

Geospatial Information System Based on Indoor Plan UKM (FKAB)

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ABSTRACT

In recent years, the academic field has seen tremendous leaps in mapping and navigation technology. Features such as accuracy, functionality, time efficiency and ease of access in mobile mapping applications have poured into the market, which has led to the near extinction of conventional paper maps. Big players such as Google Maps, MapBox, Bing Maps, OpenStreetMap and many others are enabling Geospatial Information Systems (GIS) to be accessed with ease. However, the problem arises as GIS is more tailored towards outdoor mapping and navigation information through the implementation and utilization of Global Positioning System (GPS) coordinates. The main objective of this study was to enable GIS incooperated together with georeferenced image containing global positioning coordinates (GPS) making it feasible and compatible for the purpose of positioning and navigation focusing in an indoor environment. In this research, we present a method for utilising GIS for indoor localisation focusing on using Quantum GIS (QGIS) as the open source Geospatial Data Abstraction Library (GDAL), and the rendering of raster maps by locating ground control points (GCP). As a case study, the method was implemented on the 2nd Floor, East Wing of the Faculty of Engineering and Built Environment (FKAB) of Universiti Kebangsaan Malaysia (UKM), as the indoor space of interest. The significant findings of this paper contribute to the possibility of using GPS coordinates in an indoor environment for accurate positioning. Consequently, the proposed method has the potential to perform as an easily implementable localisation technique in Simultaneous Localisation and Mapping (SLAM) applications for mobile robots.

Keywords: QGIS; GDAL; Indoor Map; GCP; SLAM; GPS

INTRODUCTION

Precise localisation in an indoor environment is a challenging problem. Various techniques have been proposed for indoor SLAM purposes. Most of these incorporate a combination of several technologies, make use of a number of sensors and/or signal transmitting beacons and requires complex computing algorithms. These techniques have been discussed by several researchers, for example one may refer to the works of Du (2018) and Karnik and Streit (2016), and the references therein.

One example of SLAM can be linked to GPS where the system is significant outdoors but practically rendered useless in indoors (Lashkari et al. 2019) due to signal attenuation causing scattering coordinates inside buildings. There is usually less margin for error in indoor environments. In most cases, errors of the order of a few metres are not significant in outdoor SLAM applications, but could mean being in a completely different room, or could result in hitting a wall or some other objects in indoor SLAM applications.

On the other hand, as discussed by Naidu (2018), GIS was fundamentally created as a framework for catching, putting away, questioning, dissecting and showing the earth's geologic referenced information related to geospatial. GIS innovation conquers any hindrance between various parts and goes about as a coordinated cross sector stage to gather, oversee, aggregate, investigate and picture geospatial, transient data for maintainable urban arranging, improvement and administration.

Nonetheless, the problem arises as SLAM and GIS are more towards outdoor geospatial mapping and navigation through the implementation and utilization of Global Positioning System (GPS) coordinates as the main donor for coordinate reference point. The problem to solve is how to obtain GPS coordinates based in an indoor environment in which GPS as we know, does not function well in indoor environments. This paper discusses the use of GDAL and georeference image as a way to enable GPS coordinates to be compatible in an indoor environment

In this work also, we propose using the novelty technique of integrating indoor map with GIS data, overlaid

in real time over an aerial map, for indoor positioning with an aim of future integration into SLAM systems. This is very crucial, as it potentially provides a much simpler method compared to many other indoor SLAM techniques. GIS differs from other methods in that it requires a collection of tilesets consisting of raster tiles or vector tiles which are broken into a uniform grid of square tiles (Tsou, 2018).

In this paper, we focus on the mapping of an indoor environment with the implementation of GIS and a raster image in a tagged image format file (TIFF). The image, as shown in Figure 1, which is a scanned floor plan of the 2nd Floor, East Wing of the Faculty of Engineering and Built Environment (FKAB) of Universiti Kebangsaan Malaysia (UKM), is used as the area of space of research. Ground control points are set to correlate coordinates between the scanned TIFF image and real world map data.

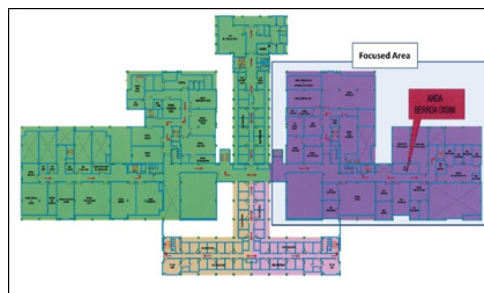


FIGURE 1. Scanned image of indoor FKAB second floor plan in TIFF format

With the integration of computer model mapping system, QGIS GDAL with the Bing Aerial Map which is used to overlay and synchronize the information data of the scanned map raster image in QGIS. A detailed and elaborate explanation of the methodology is presented further along in this paper, discussing the raster image and GCP with QGIS GDAL.

This paper is organized as follows. The problem of indoor localisation will be discussed in the next section. This is followed by a brief section describing GIS, followed by a section discussing the coordinate reference systems used in Malaysia. The next section describes the proposed indoor SLAM method, then the final section concludes this paper.

QUANTUM GEOSPATIAL INFORMATION SYSTEM (QGIS)

GIS is an extensive and multiplex subject that could take years to master. Some researchers have dedicated their research careers in studying this field. In this section, an overview of GIS, along with QGIS is explained.

GIS has the ability to process spatial data in vast volumes. This ability can also be applied to indoor spatial data in such a way that would bring a new perspective in conveying the data for indoor mapping and navigation intentions. When talking about GIS, GDAL libraries, such as Mapbox, contain data which are mainly divided into two main types of data storage: datasets and tilesets. These two types of data storage formats are created for custom data

and are compatible with GDAL mapping. Points, lines, and polygons are geometric features that datasets can provide in the GDAL dataset editor.

QGIS, which is an open source GDAL, is used as it offers the advantage of being able to run on several platforms including Windows, Linux, iPhone Operating System (iOS) and Android. When compared to other open source GDALs, for example ArcGIS, the ability of QGIS to support multiple formats such as Keyhole Markup Language (KML), ESRI's shapefiles (SHP), AutoCAD DXF, GeoTIFF/TIFF and JPEG to be imported into the GIS spatial data format gives it the advantage (Fernández-Caramés et al. 2016).

The QGIS GDAL consists of tileset data, which can be divided into two subtypes of lightweight data storage; vector and raster. Figure 2 (from Steiniger et al. 2013) shows an overview of the GIS formats of dataset and tileset.

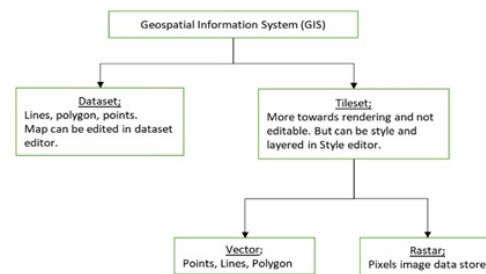


FIGURE 2. GIS overview

A tileset for a raster image is a pixelated square of constant grid, which when applied, has the ability to zoom-in up to 22 levels in depth. In the case of this research, the raster format is chosen over its vector counterpart. Each square of the pixelated area of cells in a TIFF scanned image has its own value. Tilesets are not editable GIS data, but can be styled and layered for optimized rendering of the scanned image in the style editor of GDAL.

Tilesets are highly cacheable, and are capable of loading quickly. GDAL relies heavily on both raster and vector tilesets to keep maps fast and efficient.

COORDINATE REFERENCE SYSTEM OF MALAYSIA

Coordinate reference systems (CRS) of the world can be divided into two types; geographic coordinate systems (GCS) and projected coordinated systems (PCS) (UTM, 2016). The GCS uses latitude and longitude data to define a certain location on a sphere or spheroid surface. It implies a 3D ellipse as a reference to pinpoint a location on a spherical (non-projected) map. Two most common examples of 3D ellipses for GCS are the WGS84 and the GRS80.

PCS implies a map projection which transforms locations from earth coordinates to Cartesian planar coordinates. When a location on the earth is to be mapped and projected, PCS is used as it does not consider the earth as a sphere or spheroid. Figure 3 (from JUPEM, 2009) shows a comparative overview of GCS and PCS.

A spatial reference system (SRS) consists of datums which make up the components of a coordinate reference

system (CRS) to become whole and complete. Examples are Azimuthal Equidistant, Oblique Mercator, Universal Transverse Mercator and Cassini. In Figure 3, GDM2000 (2009) / Selangor Grid applies the Cassini projection system with the GRS80 3D ellipsoid which permits the display of projected maps onto a 2D surface.

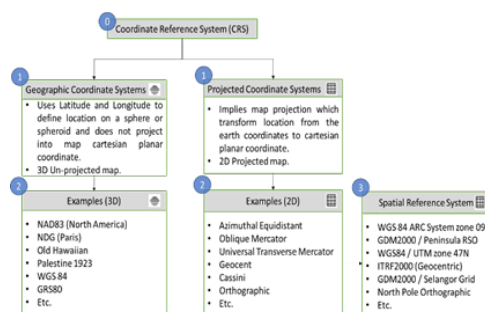


FIGURE 3. CRS overview

In Malaysia, researchers in recent years have endeavoured in the task of extracting real world data and projecting them into GDAL (Mustapha 2010; Wahab 2010 & Yusoff 2014) in order to strip off conventional models in earth mapping techniques. This new technique is a satellite-based technique established on the foundations of international mathematical models to ensure more accurate CRS selections.

Before GPS was implemented, peninsular Malaysia relied on the Malayan Revised Triangulation 1968 (MRT68) CRS and Kertau as the geodetic datum reference point. Whereas for Sabah and Sarawak, the CRS was the Borneo Triangulation 1968 (BT68), in which datum Timbalai was set as its foundation. With the presence of Global Navigation Satellite System (GNSS) and GPS, changes were made in the selection of geodetic datum, so as to be able to rapidly obtain more accurate coordinates. These differences in CRS, between GNSS, GPS and conventional coordinate systems, tended to happen due to unstandardized selections of geodetic datum for Malaysia, which resulted in the non-synchronization of coordinates.

Thus, in 2003 (later revised in 2009 due to several occurrences of earthquakes around Indonesia) the Department of Survey and Mapping Malaysia (DSMM) established and launched the Geocentric Datum of Malaysia (GDM2000) for the standardization of coordinate mapping and surveying in the country. Kadir et al. (2015) states that the new GDM2000 was built based on the GPS space geodetic technology, referencing on the International Terrestrial Reference Frame (ITRF2000) and the Geodetic Reference System 1980 (GRS80), which is the ellipsoid for the new Cassini Soldner coordinates.

The chronology of CRS development for Malaysia is shown in Figure 4.

GDM2000 incorporates and enhances the use of GPS technology in which public and private sectors gain benefit in terms of cadastral mappings and topography geographic information as the accuracy is estimated to be around

3.5mm to 4.5mm (horizontal and vertical). Selecting the right CRS is crucial for the image of the map to be processed without distortion, and for obtaining accurate coordinates. Distortion may occur in terms of shape, distance, direction and scale. The CRS selection must be compatible with the spatial reference system identifier (SRID) authorized by the European Petroleum Survey Group (EPSG), as one of the approved coordinate references. Without this validity, GDAL will not display the correct map for the selected coordinates.

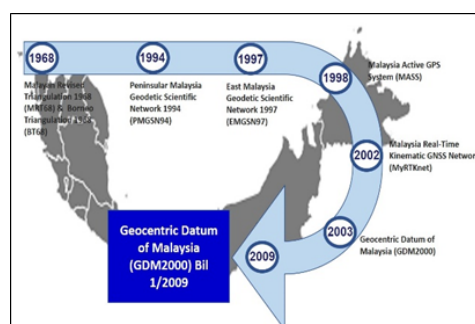


FIGURE 4. Chronology of CRS for Malaysia

In this research, selecting GDM2000 (2009) / Selangor Grid as the CRS was the best option when compared to other Malaysian CRS points, as the area of research focuses only on the FKAB 2nd Floor, East Wing, and that the target focus area is small. The map projection was the geocentric Cassini coordinate system (New Cassini) which is equirectangular, transverse and semi-geometric with the authentication number SRID EPSG:3380. FKAB, UKM is an area located in the state of Selangor, in Malaysia. The ability to minimize image distortion when overlaying on a Bing Aerial Map for an area in Selangor stands as the reason why the GDM 2000 (2009) / Selangor Grid CRS was chosen.



FIGURE 5. CRS GDM2000 / Selangor Grid

When talking about cadastral mappings and topography geographic information specifically in Malaysia, Cassini Soldner and RSO have been the map projection system of choice for years, and they still are. Apart from the difference in the respective developers (Cassini Soldner by Richardus & Adler and RSO by Hotine), there is also a difference in how the map is projected. The Cassini Soldner map is projected equirectangular and the RSO map projection is conformal and cylindrical.

Besides that, for Cassini Soldner, the map projection is based on cadastral mapping properties, whereas the RSO map projection is based on topography mapping properties. In this research, the Cassini Soldner projection with cadastral mapping properties was deemed the most suitable due to

the fact that cadastral map properties consist of mainly land boundary, geometry and ownership information. The new Cassini Soldner Geocentric is based on latitude and longitude whereas the old Cassini was based on easting and northing coordinates. For cadastral surveyor, geodetic coordinates of a point determined in GDM2000 (on the GRS80 ellipsoid) using GPS can now be projected directly to their related geocentric Cassini plane coordinate values without having to first convert to the MRT and RSO systems (Kadir et al. 2015).

A similar feature shared by both Cassini Soldner and RSO is in the usage of polynomial functions in which the functions utilise coordinates located in every state of Peninsular Malaysia for map projection.

METHODOLOGY

In order to achieve indoor mapping and navigation in the FKAB building, QGIS was selected as the GDAL due to its featured base framework and that it uses raster data storage as spatial database. When using raster, the scanned image quality is a priority. High quality scanned images in the TIFF format would enable the overlay to align properly with real map data.

Before getting started with georeferencing, in the layer section, a Bing Aerial Map is inserted from the XYZ Tiles browser as shown in Figure 6. Bing Aerial map was chosen over Google Satellite due to the clear and crisp quality of the satellite map images provided.

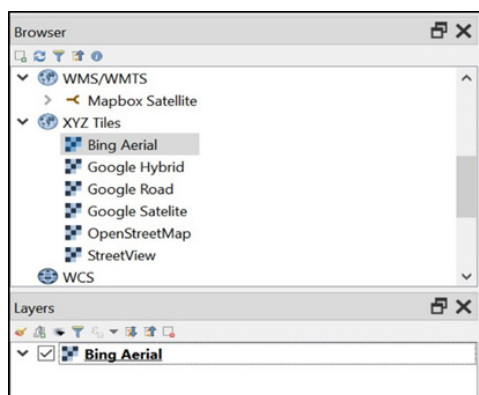


FIGURE 6. Bing Aerial Selection

The Georeference GDAL Plugin for QGIS must be installed in advance for the purpose of georeferencing raster images. This is for the purpose of determining GCP points and placing them on the map and scanned image. QGIS 3.2 and earlier versions do not come with a standard Georeferenced GDAL.

On the QGIS menu bar select Raster and click on Georeferencer. This will enable the Georeferencer GDAL window. This window will have two sections in which one will be for the raster image (in this case the FKAB 2nd floor, East Wing plan image) and the second, is for the GCP points.

Opening the TIFF scanned image is the next step by selecting File and then clicking on the Open Raster menu. Before coordinate points can be placed and determined, selecting the right raster CRS is worthy of attention. Specifying the projection and datum of the control points is key in producing an aligned and smooth navigation map. As explained in the sub topic above, GDM2000 / Selangor Grid was chosen as the CRS. Note that the CRS must be set for both the Bing Aerial map and the TIFF scanned image. Hence, as per Figure 7, CRS GDM2000 / Selangor Grid with EPSG:3380 is selected.

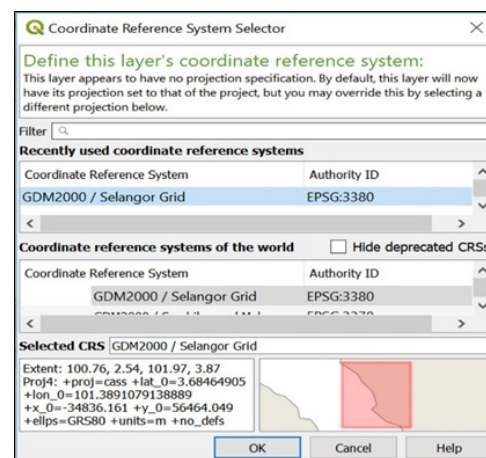


FIGURE 7. CRS Selection

In some cases, scanned images of maps or floor plans provide latitude and longitude information on the image. Hence, CRS and GCP information for georeferencing purposes can be obtained on the map itself. In this research, the scanned floor plan of the FKAB East Wing had no latitude/longitude or any coordinate information given. Thus alternatively, coordinate information was gained by inserting coordinates of certain points and selecting corresponding points on the map canvas in QGIS. The map canvas is in map units using CRS GDM2000 / Selangor Grid EPSG:3380 which is represented in metres. Figure 8 illustrates the CRS component selection flow for a projected map.

Next, select Add Points on the toolbar menu in the Georeferencer. Then, the red dot GCP is allocated by selecting the first point on the raster image of the Georeferencer. As seen in Figure 9, the first point (ID: 0) selected is on the lower left-hand side. Then a pop-up menu will appear which requires entering the map coordinates. In this research, the FKAB 2nd floor East Wing building plan has no pre-defined coordinates on the image itself as it is a scanned image and not an actual map image. Thus, using the coordinates on the map canvas is required. This is done by clicking on the pencil icon on the pop-menu which is then followed by selecting the required location on the canvas map corresponding with the points on the raster image. To get better positioning, it is required to zoom in on the map canvas and raster image to avoid any inaccuracy.

This step is repeated sequentially for points number 2 (ID: 1) to number 14 (ID: 13) which marks every corner of

the FKAB 2nd floor East Wing such that every point contains a GCP. The 14 points were selected from the floor plan raster image based on a consideration of obtaining a clear georeferenced image. All points must not be located too close to each other, and the selected point in the scanned floor plan image must lie exactly on the corresponding point selected in the Bing Aerial Map.

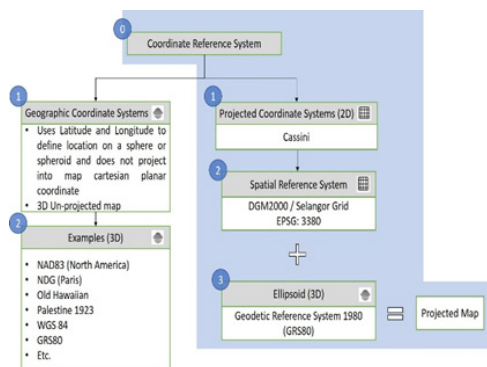


FIGURE 8. CRS flow Selection

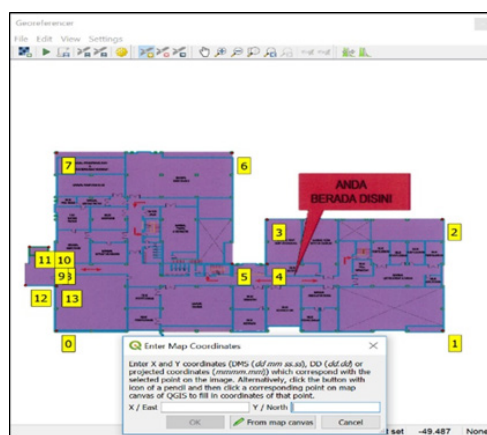


FIGURE 9. 14 points were selected for the floor plan

Transformation setting must be done in order to allocate an algorithm to render the image on to the Bing Aerial map. There are 5 common transformations associated with QGIS which are Linear, Helmert, Polynomial (1st, 2nd & 3rd), Thin Plate Spline and Projective.

For this research, the transformation type is set to Polynomial 2 which means that the transformation algorithm chosen is second order polynomial, which allows for the curvature of an image when rendering. The minimum number of GCP points required for second order polynomial transformation is 6 points to give a clear rendering, without distortion. It is important to obtain the correct polynomial function.

The next setting is to select the resampling method. The resampling method is a process of aligning the correct pixel of the scanned image on to the Bing Aerial Map which will result in an image overlay on the map. The nearest neighbour resampling method, which uses the technique of output pixel transferring to the nearest input pixel, is selected. Figure 10 shows the transformation setting selection window. After all

settings have been selected, georeferencing may begin by clicking on the georeferencer start button in the tool bar.

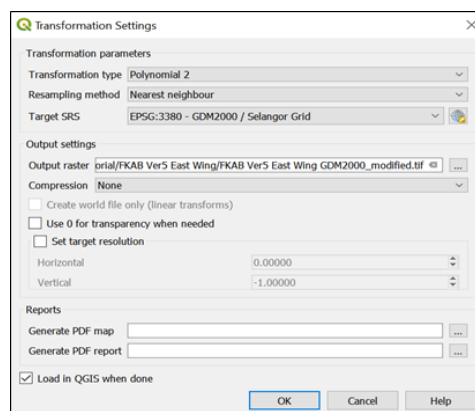


FIGURE 10. Transformation setting

A successfully georeferenced image will appear as in Figure 11. All 14 points of the scanned floor plan image are aligned with and overlaid on the actual Bing Aerial map. It is highly recommended to save the GCP points in the file menu tab for future reference and for any third-party use. This will enable constantly precise point location and navigation, without the need of re-mapping the 14 GCPs, and avoid dissimilarities in future works.



FIGURE 11. Succeeded georeferenced image

A GCP table will be generated containing the 14 ID points as shown in Table 1. The table also shows the coordinates of each point in easting and northing (X and Y) pixel units. The residual errors for X and Y pixels are generated to show the accuracy of point locations in the scanned image floor plan with respect to the Bing Aerial Map.

Adding grids on the map is required for mapping coordination and navigation. There are two common methods for adding a grid onto a QGIS canvas. The first method is by clicking on Create Grid on the search tab which will enable a parameter table to appear as shown in Figure 12. The preferred grid type must be chosen for the first parameter. The grid extent must be selected based on the area of focus on the canvas. Horizontal and vertical spacing was set to 5 x 5 metres apart, which gives a 5 metre radius inside every square box. For the purpose of indoor navigation, a 5 metre radius length is sufficient for locating particular points. Then, press run to enable the grid on the map.

TABLE 1. GCP table

ID	Enabled	Pixel X	Pixel Y	Map X	Map Y	Res X (pixels)	Res Y (pixels)	Res Total (pixels)
0								
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								

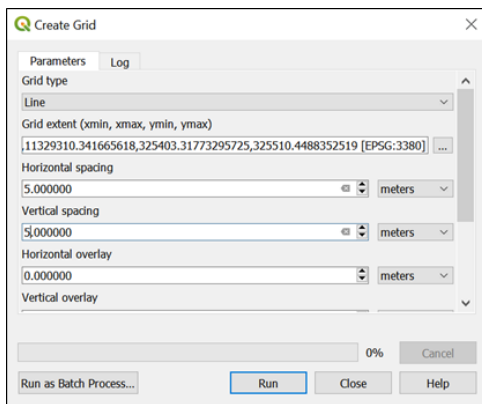


FIGURE 12. Grid parameter table

The distance is measured using the Measure Line tool located in the top area of the toolbar. It measures a start point to the required goal point in metres. The measuring tool is used to ensure the right distance in length from one point to the other. As shown in Figure 13 as an example, the distance of the hallway from one end to the other is 21.298 metres.

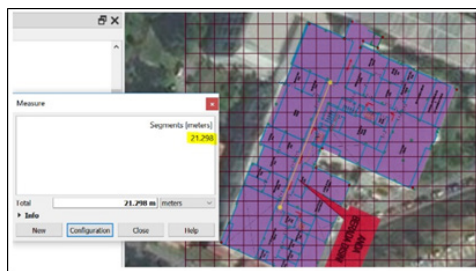


FIGURE 13. Distance measured using grid

The second method for adding a grid is by clicking on the Project Menu tab and selecting New Print Layout. Selecting this will permit a print layout window to come into view. Next is to add and save the map onto the canvas layout by renaming it to FKAB East Wing. The Item Properties tab on the left as shown in Figure 14 contains the Grid Property menu to select the required parameters for the grid.

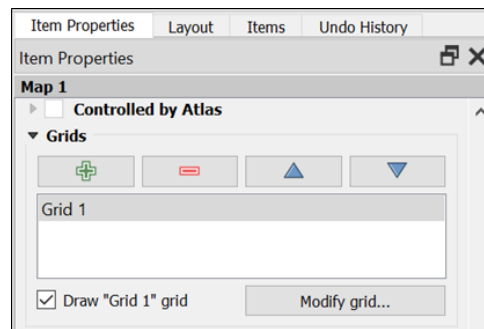


FIGURE 14. Item properties menu containing grid setting.

The X and Y grid interval was set to 5 metres by 5 metres. This was to ensure that every grid specifically occupies a space in accordance with the focus area, hence enabling more accurate navigation within 5x5 metres in every area. Furthermore, the CRS grid was set to the EPSG:3380 GDM 2000 / Selangor grid and the coordinates for X (bottom) and Y (left hand side) are in the northing and easting decimal formats. Figure 15 shows the FKAB 2nd Floor East Wing with grid marks, with X for easting and Y for northing.

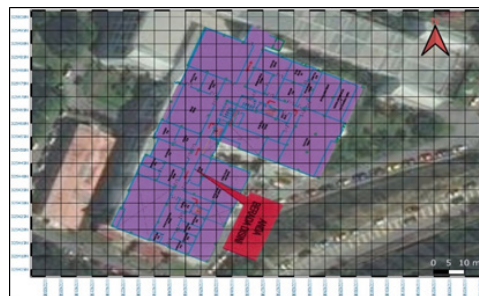


FIGURE 15. Item properties menu containing grid setting.

In this research easting and northing are chosen over latitude and longitude as it fits better when dealing with land navigation. That being said, latitude and longitude are best suited for air and marine navigation, especially when navigating long distances. Easting and northing are based

on the Universal Transverse Mercator (UTM) coordinate system, and the numbering is in metric units i.e. metres. The system has only one way of writing the coordinate which eases the plotting and identification of coordinates in a map. As shown in Figure 15, by default in QGIS, the northing value starts from 325,405N and ends at 325,500N, whereas the easting value in the canvas layout starts from 11,329,200E and ends at 11,329,340E. Thus, as an example, the way to read the coordinate values shown in Figure 16 is as elaborated below.

	1000 km	100 km	Metres	
Easting:	11	329	200	E
Northing:		325	405	N

FIGURE 16. Reading northing and easting coordinates

The first three digits on the right-hand side are in metres. The three digits in the middle are in 100 kilometres which amounts to 100,000 metres. And the last two digits (for easting only) is in 1000 kilometres which equals to 1,000,000 metres. Hence, the easting value 11,329,200E has a precision of 200 metres and the northing value 325,405N precision is 5 metres.

The coordinate of the active focus area starts from 11329221E to 11329303E (for easting) and 325406N to 325496N (for northing), as can be seen in Figure 17.

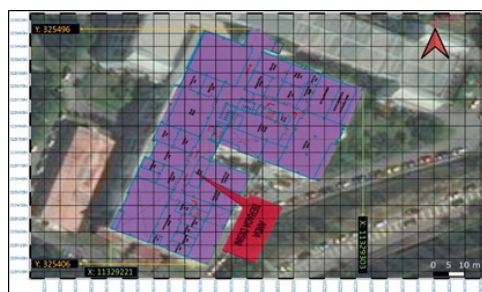


FIGURE 17. Northing and easting coordinates

RESULTS AND DISCUSSION

ROOT MEAN SQUARE ERROR

A GCP table as shown in Table 2 was generated after the raster image had been successfully georeferenced. The resultant GCP table comprises of nine columns. The first column contains ID information, where the red dot GCPs are placed. The second column is the enable column, which is set to Yes if GCP is used for the transformation and equals to the value of 1, and vice versa, equals to 0 if GCP is disabled or not in use. The third and fourth columns respectively, give the pixel X and Y values, which are the source X and Y coordinates. The fifth and sixth columns

are the X and Y map columns which are the destination X and Y coordinates. The last three columns are residual error columns which respectively, represent the residual errors for the pixel X column, the pixel Y column, and the total residual error.

Root mean square error (RMSE), on the other hand, is the distance measured between two datasets or tilesets, and gives the standard deviation value for residual error. The lower the residual error, the lower the RMSE produced, and hence, the more accurately the raster image aligns with the canvas map. RMSE varies according to the type of transformation chosen. Choosing the correct type of transformation leads to higher quality georeferenced raster image alignment, and hence lower RMSE.

As mentioned previously, the transformation type used was second order polynomial, and although it resulted in some residual error, the rendered raster image produced after georeferencing was not distorted. Selecting the right transformation type is essential to enable proper transformation for raster image rendering on the map. Aside from selecting the right CRS, poor and inappropriate selection of transformation type could lead to algorithm mismatch, which will contribute to image distortion as illustrated in Figure 18.

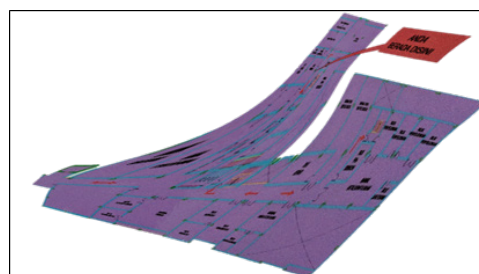


FIGURE 18. Sample of image distortion

It is recommended that the number of GCPs allocated be increased, which increases the chances of obtaining the perfect georeferenced raster image. This would be indicated by decreased RMSE values due to the errors of each pixel being minimised, resulting from the implementation of the best algorithms initiated by the second order polynomial function.

In this research, there is no absolute RMSE value taken as a standard referral due to the RMSE being dependent on the quality of the scanned image. However, for the purpose of this research, obtaining a RMSE value between 0 to 5 gives sufficient accuracy as the grid interval is set to 5 metres by 5 metres. The RMSE indicates the accuracy of the raster image being georeferenced and how it is aligned in overlaying on the canvas map (Bing Aerial). In short, it depends on the quality of the given data to be georeferenced.

In this work, the FKAB 2nd floor East Wing building plan has a rather large file size of 3.37MB in TIFF format, which is considered to be of high quality. Although the value of the RMSE obtained on the Georeferencer is 13.03, acquiring a much lower value is feasible with further corrections

TABLE 2. GCP Table generated after georeferencing

ID	Enabled	Pixel X	Pixel Y	Map X	Map Y	Res X (pixels)	Res Y (pixels)	Res Total (pixels)
0	Yes	144	-1085	11329251.712	325495.495	2.27714	-6.7402	7.11447
1	Yes	1918	-1084	11329221.405	325421.522	-0.530261	6.4621	6.48382
2	Yes	1916	-437	11329252.398	325407.940	0.304755	-5.35634	5.365
3	Yes	1111	-438	11329265.508	325440.798	12.1363	1.87098	12.2797
4	Yes	1111	-696	11329254.064	325446.824	-8.47206	-12.4262	15.0395
5	Yes	951	-696	11329256.153	325453.305	1.89883	-2.70648	3.30614
6	Yes	950	-52	11329287.296	325404.041	-6.82876	12.5462	14.2842
7	Yes	144	-51	11329302.508	325473.284	3.99575	-10.716	11.4367
8	Yes	144	-694	11329269.298	325487.470	10.2856	11.1628	15.179
9	Yes	111	-692	11329270.266	325489.757	-10.0197	11.5792	15.3125
10	Yes	108	-598	11329275.332	325487.405	-4.27581	0.191384	4.28009
11	Yes	20	-597	11329277.001	325491.062	-1.86022	-1.68856	2.5123
12	Yes	1	-821	11329266.491	325496.308	2.88935	-3.55685	4.58252
13	Yes	143	-824	11329263.838	325490.506	-1.80099	-0.622033	1.90538

and adjustments of the GCP. In terms of accuracy, the georeferenced image overlaid on the Bing aerial map is fairly inaccurate. As can be seen in Table 2, the residual errors of the 14 GCPs are significantly large ranging from 15.3125 to 1.90538. Table 2 also shows that ID numbers 4, 8 and 9 have the largest residual errors of 15.

Apart from the generated RMSE value, there are two other basic methods in determining whether or not the raster image is accurately and correctly aligned. The first method is by simply checking the raster image layer whether it fits the referenced map on the canvas. As can be seen in Figure 19, the raster image easily fits onto the Bing Aerial map.



FIGURE 19. Raster image overlays on Bing Aerial map

To see whether the red dot GCPs are aligned or not, zoom in must be initiated on the Georeferencer window. Without zooming in, the naked eye would not be able to capture the required accuracy. The location accuracy of the red dot GCPs can clearly be seen when zooming in is applied as shown in Figure 20. Zooming and planning where points should be placed is crucial to minimise error.

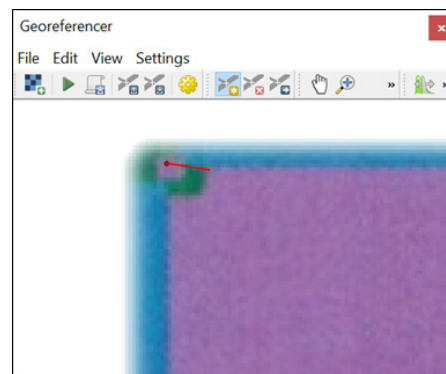


FIGURE 20. Red dot GCP misaligned

The second method is by analysing the detailed report consisting of the georeferenced raster image for the red dot GCP misalignment. The report is generated in the configure Georeferencer menu tab. As can be seen in Figure 21, the georeferenced image of the floor plan shows where the GCP points are placed and the red displacement arrows show where the points should actually be placed. Further corrections and adjustments are needed following the generated report.

Adjustment of GCP points is done by using the Move GCP Point tool on the menu tab and then adjusting the point to the tail end of the red arrow. Zoom in on the raster image on the Georeferencer and then, at the exact same point, click on the red dot. Following the arrow generated on the raster image, estimate the position to be chosen and carefully select the corresponding point on the canvas map. This is a try and error process requiring several attempts as it is quite difficult to acquire accurate location of the correct GCP on the first try. The option to delete is also available for the GCPs by using either the Delete Point tool or simply by right-clicking on the point and then selecting remove.

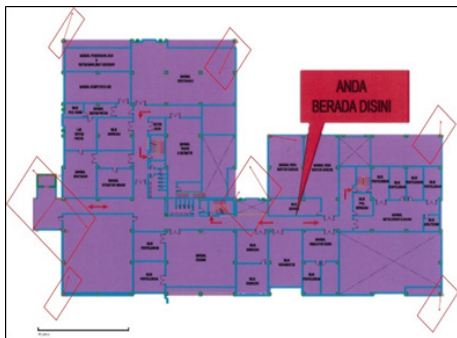


FIGURE 21. GCP point placed and the red displacement arrow

INDOOR COORDINATE NAVIGATION

The focus area of the indoor floor plan is located at the east wing FKAB 2nd Floor, UKM. With the grid implemented on the canvas where the georeferenced raster image is overlaid on the Bing Aerial map, indoor navigation is feasible. Coordinate information, available in metres for

every distance of the provided grid space enables indoor accuracy within a 5 metre range. An accuracy of 5 metre range is sufficient as the focus indoor area is not too big and the subject of navigation i.e. AGV, mobile robots, humans etc. could navigate and be located within the range provided without losing track.

As an example, referring to Figure 22, the position labelled “Anda Berada Disini” (Point A) is at X: 11329247E and Y: 325443N which is located near the entrance of the CAD/CAM laboratory on the 2nd floor of Jabatan Kejuruteraan Mekanikal dan Pembuatan (JKMP). Then, if the subject is moved to an area located at the entrance door of Makmal Struktur Ringan (Point B), the new coordinates of the subject will be at X: 11329272E, Y: 325476N. Hence, locating coordinates for future references and finding the way to desired goal points is much easier and accessible by coordinate referencing.

In cases where only coordinates are given to find a subject in an area of space, it is recommended to first identify the coordinates of the whole focus area, and then

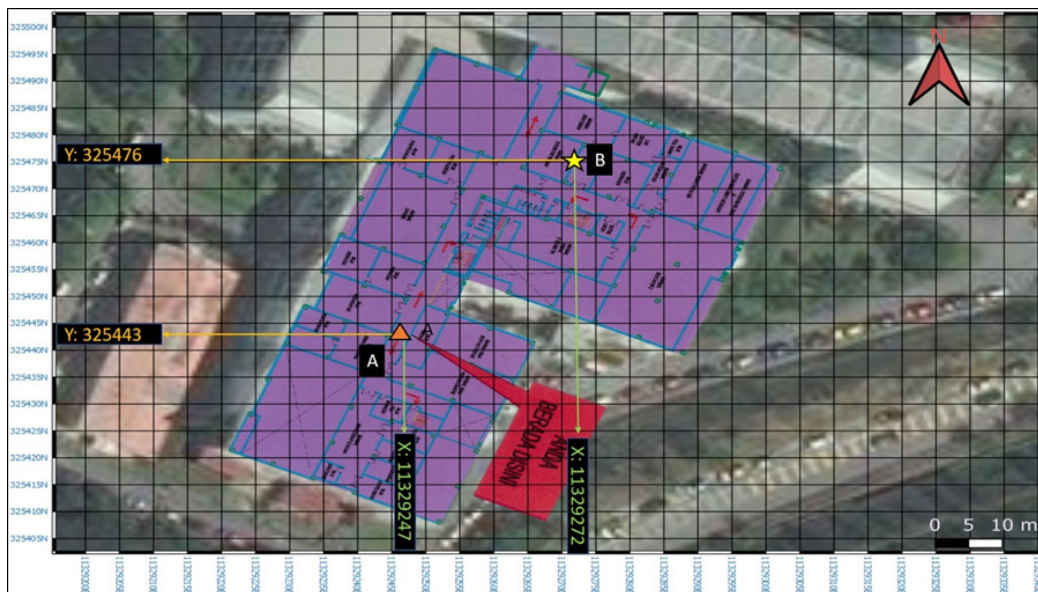


FIGURE 22. Coordinate of interest points labeled A and B

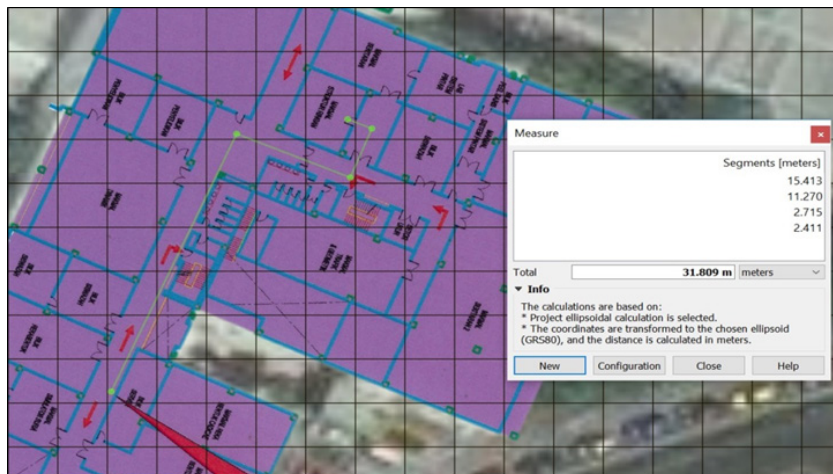


FIGURE 23. Distance measured from Point A to Point B

narrowing it down to ascertain the coordinates of the subject location.

Measuring the distance of a subject moving on a path from point A to point B can be done using the QGIS Measure Line tool located in the menu tool bar. As shown in Figure 23, the distance from Point A to Point B is 31.809 m. The distance covered contains four measurements which are 15.413 m covering the distance in the hallway, 11.270 m and 2.715 m covering the distance entering the first and second doorways. Lastly, 2.411 m is the distance of the last segment, after entering the second doorway to Point B. This measuring tool is based on the GSR80 ellipsoid, and the distance is in metres.

These techniques and methods are simple but indispensable for research work in the near future as the GIS GDAL is available as smart phone applications which makes it handy and portable for mapping and navigation, especially in an indoor environment. Thus, from this work, the map canvas containing the indoor floor plan with the Bing Aerial map can be used in smart phone applications as a navigation guide tool to locate and move a subject from one point to another in the indoor building of the FKAB 2nd floor East Wing.

It can be analysed that by using the proposed method, indoor positioning and navigation is feasible as required in the objective but if only certain criteria of the GDAL are met. Contributing criteria such as right selection of CRS, type of transformation selection, RMSE and the right georeferenced raster image used. These factors are the crucial points that made the objective to be met in the manuscript.

CONCLUSION

Indoor spaces are becoming more complex these days due to modern building designs. Interior designers, architects and construction companies can capitalise on this by collecting data of indoor spaces, which can then be analysed for better planning of public areas such as in shopping complexes.

A new method for indoor localisation has been presented. By overlaying the building floor plan of interest on a satellite image map, and using GIS, the location of an agent within the building can be pin pointed. The method can potentially be used, as examples, in smart factories with AGVs as agents, for bomb disposal using mobile robots in an evacuated building or in search and rescue missions by mobile robots in a building on fire.

This research will contribute to the development of a new algorithm for indoor mapping and path planning. Generally, the integration of GIS raster images into QGIS GDAL will enhance the ability to reliably navigate in indoor environments, by ensuring accurate positioning and precise path following.

The use of raster images in GIS format is proposed as a map layout to be aligned together with real time Bing Aerial maps. Most methods that involve GIS are for outdoor environment use and only a few researchers have studied GIS integration with indoor raster images as a way of

navigation and mapping. The reason might be due to doubts on the capability and possibility of QGIS GDAL to obtain data for indoor positioning and path navigation sufficiently accurately.

Accurate positioning and navigation requires large raster data and the selection of an appropriate CRS. Without these two main factors, distortion can occur and will affect accuracy. An understanding of map projections and transformation types, especially in Malaysia, is crucial when using GIS as there are hundreds of map projections available, and the Malaysian system itself contains several. That being said, Malaysia is moving forward in standardising to a modern geocentric datum and focusing only on one which is the GDM2000.

A limitation of this research is the accuracy of the indoor environment is limited to metres, and detailing it into centimetres or millimetres would require a different approach. There would be some error which could be improved by using more control points, changing transformation types and using different datums for different places.

Future work will be to make the method compatible with smart phone applications. Hence, when a third party is using the indoor building raster image of the FKAB 2nd floor East Wing, exchanging data containing the required position and navigation path would be feasible. The system would also be integrated with vision systems to provide real-time mapping capability, which would enable the identification and location of dynamic obstacles that could impede the agent's trajectory.

DECLARATION OF COMPETING INTEREST

None.

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