Towards augmented topographic map: Integration of digital photograph captured from MAV and UAV platform

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Background

- Department of Survey and Mapping Malaysia, in short JUPEM, sole national government mapping; 4800 personnel, Annual Budget US80 millions
- Map Update Policy at 3, 5 and 10 years interval for Topographic maps scale of 1:50,000 and 1:10,000
- Map updating focussed areas in developed, urban and rural part; especially on man-made entities and infrastructure
- Updating tasks using MAV photography are tedious, timely and costly
- Cloudy weather whole year and wasted images captured
- Integrate new UAV orthophoto with existing orthophoto in the digital topographic database
- Practical as UAV can fly under the cloud and the cost is cheaper
Background

• UAV orthophotos are used in this research to investigate issues of map updating.

• UAV technology can be appropriately used to update existing orthophoto images previously generated from MAV platform. UAV images could be stitched with previously MAV captured orthophoto to produce newly updated orthophoto which can be used to digitize fresh features of a large scale map.

• Integrate new orthophoto with existing orthophoto in the digital topographic database to yield single orthophoto output. The process was implemented by cut and append, and cautiously assemble parts of the orthophoto to form images.

• This new updated orthophoto is then should be usable to form a background image to update topographic map, thus without having need to fly repeatedly using conventional aircraft.
Study area at Kampung Laya-Laya, Tuaran, Sabah, Malaysia

Orthophotos taken using MAV Feb 2014 (left) and via UAV system in Sept 2016 (right)
Dataset of the vector map sheet of the study area produced through digital mapping.
Equipment

• Digital aerial camera Vexcel UltraCam Eagle 80 with flying height of 5000 feet above means level with 60% front overlap and 50% side overlap. Ground Sample Distance (GSD) for the mission was set to 10cm. Rectified Skew Orthomorphic (RSO) East Malaysia was applied as the coordinates system and GDM2000 Malaysia was used as the reference datum.

• UAV orthophoto, a series of aerial photography were taken on 21 September 2016 along a stretch of area 2km x 2 km using a UAV eBEE RTK model, employing compact camera Sony Cybershot DSC-WX 220 RGB 18.2 MP. GSD was set at 8.3cm with flying height of 600 feet with 80% front overlap and 60% side overlap.
Flow chart of the photograph aerial acquisition and geospatial data updating process.

Rectified Skew Orthomorphic (RSO) East Malaysia coordinates system and GDM2000 Malaysia as datum

3 colour bands of blue, green and red

Aerial Photographs

Existing Orthophoto

Overlay (Cut and Append)

Mosaic Orthophoto

Overlay with Existing Dataset

Updating and Digitisation

New Updated Map

Seamless mosaic interface

Conversion of 4 bands to 3 bands

Transformation of Coordinate System

Coordinate system of UTM Zone 50N and WGS84 as datum.

4 colour bands, i.e. blue, green, red, near infrared

similar colour bands in order to obtain a single raster image; eliminate the fourth band, near-infrared

RSO East Malaysia with GDM2000 Malaysia as the reference datum.
Digitization; New features identified were digitized as new spatial objects that would be used to update map sheets

<table>
<thead>
<tr>
<th>EXISTING ORTHOPHOTO</th>
<th>MOSAICKED ORTHOPHOTO</th>
<th>DETAILS DIGITIZED</th>
</tr>
</thead>
</table>
| ![Existing Orthophoto](image1.jpg) | ![Mosaicked Orthophoto](image2.jpg) | 1. Lake area amended and updated  
2. Swamp area amended and updated  
3. Mangrove forest amended and updated  
4. Cleared land amended and updated  
5. Scrub/Shrub (bushes) amended and updated  
6. New residential buildings added  
7. Substation & Switching Station added  
8. Fence Line inserted  
9. Irrigation Canal added  
10. Culvert added  
11. Road Line added  
12. Road Edge line added  
13. Road Surface polygon added  
14. Footpath (Recreational) added |
Analysis of images accuracy captured by MAV and UAV as compared to observed true coordinates using GNSS. Standard deviation of the differences between the two images coordinate are acceptable in the mapping accuracy of features to be plotted at large scale of 1: 10,000. The planimetric displacement allowable for smaller than 1: 20,000 scale map is 1/30 inches (0.85mm), within JUPEM’s Procedure of Survey for Map Accuracy. RMSE has shown high value (1.416) when comparing coordinates of UAV versus MAV image.

<table>
<thead>
<tr>
<th>Station No.</th>
<th>Coordinates of Orthophoto MAV</th>
<th>Observed Coordinates</th>
<th>Coordinates of Orthophoto UAV</th>
<th>Difference of Coordinates between Observed and Orthophoto MAV</th>
<th>Difference of Coordinates between Observed and Orthophoto UAV</th>
<th>Difference of Coordinates between Orthophoto MAV and Orthophoto UAV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>North East</td>
<td>North East</td>
<td>North East</td>
<td>North East Magnitude</td>
<td>North East Magnitude</td>
<td>North East Magnitude</td>
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<tr>
<td>TK01</td>
<td>681745.129</td>
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<td>682485.754</td>
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<td>TK05</td>
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<td>682578.076</td>
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<td>TK13</td>
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<td>682304.152</td>
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<td>0.110</td>
<td>0.526</td>
</tr>
</tbody>
</table>

**Average**
- Value Maximum: 0.000
- Value Minimum: -0.842
- Std Deviation: 0.316
- RMSE: 0.671
- % Precision: 100%

**Value Range**
- Maximum: 0.842
- Minimum: -0.842
- STD Deviation: 0.316
- RMSE: 0.671
- % Precision: 100%
Results

• Deployed UAV has successfully captured imageries which in turn used to generate orthophoto over the test area. The result using Pix4UAV software showed that the UAV orthophoto production conformed the accuracy requirement for town or large scale map updating or production.

• UAV orthophoto was subsequently integrated with existing MAV orthophoto previously produced from normal aircraft aerial mapping.

• Integration by means of mosaicking of both orthophotos was carried out very well and a new mosaicked orthophoto has provided source of data that is accurate and fitting for map updating.

• Quick result for a large scale map of 1:5000 around apparent area of changes and physical development be mapped.

• Fly low below the cloud is rewarding comparing to conventional aerial mapping by normal aircraft.

• Future plan; Vertical take-off type of UAV system with higher capability and carry a bigger payload of a medium format metric camera and longer flight duration and higher resolution image capture.
# UAV vs MAV in Aerial Mapping

<table>
<thead>
<tr>
<th>No.</th>
<th>Element</th>
<th>Manned Aircraft</th>
<th>eBee RTK UAV</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.</td>
<td>Area</td>
<td>1. Cost effective for large mapping area bad for small area 2. Cost per km² is high 3. Processing cost per km² is Cheaper</td>
<td>1. Cost effective for small area and bad for large area 2. Cost per km² is cheaper 3. Processing cost per km² is slightly higher</td>
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<tr>
<td>4.</td>
<td>Application</td>
<td>For mapping small scale base map (scale up to 1:50,000)</td>
<td>1. Updating large scale map 2. Boundary reconnaissance 3. Natural disaster monitoring</td>
</tr>
</tbody>
</table>