ABSTRACT

"Smart Mapping for Aerial View Captured Images" will be used as nano-satellite aerial camera system for the UTP Edusat 1. The purpose of this project is to build a satellite camera system that can be controled from the ground station and to combine the random aerial images captured by the nano-satellites to produce an aerial mapping view. The task of image reconstruction for this images combining is to determine the overlapping and hence images distribution over the cross-section using mosaicking techniques. This satellite camera system is consist of two part which are the satellite camera and the ground station interface that will include the images stitching process that use particular image processing software such as Autostich and Roborealm for the interface. For the first part, the project works required to find the suitable techniques and software to stitch the images and then develop the interface for the ground station that capable to control the camera from ground when the satellite being launch to the sky such as to contorl the images quality and the shutter timing of the camera. For the next part, author focusing in designing the aerial camera system for the nano-satellite that uses wireless technology. The results and the system that developed in this FYP will be integrated with the "UTP EDUSAT 1" project. This report will mainly reflect the background, problem statement, objectives, methodology and lastly the result of this project.

ACKNOWLEDGMENT

I would like to express my gratitude to all those who gave me the possibility to complete this project. I want to thank the Electrical & Electronic Department of Universiti Teknologi Petronas because giving me permission to commence this thesis in the first instance, to do the necessary research work and to use departmental data and equipment. I have furthermore to thank the entire lecturers that directly or indirectly help me to gain information and help me to complete this project and for their stimulating support.

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Lastly, i want to thank Allah the Almighty, Whose gave me a good health and condition to continue this project until its completed. Without His permission, this project will never reach the level that its stands now. Thank you

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CHAPTER 1
INTRODUCTION

1.1. Background

This FYP project is part of “ Nano – Satellite ” program by the “AERO UTP” team which in turn, is part of the research program targeting to design and lunch the “Edusat 1” which is UTP first nano-satellite being build. This FYP will concentrated on the camera system of the project which is also known as”Smart Mapping for Aerial View Captured Images”.

Aerial photography is the image of the ground from an elevated position. The term usually refers to images in which the camera is not supported by a ground-based structure. Cameras may be hand held or mounted, and photographs may be taken by a photographer, triggered remotely or triggered automatically. Platforms for aerial photography include fixed-wing aircraft, helicopters, balloons, blimps and dirigibles, rockets, kites, poles and parachutes. In this project, the aerial view images will be captured by a camera that being attach to a nano-satellite.

1.2. Problem Statement

The main concern for this research is to develop a system that consist of the satellite camera, the computer interface to control the camera from the ground station and lastly to find a way to combine all the aerial images captured by the satellite and turn it into an aerial mapping view. The problems that will be face in this project is to design the camera system that will be attach to the nano-satellite and can communicate with the interface at the ground station. Besides that, this project also needs to find a way to combine the images taken by the nano-satellite and produce an aerial mapping view.

The term ‘matching’ is used to describe the building of a photo mosaic which means one image being aligned to another accurately. Several issues must be addressed when matching two or more images. Firstly, most airplanes or in our case a nano-satellite do not flight straight. They may crab or yaw and may speed up or slow down. This means that aerial images may have differing flight lines across each image – not necessarily horizontal in each image. Secondly, because of speed differences the images may be of differing distances apart. Lastly, the images may have differing color. Radiometric roll-off or lack of intensity toward the boundaries is common for aerial photos. Sunlight changes over the course of a complete photo set. The mosaic process overlaps the images into one continuous path and ideally processes the differing image colors to match evenly. For aerial images this is where mosaics with extended feature processing are important [1] [2].

1.3. Objectives and Scope of Study

The objective of this project is to develop a camera system that can captured random aerial images from a nano-satellite. This system will consist of the satellite camera, the transmitter and receiver for wireless data communication between the camera and ground station, the imaging interface and the software that will be use to do the mosaicking process that combined and stitched together the images to form an aerial mapping view.

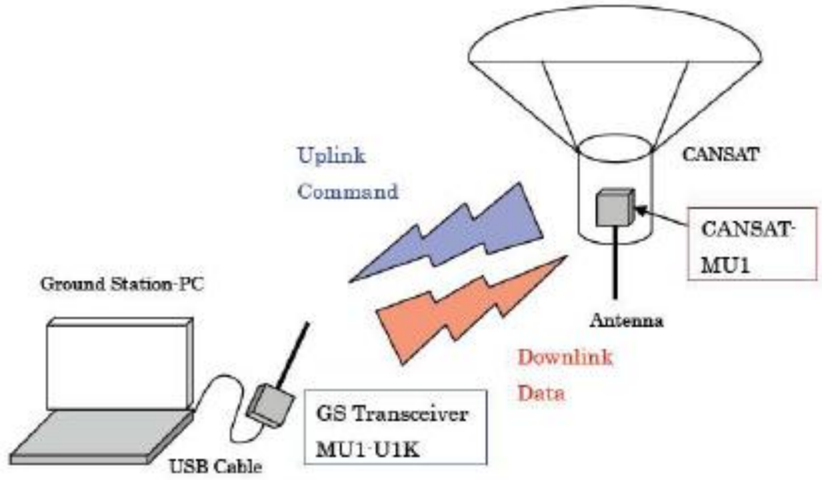

Figure 1: Camera and Ground Station Communication

The techniques that need to study called mosaicking techniques. In the field of photographic imaging, a photographic mosaic also known under the term photomosaic has been divided into equal sized rectangular sections, each of which is replaced with another photograph of appropriate average color. When viewed at low magnifications, the individual pixels appear as the primary image, while close examination reveals that the image is in fact made up of many hundreds of smaller images [1] [2].

Besides that, suitable camera that can capture images for a continuous time during the nano-satellite falling period to the ground need to be designed. The camera must follow certain criteria so that it can be attached to the nano-satellite without effect the movement and weight of the nano-satellite .The quality of the images captured by the camera also important so that the images are clear enough to be transformed to aerial mapping view.

As the problem to transformed the satellite images into aerial mapping view have been solved during FYP 1 using Autostich software that apply mosaicking techniques, FYP 2 works will more concentrated on the imaging interface for the ground station and the camera system for the satellite.

CHAPTER 2
LITERATURE REVIEW

2.1 Aerial Camera for Nano-Satellite€

There are a few criterions that need to study in order to find the suitable camera that will be attached to the nano-satellite to take the aerial images. This is important to make sure the camera will produce clear images for the mosaicking process. Furthermore, it also important to ensure the camera does not affect the movement and weight of the nano-satellite during or after launching it to the sky. Below are some key criterions that need to observe when looking for the nano-satellite camera:

2.1.1 Weight

The most crucial thing to be considered when finds a satellite camera is the weight of the camera. This is important because the satellite maximum weight that being allowed by the Siswasat Competition is 370g. It is important to make sure the camera is light enough to be attached to the satellite.

2.1.2 Size

The size of the nano-satellite must be small enough to be attached to the nano-satellite as the nano-satellite itself is only a cylinder with 5cm diameter and 1 cm long. A huge camera will cause a problem to the stability of the nano-satellite during the lunching and can increase the total weight of the nano-satellite.

2.1.3 Picture quality (pixels)

A pixel is the smallest item of information in an image. Each pixel is a sample of an original image, where more samples typically provide more-accurate representations of the original. It is necessary to find a small camera with good pixels to produce a clear aerial picture for mosaicking process. It is recommended that the aerial camera for the nano-satellite have at least 1 megapixels lens.

2.1.4 Shutter speed

In photography, shutter speed is a common term used to express exposure time, the effective length of time when a shutter is open. The total exposure is proportional to this exposure time, or duration of light reaching the film or sensor. So it is necessary to have a camera with fast shutter speed because it can reduce the noise in the pictures as the humidity and the condition of the air will affect the quality of the aerial images.

2.2 Mosaicking

In this project, all the aerial images taken by the satellite camera will be stitched together to form an aerial mapping view. In order to do this, mosaicking will be use as the technique to perform the images combination using Autostitch software. This technique is widely use in aerial imaginary photographing and below are the detail explanation on the steps that occur in images stitching process using mosaicking technique [3] [4].

2.2.1 Feature matching

The first step in the mosaicking recognition algorithm is to extract and match SIFT features between all of the images. SIFT features are located at scale-space maxima and minima of a difference of Gaussian function. At each feature location, a characteristic scale and orientation is established. This gives a similarity-invariant frame in which to make measurements. Although simply sampling intensity values in this frame would be similarity invariant, the invariant descriptor is actually computed by accumulating local gradients in orientation histograms. This allows edges to shift slightly without altering the descriptor vector, giving some robustness to affine change. The vector of gradients is normalised, and since it consists of differences of intensity values, it is invariant to affine changes in intensity.

Figure 2: Sample Image 1

Figure 3: Sample Image 2

2.2.2 Image matching

At this stage, the objective is to find all matching or overlapping images. Connected sets of image matches will later become panoramas. Since each image could potentially match every other one, this problem appears at first to be quadratic in the number of images. However, it is only necessary to match each image to a small number of neighbouring images in order to get a good solution for the image geometry. From the feature matching step, we have identified images that have a large number of matches between them. We consider a constant number of images that have the greatest number of feature matches to the current image, as potential image matches.


Figure 4: SIFT Features in Image 1


Figure 5: SIFT Features in Image 2

2.2.3 Eliminate Outliers using RANSAC

We use RANSAC to select a set of inliers that are compatible with a homography between the images. RANSAC is an abbreviation for "RANdom SAmple Consensus". It is an iterative method to estimate parameters of a mathematical model from a set of observed data which contains outliers. A basic assumption is that the data consists of "inliers", which is data that need to do the model, and "outliers" which are data that do not fit the model.Next we apply a probabilistic model to verify the match.

2.2.4 Multi-band blending using Homography

Given a set of geometrically consistent matches between the images, we use homography alignment to solve for all of the camera parameters jointly. This is an essential step as concatenation of pairwise homographies would cause accumulated errors and disregard multiple constraints between images that the ends of a images should join up. Images are added to the bundle adjuster one by one, with the best matching image which maximum number of matches being added at each step. The new image is initialised with the same rotation and focal length as the image to which it best matches.

Figure 6: Mosaicking Image

CHAPTER 3

METHODOLOGY/PROJECT WORK

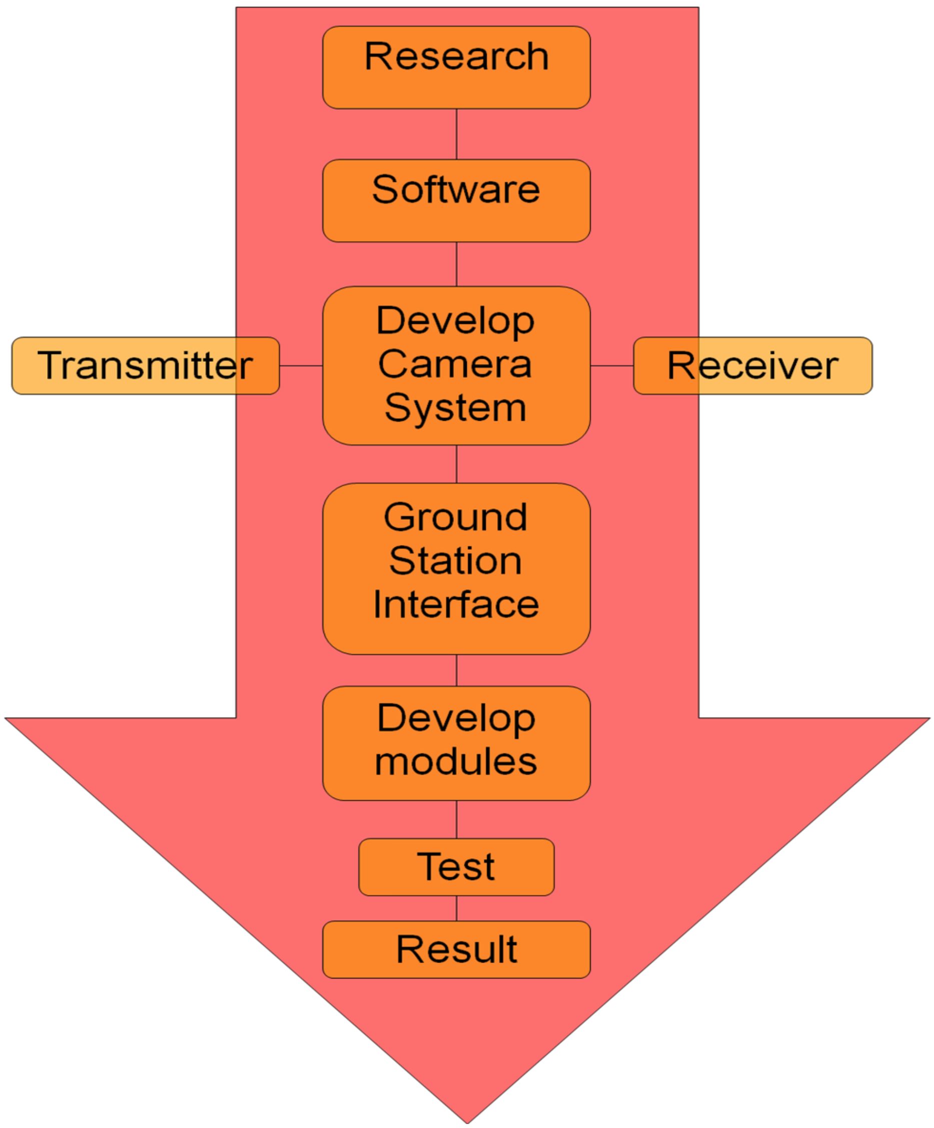

Figure 7: Flowchart of Project Works

3.1 Research

3.1.1 Aerial Images

Before the best techniques that can be use to stitch together all these random aerial images can be defined, it is important to understand the scale of the aerial images that we captured. Satellite imagery is small scale that covering a large area usually greater than 100 sq. km/frame. But for a nano-satellite like Edusat 1, it will cover approximately 100 sq. meter/frame. If a larger area is to be viewed then two or more of these frames must be connected together. Aerial photos on the other hand are large scale covering a small area usually in 23cm X 23cm format. Scale may vary for each of these images, particularly for aerial photos where flying height varies. In the case of aerial photos there is usually 60% side overlap and 30% end overlap for each pair of photos. Aerial photos, depending again on scale cover smaller areas usually less than 10 sq km/frame. It may take 100 if not thousands of aerial photos to cover the same area as one satellite image.

3.1.2 Images Combining techniques

i. Image registration

Image registration algorithms can be classified into intensity-based and feature-based [2]. One of the images is referred to as the reference or source and the second image is referred to as the target or sensed. Image registration involves spatially transforming the target image to align with the reference image. Intensity-based methods compare intensity patterns in images via correlation metrics, while feature-based methods find correspondence between image features such as points, lines, and contours.

ii. Image stitching

Image stitching or photo stitching is the process of combining multiple photographic images with overlapping fields of view to produce a segmented panorama or high-resolution image. Commonly performed through the use of computer software, most approaches to image stitching require nearly exact overlaps between images and identical exposures to produce seamless results.

3.1.3 Mosaicking techniques

After done some research, the best techniques to combine aerial random images is by using mosaicking [1] [2]. Mosaicking is a way to achieve repetitive scans by specifying just one scan in the observe file, and providing details on the repetition in the offset option card. This prevents the time overhead associated with specifying images individual scans as opposed to one scan and images repetitions.

In mosaicking, one scan consists of images equidistant pointing called 'samples' on a straight line. The position of the starting sample is specified on the source card. The location of the images subsequent samples is defined by the distance between each adjacent sample, and the position angle of the straight line on which the samples are located.

3.2 Software

3.2.1 Roborealm Interface

In this project, the software that will be use to develop the interface of the camera for the ground station is Roborealm. Roborealm is a powerful robotic vision software application for use in computer vision, image processing, and robot vision tasks. This software provided complex images analysis interface and allow us to control directly the imaging device from computer. This software allowed development of new modules for the imaging system such as filter, tracking system, distance calculation and other analysis to the images from the satellite camera besides can directly control the camera properties such as exposure and brightness from the computer by using USB or wireless connection. In this project, few program that consist of a few modules have been developed using this software to be use in the satellites imaging system. The modules will be discussed further in the methodology section of this report.

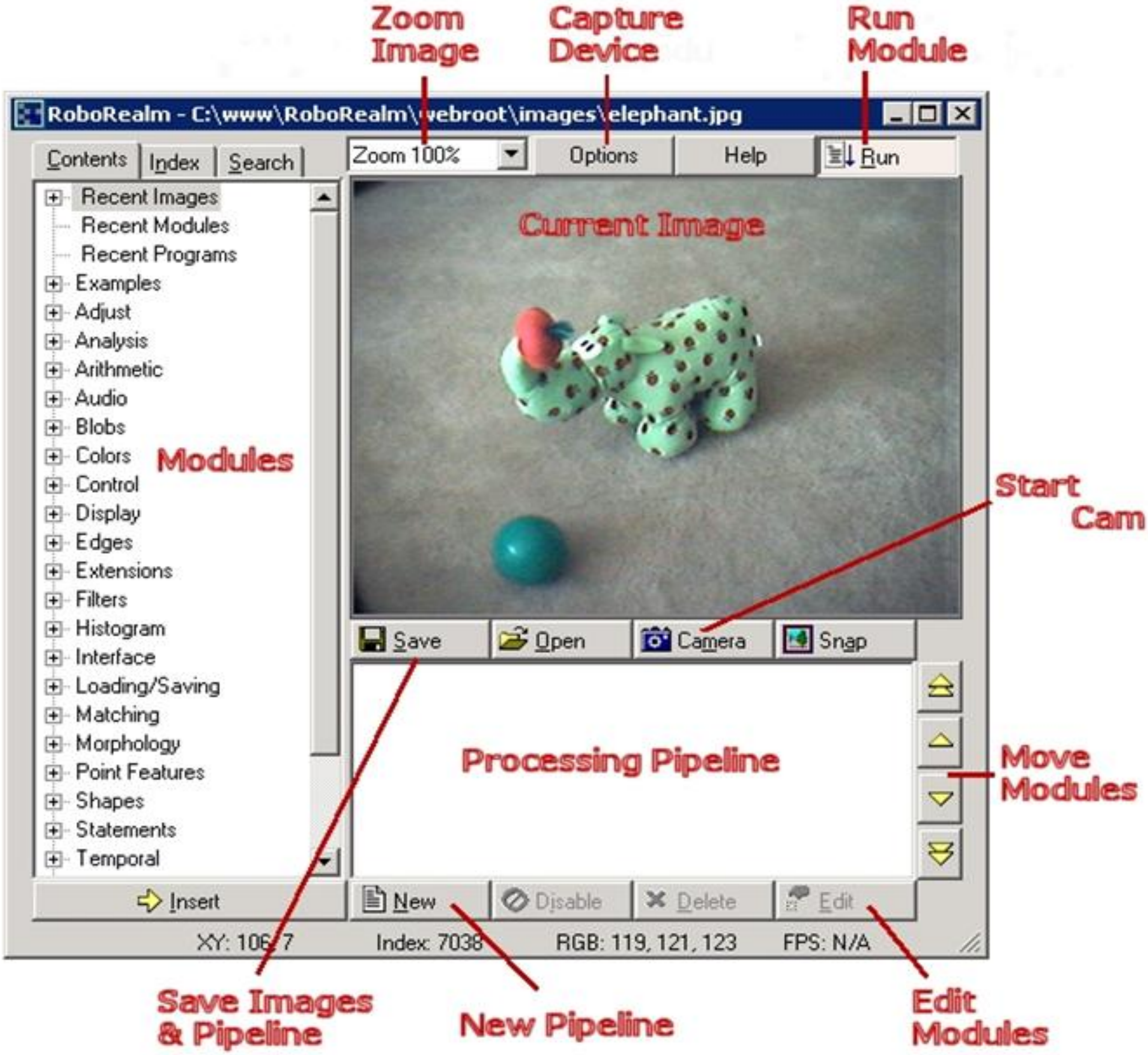

Figure 8: Roborealm Interface

3.2.2 Autostitch

For this project, the mosaicking process for the aerial images will be applied using Autostich. The user simply selects a set of aerial images captured from the satellite camera using the windows interface, and the software automatically stitched them together into an aerial mapping view. Autostitch is a breakthrough technology for aerial photography. The simplify process in Autostitch as shown below:

i. Find SIFT features in all images
ii. Match features to get correspondences
iii. Eliminate outliers using RANSAC
iv. Solve for homography
v. Project images on common “image plane”
vi. Blend overlapping images to obtain mosaicking

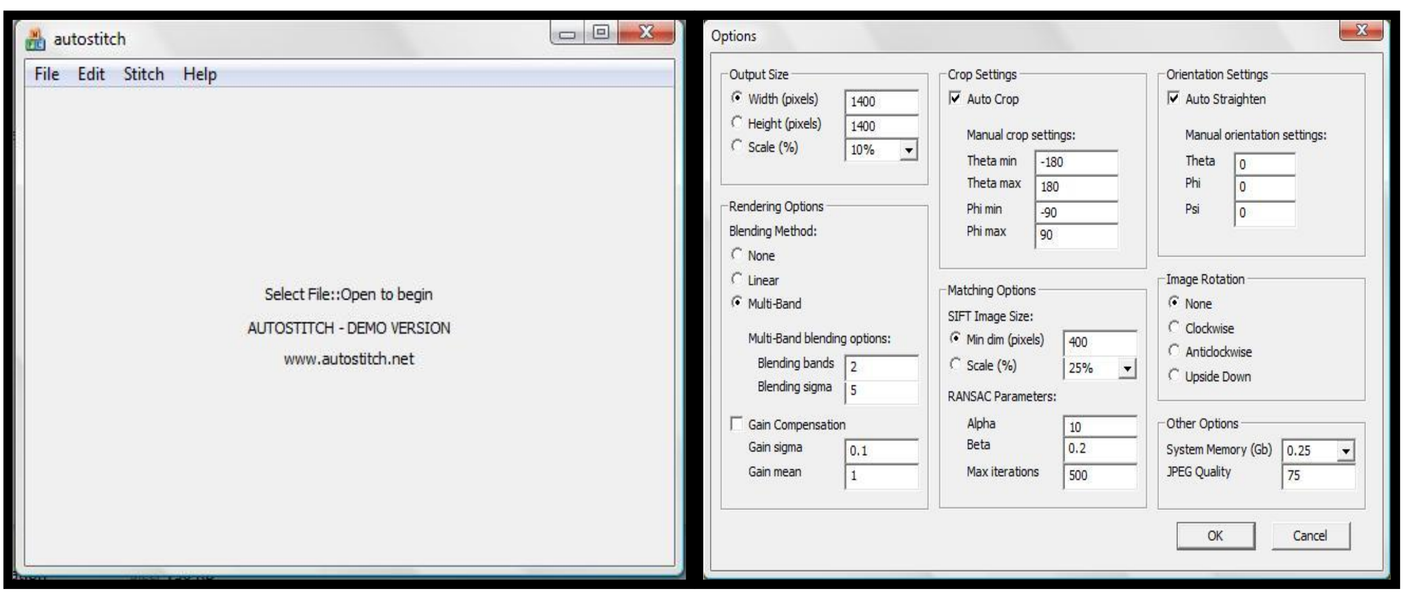

Figure 9: Autostitch Interface

3.3 Wireless Camera System

For wireless camera system developing, a wireless module, video audio driver circuit board, transmitter and CMOS camera have being bought and these component being assembled together to build the satellite wireless camera system.

3.3.1 Wireless module board

Wireless module board that will be use has operating range of 50-60 Hz frequency and capable to transmit and receive data around 100 meters range.

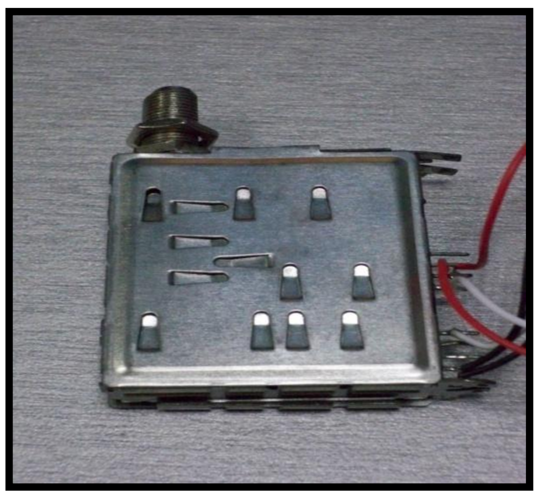

Figure 10: Wireless Module

3.3.2 Audio video driver circuit board

Audio video driver circuit board will convert the analog signal that being received from the transmitter to digital signal and will be process it into video and audio output.

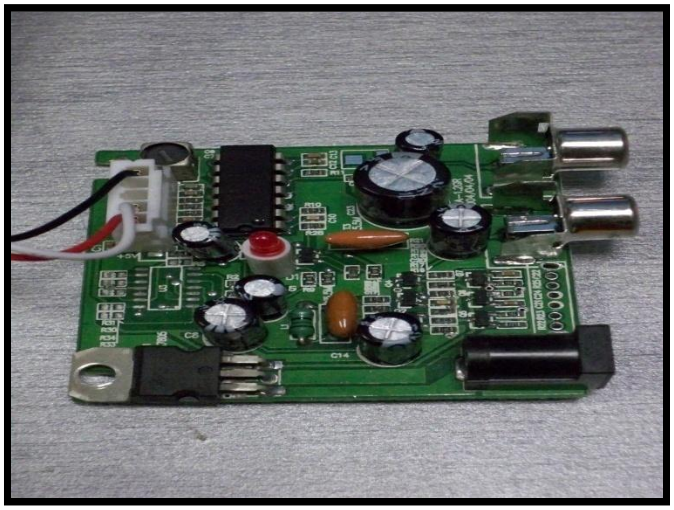

Figure 11: A/V Driver Circuit Board

3.3.3 Transmitter

The transmitter will be connected to the CMOS sensor camera and will transmit the images captured from the nano-satellite to the ground station.

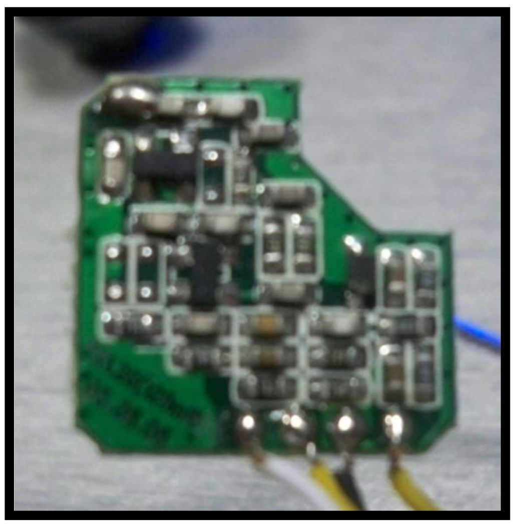

Figure 12: Transmitter

3.3.4 CMOS sensor

CMOS sensor camera will be used as the satellite camera. It support 0.3 mega pixels and capable to captured and record both images and video. The camera board also integrated with a small microphone for sound recording.

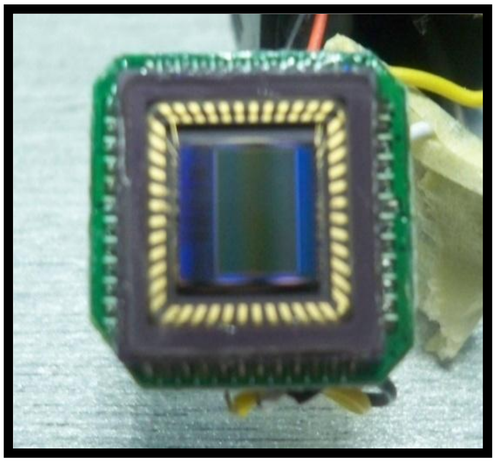

Figure 13: CMOS Sensor

3.3.5 Specification

Image Pickup Device:		1/3" inch CMOS Camera
Pixel:		0.3 mp
Picture Area:		5.78 x 4.19mm
Modulation Mode:		FM
Scan frequency:		50Hz - 60Hz
Transmission Signal:		Picture, Sound
Power Output:		50mW 200mW
Operating range:		100 Meters

Power supply:		+8V DC
Output:		RF
Power Consumption:		<=640MW

3.4 Images Quality Testing

To test the camera images quality, the CMOS camera has been attached to a kite. The purpose is to see how clear the images that been captured by the camera from the kite field of view on the computer screen at the ground station. The kite fly approximately 100 meters from the ground.

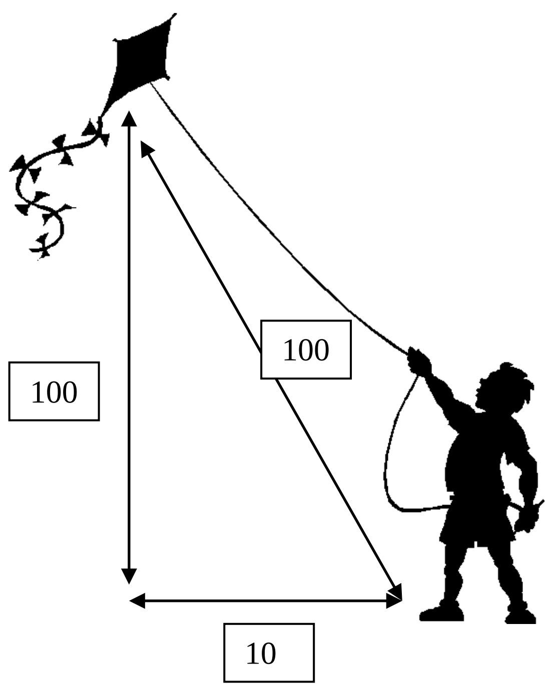

Figure 14: Kite High From Ground Approximation

3.5 Ground Station Interface Modules

This project also required to develop a few modules for the ground station interface using Roborealm so that there will be more features of the camera that can be controlled from the ground station. This interface uses the wireless camera that has being built as the imaging device which been connecting to the computer using USB. Below is the interface modules that author developed using Roborealm that will be integrated in the satellite ground station interface [5] [6] [7].

3.5.1 Camera properties

The Camera Properties module provides a way to modify the exposed DirectX camera properties integrate into the camera driver. This differs from camera to camera but can include exposure, brightness, gamma, and others. Changing these properties different from other modules in that the attribute change may be sent directly to the camera which can alter the physical capture of the image rather than just manipulating the image bytes which the other RoboRealm modules do but the features in this modules is depends on the camera.

3.5.2 Contrast

The contrast module provides a way to brighten an image by adding a specified amount to each RGB pixel value. User can specify a negative number to reduce the brightness of each pixel too. A pixels value ranges from 0 to 255. Adding 255 to each pixel turns the image white. Adding -255 will turn each pixel black [9].

3.5.3 Gamma

The Gamma module helps to map pixel intensities into a more correct viewable image depending on the viewing device you are using. As most display devices like CRT tubes alter the image to < 1.0 gamma curve user may need to balance for this display adjustment by increasing the gamma > 1.0.Adjusting the gamma for image will increase the midtones in intensity while leave the lowest and highest pixel intensities as they are not unlike contrast alteration.

3.5.4 RGB Filter

The RGB Filter uses RGB values to focus the attention towards the primary RGB colors. Depending on the color selected this filter will diminish all pixels that are not of the selected colors. This function is different than RGB Channel in that white pixels are also diminished even though they may contain the color selected.

3.5.5 Affine Transformation

The Affine Transform module provides a way to warp the image into a different image. This module will use the four selected points to create a new image that is scaled, rotated and translated based on the four coordinate points. This transform is useful for removing perspective distortion or for straightening objects within the field of view from the satellites in the aerial images because the movement of the nano-satellites during the falling mechanism maybe will cause the camera to take non-symmetrical images.

3.5.6 Distance Calculation

Distance calculation module has been developed using VB programming. This module capable to calculate a distance between 2 point in the images but the distance will be in pixels. User must estimate to meter per pixels 1st before knowing the actual distance in SI.

All the resulting images of the effect from all the modules will be shown in the result section of this report.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Nano-satellite Camera System

Below is the figure that shows the connectivity between the satellite camera and the ground station interface.

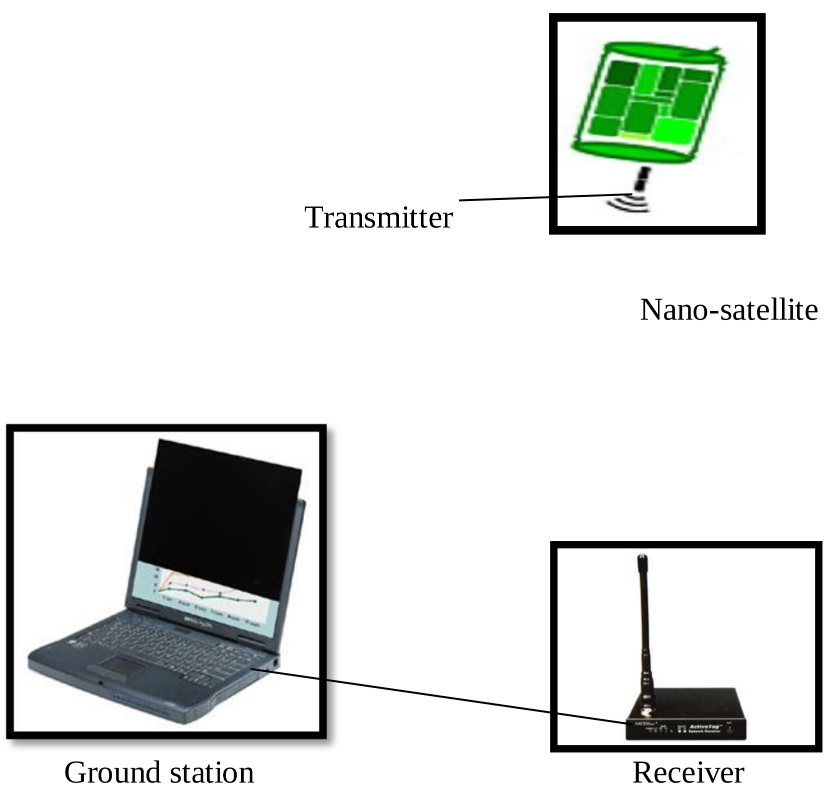

Figure 15: Nano-Satellite Camera System

The camera receiver will connected to the computer USB port using video grabber and the ground station interface will capable to control the satellite camera. Transmitter will be attached to the nano-satellite and will transmitted the captured images to the ground station. The transmitter and receiver both will be powered by 9V battery.

Figure 16: Video Grabber

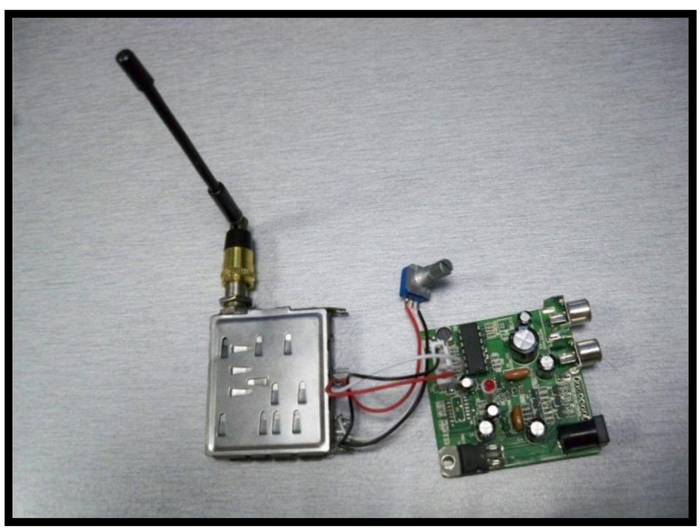

Figure 17: Ground station receiver

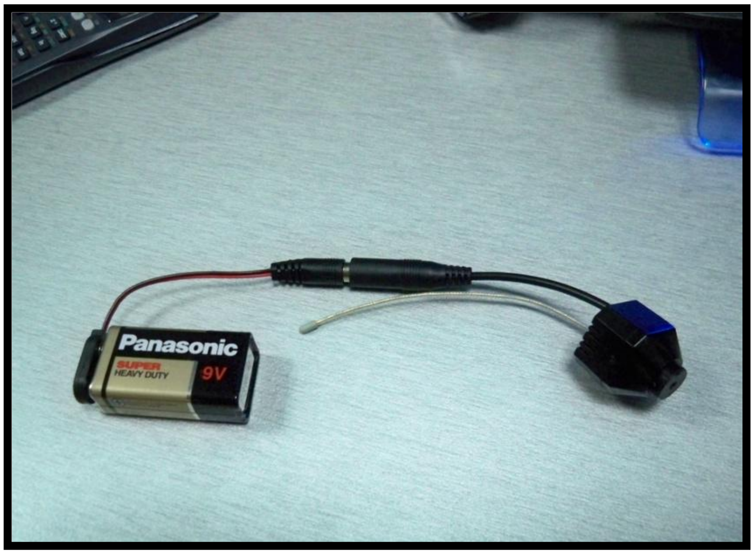

Figure 18: Camera with Transmitter

4.2 Ground Station Interface Modules

Below are some of the modules that have being developed for the ground station interface. These modules allow user to control the satellite camera from the ground such as to snap the images, adjust the images quality and to analyze the area from the camera. The wireless camera being connected to the computer using USB connector and each module being test to see the result

4.2.1 Camera properties module

This module allow user to control some of the images properties such as color, exposure and lens. The numbers of properties that can be control is not the same for all type of camera. For the wireless camera that being used, the properties that can be control are white balance, saturation and brightness.

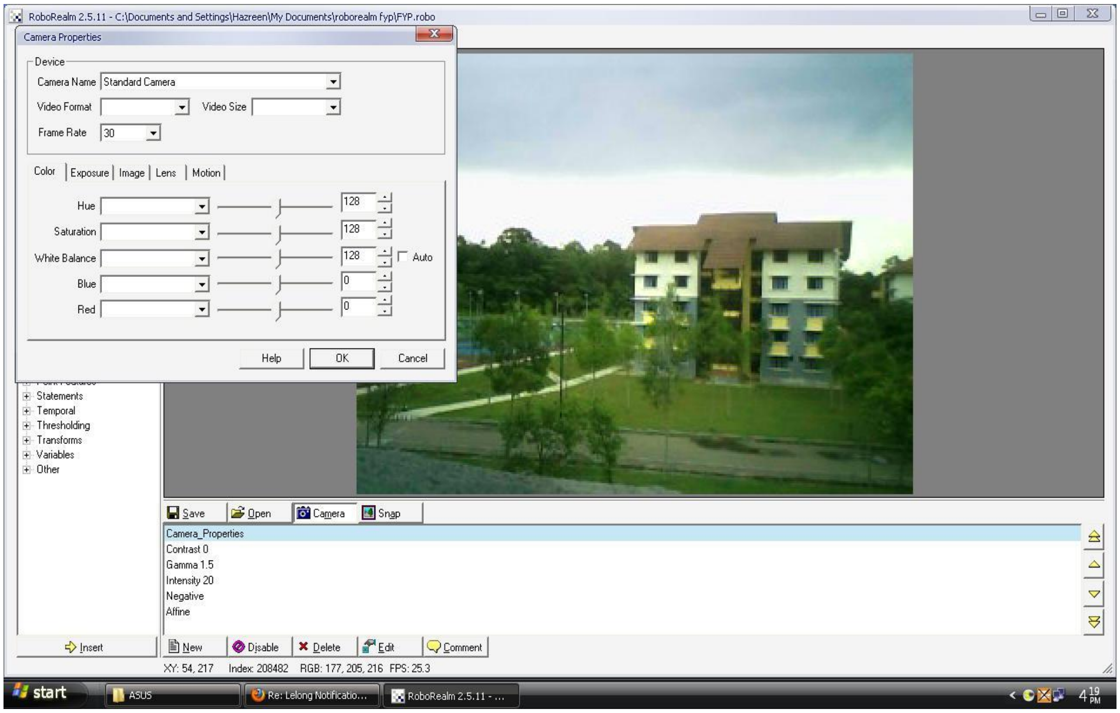

Figure 19: Camera Properties Module

Figure 19 shows the properties of the camera that can be controlled using this module and give the user to control the images quality from the ground station. For example, if the weather condition is too bright, user can reduce the brightness of the camera to improve the images quality.

4.2.2 Contrast module

Contrast module also same to camera properties which is allow user to adjust the contrast of the images to improve the images quality. The different is this module does not depend on the type of the camera. Figure 20 and figure 21 show the different when contrast being adjust from 0 to 15.

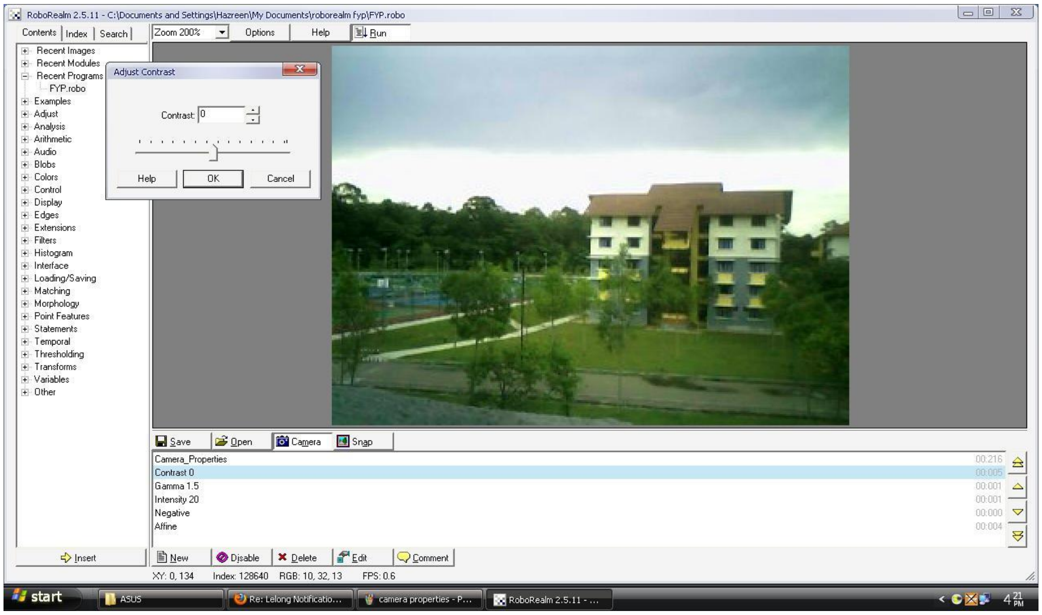

Figure 20: Contrast Set To 0

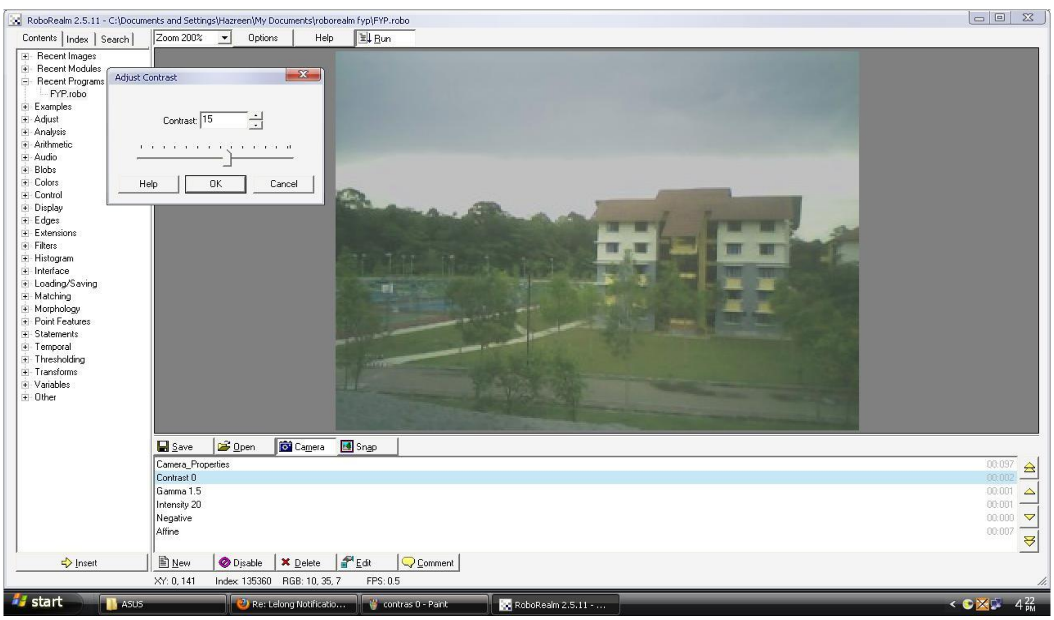

Figure 21: Contrast Set To 15

4.2.3 Gamma module

Gamma module will help user to map pixel intensities which other word to supply the images with more saturation of color. The color will be richer and improve the images quality. These modules suitable to use in bright condition which the images will be look more whiter and lack of colors saturation. Figure 22 and Figure 23 shows the different when gamma module is set from 1.04 to 1.7.

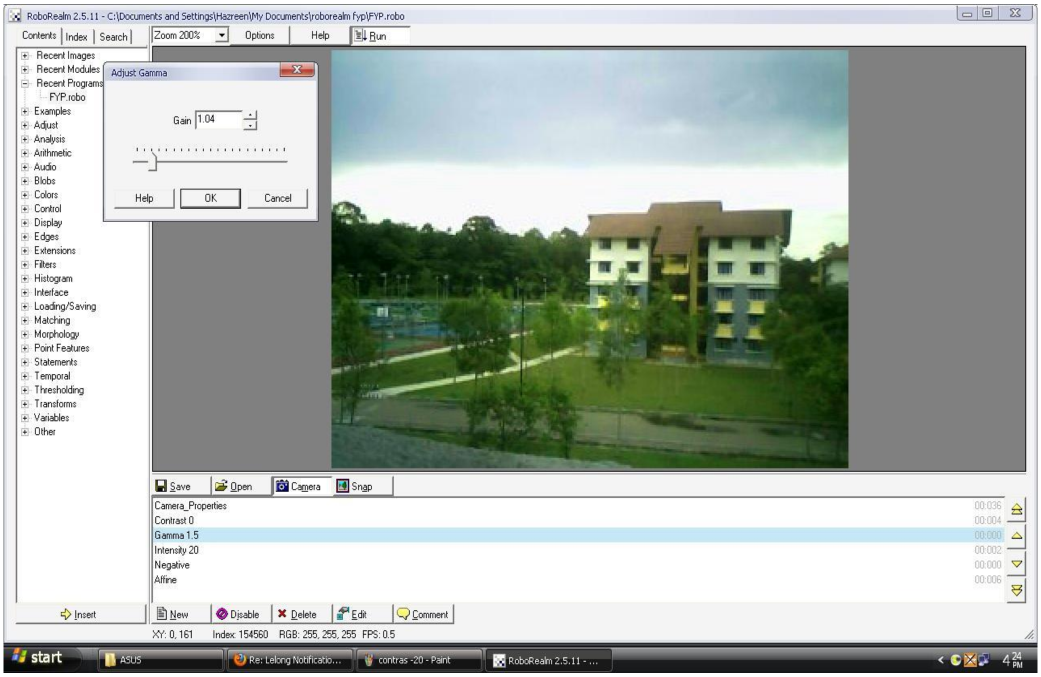

Figure 22: Gamma Set To 1.04

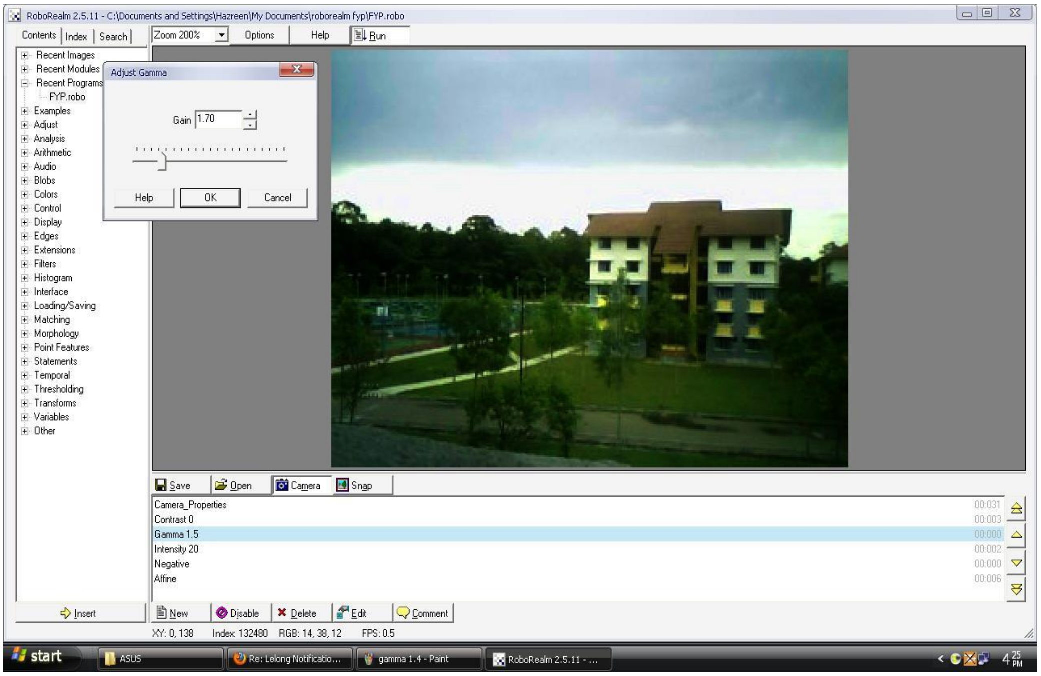

Figure 23: Gamma Set To 1.70

4.2.4 RGB Filter module

RGB filter allow user to filter other colors and penetrate only to one type of color only. It means that it will remove other pixels of color that not selected and only focus the pixels of the selected color. This modules can be use to observe an area using the color of the subject. For examples if we want to observe an area of a forest or plantation from the satellite, we can use the green color to filter the area that do not have any plant and only focus the subject area which is the plantation area. Figure 24 and figure 25 shows how this module works.

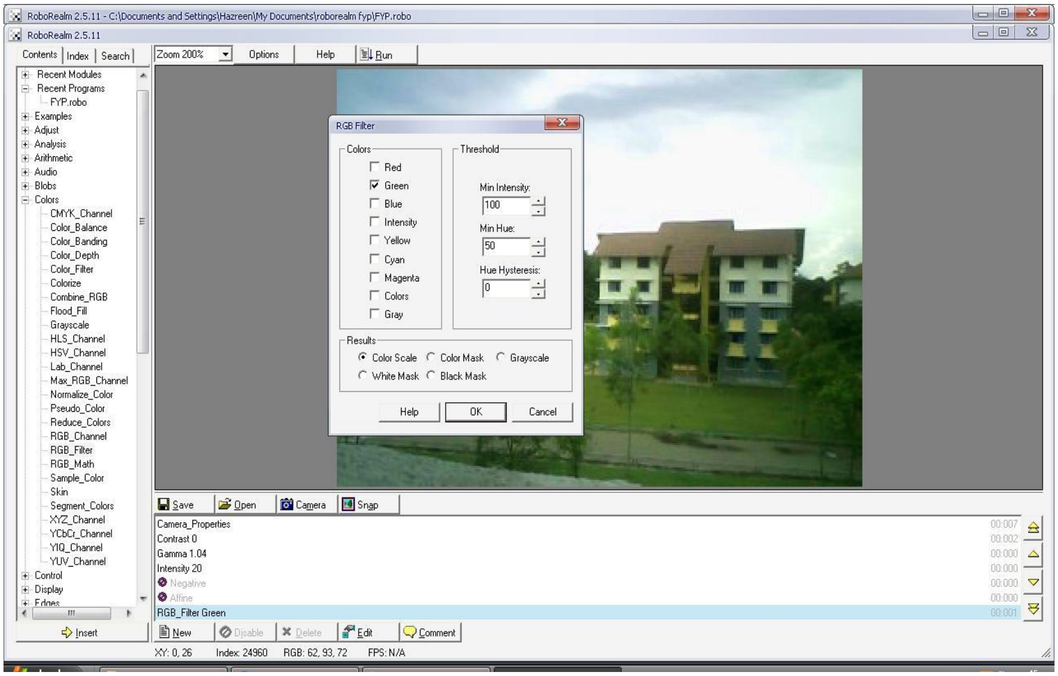

Figure 24: RGB Filter Module

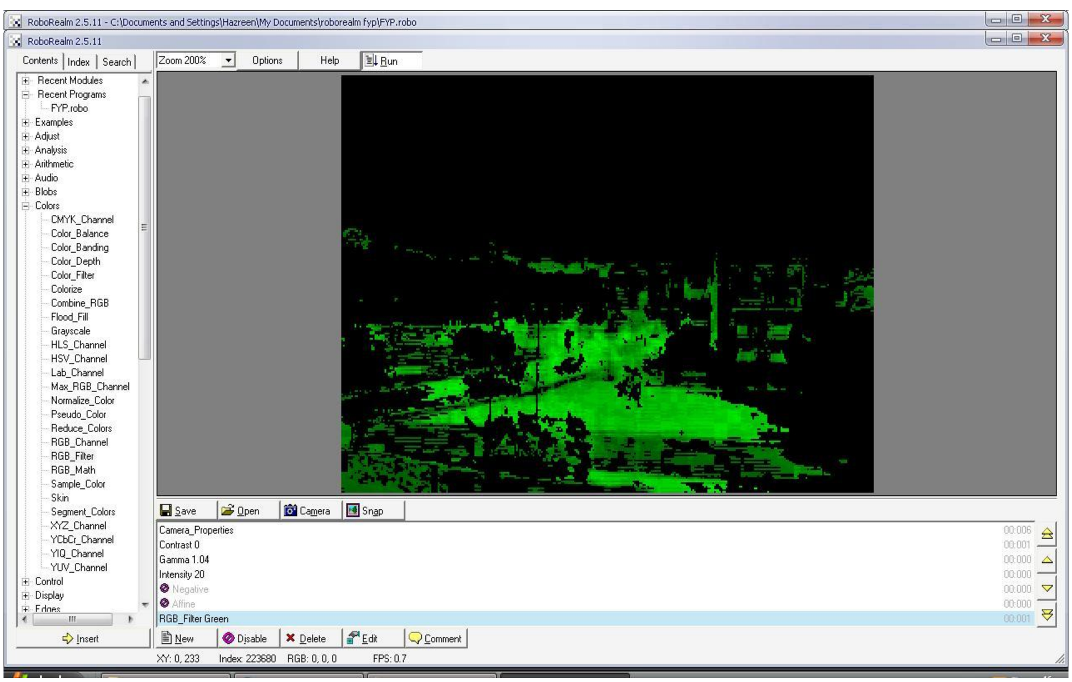

Figure 25: RGB Filter Is Set To Green

4.2.5 Affine Transformation module

This module will give the user at the ground station to zoom and focus certain area in the camera at the satellite. This module useful is if we want to take aerial images and focus only certain area in the camera images. Figure 26 and figure 27 shows how this module can be apply.

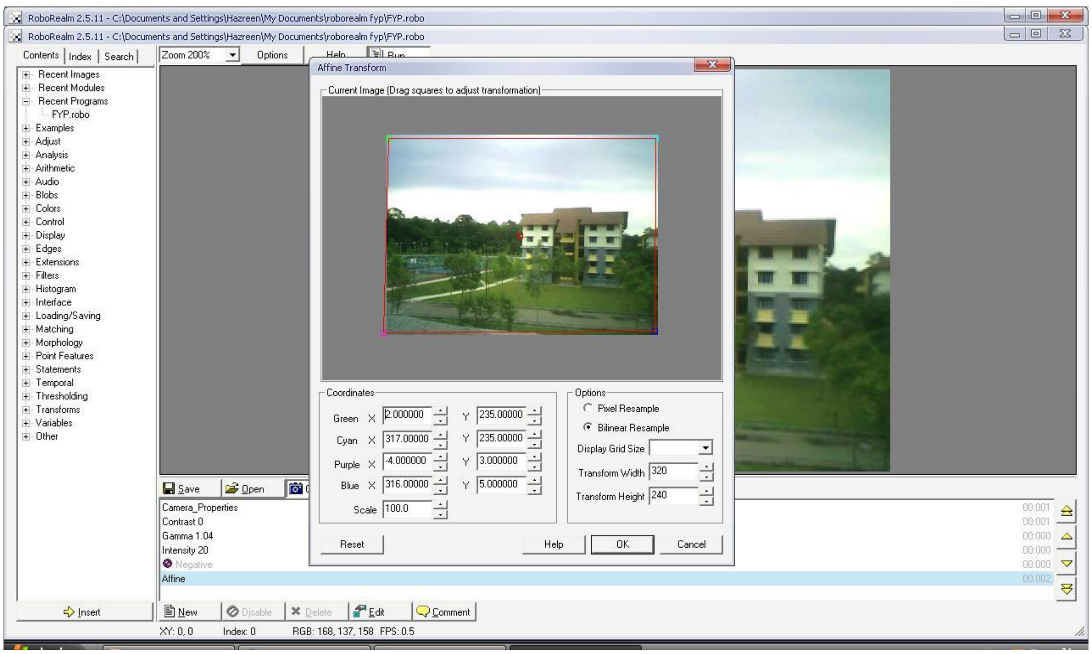

Figure 26: Focusing Using Affine Transformation

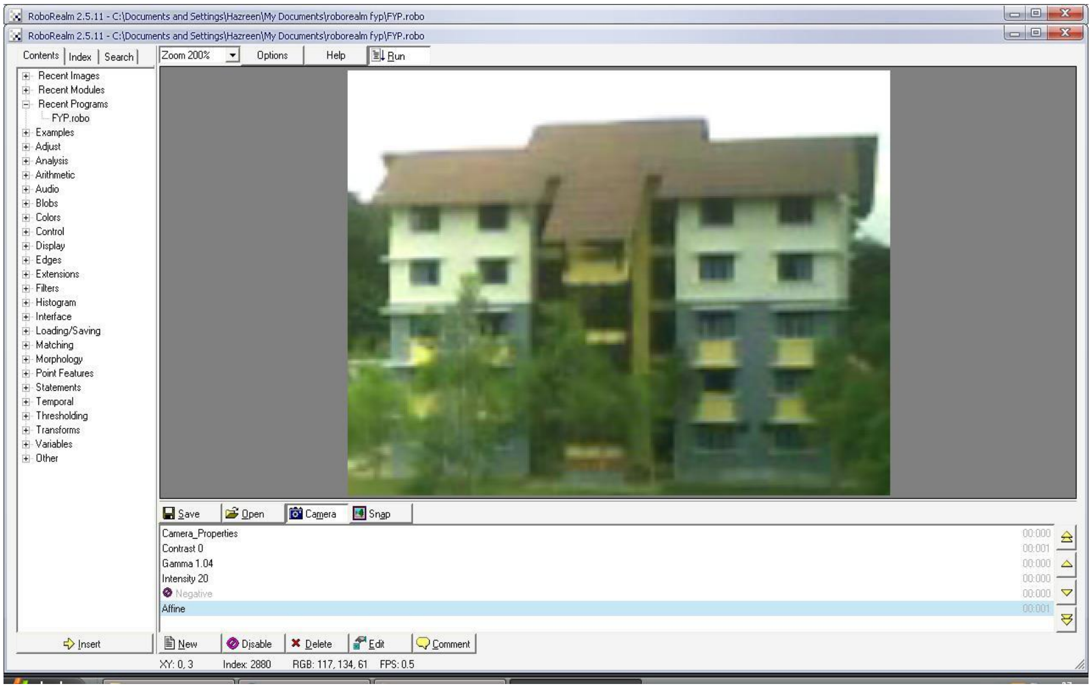

Figure 27: Focus Area Using Affine Transformation.

4.2.6 Distance calculation module

Using distance calculation module, user will capable to estimate distance between 2 points in the images. This will help in a case where user needs to assume a distance between to 2 points or to calculate a rectangular area from the images. The distance or length shows by this module is in pixels, user need to estimate in meters for each pixel to know the real distance in SI such as 1 pixel = 10m because the estimation can change depends on the high of the nano-satellite from the ground. This module has being developed using VB programming in Roborealm interface [8] [9]. Below are the VB programming scripts and figure 28 shows the distance calculations module [10] [11].

VB Scripts for Distance Calculation Module

```
x = GetVariable("MOUSE_CLICK_X")
y = GetVariable("MOUSE_CLICK_Y")          *get pixel coordinate x,y in every
                                           mouse click

if x <> GetVariable("LAST_X") or y <> GetVariable("LAST_Y")    *x and y not
                                                                 equal to last
                                                                 coordinate

if GetVariable("START_X") = 0 then        * 1st click equal zero
  SetVariable "START_X", x
  SetVariable "START_Y", y                *set variable 1st click to get variable
elseif GetVariable("END_X") = 0 then      *1st click equal zero
  SetVariable "END_X", x
  SetVariable "END_Y", y                  *set variable 1st click to get variable
else
  SetVariable "START_X", x                *1st click to get variable
  SetVariable "START_Y", y
  SetVariable "END_X", 0                  *2nd click to zero
  SetVariable "END_Y", 0
end if

SetVariable "LAST_X", x                   *start the new click with get variable
                                           again.
SetVariable "LAST_Y", y

end if
```

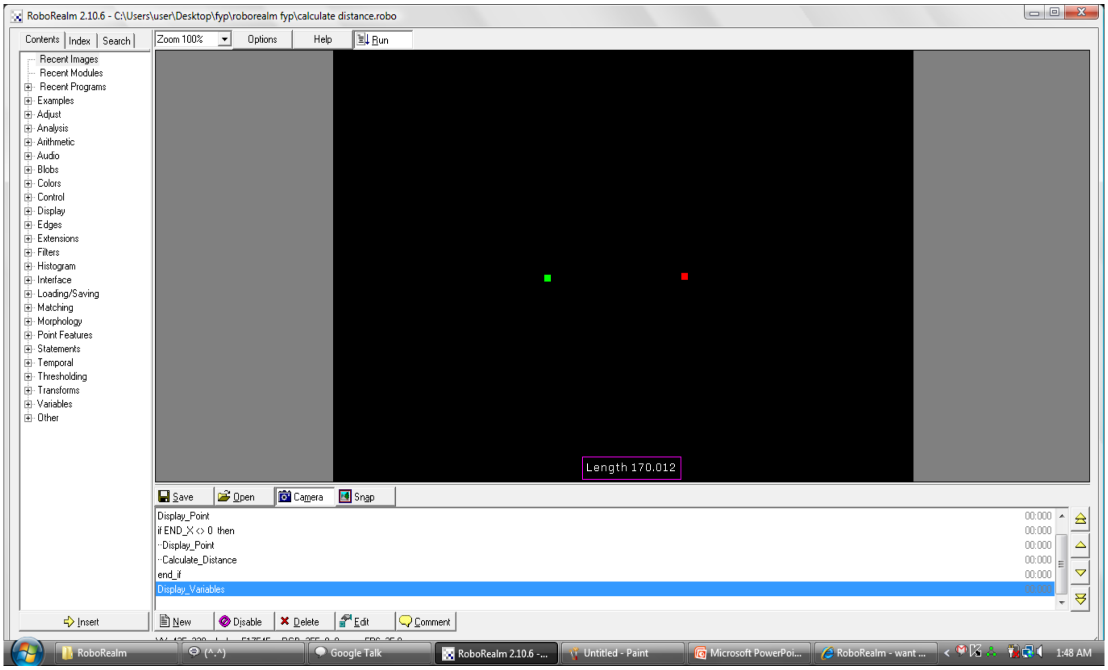

Figure 28: Distance Calculation Module

4.3 Aerial Mapping View

Author has taken a few samples of aerial images from Google Earth software as the nano-satellite still in developing process. For simulation purpose, the aerial images from Google Earth will be use to represent the images captured from the nano-satellite view.

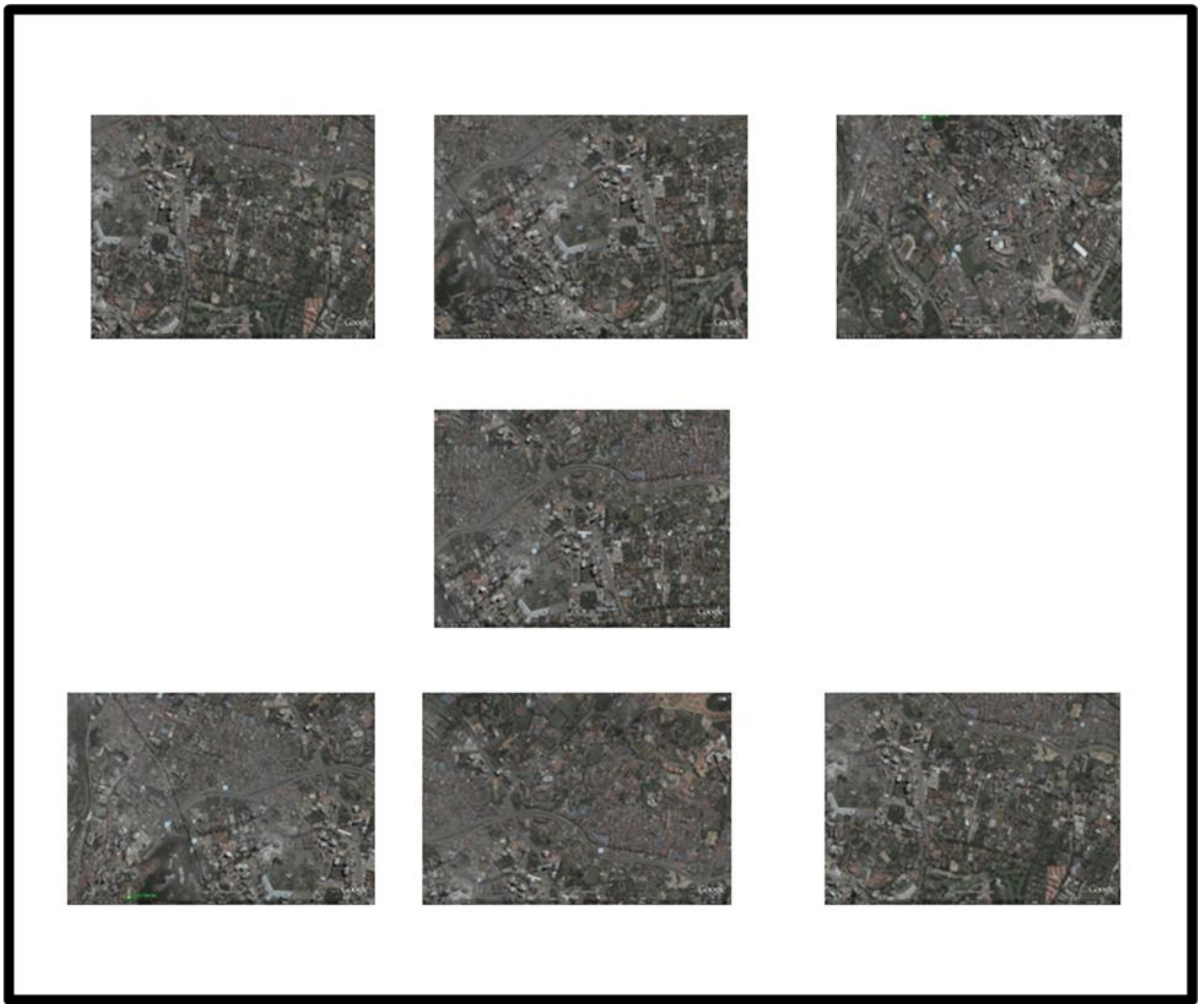

Figure 29: Aerial Images Samples

Figure 29 shows a group of aerial images examples that being taken from Google Earth as the sample images to represent the aerial images from the nano-satellite. Using Autostich software, these images will be combining and stitch together to produce an aerial mapping view as being shows in figure 30. This process will allow the nano-satellite to take random images of a huge area and user can combine all the images to produce bigger aerial view which look like a map to observe and analysis the area such as deforestation.

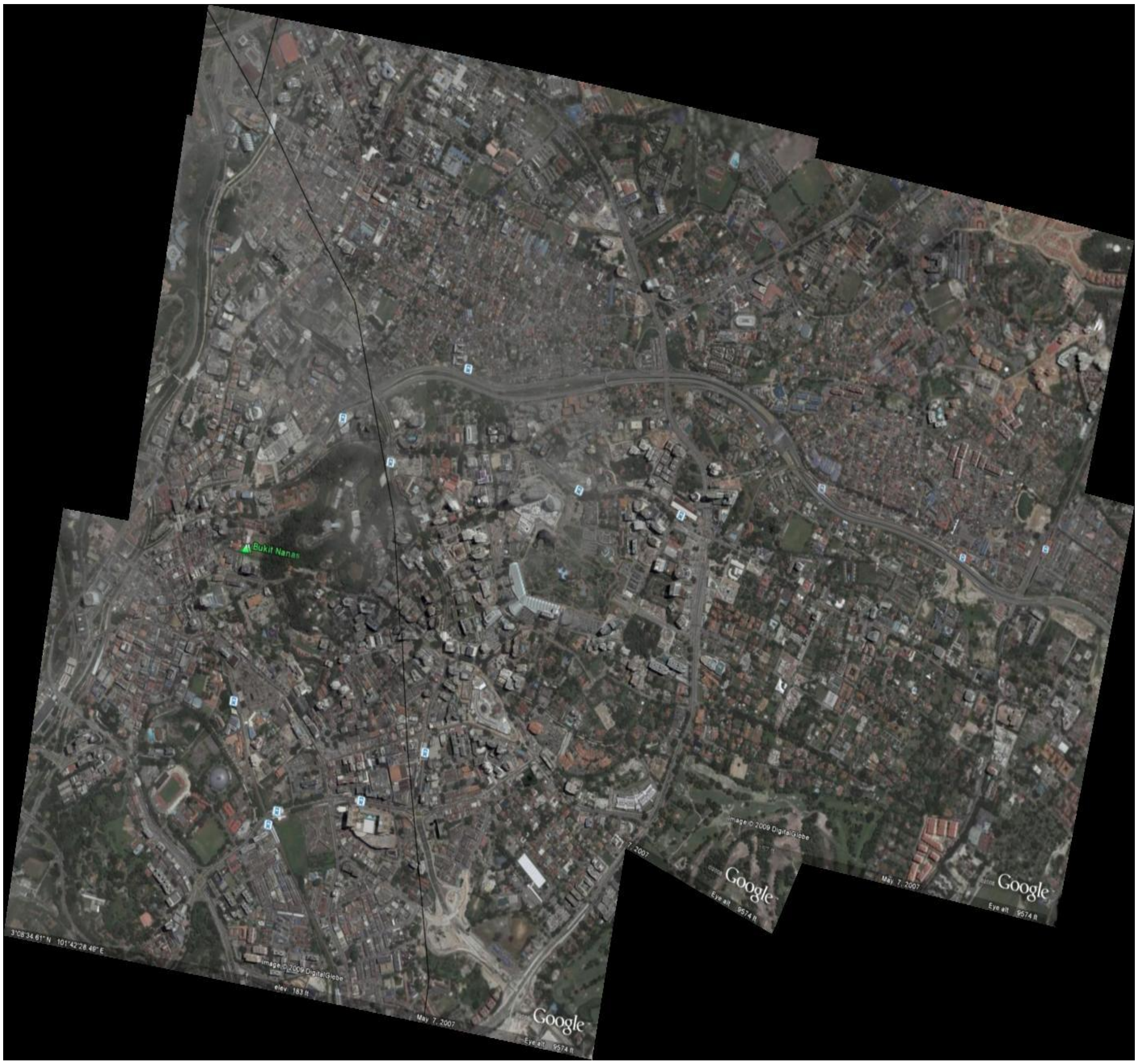

Figure 30: The Aerial Mapping View

CHAPTER 5

CONCLUSION AND RECOMENDATION

5.1 Conclusion

This system is still in development phase and a few improvement need to be made to produce more quality result before it can be attach to the nano- satellite for the real testing . The images quality when being captured from the nano- satellite are still unknown as the nano – satellite itself still in development process by the AERO UTP team.Author hope that this system can work well with the UTP EDUSAT 1 and adding new features to the nano-satellite. With this system integrated on the UTP EDUSAT 1, the nano-satellites will capable to monitor and record the images of problematic area such as illegal logging or to capture aerial images of land slide.

5.2 Recommendation

Some improvement can be made to this satellite camera system to improve the quality such as:

i. Improve the camera and the wireless system so that a better quality images and reception can be received from the satellite.
ii. Developed a new programme that has the features to control the camera images and to combine the images captured in one single software or interface.

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