Improving Guidance Information by means of Metric Optical Flow Onboard an Unmanned Aerial System

HiPerGreen Project & Robotics Lectorate Inholland

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Outline

Introduction

Figure: An orchid greenhouse and a selection of common orchid diseases.

Introduction

The problem

Scouting costs and effectiveness.

Expanded

- 5 to 25% of plants go to waste because of diseases, bacteria, fungi, damage and other causes
- Human scouting is labour intensive
- Human scouting is prone to errors
- Scouting needs to be done on a regular basis to prevent the spread of diseases
- Human scouting is expensive

Introduction

How to solve the problem

Initially "Drones in de Kas", which later continued as HiPerGreen.

- Scout more often
- Improve scouting precision
- Reduce errors
- Reduce scouting costs

How?

Using an automated drone with image recognition software to autonomously fly and detect diseases.

Background information

Why is autonomous navigation needed?

Reduce operating costs, and improve scouting frequency.

What is needed for autonomous navigation

- Precise and stable location (in reference to a world frame)
- Definition of the environment (a map also in reference to the world frame)
- A control system which can produce and execute trajectories to change the location of the drone

Background information

Location is a greenhouse

Prior research:

- GPS does not work in a greenhouse
- A technique called Ulta Wide Band (UWB) looks promising but has problems (jumpy, noisy measurements)
- Optical techniques for relative measurements look promising

Background information

The assignment

Develop a relative measurement system based on camera images and optical flow.

- Each frame a displacement of the image is calculated (optical flow)
- By using the height (measured using a distance measurement sensor) calculate the ground truth movement
- The system, called the Guidance Module (GM), should have a measurement accuracy of $\pm 1cm$

The important things

What is a Guidance Module (GM)?

- Camera
- Height sensor
- Optical flow algorithm
- Possibly also a gyro
- Measures the movement of optical phenomena in an image sequence and translates it into movement of the camera

The important things

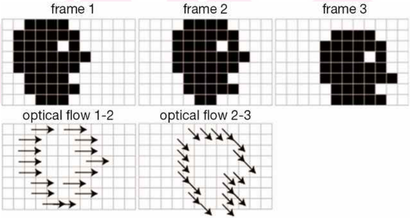


Figure: An example of optical flow.

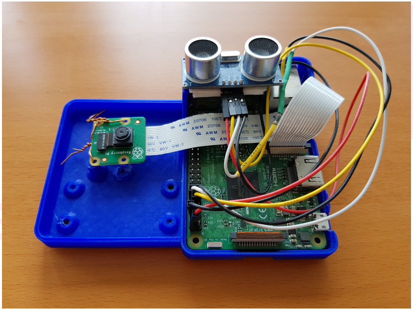


Figure: An early GM prototype.

The important things

Motivation:

- Location is needed for navigation and data geotagging
- Ultra Wide Band (UWB) is too jumpy (noisy) to be used for navigation
- Strong filtering would cause too much of a phase shift
- Realisation that the GM also has unsuitable properties
- No apparent solution available from the HiPerGreen team

The important things

The research question:

How can the provided hardware architecture and an optical flow algorithm be used to increase the accuracy of the Unmanned Aerial System (UAS)?

How to answer this question?

- Which significant parameters determine the accuracy of the GM?
- How to design the GM such that it meets all the requirements by incorporating the significant parameters?
- How can the data from the GM and UWB be combined and filtered such that useful positioning information is obtained?
- Does the GM with the design considerations applied realize the goal of increasing the accuracy of the Unmanned Aerial System (UAS)?

The important things

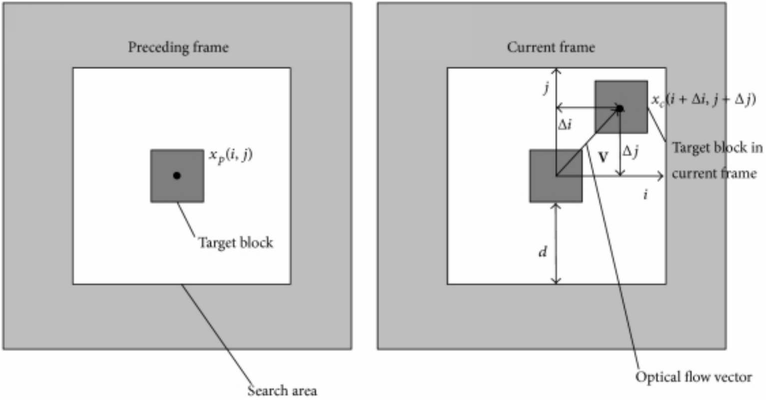


Figure: An example of block matching.

Analysis of the work

Design of the optical flow algorithm

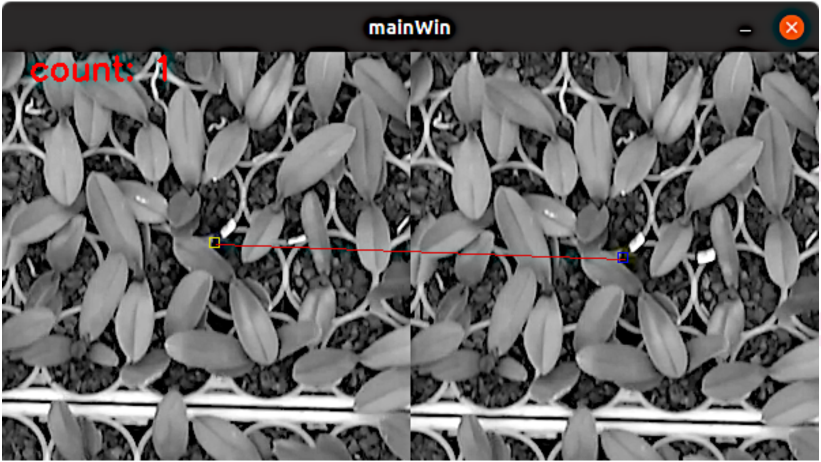
- Using block matching
- Limit the amount of matched blocks required (configurable)
- Limit the search area size, by incorporating a prediction and using the certainty of the prediction
- Prioritize blocks from the center of the frame (using a spiral selection pattern)
- Reject candidate blocks if there is not enough information contained in them (not enough vertical or horizontal gradient)
- Reject match candidates if the match quality is below some threshold (configurable)

The important things

Color legend for algorithm example

- Left picture is preceding frame, right picture is current frame
- Yellow: is used to denote a reference block in the preceding frame which is matched and accepted to the current frame
- Blue: is used to denote the position a block is matched in the current frame
- Black: used to denote a reference block which is rejected for having too little detail
- Red: used to denote a reference block which is rejected for not having a good enough match in the current frame

Analysis of the work



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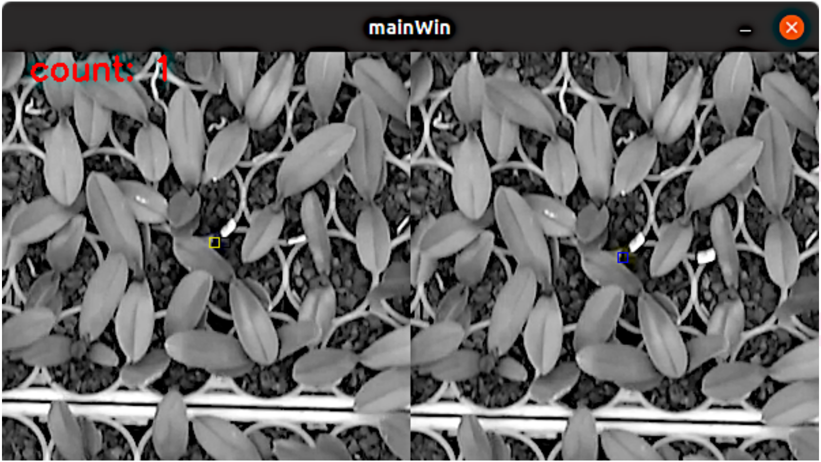

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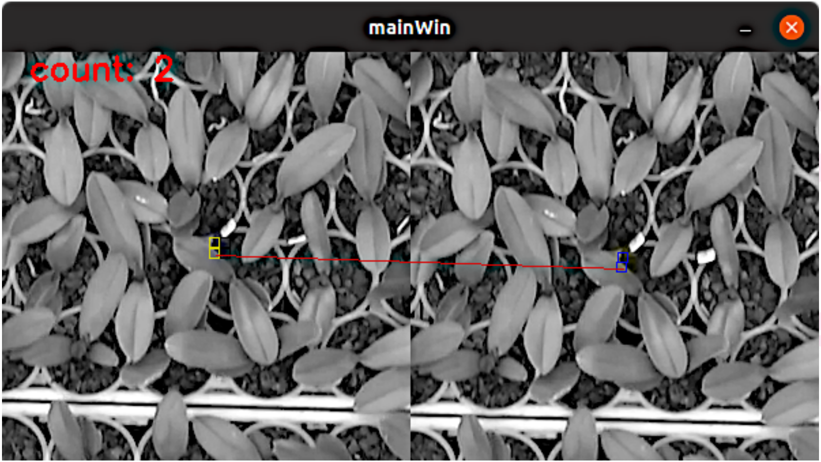

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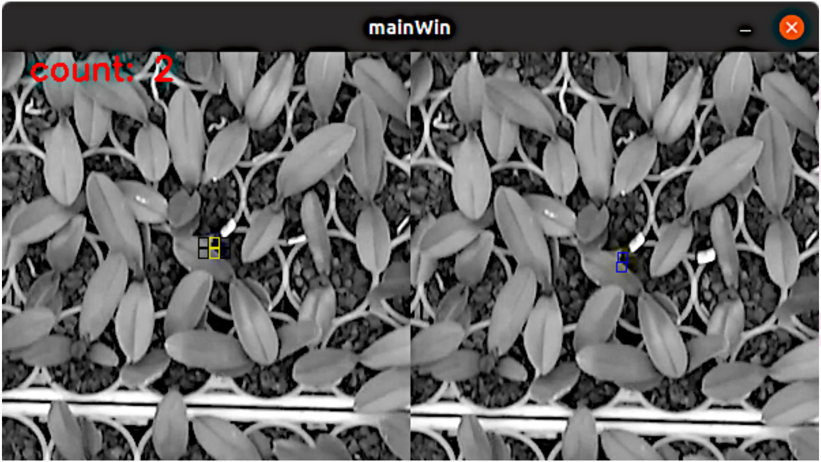

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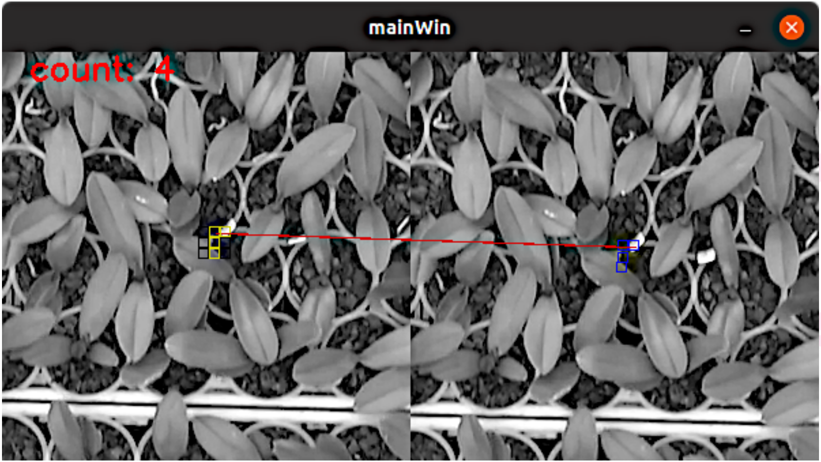

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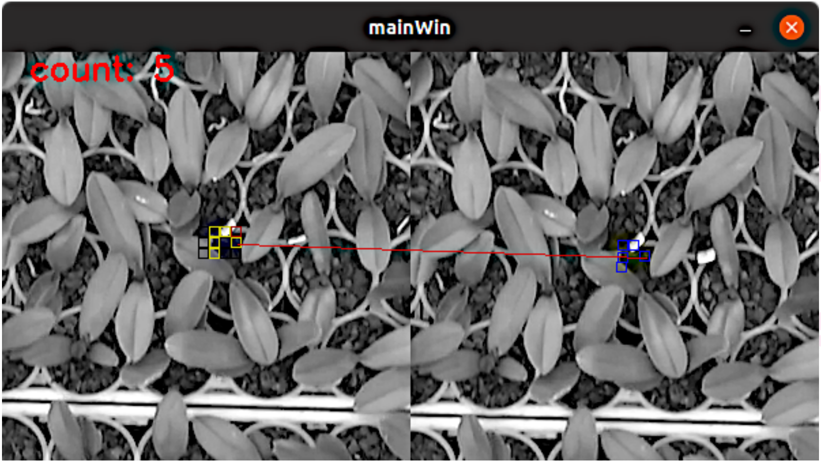

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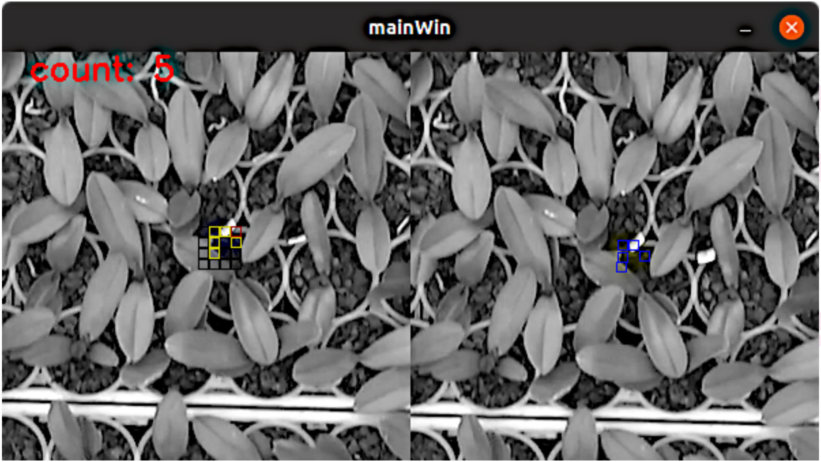

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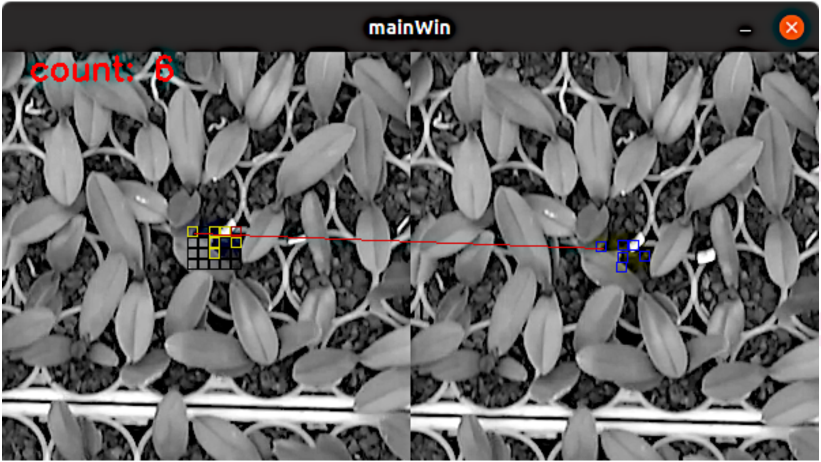

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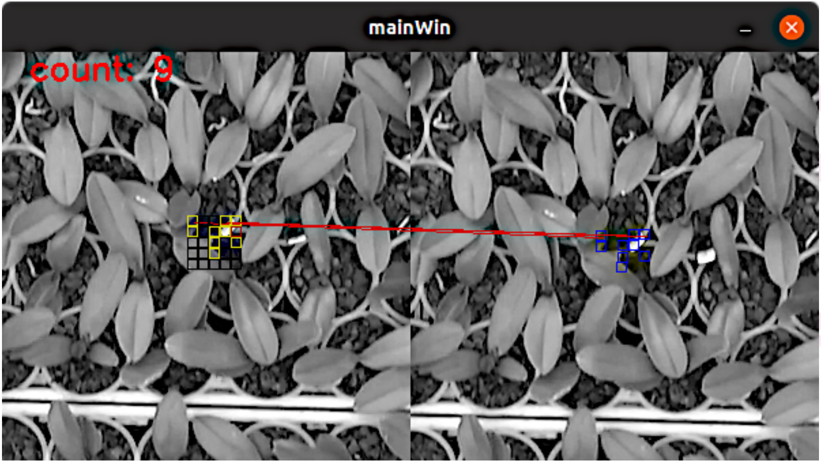

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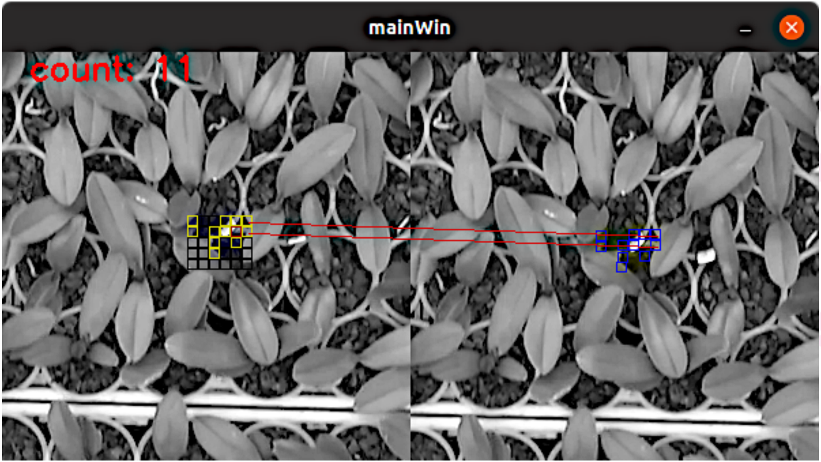

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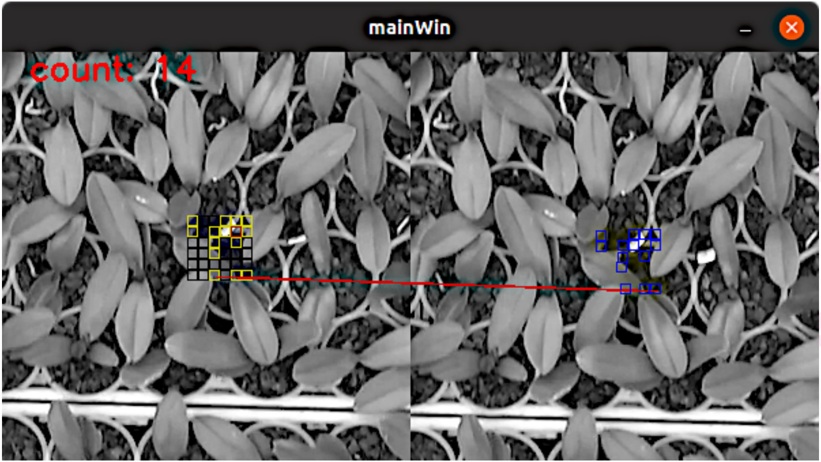

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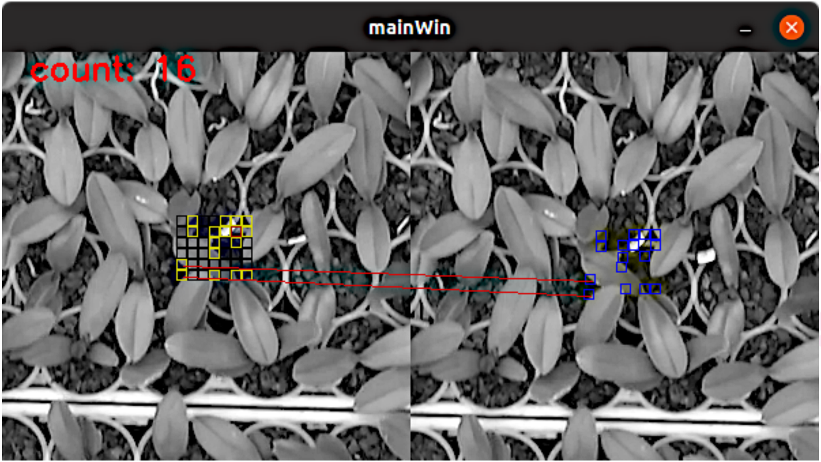

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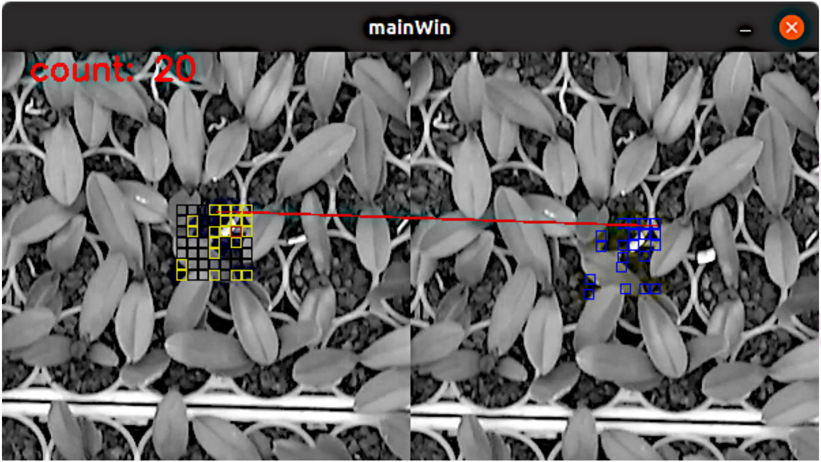

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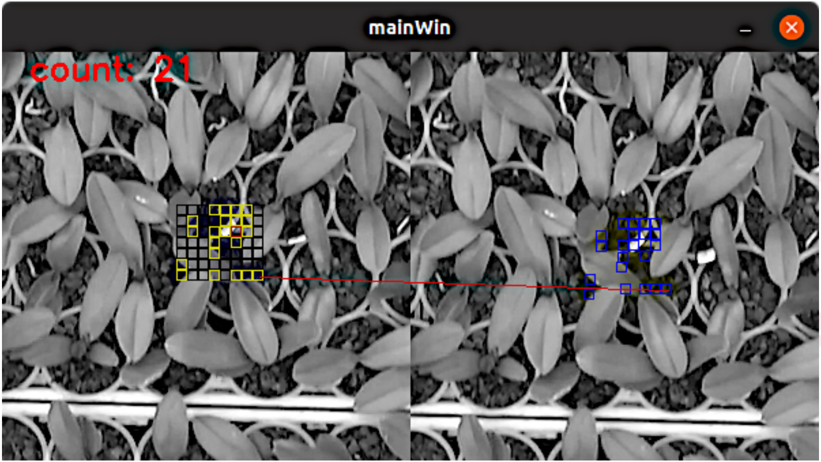

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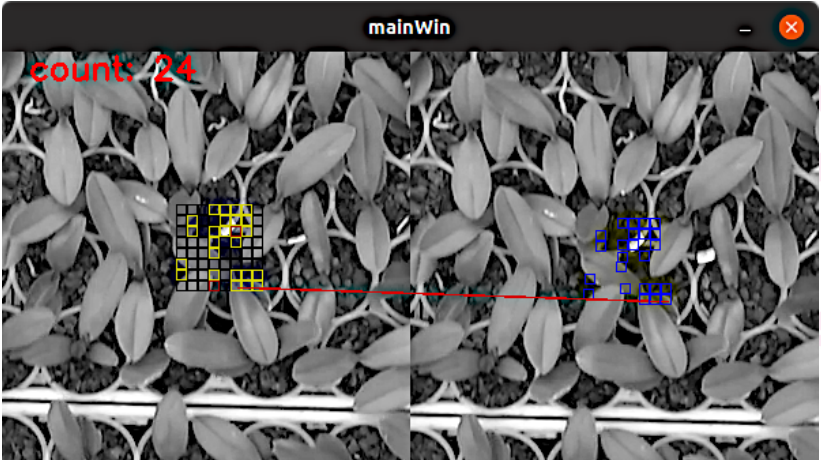

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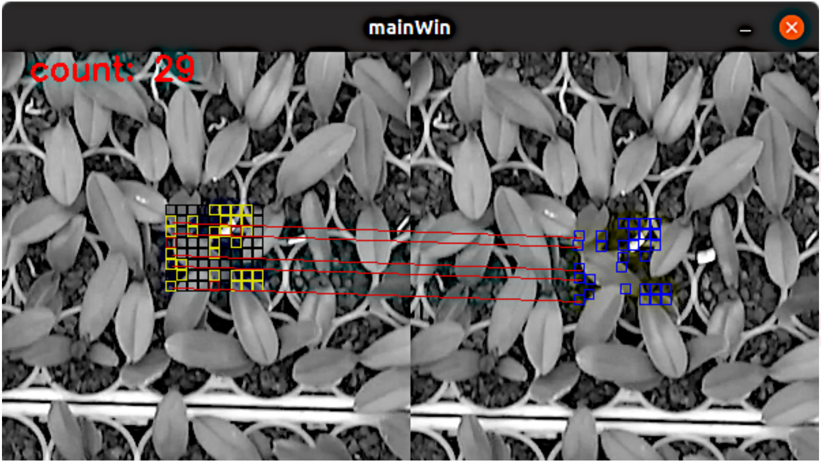

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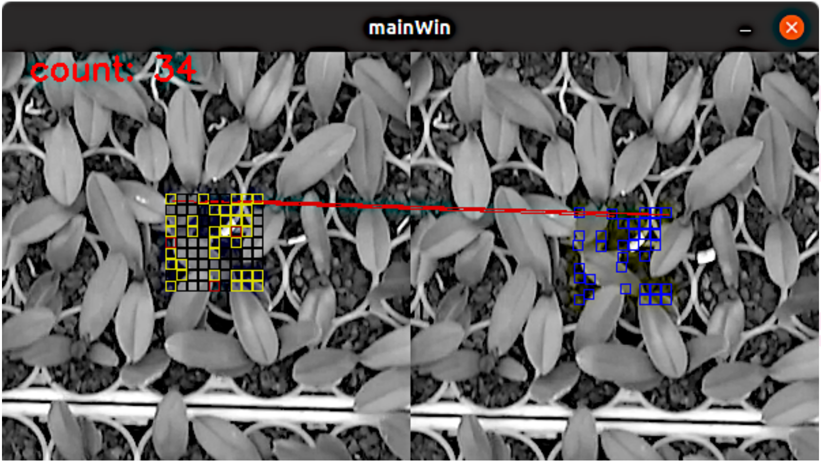

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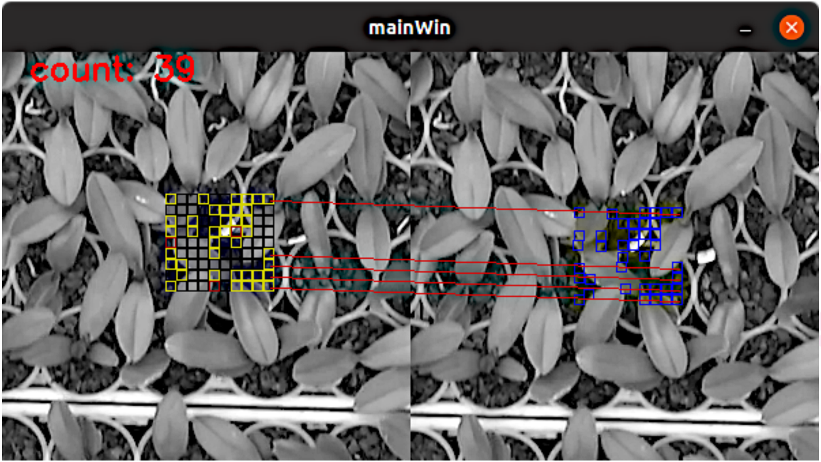

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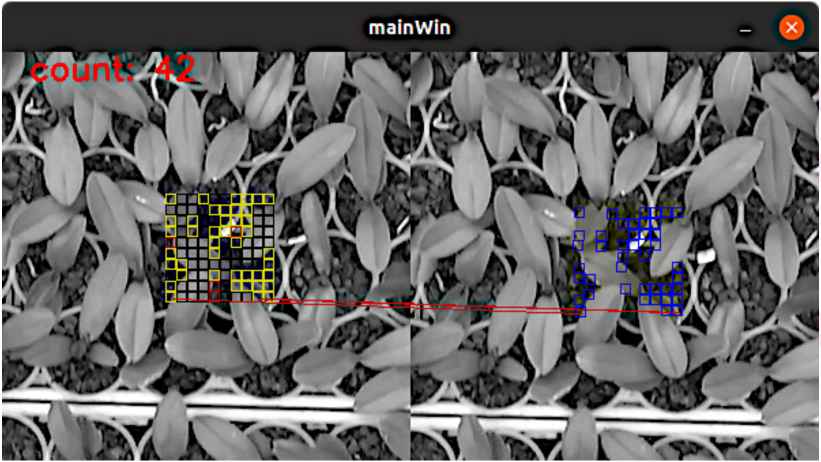

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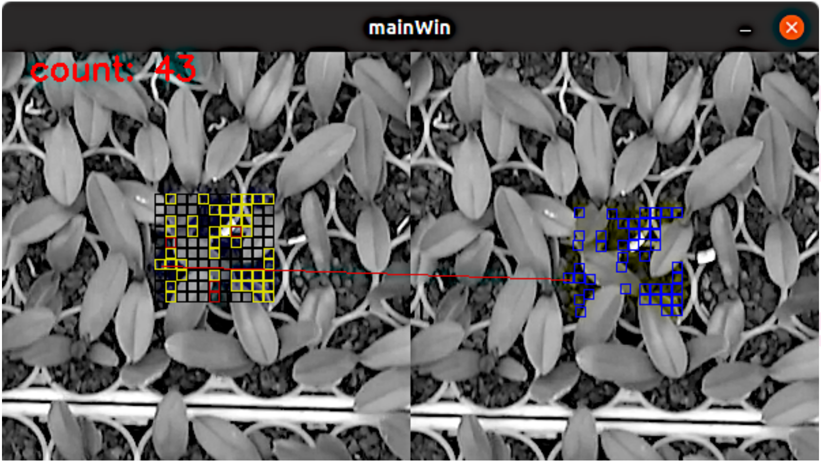

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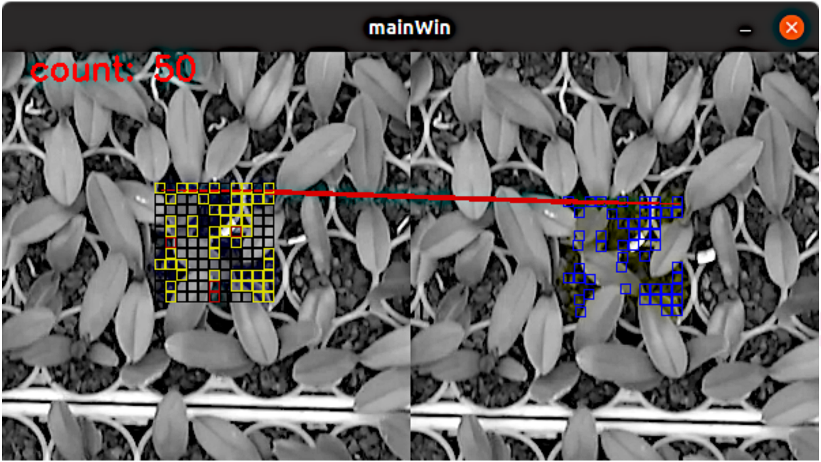

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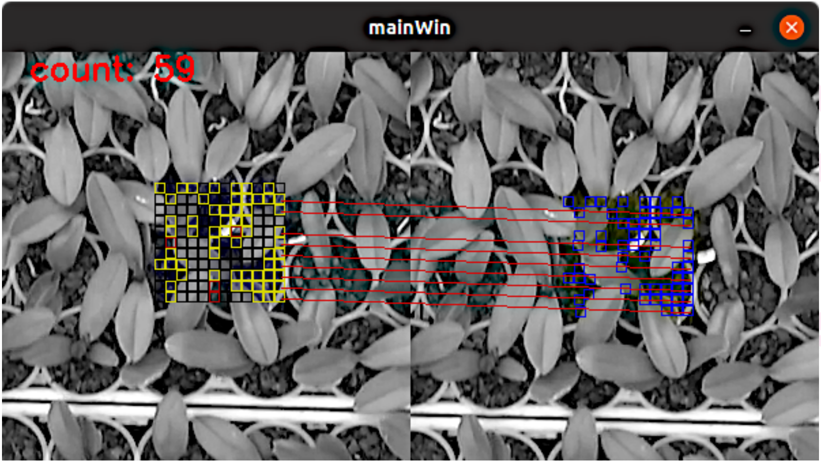

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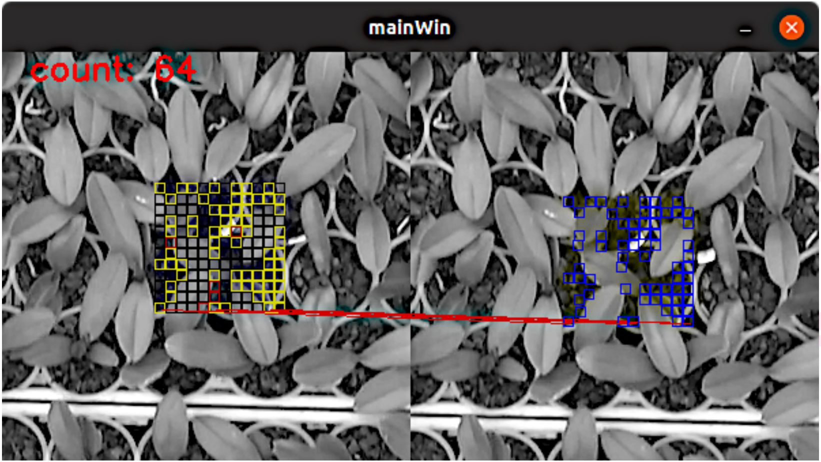

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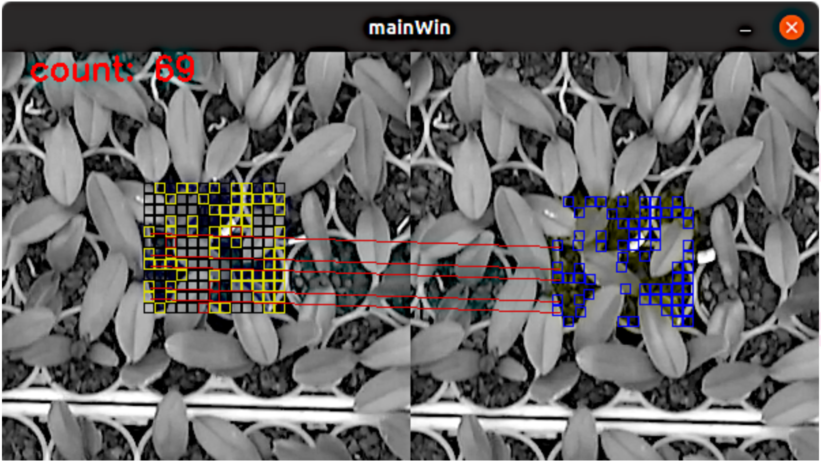

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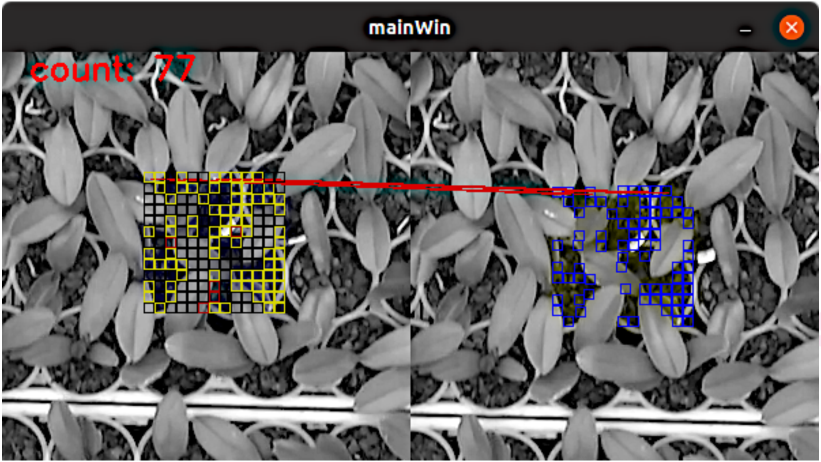

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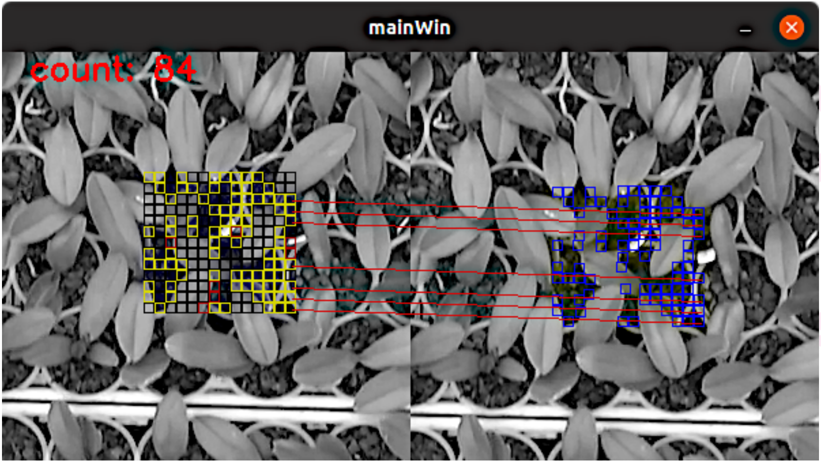

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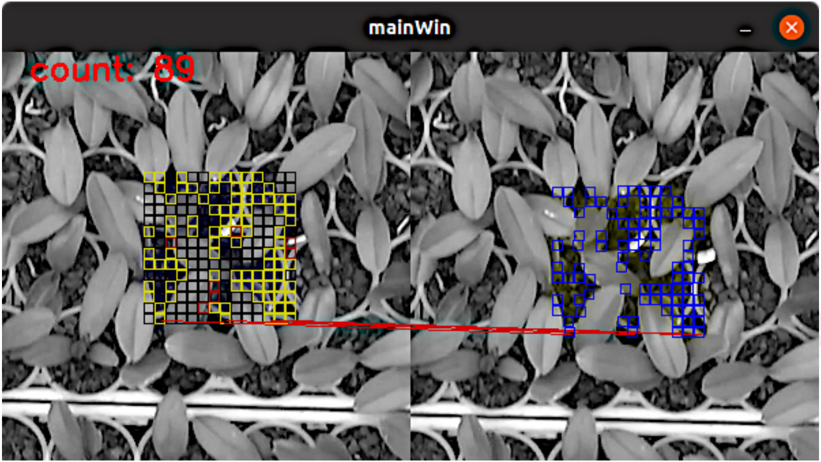

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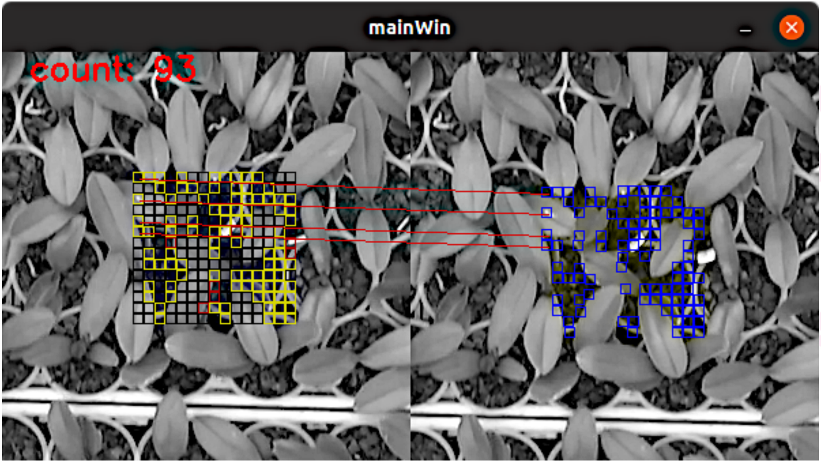

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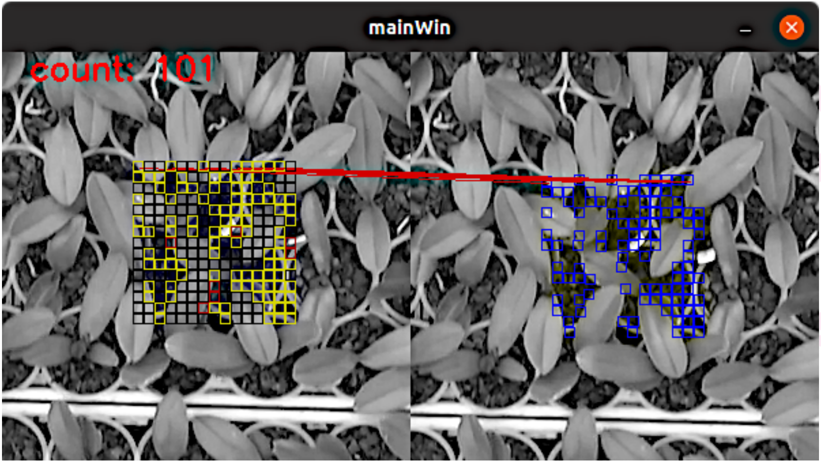


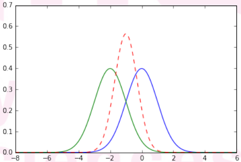
Analysis of the work

Realisations:

- The UWB is stable when observed (and averaged) over a longer period of time
- The GM is stable over a short period of time and drifts when integrated over longer periods of time

Sensor fusion with Kalman Filters:

- Fuses measurements from the GM and UWB based on their variance and the filter certainty
- Uses a model to project the filter state and certainty into the future
- Can work with mismatched sensor frequencies
- Can work while missing sensor information for short intervals



Analysis of the work

Testing goals:

- Prove the GM works as intended
- Prove the sensor fusion method works as intended
- Prove the theory of the GM precision factors

Analysis of the work

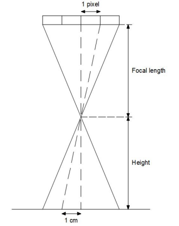
How to accomplish the testing goals?

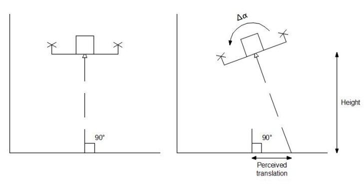
- Control all precision factors in acquiring the testing data
- Use overspecified data
- Use software techniques to reintroduce the factors as required
- Make a baseline test
- Test each precision factor as a modification of the base line test

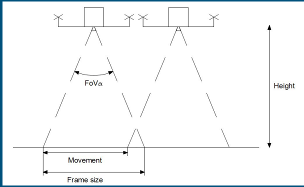
Analysis of the work

Why over specified test data?

- What is that anyway?
- Repeatability
- Controllability
- Flexibility

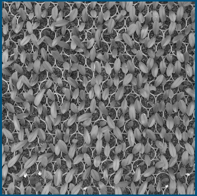


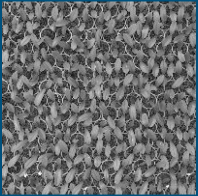


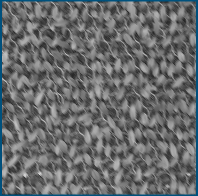


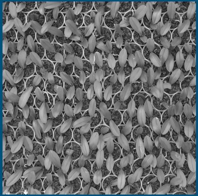
Analysis of the work

Picture quality controls


Reference picture

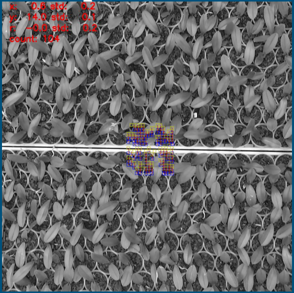

Quarter resolution


Motion blur

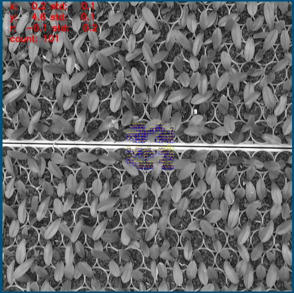

Zoomed in

Analysis of the work

Time step control

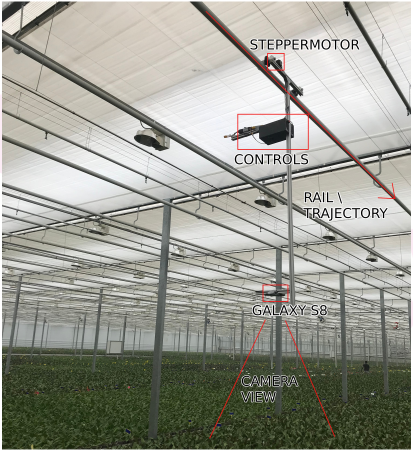


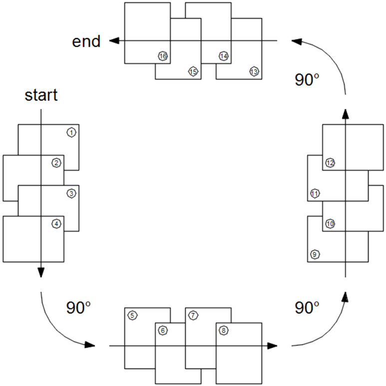
Time step times 3



Normal time step

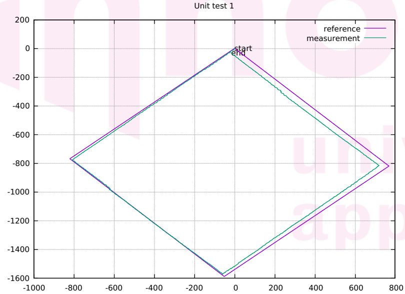
Analysis of the work

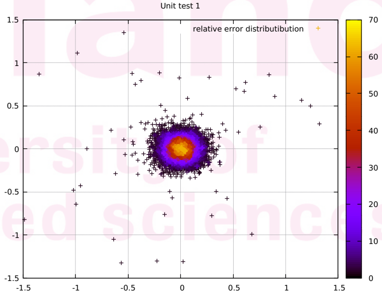




Analysis of the work

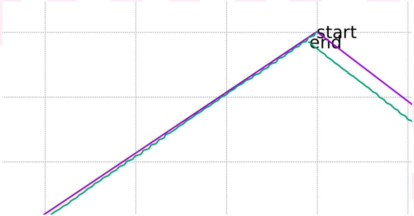
Scale (x and y) in *cm* and color scale in points per $0.0001 cm^2$

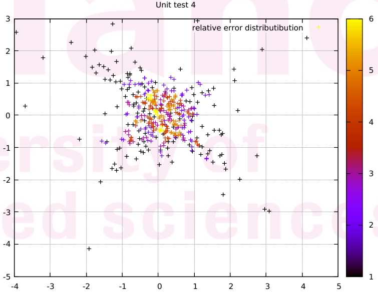




Analysis of the work

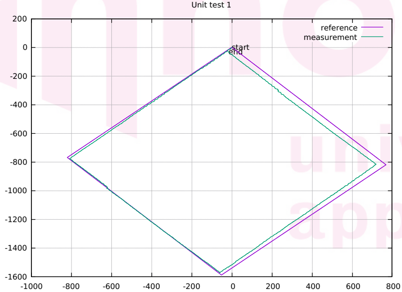
Scale (x and y) in cm and color scale in points per $0.0064cm^2$

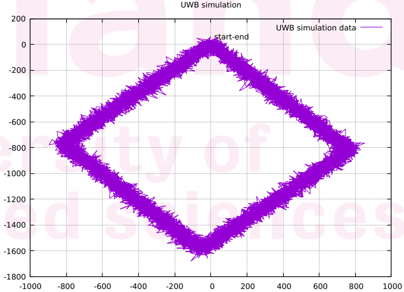




Analysis of the work

Scale (x and y) in cm





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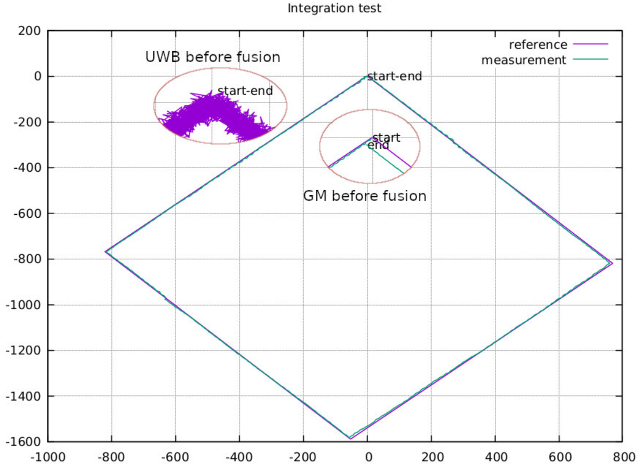
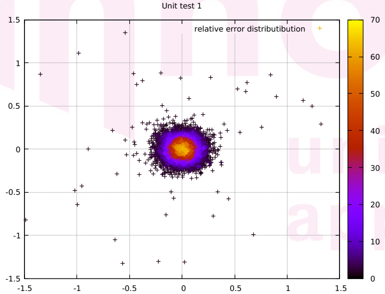
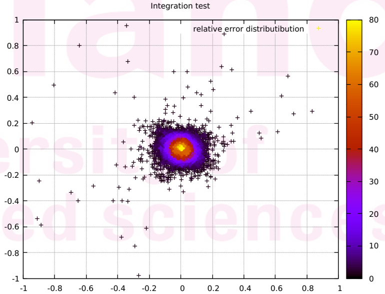
Scale (x and y) in cm



Analysis of the work

Scale (x and y) in cm and color scale in points per $0.0001 cm^2$





Conclusion

- The GM will drift over time
- The drift over time will start to play a role when distances greater than a few meters are in play
- Sensor fusion of the GM with the UWB preserves the desired characteristics of each and reduces the undesirable characteristics of each
- The testing platform introduced too much variability into the data to test all the theory
- Results from both the GM alone and the integration (sensor fusion) test were a resounding success, as the GM measurement satisfied the requirements and the sensor fusion produced a stable and precise location without the disadvantages of either sensor

Conclusion

What next?

- Implement the optical flow algorithm on an actual drone
- Validate the optical flow algorithm onboard a drone
- Implement, tune and test the kalman filter sensorfusion method
- Integrate all systems onto the drone as a single package