Drone 3D mapping in identifying Malay urban form: case study of Kota Bharu

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Abstract. Malay city was one of the oldest civilization in the world which contains unique identity of architecture, the urban design characteristic and the urban form of city planning. Kota Bharu was an example for one of the Malay city which contains the historical building which originally build from 1840 onwards that still exist in peninsular Malaysia. The location of the a few main and significant historical building scattered around the Istana Balai Besar Kelantan proved that, the area was one of the originally Malay city existed in Malaysia. This paper attempt to map an urban form and identify a historical building in Kota Bharu using Multirotor drone. Phantom 3 was used to carry out the aerial mapping and further proceed for 3D modelling at 500meter radius from the centre of study area Istana Balai Besar. the analysis of current pattern of the city, distribution of the land use and building height for the study area shows that the area still preserve the traditional Malay city element and shows the different in urban pattern between the Malay traditional city and area with the influence from the British government and planning for the area. This result proof that the use of drone in mapping and modelling helps in analyse for the urban form and building height for city area in collecting data especially for the aerial mapping. The integration between Urban Planning, GIS, and 3D are highlighted as the platform for the analysis tool and data storage.

Keyword: Drone, Built Environment, Urban Form, Building Heritage and Data Repository

1. Introduction

Rapid development taking place nowadays pushed the need for the suitable land for the new building construction, expansion and also affect towards the old building or unused building. Sometimes some of the old building carry a lot of traditional and unique in term of history, architecture value and heritage value which later reflected towards in terms of urban form aspect. Traditional Malay city for an example, there are a few Malay city but most of the city had loss their Traditional values and being replaced with the modern building and influence by the British administration system during colonial era. These Traditional Malay city have stories of events and folklore which translated into their physical evidences that still stood the test of time. The traditional Malay city also day still carry past memories that tell their own tales of the history they have seen. There are a few Traditional Malay city that influenced in term of the creating the identity of the Malay Kingdom and continues as the Malaysia country nowadays, such as Malacca, Alor Setar, Kota Bharu, Kuala Terengganu, Kuala Kangsar and a few more establish city. Evidence of town planning in the Malay Peninsula started in Melaka in the 15th century. During this century, Melaka was a thriving port of international trade. Early settlements during those days were along land, riverine and coastal routes [1]. The reflection of the town planning from the traditional Malay city can be visualised by some evidence include buildings and architecture, monuments, old sites, roads, plots and landscapes. Still nowadays some of
the monuments, traditional Malay building such as palaces, aristocrat houses, communal houses and urban form can be seen at a few cities such as, Malacca, Kota Bharu, Alor Setar, Kuala Kangsar and also Terengganu. Although being pressured by the rapid development, these places still achieve to preserve and conserved most of the traditional building that represent the traditional Malay city, but for how long these traditional treasure can absorb the pressure of development are bit challenging. Such cities are currently undergoing tremendous changes due to rapid industrialization, economic development and urbanisation. A myriad of development activities taking place across the country do not leave these towns untouched. Modern structures such as skyscrapers encroached into the town centres and Malay historic sites. This situation raises questions on the level of development planning and development control that being used as measured to control the development at the area with much building and heritage value. Various type of analysis and experimental research being done in order to produce guidelines, framework and laws especially related with the development planning covered various field of construction from sewerage systems to a complete city planning, either physical nor social planning.

Geographic Information System (GIS) was one of the tool in development planning where the use of GIS vastly spread around in not just in geomatics fields, but become one of an important family members in urban planning field. Basically GIS analysis deal with 2D visualisation where represent the spatial land use data, flood prone area, buffer analysis and a few more development planning related fields. Can’t be denied that GIS help a lot in decision making process for the development planning, but the vast evolution of the technology has created more software that using 3D as the analysis tools. More specific, the 3D GIS technology has become one of the new technology that being explore by the researchers as one of the analysis tools for planning development. Modeling city objects in 3D environments can improve the capabilities of GIS. The traditional 2D GIS does not support applications that require the data of object height or elevation, such as indoor ventilation modeling or indoor navigation [2]. Relates with Malay city, there are a lot of information and data that still hidden which can reflect towards the urban form of the Traditional Malay city. Although there are some research has been done in analyzing the Malay city urban form, but the usage of the 3D GIS method still not well explored and the advantages and benefit of using this technology evolvement can produced more details and deep of analysis and findings. Therefore this study focused on the use of the drone technology in collecting data for bigger area of a city and to construct a 3D GIS model from the data collected [3][4]. Study also focused on the use of the 3D GIS model in analyzing and determined the height and urban form of the study area and identify the traditional Malay building still existed within the study area.

The study area located in the east peninsular of Malaysia between 6° 8' 23.5392" N and 102° 14' 31.9308" E in the Kelantan state. The town of Kota Bahru in Kelantan grew around a new palace, Istana Balai Besar, which was built by Sultan Muhammad II in 1845 on the east bank of the Kelantan River, a few kilometres from its mouth. Significant of the selecting the area was due to Kota Bharu’s unique history, and also, Kelantan as one of the state that free from the British colonization until 1900. Kota Bharu, significantly means as “New Fort” which resembles the establishment new city during 1845. Traditional Malay city make the fort boundaries to resemble their main city boundaries which contains the administrative centre for the city. Istana Balai Besar which the symbol of proud for Kelantanese was one of the early palace of Sultan Kelantan during 18th century, Sultan Muhammad II built the Istana Balai Besar as a new palace and as the administrative center in Kota Bharu. From that point, the Kota Bharu city being planned by the local planner and architect during that time and growth as one establish cities until British came to Kelantan during 19th century. And until todays, the heritage building from the Traditional Malays era still exist and not much different from the original. Figure 1 shows the study area of Kota Bharu which represent the area Istana Balai Besar as the nodes and extent to 500 radius surround it.
2. Materials and Methods
Data collection are based on primary and secondary data sources. For the primary data sources includes the existing land use maps, historical data of the formation of Kelantan state, and old maps and pictures for the study area range from year 1840 till 1920. While for the secondary sources includes the aerial mapping data using drone, and picture for the traditional building. Both primary and secondary data has been compiled to and overlaying for the construction of the 3D GIS model for the study area. Three-dimensional urban models also play an important role in the entertainment industry, in particular the film and gaming industries. The processes of creating the 3D models vary from domain to domain, ranging from completely manual content creation to semi-automatic techniques making use of computer-vision or photogrammetry and of generative modelling techniques [5].

The study methodology divided into two part which the first part is to construct the 3D GIS model of the study area and analysed the data from the 3D GIS model in term of building height, urban form of the city and also how the 3D GIS model can be further analyse. Second part of the paper is examine the urban form of the city in terms of the land use arrangements, land use element that reflects to the Traditional Malay City studies. In this paper, the usage of drone was introduced for the data collection in order to construct the 3D GIS model of Kota Bharu. The drone will captured the aerial images of the study area where the important data such as GPS data and Z axis data also being captured during the flight. Captured data will be further processed using some software in order to get the better 3D model and can be used for further analysis.

2.1 Materials
There are two main type of material use in the study which are the data source and technological setting material such as equipment use for the data collection and also the software for the data processing and analysis. For the data needed, there are two main category of data which are preliminary data and 3D GIS model data. Figure 2 shows the relationship between the materials in the study.

![Figure 2. Material relationship](image-url)
2.1.1 Equipment
While for the technological setting, the main equipment use for the study was the Drone Dji Phantom 3. This drone model came with the GPS coordinate system and automatic, semi-automatic and manual setting for the flight operation and data captured. The drone selected already able to captured aerial mapping data with the X,Y and Z axis data where very important for constructing the 3D GIS model. Figure 3 shows the drone use for the aerial mapping data collection.

![Figure 3. Dji Phantom 3](image)

2.1.2 Software
Besides using technological setting for capturing data, same goes to the data processing where the demand for software for aerial images data increasing day by day. There are a few famous and popular software for the drone data processing such as, Agisoft, Pix4d, Acute 3D and the latest one was one of Autodesk product Autodesk Recap. These software produce the 3D models based from the images captured using drone. For the research, Agisoft software used as the processing medium due to the licensing issues the software covers many tools for data analysis. From Agisoft software, although the 3D GIS model not very sharp, but the advantages of it was, the software manage to convert the pictures into the point clouds.

2.2 Methods
In summary, there are three stages of methodology in this paper, first part is the data collection stages, second part is data processing stages and the last part is the output and the discussion.

2.2.1 Data Collection
Data collection part can be divided into 3 phase which are, before data collection phase, during data collection and after data collection phase. All of this three phase required different technique and data preparation used. For determination of the site selection, content analysis technique was used, where the historical data and the boundary area involved being studied and justify. The main focus building was Istana Balai Besar which located at Kota Bharu and 500 Meter radius from the palace has been determine as the area contains the historical building and places. Based on the historical data, the, base map had been produced by using spatial data by using MapInfo and aerial image data by using google earth to view and cross check between the aerial view and spatial land use data. Figure 4 shows the base map from MapInfo software which represent Istana Balai Besar as main nodes and 500 meter radius covers the area for the data captured.
There are a few methods that can be used in flying the drone to make sure the Z axis data captured either in rectangular flightpath or circular path. The intention of the paper is to create a 3D model for the whole study area so the rectangular shape of flight path was selected. Flying in a rectangular motion with horizontal and vertical path makes the drones able to make sure there are no spots of data capturing missing and in order the Z axis data is captured. Z axis data important so that the 3D model can be constructed from the data captured. Circular path usually used to cover for a single building 3D models where more details on the facade can be translated using the circular path, but for the 500 radius of city it will consume much time compared to rectangular flight path. To get the accurate data, Pix4d software was used as tool to control the drone where the altitude, percentages of overlapping and flight path was set up. This software will operate the drones automatically. Altitude of drone fly being set to 150 Meter to avoid tall buildings and only a portion of area altitude set to 200 meters due to avoid signal lost due to the telecommunication tower area. The overlapping percentages also set to 80 percent in order to make sure wide area of area being captured and most accurate data taken. Figure 5 shows the area covered by drone in a rectangular path where the drone covered more than 500 meters radius in order to get the most accurate data.

793 images being captured using the drone and every image captured contained coordinate data and Z axis data, altitude and others EXIF data. This type of information is a must for construction of 3D GIS model, where Z axis data represent the height value and coordinate or GPS data to locate the 3D model based on projection WGS 84 (EPSG::4326). Every image captured represent of 80 percent of overlapping between the pictures so that, there are no data or images within 500 m radius left over. The overlapping very important to get as much of data for accurate and clear 3D GIS model.
2.2.2 Data Processing
Four main stages that need to run through in Agisoft software which are, i) Aligned images, ii) Build Dense Cloud, iii) Build Mesh and iv) Build Texture. All of these stages represent different process required and different data output, and what important is, all types of data can be use as much as possible for the analysis stages either within same software or different. For the aligned images the main purpose is to combine all the aerial images captured to produce the aerial mapping for the study area. Aerial mapping, 147,854,582 points was created while convert the images into points clouds. From the points cloud, further analysis can be done by using ArcGIS software such as height analysis and also elevation analysis or constructing the Digital Elevation Modelling for the area.

3. Finding and Analysis
From the data processing which discussed in methodology part, resulted two main preliminary findings which are the aerial map and the dense point cloud data. Both data blend in together for constructing the final and complete 3D GIS model of the study area. Figure 6 shows the complete 3D GIS models as resulted from the data captured using drone for the study area. All of these findings from the drone processing were used as the source for the analysis part of the study.

The analysis part can be divide into two categories, which the first analysis will deal with the 3D GIS model analysis in term of the city building height, details of the 3d model produced and also the measurement of the 3D model, where the second part of analysis deals with the urban form and design of the Malay City itself. There are two method doing the analysis involved the 3d model output and point cloud data.

![Figure 6. 3D GIS Model of Kota Bharu](image)

Using the 3D GIS models as shows in Figure 6, the analysis related with measurement, area calculation and height of building being measured. Figure 7 shows the height measurement of a building which represent in the 3D GIS model. This value can be cross checked with others software such as ArcGIS or Autodesk software. Two point of the building height was measured which covers from the ground floor up to the roof edge. Both of points represent by marking A to A’ recorded height value as 50.98 Meters and B to B’ recorded as 14.06 Meters. Both of the selection buildings shows different height measured in order to compare the building height and to cross check with the ArcGIS.
Besides, based on the dense point cloud data the average height for the whole study area can be analyse. The dense point cloud data being exported to .LAS type and by using the ArcGIS software, the building height can be analysed based on points and colour range for the whole study area. Figure 8 shows the elevation represent by point and colours in ArcGIS software, where points A’ record that area represent by 51.98 m to 64.04 m while point B’ represent elevation value range from 15.79 m to 27.85 m. Both of the result tally with the value from the height measure in 3D modelling software as shows in Figure 7.

The second part of the data analysis discuss about the urban form element of the study area analysed from drone data such as the aerial images captured, 3D GIS model and density point cloud from processing stage. For this part of analysis, the overlay technique used as main method of analysis where primary and secondary data overlay together to came out with the urban form principle of the Malay city. The 3D GIS data, picture, spatial land use data and also old maps among the
important data that need to overlay together to analyse the urban form principle of Kota Bharu. There are 4 main urban form principle that studied in the paper which are street pattern, building, land use and allocation of open spaces. From the 3D drone data, the existing spatial land use data as get from the local authority can be updated according to the existing building use that captured from the drone. Figure 9 shows the data overlay process to analyse on the urban form aspect.

![Image](image_url)

**Figure 9.** Overlaying technique

4. Result and Discussion

Based on the data processing and data analysis, the result on the research can be divide into two category which are, result for the drone data analysis and for the Malay urban form analysis. Data analysis shows that, the height of the building and the area can be determined from the drone. The height data one of the important element that should be concern in every planning development especially for the new planning that will incorporate into the existing development. This was important in order to make sure the skyline view and most important is, the development of the new building did not affect the surrounding building. For the example, the Kota Bharu area which contains most of historical and unique heritage building need some preservation for the whole area development in order to maintain and preserve the historical and the characteristic of the area as one of the Traditional Malay City site in the past. Figure 10 shows the grid represent 20 meter height from the ground of the study area. From the result, the future development involved high rise building can be simulated in the existing area to analyse the impact of the development.

![Image](image_url)

**Figure 10.** Gridlines for height of 20 meters from ground

For the urban form element, there are 4 main element that being analyse for the study area and to related to the Traditional Malay City which are, street, land use, open space and building. Building more directly can be analysed from the 3D GIS model on the height, façade and structure form, while for the land use, open spaces allocation and street pattern being analysed from the overlaying technique. Figure 11 shows the distance analysis result that show the connectivity of the street, main
land use building and open spaces related to the Traditional Malay City where, the location of the building and land use from 1945 till 1910 still intact at the site and still preserved until today. Based on the result, the formation of Palace integrated with the location of mosque which the distance between the palace and the mosque only 100 meters and from palace to nearest communal area only 200 meter where shows how the integration and blend in between the palace and the communal during the traditional Malay city era. Besides, the allocation of the open spaces near to the palace also shows the important of the open spaces or urban space for the city that already being applied 100 years ago in Kota Bharu.

![Figure 11. Distance and land use connectivity analysis](image1)

Study also analyse the urban pattern for overall study area where there are two different pattern regarding to locational the land use and building where the area existed since 1845 the urban form more towards organic pattern while for the area develop after the British influences are planned based on grid pattern. Besides, the façade and design between both of this area also shows the different architecture and design between Malay Traditional design and British design. Figure 12 shows the different between the land use and building pattern of two different area in the study area. Point A represent communal settlement area where there are still Traditional Malay architecture design such as roof were preserve and the arrangement of the building arrangement are in organic pattern which differ with point B area which being planned based on grid pattern, and the façade and building design not much preserve or using the traditional Malay design but more toward Islamic and modern design where the roof pattern varies within flat roof and dome roof pattern. Area represent point A was the area exist since 1840s while area B starts to developed after British influences in Kelantan governance after years 1910.

![Figure 12. Facade and design difference](image2)
5. Conclusion and Future Outlook

The process of collection and data analysis, using the aerial images data captured by drone can provide the Z axis data, lead to constructing the 3D GIS model and further analysis. As the result the analysis using ArcGIS can provide for the length measurement, DEM analysis and also profile view of the area. Besides, there are also some limitation on the use of the drone technology where, the 2D model not very sharp due to the missing point of data during the data captured, drone can’t capture the water bodies Z axis data because of the water flow and movement and the compatibility of the software that can produce point cloud data. For future outlook and research that can be done by others research from using the drone is to study on parameters that will help in capturing water elements using drone, investigation on how point cloud formats from drone analysis can be beneficial for other uses and the technique to get clear and sharp 3D model by using drone as tool for data captured. To conclude, the drone technology can assist more in development planning, capturing data and even for the decision making process for the planning permission by authority. Besides, from the 3D model also can be analyse on the pattern and the city skyline where the study area are contain with most of the historical building and heritage that should be preserved.

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