WEEKLY REPORT DE BENEDETTI MATTEO

WEEK 14: 02/12/2019 - 06/12/2019

CONTROL OF THE SPARTAN VO FREQUENCY

Controlling the VO frequency actually means controlling the frequency of the images that are used by the VO to estimate the motion.
The camera on the rover can only be controlled with a specific set of framerates: 1.875, 3.75, 7.5, 15, and 30. Note that since it is a stereo camera, the actual framerate of the left and right channel will be half of it.

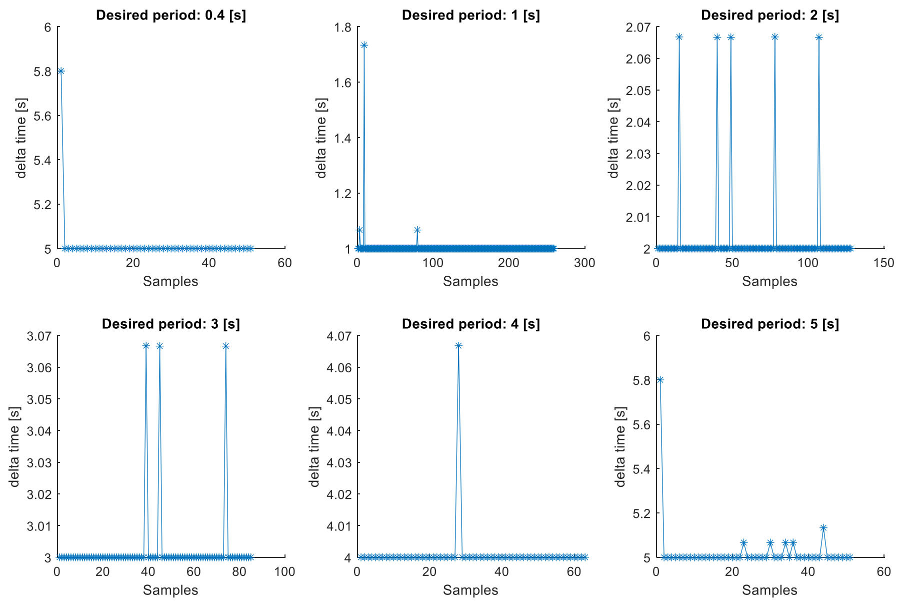
The VO computation time cannot be controlled, so to get an idea of it, the computation time is measured at every VO step and logged in an output port. 10 different tests (with different velocities, trajectories, and ambient light, to try to cover as much as possible of the input space) have been analyzed and the results are the following:

- Average Computation Time: 0.3192 seconds
- Standard Deviation: 0.0975 seconds
- Worst-case Observed Execution Time (WOET): 0.7566 seconds
  Ideally the WCET (Worst Case Execution Time) would be used, but this is computed analytically by looking at the worst case flowchart and the specific instructions that are executed in a task step. This is impossible at the current state since the rover is not running a Real Time OS and therefore there could, and for sure will, be preemptions from other tasks.

This means that, while it would be interesting to investigate even slower framerates, already the second slowest setting of 3.75 fps will start skipping frames.

To be able to achieve any desired and also slower framerate, the solution that has been implemented is to run the camera at the highest framerate (30) and then the VO task has been slightly modified to skip frames in order to achieve a desired period.

This plot shows that this strategy is able to obtain a desired framerate (lower than 30) with an acceptable precision and few samples that are unsynchronized (the y axis shows the time from the previous sample).

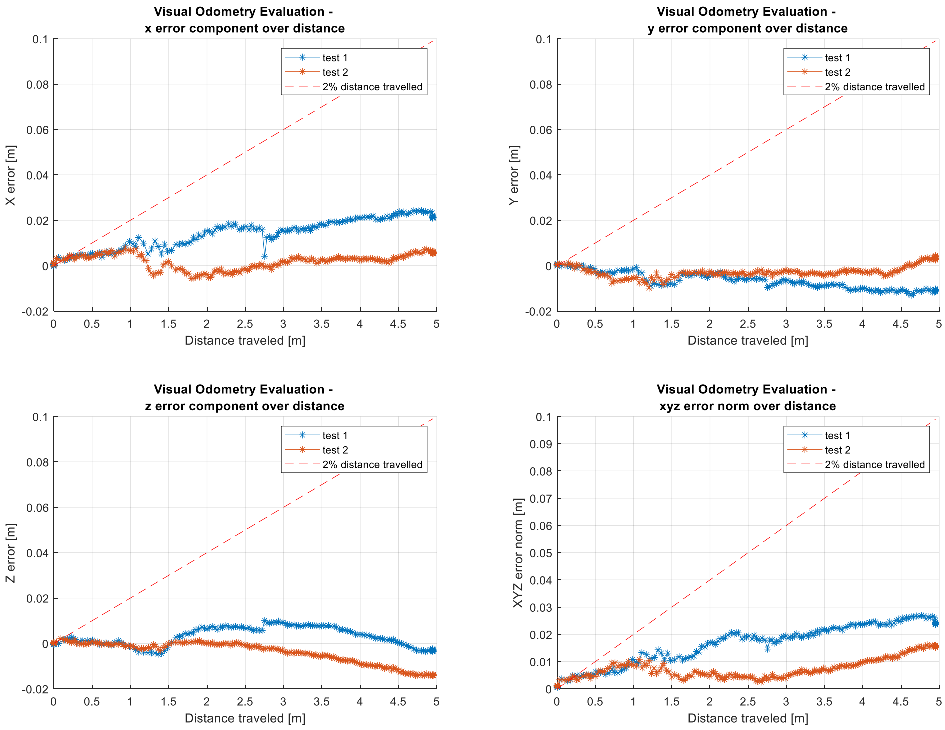


ADDITION OF THE STREAM ALIGNER

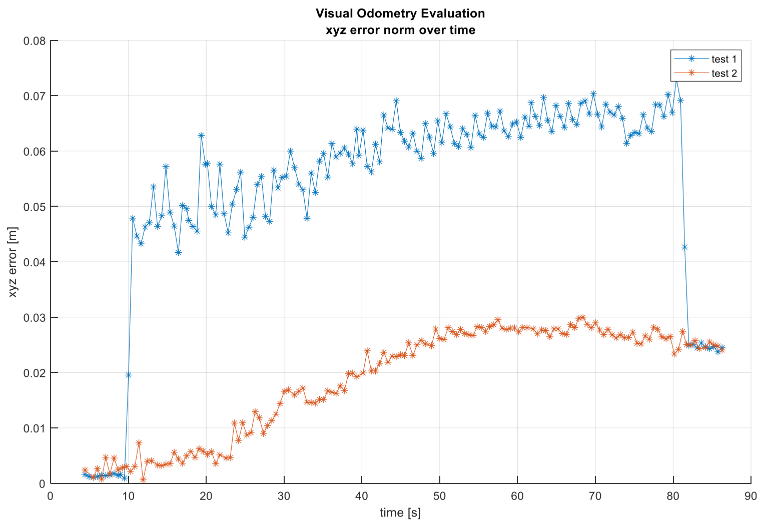
A RoCK feature called stream aligner has been added to two of the tasks of the VO pipeline.

The task that fuses the VO pose with the IMU readings was using the VO estimate combined with the last IMU measurement, which is the measurement obtained when the VO estimate is completed, not when the pictures used for the VO are acquired (between the 2 there is the VO step computation time).
Now, using the stream aligner, it aligns the timestamps of the signals of the VO and IMU.

With this addition a little improvement in the estimate has been achieved.



The task that takes the final VO estimate and compares it with the GT from the Vicon System had the same problem, it would compute the difference between V and GT using misaligned data.
This have been fixed with the stream aligner and also now the task allows to see the real error and other useful outputs (VO estimate in position and orientation, GT in position and orientation, distance travelled, error in percentage) directly at runtime.



EFFECTS OF VO FREQUENCY

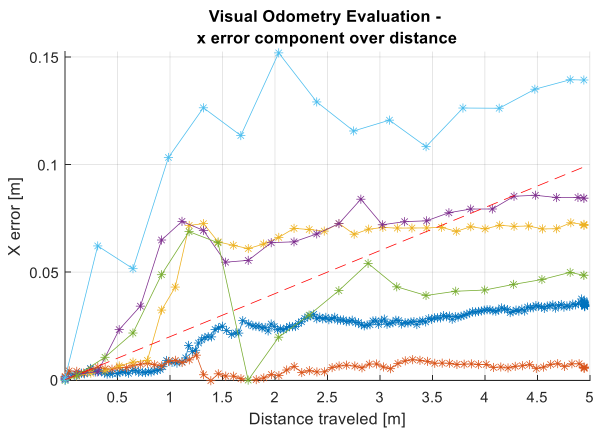
The Frequency of the images that the VO uses to estimate the motion, which from now on will be just called VO frequency for convenience, is coupled with many other aspect of the whole VO estimation process.
It mostly affect the *interframe distance*, which is defined as the distance, in meters, between two sets of stereo images. The interframe distance is also function of the rover speed.

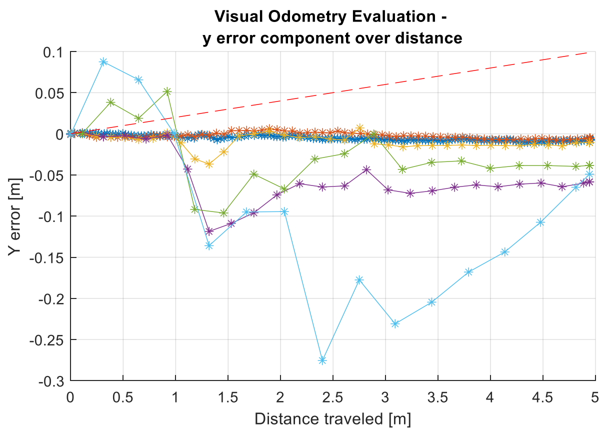
Another way that could be used to express the same concept is the *image overlap*, which is a percentage of the area of the image that is common between two images at two consecutive time-steps.
The image overlap is also function of the camera pitch and height, since when the rover moves a camera aimed to the ground will be capturing a completely different scene earlier than a camera that is pointed forward and includes in its scene objects that are far away.
This concept is more general, since it also depends on the camera placement, but also loses information about the physical distance between the frames.

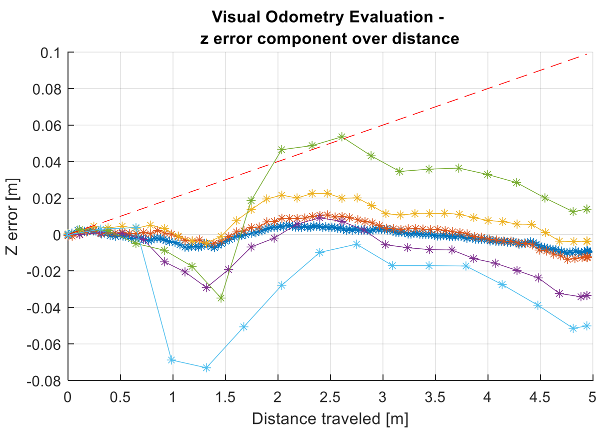
TEST AT DIFFERENT VO FREQUENCES

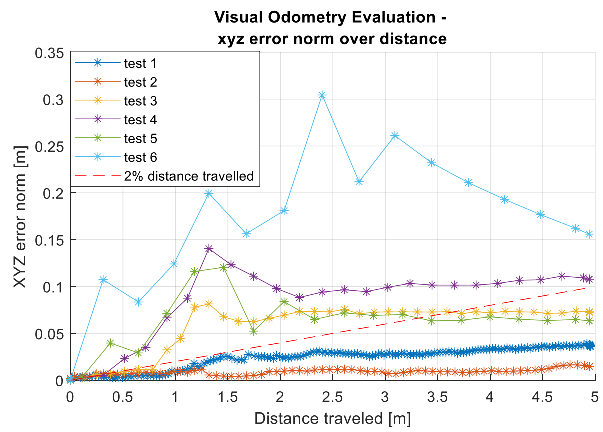
This tests show the effect of different VO frequencies (so also different interframe distances (IFD)) at 0.07 m/s for a 5m traverse.

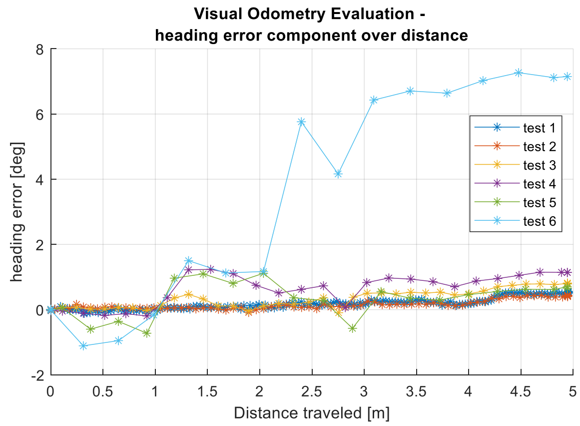
Test1: VO frequency = 2.5 [Hz], IFD = 0.028 [m]
Test2: VO frequency = 1.0 [Hz], IFD = 0.07 [m]
Test3: VO frequency = 0.5 [Hz], IFD = 0.14 [m]
Test4: VO frequency = 0.33 [Hz], IFD = 0.21 [m]
Test5: VO frequency = 0.25 [Hz], IFD = 0.28 [m]
Test6: VO frequency = 0.20 [Hz], IFD = 0.35 [m]

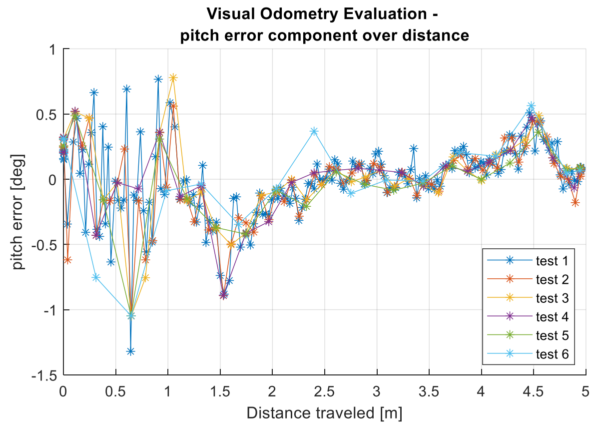


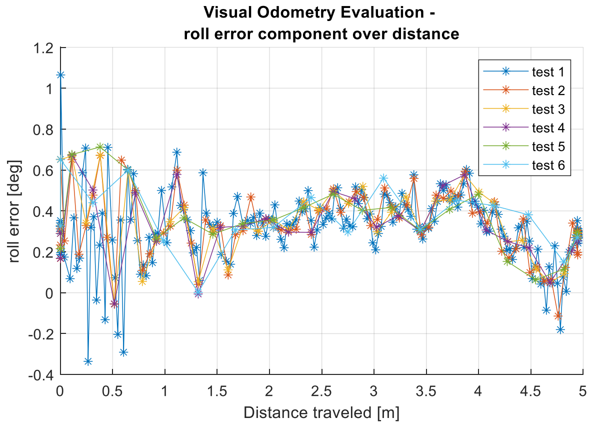


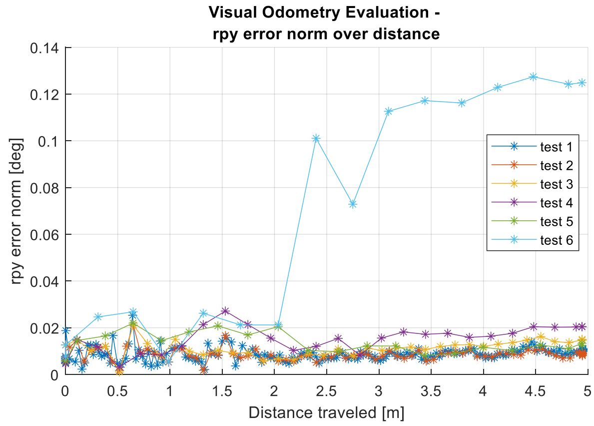










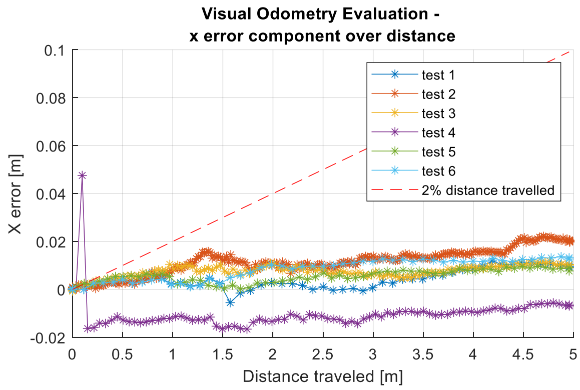


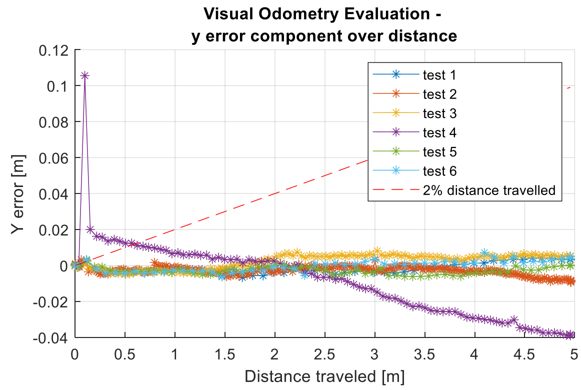
The results show that slower frequency seems not to affect the slope of the error curve but to have larger sudden jumps, as if a higher frequency amplifies error jumps that are considerably smaller at faster frequency.

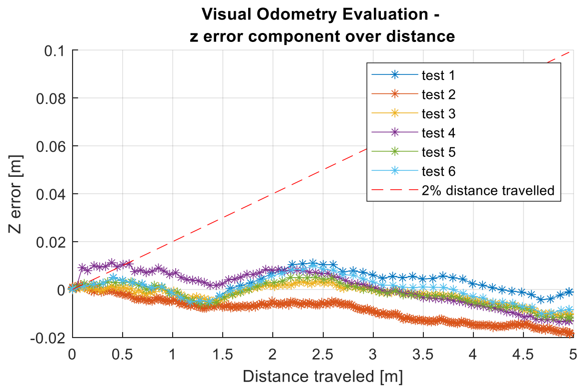
Then I run another sequence of tests with the same VO frequencies but for a traverse of 5m at 0.02 m/s. I was hoping to be able to catch a problem where a very small difference in position in the temporal matches, that can be achieved running the VO at a high frequency and moving the rover slowly, leads to inaccuracies in the motion estimation.
This problem is very well known in VO and is usually counteracted using a technique called *keyframes selection* [1], [2] which consists in skipping frames until the uncertainty of the matches, or many other possible metrics, decreases under a certain threshold.

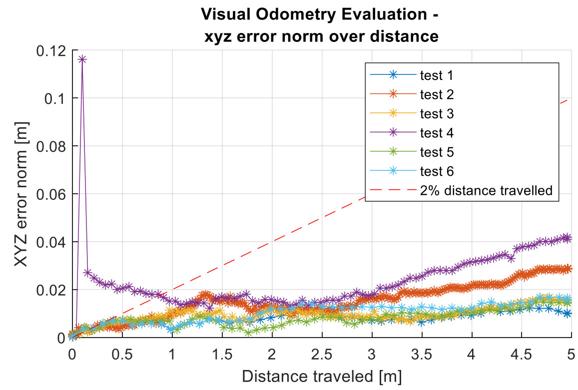
Unfortunately the results do not show this and, except for a big jump in the error in one of the tests, all of them behave very similarly with good performances.

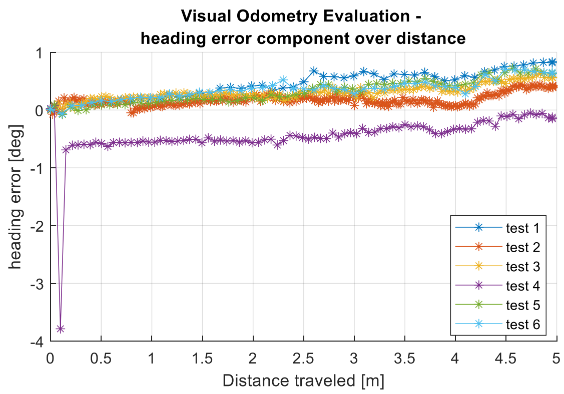
Test1: VO frequency = 2.5 [Hz], IFD = 0.008 [m]
Test2: VO frequency = 1.0 [Hz], IFD = 0.02 [m]
Test3: VO frequency = 0.5 [Hz], IFD = 0.04 [m]
Test4: VO frequency = 0.33 [Hz], IFD = 0.06 [m]
Test5: VO frequency = 0.25 [Hz], IFD = 0.08 [m]
Test6: VO frequency = 0.20 [Hz], IFD = 0.1 [m]

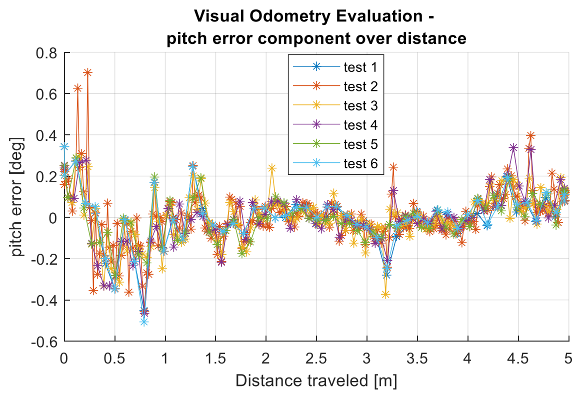

Visual Odometry Evaluation -
x error component over distance
X error [m]
Distance traveled [m]
test 1
test 2
test 3
test 4
test 5
test 6
2% distance travelled

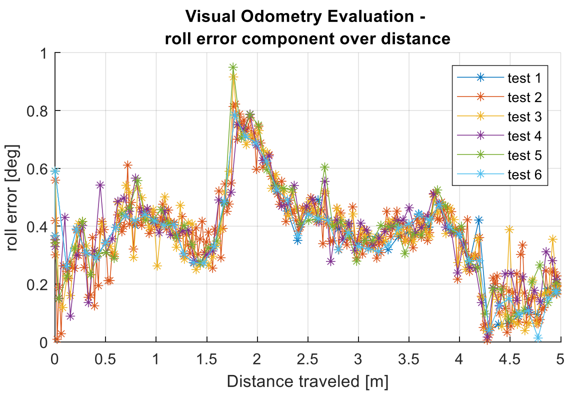

Visual Odometry Evaluation -
y error component over distance
Y error [m]
Distance traveled [m]
test 1
test 2
test 3
test 4
test 5
test 6
2% distance travelled

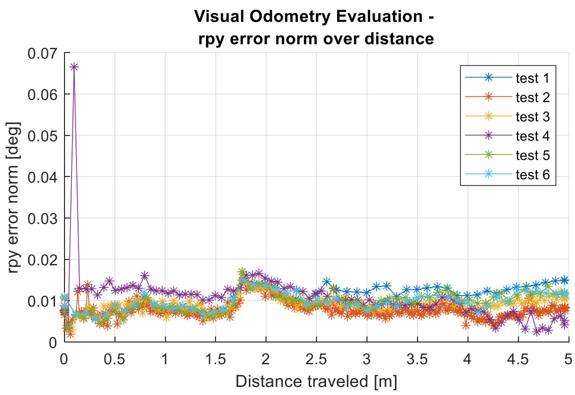

Visual Odometry Evaluation -
z error component over distance
Z error [m]
Distance traveled [m]
test 1
test 2
test 3
test 4
test 5
test 6
2% distance travelled


Visual Odometry Evaluation -
xyz error norm over distance
XYZ error norm [m]
Distance traveled [m]
test 1
test 2
test 3
test 4
test 5
test 6
2% distance travelled


Visual Odometry Evaluation -
heading error component over distance
heading error [deg]
Distance traveled [m]
test 1
test 2
test 3
test 4
test 5
test 6


Visual Odometry Evaluation -
pitch error component over distance
pitch error [deg]
Distance traveled [m]
test 1
test 2
test 3
test 4
test 5
test 6


Visual Odometry Evaluation -
roll error component over distance
roll error [deg]
Distance traveled [m]
test 1
test 2
test 3
test 4
test 5
test 6


Visual Odometry Evaluation -
rpy error norm over distance
rpy error norm [deg]
Distance traveled [m]
test 1
test 2
test 3
test 4
test 5
test 6

FUTURE OBJECTIVES:

In the next week I would like to quickly discuss with my supervisor if it makes sense to investigate potential inaccuracies due to too little displacement in temporal matches, and if so I would try an even slower velocity for the test and see if I can manage to find the inaccuracies I was expecting.

Then I want to study the effect of keeping the IFD constant while changing the rover speed, new camera positons and orientations to see the effect that different IFD and image overlap percentages have on the VO performances.

At the moment there is only one different position for the camera that is on the PTU on top of the mast, with the advantage that there I can easily control the pitch using the PTU.
If these settings are not enough maybe a new camera bracket, with changeable pitch and height, could be designed and produced.

REFERENCES

[1]: D. Scaramuzza, F. Fraundorfer "*Visual Odometry: Part I - The First 30 Years and Fundamentals*", IEEE Robotics and Automation Magazine, Volume 18, issue 4, 2011.

[2]: Fanfani, M., Bellavia, F. & Colombo, C. "*Accurate keyframe selection and keypoint tracking for robust visual odometry*", Machine Vision and Applications (2016) 27: 833. https://doi.org/10.1007/s00138-016-0793-3