ENCODER ANALYSIS

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1 Problem Statement

For quite a while it has been a known fact that our robots misreport their absolute speeds in both the u and v directions. The last known factors are in the forward, v, direction 1.12 and in the sideways, u, direction 1.1.
Hence the search for this particular offset of measured speeds has been ongoing for quite a while now too, dating back to at least 2019. This year this phenomenon has been thoroughly validated with the following checks:

- Re-validation of the (reverse-)kinematics equations, which can now be found in detail at our wiki[1].
  - This turned out to be fully correct. However in the process conventions have been standardized and the kinematics have been completely documented on our wiki.
- A thorough check of our constants.
  - Wheel radius
  - Robot radius (distance between the center of the robot and the contact point of a subwheel).
  - The gear-ratio between the motor and wheels.
- Validation of influence of the accelerometer.
  - By turning of the sensor-fusion solution (Kalman filter) in our robots we did not observe a different relative error.
- A possible error in the actual angles of our wheels.
  - By solving the kinematics equations with the given offsets we found wheel angles that are realistically not possible.

Link to the state estimation report

- Checking our (assumed) true reference point.
  - We validated that the camera system reports identical speeds in comparison to speeds calculated with a timer and a given distance.

[1] https://wiki.roboteamtwente.nl/technical/control/omnidirectional

- Checking the reported wheel speed of each wheel on the table.
  - By using a tachometer we validated that reported RPMs of the wheels are accurate when measured them of the ground.

Link to the report

After all of these tests we found out that the rotational velocity of the robot's perspective, ω, was never checked for a possible relative error. Hence this report will check whether by purely rotating in place, the robot reports a faulty speed.

2 Test setup

We are able to measure our rotational velocity (also known as rate-of-turn or just RoT) with three different, and independent sensors:

1. SSL Vision & World (our camera system)
2. The IMU, more specifically our gyroscope
3. The wheel encoders

We assume that our camera system provides true values and that our IMU should also be fairly accurate. This setup is meant to specifically validate our encoder values in a moving situation (since we already checked their accuracy in a static situation).
For each test, the robot is instructed to achieve a given angular velocity with the help of the `testRobot.py` script, which can be found in our GitHub repository[2]. When tests have been conducted on the field data from all the three sensors are available. When tests have been conducted on office flooring only data from the IMU and encoders are available. Later in the report it will be shown that the IMU can also be assumed as the true value.
During theses tests the robot has been running on the following commit bc1aaa369[3]. With one small change, since in normal solutions the robot does not actually provide the gyroscope data we have chosen to override the yaw value in the network packet with this data, since this will not be used during these tests.

3 Measurements

During initial measurements that have been conducted on the field we have ended up with measurements that can be found in Figure 1. From the same measurements the average error and standard deviation between the IMU and encoders can be found in Table 1. Over here CCW stands for Counter-Clock-Wise and CW for Clock-Wise. Upon closer inspection the IMU values are very similar (but deviate less) to the vision measurements, if one ignore the spikes that happen. Hence for increased visibility Figure 2 has the same measurements as Figure 1, but without any vision data in the mix. It is worth noting that the average error and standard deviation are also based on the difference between the IMU and encoder values.

Replace with a tikz picture

As one can already tell from both Table 1 and Figure 2 the error between the encoders and IMU is too big. Hence it might look like that perhaps our encoders do not function properly when driving on the field. **Explain this more with the help of constants and etc in another section**. It is worth noting that at this point in time this test has only been conducted with

[2] https://github.com/RoboTeamTwente/Basestation/blob/development/python_utils/testRobot.py
[3] https://github.com/RoboTeamTwente/roboteam_microcontroller5.0/tree/bc1aaa3690a9e0ee013cf7328d4d7ab5191e3318

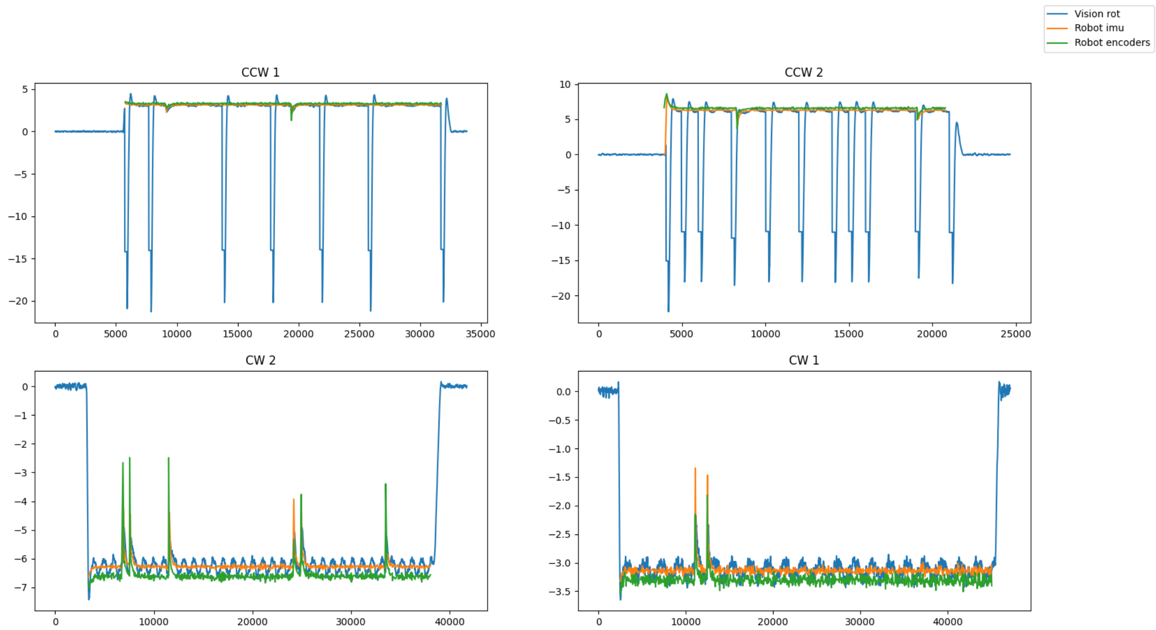

Figure 1: Measurements on the field

Direction	Velocity	Average error	Standard deviation
CCW	1 rad/s	1.051	0.031
CCW	2 rad/s	1.046	0.031
CW	1 rad/s	1.055	0.032
CW	2 rad/s	1.052	0.050

Table 1: Reported error on state estimation of angular velocity

a single robot on the field, which is for many reasons not ideal. Hence more testing in the future is encouraged in order to increase our confidence in these measurements.
Since there is roughly a 5% error on our measurements on the field, but no error on a roll of tape, we decided to conduct the same test on other types of flooring. In the following test the practice field has been replaced by office flooring. Interestingly the reported rotational velocity from both the IMU and encoders (cameras are not available in this scenario) deviate less than 0.2%, as can be observed from both Figure 3 and Table 2.

Direction	Velocity	Average error	Standard deviation
CW	2 rad/s	1.000	0.009
CW	2 rad/s	1.001	0.003

Table 2: Reported error on state estimation of angular velocity on office flooring

4 Conclusions

From these measurements we have learned that our encoders work, but that they misreport information on given flooring, like our test field. At least, in the case of sending only an angular velocity. This error seems to be dependent on the flooring that the robot is driving on, and not on the instructed speeds. However, more testing is needed since we have only

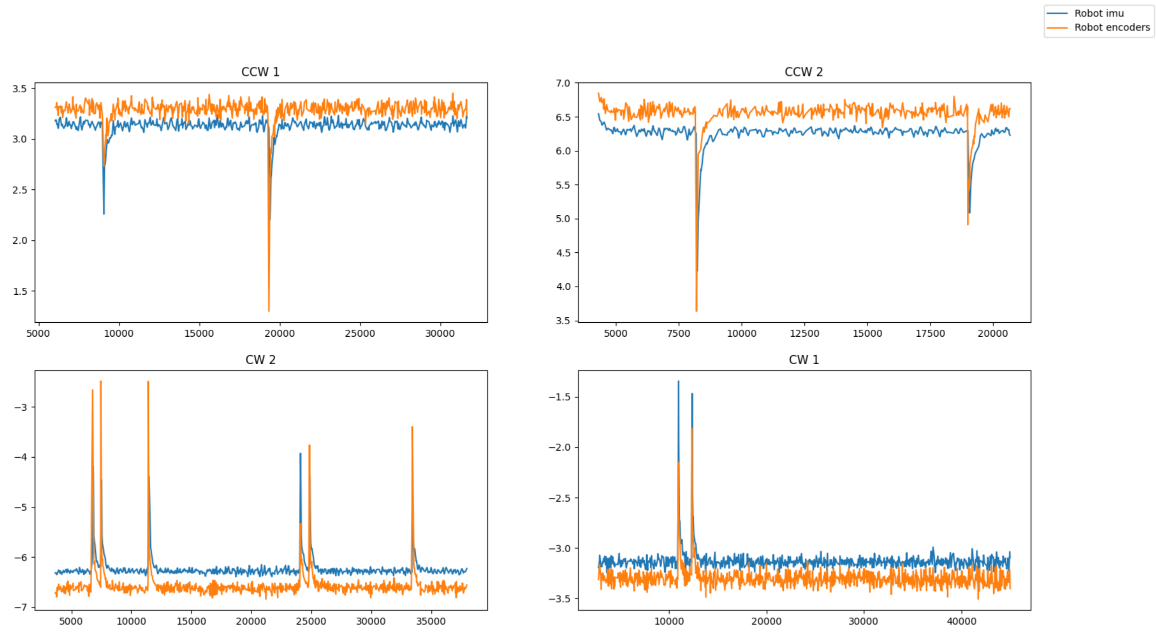

Figure 2: Angular velocity measured by IMU & encoders only

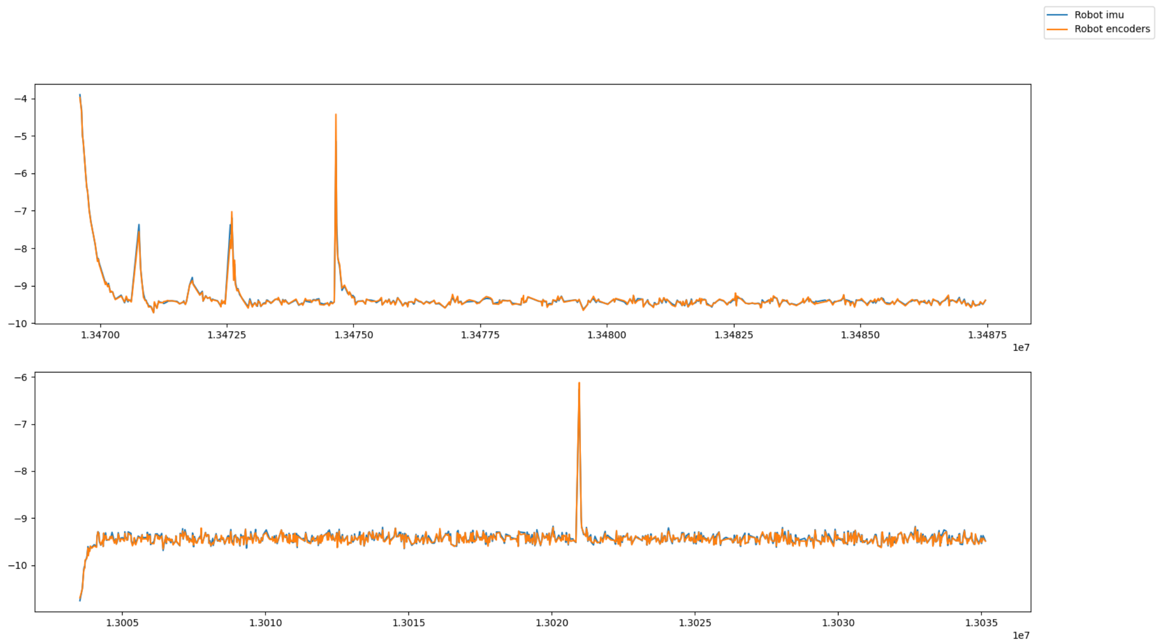

Figure 3: Angular velocity on office flooring, measured by the IMU & encoders

been able to use two robots so far, which is not a big enough sample size. Additionally it would be a good practice to also validate the flooring hypothesis with forward and sideways velocities, unfortunately we cannot use our IMU for this yet, since its measurements are too unstable in order to be actually used.
Other conclusions that we can now fully support are that the wheel radius, robot radius and wheel angles do not influence this error, since they are cancelled out in the calculations that have been used . The only possible option that we can think of that due to perhaps a more unstable robot the encoders are vibrating and miscounting rotations .

Mathema proof these claims

Are more as- sump- tions possi- ble?