Data Processing of LAPAN-A3 Thermal Imager

R Hartono, P R Hakim and AH Syafrudin

1) Satellite Technology Centre, National Institute of Aeronautics and Space (LAPAN), Bogor 16310, Indonesia
* rommyhartono@ymail.com

Abstract. As an experimental microsatellite, LAPAN-A3/IPB satellite has an experimental thermal imager, which is called as micro-bolometer, to observe earth surface temperature for horizon observation. The imager data is transmitted from satellite to ground station by S-band video analog signal transmission, and then processed by ground station to become sequence of 8-bit enhanced and contrasted images. Data processing of LAPAN-A3/IPB thermal imager is more difficult than visual digital camera, especially for mosaic and classification purpose. This research aims to describe simple mosaic and classification process of LAPAN-A3/IPB thermal imager based on several videos data produced by the imager. The results show that stitching using Adobe Photoshop produces excellent result but can only process small area, while manual approach using ImageJ software can produce a good result but need a lot of works and time consuming. The mosaic process using image cross-correlation by Matlab offers alternative solution, which can process significantly bigger area in significantly shorter time processing. However, the quality produced is not as good as mosaic images of the other two methods. The simple classifying process that has been done shows that the thermal image can classify three distinct objects, i.e.: clouds, sea, and land surface. However, the algorithm fail to classify any other object which might be caused by distortions in the images. All of these results can be used as reference for development of thermal imager in LAPAN-A4 satellite.

1. Introduction
LAPAN-A3/IPB is a 3rd microsatellite developed by LAPAN. The assembly, integration, and testing of LAPAN-A3/IPB is done completely by satellite technology center of LAPAN. LAPAN-A3 micro-satellite was launched by Indian PSVL as piggy back on 22th of June 2016. LAPAN-A3 satellite project aims to support the national food sustainability program. Therefore the payloads requirement are defined by the Bogor Agricultural Institute (IPB). IPB in an academic institution that is specialized in agricultural science and technology, which is used as national academic reference for the Indonesian food sustainability program. Based on such cooperation, the satellite is also named as LAPAN-IPB satellite. The main payload of the satellite is a 4-bands multispectral imaging line-imager (using 4 Kodak 8023 sensor with spectral filter on 450-520 nm, 520-600 nm, 630-690 nm, and 760-900 nm) with 1000 Mm Nikon Lens, to produce spatial resolution of 18 m, swath width of 110 km. The satellite also carry digital camera similar to LAPAN-A2, so that it may provide image with 3.5 m resolution. Another payload is a low resolution video camera, with has CCD video camera with effective picture element of 752 x 582. 100 mm lens is mounted on the camera so that it can produce image with 35 km swath. The last payload of satellite LAPAN A3 is thermal imager which is called micro-bolometer, which the hardware is provided by FLIR, and has resolution of 640x512 with 60mm lens and swath width of 92 KM.
Payload of micro-bolometer/thermal imager has specifications of spectral bands 8-12 μm, operating voltage range 4-6 Vdc, temperature range between -40°C until +80°C, and video output using PAL standard video format. Micro bolometer actually has 14 bits image data, but actually the data that goes from satellite to ground station is only 8 bits (0-255), which the data processing from 14 bits to 8 bits is done automatically in the camera. For the processing of transmitting data camera micro bolometer from satellite to ground station uses S-band transmission system. The system uses the frequency of 2200 Mhz and FM video modulation, the transmission has 5 W output, and uses helical antenna. Meanwhile, ground station which receives video data from LAPAN-A3/IPB satellite uses antenna orbital with 3.0m diameter antenna, computer for controller antenna, FM analog video receiver and PAL Video record or display, and an additional computer to convert analog video into digital image. Figure 1-1 shows micro-bolometer camera on payload block of LAPAN-A3/IPB satellite, where micro-bolometer is place on the top of digital camera with additional brackets to disprove.

![Payload block and micro-bolometer camera of LAPAN-A3 satellite](image)

Figure1-1. Payload block and micro-bolometer camera of LAPAN-A3 satellite

Processing of video data into an image takes several steps. First, video data of thermal imager will be downloaded at highest elevation in Rancabungur-Bogor ground station, most of downloading video data is at elevation of 45° degree or more. Next process is, person who was in charge at acquisition of satellite LAPAN A3/IPB data will prepare everything such as update of TLE antenna orbital, controlling antenna software, turn on video receiver, DVD player and anything else, so that video thermal imager is ready to be recorded at the ground station. After that, next process is image acquisition, where the data video is converted to image sequence, blended, stitched into a mosaic image, and the final classify the image.

This research aims to describe a simple mosaicing and classifying process of LAPAN-A3/IPB thermal imager based on several videos that have been produced by the imager. Three mosaicing methods are used in this research, i.e.: manual approach using ImageJ software, auto stitching method provided by Adobe Photoshop, and also image cross-correlation method developed by using Matlab software. The performance of these three approaches will be compared in terms of image quality produced, time processing needed as well as flexibility of the methods. For classification purpose, simple algorithm is used based on digital number of the image, i.e.: lower digital number means lower temperature and vice versa. This research uses video data captured from LAPAN-A3/IPB thermal imager. Most of observation area is restricted to neighborhood of West Java for real-time acquisitions, while other Indonesia region can also be observed using recorded acquisition mode.
2. Methodology
The goal of this research is to mosaic images of LAPAN-A3/IPB thermal imager and then to classify the objects in the images. First step that is done is pre-processing video data received into a sequence of grayscale images. This is done using Avidemux by determining the wanted image frame rate from original video data of 28 frames per second. Second step is to mosaic the resulted image sequences into single mosaiced image. For illustration, usually thermal imager of LAPAN-A3/IPB satellite will observe the target area for averaged two minutes, which means that there will be more than 500 images in case of 4 frames per second is used, that needs to be mosaiced. There are three methods that will be used for this mosaicing process, i.e.: manual approach using ImageJ software, stitching method provided by Adobe Photoshop and also image cross-correlation method developed in Matlab software. These three methods are run independently, thus the result can be compared each other to determine which method is most suit to be used on actual LAPAN-A3/IPB thermal imager data processing. Third step in this research is to reference the mosaiced image using referenced map, and then classify the image produced into few distinct object such as cloud, sea and land surface. This done by using simple classification based on image digital-number and edge detection. The overall research flowchart and methodology can be seen in Figure 2-1.

![Figure 2-1. General research methodology used in this research](image)

Figure 2-2 shows flowchart of image cross-correlation procedure used for mosaicing process which is developed by using Matlab software. The algorithm consists of four stages, which are image edge detection\(^5,6\), image cross-correlation\(^7,8\), image resampling and image blending process\(^9,10\). All of these processes are pretty simple in nature thus the whole algorithm can be executed in reasonable processing time.

![Figure 2-2. Flowchart of image cross-correlation method for image mosaicing](image)

3. Results and Discussion
This section discusses the result of this research which describes data processing of LAPAN-A3/IPB thermal imager, which consists of video-to-image data conversion by using Avidemux software, image mosaicing by using three different approaches, as well as objects classification of the mosaiced image.

3.1. Video-to-Image Conversion using Avidemux
Avi-Demux is an open source software used for video and image editing, as converter from video to an image. The video of micro-bolometer that have been downloaded by S-band antenna then recorded by video recorder, and the resulting recorded video are opened by Avi-demux software. After that the video will be cut into pieces every four frame per second, so that if the thermal imager video have been recorded about 4 minutes then the resulting image is about 960 images. The next process is to organize the image into a whole image or image stitching process.

3.2. Image Mosaicing (Stitching) 
Three different methods will be compared, which are manual approach by using ImageJ software, image auto stitching method by using Adobe Photoshop software and image cross-correlation method developed in Matlab software. Each method has its own advantages and disadvantages which will be
compared in terms of mosaiced image quality, size of image area that can be processed and time processing needed by each method.

### 3.2.1. Manual Approach using ImageJ software

ImageJ is a public domain, Java-based image processing program developed at the National Institutes of Health. ImageJ also has a Java plugin and custom recordable macros. Custom acquisition, analysis and processing of plugins can be developed using the built-in ImageJ editor and Java compiler. User-written plugins allow to solve many image processing and analysis problems, from cell imaging to three-dimensional images for radiological image processing, to a comparison of multi-imaging systems. ImageJ plugin architecture and built-in development environment have made it a popular platform for teaching image processing. Example of manually mosaiced LAPAN-A3/IPB thermal imager images using ImageJ software by determining several pairs of GCP of two consecutive images in image sequence. Major results image geometry and radiometry produced is good but it needs long processing time. Figure 3-1 below shows some manual image processing done by using ImageJ software.

![Figure 3-1. Image mosaic using ImageJ](image1)

### 3.2.2. Image Stitching using Adobe Photoshop

Image stitching using Adobe Photoshop to combine more than 500 images into a single complete image is very easy and simple. The step is to select automate, then photomerge with auto layout and select the image to be blend, and finally mosaic of thermal camera images is produced. It seems that it requires a good picture quality from downloaded thermal camera in ground station. Major result shows that this method ideally will produces good mosaiced image, but it has limitations, which are in terms
of long processing time and inability to process all of the images at once. Figure 3-2 shows example of image mosaic results using Adobe Photoshop software.

![Image mosaic results using Adobe Photoshop](image)

**Figure 3-2. Image mosaic using Adobe Photoshop**

### 3.2.3. Image Cross-Correlation using Matlab

To avoid long processing time and provide the ability to process all of the images at once, image mosaic process is done by using image cross-correlation method implemented in Matlab software. Figure 3-3 shows the results of several mosaiced images of LAPAN-A3/IPB thermal imager video data. It can be seen that although the algorithm can handle all the images sampled from the video, the quality produced is not as good as the other methods. However, the time needed to process even the longest video captured is not more than five minutes, much faster compare to the other methods. There are two disadvantages of using this method. First only simple blending algorithm is performed in this method which causes intersection area of two consecutive images will slightly discontinues. Second, the algorithm often fails to find actual image angle, which correspond to satellite attitude of yaw angle. This incorrect image angle in turn will affect direct geo-referencing process which will produces incorrect latitude-longitude information.
3.2.4. Comparison of Image Mosaicing Methods

Based on several image mosaicing that have been done, it can be concluded that each method has its own advantages and disadvantages. Manual approach using ImageJ software for example, could produce very accurate result in terms geometry and color blending. However, the process needs a lot of hard works to find control-point pairs of each successive images, and considering that the a video data consists of at least 1000 images, the full image-sequence processing can take hours to complete. Meanwhile, mosaicing with Adobe Photoshop software offers good geometry accuracy and image blending result but sometimes it cannot produce accurate mosaicing geometry, meaning that the image sequences fail to be stitched, usually for long sequence of images. The processing time needed is also a burden for this method as 500 image processing could take one hour to complete. The other method by using Matlab software to do image-mosaicing offers another advantage compare the other two methods, mainly in terms of processing time. For 1000 image sequence processed, it took only around five minutes to complete, although the quality both in geometry and image blending is not optimal. Therefore, this method is suitable for quick-look application which needs fast processing algorithm. Table 3.1 shows complete comparison between the tree image-mosaicing methods that have been employed to process thermal imager data of LAPAN-A3 satellite.
Table 3.1 Comparison between image-mosaicing methods

| Parameter               | ImageJ            | Photoshop                  | Matlab                      |
|-------------------------|-------------------|----------------------------|-----------------------------|
| Mosaicing-geometry      | Very good, if done carefully | Very good in general, but sometimes fail to stitch the images | Generally poor, but sometimes can produces fairly good result |
| Image-blending          | Good, as it uses good algorithm | Very good, as it uses proven algorithm | Fairly good, as it uses simple algorithm |
| Processing time         | Very long, need a lot point matching | Fairly long, especially for big data | Very fast, even for long video data |
| User work-rate          | A lot of effort is needed to match all successive pairs of images | No effort needed by the user, just wait and see | No effort needed by the user, although the algorithm have to be developed by satellite data owner |
| Suited application      | For accurate result for small area of images | For casual user who wants fairly good result without big effort and time constraint | For quick-look application which needs fast processing and allows medium result |

3.3. Object Classification

After converting LAPAN-A3 thermal imager video data into sequence of images and mosaicing the images into one mosaiced image, the final step is to classify objects that appear on the image. To provide valid image reference, image produced by thermal imager is compared to image produced by LAPAN-A3 analog video camera. The analog video camera image processing is similar to thermal imager one, but the mosaicing process is easier since the camera has visible spectrum color and therefore the images produced are easier to manipulate. Figure 3-4 shows comparison between mosaiced imaged produced by thermal imager and analog video camera using kappa camera of LAPAN-A3/IPB satellite.

Figure 3-4. Mosaiced images of LAPAN-A3 analog video camera (a), thermal imager camera (b), and comparison between the two mosaiced images (c)
It can be seen from analog video camera image that sea is represented by blue color as usual while cloud is represented by mostly white and some of yellow. In the other hand in thermal image, cloud is represented by black color since the temperature is low while the sea is represented by white color since normally sea temperature is higher compare to cloud temperature. These two mosaiced images can be directly compared because field of view (FoV) of analog video camera is inside the FoV of thermal imager. Although the comparison is not trivial, but with careful matching it can be seen that the shape of many clouds that appear in both images are similar. These fact shows that LAPAN-A3 thermal imager can differentiate the cloud from the sea. However, the object detection capability of the camera should be more than detecting between cloud and sea. Figure 3-5 below shows that the thermal imager also capable of differentiating land surface from both sea and cloud.

![Figure 3-5. Capability of LAPAN-A3 thermal imager to classify land surface, sea and cloud](image)

However, although LAPAN-A3 thermal imager can differentiate between land surface, sea and cloud as shown in Figure 3-5, it seems that with current image quality produced, the imager cannot classify any other objects which appear on the image. Natural object such as river or mountain, or human-made object such as building, farm or road, cannot be seen on the images. This happen because the thermal imager has 143 meter resolution, therefore the imager could not detect small object. Beside, the imager works based on surface temperature, so any object on the surface with relatively similar temperature will looks like the same. This is why the objects with significant temperature differences, such as land surface, sea and cloud, and perhaps if there is fire on the forest, can be identified by LAPAN-A3 thermal imager.
4. Conclusions
This research discusses about mosaic and classification process of LAPAN-A3/IPB thermal imager. Results show that image mosaic by using Adobe Photoshop produces good result, both in geometry and radiometry point of view, but it needs long time processing time and can only process small image sequence. Manual approach using ImageJ software can produce a very good result but needs a lot of works and time-consuming. Meanwhile, mosaic process using image cross-correlation method can process all of the images at once in significantly shorter time processing, but the quality produced is not as good as other methods. Direct geo-referencing has also been done but the quality is only moderate because the process does not use any metadata at all such as satellite orbit and satellite attitude. Image classification that has been done also shows that simple algorithm can only classify three objects in the images, which are clouds, sea, and land surface, and fail to classify any other object in the images.

Acknowledgments
The authors would like to thank Director of LAPAN Satellite Technology Center and Chief Engineer of LAPAN-IPB satellite, for their support and assistance so that this work can be well completed.

References
[1] W. Hasbi, and Suhermanto, 2013. Development of LAPAN-A3/IPB Satellite an Experimental Remote Sensing Microsatellite, Proceedings of 34th ACRS, Bali, Indonesia.
[2] A.H. Syafrudin, W. Hasbi, and A. Rahman, 2013. Camera Payload Systems for LAPAN-A2 Experimental Microsatellite, Proceedings of 34th ACRS, Bali, Indonesia.
[3] FLIR Commercial Systems, 2010. Tau 640 Slow Video Camera: User’s Manual, Document Number: TAU-0640-00-10, Version 100.
[4] M.H. Shokhan, 2014. An Efficient Approach for Improving Canny Edge Detection Algorithm, International Journal of Advances in Engineering and Technologies, Vol. 7, Issue 1, pp. 59-65.
[5] P. Tiwari, 2015. Edge Detection Algorithm-A Review, International Journal of Computer Science and Information Technology Research, Vol. 3, Issue 4, pp. 9-12.
[6] F.A. Pellegrino, W. Vanzella, and V. Torre, 2004. Edge Detection Revisited, IEEE Transactions on Systems, Man, and Cybernetics, Vol. 34, No. 3, pp. 1500-15018.
[7] J.N. Sarvaiya, S. Patnaik, and S. Bombaywala, 2009. Image Registration by Template Matching Using Normalized Cross-Correlation, International Conference on Advances in Computing, Control, and Telecommunication Technologies, IEEE, pp. 819-822.
[8] N. Jayanthi, and S. Indu, Comparison of Image Matching Techniques, International Journal of Latest Trends in Engineering and Technology, Vol. 7, Issue 3, pp. 396-401.
[9] A. Levin, A. Zomet, S. Peleg, and Y. Weiss, 2004. Seamless Image Stitching in the Gradient Domain, 8th European Conference on Computer Vision, Prague.
[10] W. Wang and K.N. Michael, 2012. A Variational Method for Multiple-Image Blending, IEEE Transactions on Image Processing, Vol. 21 No. 4, pp. 1809-1822.