



MINISTRY OF HIGHER EDUCATION

SINGLE DISCIPLINARY PROJECT

APPLICATION FORM  
FUNDAMENTAL RESEARCH GRANT SCHEME (FRGS)  
*Skim Geran Penyelidikan Fundamental*  
(Pindaan 1/2012)

JABATAN PENDIDIKAN TINGGI  
KEMENTERIAN PENGAJIAN TINGGI

**A. Application Details**

|                                           |                                                                                                                                                                           |
|-------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Application ID                            | 391550-424952                                                                                                                                                             |
| Reference Code                            | FRGS/1/2021/WAB04/UITM/02/14                                                                                                                                              |
| A(i). Selected Grant Scheme               | FRGS 2021-1                                                                                                                                                               |
| A(ii). Title of Proposed Research Project | Modeling precision agriculture-guided agronomic practices for nutrient management of <i>Mangifera indica</i> using multispectral sensors and Artificial Intelligence (AI) |
| A(iii). Keywords                          | Precision Agriculture; Multispectral; Artificial Intelligence; Fertilizer Application                                                                                     |

**B. Details of Project Leader**

|                                                         |                                                                 |
|---------------------------------------------------------|-----------------------------------------------------------------|
| B(i). Name                                              | <a href="#">Mohammad Hafiz Bin Ismail</a>                       |
| B(ii). Academic Qualification                           | BSc. Computer Science (UTM)<br>MSc Information Technology (UUM) |
| B(iii). Nationality                                     | Malaysia                                                        |
| B(iv). IC/Passport No.                                  |                                                                 |
| B(v). Position                                          | Senior Lecturer                                                 |
| B(vi). Institution                                      | Universiti Teknologi MARA (UITM)                                |
| B(vii). Faculty/Centre                                  | Faculty of Computer and Mathematical Sciences                   |
| B(viii). Unit/Department                                | Department of Computer Science                                  |
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| B(xii). Date of First Appointment with this Institution | 24/06/2008                                                      |
| B(xiii). Type of Service (Permanent/Contract)           | Permanent 28/10/2039                                            |

**C. Research Information**

**C(i). Research Domain**

| Research Domain               | Sub Research Domain |
|-------------------------------|---------------------|
| Natural and Cultural Heritage | Agriculture         |

**C(ii). Research Cluster**

Cluster: Food Safety & Security

**C(iii). 10-10 Malaysia Science, Technology, Innovation and Economy (MySTIE) - based on 10 Socio-Economic Drivers**

MySTIE: Agriculture and Forestry

C(iv). Shared Prosperity Vision 2030 (SPV 2030)

SPV: KEGA 13 – Smart & High Value Agriculture

C(v). Sustainable Development Goals (SDGs)

SDG: SDG 9 – Industry, Innovation and Infrastructure

C(vi). Location of Research

Location

Universiti Teknologi MARA, Perlis

C(vii). Duration of this research

From

7/September/2021

To

6/September/2024

Duration

3 years

C(viii). Other Researchers

| Rese<br>arche<br>r Id | Name                                                        | IC /<br>Passport<br>Number | Faculty/<br>School/<br>Centre/<br>Unit/<br>Department | Position                                     | Area of Expertise                                                                                                                                                                    | Next<br>App<br>oint<br>ed<br>Lea<br>der | Role                                                                                            |
|-----------------------|-------------------------------------------------------------|----------------------------|-------------------------------------------------------|----------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------|-------------------------------------------------------------------------------------------------|
| 20738                 | <a href="#">CHUAH<br/>TSE<br/>SENG</a>                      | 7307050<br>85791           | Universiti<br>Teknologi<br>MARA                       | Associate<br>Professor<br>(Lecturer)         | Weed Science                                                                                                                                                                         | <input type="checkbox"/>                | Provide advice on<br>Harumanis ground<br>data collection and<br>processing the soil<br>sampling |
| 20930                 | <a href="#">Zulkiflee<br/>Bin Abd<br/>Latif</a>             | 7205310<br>16083           | Universiti<br>Teknologi<br>MARA                       | Professor<br>(Professor)                     | Remote Sensing, LiDAR,GIS, Biodiversity,<br>Microclimate , Carbon, Biomass, Forestry<br>remote sensing                                                                               | <input type="checkbox"/>                | Provide advice on<br>UAV multispectral<br>data collection                                       |
| 24192                 | <a href="#">Farrah<br/>Melissa<br/>Binti<br/>Muharam</a>    | 8201270<br>15976           | Universiti<br>Putra<br>Malaysia                       | Associate<br>Professor<br>(Dr)               | Precision Agriculture, Remote Sensing,<br>GIS, Remote Sensing                                                                                                                        | <input type="checkbox"/>                | Provide advice on<br>Precision Agriculture<br>practices                                         |
| 39476                 | <a href="#">Shukor<br/>Sanim<br/>Bin<br/>Mohd<br/>Fauzi</a> | 8011040<br>95041           | Universiti<br>Teknologi<br>MARA                       | Associate<br>Professor<br>(Assoc Prof<br>Dr) | Mining Software Repository, Software<br>Engineering, Big Data, Socio-technical<br>Congruence, Global Software Development,<br>Software Process, Software Quality, Socio<br>Computing | <input type="checkbox"/>                | Provide advise on<br>development of AI<br>model.                                                |
| 94420                 | <a href="#">Nurul Ain<br/>Mohd<br/>Zaki</a>                 | 8608293<br>55170           | Universiti<br>Teknologi<br>MARA                       | Senior<br>Lecturer<br>(SENIOR<br>LECTURER)   | Remote sensing and GIS, Remote sensing<br>and GIS, Remote sensing and GIS                                                                                                            | <input checked="" type="checkbox"/>     | Advise on modelling<br>and remote sensing                                                       |

C(ix). Research projects that have been completed or are on-going by project leader in the last three years

| Title | Grant Name | Role | Progress (%) | Status | Duration | Start Date | End Date |
|-------|------------|------|--------------|--------|----------|------------|----------|
|-------|------------|------|--------------|--------|----------|------------|----------|

C(x). Academic publications that have been published by the project leader in the last five years

| Title                                                                      | Name of Journal                   | Year |
|----------------------------------------------------------------------------|-----------------------------------|------|
| Towards Designing A Hierarchical Fuzzy System For Early Diagnosis Of Heart | Journal of Computing Research and | 2019 |

| Disease                                                                                | Innovation                          | 2019 |
|----------------------------------------------------------------------------------------|-------------------------------------|------|
| An Exploratory Study of Hierarchical Fuzzy Systems Approach in A Recommendation System | Jurnal Intelek, (Indexed by MyCITE) | 2019 |

## C(xi). Executive Summary of Research Proposal

(Please include the problem statement, objectives, research methodology, expected output/outcomes/implication, and significance of output from the research project)

Malaysia National Agro-Food Policy 2011-2020 with food security agenda, targets to incline the production of the fruits for commercialization and export purposes and this includes mango. However, the Department of Statistics Malaysia revealed that per capita consumption of mango and Self Sufficiency Ratio is 1.5 kg/year and 32.1% respectively, indicating that the mango production in Malaysia is insufficient to fulfill the local demand. In addition, the current conventional farming of mango is threatened by a lack of fertilizer optimization that causes insidious fruit rot (IFR) which consequently increases production cost, thus causing unresolved difficulties for the Harumanis plantation. The gap between supply and demand requires a pragmatic shift from conventional farming to smart farming for sustainable mango production through IR 4.0 revolution. This research is aiming to propose the model of precision agriculture-guided agronomic practices for nutrient management ( Nitrogen (N), Phosphorus (P), Potassium (K), Magnesium (Mg), Calcium (Ca), and Boron(B)) of *Mangifera indica* using multispectral sensors and Artificial Intelligence (AI). Proximal sensor data such as soil moisture, spectroradiometer, and weather stations data will be collected concurrently with the ground data including mango leaf nutrient, leaf area index, SPAD, soil nutrients, canopy growth parameters, along with UAV mounted sensors such as RGB camera, forward-looking infra-red camera, red-edge multispectral UAV in mature plots during vegetative, flowering and fruiting seasons. It is expected these data could be used to develop a precision-guided system for fertilization and management of Harumanis mango. The whole research focused on fundamental studies to enhance MaIF-Sys measurement interconnects proximal and remote sensors, Artificial Intelligence, and the Internet of Things (IoT). This modeling will explore cutting-edge technology, portable and affordable smart technology to prevent or reduce the risk of fruit disease and increase the production and technique of Harumanis plantation.

## C(xii). Detail Planning

(a) Research background

### 1. Problem Statement

According to the Department of Statistics Malaysia (2019), per capita consumption of mango and Self Sufficiency Ratio (SSR) is 1.5 kg/year and 32.1% respectively. The report indicates that mango production in Malaysia is insufficient to fulfill the local demand. Perlis has the largest planting area of mango for about 2290 ha producing 2343 metric tons for all mango varieties in the year 2014 to 2018. However, the production is second in the list after Perak with planting area and production is 462 ha and 4340 metric ton, respectively (Statistik Tanaman, 2019). The production of Harumanis mango in Perlis highly depends on single-season yearly under field conditions. The most popular mango in Malaysia is 'Harumanis' was planted in Perlis states due to its aroma, texture, and sweetness. The high demand for Harumanis increases year by year and the selling price is almost double compared to the others type of mango. According to Azizan et al, (2019) in 2010, has been reporting that the export of Harumanis has reached 3.1 metric stone and most production was exported to Japan country. They have a positive acceptance towards Harumanis mango (Farook et al, 2013). The soil condition in Perlis is a major factor why these special fruits are suitable to be grown there. It consists of nutrients needed by plants and the main nutrients in the most important soil nutrients are phosphorus (P), nitrogen (N), and potassium (K). Adequate nutrients will produce good fruit quality and high yield. Besides, this conventional farming is threatened by insidious fruit rot (IFR) disorder, pest and disease attack besides being labor-intensive especially during pruning, fruit wrapping, and pesticide application, thereby causing an increase in the production cost (DOA, 2019).

The nutrient imbalance will lead to improper growth and development of plants. Nutrients such as Nitrogen (N), phosphorus (P), and potassium (K) is needed as macronutrient and need in a huge quantities. UF, (2013). The nutrient imbalance will affected the plants productivity. Moreover, declining of potassium, sulphur and micronutrients as major constraints for sustaining and improving productivity under intensive crop production systems. The nutrient imbalance will lead to many problem such as declining cropped productivity, stagnant yields and will lead to deficiencies of major food crops. Previous reseracher proven that the importance of the balance nutrient in the plantation, for an instance, nitrogen is crucial for the productivity and fruit quality. (Azizan et al., 2019). In addition, the deficiency of phosphorus (P) will lead to the root and tree and make the plant growth is retarded (Azizan et al., 2019). However, there is no study had been done for the guideline of the proper balanced of the fertilizer usage for Harumanis. Therefore, the intensive study of the sufficient amount of nutrient , is crucial to increase the growth of this mango in order to produce a high quality of the fruits.



Figure 2 :Potassium Deficiency in Mango (*Mangifera indica*) Sources : UF, 2013.

Due to the high demand for Harumanis, Malaysia's industries need to find the best solution to produce a large number of fruits and high yield production to be commercialized. Rising in the demand and price of Harumanis encourages growers to compete for better yield production without considering the soil health and amount of fertilizer added to the plant. Excess nutrient application leads to environmental pollution but inadequate nutrient application results in an unhealthy plant whereas imbalance nutrient application will limit nutrient uptake by the plant. The 'Insidious Fruit Rot' (IFR) disorder is one of the main concerns in mango production due to an imbalance of nutrients, especially N and Ca (Tarmizi et al., 1993). The mango trees can be grown in a variety of soils and require comparatively low maintenance costs, but poor nutrient and water management are the key factors for the declining productivity of mango over the years (Ganeshamurthy et al, 2018). One of the main reasons for the low productivity is imbalances in the nutrient application and inadequate fertilization. It can cause various problems to the health of the trees and fruit produced. Among the common problems with Harumanis fruit is insidious fruit rot (IFR) (Shivashankar, 2014). IFR is categorized as a physiological disorder (Khalid et al, 2020). This IFR disorder contributes 80% of total loss characterized by poor quality fruits thus reducing the market price. The study conducted by Tarmizi et al. (1993) indicates that high N and low Ca in the fruits and leaves positively correlated to IFR. In addition, previous researchers, Khalid et al. (2020) and Zakaria et al. (2012) focused on early detection of IFR but the studies did not fix the root cause of the disease. According to Chen et al, (2015) soil and nutrients such as nitrogen, phosphorus and potassium play a vital role in plant growth. Potassium should be applied to both the young trees as well as the fruit-bearing trees. Nevertheless, the world agricultural systems are using a large number of chemicals such as fertilizers, pesticides, herbicides to produce more production per unit area but using more doses than optimum or recommended of these chemicals and fertilizers leads to several problems like environmental pollution (Kumar et al, 2019). The IFR in Harumanis occurs as the fruit approaches maturity (Tarmizi et al, 1993). The affected fruit does not show external damage at the time of harvest or at the ripe stage but occasionally a lack of firmness in the sinus region can be detected (Lim and Khoo 1985). The causes of IFR are due to the imbalance concentration of nitrogen and calcium in the soil and leaf tissues which result in the low quality of mango (Wainwright et al, 1989). The imbalance amount of nutrients especially high nitrogen and low calcium concentration in mango leaf will cause internal flesh breakdown or known as fruit rot. According to Galan Sauco et al (2009), a direct relationship between insidious fruit rot and the contents of pulp, calcium, and nitrogen has been confirmed by the analysis of healthy and affected fruits of 'Harumanis'. Moreover, the lack of nutrients especially calcium in leaf tissues could result in the immobility of this nutrient. Besides, agricultural practices such as pruning time, application of herbicide, and management field could be a factor that leads to IFR problems. Therefore, the soil is an important component to provides necessary moisture and nutrients for plant growth.

Conventionally, Harumanis quality was monitored manually and incredibly dependent on the human visual system. Besides, a traditional method such as water transfer or floating method was applied as a method to predict the internal properties or quality of fruit by applying the concept of density (Khalid et al, 2020). It also includes field and laboratory measurements. There is no denying that provides an accurate result for soil nutrient estimation. Nevertheless, this method is very time-consuming and very expensive to cover the whole study area (Pong et al, 2019). Therefore, a fast and reliable method to evaluate the fruit quality to overcome this problem. At the same time, farmers are not really aware of the impact of and the need for Industry 4.0 technologies. They have an inadequate understanding of the cost and benefit of implementing digital technologies. As a result, the implementation of smart agriculture is quite slow and receives less response from farmers, especially the senior generation. On the other hand, young farmers are starting to embark on modern farming such as using drones for fertilizing and managing pests in their farms (Tambi and Dardak, 2020). Realizing the low level of awareness of the digital technologies may contribute to the agricultural activities, this research will provide the assessment of cost and benefit between the conventional practices and AI-Guided System specifically of the Harumanis plantation.

According to Liu et al, (2019), by using current technology which is remote sensing technologies can be applied to estimates of soil nutrient contents and monitor on a large scale in a short time with low cost. This is because by using remote sensing images provide different spectral value and high spatial resolution with large coverage area. Nowadays, machine learning (ML) has been shown a remarkably efficient evolution utilized in artificial intelligence along with the inclination of deep learning (DL) usage in many research, and this includes precision agriculture. Deep learning is a representation-learning method that could automatically learn internal feature representations with manifold levels from original images instead of empirical feature design and has verified to be very effective in image classification and object detection (Natteshan & Suresh Kumar, 2020). However, there are yet imbalanced data

that will give poor classification outcomes, which will be worse than the one reported in other existent studies, even though numerous existing researches that provided comparison results among these ML algorithms, (Sonobe, 2019).

## 2. Hypothesis

1. The usage of UAV mounted multispectral and proximal sensors can improve the management of fertilizer application.
2. Harumanis crops' health can be determined in real time by the colour hues of their foliage and soil captured in aerial images.

## 3. Research Questions

1. How to determine the effect of nutrient content (N, P, K, Mg and Ca and B) with weather variables, plant physiology data and multispectral sensors data?
2. How to integrate the nutrient content with the machine learning algorithm?

## 4. Literature Reviews

According to the Department of Statistics Malaysia (2019), per capita consumption of mango and Self Sufficiency Ratio (SSR) is 1.5 kg/year and 32.1% respectively. The report indicates that the mango production in Malaysia is insufficient to fulfil the local demand. Perlis has the largest planting area of mango for about 2290 ha producing 2343 metric ton for all mango varieties in the year 2014 to 2018. However, the production is second in the list after Perak with planting area and production is 462 ha and 4340 metric ton, respectively (Statistik Tanaman, 2019). The production of Harumanis mango in Perlis highly depends on single season yearly under field conditions. Besides, this conventional farming is threatened by insidious fruit rot (IFR) disorder, pest and disease attack besides being labour intensive especially during pruning, fruit wrapping, and pesticide application, thereby causing an increase in the production cost (DOA, 2019).

Rising in the demand and price of harumanis encourages growers to compete for better yield production without considering the soil health and amount of fertilizer added to the plant. Excess nutrient application leads to environmental pollution but inadequate nutrient application results in an unhealthy plant whereas imbalance nutrient application will limit nutrient uptake by the plant. The poor quality of the fruit is also attributed to the presence of insidious fruit rot (IFR) in harumanis mango, suspected to have occurred as a result of input misallocation and improper management practices. The IFR disorder is one of the main concerns in mango production due to imbalance of nutrients, especially N and Ca (Tarmizi et al., 1993). This IFR disorder contributes 80% of total loss characterized by poor quality fruits thus reducing the market price. The study conducted by Tarmizi et al. (1993) indicates that high N and low Ca in the fruits and leaves positively correlated to IFR. The study conducted by Khalid et al. (2020) and Zakaria et al. (2012) focused on early detection of IFR but the studies did not fix the root cause of the disease. Bruising and internal defects as a result of IFR degrades the quality and appearance of the fruit. Lower fruit quality contributes to lower selling prices, leading to inadequate farm income for the farmers.

Canopy management is one of the most important factors to sustain the yield and quality of fruits in mango. According to Muhamad Hafiz et al. (2017), an increased yield of mango production is commonly emphasized on fertilization and hormone induction. However, other agronomic practice such as pruning also plays an important role for continuous high yield production. Hence, Muhamad Hafiz et al. (2017) have developed an architectural approach for pruning Harumanis mango that is convenient for maintenance and yield improvement. Pruning activities will rejuvenate the tree as well as provide optimum light penetration and improve air circulation. In addition, pruning can also stimulate the flower formation by increasing the shoot formation by 78% and the flower buds number of 31% (Kuswandi et al., 2013). Fruit quality characterizations and branch strength analysis revealed significant variation between droop and erect Harumanis mango. Fruits harvested from droop Harumanis trees were bigger than erect Harumanis. Droop Harumanis fruit samples recorded higher value for relative water content, moisture content, and modulus of elasticity while erect Harumanis recorded higher value for fresh-weight basis density and modulus of rupture (Sani et al. 2018)

Harumanis mango diseases become a major problem for most farmers. For example, *Colletotrichum gleosporide*, *Meliola mangiferae* and *Cortitium Salmonicolor* affect tender leaves, stems, flowers and fruit, thus leading to poor quality of fruit production (MOA, 2019). On the other hand, *Ageratum conyzoides* and *Phyllanthus amarus* were demonstrated to have the highest relative abundance values under the canopy of mature mango. Annual weeds such as *Euphorbia hirta* and *Alysicarpus vaginalis* showed the greatest relative abundance value at the inter-rows of mature mango (Nurhafizah 2019). These weeds could compete with Harumanis mango to obtain nutrients from soil besides harboring insect and disease organisms that attack Harumanis mango. As a result, multiple applications of pesticides are required for pest and disease management in Harumanis mango.

Precision agriculture (PA) is the lead to the direction towards Industry 4.0 in the plantation basis. The evolving of technology had led to the transformation of the agricultural sector, which promises to increase the production rate and improve the quality (Triantafyllou et al., 2019). The advancement of modern technology using Unmanned Aerial Vehicles (UAV) with various types of sensors with different purposes can benefit a huge revolution of existing agricultural processes towards farming systems. In the recent 2021 Budget, the government also allocated RM10 million matching grants for the implementation of the e-satellite Farm Program for farmers, including IoT equipment and drones (KKM, 2021) (Refer Figure 1). Parallel to IR 4.0, the agriculture sector has tremendously transformed through smart agriculture. It is an approach that interconnects proximal and remote sensors, Artificial Intelligence, and the Internet of Things (IoT), aims to improve yield and quality, increase farm productivity and conserve valuable resources. The feasibility and applicability of smart farming technologies such as spraying drones have been proven useful for the applications of fertilizers and pesticides in annual crops such as rice, tea, and leafy vegetables (Norasma et al., 2018; Andri et al., 2019) but not yet in mango cultivation. Hypothetically, smart agriculture technology is expected to assist the applications of fertilizers usage and increase the yields and productivity of the farming technique.



Figure 1 : Budget 2021 Malaysia

Researchers have also used image processing technique which involves similar steps such as image acquisition, image pre-processing, image segmentation, feature extraction and classification (Patil et al., 2017, Patki et al., 2016, Rastogi et al., 2015 and Sethupathy et al., 2016). In these papers, during the image segmentation, Otsu's method and K-means clustering are used to classify the object based on a set of the features into K number of classes. K-means clustering is more superficial than other clustering methods and works with a vast number of variables as well. However, a different number of cluster numbers and different initial centroid values produces a different cluster result. Hence, initializing the appropriate number of cluster k and the correct initial centroid number is necessary.

Some of the drawbacks of the molecular and hyperspectral technique are time-consuming, labor-intensive, and requires an elaborate process. The drawback occurred, especially during sample preparation (collection and extraction) to obtain reliable and accurate results on the identification of plant disability (Sankaran., 2010). The image processing technique, on the other hand, minimizes the subjectivity of traditional classification methods and mistakes committed by human beings (Patil et al., 2017). Thus, the reliability of the estimation is enhanced, and reliable data for disease studies are given. The approach is also simple, in which it only needs merely computers, digital cameras, as well as software programs. The image processing approach also minimizes the subjectivity of traditional classification methods and is more straightforward.

## 5. Relevance to Government Policy (if any)

This research proposal confirms two of the National Priority Areas (NPAs), which is Plantation Crops, and Food Security. This NPAs, was referred to the National Policy on Industry 4.0, which is Cyber Security, Big Data, Artificial Intelligence. This research also will support the objectives stated for Malaysia National Agro-Food Policy 2011-2020, which emphasize with a food security agenda, targets to incline the production of the fruits for commercialization and export purposes and this includes mango. This research proposal is also relevant to the Sustainable Development Goals (SDGs) under the United Nations, under the 15th item, which is Life on Land and also the 2nd item, Zero Hunger. These goals are targeted to end hunger, achieve food security and also promote sustainable agriculture.

## (b) References

### References

Azizan, F. A., Roslan, N., Ruslan, R., Aznan, A. A., & Mohamed Yusoff, A. Z. (2019). Soil NPK variability mapping for Harumanis mango grown in a greenhouse at Perlis, Malaysia. *International Journal on Advanced Science, Engineering and Information Technology*, 9(2), 495–501. <https://doi.org/10.18517/ijaseit.9.2.2989>

Triantafyllou, A., Sarigiannidis, P., & Bibi, S. (2019). Precision agriculture: A remote sensing monitoring system architecture. *Information (Switzerland)*, 10(11). <https://doi.org/10.3390/info10110348>

Muhamad Hafiz, M.H, Hartinee, A., Nor Dalila, N.D., Mohd Asrul, S., Mohd Ridzuan, D., Ahmad Mahdzir, A. & Ros Shahidan, A.A.(2017). Improving the fruiting probabilities of Harumanis mango through the architectural approach. Transactions of the Malaysian Society of Plant Physiology 24: 72-78.

Nurhafizah, R. 2019. Characterizing weed population at two growth stages of Harumanis mango. Bachelor Thesis. University of Technology Mara, Perlis Branch.

Khalid, N. S., Shukor, S. A. A., & Syahir, A. F. (2020). Specific gravity-based of post-harvest *Mangifera indica* L. cv. Harumanis for 'Insidious Fruit Rot'(IFR) detection using image processing. In Computational Science and Technology (pp. 33-42). Springer, Singapore.

Kuswandi, Fitriana N. & Nofiarli. 2013. The pruning on mango (*Mangifera indica* L.). Journal of Agricultural and Biological Science 8(2): 116-118

Department of Agriculture (DOA). 2019. Manual Tanaman Mangga Harumanis (MA128). *Mangifera indica* L. Department of Agriculture, Putrajaya.

Department of Statistics Malaysia (2019). Supply and Utilization Accounts Selected Agricultural Commodities, Malaysia 2015-2019. Retrieved at Department of Statistics Malaysia Official Portal (dosm.gov.my).

Pena, J. E. (1998). A review of the pest management situation in mango agroecosystems. *Phytoparasitica*, 26(2): 129 – 148.

Rattanapun W. (2009). Mango varietal preference and the effect of physiological changes during mango ripening on host utilization by *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae). PhD thesis, Bangkok: Kasetsart University.

Razak, A., & Ghani, A. I. (1995). The biology of the mango leafhopper, *Idioscopus nitidulus* in Malaysia. *Pertanika Journal of Tropical Agricultural Sciences*, 18(3): 159 – 162.

Sani, M.A. Abbas, H Jaafar, M.N. Abd M.B. (2018). Morphological characterization of Harumanis mango (*Mangifera indica* Linn.) in Malaysia. *International Journal of Environmental & Agriculture Research*, 4 (1): 35-41.

Statistik Tanaman (Sub-sektor tanaman makanan) (2019). Unit Geospasial Pertanian dan Statistik. Bahagian Perancangan Strategik, Jabatan Pertanian Semenanjung Malaysia.

KKM. (2021). Laman Khas Belanjawan 2021. <http://www1.treasury.gov.my/index.php/ms/ap-2021>

Natteshan, N. V. S., & Suresh Kumar, N. (2020). Effective SAR image segmentation and classification of crop areas using MRG and CDNN techniques. *European Journal of Remote Sensing*, 53(sup1), 126–140. <https://doi.org/10.1080/22797254.2020.1727777>

Azizan, F. A., Roslan, N., Ruslan, R., Aznan, A. A., & Mohamed Yusoff, A. Z. (2019). Soil NPK variability mapping for Harumanis mango grown in greenhouse at Perlis, Malaysia. *International Journal on Advanced Science, Engineering and Information Technology*, 9(2), 495–501. <https://doi.org/10.18517/ijaseit.9.2.2989>

Lim, T. K. and Khoo, K. C. (1985). Diseases and disorders of mango in Malaysia p. 55–6. Kuala Lumpur: Tropical Press Sdn. Bhd.

Khalid, N. S., Shukor, S. A. A., & Fathinul Syahir, A. S. (2020). Specific Gravity-based of Post-harvest *Mangifera indica* L. cv. Harumanis for 'Insidious Fruit Rot' (IFR) Detection using Image Processing. *Lecture Notes in Electrical Engineering*, 33–42. [https://doi.org/10.1007/978-981-15-0058-9\\_4](https://doi.org/10.1007/978-981-15-0058-9_4)

Wainwright, H., & Burbage, M. B. (1989). Physiological disorders in mango (*Mangifera indica* L.) fruit. *Journal of Horticultural Science*, 64(2), 125–135. <https://doi.org/10.1080/14620316.1989.11515936>

Galan Sauco, V. 2009. Physiological disorders. p. 303–316. In: R.E. Litz (ed.), *The mango: Botany, production and uses*. 2nd edition. CAB Intl., Oxford, UK.

R. S. M. Farook, H. Ali, Harun, D. L. Nadzi, a Y. M. Shakaff, & M. Nor. "Harumanis Mango Flowering Stem Prediction using Machine Learning Techniques", 13(May), 46–51. <http://doi.org/10.4156/mis.vol13.10, 2013>.

Chen, L.F.; He, Z.B.; Du, J.; Yang, J.J.; Zhu, X. Response of soil carbon cycling to climate warming: Challenges and perspectives. *Acta Prataculturae Sin.* 2015, 24, 183–194.

Azizan, F. A., Roslan, N., Ruslan, R., Aznan, A. A., & Mohamed Yusoff, A. Z. (2019). Soil NPK variability mapping for Harumanis mango grown in greenhouse at Perlis, Malaysia. *International Journal on Advanced Science, Engineering and Information Technology*, 9(2), 495–501. <https://doi.org/10.18517/ijaseit.9.2.2989>

Lim, T. K. and Khoo, K. C. (1985). Diseases and disorders of mango in Malaysia p. 55–6. Kuala Lumpur: Tropical Press Sdn. Bhd.

Khalid, N. S., Shukor, S. A. A., & Fathinul Syahir, A. S. (2020). Specific Gravity-based of Post-harvest *Mangifera indica* L. cv. Harumanis for 'Insidious Fruit Rot' (IFR) Detection using Image Processing. *Lecture Notes in Electrical Engineering*, 33–42. [https://doi.org/10.1007/978-981-15-0058-9\\_4](https://doi.org/10.1007/978-981-15-0058-9_4)

- Wainwright, H., & Burbage, M. B. (1989). Physiological disorders in mango (*Mangifera indica* L.) fruit. *Journal of Horticultural Science*, 64(2), 125–135. <https://doi.org/10.1080/14620316.1989.11515936>
- Galan Sauco, V. 2009. Physiological disorders. p. 303–316. In: R.E. Litz (ed.), *The mango: Botany, production and uses*. 2nd edition. CAB Intl., Oxford, UK.
- R. S. M. Farook, H. Ali, Harun, D. L. Nadzi, a Y. M. Shakaff, & M. Nor. "Harumanis Mango Flowering Stem Prediction using Machine Learning Techniques", 13(May), 46–51. <http://doi.org/10.4156/mis.vol13.10>, 2013.
- Chen, L.F.; He, Z.B.; Du, J.; Yang, J.J.; Zhu, X. Response of soil carbon cycling to climate warming: Challenges and perspectives. *Acta Prataculturae Sin.* 2015, 24, 183–194.
- Tarmizi, A. S., Tengku, T. M., Pauziah, M., & Zahrah, T. (1993). Incidence of insidious fruit rot as related to mineral nutrients in Harumanis mangoes. *Journal of the Malaysian Agricultural Research and Development Institute*, 21, 43–49.
- Patil, B., Hemant, P., Shubham, Y., Arvind, S., & Patil, D. (2017). Plant Monitoring Using Image Processing, Raspberry PI & IoT. *International Research Journal of Engineering and Technology (IRJET)*, 04(10), 1337–1342.
- Patki, S. S., & Sable, G. S. (2016). Cotton Leaf Disease Detection & Classification using Multi SVM. 5(10), 165–168. <https://doi.org/10.17148/IJARCCCE.2016.51034>
- Omar, H. (2016). Digital Globe® 8 Bands Research Challenge Commercial Timber Tree Species Identification Using Multispectral Worldview 2 Data. *Forest Research*, December 2010.
- Rastogi, A., Arora, R., & Sharma, S. (2015). Leaf disease detection and grading using computer vision technology & fuzzy logic. 2nd International Conference on Signal Processing and Integrated Networks, SPIN 2015, 500–505. <https://doi.org/10.1109/SPIN.2015.7095350>
- Sethupathy, J., & Veni, S. (2016). OpenCV-based disease identification of mango leaves. *International Journal of Engineering and Technology*, 8(5), 1990–1998. <https://doi.org/10.21817/ijet/2016/v8i5/160805417>
- Sankaran, S., Mishra, A., Ehsani, R., & Davis, C. (2010). A review of advanced techniques for detecting plant diseases. *Computers and Electronics in Agriculture*, 72(1), 1–13.
- Sonobe, R. (2019). Parcel-based crop classification using multi-temporal terrasars-x dual polarimetric data. *Remote Sensing*, 11(10), 1148.
- Tambi, M. F., & Dardak, R. A. Emerging Industry Revolution 4.0 and Its Relationship with the Agriculture Sector in Malaysia Emerging Industry Revolution 4.0 and Its Relationship with the Agriculture Sector in Malaysia.
- Zakaria, A., Shakaff, A. Y. M., Masnan, M. J., Saad, F. S. A., Adom, A. H., Ahmad, M. N., ... & Kamarudin, L. M. (2012). Improved maturity and ripeness classifications of *Mangifera indica* cv. harumanis mangoes through sensor fusion of an electronic nose and acoustic sensor. *Sensors*, 12(5), 6023–6048
- Kutner, M. H., C. J. Nachtsheim, and J. Neter. 2008. *Applied Linear Regression Models*. New York, NY: Mc Graw Hills.
- UF. (2013). Plant Nutrition Deficiency Database. <https://hort.ifas.ufl.edu/database/nutdef/pic53.shtml>

#### (c) Objective(s) of the Research

The aim of this research is to model the precision agriculture-guided agronomic practices for nutrient management (Nitrogen (N), Phosphorus (P), Potassium (K), Magnesium (Mg), Calcium (Ca) and Boron(B)) of *Mangifera indica* using multispectral sensors and Artificial Intelligence (AI)

1. To investigate the relationship between nutrient content (N, P, K, Mg and Ca and B) with weather variables, plant physiology data and multispectral sensors data at there different spatial scales (Leaf, canopy and scene).
2. To formulate the nutrient content models based on significant variables tested in objective 1 using machine learning algorithms.
3. To develop *Mangifera indica* System (MaIF-Sys); a smart precision farming system based on machine learning formulated nutrient models.

#### (d) Methodology:

##### 1. Description of Methodology

###### Plot set-up and Data Collection

###### Study Area

This study will be conducted in Universiti Teknologi MARA (UiTM) Perlis Branch located in Arau, Perlis, Malaysia (Figure 2.) UiTM Perlis Branch has seven (7) different faculty and one of them is the Faculty of Plantation and Agrotechnology (FPA). The plantation with approximately 197 acres consists of various types of crops such as paddy, jatropha and one of the prominent plantations is Harum Manis mango. The study area will be divided into two blocks of Harumanis trees and will be identified for the conventional practice and IR4.0 guided practices. A weather station will be installed in the study area and will provide a temperature, rainfall, and relative humidity dataset. A field survey on mango leaf greenness, leaf nutrient, soil nutrient, soil texture, disease infection, weed

composition, insect diversity, and population will be carried out in the mature Harumanis plot (11-year old) during vegetative, flowering, and fruiting seasons at Plantation Unit, Universiti Teknologi MARA, Perlis. There are approximately 300 mango trees in the plot but only 75 mango trees are systematically selected for the survey.

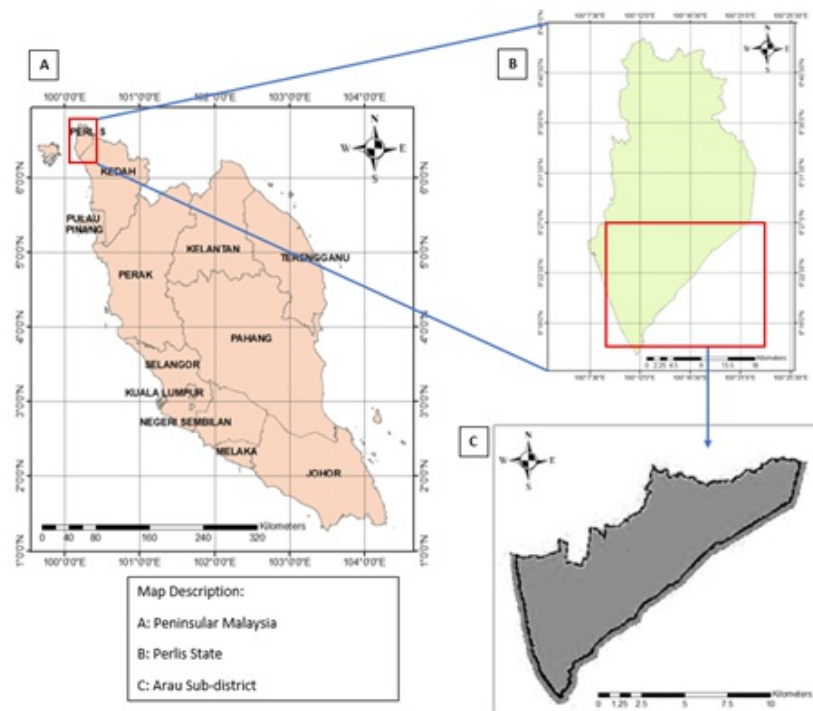


Figure 3: The study area at UiTM Arau, Perlis. A.) Map of Peninsular Malaysia ; B) Map of Arau District; C.) Map of location UiTM Perlis.

## Data collection

### Ground Data Collection

The nutrient content of the leaf and soil samples will be monitored according to its growth stage, the first stage between the harvesting and flowering stage, and the second stage between the fruiting and harvesting stage (Ram et al., 2020). The greenness of the leaf will be measured non-destructively using a SPAD meter according to the work done by Roslan et al. (2019) while the leaf area index (LAI) will be measured using a leaf area meter. The leaf samples will be subjected to the N, P, K, Ca, B and Mg content determination. Leaf samples will be taken from the recently matured leaf which is positioned 5th from the top branch and will be oven-dried at 60°C and ground for the laboratory analysis. The leaf N content will be analyzed by using the Kjeldahl method and P concentration will be analyzed by UV Spectrophotometer while K, Ca, B and Mg contents will be measured using Atomic Absorption Spectrophotometer (Azizan et al., 2019). The result will be expressed in unit percentage (%). The soil samples will be collected by using an auger at 0–15 cm of soil depth, under the tree canopy, and a few meters away from the stand base. The soil samples will be air-dried, ground (using mortar and pestle), and then passed through a 2 mm mesh sieve for laboratory analysis. The soil samples will be analyzed for basic fertility like pH, N, P and K. The soil particle analysis (clay, silt, and sand) will be determined by using the pipette method. The fruits will be harvested from the selected trees at the commercial harvest maturity stage (90–100 days after the fruit set). These fruits will be packed in ventilated paper box cartons and will be ripened at ambient conditions (25–30°C, relative humidity = 80%). After a week, these fruits will be checked for insidious fruit rot based on their specific gravity (Khalid et al. 2020). The affected fruits will be cut into halves for physical examination.

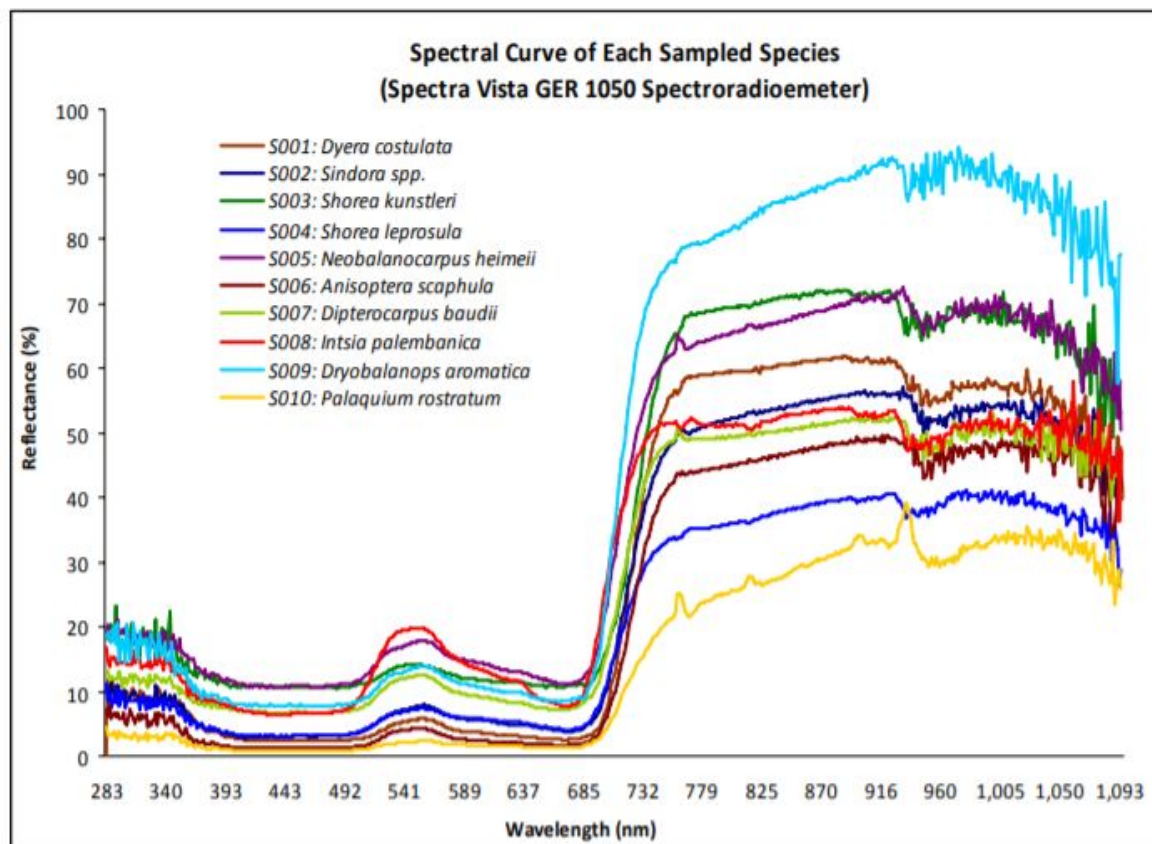
Field plot and tree coordinates were located by traversing using a total station to the plot edge coordinate. Each coordinate was tied by Global Positioning System (GPS) observation of Topcon GTS using static observation L1/L2 and L5 bands. The positional accuracy of the plot coordinates was generally within  $\pm 0.5$  m of the acceptable tolerance. Single tree locations that consist of coordinate, bearing, and slope distance were measured for each individual tree in relation to the center plots for future use. In all plots, the tree height of forest stands was measured using a digital DISTO D5 laser ranger while the DBH (1.3 m above ground height) was measured using a DBH tape.

### Spectral Data Collection

Super-spectral high resolution of WV-3 (8 bands) 25 km<sup>2</sup> with the projection of UTM47 N and WGS84 datum will be used in this study. The data consist of 31 cm panchromatic bands, 4 bands Visible-Near Infrared (VNIR) colors (blue, green, red, and NIR-1) and 4 added VNIR colors: coastal, yellow, red-edge, and near-IR2. The spatial resolution was 0.30 m (panchromatic) and 1.2 m (multispectral). The sensors consist of 0.30 (panchromatic bands), as well as 4 bands VNIR colors (blue, green, red and NIR-1) and an additional four added VNIR colors (coastal, yellow, red edge, and NIR-2) with spatial resolution 1.2m. The spectral range of this 8 bands WV-3 is Coastal blue (400 – 450  $\mu$ m), Blue (450 – 510  $\mu$ m), Green (510 – 580  $\mu$ m), Yellow (585 – 625  $\mu$ m), Red (630-690  $\mu$ m), Red edge (705-745  $\mu$ m), NIR 1 (770 -895  $\mu$ m) and NIR 2 (860 – 1040  $\mu$ m). In order to reduce error, the pre-processing stage was conducted which include atmospheric correction, geometric and radiometric calibration. The classification was performed on a pan-sharpen WV-3 image, using hyperspherical color sharpening (HCS) techniques for better visualization. The image segmentation of high-resolution imageries is classified using object-based image analysis (OBIA) techniques in eCognition software. In OBIA

techniques, the segmented features that are initially segmented into homogeneous regions are known as image-segmented or image objects. Next, the image object is classified into spectral (e.g.: Normalized Difference Vegetation Index(NDVI), band ratio, standard deviation, mean) and non-spectral (shape, texture, size, etc.)

The spectroradiometer will be used in the data collection for spectral acquisition. The leaf sample will be collected, and measurement was taken for each sampled species by using a spectroradiometer (Omar, 2016) The leaf sample will be collected and the spectral profile will be converted into indices.



Sources : Omar, (2016) Figure 4: Spectral profile for each sample

Objective 1 :

Step 1: Pre-processing

The collected aerial images are used as datasets that compare the results of the proposed images feature (foliage and soil hues, diseases, and crop shape) and segmentation models with existing state-of-the-art models. Due to this inherent characteristic of the collected dataset, the proposed model results become more applicable and reliable compared to any small-sized exclusive dataset. Using the absolute calibration factor and effective band width coefficients included the header files, the digital number were converted to top-of-atmosphere reflectance using the formula from Digital Globe (DigitalGlobe, 2010). To reduce the atmospheric and radiometric effect for the imagery, the imagery had been applied haze reduction in ERDAS software. The WV-3 imageries will be applied geometric correction of first-order polynomial, using ground control point (GCPs) collected from GPS L1/L2 observation, and projection used in WGS 1984 Zone UTM47.

The digital number (DN) of archive WorldView-4 (0.3m Panchromatic and 2.0m, 8 bands MSI) product are unsigned 16-bit is provided by Digital Globe. The DN was converted to spectral radiance ( $W m^{-2} sr^{-1} \mu m^{-1}$ ) using the equation

$$L_{(\lambda Pixel, Band)} = L_{(Pixel, Band)} / (\Delta \lambda_{Band}) \dots \dots \dots \text{Equation(1)}$$

Where  $L_{(\lambda Pixel, Band)}$  are TOA spectral radiance image pixels ( $W m^{-2} sr^{-1} \mu m^{-1}$ ),  $L_{(Pixel, Band)}$  are top-of-atmosphere band – integrated radiance image pixels [ $W m^{-2} sr^{-1}$ ], and  $\Delta \lambda_{Band}$  is the effective bandwidth ( $\mu m$ ) for each band.

$$D = JD - 2451545.0 \dots \dots \text{Equation(2)}$$

$$g = 357.529 + 0.98560028 \times D \dots \dots \text{Equation(3)}$$

$$des = 1.00014 - 0.01671 \cos(g) - 0.00014 \cos(2g) \dots \dots \text{Equation(4)}$$

Where JD are the Julian Day, g is in degrees, des is the Earth-Sun distance in Astronomical Units (AU) that should have value within 0.983 and 1.017 (DigitalGlobe, 2010).

$$\rho_{(\lambda Pixel, Band)} = L_{(Pixel, Band \times d_{(es^2)})} \times \pi / (E_{sun}(\lambda_{Band}) \times \cos(\theta_s)) \text{Equation (5)}$$

Where the  $\rho_{(\lambda Pixel, Band)}$  is the target diffuse spectral reflectance,  $L_{(Pixel, Band)}$  is the top of atmosphere band averaged

spectral radiance image pixels from equation (1),  $d_{(es^2)}$  is the Earth-Sun distance (Astronomical Unit) using equation (2)- (5),  $\pi$  is the constant's value 3.142,  $E_{sun}(\lambda_{Band})$  is the band averaged solar spectral irradiance [ $W\ m^{-2}\ \mu m^{-1}$ ] at the average Earth-Sun distance listed in Table 1 and  $\theta_{sis}$  is the solar zenith angle in degrees during the image acquisition. The model maker in ERDAS 2014 had been used to generate the model top of the atmosphere, conversion DN to radiances, radiance to reflectance value before performing any multispectral image analysis.

#### Step 2: Statistical analysis

Data of soil nutrients and leaf nutrients, leaf area index (LAI), and SPAD values will be subjected to One-way ANOVA and correlation test. Multispectral UAV images obtained from multiple flying heights will be processed and transformed into indices and classified images. Common agriculture indices generated from the multispectral images will be analyzed statistically using correlations and ANOVA ( $\alpha < 0.05$  level) in respective to the NPK, Ca, Mg data collected in order to select the most representative crop and soil nutrient indices. In an effort to see the relationship between these variables, the Pearson product-moment correlation coefficient or Pearson correlation coefficient was used to measure the correlation between independent variables of nutrient content estimation. In addition, examining scatter plots of the response variables (Nutrient, Y) versus each of the attributes (predictor variables, X) were useful in determining the nature and strength of the bivariate relationship between each X and Y variable (Kutner et al.2008).

$$r = \frac{\sum_{i=1}^n (x_i - \bar{x}) \cdot (y_i - \bar{y})}{\sqrt{\sum_{i=1}^n (x_i - \bar{x})^2 \cdot \sum_{i=1}^n (y_i - \bar{y})^2}}$$

Figure 5: Correlation equation (Kutner et al.2008).

#### Objective 2 :

##### Step 1: Data Pre-Processing & Normalization

In this step, the nutrient composition data from Objective 1 will be subjected to data-preprocessing and normalization. The dataset will be processed so it could be subjected to Random Forest, Neural Network, Deep Learning, Support Vector Machine, and K-Nearest Neighbor

##### Step 2: Defects Feature Definition and Knowledge Extraction

In this step, a domain expert's knowledge extraction is performed where a domain expert will be interviewed and asked to perform identification tasks on the collected aerial images. This step's identification process will identify the features that would help achieve the three previously mentioned functions: foliage and soil hues, diseases, and crop shape. The extracted knowledge will be recorded and classified based on its feature, and each feature definition will be formulated in this step. The features for the training dataset will be annotated with the assistance of the domain experts.

##### Step 3: Training and Validation

The annotated data will be trained against Random Forest, Neural Network, Deep Learning, Support Vector Machine, and K-Nearest Neighbor. To achieve maximal optimization potential, the machine learning model will be subjected to Grid Search hyperparameters tuning.

Due to extensive computational requirements in this step, Amazon EC2 Cloud-based machine learning instance with Graphical Processing Unit (GPU) will be used for accelerating machine learning training and validation.

##### Step 4: Performance Evaluation

Each of the trained models will be evaluated using Precision, Accuracy, Recall and F1 metrics with k-fold cross-validation technique to ensure that the model produced is robust and able to represent perform prediction perfectly.

#### Objective 3:

##### Step 1: System Development & Model Integration

In this step, the primary system that encompasses all three functions will be developed and integrated with the previous steps' model. The model will provide input to the system based on data streaming from the drone. A suitable camera will be installed on the drone and connected via a network. It will be used to capture the aerial images to simulate the production environment situation for comparing the model image with ground truth. The system will display the received input's relevant results after going through some process based on the selected function. The detected features of the preprocessed image from the preceding step are inputted to the CDNN. The CDNN is an amalgamation of Convolutional Neural Network (CNN) with the deep neural network (DNN). (Natteshan & Suresh Kumar, 2020)

##### Step 2: System Evaluation

In this step, the system will be evaluated to determine its performance. The system, specifically on the integrated model, will be evaluated against its pixel accuracy, Jaccard Index, Dice Coefficient, and overall accuracy on collected images. The step will assess the segmentation model level of reliability and robustness against the ground truth (domain expert results).

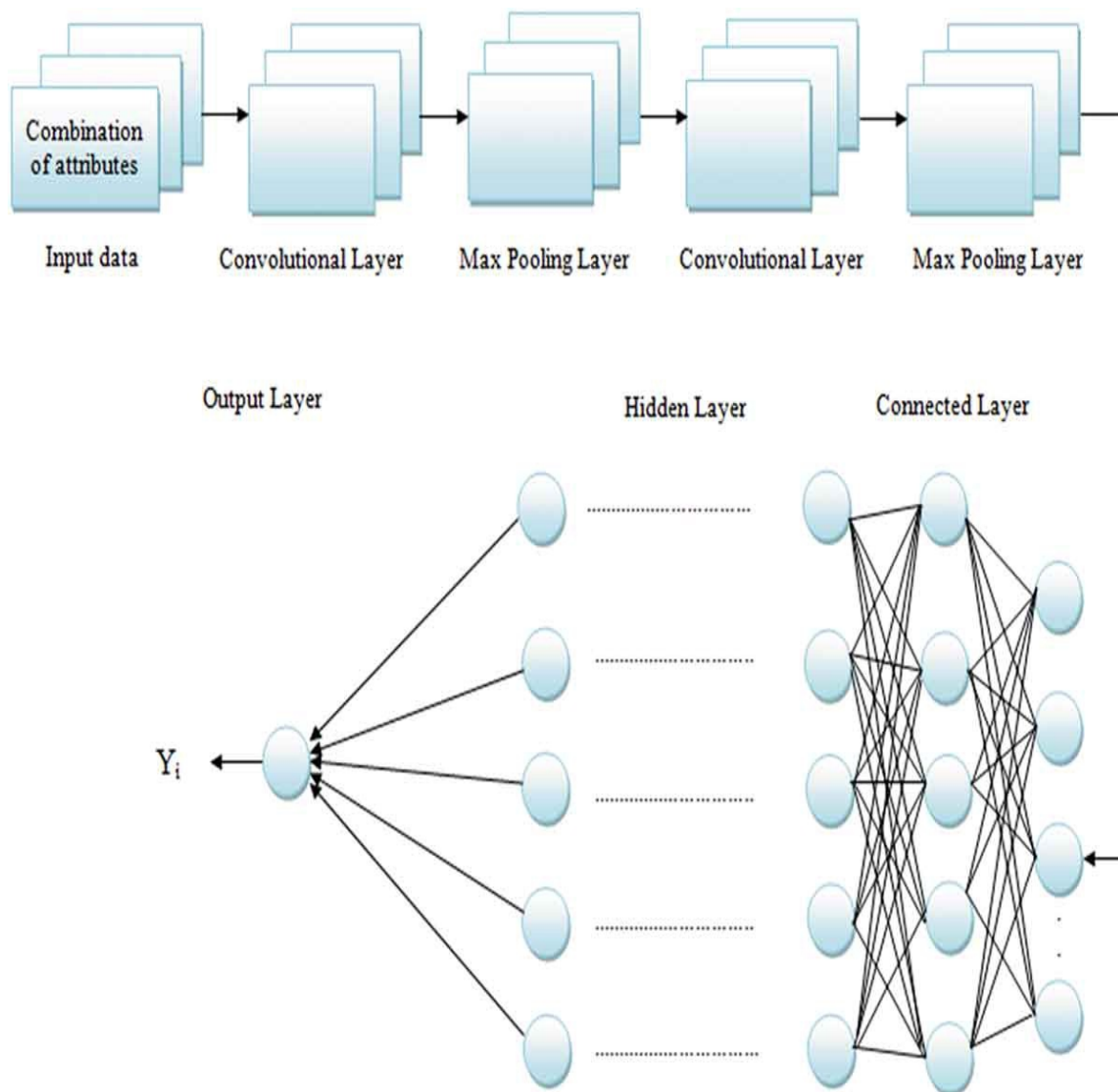


Figure 6: Architecture for the CDNN classifier. Sources: (Natteshan & Suresh Kumar, 2020)

## 2. Flow Chart of Research Activities

['Methodology\\_Flowchart\\_FRGS\\_update2.pdf'](#)

## 3. Research Activities

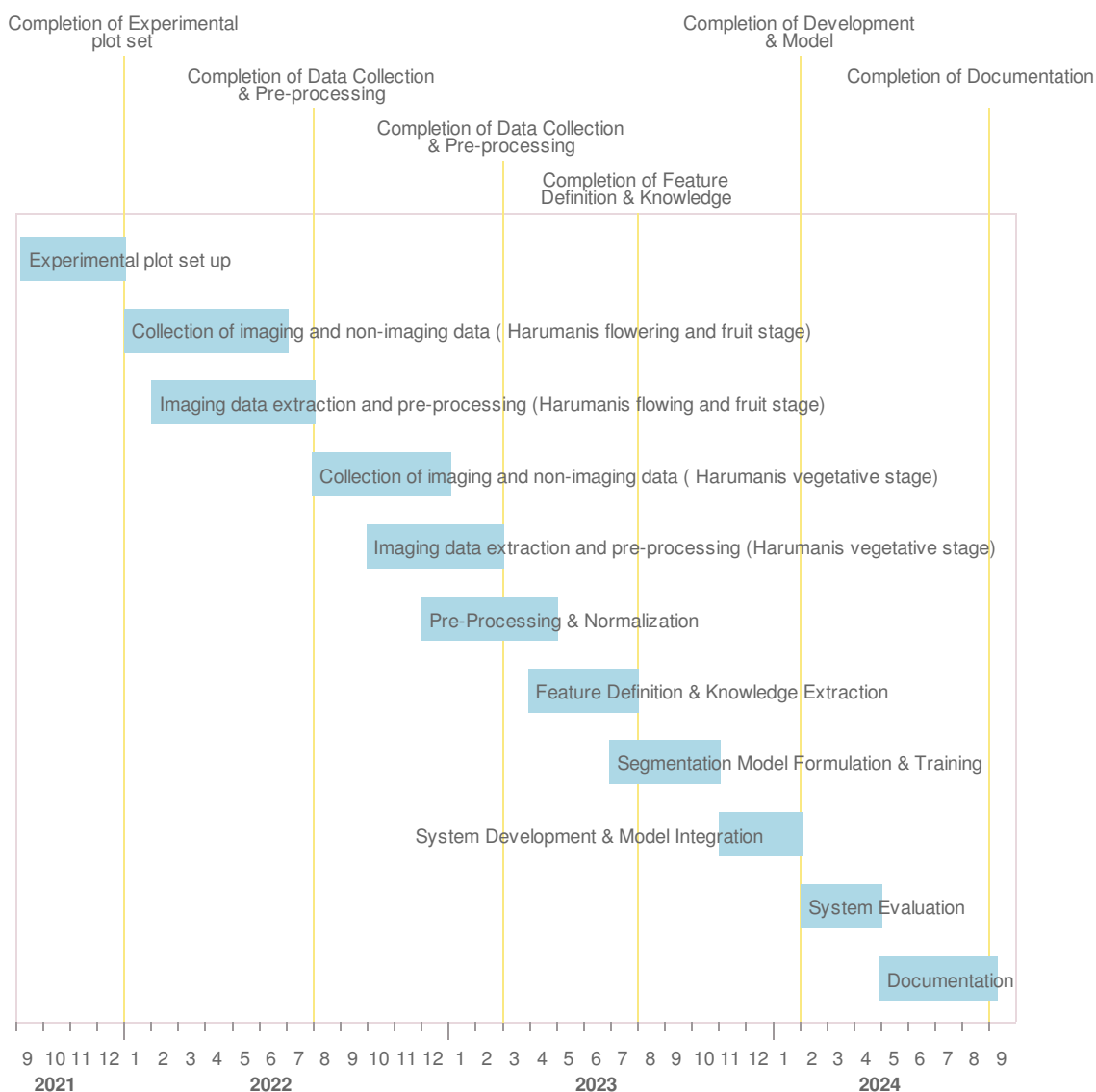
| Activity                                                                          | Start Date | End Date   |
|-----------------------------------------------------------------------------------|------------|------------|
| Experimental plot set up                                                          | 07/09/2021 | 31/12/2021 |
| Collection of imaging and non-imaging data ( Harumanis flowering and fruit stage) | 01/01/2022 | 30/06/2022 |
| Imaging data extraction and pre-processing (Harumanis flowing and fruit stage)    | 01/02/2022 | 31/07/2022 |
| Collection of imaging and non-imaging data ( Harumanis vegetative stage)          | 01/08/2022 | 31/12/2022 |
| Imaging data extraction and pre-processing (Harumanis vegetative stage)           | 01/10/2022 | 28/02/2023 |
| Pre-Processing & Normalization                                                    | 01/12/2022 | 30/04/2023 |
| Feature Definition & Knowledge Extraction                                         | 01/04/2023 | 31/07/2023 |
| Segmentation Model Formulation & Training                                         | 01/07/2023 | 31/10/2023 |
| System Development & Model Integration                                            | 01/11/2023 | 31/01/2024 |
| System Evaluation                                                                 | 01/02/2024 | 30/04/2024 |
| Documentation                                                                     | 30/04/2024 | 06/09/2024 |

## 4. Milestones

| Description | Date | Cumulative Project Completion Percentage(%) |
|-------------|------|---------------------------------------------|
|-------------|------|---------------------------------------------|

|                                                         |            |     |
|---------------------------------------------------------|------------|-----|
| Completion of Experimental plot set up                  | 31/12/2021 | 10  |
| Completion of Data Collection & Pre-processing I        | 31/07/2022 | 30  |
| Completion of Data Collection & Pre-processing II       | 28/02/2023 | 50  |
| Completion of Feature Definition & Knowledge Extraction | 31/07/2023 | 60  |
| Completion of Development & Model Integration           | 31/01/2024 | 80  |
| Completion of Documentation                             | 31/08/2024 | 100 |

Gantt Chart of Research Activities with Milestones



#### (e) Expected Results/Benefit

##### 1. Novel theories/New findings/Knowledge

1. Mangifera indica System (MaIF-Sys); a smart precision farming modeling using artificial intelligence for fertilization practices in Harumanis mango
2. Evaluation of the parameter for nutrients using integrated multispectral sensors and site-specific data for Harumanis mango.

##### 2. Impact Statement on Quintuple Helix (please delineate/describe expected research deliverables on Society, Academia, Government, Industry and Environment)

The outcomes of this research will ensure the productivity of the crops' can be maximized, in line with the Malaysia National Agro-Food Policy 2011-2020. In detail, the outcome of the output is a technology that could assist the farmers to determine crops' health in real-time basis based on the color hues and soil. Apart of that, with the advancement of the proposed system, this project also could provide an early assessment of the disease-related to harumanis. The early assessment would assist the farmers to plan for pesticides. In addition, the proposed advanced system also would assist the farmers to identify the best time to prune Harum manis based on the aerial images.

Furthermore, the outcome of this comprehensive study is expected to enhance agricultural productivity towards the achievement of

the food security agenda outlined in the Malaysia National Agro-Food Policy 2011-2020. The proposed project will enable the effective management of Harum manis which will result in the increment of Harum manis production. This outcome will address both the social and economic standing of the country. At the macro level, the increase of production will contribute to the national income, while at the micro level the small-medium Harum manis farmers will benefit with economies of scale and eventually better profit margin. The domino effect of this will also serve the people of the nation by supplying an affordable source of good and quality harum manis into the market.

3. Research Publications (Each proposal must produce at least two (2) papers in indexed journals, one of which should be in Web of Science (WoS))

| Indexing Body         | Indexed Journal |                                                                                    |
|-----------------------|-----------------|------------------------------------------------------------------------------------|
| Number of Publication | Name of Journal |                                                                                    |
| WoS                   | 1               | Precision Agriculture (Q1) Impact Factor: 4.454                                    |
| SCOPUS                | 1               | Computers and Electronics in Agriculture (Q1) Impact Factor: 3.858Computer Science |
| ERA                   |                 |                                                                                    |
| MyCITE                |                 |                                                                                    |
|                       | <b>Total 2</b>  |                                                                                    |

#### 4. Specific or Potential Applications of the Research Findings

Evaluation on the use of UAV mounted sensors and proximal sensors for site-specific management of fertilization in Harumanis mango

Talent development in the areas of UAV and GIS will enhance the country's capacity to undertake challenging research problems in the future. Experience gained in the use of state-of-the-art technologies, especially in the application of UAV and GIS will give a sturdy platform for these young talents to further their potential and capacity in providing solutions to problems and cater to the needs of the industry, nationally and globally.

Smart Agriculture System for Monitoring of Harumanis Nutrient

The topic of the research is related to the current or emerging trend in information technology - for instance, artificial intelligence, deep learning, machine learning. Thus, the skills and knowledge developed during their tenure as postgraduate students can be applied in most of the fields. 2) The students will undergo specific training - ranging from the use of basic to advanced levels of artificial intelligence and big data training. Students also will be exposed to highly demanded skills such as presentation skills and communication skills.

Cost-Benefit Analysis of Precision Agriculture guided Agronomic Practice

The students will be expected to take several subjects/courses including research methods, agribusiness, and policy courses. Besides, students will also be sent for conference presentations and knowledge-sharing sessions. Within the study duration, students will be exposed to agriculture and related agencies. This will in whole contribute to building competent individuals that can contribute to this niche field in which the government has identified as the value-adding sector not only for the national income but also to the agriculture development policy.

Total Number of Applications: 2

#### 5. Number of PhD and Masters (by research) Students

Total Number of PhD (by research) Student(s):

1

Total Number of Masters (by research) Student(s):

Remark (if any):

Potential Topic :

1. Evaluation on the use of UAV mounted sensors and proximal sensors for site-specific management of fertilization in Harumanis mango

2. Smart Agriculture System for Monitoring of Harumanis Nutrient

#### 6. Intellectual Properties (IPs)

1. Mangifera indica System (MaIF-Sys); a smart precision farming system using the modeling of artificial intelligence for fertilization practices in Harumanis mango

2. Evaluation of the parameter for nutrients using integrated multispectral sensors and site-specific data for Harumanis mango.

Total Number of IP: 2

Access to Equipment & Material(s)

| Type                           | Description                                                      | Owner                 | Location              | Address                                                    |
|--------------------------------|------------------------------------------------------------------|-----------------------|-----------------------|------------------------------------------------------------|
| Multispectral Micasense Camera | To collect the Harum manis dataset at the plantation area        | UPM                   | UPM Serdang           | JALAN UNIVERSITI 1 Serdang, 43400 Seri Kembangan, Selangor |
| Weather station Davis Pro      | To collect temperature, humidity and rainfall of the study area. | UPM                   | UPM Serdang           | JALAN UNIVERSITI 1 Serdang, 43400 Seri Kembangan, Selangor |
| Spectroradiometer              | To collect the spectral profile for leaves sample                | PPSUG, UiTM Shah Alam | PPSUG, UiTM Shah Alam | PPSUG, UiTM Shah Alam                                      |

## E. Budget

| Budget Type                                    | Description                                                                 | Year 1                            | Year 2 | Year 3 | Grand Total |
|------------------------------------------------|-----------------------------------------------------------------------------|-----------------------------------|--------|--------|-------------|
| 11000 - Allowance                              |                                                                             |                                   |        |        | 0           |
| GRA Master (Max RM2,000.00/person for 2 years) |                                                                             |                                   |        |        |             |
| Sub-Total                                      |                                                                             | 0                                 | 0      | 0      | 0           |
| GRA Ph.D (Max RM2,500.00/person for 3 years)   | GRA 1 PhD RM2200 x 36 months                                                | 26400                             | 26400  | 26400  | 79200       |
| Sub-Total                                      |                                                                             | 26400                             | 26400  | 26400  | 79200       |
| Vot-Total                                      |                                                                             | 26400                             | 26400  | 26400  | 79200       |
| Recommended Sub-Total:RM79200                  |                                                                             |                                   |        |        |             |
| 21000 - Travelling and Transportation          |                                                                             |                                   |        |        |             |
| Local                                          | 1. Meeting, workshop and training                                           |                                   | 1000   |        | 1000        |
|                                                | 2. Conferences                                                              |                                   | 2000   |        | 2000        |
| Sub-Total                                      |                                                                             | 0                                 | 3000   | 0      | 3000        |
| Overseas                                       | 1. Conferences and trainings                                                |                                   |        | 2000   | 2000        |
| Sub-Total                                      |                                                                             | 0                                 | 0      | 2000   | 2000        |
| Field work                                     | Data collection                                                             | 4000                              |        |        | 4000        |
| Sub-Total                                      |                                                                             | 4000                              | 0      | 0      | 4000        |
| Vot-Total                                      |                                                                             | 4000                              | 3000   | 2000   | 9000        |
| Recommended Sub-Total:RM9000                   |                                                                             |                                   |        |        |             |
| 24000 - Rental                                 |                                                                             |                                   |        |        |             |
|                                                | UAV Multispectral rental and Processing                                     | 9000                              |        |        | 9000        |
|                                                | Amazon EC2 GPU Machine Learning Instances                                   | 1000                              |        |        | 1000        |
| Vot-Total                                      |                                                                             | 10000                             | 0      | 0      | 10000       |
| Recommended Sub-Total:RM10000                  |                                                                             |                                   |        |        |             |
| 27000 - Research Materials and Supplies        |                                                                             |                                   |        |        |             |
|                                                | Chemical for soil analysis and leaf nutrient analysis (N,P,K, Ca,Mg)        | 1500<br><a href="#">chemic..</a>  |        |        | 1500        |
|                                                | Apparatus for Soil Analysis                                                 | 4000<br><a href="#">appratu..</a> |        |        | 4000        |
|                                                | Auger (2unit)                                                               | 1500<br><a href="#">auger.p..</a> |        |        | 1500        |
|                                                | Pesticide, fertilizer, plant hormone wrapping bags for Harumanis management | 1000<br><a href="#">agrotan..</a> |        |        | 1000        |
| Vot-Total                                      |                                                                             | 8000                              | 0      | 0      | 8000        |
| Recommended Sub-Total:RM8000                   |                                                                             |                                   |        |        |             |

|                                                    |                                                                   |                                  |       |       |                     |
|----------------------------------------------------|-------------------------------------------------------------------|----------------------------------|-------|-------|---------------------|
| 28000 - Maintenance and Minor Repair Services      |                                                                   |                                  |       |       | 0                   |
| Vot-Total                                          |                                                                   | 0                                | 0     | 0     | 0                   |
| Recommended Sub-Total:RM0                          |                                                                   |                                  |       |       |                     |
| 29000 - Professional Services                      |                                                                   |                                  | 500   | 500   | 1000                |
| Services/Consultancy                               | Proofreading Services                                             |                                  |       |       |                     |
|                                                    | Conference fees                                                   |                                  |       | 1000  | 1000                |
|                                                    | Honorarium for enumerator ( provide assistant in data collection) | 1000                             |       |       | 1000                |
| Sub-Total                                          |                                                                   | 1000                             | 500   | 1500  | 3000                |
| Short term course                                  |                                                                   |                                  |       |       | 0                   |
| Sub-Total                                          |                                                                   | 0                                | 0     | 0     | 0                   |
| Journal Page Charges (WoS / SCOPUS / ERA / MyCITE) | Publication fees                                                  |                                  | 1500  | 1500  | 3000                |
|                                                    |                                                                   |                                  |       |       | 0                   |
| Sub-Total                                          |                                                                   | 0                                | 1500  | 1500  | 3000                |
| Vot-Total                                          |                                                                   | 1000                             | 2000  | 3000  | 6000                |
| Recommended Sub-Total:RM6000                       |                                                                   |                                  |       |       |                     |
| 35000 - Accessories and Equipment                  | Soil moisture, EC and temperature meter                           | 2000<br><a href="#">Q21-09..</a> |       |       | 2000                |
| Vot-Total                                          |                                                                   | 2000                             | 0     | 0     | 2000                |
| Recommended Sub-Total:RM2000                       |                                                                   |                                  |       |       |                     |
| Grand Total                                        |                                                                   | 51400                            | 31400 | 31400 | (100.00%)<br>114200 |

**F(i). Patent Search (describe how your research output shall produce an innovative idea or technology that has the potential to be a solution for stakeholders (community, industry, government etc.) and offers a unique proposition)**

*To identify if the researcher is able to coherently present a compelling argument for his/her proposal in light of the IP landscape and factors identified in the (Yes/No) Section. The answer would reflect an understanding of the applicant's research advantage and limitations and the prospect of moving the completed research beyond this stage of funding.*

Keyword used

(precision agriculture) OR UAV OR multispectral OR (artificial intelligence)

<https://link.lens.org/mjcbWkPkFFb>

The result of the patent search showed two patents in Malaysia, in the year 2020 but no patent is on the same idea that the research is going to produce. The aim of this project is to model the precision agriculture-guided agronomic practices for nutrient management ( Nitrogen (N), Phosphorus (P), Potassium (K), Magnesium (Mg), Calcium (Ca), and Boron(B)) of Mangifera indica using multispectral sensors and Artificial Intelligence (AI). The search for the previous application of patent showed in the year 2018 and increased to 33 in the year 2020 but no patent is on the same idea that the research is going to produce. So far no one patent search has the same idea as our research objective, even in Malaysia.

[Simplified Patent Search Report \(MyGRANTS\) 2021 \(1\).pdf](#)

**F(ii). Research Collaborator**

☒ Industrial Linkages (Please identify any industry or end-user group involved in the project, and describe its role/contribution to the project)

The research collaboration was done with MARDI and FAMA, Perlis. They also highlight the problem that had been faced and needs to be tackled by the researcher to help them, regarding the fruit quality and nutrient management, especially the IFR problem.

[letterhead sintok \(Surat Lawatan UiTM\) \(1\).pdf](#)

☐ Agency/Organisation (Please identify all agencies/organisations collaborating in the project, and describe their role/contribution to the project)

**F(iii). Risk Assessment (Please describe factors that may cause delays in, or prevent implementation of, the project as proposed above; estimate also the degree of risk)**

*Please consider an appropriate approach to working in the current conditions (pandemic, travel ban, social distancing etc.)*

The technical is medium as the Mangifera Indica Harumanis cultivar tree only went through the flowering and fruiting stage once a year in between October to May, and between that time the data collection must be done on the same group of trees which some of them may be affected by uncontrollable circumstances. The timing is also a factor as the study and data collection samples must be taken within a strict and specific timeframe from October to May. The budget risks are tied with the market cost of the research material and fertilizers which may be affected by rising demand and lower supply of material due to pandemic.

| Risk         | Low                      | Medium                              | High                     |
|--------------|--------------------------|-------------------------------------|--------------------------|
| 1. Technical | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> |
| 2. Timing    | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> |
| 3. Budget    | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> |

## G. Declaration

- ☒ All details provided in this application are accurate. KPT has the right to reject or to cancel the offer without prior notice if there is any inaccurate information given.
- ☒ This proposal is not currently considered for any other research grant(s).
- ☒ The exact proposed work has not been funded through other research grant(s).
- ☐ Necessary approvals from relevant bodies (i.e.: Ethics Committee) are granted before related research activities commence.
- ☐ I have an on-going Fundamental Research Grant Scheme (FRGS) project.
- ☒ This proposed research is my original work, is not copied from my MSc. or Ph.D. thesis or any other work (published or unpublished), and has not been submitted for grant application either at KPT or elsewhere.

Name: Mohammad Hafiz Bin Ismail

Signature:

Date: 22/02/2021

Approved By:

Signature:

RMC

Date:

## Appendix

Flow Chart

[Methodology\\_Flowchart\\_FRGS\\_update2.pdf](#)

| Appendix | Name                                  | File Name                                                                |
|----------|---------------------------------------|--------------------------------------------------------------------------|
| A        | Dr Nurul Ain Mohd Zaki                | <a href="#">CURRICULUM VITAE NAMZ PHD update 15Feb2021.pdf</a>           |
| B        | Prof Madya Dr Shukor Sanim Mohd Fauzi | <a href="#">Resume Shukor Sanim MOHD FAUZI V2 as of Aug 2020 (2).pdf</a> |
| C        | Prof Sr Dr Zulkiflee Abd Latif        | <a href="#">CV Prof Sr Dr Zulkiflee169721_Jul2020 (5).pdf</a>            |
| D        | Mohammad Hafiz bin Ismail             | <a href="#">CV-Hafiz.pdf</a>                                             |
| E        | Prof Madya Dr Chuah Tse Seng          | <a href="#">CV .21 Feb 2020.pdf</a>                                      |
| F        | Prof Madya Dr Farrah Melissa          | <a href="#">CV Farrah Melissa Muharam UPM 13012021.pdf</a>               |



MINISTRY OF HIGHER EDUCATION

SINGLE DISCIPLINARY PROJECT

APPLICATION FORM  
FUNDAMENTAL RESEARCH GRANT SCHEME (FRGS)  
*Skim Geran Penyelidikan Fundamental*  
(Pindaan 1/2012)

JABATAN PENDIDIKAN TINGGI  
KEMENTERIAN PENGAJIAN TINGGI

**A. Application Details**

|                                           |                                                                                                                                        |
|-------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------|
| Application ID                            | 438464-461403                                                                                                                          |
| Reference Code                            | FRGS/1/2022/WAB09/UITM/02/1                                                                                                            |
| A(i). Selected Grant Scheme               | FRGS 2022-1                                                                                                                            |
| A(ii). Title of Proposed Research Project | Digital Imagery Sensor Network Configuration of Structure-from-Motion Towards 3D Modelling of High Above Ground Rock Art Documentation |
| A(iii). Keywords                          | structure-from-motion (SfM), close-range-photogrammetry, multispectral camera, rock art documentation                                  |

**B. Details of Project Leader**

|                                                         |                                                                                                                                                                   |
|---------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| B(i). Name                                              | <a href="#">Khairulazhar Bin Zainuddin</a>                                                                                                                        |
| B(ii). Academic Qualification                           | Master of Science (Industrial Surveying)<br>BSc Surveying Science & Geomatic<br>Diploma in Geomatics Science (GIS)<br>DOCTOR OF PHILOSOPHY (GEOMATIC ENGINEERING) |
| B(iii). Nationality                                     | Malaysia                                                                                                                                                          |
| B(iv). IC/Passport No.                                  | 810527055425                                                                                                                                                      |
| B(v). Position                                          | Senior Lecturer                                                                                                                                                   |
| B(vi). Institution                                      | Universiti Teknologi MARA (UITM)                                                                                                                                  |
| B(vii). Faculty/Centre                                  | Faculty of Architecture, Planning & Surveying, Centre of Studies for Surveying Science & Geomatics                                                                |
| B(viii). Unit/Department                                | Centre of Studies for Surveying Science & Geomatics                                                                                                               |
| B(ix). Office Phone No.                                 | 049882198                                                                                                                                                         |
| B(x). Handphone No.                                     | 0122629039                                                                                                                                                        |
| B(xi). E-mail Address                                   | khairul760@uitm.edu.my                                                                                                                                            |
| B(xii). Date of First Appointment with this Institution | 07/01/2010                                                                                                                                                        |
| B(xiii). Type of Service (Permanent/Contract)           | Permanent 27/05/2038                                                                                                                                              |

**C. Research Information**

**C(i). Research Domain**

| Research Domain               | Sub Research Domain                 |
|-------------------------------|-------------------------------------|
| Natural and Cultural Heritage | Built Environment (Heritage Aspect) |

**C(ii). Research Cluster**

Cluster: Climate Change & Environment

**C(iii). 10-10 Malaysia Science, Technology, Innovation and Economy (MySTIE) - based on 10 Socio-Economic Drivers**

MySTIE: Culture, Arts and Tourism

**C(iv). Shared Prosperity Vision 2030 (SPV 2030)**

SPV: KEGA 3 – Industrial Revolution 4.0

**C(v). Sustainable Development Goals (SDGs)**

SDG: SDG 9 – Industry, Innovation and Infrastructure

**C(vi). Location of Research**

| Location                                                    |
|-------------------------------------------------------------|
| Photogrammetry Lab, Universiti Teknologi MARA Kampus Perlis |
| Gua Tambun Rock Art Shelter, Perak                          |

**C(vii). Duration of this research**

|          |                  |
|----------|------------------|
| From     | 1/September/2022 |
| To       | 31/August/2024   |
| Duration | 2 years          |

**C(viii). Other Researchers** *To add a project member from a government agency/foreign institution/industry, the project leader needs to register the new member if he/she is still not registered in MyGRANTS database. Please click the icon to search for existing or add new members.*

| Researcher Id | Name                                      | IC / Passport Number | Faculty/ School/ Centre/ Unit/ Department | Position                  | Area of Expertise                                                                                             | Next Appointed Leader               | Role                                          |
|---------------|-------------------------------------------|----------------------|-------------------------------------------|---------------------------|---------------------------------------------------------------------------------------------------------------|-------------------------------------|-----------------------------------------------|
| 10446         | <a href="#">MOHD FARID BIN MOHD ARIFF</a> | 800410015121         | Universiti Teknologi Malaysia             | Senior Lecturer (Dr)      | Photogrammetry, Close Range Photogrammetry, Terrestrial Laser Scanning, Surveillance System, Forensic Mapping | <input type="checkbox"/>            | Photogrammetry expert                         |
| 10714         | <a href="#">ZULKEPLI BIN MAJID</a>        | 720401016253         | Universiti Teknologi Malaysia             | Associate Professor (Dr)  | PHOTOGRAMMETRY, 3D LASER SCANNING, INDUSTRIAL SURVEYING, 3D MODELING                                          | <input type="checkbox"/>            | Photogrammetry expert and mentor for research |
| 11793         | <a href="#">Mimi Diana Binti Ghazali</a>  | 801027035204         | Universiti Teknologi MARA                 | Senior Lecturer (Sr.)     | Ground Penetrating Radar, Subsurface Contaminated                                                             | <input type="checkbox"/>            | Engineering expert for network design         |
| 22327         | <a href="#">Abd Manan Bin Samad</a>       | 600819106487         | Universiti Teknologi MARA                 | Professor (Professor)     | Engineering Surveing, Photogrammetry, Remote Sensing and GIS                                                  | <input type="checkbox"/>            | Mentor for research                           |
| 37656         | <a href="#">Faradina Binti Marzukhi</a>   | 841207025296         | Universiti Teknologi MARA                 | Senior Lecturer (Sr. Gs.) | Applied Geomatics, Applied GIS and remote sensing, Applied GIS and remote sensing                             | <input checked="" type="checkbox"/> | Multispectral processing expert               |

**C(ix). Research projects that have been completed or are on-going by project leader in the last three years**

| Title                                                                 | Grant Name | Role   | Progress (%) | Status | Duration | Start Date | End Date   |
|-----------------------------------------------------------------------|------------|--------|--------------|--------|----------|------------|------------|
| OPTIMISING STRUCTURE-FROM-MOTION NETWORK CONFIGURATION TOWARDS METRIC | ERCC       | Member | 40           | In     | 2 years  | 07/09/2021 | 06/09/2023 |

|                                                  |      |        |    |          |         |            |            |
|--------------------------------------------------|------|--------|----|----------|---------|------------|------------|
| PARAMETER ESTIMATION OF MULTISPECTRAL CAMERA RIG | FRGS | Member | 40 | Progress | < years | 01/09/2021 | 06/09/2023 |
|--------------------------------------------------|------|--------|----|----------|---------|------------|------------|

### C(x). Academic publications that have been published by the project leader in the last five years

| Title                                                                                                                                    | Name of Journal                                                                                                                             | Year |
|------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|------|
| 3D MODELLING METHOD OF HIGH ABOVE GROUND ROCK ART PAINTING USING MULTISPECTRAL CAMERA                                                    | INTERNATIONAL ARCHIVES OF THE PHOTOGRAMMETRY, REMOTE SENSING AND SPATIAL INFORMATION SCIENCES - ISPRS ARCHIVES : 9TH INTL. WORKSHOP 3D-ARCH | 2022 |
| Three-Dimensional Data Quality Assessment: Unmanned Aerial Vehicle Photogrammetry and Mobile Laser Scanner                               | Engineering Journal                                                                                                                         | 2021 |
| Tree inundation period determination for mangroves rehabilitation monitoring                                                             | IOP Conference Series: Earth and Environmental Science                                                                                      | 2021 |
| Accuracy Assessment of Atlas L-band GNSS Global Correction Service and Autonomous Positioning at Perlis, Malaysia                        | Built Environment Journal                                                                                                                   | 2021 |
| Tree inundation period determination for mangroves rehabilitation monitoring                                                             | IOP Conference Series: Earth and Environmental Science                                                                                      | 2021 |
| MEASUREMENT ACCURACY ON 3D POINT CLOUD GENERATED USING MULTISPECTRAL IMAGERY BY DIFFERENT CALIBRATION METHODS                            | International Archives of the Photogrammetry, Remote Sensing & Spatial Information Sciences                                                 | 2019 |
| PRACTICAL TERRESTRIAL LASER SCANNING FIELD PROCEDURE AND POINT CLOUD PROCESSING FOR BIM APPLICATIONS–TNB CONTROL AND RELAY ROOM 132/22KV | International Archives of the Photogrammetry, Remote Sensing & Spatial Information Sciences                                                 | 2019 |
| THE SUITABILITY OF TERRESTRIAL LASER SCANNING FOR BUILDING SURVEY AND MAPPING APPLICATIONS                                               | International Archives of the Photogrammetry, Remote Sensing & Spatial Information Sciences                                                 | 2019 |
| THREE-DIMENSIONAL RECORDING AND PHOTOREALISTIC MODEL RECONSTRUCTION FOR VIRTUAL MUSEUM APPLICATION – AN EXPERIENCE IN MALAYSIA           | International Archives of the Photogrammetry, Remote Sensing & Spatial Information Sciences                                                 | 2019 |
| Empowering Halal in Waqaf Land Property Management Using Geographic                                                                      | Contemporary Management and Science Issues in the Halal Industry                                                                            | 2019 |
| 3D MODELING FOR ROCK ART DOCUMENTATION USING LIGHTWEIGHT MULTISPECTRAL CAMERA                                                            | International Archives of the Photogrammetry, Remote Sensing & Spatial Information Sciences                                                 | 2019 |
| The Accuracy Evaluation of Unmanned Aerial Vehicle Technology for Different Coastal Terrain Mapping                                      | 8th IEEE International Conference on Control System, Computing and Engineering (ICCSCE)                                                     | 2018 |
| Lightweight multispectral camera calibration for photogrammetric applications                                                            | 9th IEEE Control and System Graduate Research Colloquium (ICSGRC)                                                                           | 2018 |
| 3D Data Fusion Using Unmanned Aerial Vehicle (UAV) Photogrammetry and Terrestrial Laser Scanner (TLS)                                    | Second International Conference on the Future of ASEAN (ICoFA) 2017–Volume 2                                                                | 2018 |
| Integration of Digital Cadastral Database Spatial Coordinates Towards Mapping in Google Earth                                            | Jurnal Intelek                                                                                                                              | 2017 |
| Mangrove area detection by using high resolution satellite imagery                                                                       | IEEE 13th International Colloquium on Signal Processing & its Applications (CSPA)                                                           | 2017 |
| Three-Dimensional Mapping of an Ancient Cave Paintings Using Close-Range Photogrammetry and Terrestrial Laser Scanning Technologies      | International Archives of the Photogrammetry, Remote Sensing & Spatial Information Sciences                                                 | 2017 |

### C(xi). Executive Summary of Research Proposal

(Please include the problem statement, objectives, research methodology, expected output/outcomes/implication, and significance of output from the research project)

The automation of the image orientation by the Structure-from-Motion (SfM) approach enables users without in-depth photogrammetric knowledge to construct the three-dimensional (3D) model of an object from two-dimensional (2D) images. However, the approach is more relevant to non-metric measuring applications, as the procedure typically results in a deformed 3D model due to the lack of a properly configured camera network. The camera network design is essential when the object is modelled into 3D for

metric measurement. However, there is a limited number of studies focusing on the network configuration to acquire and model a large object captured from limited elevation and control point distribution. The problem is more applicable to rock art geometric documentation, specifically for painting located at high above the ground surface and inaccessible to attach the control point target surrounding the object. This necessitates an optimum camera network configuration that considers the SfM processing limitations to achieve accurate 3D modelling by incorporating the tilted camera angle and minimal control point distribution. The first phase of the study will modify the typical SfM camera network by including the tilted image in extending the recording coverage of a tall structure acquired from limited elevation. The second phase will configure the control point distribution, which cannot be attached surrounding the object due to its massive dimension. The final phase will examine the configured camera network on an actual rock art to validate the accuracy of the generated 3D model. The outcome from this study is expected to improve the current documentation practice by non-photogrammetrist towards a metrically accurate 3D modelling involving massive objects in rapid time without requiring additional apparatus on-site. The outcome also supports the national and global agenda (KEGA-3 and SDG-9) through an accurate automation process in promoting the integration of creative and innovative solutions in heritage conservation.

## C(xii). Detail Planning

### (a) Research background

#### 1. Problem Statement

In analytical photogrammetry, camera network configuration is essential to design an optimal camera placement in the sense that they will satisfy the network quality requirement at a minimum cost (Stylianidis et al., 2016). Image network geometry should be carefully designed prior to data acquisition for proper camera placement according to the 3x3 rule of photogrammetric documentation of heritage objects (Waldhäusl & Ogleby, 1994). According to the geometric rule section, the camera should be positioned to cover a complete object with a suitable image overlap greater than 60% by convergent orientation (or angle). The reason to configure the network according to the rule is to ensure the object point is visible in at least two to three photographs. Additionally, the mentioned configuration also ensures the captured images incorporate standard stereoscopic geometry and have a good depth determination as a function of object scaling in model space.

Nowadays, the Structure-from-Motion (SfM) processing approach is preferable by non-photogrammetrist for 3D modelling instead of using analytical close-range photogrammetry. SfM allows users to capture images without a proper camera network for 3D modelling. However, SfM requires the image captured parallelly to the object with high overlap between photographs greater than 85% to ensure a successful image orientation through an automatic image matching procedure. Consequently, the SfM approach consistently produces a deformed 3D model due to missing or weak camera network configuration (Aicardi et al., 2018; Nocerino et al., 2014; Stylianidis et al., 2016). Moreover, SfM cannot process the images acquired in convergent geometry, leading to a low point intersection angle during 3D model construction.

Regarding 3D modelling, abundant numbers of ground control points (GCP) are also required in SfM processing for correct model scaling and georeferencing. The GCPs should be well distributed and frequently located around the object to minimize model distortion. The control point distribution will function as a control frame to adjust the constructed point cloud for accurate 3D modelling through bundle adjustment for metric measurement (Mlambo et al., 2017; Villanueva & Blanco, 2019). This method is appropriate when the rock art is in an easily accessible area. However, not all rock arts are reachable by human height without elevated aid apparatus.

Additionally, some shelters are located in remote areas with limited access, making the mobilization of such tools complicated and incurring the project cost (Brandolini et al., 2021). Meanwhile, remotely unmanned aerial vehicles are not necessarily suitable, mainly when the painting panels are located on or under a massive structure, which blocks the global positioning system (GPS) signal for a smooth manoeuvre (Wang et al., 2019). Therefore, it is necessary to design a control point distribution at a limited high that can be used to scale and orientate the 3D model without sacrificing the output accuracy.

Theoretically, the object positioned high above the ground can be captured and modelled from a human height level by tilting the camera angle upward. The technique is similar to oblique aerial photogrammetry, which is purposely used to extend image coverage over a large area. However, as mentioned previously, SfM orientation is limited to the normal image geometry with a large overlap, thus requiring additional elevated aid devices to reach the upper area of the object. Meanwhile, using a tilted image leads to an inconsistent image scale due to different object relief over the entire picture. Thus, the point intersection will distort during 3D model construction. Therefore, this study intends to optimize the typical SfM camera network configuration by experimenting with integrating the normal and tilt cameras angle for 3D modelling. Finally, the current trend in cultural heritage documentation is practising multispectral 3D modelling, which extends the research opportunity in cultural heritage (Adamopoulos et al., 2020; Jalandoni, 2021). Thus, the network configuration in this study will purposely design for a multispectral camera. The output from this research will enhance the ability to acquire and model the rock art panel located high above the ground with reasonable accuracy to be used for geometric documentation. Moreover, the outcome of the study is not limited to rock art but can be extended to any similar application such as road tunnel (Attard et al., 2018) and building inspection (Lee et al., 2019).

#### 2. Hypothesis

- i. The inclusion of tilted camera angle into the typical SfM camera network enables extending the coverage of rock art painting located high above the ground with accurate results.
- ii. A proper camera configuration with limited control point distribution can assist the SfM to scale and orientate the images without sacrificing the 3D model accuracy.

#### 3. Research Questions

This study focuses on addressing the following general questions:

- i. What is the optimal camera network for SfM, and how to place the camera to capture the object located high above the ground from a limited human height range?
- ii. How to distribute limited control points on the tall object without deforming the 3D model?
- iii. How can the configured optimal camera network affect the accuracy of generated 3D model?

## 4. Literature Reviews

### 4.1 Fundamental of photogrammetric orientation

Photogrammetric orientation is a process to recover the acquired image in the model space. The estimated orientation is then helpful to project the features (pixel) contained on their image to the model space to construct the 3D model. The essential input for photogrammetric orientation comprises the camera interior parameter and the control point coordinate in estimating the exterior parameter of the camera. The camera interior parameter or calibrated parameter is used to compensate for the image distortion due to lens characteristics, thus the pixel on the image will accurately project into the model space (Aicardi et al., 2018).

However, SfM does not require a pre-calibrated camera prior to data capture and processing, where the value is estimated during processing through self-calibration. In analytical close-range photogrammetry, self-calibration requires the image to be captured in a good camera network. The camera is placed with a large baseline (or small overlap) convergently with the inclusion of roll camera angle. Additionally, analytical CRP orientates the images based on point resection, where this point is manually registered on the image during orientation before constructing the 3D model (Remondino et al., 2017). Meanwhile, SfM cannot orientate the camera having a small overlap due to its operation being based on features matching, which requires an image having a large overlap of normal camera geometry.

On the other hand, the ground control point (GCP) is required for successful orientation and modelling. The control point is used to orientate the image and scale the projected points through bundle adjustment. Bundle adjustment is used to minimise the errors between the computed and the observed image coordinates (Aicardi et al., 2018). However, without a good camera network leads to point intersection failure, producing abundance of noise point and leads to less accurate output of the 3D model (Stylianidis et al., 2016).

### 4.2 Network Configuration for Close-Range Photogrammetry

The purpose of a camera network in close-range photogrammetry is to design an optimal network configuration for camera placement in sense that they will satisfy the network quality requirement at a minimum cost (Stylianidis et al., 2016). They include how many camera stations, how many images per station are required, and the distribution of control points for scaling and model orientation. According to Georgopoulos & Stathopoulou (2017), the exact number of photographs to be acquired depends on the object's occlusion, shape complexity, and scale.

The accuracy of projected point rays from its image to model space depends on the geometric consideration of angular orientation of the camera stations. According to Fraser (1984), the highest overall accuracy will be achieved when the angles of the rays' intersection are near  $90^\circ$ . As illustrated by Figure 1, the parallax angle,  $\phi_1$ , to object point based on a normal camera is approximately  $35^\circ$ . When the same object is obtained from the convergent camera, the parallax angle,  $\phi_2$ , is approximately  $95^\circ$ . Since the  $\phi_2$  is closer to  $90^\circ$ , the overall accuracy computed is higher than  $\phi_1$ .

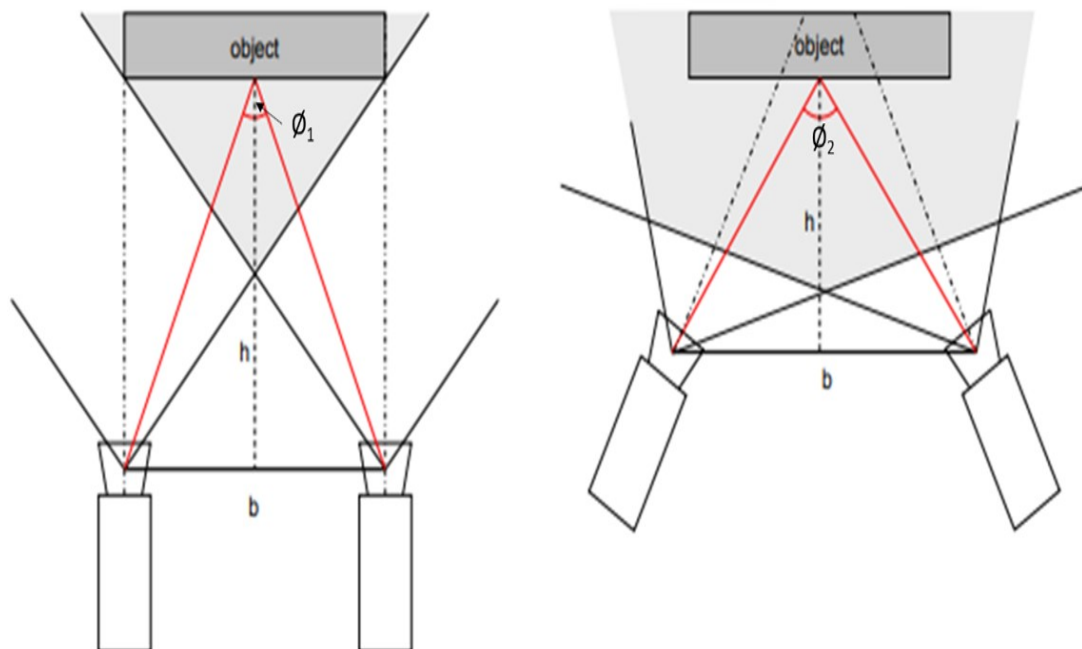


Figure 1: Parallax angle between normal and convergent camera.

A similar problem occurs when the captured image is not in normal geometry. Meanwhile, the feature on tilted camera angle which used to extend area coverage is in a trapezoid. Thus, the image scale varies on the entire image due to different depths, leading to producing deformed point projection. According to Figure 2, the point projection depends on the camera focal length as a function of the projection scale. In SfM, the parameter is estimated in a self-calibration sense with the aid of the control point and favour network geometry. When the convergent and roll camera is not included, the point will project at the wrong location, producing unnecessary point (outliers) and reducing the accuracy of the 3D model.

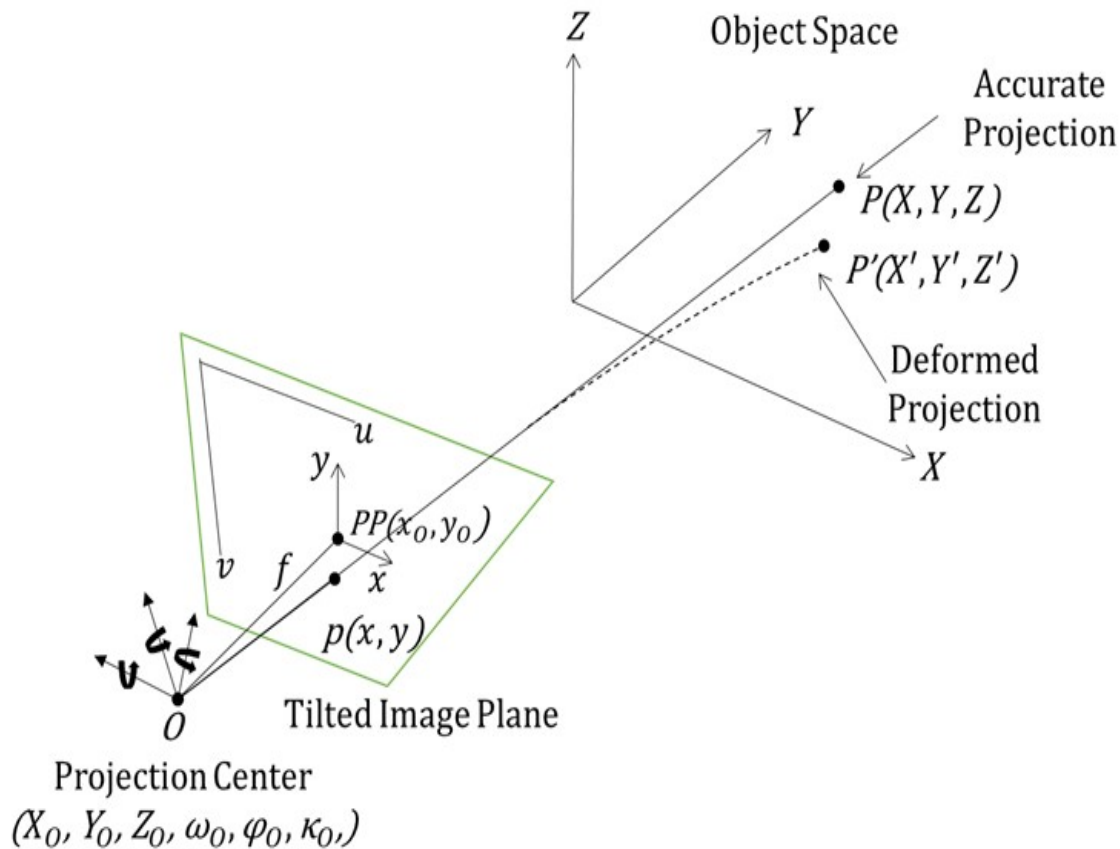


Figure 2: Concept of point projection from tilted image to object space.

The SfM cannot process images acquired using convergent images since the orientation is calculated using the feature-based approach. The feature-based on SfM requires the image to be acquired with a large overlap, hence, lowering the image baseline and intersection angle (Stylianidis et al., 2016). Research by Nocerino et al. (2014) and Jalandoni et al. (2018) had demonstrated that using a single camera strip with normal angle geometry has produced a deformed 3D model due to the weak network.

Based on 3x3 rules for photogrammetric documentation, the camera network should consider the camera base-to-object ratio to balance the image overlap and the geometric strength (Stylianidis et al., 2016). Besides, the camera base-to-object distance design also needs to consider the expected accuracy of the generated 3D model. The expected accuracy requirement for SfM 3D modelling can be quantified based on image ground sampling distance (GSD), which should be set at least half of the final 3D model's required accuracy. The previous statement is applicable to the multispectral camera since the image produced has a low spatial resolution, limiting the point extraction for parameter estimation. Additionally, the configured network should consider the repeatability to be used in any similar object to reproduce to a certain extent the same result.

##### 5. Relevance to Government Policy (if any)

This research strengthens the key policy of the National Heritage Department for heritage documentation, which strives to protect, preserve, and safeguard the national heritage through research, documentation, enforcement, and education. The study also supports in catch-up current technologies in using the visual sensor technology (S&T driver 2) and advanced intelligent system (S&T driver 5) to create 3D models for documentation to preserve heritage objects as outlined by the 10-10 Malaysian Science, Technology, Innovation and Economy (MySTIE) framework to the Culture, Arts and Tourism. The main idea of the research is to optimise the digital working environment in supporting the Key Economic Growth Activities 3 (KEGA 3 - Industrial Revolution 4.0, and Sustainable Development Goals for Industry, Innovation, and Infrastructure (SDGs-9) in automating the documentation process and eliminating human biases in interpreting the cultural heritage objects.

##### (b) References

1. Adamopoulos, E., Bovero, A., & Rinaudo, F. (2020). Image-based metric heritage modeling in the near-infrared spectrum. *Heritage Science*, 8(1), 1–12. <https://doi.org/10.1186/s40494-020-00397-w>
2. Aicardi, I., Chiabrando, F., Maria Lingua, A., & Noardo, F. (2018). Recent trends in cultural heritage 3D survey: The photogrammetric computer vision approach. *Journal of Cultural Heritage*, 32, 257–266. <https://doi.org/10.1016/j.culher.2017.11.006>
3. Attard, L., Debono, C. J., Valentino, G., & Di Castro, M. (2018). Tunnel inspection using photogrammetric techniques and image processing: A review. *ISPRS Journal of Photogrammetry and Remote Sensing*, 144(February), 180–188. <https://doi.org/10.1016/j.isprsjprs.2018.07.010>
4. Brandolini, F., Cremaschi, M., Zerboni, A., Esposti, M. D., Mariani, G. S., & Lischi, S. (2021). SfM-photogrammetry for fast recording of archaeological features in remote areas. *Archeologia e Calcolatori*, 31.2, 33–45. <https://doi.org/10.19282/ac.31.2.2020.04>
5. Fraser, C. S. (1984). Network Design Considerations for Non-Topographic Photogrammetry. *Photogrammetric Engineering & Remote Sensing*, 50(8), 1115–1126.

6. Georgopoulos, A., & Stathopoulou, E. K. (2017). Data Acquisition for 3D Geometric Recording: State of the Art and Recent Innovations. In M. L. Vincent, V. M. López-Menchero Bendicho, M. Ioannides, & T. E. Levy (Eds.), *Heritage and Archaeology in the Digital Age: Acquisition, Curation, and Dissemination of Spatial Cultural Heritage Data* (pp. 1–26). Springer International Publishing. [https://doi.org/10.1007/978-3-319-65370-9\\_1](https://doi.org/10.1007/978-3-319-65370-9_1)
7. Jalandoni, A. (2021). An overview of remote sensing deliverables for rock art research. *Quaternary International*, 572, 131–138. <https://doi.org/10.1016/j.quaint.2019.10.008>
8. Jalandoni, A., Domingo, I., & Taçon, P. S. C. (2018). Testing the value of low-cost Structure-from-Motion (SfM) photogrammetry for metric and visual analysis of rock art. *Journal of Archaeological Science: Reports*, 17(December), 605–616. <https://doi.org/10.1016/j.jasrep.2017.12.020>
9. Lee, S. H., Woo, S. H., Ryu, J. R., & Choo, S. Y. (2019). Automated building occupancy authorization using BIM and UAV-based spatial information: photogrammetric reverse engineering. *Journal of Asian Architecture and Building Engineering*, 18(2), 154–161. <https://doi.org/10.1080/13467581.2019.1631172>
10. Mlambo, R., Woodhouse, I. H., Gerard, F., & Anderson, K. (2017). Structure from motion (SfM) photogrammetry with drone data: A low cost method for monitoring greenhouse gas emissions from forests in developing countries. *Forests*, 8(3). <https://doi.org/10.3390/f8030068>
11. Nocerino, E., Menna, F., & Remondino, F. (2014). Accuracy of typical photogrammetric networks in cultural heritage 3D modeling projects. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives*, 40(5), 465–472. <https://doi.org/10.5194/isprsarchives-XL-5-465-2014>
12. Remondino, F., Nocerino, E., Toschi, I., & Menna, F. (2017). A Critical Review of Automated Photogrammetric Processing of Large Datasets. *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLII-2/W5(September), 591–599. <https://doi.org/10.5194/isprs-archives-XLII-2-W5-591-2017>
13. Stylianidis, E., Georgopoulos, A., & Remondino, F. (2016). Basics of Image-Based Modelling Techniques in Cultural Heritage 3D Recording. In E. Stylianidis & F. Remondino (Eds.), *3D recording, documentation and management of cultural heritage* (pp. 253–304). Whittles Publishing.
14. Villanueva, J. K. S., & Blanco, A. C. (2019). Optimization of ground control point (GCP) configuration for unmanned aerial vehicle (UAV) survey using structure from motion (SfM). *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives*, 42(4/W12), 167–174. <https://doi.org/10.5194/isprs-archives-XLII-4-W12-167-2019>
15. Waldhäusl, P., & Ogleby, C. L. (1994). 3 x 3 rules for simple photogrammetric documentation of architecture. *International Archives of Photogrammetry and Remote Sensing*, 30, 426–429.
16. Wang, S., Wang, Y., Hu, Q., Li, J., & Ai, M. (2019). Unmanned aerial vehicle and structure-from-motion photogrammetry for three-dimensional documentation and digital rubbing of the Zuo River Valley rock paintings. *Archaeological Prospection*, May. <https://doi.org/10.1002/arp.1739>

#### (c) Objective(s) of the Research

The following objectives are designed to achieve the aim of the study:

- i. To optimise camera network by including the tilt camera angle for modelling object locating high above ground.
- ii. To optimise control point distribution which suits the optimal camera network configuration from the first objective.
- iii. To examine the precision and accuracy of the 3D model generated using configured camera network.

#### (d) Methodology:

##### 1. Description of Methodology

The research methodology of this study consists of three phases:

First phase:

The first phase will optimize the typical SfM camera network for 3D modelling. The network will apply to a lightweight multispectral camera, allowing users to photograph a tall and complex object from the ground level using the close-range photogrammetry technique. As a result, the camera network in this study will be configured so that a tall object can be captured. The experiment will select a single large and tall object that is accessible to locate the control point at such an elevation, for example, the elevated façade of a multi-storey building with an approximate 12m to 20m height.

The optimal camera configuration begins with the initial camera network design to determine the limit of the sensor coverage. The design will adopt traditional aerial photogrammetric image block configuration, which captures photographs with near-vertical geometry. The vertical orientation will be set to horizontal in the case of close-range modelling in this proposal.

Theoretically, using the parallel camera strips will only covers a small area up to the height at which a human can hold the camera. Thus, unless additional strips are added to the network, the configuration will not cover the upper part of the building. However, by including more strips in the image block, the total number of photographs will also increase. Therefore, this study propose to include the tilted camera angle to extend the area coverage of object located high above ground level from limited human height.

The inclusion of tilt photograph in the experiment is motivated by the oblique camera geometry used in the aerial photogrammetric mapping application (Nesbit & Hugenholtz, 2019). The difference between a normal and a tilt camera is illustrated in Figure 3. The normal camera viewing angle will be set horizontally to the study object (Figure 3(a)). In comparison, the viewing angle of the tilted camera (Figure 3 (b)) will be slightly angled upward (about 45°) to focus on the object upper area.

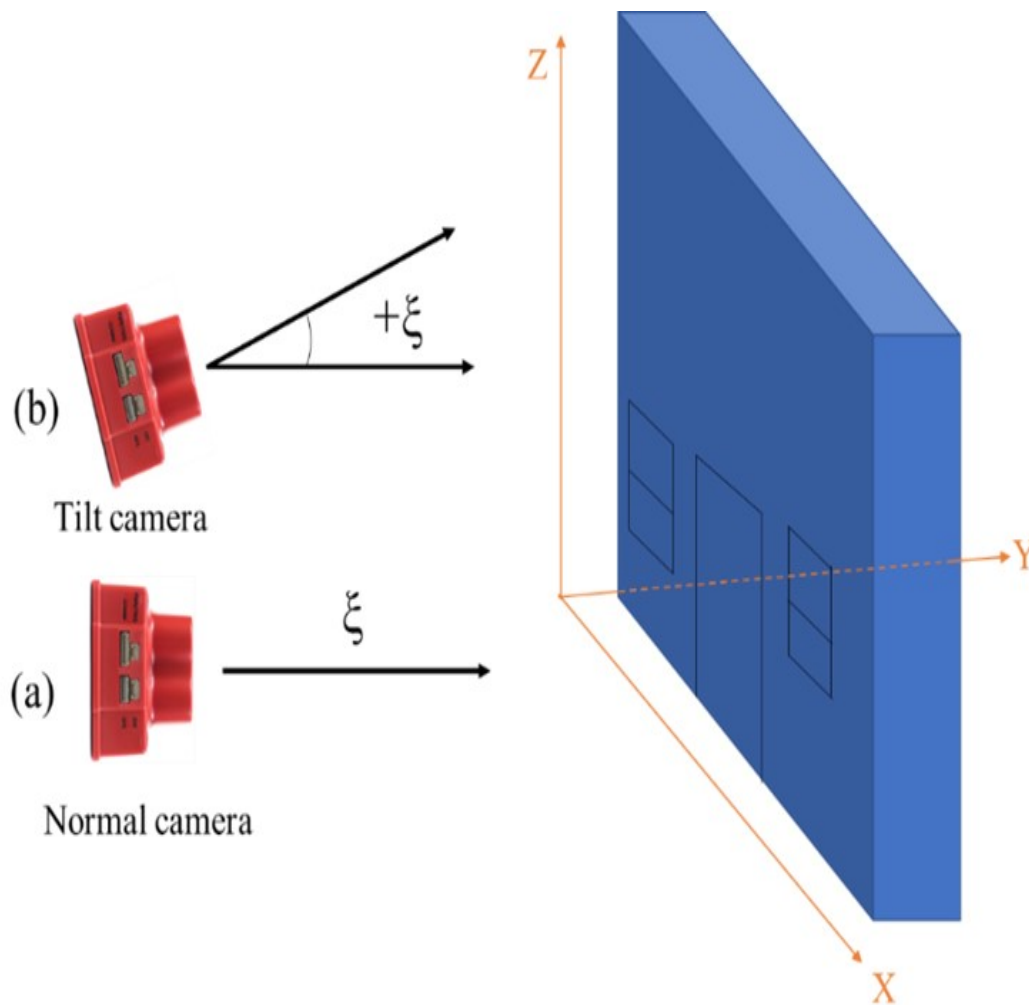


Figure 3: Conceptual of inclusion of tilt and normal camera.

Even though the proposed of using tilted image can extend the area coverage from limited height for 3D modelling, however, it is also expected that the lower area of the test object may be missed since the camera viewing angle is only focus to the upper side of the object. Therefore, the third experiment in the first phase will combine the parallel and tilt camera geometry into the camera network to cover the entire object surface area while photographing from a low height. All experiments proposed in the study will include the convergent photographs to enhance the network geometry based on the analytical photogrammetric 3D modelling approach.

The initial network configuration is expected to consist of dense image strips in the image block due to inclusion of various camera angle configurations. Consequently, having a network with an excessively dense camera strip increases the computational cost of SfM processing, therefore, need to reduce some potential redundant image in the image block. This study is propose to reduce the number of image by lowering the image overlap from typical 90% to expected of 80%-70%. In the same time, reducing the image strip in the block needs to maintain the accuracy of the 3D model. Motivated by the constraint, the final experiment in the first phase will optimise the initial configuration camera network to have the fewest possible strips.

The root mean square error (RMSE) of the checkpoint will determine the accuracy of all tested configurations. The study will use the tacheometry technique to calculate the check point coordinate and then export to Agisoft Metashape for coordinate adjustment analysis.

#### Second phase:

The second phase of the study will examine the distribution of control points placed at a limited elevation for accurate 3D modelling. Since SfM relying on a large number of control points to improve the accuracy of the constructed 3D model (Remondino et al., 2017; Aicardi et al., 2018), this study will examine the optimal configuration of control point distribution located within the reachable area.

The experiment will process the image from selected optimal camera network configuration from previous phase with different number of control points distributions including random and systematic pattern at a lower elevation of the test object. The investigation will start with maximum 30 control points and gradually reduce by 5% until the optimum or minimum number of control points is reached.

The F-variance ratio and t-test will be used to analyze the results of various control point configurations. Both statistical tests will determine the significance of the configured control point based on various number and distributions in term of 3D model accuracy. All experiments will be conducted using Agisoft Metashape software.

#### Third phase:

The final phase of the proposed study will evaluate the accuracy, reliability and repeatability of the propose camera network configuration on actual heritage object. For that purpose, Gua Tambun rock art shelter in Ipoh, Perak, is selected for verification to demonstrate a new 3D modelling technique for rock art geometric documentation. The reason of the site selection is due to the features of the painting are located at high above the ground, while the shelter is located in a remote area, which is suitable to test the accuracy assessment. Additionally, the rugged topography and their shape complexity are also suitable to test the reliability and

repeatability of the developed method for the non-expert to document the heritage object.

For accuracy assessment, data will acquire using a lightweight multispectral camera based on the configured network to generate multispectral 3D model. The captured image then will process using Agisoft Metashape to construct the multispectral 3D model. The 3D model then verify using Cloud Compare software. Cloud Compare is an open-source software which able to analyze large datasets by calculate the shape, size, and distance deviation of the test model/object. In this study, the accuracy assessment will examine the root mean square error (RMSE) of the generated 3D model (multispectral) with the reference model (TLS). The evaluation will also consider the point of view from the expert. In this study, the Department of National Heritage review is essential to validate the accuracy requirement for geometric documentation.

2. Flow Chart of Research Activities

'methodology flow.pdf'

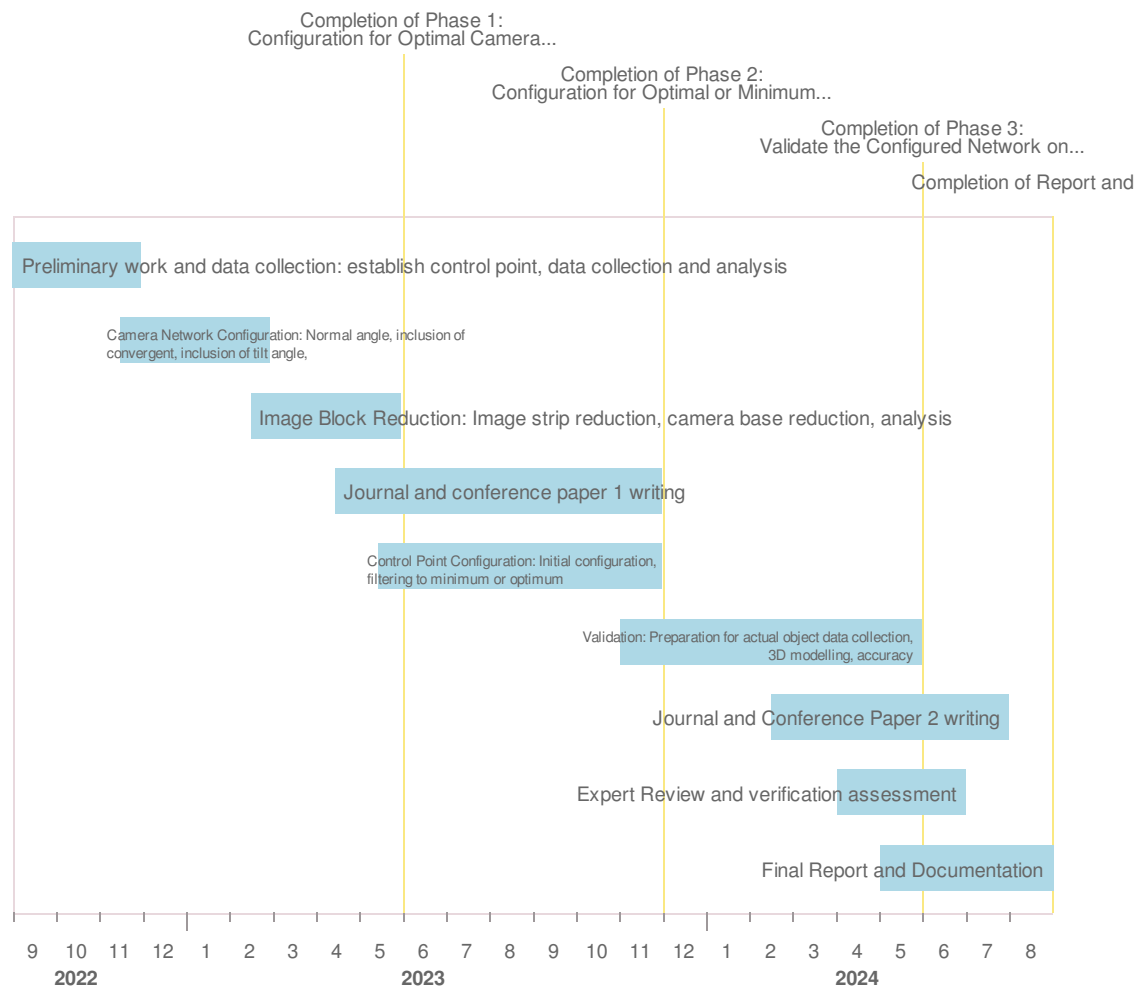
3. Research Activities

| Activity                                                                                               | Start Date | End Date   |
|--------------------------------------------------------------------------------------------------------|------------|------------|
| Preliminary work and data collection: establish control point, data collection and analysis            | 01/09/2022 | 30/11/2022 |
| Camera Network Configuration: Normal angle, inclusion of convergent, inclusion of tilt angle, analysis | 15/11/2022 | 28/02/2023 |
| Image Block Reduction: Image strip reduction, camera base reduction, analysis                          | 15/02/2023 | 31/05/2023 |
| Journal and conference paper 1 writing                                                                 | 15/04/2023 | 30/11/2023 |
| Control Point Configuration: Initial configuration, filtering to minimum or optimum distribution       | 15/05/2023 | 30/11/2023 |
| Validation: Preparation for actual object data collection, 3D modelling, accuracy assessment           | 01/11/2023 | 31/05/2024 |
| Journal and Conference Paper 2 writing                                                                 | 15/02/2024 | 31/07/2024 |
| Expert Review and verification assessment                                                              | 01/04/2024 | 30/06/2024 |
| Final Report and Documentation                                                                         | 01/05/2024 | 31/08/2024 |

4. Milestones

| Description                                                                            | Date       | Cumulative Project Completion Percentage(%) |
|----------------------------------------------------------------------------------------|------------|---------------------------------------------|
| Completion of Phase 1: Configuration for Optimal Camera Network                        | 31/05/2023 | 40                                          |
| Completion of Phase 2: Configuration for Optimal or Minimum Control Point Distribution | 30/11/2023 | 65                                          |
| Completion of Phase 3: Validate the Configured Network on Actual Object                | 31/05/2024 | 90                                          |
| Completion of Report and Documentation                                                 | 31/08/2024 | 100                                         |

Gantt Chart of Research Activities with Milestones



#### (e) Expected Results/Benefit

##### 1. Novel theories/New findings/Knowledge

- The expected outcome of this study is a better understanding of how to place the multispectral camera during data acquisition for a 3D modelling for massive objects, especially for non-photogrammetrist.
- As a recent 3D modelling approach utilizes the multispectral camera for geometric documentation of different spectra, hence, a proper camera network ensures data assurance, reliability, and repeatability of a generated 3D model for metric measurement and documentation.

##### 2. Impact Statement on Quintuple Helix (please delineate/describe expected research deliverables on Society, Academia, Government, Industry and Environment)

The proposed approach will eventually save cost, time and manpower. Additionally, the advantages of the proposed technique will benefits;

- The government, as the national heritage monument, can be accurately documented in a rapid time.
  - Jabatan Warisan Negara: in digitalizing the national heritage for future reference, education and dissemination, and towards UNESCO recognition in establishing a new global heritage site in Malaysia.
  - Tourism Malaysia: Promotes national pride and identity through national own global heritage sites towards increasing national revenue through tourism and edutainment.
- Academia: The proposed technique will open a new research agenda for academicians to engage multispectral sensors toward objects documentation, inspection and monitoring.
- Industry: Offer a new solution for rapid inspection involving large structures such as road tunnels.
- Society: Increase national heritage awareness toward a knowledgeable society in safeguarding national monuments for next-generation references.
- Environmental: Protect and safeguard the heritage area.

##### 3. Research Publications (Each proposal must produce at least two (2) papers in indexed journals, one of which should be in Web of Science (WoS))

| Indexing Body         | Indexed Journal |
|-----------------------|-----------------|
| Number of Publication | Name of Journal |

|        |                |                                                                                                                                                                                                                                                                         |
|--------|----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| WoS    | 1              | Heritage (WoS-) - "Optimized SfM camera configuration in modelling high above-ground rock art painting using SfM Photogrammetry"                                                                                                                                        |
| SCOPUS | 1              | Journal of Cultural Heritage (Scopus 5.1) or Digital Applications in Archaeology and Cultural Heritage (Scopus 3.7) - Non-APC option "Accuracy assessment on the 3D model generated using the multispectral image and SfM for high above-ground rock art documentation" |
| ERA    |                |                                                                                                                                                                                                                                                                         |
| MyCITE |                |                                                                                                                                                                                                                                                                         |
|        | <b>Total 2</b> |                                                                                                                                                                                                                                                                         |

#### 4. Specific or Potential Applications of the Research Findings

- The findings of this study can improve the methodology of documenting high above ground rock art and any massive national heritage objects to authorities such as the Department of National Heritage.
- The research outcome will enhance the national policy on rock art geometric documentation, by considering the metric measurement in future documentation exercises.
- The research outcome also can be proposed to any other agencies in applying the same technique involving complicated tall structures, either for documentation, inspection and monitoring in which any other technologies are not suitable. For example, tunnel inspection (PLUS Highway), in which the current practice of using mobile skylift to reach the tunnel ceiling is time-consuming and dangerous to traffic. Moreover, the technique is also suitable for data collection for building inspection at drone-restricted areas such as government buildings.
- The research outcome will also assist future research in automating object recognition through artificial intelligence (AI) on multispectral orthophoto.

Total Number of Applications: 3

#### 5. Number of PhD and Masters (by research) Students

Total Number of PhD (by research) Student(s):

Total Number of Masters (by research) Student(s):

1

Remark (if any):

One MSc. student will be trained with thesis title "Optimization of a camera network configuration of Structure-from-Motion for massive heritage object geometric documentation"

Students will be given intensive skills in data collection, data processing and analysis.

#### 6. Intellectual Properties (IPs)

- Copyright on a new data acquisition technique in acquiring a tall object for metrically accurate multispectral 3D modelling of rock art documentation.

Total Number of IP: 1

### Access to Equipment & Material(s)

| Type                                      | Description                                  | Owner              | Location                                            | Address                              |
|-------------------------------------------|----------------------------------------------|--------------------|-----------------------------------------------------|--------------------------------------|
| Cloud Compare                             | 3D modelling analysis software (open-source) | Photogrammetry Lab | Pusat Pengajian Sains Ukur dan Geomatik UiTM Perlis | Universiti Teknologi MARA Caw Perlis |
| Agisoft Multispectral (Education License) | 3D modelling software                        | Photogrammetry Lab | Pusat Pengajian Sains Ukur dan Geomatik UiTM Perlis | Universiti Teknologi MARA Caw Perlis |
| Total Station                             | For control point measurement                | Makmal Ukur        | Pusat Pengajian Sains Ukur dan Geomatik UiTM Perlis | Universiti Teknologi MARA Caw Perlis |

## E. Budget

| Budget Type                                           | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Year 1       | Year 2       | Grand Total  |  |
|-------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|--------------|--------------|--|
| <b>11000 - Allowance</b>                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 24000        | 24000        |              |  |
| <b>GRA Master (Max RM2,000.00/person for 2 years)</b> | One (1) Master of Science (Built Environment) student will be appointed as GRA - RM2000/monthly for two years                                                                                                                                                                                                                                                                                                                                                                                             |              |              | <b>48000</b> |  |
| <b>Sub-Total</b>                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | <b>24000</b> | <b>24000</b> | <b>48000</b> |  |
| <b>GRA Ph.D (Max RM2,500.00/person for 3 years)</b>   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |              |              | <b>0</b>     |  |
| <b>Sub-Total</b>                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | <b>0</b>     | <b>0</b>     | <b>0</b>     |  |
| <b>Vot-Total</b>                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | <b>24000</b> | <b>24000</b> | <b>48000</b> |  |
| <b>Recommended Sub-Total:RM48000</b>                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |              |              |              |  |
| <b>21000 - Travelling and Transportation</b>          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |              |              |              |  |
| <b>Local</b>                                          | <p>Travelling for meetings and related matters - 2 times/ year (with UTM and National Heritage Department) x 2 pax on each meeting involving face to face discussion.</p> <p>Travelling 1 day, meeting 1 day on each session:</p> <p>cost for each session (2 pax):</p> <p>i) Travelling cost ~ RM500 (KL)/ RM1000 (JB)</p> <p>ii) Accomodation ~ RM250 (1 nights)/ RM500 (if involve different gender)</p> <p>iii) Meals ~ RM480 (2 days)</p> <p>Other monthly progress meetings will conduct online</p> | 1980         | 1980         | <b>3960</b>  |  |
|                                                       | <p>Travelling to local conference - Conference on Geomatics and Geospatial Technology (GGT) 2024, or IEEE (which any relevant)</p> <p>1 pax:</p> <p>i) Travelling cost ~ RM1000</p> <p>ii) Accomodation ~ RM500 (2 nights)</p> <p>iii) Meals ~ RM360 (3 days)</p>                                                                                                                                                                                                                                         |              | 1860         | <b>1860</b>  |  |
| <b>Sub-Total</b>                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | <b>1980</b>  | <b>3840</b>  | <b>5820</b>  |  |
| <b>Overseas</b>                                       | <p>International Conference - 10th 3D Arch 2024 by CIPA and ISPRS (estimates will happen in the first quarter of 2024)</p> <p>1 pax:</p> <p>i) Travelling cost ~ RM6000</p> <p>ii) Accomodation ~ RM2000 (4 nights)</p> <p>iii) Meals ~ RM1250 (5 days)</p>                                                                                                                                                                                                                                               |              | 9250         | <b>9250</b>  |  |
| <b>Sub-Total</b>                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | <b>0</b>     | <b>9250</b>  | <b>9250</b>  |  |
| <b>Field work</b>                                     | <p>Travel to Gua Tambun for validation</p> <p>4 pax (Data collector (Control Point, multispectral, tacheometry)) x 3 days:</p> <p>i) Travelling cost ~ RM500</p> <p>ii) Accomodation ~ RM1500 (3 nights)</p> <p>iii) Meals ~ RM120/day/pax x 4 days = RM1920</p>                                                                                                                                                                                                                                          |              | 3920         | <b>3920</b>  |  |
| <b>Sub-Total</b>                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | <b>0</b>     | <b>3920</b>  | <b>3920</b>  |  |
| <b>Vot-Total</b>                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | <b>1980</b>  | <b>17010</b> | <b>18990</b> |  |

|                                                    |                                                                                                                                                   |                                   |                                    |       |
|----------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|------------------------------------|-------|
| Recommended Sub-Total:RM18990                      |                                                                                                                                                   |                                   |                                    |       |
| 24000 - Rental                                     | Rental for Multispectral camera (RM500/day x 10 days) - data acquisition for network configuration design stage - (buying cost - appx. RM40,000). | 5000<br><a href="#">PLG Q...</a>  |                                    | 5000  |
|                                                    | Rental for Multispectral camera (RM500/day x 5 days) - data acquisition for validation at Gua Tambun - (buying cost - appx. RM40,000).            |                                   | 2500<br><a href="#">PLG Q...</a>   | 2500  |
|                                                    | Rental for Terrestrial Laser Scanner for validation work (RM1500/day x 5 days (including 1 TLS operator) (buying cost - appx. RM400,000)          |                                   | 7500<br><a href="#">PLG Q...</a>   | 7500  |
| Vot-Total                                          |                                                                                                                                                   | 5000                              | 10000                              | 15000 |
| Recommended Sub-Total:RM15000                      |                                                                                                                                                   |                                   |                                    |       |
| 27000 - Research Materials and Supplies            |                                                                                                                                                   |                                   |                                    | 0     |
| Vot-Total                                          |                                                                                                                                                   | 0                                 | 0                                  | 0     |
| Recommended Sub-Total:RM0                          |                                                                                                                                                   |                                   |                                    |       |
| 28000 - Maintenance and Minor Repair Services      |                                                                                                                                                   |                                   |                                    | 0     |
| Vot-Total                                          |                                                                                                                                                   | 0                                 | 0                                  | 0     |
| Recommended Sub-Total:RM0                          |                                                                                                                                                   |                                   |                                    |       |
| 29000 - Professional Services                      |                                                                                                                                                   |                                   | 1500                               | 1500  |
| Services/Consultancy                               | Local conferences fee - GGT or IEEE                                                                                                               |                                   | <a href="#">ggt.pdf</a>            | 1500  |
|                                                    | International conferences fee - 3D Arch 2024                                                                                                      |                                   | 1500<br><a href="#">3dArch...</a>  | 1500  |
|                                                    | Proofreading services at the professional services.<br>For journal ~ RM3105 x 2<br>For conference ~ RM1440 x 2                                    | 4545<br><a href="#">Langua...</a> | 4545<br><a href="#">Langua...</a>  | 9090  |
| Sub-Total                                          |                                                                                                                                                   | 4545                              | 7545                               | 12090 |
| Short term course                                  |                                                                                                                                                   |                                   |                                    | 0     |
| Sub-Total                                          |                                                                                                                                                   | 0                                 | 0                                  | 0     |
| Journal Page Charges (WoS / SCOPUS / ERA / MyCITE) | Heritage (MDPI journal fee)                                                                                                                       |                                   | 6400<br><a href="#">heritag...</a> | 6400  |
| Sub-Total                                          |                                                                                                                                                   | 0                                 | 6400                               | 6400  |
| Vot-Total                                          |                                                                                                                                                   | 4545                              | 13945                              | 18490 |
| Recommended Sub-Total:RM18490                      |                                                                                                                                                   |                                   |                                    |       |
| 35000 - Accessories and Equipment                  |                                                                                                                                                   |                                   |                                    | 0     |
| Vot-Total                                          |                                                                                                                                                   | 0                                 | 0                                  | 0     |
| Recommended Sub-Total:RM0                          |                                                                                                                                                   |                                   |                                    |       |

|             |       |       |                     |
|-------------|-------|-------|---------------------|
| Grand Total | 35525 | 64955 | (100.00%)<br>100480 |
|             |       |       |                     |

**F(i). Patent Search (describe how your research output shall produce an innovative idea or technology that has the potential to be a solution for stakeholders (community, industry, government etc.) and offers a unique proposition)**

*To identify if the researcher is able to coherently present a compelling argument for his/her proposal in light of the IP landscape and factors identified in the (Yes/No) Section. The answer would reflect an understanding of the applicant's research advantage and limitations and the prospect of moving the completed research beyond this stage of funding.*

The patent search has shown an increasing trend in the topics for the last ten years. Most patents were filed in the United States of America (WIPO - World Intellectual Property Organization), European, and China regions. In contrast, a few patents were filed in the ASEAN region. Therefore, there is an opportunity to patent the proposed method in Malaysia and ASEAN to take advantage of the region's dense population and growing economy. The patent might be suitable for government agencies such as museums, heritage departments, local authorities and councils that impact tourism and UNESCO recognition.

[Simplified Patent Search Report \(MyGRANTS\) 2022 \(2\).pdf](#)

**F(ii). Research Collaborator**

- ☐ Industrial Linkages (Please identify any industry or end-user group involved in the project, and describe its role/contribution to the project)
- ☒ Agency/Organisation (Please identify all agencies/organisations collaborating in the project, and describe their role/contribution to the project)

Department of National Heritage (JWN) is committed to exploring all possible solutions to improve the effectiveness of rock art documentation practice. They agreed to assist researchers from the university with this solution following a series of meetings and talks with JWN. JWN will assist this project by providing information and granting researchers access to the study area, such as Gua Tambun Shelter in Ipoh Perak. Since JWN recently discovered new shelters, the method will be more applicable to document the paintings rapidly and adopt digital technology in their practice.

[UiTM-surat sokongan.pdf](#)

**F(iii). Risk Assessment (Please describe factors that may cause delays in, or prevent implementation of, the project as proposed above; estimate also the degree of risk)**

*Please consider an appropriate approach to working in the current conditions (pandemic, travel ban, social distancing etc.)*

Technical: All team members have a solid technical background in photogrammetry and 3D modelling, conduct research activities to fulfil grant requirements, and have experienced senior members writing journals and filing intellectual property.

Timing: Covid-19 pandemic is the biggest threat to progress the research according to the specific timeline. However, most of the experiment works require access to the computer. Thus there will be flexibility to conduct the work anywhere. Only the data acquisition for the experiment and the actual site will expose to the threat, which considers not too high.

Budget: The research has been designed with a minimum budget required, especially for data collection. Thus, the proposed budget is very sensitive to any amendment. Besides, if JWN offers another rock art shelter will also incur the budget for data collection. As for prevention, the proposed verification site will remain the same according to plan and will figure out additional costs if the agency offers any other suitable sites.

| Risk         | Low                                 | Medium                              | High                     |
|--------------|-------------------------------------|-------------------------------------|--------------------------|
| 1. Technical | <input checked="" type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/> |
| 2. Timing    | <input type="checkbox"/>            | <input checked="" type="checkbox"/> | <input type="checkbox"/> |
| 3. Budget    | <input type="checkbox"/>            | <input checked="" type="checkbox"/> | <input type="checkbox"/> |

## G. Declaration

- ☒ All details provided in this application are accurate. KPT has the right to reject or to cancel the offer without prior notice if there is any inaccurate information given.
- ☒ This proposal is not currently considered for any other research grant(s).
- ☒ The exact proposed work has not been funded through other research grant(s).
- ☐ Necessary approvals from relevant bodies (i.e.: Ethics Committee) are granted before related research activities commence.
- ☐ I have an on-going Fundamental Research Grant Scheme (FRGS) project.
- ☒ This proposed research is my original work, is not copied from my MSc. or Ph.D. thesis or any other work (published or unpublished), and has not been submitted for grant application either at KPT or elsewhere.

Name: Khairulazhar Bin Zainuddin

Signature:

Date: 26/01/2022

Approved By:

Signature:

RMC

Date:

Appendix

|            |          |                                      |                                                                 |
|------------|----------|--------------------------------------|-----------------------------------------------------------------|
| Flow Chart |          | <a href="#">methodology flow.pdf</a> |                                                                 |
|            | Appendix | Name                                 | File Name                                                       |
|            | A        | CV KHAIRULAZHAR                      | <a href="#">1429530-CV_Khairulazhar_Zainuddin_UiTM_2021.pdf</a> |
|            | B        | CV PROF MANAN                        | <a href="#">1478429-CV_Prof_Manan_1.pdf</a>                     |
|            | C        | CV PM ZUL                            | <a href="#">PPRN CV_PROF_ZULKEPLI_MAJID-converted.pdf</a>       |
|            | D        | CV FARADINA                          | <a href="#">1430373-CV_Faradina_Marzukhi_UiTM_2021.pdf</a>      |
|            | E        | CV MIMI                              | <a href="#">1429535-CV_Mimi_Diana_Ghazali_UiTM_2021.pdf</a>     |
|            | F        | CV FARID                             | <a href="#">PPRN CV_DR_FARID-converted.pdf</a>                  |
|            |          |                                      |                                                                 |



MINISTRY OF HIGHER EDUCATION

SINGLE DISCIPLINARY PROJECT

APPLICATION FORM  
FUNDAMENTAL RESEARCH GRANT SCHEME (FRGS)  
*Skim Geran Penyelidikan Fundamental*  
(Pindaan 1/2012)

JABATAN PENDIDIKAN TINGGI  
KEMENTERIAN PENGAJIAN TINGGI

**A. Application Details**

|                                           |                                                                                                             |
|-------------------------------------------|-------------------------------------------------------------------------------------------------------------|
| Application ID                            | 439638-446270                                                                                               |
| A(i). Selected Grant Scheme               | FRGS 2022-1                                                                                                 |
| A(ii). Title of Proposed Research Project | RECONSTRUCTION THE MISSING PART OF CRANIOFACIAL FRACTURE IMAGE BY USING QUINTIC TRIGONOMETRIC BEZIER CURVE. |
| A(iii). Keywords                          | curve reconstruction, quintic bezier trigonometric bezier curve                                             |

**B. Details of Project Leader**

|                                                         |                                                                       |
|---------------------------------------------------------|-----------------------------------------------------------------------|
| B(i). Name                                              | <a href="#">Siti Sarah Binti Raseli</a>                               |
| B(ii). Academic Qualification                           | BACHELOR OF MATHEMATICS, UITM SHAH ALAM<br>MASTER IN MATHEMATICS, USM |
| B(iii). Nationality                                     | Malaysia                                                              |
| B(iv). IC/Passport No.                                  | 830511095068                                                          |
| B(v). Position                                          | Senior Lecturer                                                       |
| B(vi). Institution                                      | Universiti Teknologi MARA (UITM)                                      |
| B(vii). Faculty/Centre                                  | Department of Mathematics, Mathematics                                |
| B(viii). Unit/Department                                | Mathematics                                                           |
| B(ix). Office Phone No.                                 | 049882714 Ext.2714                                                    |
| B(x). Handphone No.                                     | 0164440583                                                            |
| B(xi). E-mail Address                                   | sitisarahraseli@uitm.edu.my                                           |
| B(xii). Date of First Appointment with this Institution | 05/06/2012                                                            |
| B(xiii). Type of Service (Permanent/Contract)           | Permanent 05/06/2043                                                  |

**C. Research Information**

**C(i). Research Domain**

| Research Domain          | Sub Research Domain        |
|--------------------------|----------------------------|
| Pure and Applied Science | Mathematics and Statistics |

**C(ii). Research Cluster**

Cluster: Health

**C(iii). 10-10 Malaysia Science, Technology, Innovation and Economy (MySTIE) - based on 10 Socio-Economic Drivers**

C(iv). Shared Prosperity Vision 2030 (SPV 2030)

SPV: KEGA 3 – Industrial Revolution 4.0

C(v). Sustainable Development Goals (SDGs)

SDG: SDG 4 – Quality Education

C(vi). Location of Research

| Location                         |
|----------------------------------|
| UNIVERSITI TEKNOLOGI MARA PERLIS |

C(vii). Duration of this research

|          |                  |
|----------|------------------|
| From     | 1/September/2022 |
| To       | 31/August/2024   |
| Duration | 2 years          |

**C(viii). Other Researchers** *To add a project member from a government agency/foreign institution/industry, the project leader needs to register the new member if he/she is still not registered in MyGRANTS database. Please click the icon to search for existing or add new members.*

| Researcher Id | Name                                 | IC / Passport Number | Faculty/ School/ Centre/ Unit/ Department | Position               | Area of Expertise | Next Appointed Leader               | Role |
|---------------|--------------------------------------|----------------------|-------------------------------------------|------------------------|-------------------|-------------------------------------|------|
| 112616        | <a href="#">Nurhuda Binti Ismail</a> | 830102015100         | Universiti Teknologi MARA                 | Senior Lecturer (Puan) | Mathematics       | <input type="checkbox"/>            |      |
| 135058        | <a href="#">Norpah Binti Mahat</a>   | 801205016066         | Universiti Teknologi MARA                 | Senior Lecturer (Mrs)  | Neural Network    | <input checked="" type="checkbox"/> |      |

C(ix). Research projects that have been completed or are on-going by project leader in the last three years

| Title | Grant Name | Role | Progress (%) | Status | Duration | Start Date | End Date |
|-------|------------|------|--------------|--------|----------|------------|----------|
|-------|------------|------|--------------|--------|----------|------------|----------|

C(x). Academic publications that have been published by the project leader in the last five years

| Title | Name of Journal | Year |
|-------|-----------------|------|
|-------|-----------------|------|

C(xi). Executive Summary of Research Proposal

(Please include the problem statement, objectives, research methodology, expected output/outcomes/implication, and significance of output from the research project)

This study is conducted to propose a new method in reconstruction of craniofacial fracture image to improve the reconstructed craniofacial curve to be more precise and less error determined.

The main objectives involves in this study is to reconstruct the missing part of craniofacial image by using quintic trigonometric Bezier curve. The sub-objectives are

- i. To extract the boundary from a real image of craniofacial fracture.
- ii. Determine the corner points of the image and reconstruct the missing part of craniofacial image by using quintic trigonometric bezier curve.

This technique is introduced in order to reconstruct the missing parts of the craniofacial which can give an accurate result and becomes a user friendly references for the doctors and physicians in conducting their medical treatment to the patients who have craniofacial fracture injuries.

C(xii). Detail Planning

(a) Research background

1. Problem Statement

This study is conducted to propose a new method in reconstruction the missing part of craniofacial fracture to improve the reconstructed craniofacial curve to be more precise and less error determined.

The quintic trigonometric bezier curve is used to reconstruct the curve for the missing part of the craniofacial from real sample of craniofacial fracture. The process involved is boundary extraction, corner detection, control points determination and craniofacial reconstruction.

This study will be implemented based on a sample from the real case of craniofacial fracture to verify the application of quintic trigonometric bezier curve for a new reconstruction of a curve in order to reduce the error occurred from the previous study.

## 2. Hypothesis

Curve reconstruction or curve fitting is the combination of interpolation and approximation technique. This technique is used in order to produce a smooth curve that is similar with the original image by using a suitable method. It is widely used in image processing application to help the researchers to reconstruct a smooth and accurate curve.

## 3. Research Questions

What is the new method in reconstruction of craniofacial fracture to improve the reconstructed craniofacial curve to be more precise and less error determined?

## 4. Literature Reviews

There are many previous papers and researcher articles about the reconstruction of curves, craniofacial and skull regarding the methods in CAGD .

### CRANIOFACIAL RECONSTRUCTION

The study about the reconstruction the curve of craniofacial by using rational cubic ball curve is introduced by Majeed et al. (2015). The paper use a sample of the real case of craniofacial fracture image from University Sains Malaysia (USM) Health Campus in order to show the capability of the method. There are several features of cubic ball curves such as symmetry, satisfies convex hull property, variation diminishing property, coordinate system independence, invariant under affine transformation and end points interpolation. These features are some factors that contributes to the reconstruction of a smooth curve. A sample of craniofacial fracture is from a CT scan data which has 189 slices and 55 slices are from the fracture part. The process involved in this study are boundary extraction of the craniofacial image, corner points detection, parameterization and craniofacial reconstruction by using cubic ball curve. The results from this study is the cubic ball curve for the missing part of the craniofacial. The last step in this paper is to compute the error occurred for the 189 slices by using normalized mean square error. Hence, this proposed method is very suitable to reconstruct the missing craniofacial image however some improvement should be done due to the errors that occurs in every segments of the image.

In addition, the study about the craniofacial fracture is proposed again by Abdul Majeed, Zainor Ridzuan Yahya, Abd Rahni Mt Piah and Muhammad Zaini Ahmad, (2015) for another real case of craniofacial fracture injuries by using  $GC^1$  rational cubic Ball curves. The paper use another sample of a real case of craniofacial fracture image from University Sains Malaysia (USM) Health Campus which has different part of craniofacial fracture compared to the previous paper. This sample is from a CT scan data which has 188 slices. The process involved in this study are boundary extraction of the craniofacial image, corner points detection and craniofacial reconstruction by using  $GC^1$  rational cubic Ball curves. This reconstruction technique is different from the reconstruction of cubic ball because this technique use  $GC^1$  rational cubic Ball curves with three free parameters. These free parameters is optimized by using Genetic algorithm. The parameters becomes the important element in this study because the curve will change depends on the chosen parameter. From the result obtained, the last step in this paper is to compute the error occurred from 188 slices by using normalized mean square error. This reconstruction technique is very flexible compared to the previous technique.

Furthermore, from the technique using  $GC^1$  rational cubic Ball curves, Abdul Majeed and Abd Rahni Mt Piah, (2016) proposed another technique that is flexible and user friendly to the user like physicians and doctors. This proposed reconstruction of craniofacial fractured use  $GC^2$  rational cubic Ball curves with four free parameters. The technique is arrange from the pre-processing process to the main process. In the pre-processing process, a CT scan image of craniofacial fracture in DICOM format is choose. Then, the pre-processing process is implemented starting with boundary extraction, corner point detection to create curve segments. Next,  $GC^2$  rational cubic Ball curve is reconstructed for each segment by using four free parameters. A Genetic algorithm is used to optimize these four free parameters. This reconstruction involved with the craniofacial fractured part for the inner and outer curve.

From the reconstruction of a curve, there are another study about the reconstruction of a surface proposed by Abdul Majeed, Abd Rahni Mt Piah dan Zainor RidzuanYahya,(2016). This paper reconstruct the 3D surface parietal bone fracture using 2D Computerized Tomography (CT) scan contours. The DICOM data of a real case for parietal bone fracture is contributed by Hospital University Sains Malaysia (HUSM). The procedure is extension from the reconstructed 2D curve by using geometric continuity for three parameters,  $GC^1$  rational cubic Ball proposed by Majid et al. (2015). Then the 2D CT scan data is converted to 3D format and the curves is reconstructing by taking the equidistant z component. Next, the 3D image of front and side part for the parietal bone fracture is reconstructed using proposed contour blending function. This proposed method is time saving and user friendly whereby the surgeon can design the implant geometry without cooperation from the technicians and external helper.

Moreover, there are another proposed method for the reconstruction of multiple bones fracture introduced by Abdul Majeed, Abd Rahni Mt Piah, Muhammad Rafique, Johari Yap Abdullah dan Zainul Ahmad Rajion,(2017). This study use Non- Uniform Rational B-Splines (NURBS) curve to reconstruct the inner and outer curve of fractured part and presented into DICOM format. Another objective in this study is to help the patient that has craniofacial fracture injuries by providing the custom-made implant. The process in this is started with a DICOM data as a sample for this study which is obtained from Hospital University Sains Malaysia (HUSM). Then, the boundary from the image is extracted and the corner points is identified by using method from Safraz et.al. (2006). Next, the knot values are estimated by using chord length parameterization and reconstruction of the NURBS curves is conducted. The

reconstructed curve is compared with the original image and the result is similar with the original image. The error for using this method is not calculated therefore the precision of this method cannot be measured. By using this proposed method, the average thickness can be obtained and it is easier in order to construct the custom made cranial implant for each patient who has the craniofacial fracture injuries.

Another study proposed by Nur Afifah Rusdi, Zainor RidzuanYahya, Nurshazneem Roslan and Wan Zuki Ahmad Wan Muhammad, (2018) is about the reconstruction of a skull by using artificial bee colony algorithm. The process involved in this study is started with conversion the image from Digital and Communications in Medicine (DICOM) images to binary image. This study use two different skull's image from two different patients. Then the process is continue with boundary extraction, corner point determination and parameterization. Next, the main process is to reconstruct the skull by using Artificial Bee Colony (ABC) algorithm. In order to verify the method of reconstruction, the error is determined by using Sum Square Error (SSE). This error is calculated to measure the difference between the reconstructed curve with the original image. The first sample of skull by one patient give the error 57.5754 and the second patient gives 28.8628. Therefore, this proposed method of Artificial Bee Colony (ABC) algorithm is suitable to reconstruct the medical image due to the lesser error presented.

## 5. Relevance to Government Policy (if any)

### (b) References

#### REFERENCES

- Majeed,A.,Mt Piah, A.R., R.U. Gobithasan,Yahya ,Z.R.(2015). Craniofacial reconstruction using rational cubic ball curves, PLoS One Journal, 1-14.
- Majeed A.,Mt Piah, A.R.,Yahya, Z.R.&Ahmad, M.Z.(2015). Reconstruction of craniofacial image using GC<sup>1</sup>cubic Ball Curves, India n Journal of Science and Technology, 8(32),1-7
- Majeed, A. & Mt Piah, A.R.(2016). GC<sup>2</sup> Rational Ball Curves with an Application to Craniofacial Image Reconstruction, Journal of Advances in Industrial and Applied Mathematics, 1-7
- Majeed ,A,Mt Piah A.R.,Yahya, Z.R.(2016). Surface Reconstruction from Parallel curves with application to Parietal Bone Fracture R econstruction, PLoS One Journal, 1-16.
- Majeed, A., Mt Piah, A.R, Rafique, M.,Abdullah, J.Y& Rajion, Z.A.( 2017). NURBS curves with the application of multiple bones fracture reconstruction, Journal of Applied Mathematics and Computation, 315(2017),70-84.
- Safraz, M., Asim M.R., Masood, A. (2006) A new approach in corner detection, Computer Vision and Graphics (Springer,2006) 528-533
- Rusdi N.R.,Yahya Z.R., Roslan N.& Muhammad W.Z.A. (2018). Reconstruction of Medical Images Using Artificial Bee Colony Algorithm, Journal of Hindawi Mathematical Problems in Engineering, 2018 1-7.
- Helmee N.A.,Yahya Z.R.,Hasan Z.A. (2013). Implementation of whale optimization algorithm for handwriting representation, AIP Conference Proceedings 2013,020007 1-6.<https://doi: 10.1063/1.5054206>
- Misro, M. Y., Ramli A., Ali J.M., Hamid N.N.A. (2017). Pythagorean Hodograph Trigonometric Bezier Transition Curve, Proceedings of 14th International Conference on Computer Graphics, Imaging and Visualization 2017,1-7.<https://doi: 10.1109/CGiV.2017.26>
- Mirjalili S. & Lewis. A. (2016). The Whale Optimization Algorithm, Journal of Advances in Engineering Software, 95(2016), 51-67.

### (c) Objective(s) of the Research

The main objectives involves in this study is to reconstruct the missing part of craniofacial by using quintic trigonometric Bezier curve. The sub-objectives are

- i. To extract the boundary from a real image of craniofacial fracture.
- ii. Determine the corner points of the image.
- iii. Reconstruct craniofacial missing parts by using quintic trigonometric Bezier curve.

### (d) Methodology:

#### 1. Description of Methodology

In order to reconstruct the craniofacial fracture, the first technique is pre-processing methods, boundary extraction and data extraction. From the boundary extraction it will be able to detect the data points. To get the most accurate data, it is important to choose the best algorithm in boundary determination and data extraction.

Next, the corner detection technique is used to find the corner points or important points at the craniofacial image. These corner points will be used for the next process, segmentation the fracture and findings the endpoints. Then, the control points for the curve fitting of craniofacial image is determined. In the last process, the error is determined.

#### BEZIER CURVE

#### QUINTIC TRIGONOMETRIC BEZIER CURVE

The quintic trigonometric Bezier curve is given by:

$$z(t)=P_0 f_0(t)+P_1 f_1(t)+P_2 f_2(t)+P_3 f_3(t)+P_4 f_4(t)+P_5 f_5(t) \quad (7.1)$$

where  $P_0, P_1, P_2, P_3, P_4$  and  $P_5$  are the control points and  $f_0(t), f_1(t), f_2(t), f_3(t), f_4(t)$  and  $f_5(t)$  are the quintic trigonometric basis function that is defined by:

$$f_0(t)=(1-\sin \pi t/2)^4 (1-p \sin \pi t/2)$$

$$f_1(t)=\sin \pi t/2 (1-\sin \pi t/2)^3 (4+p-p \sin \pi t/2 )$$
$$f_2(t)=(1-\sin \pi t/2)^2 (1-\cos \pi t/2 )(8 \sin \pi t/2+3 \cos \pi t/2 +9 )$$
$$f_3(t)=(1-\cos \pi t/2)^2 (1-\sin \pi t/2 )(8 \cos \pi t/2+3 \sin \pi t/2 +9 )$$
$$f_4(t)=\cos \pi t/2 (1-\cos \pi t/2)^3 (4+q-q \cos \pi t/2 )$$
$$f_5(t)=(1-\cos \pi t/2)^4 (1-q \cos \pi t/2 )$$

2. Flow Chart of Research Activities

['FLOWCHART TRIGOQUARTIC.pdf'](#)

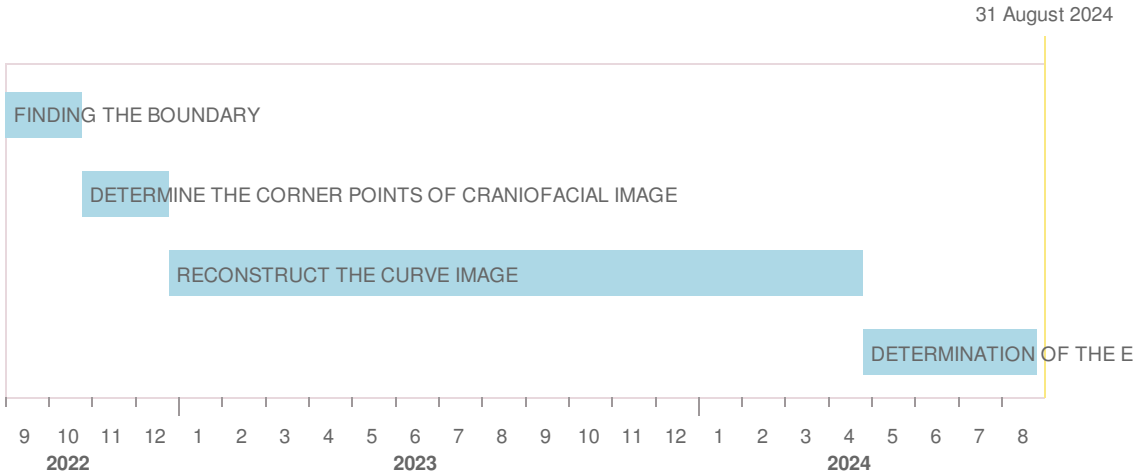
3. Research Activities

| Activity                                          | Start Date | End Date   |
|---------------------------------------------------|------------|------------|
| FINDING THE BOUNDARY                              | 01/09/2022 | 25/10/2022 |
| DETERMINE THE CORNER POINTS OF CRANIOFACIAL IMAGE | 25/10/2022 | 25/12/2022 |
| RECONSTRUCT THE CURVE IMAGE                       | 25/12/2022 | 25/04/2024 |
| DETERMINATION OF THE ERROR                        | 25/04/2024 | 25/08/2024 |

4. Milestones

| Description    | Date       | Cumulative Project Completion Percentage(%) |
|----------------|------------|---------------------------------------------|
| 31 August 2024 | 31/08/2024 | 100                                         |

Gantt Chart of Research Activities with Milestones



(e) Expected Results/Benefit

1. Novel theories/New findings/Knowledge
- A new method in reconstruction of missing part of craniofacial fracture to improve the reconstructed craniofacial curve to be more precise and less error determined.
2. Impact Statement on Quintuple Helix (please delineate/describe expected research deliverables on Society, Academia, Government, Industry and Environment)
- Craniofacial fracture is a damage of the facial structure in the skull. The principal causes due to this craniofacial trauma most commonly from the injuries of road accidents, gunshot wounds and sport-related injuries. This study is to design the craniofacial image which can be useful for the researcher in their study and treatment for facial injuries. The reconstruction of craniofacial is a basic procedure in the surgery process in order to solve the injuries regarding the craniofacial fracture.
3. Research Publications (Each proposal must produce at least two (2) papers in indexed journals, one of which should be in Web of

Science (WoS))

| Indexing Body         | Indexed Journal |                                                   |
|-----------------------|-----------------|---------------------------------------------------|
| Number of Publication | Name of Journal |                                                   |
| WoS                   | 1               | Malaysian Journal of Mathematical Sciences (MJMS) |
| SCOPUS                |                 |                                                   |
| ERA                   |                 |                                                   |
| MyCITE                | 1               | Menemui Matematik                                 |
|                       | Total 2         |                                                   |

4. Specific or Potential Applications of the Research Findings

This study will be useful for the researcher in their study and treatment for facial injuries. The reconstruction of craniofacial is a basic procedure in the surgery process in order to solve the injuries regarding the craniofacial fracture.

Total Number of Applications: 1

5. Number of PhD and Masters (by research) Students

Total Number of PhD (by research) Student(s):

Total Number of Masters (by research) Student(s):

1

Remark (if any):

6. Intellectual Properties (IPs)

Total Number of IP: 1

Access to Equipment & Material(s)

## E. Budget

| Budget Type                                        | Description | Year 1 | Year 2 | Grand Total     |  |
|----------------------------------------------------|-------------|--------|--------|-----------------|--|
| 11000 - Allowance                                  |             | 18000  | 18000  | 36000           |  |
| GRA Master (Max RM2,000.00/person for 2 years)     |             |        |        |                 |  |
| Sub-Total                                          |             | 18000  | 18000  | 36000           |  |
| GRA Ph.D (Max RM2,500.00/person for 3 years)       |             |        |        | 0               |  |
| Sub-Total                                          |             | 0      | 0      | 0               |  |
| Vot-Total                                          |             | 18000  | 18000  | 36000           |  |
| 21000 - Travelling and Transportation              |             | 2000   | 2000   | 4000            |  |
| Local                                              |             |        |        |                 |  |
| Sub-Total                                          |             | 2000   | 2000   | 4000            |  |
| Overseas                                           |             |        |        | 0               |  |
| Sub-Total                                          |             | 0      | 0      | 0               |  |
| Field work                                         |             |        |        | 0               |  |
| Sub-Total                                          |             | 0      | 0      | 0               |  |
| Vot-Total                                          |             | 2000   | 2000   | 4000            |  |
| 24000 - Rental                                     |             |        |        | 0               |  |
| Vot-Total                                          |             | 0      | 0      | 0               |  |
| 27000 - Research Materials and Supplies            |             | 13500  | 13500  | 27000           |  |
| Vot-Total                                          |             | 13500  | 13500  | 27000           |  |
| 28000 - Maintenance and Minor Repair Services      |             | 2000   | 2000   | 4000            |  |
| Vot-Total                                          |             | 2000   | 2000   | 4000            |  |
| 29000 - Professional Services                      |             | 2000   | 2000   | 4000            |  |
| Services/Consultancy                               |             |        |        |                 |  |
| Sub-Total                                          |             | 2000   | 2000   | 4000            |  |
| Short term course                                  |             |        |        | 0               |  |
| Sub-Total                                          |             | 0      | 0      | 0               |  |
| Journal Page Charges (WoS / SCOPUS / ERA / MyCITE) |             | 2000   | 2000   | 4000            |  |
| Sub-Total                                          |             | 2000   | 2000   | 4000            |  |
| Vot-Total                                          |             | 4000   | 4000   | 8000            |  |
| 35000 - Accessories and Equipment                  |             |        |        | 0               |  |
| Vot-Total                                          |             | 0      | 0      | 0               |  |
| Grand Total                                        |             | 39500  | 39500  | (100.00%) 79000 |  |

**F(i). Patent Search (describe how your research output shall produce an innovative idea or technology that has the potential to be a solution for stakeholders (community, industry, government etc.) and offers a unique proposition)**

*To identify if the researcher is able to coherently present a compelling argument for his/her proposal in light of the IP landscape and factors identified in the (Yes/No) Section. The answer would reflect an understanding of the applicant's research advantage and limitations and the prospect of moving the completed research beyond this stage of funding.*

**F(ii). Research Collaborator**

- ☐ Industrial Linkages (Please identify any industry or end-user group involved in the project, and describe its role/contribution to the project)
- ☐ Agency/Organisation (Please identify all agencies/organisations collaborating in the project, and describe their role/contribution to the project)

**F(iii). Risk Assessment (Please describe factors that may cause delays in, or prevent implementation of, the project as proposed above; estimate also the degree of risk)**

*Please consider an appropriate approach to working in the current conditions (pandemic, travel ban, social distancing etc.)*

the time consuming in collecting the type of data for craniofacial image and the budget in collecting the data and constructing the curve

| Risk         | Low                      | Medium                              | High                                |
|--------------|--------------------------|-------------------------------------|-------------------------------------|
| 1. Technical | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/>            |
| 2. Timing    | <input type="checkbox"/> | <input type="checkbox"/>            | <input checked="" type="checkbox"/> |
| 3. Budget    | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/>            |

## G. Declaration

- ☒ All details provided in this application are accurate. KPT has the right to reject or to cancel the offer without prior notice if there is any inaccurate information given.
- ☒ This proposal is not currently considered for any other research grant(s).
- ☒ The exact proposed work has not been funded through other research grant(s).
- ☐ Necessary approvals from relevant bodies (i.e.: Ethics Committee) are granted before related research activities commence.
- ☐ I have an on-going Fundamental Research Grant Scheme (FRGS) project.
- ☒ This proposed research is my original work, is not copied from my MSc. or Ph.D. thesis or any other work (published or unpublished), and has not been submitted for grant application either at KPT or elsewhere.

Name: Siti Sarah Binti Raseli

Signature:

Date: 27/01/2022

Approved By:

Signature:

RMC

Date:

| Appendix   |                                            |
|------------|--------------------------------------------|
| Flow Chart | <a href="#">FLOWCHART TRIGOQUARTIC.pdf</a> |
|            |                                            |