EPSCoR Greenhouse 9C

- Summary:
  - 180 Raspberry Pi bramble above GH9C on a gantry in a grid formation.
  - Goal: Capture and pull images autonomously then analyze pictures for phenotypic traits of plants in the greenhouse.

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Previous Efforts

- Physical & Hardware:
  - All Raspberry Pis placed on overhead gantry in a grid formation
  - Power strips with adapters and USB cables connected to Raspberry Pis
    - USB cable is Micro to Type A
    - Very similar (almost identical) to most Android smartphone chargers
      - Power adapter for Raspberry Pi provides exactly 5V, 1A
  - WiFi Dongles attached for internet access
    - Initially, Adafruit dongles used for the Raspberry Pi
    - Changed to Element14 WiPi dongles because of WiFi issues
      - More powerful signal and ability to hold a signal connected longer

Current Efforts

- Physical & Hardware:
  - The power strips and cables have remained the same, however, Stuart has made sure the power cables don’t have any loops to reduce electromagnetic interference
  - WiFi dongles remain the same as the Element14 WiPi
  - Stuart is changing the angle of the cameras in order to increase the resolution of the 3D reconstruction

Previous Efforts cont.

- Software & Management:
  - Raspberry Pi used Debian *Wheezy* (Raspbian version)
  - Quadrants of Raspberry Pis would reboot at scheduled times
  - Ganglia installed on all the Raspberry Pis to have an overview of the bramble with a 5-second delay
  - Any change to the bramble required changing each and every Raspberry Pi manually
    - The scheduled reboots would cause management to be unduly difficult
  - Pictures taken using cronjob on each Raspberry Pi independent of internet access
  - Pictures pushed to the infrastructure by each Raspberry Pi also using cronjobs.
    - Aside from files appearing on the infrastructure, no way to know how a file failed or if it failed to transfer

Current Efforts cont.

- Software & Management
  - Raspberry Pi now have Debian *Jessie* (Raspbian version)
    - Raspbian has been integrated into the proper Linux branch making it a less experimental and more stable Linux OS with access to all the proper drivers
  - All Raspberry Pis remain on at all times.
  - Ganglia reinstalled on Raspberry Pis. All rPIs report to serverpi
  - Pictures taken with cronjob on each of the Raspberry Pi independent of internet access
  - Pictures pulled onto the infrastructure from each Raspberry Pi using a cronjob on *chronos (*DDPSC rsync server)
    - Logs kept from each job when pulled from the bramble
  - Using a deployment configuration engine called Ansible to manage the Raspberry Pi bramble from *chronos*
    - Doesn't require specialized setup on the Raspberry Pis aside from Python 2.7+ and ssh
    - Can be installed via package manager or GitHub on the centralized server allowing for installation without administrator privileges

WiFi Issues

- The majority of the problems with the system stem from connection to each Raspberry Pi for either short time spans or the amount of time it takes to transfer a file
- WiFi interference is the main cause of these issues
  - There are numerous wireless access points (WAPs) stationed in and around the greenhouse that cause interference as well as the 180 rPIs themselves causing interference issues
- Current solutions to WiFi interference:
  - We have two extra WAPs and four SSIDs being used exclusively for the bramble that stop the Raspberry Pis being dropped from the network
  - The new WiFi dongles also help with stability of connection and ability to establish a connection
  - Decrease transmit power from each Raspberry Pi until it's time to transfer files then up the transmit power for the duration of transfer time
- Possible solutions to WiFi interference:
  - As recommended by IT, wire every Raspberry Pi to a switch that is directly connected to the internet
    - No WiFi, no interference
  - Halfway wire the Raspberry Pis, six at a time to a wireless bridge bringing the number of devices connected to each SSID/WAP to around 8 per SSID instead of 45 per SSID
  - If each Raspberry Pi has to be wireless and not just the entire system, then we can get WiFi dongles with directional antennas

WiFi Issues cont.

- In order to reduce the amount of data transferred between the Raspberry Pis and the centralized server:
  - Removed reverse DNS lookup in SSH
  - SSH authorization is assumed to be correct instead of verified
  - All the Raspberry Pi IP addresses are assumed to be the correct ones and given to the correct machines
  - UTMP is disabled on the Raspberry Pis
  - Enabled ControlMaster for SSH which keeps an established connection open so multiple commands can use the same connection
- RSH can be used, but is more insecure than SSH even with all the previous changes

SD Cards: Labeled!

Management of Raspberry Pi bramble

- To manage the bramble, Ansible needs a list of host names or IP addresses
  - All of the rPIs have been given static IP addresses ranging from 10.9.0.11 to 10.9.0.190
  - They are spaced out in a grid pattern and given their IP addresses in that order.
  - The IP addresses are also translated into grid matrix coordinates (2D array instead of 1D array coordinates)

Raspberry Pi Bramble: Octet and Grid Forms

10.9.0.190	10.9.0.189	10.9.0.188	10.9.0.187	10.9.0.186	10.9.0.185
10.9.0.184	10.9.0.183	10.9.0.182	10.9.0.181	10.9.0.180	10.9.0.179
10.9.0.178	10.9.0.177	10.9.0.176	10.9.0.175	10.9.0.174	10.9.0.173
10.9.0.172	10.9.0.171	10.9.0.170	10.9.0.169	10.9.0.168	10.9.0.167
10.9.0.166	10.9.0.165	10.9.0.164	10.9.0.163	10.9.0.162	10.9.0.161
10.9.0.160	10.9.0.159	10.9.0.158	10.9.0.157	10.9.0.156	10.9.0.155
10.9.0.154	10.9.0.153	10.9.0.152	10.9.0.151	10.9.0.150	10.9.0.149
10.9.0.148	10.9.0.147	10.9.0.146	10.9.0.145	10.9.0.144	10.9.0.143
10.9.0.142	10.9.0.141	10.9.0.140	10.9.0.139	10.9.0.138	10.9.0.137
10.9.0.136	10.9.0.135	10.9.0.134	10.9.0.133	10.9.0.132	10.9.0.131
10.9.0.130	10.9.0.129	10.9.0.128	10.9.0.127	10.9.0.126	10.9.0.125
10.9.0.124	10.9.0.123	10.9.0.122	10.9.0.121	10.9.0.120	10.9.0.119
10.9.0.118	10.9.0.117	10.9.0.116	10.9.0.115	10.9.0.114	10.9.0.113
10.9.0.112	10.9.0.111	10.9.0.110	10.9.0.109	10.9.0.108	10.9.0.107
10.9.0.106	10.9.0.105	10.9.0.104	10.9.0.103	10.9.0.102	10.9.0.101
10.9.0.100	10.9.0.99	10.9.0.98	10.9.0.97	10.9.0.96	10.9.0.95
10.9.0.94	10.9.0.93	10.9.0.92	10.9.0.91	10.9.0.90	10.9.0.89
10.9.0.88	10.9.0.87	10.9.0.86	10.9.0.85	10.9.0.84	10.9.0.83
10.9.0.82	10.9.0.81	10.9.0.80	10.9.0.79	10.9.0.78	10.9.0.77
10.9.0.76	10.9.0.75	10.9.0.74	10.9.0.73	10.9.0.72	10.9.0.71
10.9.0.70	10.9.0.69	10.9.0.68	10.9.0.67	10.9.0.66	10.9.0.65
10.9.0.64	10.9.0.63	10.9.0.62	10.9.0.61	10.9.0.60	10.9.0.59
10.9.0.58	10.9.0.57	10.9.0.56	10.9.0.55	10.9.0.54	10.9.0.53
10.9.0.52	10.9.0.51	10.9.0.50	10.9.0.49	10.9.0.48	10.9.0.47
10.9.0.46	10.9.0.45	10.9.0.44	10.9.0.43	10.9.0.42	10.9.0.41
10.9.0.40	10.9.0.39	10.9.0.38	10.9.0.37	10.9.0.36	10.9.0.35
10.9.0.34	10.9.0.33	10.9.0.32	10.9.0.31	10.9.0.30	10.9.0.29
10.9.0.28	10.9.0.27	10.9.0.26	10.9.0.25	10.9.0.24	10.9.0.23
10.9.0.22	10.9.0.21	10.9.0.20	10.9.0.19	10.9.0.18	10.9.0.17
10.9.0.16	10.9.0.15	10.9.0.14	10.9.0.13	10.9.0.12	10.9.0.11

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6
7,1	7,2	7,3	7,4	7,5	7,6
8,1	8,2	8,3	8,4	8,5	8,6
9,1	9,2	9,3	9,4	9,5	9,6
10,1	10,2	10,3	10,4	10,5	10,6
11,1	11,2	11,3	11,4	11,5	11,6
12,1	12,2	12,3	12,4	12,5	12,6
13,1	13,2	13,3	13,4	13,5	13,6
14,1	14,2	14,3	14,4	14,5	14,6
15,1	15,2	15,3	15,4	15,5	15,6
16,1	16,2	16,3	16,4	16,5	16,6
17,1	17,2	17,3	17,4	17,5	17,6
18,1	18,2	18,3	18,4	18,5	18,6
19,1	19,2	19,3	19,4	19,5	19,6
20,1	20,2	20,3	20,4	20,5	20,6
21,1	21,2	21,3	21,4	21,5	21,6
22,1	22,2	22,3	22,4	22,5	22,6
23,1	23,2	23,3	23,4	23,5	23,6
24,1	24,2	24,3	24,4	24,5	24,6
25,1	25,2	25,3	25,4	25,5	25,6
26,1	26,2	26,3	26,4	26,5	26,6
27,1	27,2	27,3	27,4	27,5	27,6
28,1	28,2	28,3	28,4	28,5	28,6
29,1	29,2	29,3	29,4	29,5	29,6
30,1	30,2	30,3	30,4	30,5	30,6

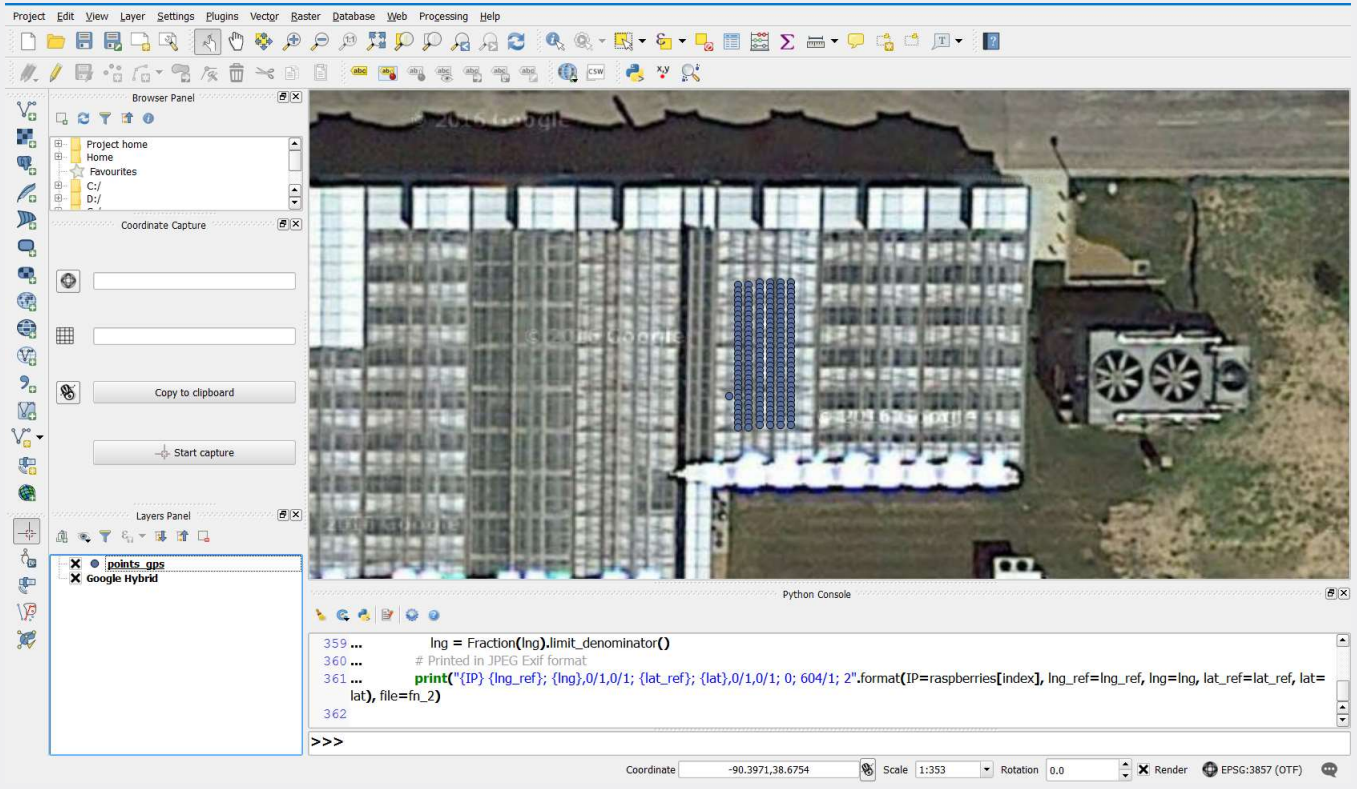
Management of Raspberry Pi bramble

- Ansible uses playbooks to execute plays that are then executed on all or a limited number of hosts
- I made several playbooks to handle:
  - Taking test pictures
  - Copying pictures from the bramble
  - Transferring the picture taking python script
  - Changing all of the SSH options (and reverting changes)
- A full documentation of the process from initial SD cards to fully setup Ansible management can be found at my github:
  - https://github.com/calizarr/EPSCoR_Bramble_GH9C/

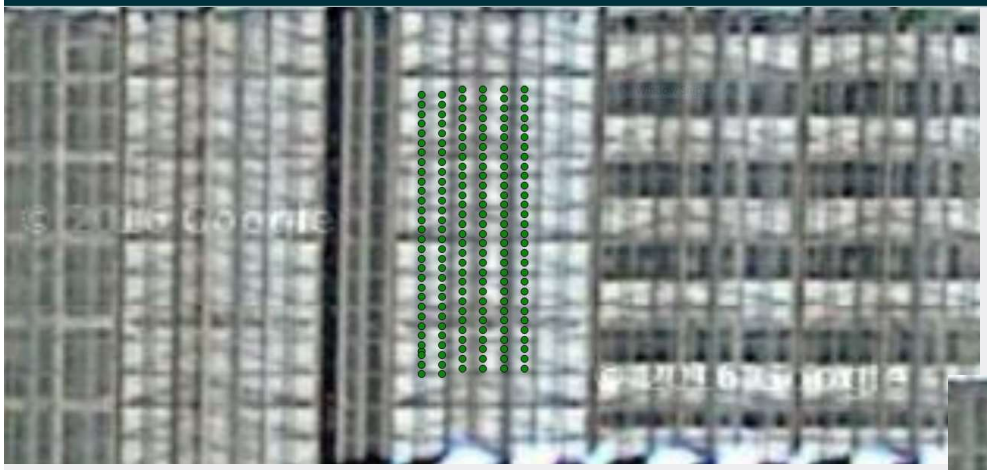
Adding GPS units to images

- During the 3D reconstruction process, we found out that VisualSFM can use GPS data.
- I chose a spot in Greenhouse 9C found its GPS coordinates, measured the distance from the spot to ShakoorCamera145.
  - Using ShakoorCamera145 as an origin, I used QGIS and PyQGIS to reconstruct the positioning of the bramble as a matrix
- Stuart measured the corners of the greenhouse and found their coordinates as well as the distance from the northeast corner to ShakoorCamera21
  - Reconstructed bramble as matrix using ShakoorCamera21 as the origin.
- Still a work in progress, but it should allow the 3D reconstruction to use real units when scaling and therefore allow us to measure items in the reconstruction

QGIS Overlay (Google Maps Hybrid)

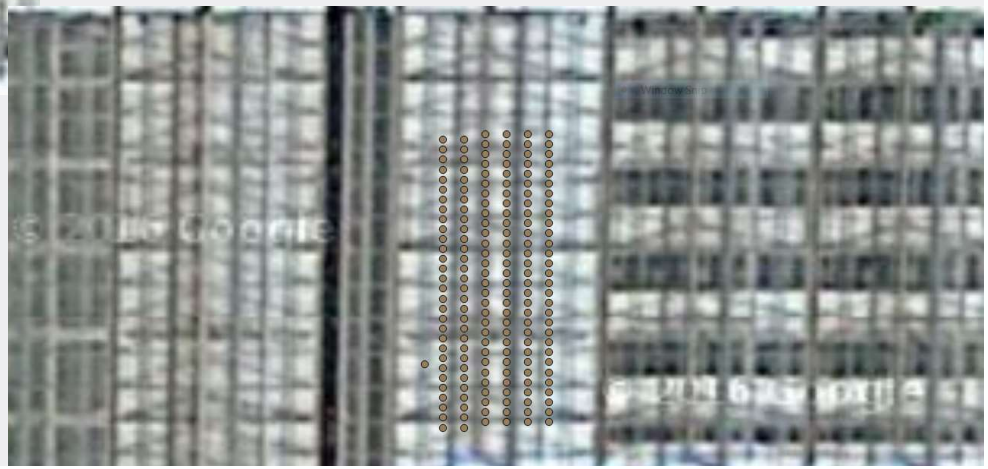


Raspberry Pi Cluster On QGIS



Stuart's Coordinates

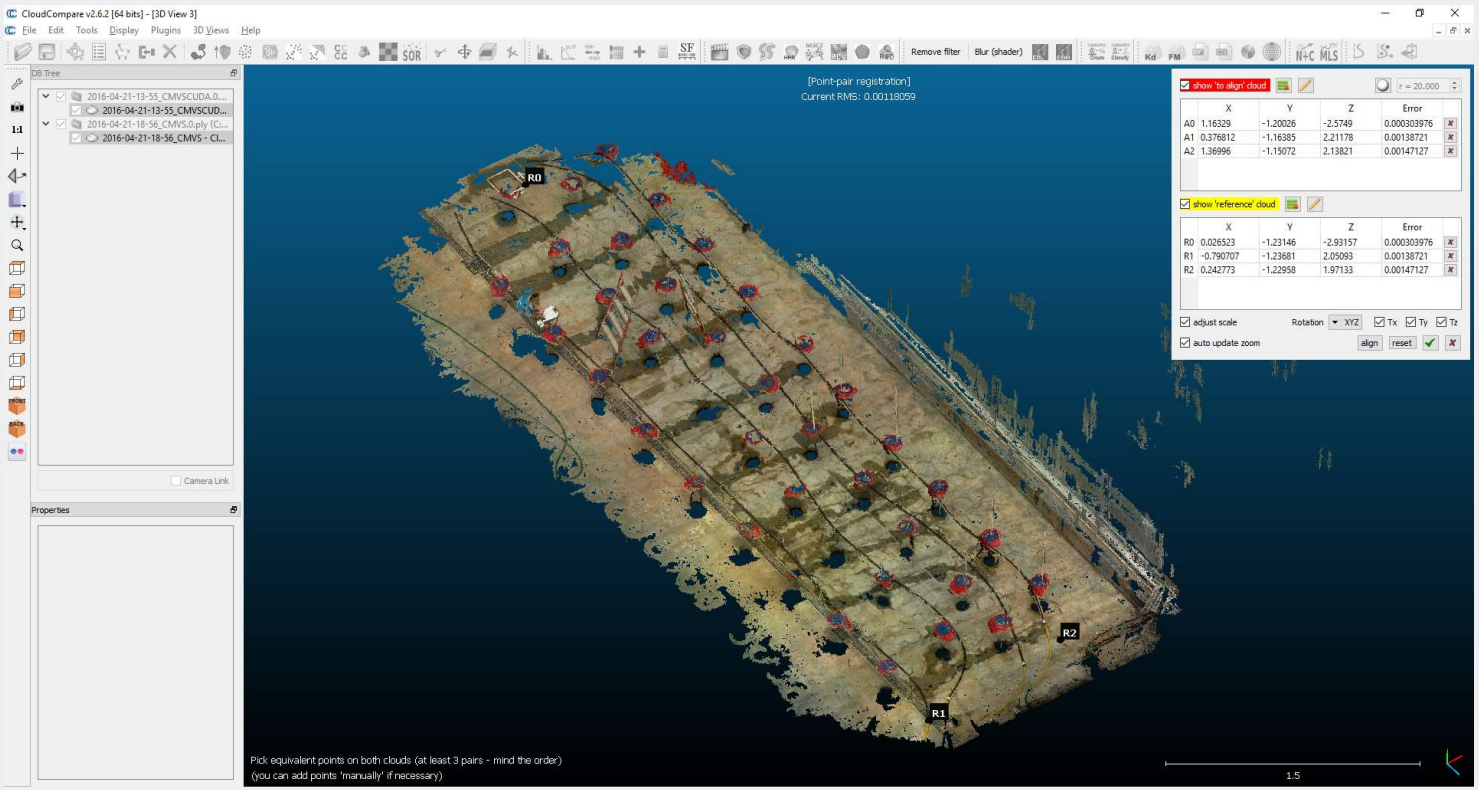
César's Coordinates



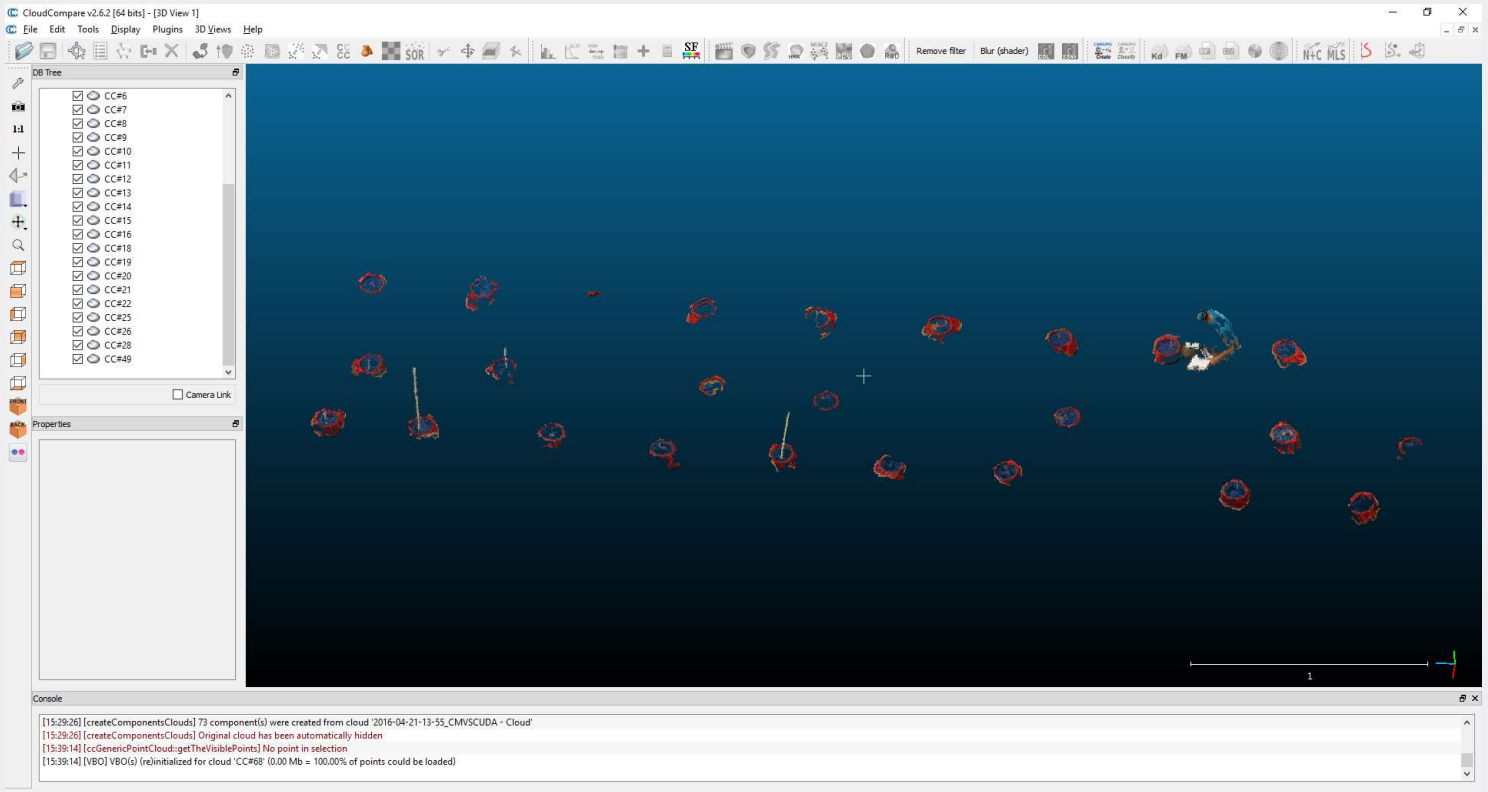
Results

- 165 Raspberry Pis are consistently reporting and establishing connections. Between 170-172 occasionally establish connection
- Initial 3D reconstructions exist and as camera positions and angles are finalized, we keep improving them
- Fully documented process

3D Reconstruction



3D Reconstructions: Connected Components



Next Steps

- Adding GPS units to image files to aid in 3D reconstruction
  - Also have proper units and scale for the 3D reconstruction
- Finalize camera angles and positions to improve 3D reconstruction
- Set the bramble to run autonomously
- Take 3D reconstruction point cloud and analyze subsections (plants) to extract phenotypes