally we compute a force towards or from the other swarm entities that is based on distance and direction. This way is still blocked for us as we can't measure direction.

5.2.2 Distance Based Swarm Objectives

Swarm behavior can be used for multi objective optimization. One of those objectives might be based on the measured distance i.e. stay close to a specific node or stay away from a specific node. Keeping a minimal distance and maximizing the distance between the robots might be used to avoid collisions between multiple robots. Avoiding collisions of course is one of the most important requirement for ermergence of swarm behavior in a robotic swarm.

5.2.3 Formation Flying

One of the next steps is to algorithms from swarm intelligence to the FINken robots. The robots should be able to form a stable formation by using virtual attraction and repulsion forces to hold a given distance to their neighbors. If those distances are stable enough formations like triangle meshes can be formed.

get simulation data

übertragen

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