Robotic Platform Research

Explorative research into performance improvements for a greenhouse sensing robotic platform

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Problem definition

- Bird’s eye perspective in greenhouse
- Drones not quite ready
- Current mechanical platform not suitable for imaging
- Current mechanical platform hard to operate

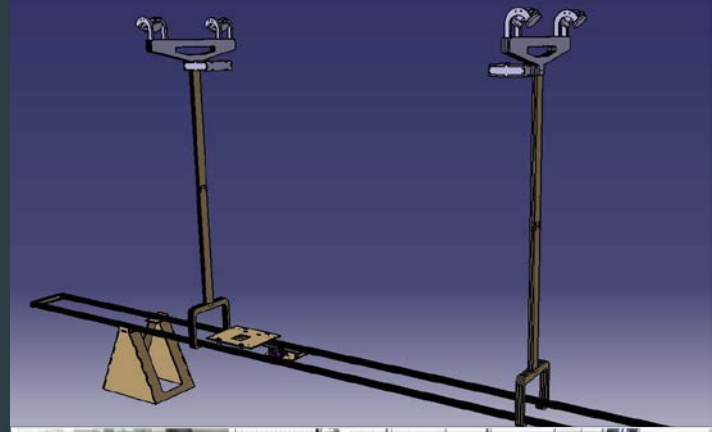
- ***How can HiPerGreen's pre-existing robotic platform be modified to effectively produce good imagery and be user efficient?***

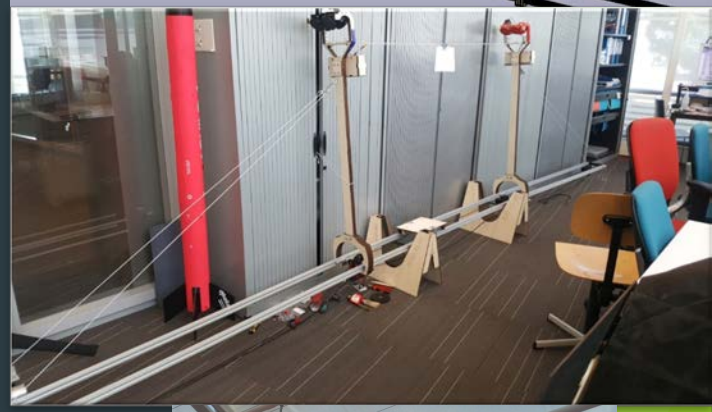
Current State-of-Art

HiPerGreen’s R.S. V1

- First Attempt at a Rail System
- Aimed at testing of drone’s components
- Two vertical arms and a lateral component with moving cart

- Very large
- Complex electronics
- Was never used





HiPerGreen’s R.S. V2

- Single arm, single lateral beam
- Aimed to be used as a product

- Difficult to wield
- Persisting oscillations within the system
- Produced images turned sometimes (too) blurry

Imaging during oscillation

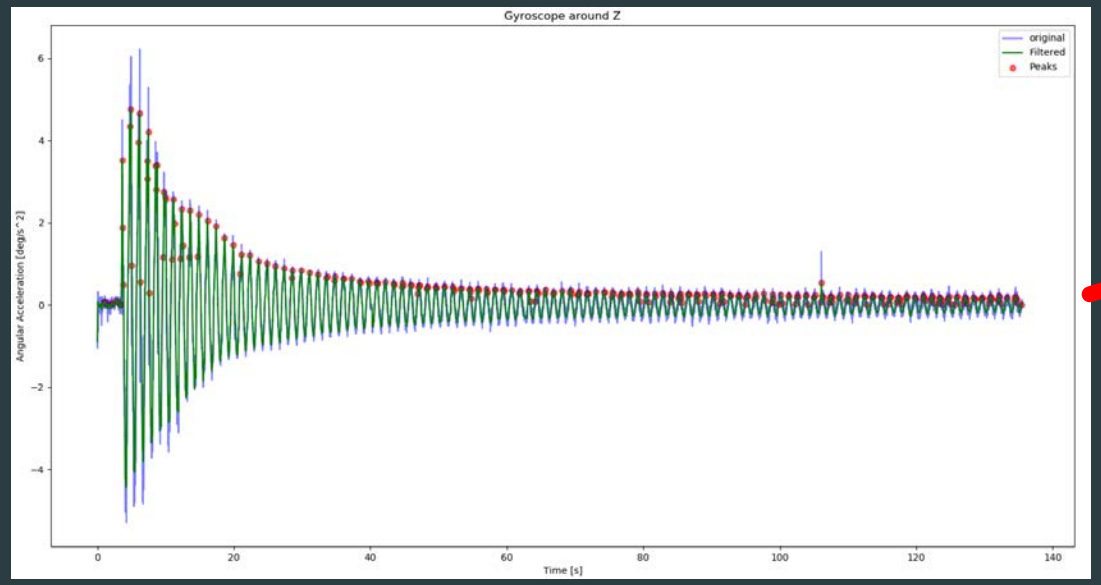
- Developed Blurriness index based on variation of Laplacian transform
- The higher the index, the less blurry the image
- Currently, images during oscillation around 250

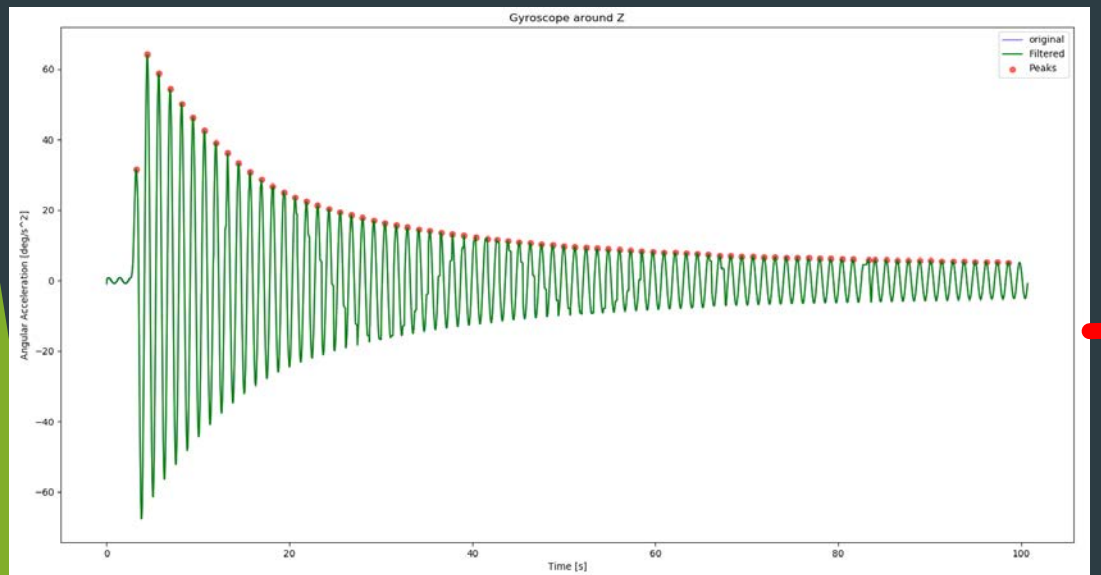
a) very blurry
Blur index: 163

b) moderate blurry
Blur index: 254

c) none blurry
Blur index: 630

Oscillations analysis



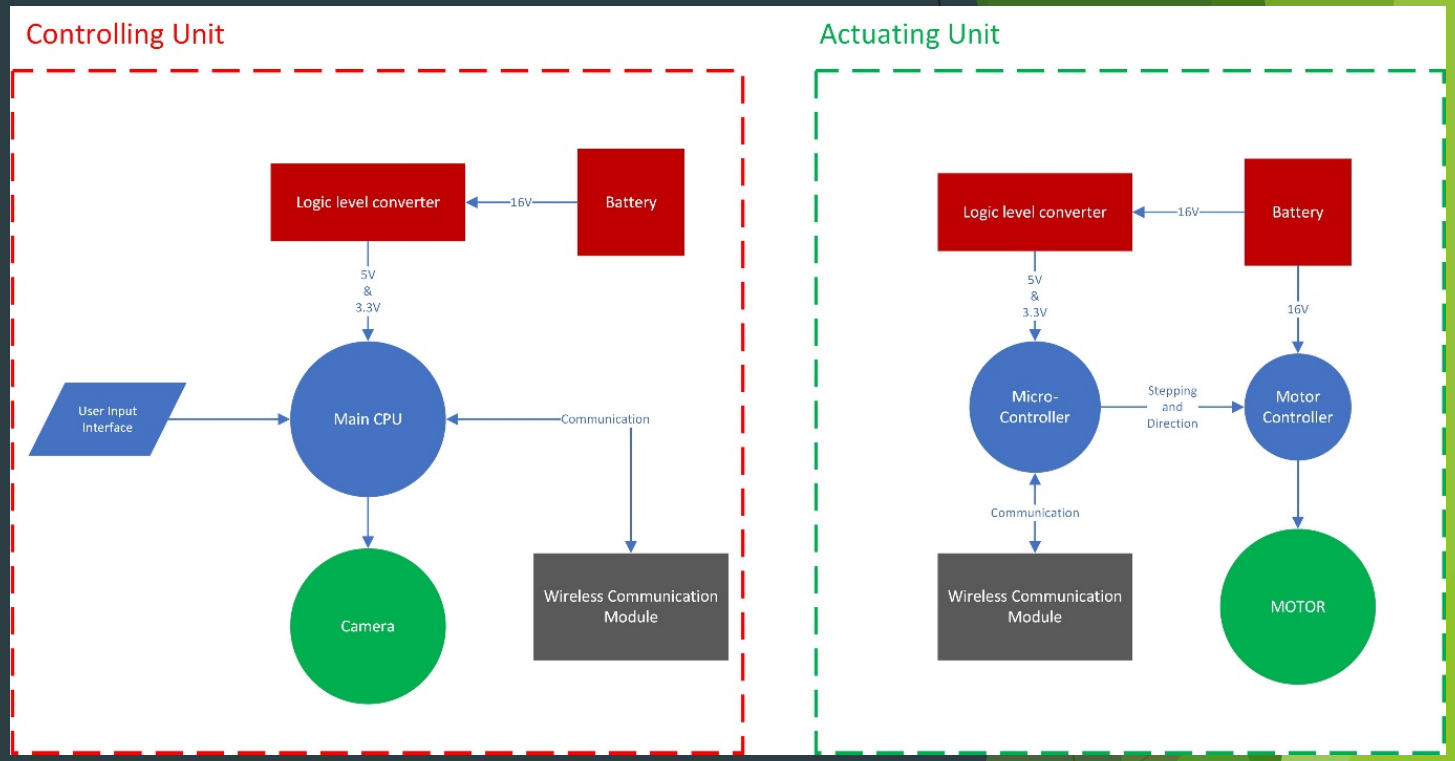


Oscillations analysis

- Frequency: 0.819 Hz
- Max amplitude: 12.6 deg
- Settling time: 62.8 sec
- Damping ratio: 0.013

Control method

- Two separate units
- Manual control through text input
- No environmental reaction possible e.g. emergency stop
- Complex and heavy
- Low usability

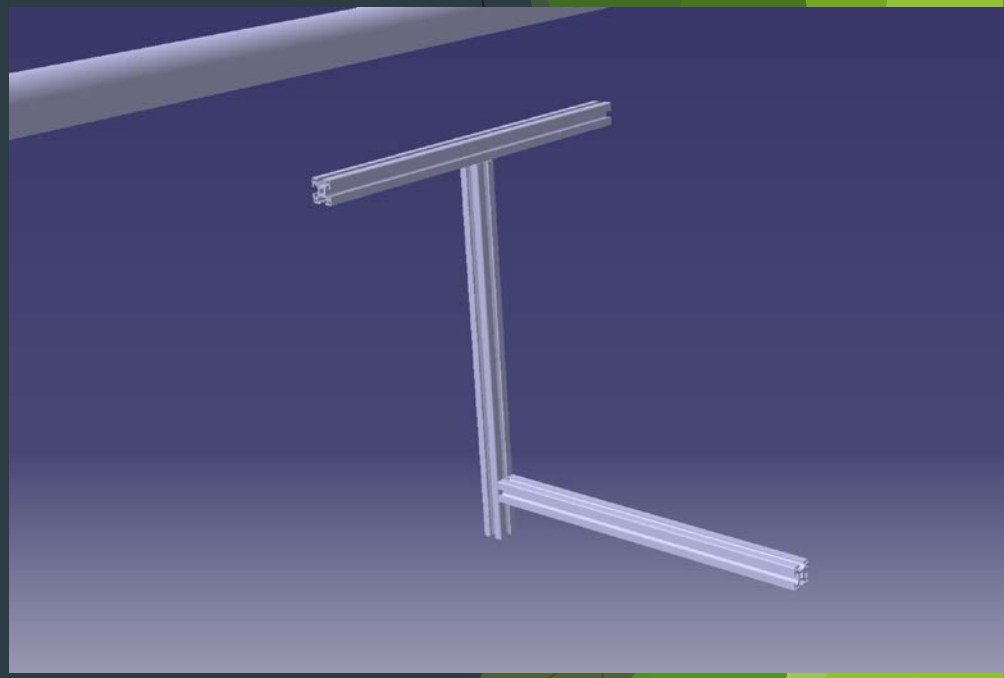


Requirements

Reference	Description	Additional Information
Req-01	The structure shall be usable by maximum of one person	The system can be used by only one person throughout a session: carrying it from the transportation vehicle to the greenhouse, ease of installing onto a heat pipe, regardless of the height of pipe, and removing from the heat pipe
Req-02	The system shall have a maximum weight of 10 [kg]	This is to limit the effort of installing the system
Req-03	The system shall be able to scout a lane in less than 10 minutes	The longest lane known to HiPerGreen is 140 [m] long, this means that the system shall go the entire length AND back within 600 [s].
Req-04	The system shall have oscillations around any axis with an amplitude of less than 3 degree	
Req-05	When oscillation occurs, the settling time shall be below 1 [s]	The camera takes approximately 1 image per second.
Req-06	The system shall not interfere with any other object in the vicinity of the heat-pipes	Objects such as fans, lights and other greenhouse installations.
Req-07	The system shall be operable by one person	During operations, the system will not require more than 1 person, e.g. a pilot and a sensory equipment is not permitted.
Req-08	The system shall have as longest dimension in any direction a maximum length of 2.5 [m]	This is to make sure it can fit within a van for transportation.
Req-09	The system shall be able to operate for a continuous time of at least 30 [min] without human intervention	Some of the greenhouses have a harsh climate, with temperature around 30 [°C] and 90 % relative humidity. The system needs to be sufficiently isolated and cooled to be able to continuously operate without failure.
Req-10	The system shall react to user input at any given time with a latency no bigger than 2 [s]	The user needs to be able to react to any unforeseen elements, such as the system moving too fast, or realising something is in the path of the system.
Req-11	Produced images shall have a blur index above 300	The index is calculated using variance of Laplacian transform, outlined in 2.4.
Req-12	Images shall be consistent through a same run, with a maximum deviation of landmarks of 1 % within the image.	Alignment is an important aspect, and therefore consistency is important throughout a run. A landmark such as the edge of a table has to be consistent throughout images. With an image size of 4500 pixels, 1 % is 45 pixels.
Req-13	The communication between the user and the system shall be uninterrupted over a distance of at least 200 [m]	Greenhouses compartment have been recorded to be up to 150 [m] long and 100 [m] wide, making a diagonal of just over 180 [m].

Mechanical Re-design

- Trade off study of three potential skeleton.
- Trade off based on
  Stability
  Estimated Weight
  Ease of Assembly
  Versatility
  Estimated Power Consumption
- The new skeleton is to be changed to more compact design



Mechanical Re-design

- Main Re-design focused on vertical beam
- Torsion Equation

$$\theta = \frac{\tau * l}{G * J}$$

- Modulus of Rigidity relation with Young's Modulus

$$G = \frac{E}{2(1+v)}$$

- For given beam, the relation is:

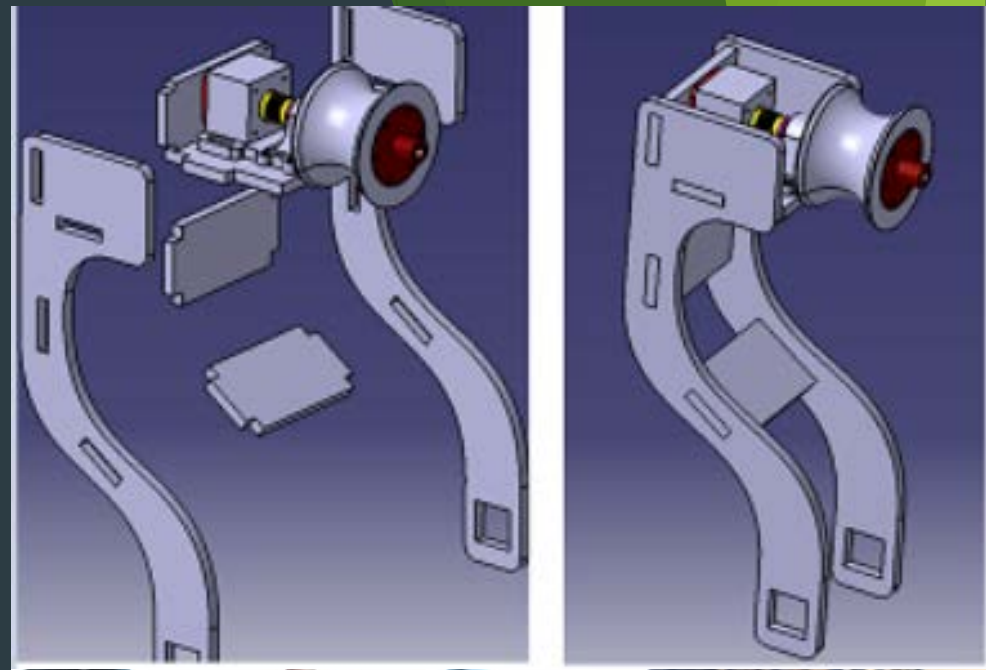
$$\theta = \frac{67}{5075} * \tau * L$$

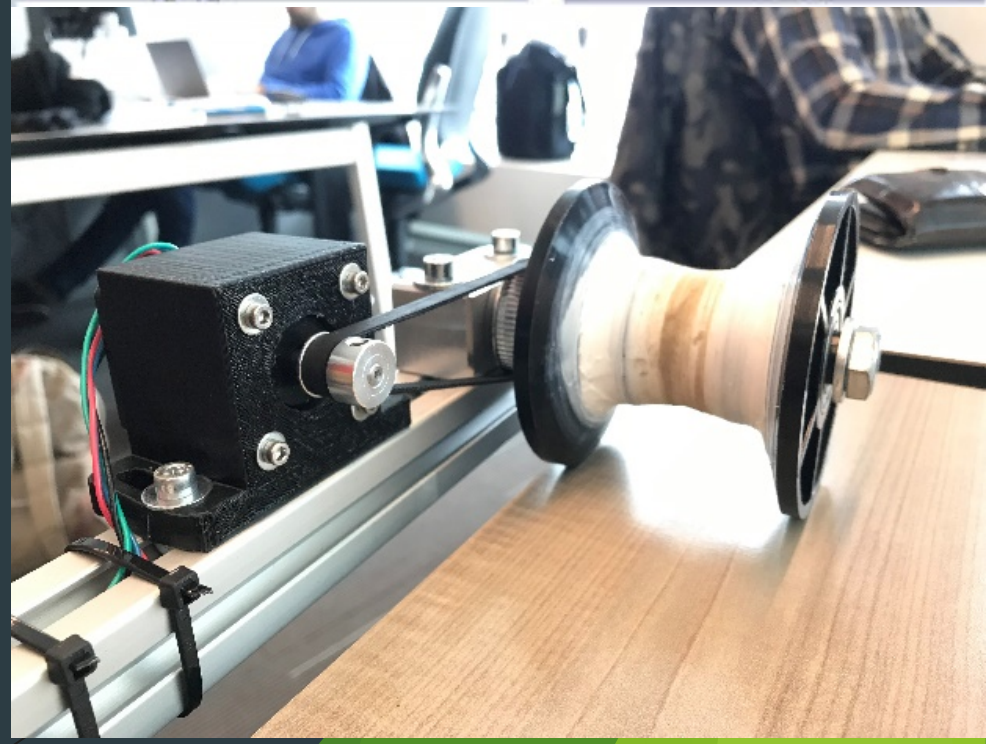
- For a max angle of 3 deg, the new length needs to be below:

$$new\ beam \leq length_{old\ beam} * \frac{3}{12.6} = \frac{6}{12.6} = 0.47\ [m]$$

Mechanical Re-design

- New Wheel mount
- More sturdy, through more direct connections
- Usage of a drive belt
- Coating of the wheel in rubber

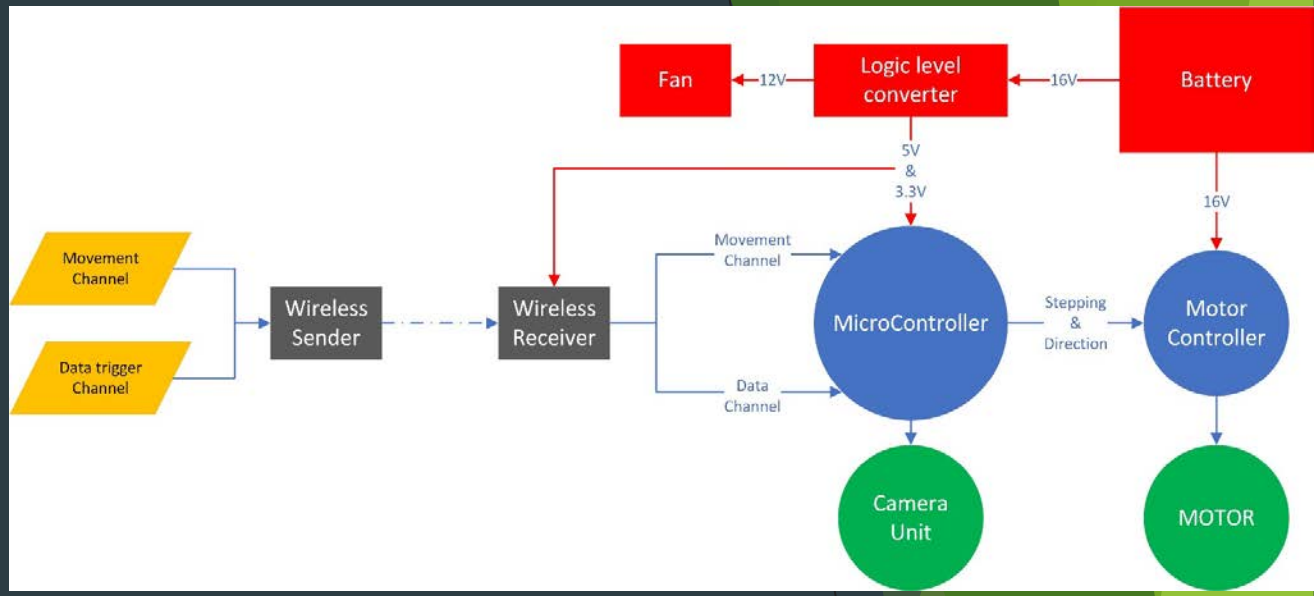


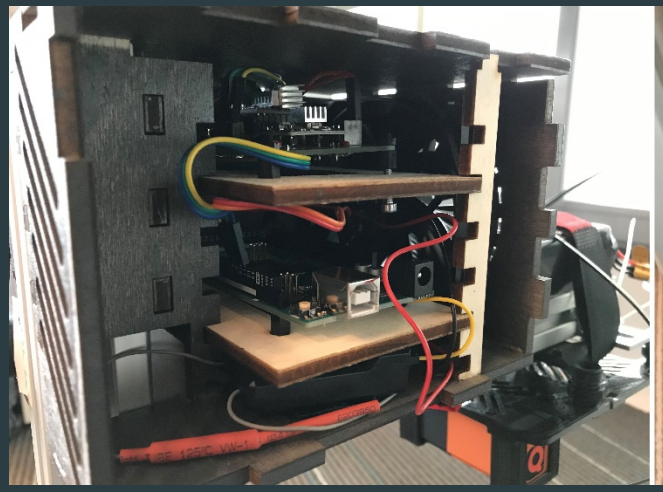


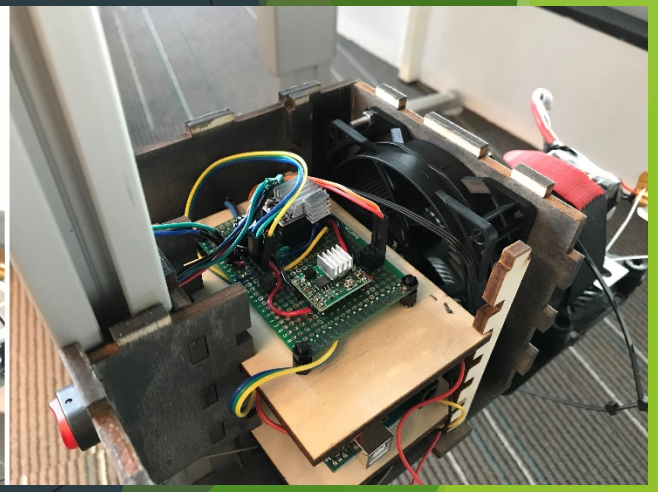
Electronic Re-design

- Direct constant communication through drone wireless technology
- Single computing unit
- Better heat dissipation, encasing and airflow

$$\dot{Q} = -kA\left(\frac{dT}{dt}\right)$$





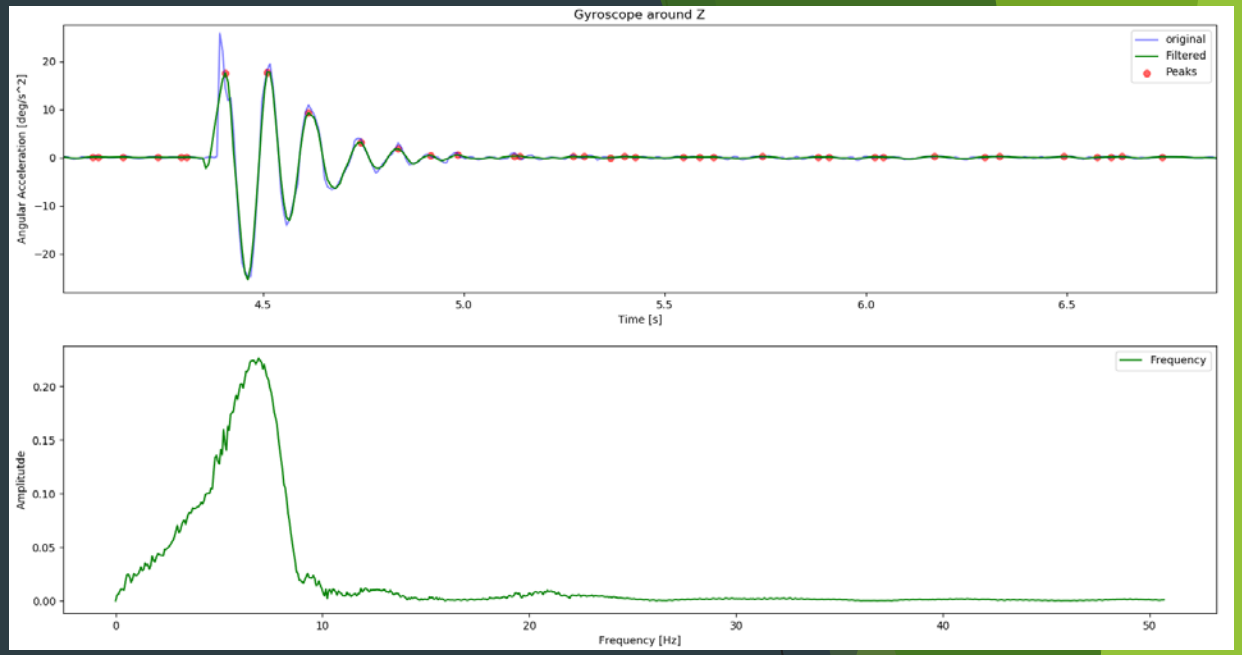


Software Re-Design

- Direct reaction to input
- First program was very slow, so needed runtime improvement such as:
  - Making own functions
  - Defining data types
  - Usage of interrupt routines
  - Toggling debugging statements

Testing of R.S. V3 Induced oscillations

- Frequency: 6.9 Hz
- Max amplitude: 0.17 deg
- Settling time: 0.6 sec
- Damping ratio: 0.125

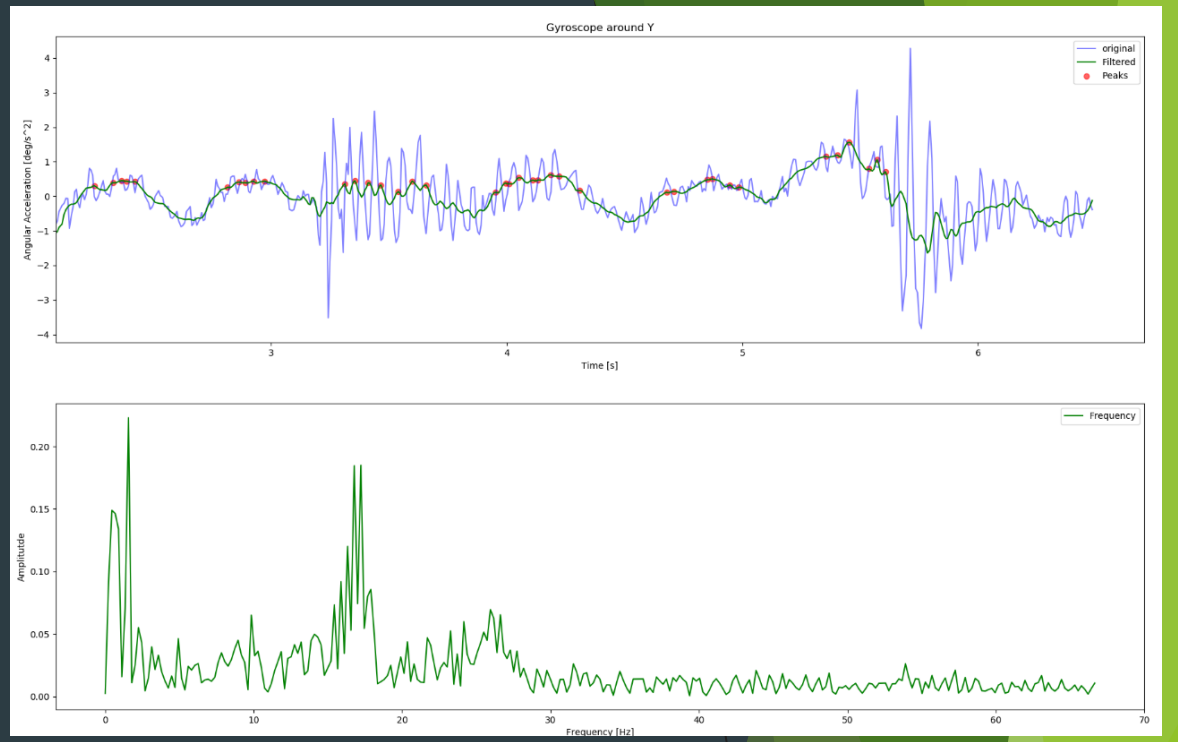


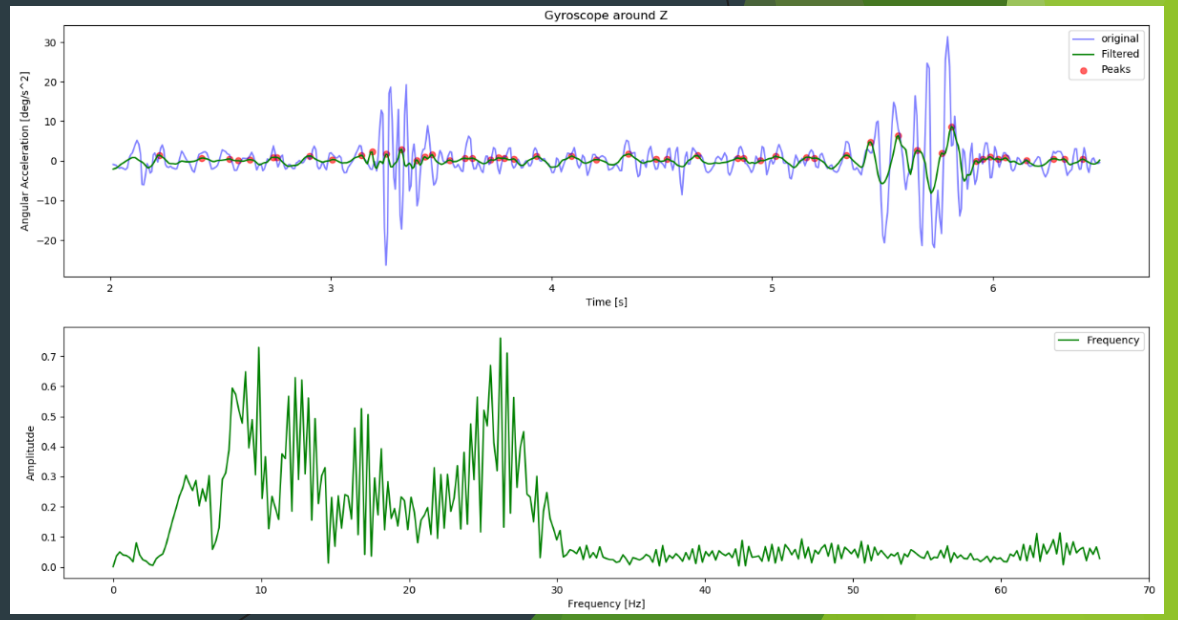
- R.S. V2 Data

- Frequency: 0.819 Hz
- Max amplitude: 12.6 deg
- Settling time: 62.8 sec
- Damping ratio: 0.013

Testing of R.S. V3
Weld points in pipes

- Similar to induced





Testing of R.S. V3 Image produced

- During induced oscillation : 502
- During passing over weld: 575

Testing of R.S. V3 Requirement compliance

- In conclusion, V3 complies with requirements

Reference	Description	Requirement achievement
Req-01	The structure shall be usable by maximum of one person	During testing, the system has been handled only by one person
Req-02	The system shall have a maximum weight of 10 [kg]	The weight of the system is weighted at 3.84 [kg]
Req-03	The system shall be able to scout a lane in less than 10 minutes	The system took 6.2 [min] to go through an entire lane.
Req-04	The system shall have oscillations in any direction with an amplitude of less than 3 degree	The oscillations have been calculated to be 0.17 [deg]
Req-05	When oscillation occurs, the settling time shall be below 1 [s]	The system has a settling time of 0.6 [s]
Req-06	The system shall not interfere with any other object in the vicinity of the heat-pipes	No object has interfered during runs
Req-07	The system shall be operable by one person	During testing, the system was operated by only one person
Req-08	The system shall have as longest dimension in any direction a maximum length of 2.5 [m]	The longest dimension, in diagonal, is of 0.56 [m]
Req-09	The system shall be able to operate for a continuous time of at least 30 [min] without human intervention	The system has run in the greenhouse for 1.5 hours with no interruption
Req-10	The system shall react to user input at any given time with a latency no bigger than 2 [s]	The latency measured is of maximum 0.5 [s]
Req-11	Produced images shall have a blurriness index above 300	The lowest index recorded is 502
Req-12	Images shall be consistent through a same run, with a maximum deviation of landmarks of 1 % within the image.	The variation of pixels is maximum of 11 pixels, less than the 45 requried
Req-13	The communication between the user and the system shall be uninterrupted over a distance of at least 150 [m]	The maximum range tested was of 220 [m]

Recommendations

- Aluminium Bosch profiles are bad at taking moments, using different material, such as composites, would make the system stronger and lighter
- The wheels are have been bought for relatively high cost. A re-design and using additive material printing technology could bring the cost down. However, be mindful of using material resistant to >70 deg C!