Orchard Structure Classification

Project Proposal

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Abstract

Different planting patterns are able to produce better yields for crops, thus this project aims to develop software that can identify these patterns within aerial images. Using this information farmers are able to make informed decisions about the layout of their orchards. Three approaches will be taken in order to establish the best method of pattern identification. These approaches are the Hough Transform, Template Matching and 2D image comparison with Hausdorff Distance. These approaches are explored giving a broad overview as to how each one will solve the problem and giving some background of the literature. The project is then outlined in terms of milestones, success metrics, and deliverables.

1. Project Description

Food security is a large problem faced globally with many factors influencing it such as high population growth, global warming and poor agricultural systems [5]. As the population increases exponentially, the demand for food will follow this trend [6]. Farmers need to ensure that they can keep up with this demand, whilst facing land constraint problems. Thus, they need to take the best approach that will improve their yield. Precision agriculture is the science of improving crop yields and increasing cost-effectiveness by assisting management decisions using high technology sensors [7]. Aerobotics, a South African company specializing in tree crop protection, utilizes unmanned aerial vehicles (UAV) to acquire high resolution images of agricultural land. These are then processed to establish data on productivity of the crops. This information can be used to evaluate yield, soil condition, plant health, fertilizer and pesticide effect and irrigation [7], assisting farmers in keeping a large-scale idea of their crop management and problems.

The focus of the upcoming project is to identify planting patterns for crop/orchard management. These have a major effect on the final yield of the crops for the farmer as different patterns yield different advantages for the farm such as effective cross-pollination, efficient irrigation, and accessibility.

Our project will focus on identifying and classifying planting patterns (Figure 1) such as:

- Square patterns
- Hedgerow or border patterns
- Quincunx/hexagonal patterns
- Double row planting patterns

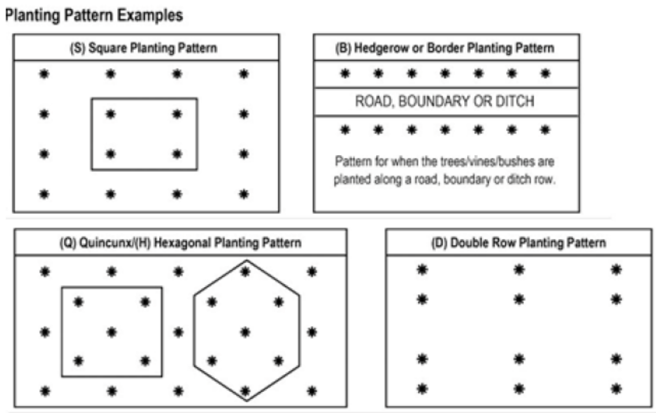

Figure 1: demonstrates some of the planting patterns

If time permits, we will also look at recovering the parameters for the structure of the identified planting pattern. These parameters are different for each planting pattern but generally include the spacing between trees, the spacing between rows, and position of a corner tree to the crop.

We will be using three approaches in order to identify these patterns, namely Template Matching, Hough Transform and 2D Image Comparison using Hausdorff Distance.

2. Problem Statement

This project investigates the ability of these three methods to identify planting patterns within an image. These methods will also attempt to extract the parameters of the planting pattern identified. We can then determine the best approach that is suited to identifying and matching orchard patterns. The algorithms need to accurately be able to account for missing trees and irregularity of tree positions within their rows. The input data and system outputs will need to undergo a level of pre-processing and postprocessing respectively, in order to account for these inaccuracies. Aerobotics currently has no out of the box solution for this process. As this software will not translate into a finished product, we are not concerned with client usability and ease of use, however we need to ensure that Aerobotics can understand the results and correctly integrate the software into their current system. They will need to provide an interface in which users (farmers) can abstract data about their crops and make management decisions from that point.

3. Aims of the work

The aims of the three approaches are:

Template Matching: The objective of this research is to see whether template matching can be used to accurately identify planting patterns in crops/orchards.

Hough Transform: The objective of this method is to identify the main row orientations, and lengths within the orchard image. The data generated by this output would then be used to identify planting patterns and spatial differences between individual trees and rows.

2D image comparison using Hausdorff Distance: The main research objective is to determine whether the Hausdorff distance can effectively identify patterns. This technique measures the distance of a model to an image, by superimposing the objects on one another and calculating the similarity.

4. Procedures and Methods:

4.1 Data Acquisition

Aerobotics will provide data samples of the orchards they facilitate. The data includes an aerial image of the farmland, an image of the boundary of the orchard and a geojson file. This file includes the tree polygons along with their classification, confidence intervals and coordinates.

4.2 Data Abstraction

The geojson file can be abstracted into a coordinate reference system using the pyproj library. This file includes the tree detections and each detection contains a confidence interval, which can be used to determine whether a tree is present. In order to easily work with the data, the centroid of each tree polygon can be taken to represent the tree. This can be achieved through taking an average of the polygon coordinates, which may result in a slight distortion if the polygon leans in a certain direction, however it allows for the pattern detection problem to be recast in terms of 2D point processing.

4.3 Template Matching

Template matching is the process of finding the presence and or position of a predetermined image, called a template in another image. This approach will have at least one template for every planting pattern that we are going to try to identify as well as a template as well as a template for each pertinent variation of the planting pattern. These templates will be developed from an amalgamation of crop patterns of the template type. That will stem from an idealised template of each pattern that can produce correct output for an idealised image. As the system correctly identifies more data the input can be added to the database for each template which will help in making a more general template for that planting pattern type and account for noise.

The major challenge that faces template matching techniques, especially as the number of templates increase, is efficiency. This problem is compounded by the use of similarity measures such as normalised cross-correlation or zero means normalised cross-correlation which are more robust but cannot account for rotation changes. As the complexity of the data grows the system will incorporate feature and geometric based techniques to solve the issues of scale and rotation. This can be done by identifying features such as corners of the orchard for scale and/or rotation or calculating angles of the direction of the lines to work out the orchard rotation. This will evolve into a system that uses multiple template matching passes over the image to identify the rotation, scale, planting pattern, and then extract information. This will have to be balanced with program efficiency.

To maximise efficiency, the image will be converted to grey-scale so the algorithm only needs to deal with a single channel of data. The similarity measure calculations can also be parallelized by doing the matrix calculation on the GPU. To deal with noise more effectively the pre-processing of the data will create a centroid with a max pixel value. The centroid will be surrounded by a gaussian noise polygon so each tree will return high correlations at matches close to the centroid but can still account for noise somewhat. The centroid will also be used to extract the information about the crops for parameters such as intra and inter row spacings.

The program will then output the correlation measure of each planting pattern order in descending order. Ideally this will have one or a group of very similar patterns with a high correlation then a big decrease in correlation for the rest of the list. Each extracted information parameter will be presented in its own way but could be a range of distance for spacings or coordinates of the centroid for tree positions.

4.4 Hough Transform:

The HT method follows three main steps (Figure 2): Firstly, the coordinates of a pixel in the cartesian image space is transformed into a sinusoidal curve in the parameter space. Secondly, an accumulator with a cell array (which is equal to the size of the unknown dimensions) is laid on the parameter space and each pixel adds one vote to the cells lying on its sinusoidal curve. Thirdly, cells with global or local maximum votes are selected and the parameter coordinates (p, θ) can be used to determine the line as well as its orientation in the cartesian space [22]. Prior to the Hough Transform being applied, there may be a need to convert the source image to grey-scale and apply a Canny Edge detector to the image.

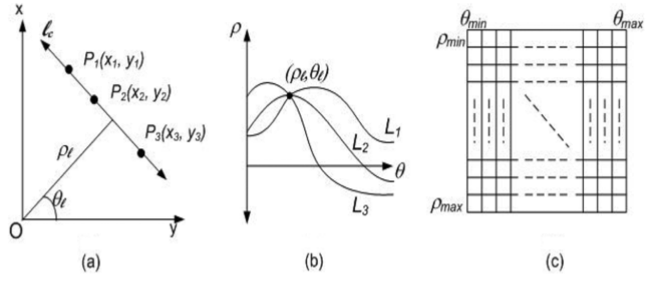

Figure 2. Straight line Hough Transform. (a) Collinear points in the image plane. (b) Intersecting sinusoids in Hough space. (c) Implementation as a two-dimensional array of accumulators

Images may need to be segmented with a windowed approach being used in order to identify different planting patterns within one image. The use of the matplotlib library may be useful for deciding on the sliding window or region of interest within the image.

The output of the HT is a two or three element vector of the lines containing the distance from the co-ordinate origin, the line rotation and the accumulator votes. These outputs can be used to determine points, which can then be used to determine potential lines.

This HT output can be used in post-processing and plotted onto histograms or used to segment images. Line filtering could then be used to try to identify the correct rows by using analytic geometry.

The analytic geometry techniques that will be applied to help reduce false positives would involve the use of linear line equations, finding the points of intersection between lines, identifying parallel lines using gradients and calculating the distance between parallel lines and deciding if this spacing may be too low indicating line repetition.

After line filtering is applied and main row orientations are identified, it may be possible to detect distances between the rows and individual trees by using differences between points on the lines.

There will be certain challenges that will need to be overcome using this method. These would include ground noise conditions, limiting false positives and detecting curvature if they exist in the image. As trees in the orchards could be quite dense, there is a good possibility of surrounding ground noise, which will make it difficult to identify main row orientations. The limitation of false positives may be difficult to achieve and may only be able to be reduced. Curvature within row lines may be problematic but could be attempted to be addressed through overlapping windowing of the image.

Lines will be overlaid on the original image of the orchard that is provided. These can then be visually inspected. If distances are measured, these would need to be confirmed against ground truth information. It would also be useful to have the scale of the image that is provided. Both the scale and ground truth conditions would need to be requested from Aerobotics. Histograms and Hough maps will be inspected for local and global maximums, which will indicate prevalent lines.

4.5 Pattern identification utilizing image comparison based on Hausdorff Distance

This approach is based on point pattern matching under rigid motion. We aim to solve this problem through utilizing mathematical optimization, which is expressed using matrix algebra. The Hausdorff distance determines the similarity between two images, using the Euclidean distances of the images. Where a strong similarity between images will result in a low value if they are similar and high if they are not. This approach allows for planting patterns to be matched against the point data set. This will be implemented in Python3 and use applicable libraries where possible.

The Hausdorff distance uses the distance between each point in the data, this is optimal for this case as each tree polygon would have gone through pre-processing to ensure an effective point coordinate system can be used. As this approach looks at the similarities between two images, we will need to create data sets which contain the planting patterns needed. These sets will act as our constant variable and can be generated using the Python Shapely module. The next element is the optimization model in which we will perform several affine transformations on the data set, namely rotation and translation. This will ensure the optimal distance is achieved between the two images. This optimization search will be attained through an exhaustive linear search using the parameters x, y for translation and θ for rotation in order to achieve the lowest value for the Hausdorff distance. This method also does not account for scaling which could be a problem if the data is very different. To approach this, we could use a calibration method, whereby we use a density metric and scale the data to the same density of our constant variable. Another approach which could be taken is to use a genetic algorithm which is another optimization technique based on evolutionary algorithms. This could be used to speed up the matching process or yield better results, however it will only be implemented if time permits.

The challenges imposed by this approach are ensuring that the data can somewhat effectively correlate to the generated data, which could be problematic if there are many different patterns within the data. This approach will only be able to handle one matched pattern at a time, for example it will not be able to detect zig zag data and square patterns within the same field. In an attempt to achieve this, we could use a segmentation approach in which we could take a specific sample size of each portion of the data, or we could use a more sophisticated approach based on thresholding. However, given time constraints, it is likely that we will use a straightforward sample size approach. This will need to be executed with many different sample sizes in order to ensure that a portion of the pattern is not obscured when the sample is taken. Another problem may be identifying the hedgerow or border planting pattern, as the point data will not account for this, thus there may need to be a pre-processing segmentation algorithm that can identify these roads or boundaries. This could be achieved through using OpenCV in conjunction with many online resources.

When evaluating our results, we will have the exact value of similarity between images, as the algorithm already operates on the basis of an optimisation metric. The output will produce the Hausdorff distance between images, thus determining a “confidence parameter”. It will also output the shape of the pattern and the location.

4.6 Evaluation

To evaluate our system through the development cycles we intend to use an idealised form of the data, to create ground truths for the planting patterns we intend to test. Initially this ideal data will have negligible noise, with perfectly straight rows and would return a very high match to the templates (>95%). As these systems succeed in correctly identifying the patterns in the ideal data we will gradually add more noise of different types. For example, missing trees, curved lines. Eventually this will graduate to real world data that we have received.

5. Ethical, Professional and Legal Issues

As there will be no human subjects required to test the software, we will not require an ethics clearance. Aerobotics have the responsibility to make sure their images do not contain people and only orchards. They would also ensure the farmers allow the distribution of aerial images of their orchards for research. They have also provided data they own for our experiments

6. Related Work

6.1 Template Matching

Template matching has not been used to detect planting patterns or general patterns in orchards. There are several successful implementations of Template matching being used to identify trees within an image [1,2,3,4]. The problems that are faced by this implementation are rather classic problems for template matching, namely rotation and efficiency. The efficiency will be optimised through the use of single-channel (greyscale) images[16] and the parallelization of the similarity measures [17]. The rotation issue is not using a complex measure such as the Best Buddies Pairs [18] but is testing multiple rotations of the template so this becomes an efficiency issue as well.

6.2 Hough Transform:

The Hough Transform has been used in order to identify rows within orchards/crops. A study by J.A Reico et al [12], used the HT to identify the major row orientations within images of crops. This information was then used to determine lengths between rows and trees. This study managed to identify the main row orientations even with individual trees missing.

G. A Soares et al [13] used a windowed technique to detect the curvature of coffee plantation rows, due to geographic ground conditions. This had relative success, but the results were not perfect as there was still line overlap and false positives detected. Breaking up the image into windows was used to detect curvature, but this technique may be applied to an image where the planting pattern has straight lines. The purpose of doing this would be to try and detect different planting patterns within the same image.

In [15], it was observed that ground noise conditions were a problem in identifying the major row directions. This was primarily overcome in the study through the application of a line filter in the post-processing stage. This was applied on the data outputted by the HT and seemed to have positive results and may be suitable for this project.

6.3 2D image recognition using Hausdorff Distance

The Hausdorff distance identifies the degree of similarity between two sets of points using an optimisation technique. This involves rotating and translating the image to be matched until the minimum Hausdorff distance is achieved. Huttenlocher et al. [19] proposes an extension of the original algorithm that is extended to rigid motion that accounts for and is tolerant of dissimilarity between the images, whereas previous work would reject dissimilar images. Chew et. al [20] improve upon this algorithm by implementing a parallel algorithm using the technique of parametric searching that greatly speeds up the original runtime. Kharbach [21] proposes using a genetic algorithm in order to improve upon this search speed, which yielded poorer results opposed to the linear search, but may produce better results in a larger sample size.

7. Anticipated Outcomes:

7.1 System

The system will take in input of .geojson and .tif files provided by the Aerobotics company. These will be pre-processed so that each of them only contains a single planting pattern. These images will then be processed by a system of one of the three approaches. These approaches will use their techniques to identify what planting patterns are present in the image. Once this is successfully implemented and working the system will also extract information from the image, such as the space between crops.

7.2 Challenges

The challenges of design and implementation of the system are as follows. We may not have enough data to fully test our programs as data comes from an outside source and we cannot generate our own beyond idealised versions. There could also be an issue of bias in the data that skews the system to only be able to detect patterns in certain areas. Noise can impact the certainty of the results for each of our methods, leading to false negatives or much lower confidence levels for planting patterns or information. The amount of noise reduction processing that will occur will be dependent on the approach and its level of robustness to noise. The presence of multiple planting patterns may also be a challenge in real-world implementation of our software. The data will be processed so each image only contains a single planting pattern. This could lead to a large amount of time spent on pre-processing the data or developing idealised data that could impact development time.

7.3 Expected impact of the project

As the project is for the Aerobotics company, a successful implementation could lead to real world use. There is a possibility for real world impact of this project in aiding farmers in crop and orchard management by providing them with accurate analysis of the state of their crops. This data could then be used to test yields of planting patterns or easily identify areas that are missing trees, thus enabling farmers to easily find issues and giving them data to improve their farm.

7.4 Key success factors

The primary success factor for this project is the ability to determine planting patterns in the image of the crops. The secondary success factors being the ability to then extract information such as the distance between plants and rows, from the image. To achieve the primary goals, we need to consider the accuracy and efficiency of the program. The success factor for accuracy is detecting the presence of planting patterns with a high probability (>95%). There are partial successes for these criteria such as the correct planting pattern having the highest probability even if its probability is below the threshold. The success factor for efficiency is that the runtime of the program is that the program can execute on a laptop or computer with a GPU in under five minutes. Though if there is an efficiency versus accuracy trade off then the customer should be able to choose which one to prioritise.

8. Project Plan:

8.1 Risks

The risks for the project have been tabulated in the form of a Risk Matrix (Appendix 9.2) and Risk response Plan (Appendix 9.3). This identifies the potential risks for the project, the mitigation plan for risks that may occur and how to monitor each risk so that the members of the project team can be aware if a potential risk may be starting to occur.

8.2 Timeline

The timeline for the project can be seen in the Gantt Chart (Appendix 9.1). This project plan is started in June, post the literature reviews done on each methodology that is going to be followed. The last project deliverable that is highlighted is the webpage that is due on the 18th October 2021. Post this, there will be preparation on showcasing the project findings, but this date is yet to be confirmed.

8.3 Resources required

The project will be developed in Python3 and written using PyCharm.

Python3 packages:

- affine: Working with affine transformations.

- geopy: Particularly for calculating the geodesic distance between two points in a geographic coordinate system.
- numpy: Fundamental scientific computing.
- scipy: Fundamental scientific computing.
- scikit-image: Image processing toolbox.
- scikit-learn: Machine learning toolbox.
- Pyproj
- OpenCV
- Matplotlib
- Python Shapely module

Possible need of use of the UCT High Performance Computer.

8.4 Deliverables

Deliverable	Due Date
Literature Review	4th June 2021
Project proposal	24tht June 2021
Proposal Presentations	9th July 2021
Revised Proposal Finalized	30th July 2021
Initial Software Feasibility Demonstration	10th - 13th August 2021
Complete Draft of final paper	6th September 2021
Final Paper Submission	17th September 2021
Project Code Submission	20th September 2021
Demonstration	4th - 8th October 2021
Poster	11th October 2021
Web Page	18th October 2021
Show Case	TBA

8.5 Milestones

- Literature Review
- First Draft of Project Proposal
- Second Draft of Project Proposal
- Final Project Proposal
- Proposal Presentation
- Revision of Project Proposal based on presentation feedback
- Project Proposal Finalized
- Software Feasibility Implementations
- Testing
- Software Feasibility Demonstration
- Software Implementation Prototype
- Final paper first draft
- Software Finalisation
- Final Paper Second Draft
- Completion of Final Paper
- Demonstration Run through
- Demonstration
- Poster Draft
- Poster
- Webpage Draft
- Webpage
- Showcase

8.6 Work Allocation

The work will be done following three different approaches in order to identify planting rows and patterns. These approaches are:

- The pre-processing framework will be developed by all members.
- 2D image recognition using Hausdorff distance, which will be implemented by Chelsea van Coller
- Hough Transform, which will be implemented by Piero Puccini
- Template Matching, which will be implemented by Jonathon Everatt.

Each methodology will be implemented independently, with the goals and objectives staying the same. Ideas and methods in pre-processing or post-processing may overlap. Each method will be compared following the same measures in order to ascertain which may be the best to use in this problem space.

8. References

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9. Appendix

9.1 Gantt Chart:

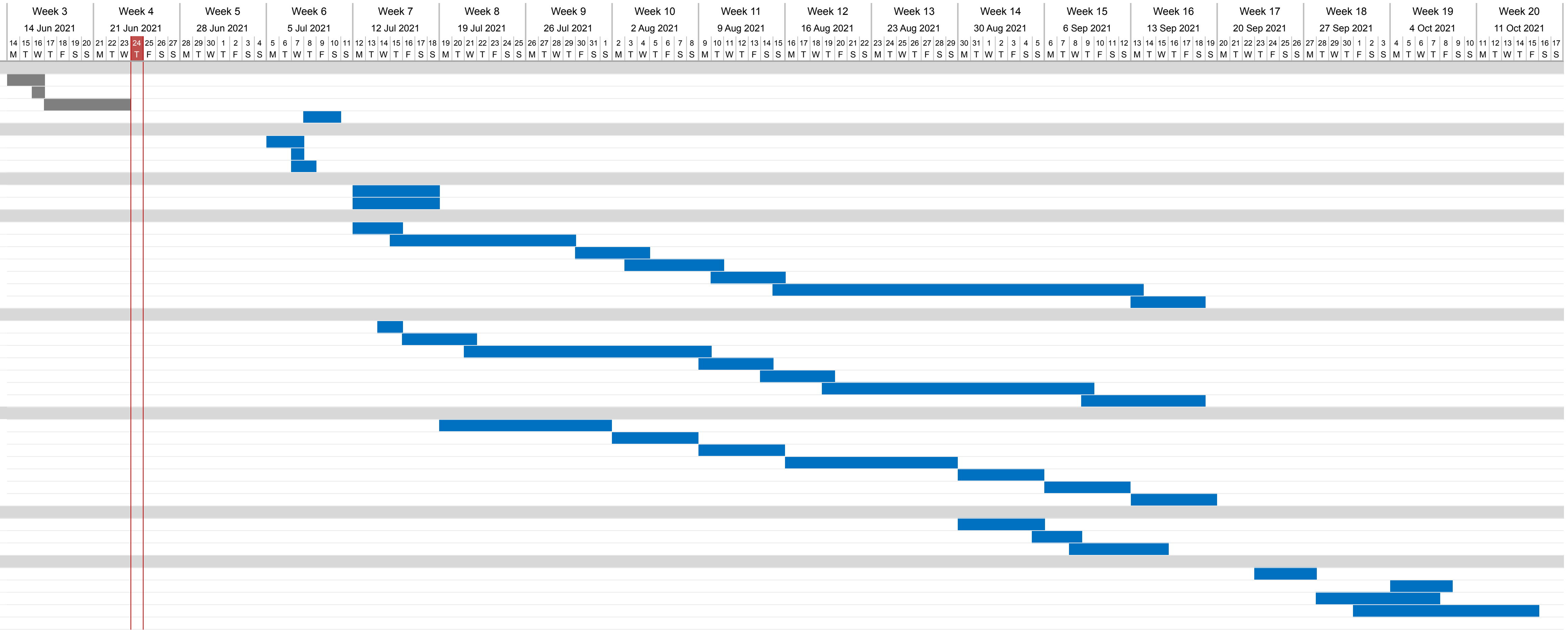
Orchard Identification: Project Schedule

Gantt Chart Template © 2006-2018 by Vertex42.com.

Team Orchard

Project Start Date: 6/1/2021 (Tuesday)   Display Week: 3

WBS	TASK	LEAD	START	END	DAYS	%	WORK
1	**Project Proposal**			-			-
1.1	Draft Project Proposal	All Team	Mon 6/14/21	Wed 6/16/21	3	100%	3
1.2	Review Draft Proposal	All Team	Wed 6/16/21	Wed 6/16/21	1	100%	1
1.3	Project Proposal Second Draft	All Team	Thu 6/17/21	Wed 6/23/21	7	100%	5
1.4	Revision of Proposal Feedback	All Team	Thu 7/08/21	Sat 7/10/21	3	0%	2
2	**Presentation**			-			-
2.1	Construction of Presentation	All Team	Mon 7/05/21	Wed 7/07/21	3	0%	3
2.2	Presentation Review	All Team	Wed 7/07/21	Wed 7/07/21	1	0%	1
2.3	Finalisation	All Team	Wed 7/07/21	Thu 7/08/21	2	0%	2
3	**Preprocessing**						
3.1	Translating data into coordinates	All Team	Mon 7/12/21	Sun 7/18/21	7	0%	5
3.2	Creating sample tree templates	All Team	Mon 7/12/21	Sun 7/18/21	7	0%	5
4	**Template Matching**			-			-
4.1	Design of Templates for Idealised data	Jonathon	Mon 7/12/21	Thu 7/15/21	21	0%	4
4.2	Implement ideal scenario software feasibility	Jonathon	Thu 7/15/21	Thu 7/29/21	8	0%	11
4.3	Test ideal scenario	Jonathon	Fri 7/30/21	Wed 8/04/21	4	0%	4
4.4	Implement robustness to noise	Jonathon	Tue 8/03/21	Tue 8/10/21	4	0%	6
4.5	Testing	Jonathon	Tue 8/10/21	Sun 8/15/21	0	0%	4
4.6	Implement Rotation, scaling and Parameter Extraction	Jonathon	08/15/21	Mon 9/13/21	0	0%	21
4.7	Testing	Jonathon	Mon 9/13/21	Sat 9/18/21	0	0%	5
5	**Hough Transform**			-			-
5.1	Design implementation method	Piero	Wed 7/14/21	Thu 7/15/21	2	0%	2
5.2	First Implement of HT on created test data	Piero	Fri 7/16/21	Wed 7/21/21	6	0%	4
5.3	Post processing on results to dectect lines and patterns	Piero	Wed 7/21/21	Mon 8/09/21	20	0%	14
5.4	Testing	Piero	Mon 8/09/21	Sat 8/14/21	6	0%	5
5.5	Second HT Implementation iteration with real data	Piero	Sat 8/14/21	Thu 8/19/21	6	0%	4
5.6	Post processing on results to dectect lines and patterns	Piero	Thu 8/19/21	Thu 9/09/21	22	0%	16
5.7	Testing	Piero	Thu 9/09/21	Sat 9/18/21	10	0%	7
6	**Hausdorff distance**						
6.1	Implement Hausdorff distance algorithm	Chelsea	Mon 7/19/21	Sun 8/01/21	14	0%	10
6.2	Testing	Chelsea	Mon 8/02/21	Sun 8/08/21	7	0%	5
6.3	Implement scaling complexity	Chelsea	Mon 8/09/21	Sun 8/15/21	7	0%	5
6.4	Complex pattern detection	Chelsea	Mon 8/16/21	Sun 8/29/21	14	0%	10
6.5	Road boundry detection	Chelsea	Mon 8/30/21	Sun 9/05/21	7	0%	5
6.6	Implement evolutionary algorithm	Chelsea	Mon 9/06/21	Sun 9/12/21	7	0%	5
6.7	Testing	Chelsea	Mon 9/13/21	Sun 9/19/21	7	0%	5
7	**Final Paper**			-			-
7.1	First Draft of Final Paper	All Team	Mon 8/30/21	Sun 9/05/21	7	0%	5
7.2	Team Review of Final Paper first Draft	All Team	Sun 9/05/21	Wed 9/08/21	4	0%	3
7.3	Final Draft edits	All Team	Wed 9/08/21	Wed 9/15/21	8	0%	6
8	**Final Demonstration, Poster and WebPage**			-			-
8.1	Final Demonstration preparations	All Team	Thu 9/23/21	Mon 9/27/21	5	0%	3
8.2	Final Demonstration	All Team	Mon 10/04/21	Fri 10/08/21	5	0%	5
8.3	Poster	All Team	Tue 9/28/21	Thu 10/07/21	10	0%	8
8.4	Webpage	All Team	Fri 10/01/21	Fri 10/15/21	15	0%	11
							-



9.2 Risk Matrix:

Risk Matrix:

		Probability		
		Low	Medium	High
Impact	Catastrophic	C	B	A
	Critical	D	C	B
	Marginal	E	D	C
	Negligible	F	E	D

Figure A: Risk Matrix rating risk according to Probability and Impact

9.3 Risk Response Plan

Rank	Risk Condition	Consequence	Cat	Prob	Impact	Mitigation	Monitoring	Management
B	Miscommunication between project team and supervisor	Project team might not understand what the scope is which will lead to the entire project failing as the project will not satisfy the expectations.	Communication	Medium	Catastrophic	Engage with Supervisor and clarify any confusions before starting/during the project. Ask for example to add context. Arrange meetings ahead of time and provide constant updates on deliverables.	Constantly follow up with supervisor to see if we are on the correct track. Raise concerns if communication flow seems staggered	Set up an emergency meeting in order to clarify the confusion as soon as possible.
C	Connection outages could disrupt the project (load shedding, WIFI connectivity issues	The project will be delayed as we will lose valuable working time due to lack of connection	Technology	High	Marginal	Have a UPS and back-up power and ensure you have mobile data as back up. Always make sure your device is fully charged if you know you will experience load-shedding soon	Keep an eye on your ISPs network update page for any maintenance or outage alerts. Keep an eye on any news relating to load-shedding	Use back-up power supply and mobile data. Choose to work outside of your areas scheduled load-shedding times
C	Health due to COVID-19(one member may get the virus)	Productivity will decrease as one member will not be able to perform their role to their full capacity	Human resources	Medium	Critical	Practice social distancing and stay home as much as possible as well as take immune boosters	Once you experience symptoms. Go for a test as soon as possible.	Spilt the work evenly between the other members while the other member is recovering and maybe give them small task to do that they will be able to do while recovering in bed to ensure the project does not get delayed.
D	The project solution does not cover all the requirements of the sponsor	Project does not meet sponsor requirements and is considered substandard or failed	Scope/Communication	Low	Critical	Have continuous communication with Project Sponsor and Supervisor to ensure requirements are being fulfilled	Check standards against other platforms, past projects or documentation.	Create meeting minutes for all meetings with Supervisor to document what has been said and that the work being done adheres to the supervisors expectations and specifications.
D	Data being stored may become corrupted due to hardware/software problems	Project data is lost and would need to be re-implemented	Integration	Low	Critical	Have backups of all files made. Use Git-hub for version control	Do continuous random code checks to ensure code fortitude	Continuous code testing to ensure it is operational and all data integrity maintained
D	The project deliverables run over time due to improper scheduling and time management within team	Project is incomplete or does not function as it is supposed to	Time	Low	Critical	Meet well ahead of deadlines and ensure documentation is up to date	check deliverables are complete on or before deadline dates.	Constantly check if project is running according to the suggested timeline and that no deliverables are running overtime
D	Lack of experience in Pattern Matching, Graphs and Hough Transform	The project might take longer than the expected deadline or the final project will be completed with low standards	Human Resources	Med	Marginal	Search and self-teach various implementation techniques.	Check fellow team mates progress weekly to ensure they are on track.	At least try to finish the project with the minimum specification or spend more time on development of technique that is not meeting the project schedule.
E	Project Supervisor is newly appointed and may not have time for the teams queries, be overloaded with work or not up to date with the company's current practices.	The team may not get relevant answers to queries needed in order to fulfil requirements	Human Resources	Low	Marginal	Send email queries ahead of time when information is needed.	Check and note response times from Sponsor	Escalate concerns with project supervisor and request they contact the sponsor directly.
C	Productivity of team mates is decreased	Team may have low morale due to work overload, burnout or social issues	Human Resources	Medium	Critical	Create team support structure and team building to generate motivation. Build down-time into project plan	Regular check ins with team members to check mental wellbeing	Set-up an emergency meeting with Supervisor raising concerns.
D	Final report not fully understood or not in an understandable format	Work done is not represented properly and results mis-interpreted	Communication	low	Critical	Creation of different draft versions to be sent to Supervisor for comments	Checks that previous comments made by supervisor have been implemented	Peer review of changes that have been implemented to ensure correct updates and standards.
E	Computer Hardware malfunction	Work is not able to be done as there is no device to work on	Risk	low	Marginal	Make use of lab machines so no loss of time	Check if there is any glitches appearing on working machines or if the device is running slower than usual.	Ensure that correct software needed is installed on lab computers by contacting ITCS support.
D	Inadequate Research Methods were used understand software to be implemented	Team member not able to fulfil their section of the project	Scope/Communication	Medium	Marginal	Do further research in topic area	Check in from other team members to ensure everyone is up to date on their methodology	Ask supervisor for additional resources to help further understand the topic being implemented.
F	Conflict between Team members	Low team work and support, no synergy between solutions	Communication	Low	Negligible	Third team member to mediate between conflict pair	Each member watches interaction of the other two and flags conflict.	Sit down mediation meeting to erase conflict. If this cannot be settled within the team it must be escalated to the supervisor.