1. Introduction
   1. Abstract
   2. Overview
      1. What mapping/identification is (assigning coordinates, family IDs)
      2. How accurate must be (to distinguish from other plants)
      3. Why it needs to be somewhat automated
      4. Thesis statement about using image based mapping
   3. Motivation
      1. Benefits Perennial agriculture research - the need to locate same plant year after year. Talk about Land Institute.
      2. Also benefits one year crops because it allows easy look-up in database.
      3. Existing methods are slow or unreliable.
      4. Other benefits of mapping - precise weeding
   4. Summary
      1. Link results/analysis back to thesis statement
      2. Do I state my opinions here or just results?
2. Background
   1. Phenotyping
      1. Probably not phenotyping… could be background for image analysis?
      2. What it is... why it's useful... ]
   2. Coordinate Systems Used
   3. Image Projection
   4. Existing Research
      1. Beam Splitting
         1. Include figure from other paper
         2. There’s a paper about mapping seeds, should I cover that too?
      2. Image Based Mapping
         1. Include figure from other paper
3. System Design
   * 1. Plant Identification
        1. QR Codes. Error correction settings, versions, content.
        2. Mention other types of 2d codes and why we chose QR codes.
        3. Important of size (to fit through transplanter)
        4. Include figure of QR code
     2. Additional Markers
        1. Using blue sticks – explain why blue
        2. Include figure of blue stick
        3. Row End Markers – include figure of row end QR code
     3. Platform Design
        1. Include figure of robot with 2 cameras. IMU
        2. Talk about specific hardware used and why (QR resolution, GPS accuracy)
     4. Mode of Operation
        1. Make a point about this is why a robot was used instead of a push cart.
        2. Autonomous vs. Cruise control.
        3. Briefly about ROS package.
     5. Data Collection Software
        1. DySense – include screenshot of main screen (looks better now)
        2. What it’s useful (combine platform orientation/position with images)
        3. Getting images back in real-time vs. CF Card
4. Post-Processing Pipeline
   * 1. Pipeline Overview
        1. What stages are (command line scripts)
        2. Why split up into stages.
        3. What the inputs are and what the desired output of the whole post-processing.
        4. How intermediate data between stages is stored.
     2. Stage 1 - Extracting QR Codes
        1. Finding Codes – HSV filter, filter by size, scan using ZBar
        2. Include figure of HSV coordinate space.
        3. Classify code (row end vs. group code)
        4. Calculating coordinates
        5. Include figure showing coordinate transformation
        6. Send others to be review later.
     3. Stage 2 - Creating Field Structure
        1. Add in Missed Codes
        2. Calculating “Field Coordinates” (should I call this something different?)
        3. Use row codes to make rows/passes
        4. Projection Algorithm – Include Figure
        5. Form groups from segments
        6. Include figure showing how groups are formed between multiple rows.
     4. Stage 3 - Extracting Plant Parts
        1. Why this is separate from QR stage (it excludes non-possible images).
        2. Relate back to finding QR codes, but now filtering for green instead of white
        3. Finding blue sticks.
     5. Stage 4 - Locating Plants
        1. Clustering parts into plants – include figure
        2. Relating plants between images
        3. Recursive plant filter – include figure
     6. Stage 5 – Saving Field Map
        1. Validating # of plants in each group.
        2. Numbering (serpentine ordering) – include figure
        3. Shifting coordinate system.
5. Experimental Setup
   1. Field Setup
      1. Crop type, time of year, location, researcher, etc
      2. Size of field - number of rows, number of plants
      3. Two row transplanter. Straight rows - doesn't matter north/south.
      4. Figure of transplanter.
      5. QR codes automatically deposited as plants.
      6. Row end codes placed manually.
   2. Mapping Process
      1. Robot used in cruise control mode.
      2. Setting up cameras (white balance, mode, etc)
      3. Mapping at nighttime vs. daytime. Importance of shade.
      4. Could include figure of robot with umbrellas
6. Results and Analysis
   1. Percentage of QR codes that were detected
   2. Analysis of why QR codes weren’t detected – including figures of each
   3. Average (absolute) error of QR codes in forward/lateral direction
   4. Total number of plants detected, total number ‘created’
   5. We didn’t really survey any plants, but I could have Lee do that for me now before it gets too cold?
7. Conclusion
   1. Summarize results
   2. What worked and what didn't.
   3. Recommendations
      1. Paying close attention to camera settings.
      2. Using Tags instead of sticks
      3. Faster cameras, lower latency
      4. Using extracted plants for phenotyping.
      5. Manual-based trigger mapping
8. References
   1. I’m kind of worried I won’t have a lot of references.
9. Appendices
   1. Should I include code? Links to repositories?