# $360^{O}$ Omni-directional observation technique for biodiversity monitoring

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**Abstract**

Panoramic images have been used as a useful and inexpensive tool to provide "surround-imagery" that are widely used in areas such as surveillance and virtual tourism to provide an immersive experience to viewers. The 360° degree photo-monitoring uses an omni-directional single image for records and monitoring purposes where users can view the complete 360° panoramic image. In this paper, we present a documented effort to utilise the 360° omni-directional observation technique that has been deployed over various sites in Malaysia. These sites includes high altitudes such as peaks of Mt. Ledang, Mt. Panti, Mt. Belumut, Mt. Kinabalu, underground caves in Lenggong, Wang Burma and Langkawi, horizontal monitoring in Denai Alam, Bangi and temporal monitoring in Johor Botanical Gardens in Batu Pahat. During the deployment, we tested various aspect of the technology such as field deployment, practicality, software availability, technical challenges and long and short term factors that would affect deployment of this technology in biodiversity monitoring. The study showed that it provides a less expensive alternative with a higher resolution imagery compared to existing video monitoring technology. Other advantages include smaller data storage, thus requiring minimal bandwidth when viewing online. The resolution of the generated images is only limited to the available hardware and the smallest setup cost are negligible as open source technology and improvisation of existing photography equipment is sufficient to create a basic monitoring system. The images can generate ''walk-throughs'' that capture and annotate the rich detail of the forest flora, monitor changes over time, provide context and functions as a decision support when deriving conclusions regarding the site. The 360° images can be viewed at http://birg2.fbb.utm.my/birg360/page.php?pageid=portfolio3

## Introduction

Fixed-point photography has always been the basis of image based recording in monitoring habitats and land-uses because it is simple yet very objective method. Simple since it requires no extensive and high cost training; objective since it prevents any observer-related biases. The technique involves establishing a fixed point and photographing the area from this vantage point at regular intervals, providing information on detectable variations of size and conditions (Sharma 2004). This method is applicable in land and aquatic habitats, in undulating terrain such as hills, river valleys and along the shoreline of lakes, swamps and coasts. In this paper, we present a documented effort to utilise the 360° Omni-directional observation technique that has been deployed over various sites in Malaysia. These sites includes high altitudes such as peaks of Mt. Ledang, Mt. Panti, Mt. Belumut, underground caves in Lenggong, Wang Burma and Gua Langkawi, horizontal monitoring in Denai Alam, Bangi and temporal monitoring in Johor Botanical Gardens in Batu Pahat. 360° Omni-directional is a technique of photography, which captures images with elongated fields of view. 360° Omni-directional may be termed an image showing a field of view approximating or greater than, that of the human eye about 160° by 75°. A 360° Omni-directional is made by rotating the camera through a series of steps to take a complete panoramic image that overlaps each other by 40-50%. An example of a complete 360° by 180° spherical panorama is shown in Figure 1. Photo-monitoring uses an Omni-directional single image for records and monitoring purposes where users can view the complete 360° panoramic image using visualization software.

**Figure 1: A 360° by 180° spherical panorama.**

Panoramic or Omni-directional cameras allow the opportunity to capture data rich environment that can then be used to generate ‘‘walk-throughs’’ for an immersive experience in virtual reality, backgrounds for games, or digital tourism (Gledhill 2009). In this study, we examined if the 360° Omni-directional imagery can be used as a photo-monitoring method to capture the rich detail of the forest flora and the forest canopy.

## Methodology

Nowadays, digital compact or digital single lens reflex (DSLR) camera have advanced and high-resolution sensors, which capture a significant visual details of the scene being photographed. For panoramic imaging, differing amounts of images need to be taken, depending on the camera, lens, and type of panorama required. Sometimes, the camera itself has a panoramic function to capture panorama picture. Many panoramic image sensors have been developed, from low cost cameras that take a large number of sequential images to panoramic imaging from multiple images by either a camera rotated about its optical centre, or using multiple cameras capturing different areas around them. Then different image techniques can be used to stitch the panoramic scene together.

We used an entry level single (DSLR) Nikon D90 mounted on a Nodal Ninja 3 MKII tripod mount (Figure 2). When taking photographs for a stitched panorama, shots needs to taken from a single viewpoint so that objects in proximity do not change their position against the background in successive shots. This will greatly ease the task of joining the images seamlessly to form a perfect panorama image. Hence, the lens of the camera needs to be kept in a constant position when the camera is rotated to point in a different direction for each shot. The panoramic tripod head and tripod are used for minimise errors by maintaining a constant camera alignment, viewpoint and to allow for rotations and tilting between images.

**Figure 2 : Nikon D90 mounted on a Nodal Ninja 3 MKII tripod mount.**

Panoramic images are captured by turning the camera on the tripod about the optical centre of the camera when taking vertical shot. Vertical shot images which capture more of the sky and ground yield higher resolution panoramas. When photographing stand in the same position and rotate the camera. Starting point of the camera is on the left and takes the first picture. Before rotating the camera, it is necessary to remember where the centre focus point inside the viewfinder is pointing. Then the camera is rotated to the right, until that point is at the centre edge of the frame (Figure 3). This basically means that we are overlapping new image with the first one by approximately 50%. A picture is taken and this process is repeated until the end point. Remembering where the centre focus point is, relative to the scene is the easiest and safest way to ensure the images overlap enough for post-processing software to be able to stitch them later. The selection of photo point locations depends on local topography, accessibility, site specific information that users which to capture, and availability of geo-referenced points (latitude and longitude) in the landscape. The sampling setup should reflect the objectives of monitoring and focus on visible changes. The time interval is also important as photo taken approximately the same time of year when making statements about changes from one year to the next.

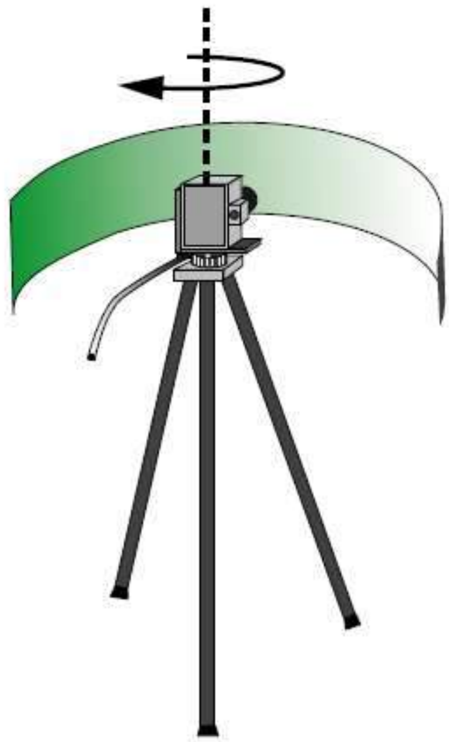

**Figure 3: Turning the camera on the tripod about the optical centre of the camera clockwise direction**

After all photos have been taken, they will be stitched by overlapping the field of view to produce a segmented panorama called photo stitching. Computer software is commonly used to perform this step to produce seamless panorama that can be viewed using a panoramic viewer. Currently there are 36 available photo stitching software on the market, ranging from propriety (Adobe Photoshop;RM2100) to open source (Montage Image Mosaic;free), making deployment costs negligible. Image registration, calibration and blending are the main components in image stitching process. Image registration involves matching features in a set of images or using direct alignment methods to search for image alignments that minimize the sum of absolute differences between overlapping pixels. Image calibration aims to minimize differences between an ideal lens models and the camera-lens combination that was used, optical defects such as distortions, exposure differences between images, vignetting, camera response and chromatic aberrations. While image blending involves executing the adjustments figured out in the calibration stage, combined with remapping of the images to an output projection.

## Result and Discussion

In the 360° Omni-directional imagery study, we tested various aspect of the technology such as field deployment, practicality, software availability, technical challenges and long and short term factors that would affect deployment of this technology in biodiversity monitoring. We took two sets of photos using all-purpose lenses focal length 18-105mm and fisheye lenses focal length 10.5mm at the Hill of Botanical Garden Johor. Each lenses were mounted on a DSLR camera mounting head to ensure a consistent viewpoint. The all-purpose lens required ten photos (Figure 4) while the fish lens only required six photos (Figure 5). Both methods have successfully captured the image of the hill (Figure 6). Zooming the lens to a wide angle, or using a short focal length lens, requires fewer pictures to cover the same view but makes objects in the panorama appear smaller and farther. Using fisheye lenses have disadvantage that distort the image. It provides a relatively rapid and less expensive alternative and higher resolution imagery compared to video as well as the obvious data storage reduction as it generates a smaller data file..

**Figure 4 : 10 Vertical Shot using all-purpose lenses with focal length 18-105mm**

**Figure 5: 6 Vertical Shot using Fisheye lenses with focal length 10.5mm**

**Figure 6: The composite image stitched from the photos taken from the hill in Botanical Gardens Johor**

Monitoring of major changes in forest cover and wetlands is best undertaken by comparing remote-sensing images (photos) taken from air planes or satellites at regular time intervals. However, these methods require funds and especially needs skilled staff, which is not usually available locally in the protected areas. Taking ground-based photos ('360° Omni-directional'), on the other hand, is rather simple, inexpensive often built upon traditional photography skills. The 360° images should be obtained using techniques established in traditional photography. A recording for an area should be taken at least two sequential days in a month, season, or more usually a year, and repeated on the same dates over the desired intervals using similar camera equipment, identical vantage points and photographic scale. This involves measurement of two distinct landmarks or subjects in the photograph. Scales on photographs can help in measuring the extent of impact, i.e. quantitative changes, objectively.

Examination of the images showed that various features crucial in photo-monitoring are visible in the image. The imagery are able to convey information on the flora that provides the different types, structure and health; surrounding environment that provides areas where animals and plants can live and grow and disturbances that shows damage the health of plants and habitats such as surface erosion, invasive species, illegal timber collection and illegal land clearing. It should be able to provide alternative method to improve monitoring and archiving environmental records and is only limited to the static nature of the points and the technological capability of the camera.

Choosing the right site or location is really crucial in producing good quality of 360° Omni-directional images. The best candidates for panoramic images are overlooks, i.e. standing on the top of a mountain or hill, or looking down from an elevated area with no near objects. Watch for wind and other moving objects. Windy condition can cause irregular movement of leaves, grass, water, and sand in different directions, which will result in a bad quality of panorama, hence, if the weather is unavoidable, we can shoot the picture when all the movement is in a single direction. Moving waters (rivers, etc) are best to avoid when taking panoramic picture, since this will cause unclear overlapping region which then affect the stitching process. Tripod has to set on a firm and leveled surface. Unleveled surface will affect the whole process and produce unbalance panoramic image. The software we use to stitch images together can even out the lighting in a scene but it helps if we give it good images to work with. Setting the cameras to autoexposure lock (AE Lock) is essential, to ensure that exposure and white balance are consistent throughout the series of images. Another best practice is to avoid extremes lighting. This issue is clearly occurred on bright sunny days when there are bright highlights and dark shadows. The problem is compounded if we have to shoot some of the pictures facing the sun. The best weather to shoot panoramic pictures is when it's cloudy bright—overcast but with slight shadows on the ground. However, if it is sunny throughout, we can shoot during midday to keep the lighting even.

During our studies, we surveyed and captured 360 imagery in various sites in Malaysia (Table 1) and selective examples of composite images of these sites (Figure 7a, 7b, 7c)

**Table 1: Lists of sites surveyed in the study, their owners (where applicable) and the number of vantage points per site.**

| No. | Site name | No of vantage points |
|---|---|---|
| 1 | Denai Alam UKM, UKM Forest Reserve, Selangor | 29 |
| 2 | Taman Botani Johor, Department of Landscape Johor, Johor, Johor | 31 |
| 3 | Gunung Ledang, Perbadanan Taman Negara Johor, Muar, Johor | 33 |
| 4 | Gunung Panti, Jabatan Perhutanan Negeri Johor, K.Tinggi, Johor | 11 |
| 5 | Gunung Belumut, Jabatan Perhutanan Negeri Johor, Kluang, Johor | 16 |
| 6 | Sungai Bantang, Jabatan Perhutanan Negeri Johor, Segamat, Johor | 8 |
| 7 | Pulau Tioman, Pahang | 10 |
| 8 | Bundu Tuhan, Sabah | 27 |
| 9 | Gua Kelawar, Langkawi, Kedah | 56 |
| 10 | Gua Perak Man, Lenggong, Perak | 2 |
| 11 | Gua Wang Burma, Perlis | 2 |
| 12 | Gua Gelap, Batu Caves, Gombak | 10 |

**Figure 7a: The composite image stitched from the photos taken from cave in Gua Kelawar, Langkawi**

**Figure 7b: The composite image stitched from the photos taken from the top of Gunung Ledang Johor**

**Figure 7c: The composite image stitched from the photos taken from the forest in Sungai Bantang Johor**

## Conclusion

Hence, our result showed that the 360° Omni-directional provides a less expensive alternative with a higher resolution imagery compared to existing video monitoring technology. Other advantages include smaller data storage, thus requiring minimal bandwidth when viewing online. The resolution of the generated images is only limited to the available hardware and the smallest setup cost are negligible as open source technology and improvisation of existing photography equipment is sufficient to create a basic monitoring system. The images can generate ‘‘walk-throughs’’ that capture and annotate the rich detail of the forest flora, monitor changes over time, provide context and functions as a decision support when deriving conclusions regarding the site. It also can be useful for site familiarization during desk studies and provision of illustrative material for report. Photos can be used for discussion as well as demonstration and education purposes. It provides permanent documentation which does not depend on identification skills. The accurate comparison between photographs would allow stakeholders to determine the changes that occur over time. Well-documented images will then be used as a decision support function when deriving conclusions regarding the site. The use of this imagery would be useful in providing “context” and location information to better record, understand and examine our forest biodiversity via a contextual and virtual photo-monitoring imagery. Photos are very useful when presenting and discussing the results of biodiversity monitoring, as most people will be convinced by photographic documentation. We believe that the technology should be taught and used to enhance the practise of monitoring biodiversity.

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