The determination of area and time comparison of the partial solar eclipse at space science center, LAPON

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Abstract. The observation of the partial solar eclipse in Bandung on March, 9th 2016 was done to measure the surface coverage area and to compare to NASA calculation. We have calculated solar disk coverage area based on image data at the maximum contact until final contact of the eclipse. We obtained that maximum eclipse was at 7:21 a.m. (UT+7) with 84.81 % area of solar disk covered by Moon and the end of eclipse was at 8:31 a.m. (UT+7).

1. Introduction
The partial solar eclipse (PSE) occurred in Bandung is in conjunction with the solar eclipse at some regions in Indonesia. Some of Indonesia regions had total solar eclipse occurrence i.e. Bengkulu, Bangka Belitung, Palembang, Palangkaraya, Balikpapan, Palu, Poso, Ternate, and Halmahera. While other regions including Bandung only had a partial solar eclipse.

Solar eclipse occurs when the Moon is between the Sun and the Earth. There are three types of solar eclipse: total, annular, and partial. The types of the solar eclipse depend on the distance and position of the Sun, Moon, and Earth. The total solar eclipse will occur if the angular diameter of the Moon is equal to the angular diameter of the Sun with the position of the Sun, Moon, and observers on the Earth in a line. Partial solar eclipse occurs when the position of the Sun, Moon, and observers on Earth is not perfectly in a line. Whereas, annular solar eclipse occurs when the Moon is too far from the Earth, so the angular size of Moon will be smaller.

The solar eclipse that occurred in Bandung is a partial solar eclipse, which occurred at 6:19 a.m. and ended at 8:31 a.m. based on NASA’s prediction. Observation of partial solar eclipse in Bandung conducted by Pussainsa Eclipse Observation Team. The observations were made on the rooftop Pussainsa. There were also Network Team, Security Team, and Public Relations Team who participated in this event.

Solar eclipse observation has been done by using a telescope system with image recording interval time between 30 to 60 seconds, depend on eclipse's phases. This paper aims to determine the area of Moon that covered the Sun and time for the maximum contact and final contact of the eclipse. The results of these calculations will be compared to NASA calculation or prediction.
2. **Method**

Image data of the partial solar eclipse was observed and documented at 6:53 p.m. Although partial solar eclipse began at 6:19 a.m., this was caused by cloudy conditions. The eclipse observation was done by using BabyQ Takahashi telescope, mounting VIXEN AXD ATLUX DELUX 2115, VIXEN Star Book Ten, Nikon D5500, and VIXEN tripod. Image data were taken every 60 seconds, but approaching the maximum of partial solar eclipse, the data were taken every 30 seconds. The size of images is 4000×6000 pixels. We used MATLAB and Photoshop software to calculate the surface area of the Sun that are not covered by the Moon. However, we had intermittent cloudy conditions. Therefore, the eclipse data were converted into a binary image so that they can be easily proceed. The differences between binary image processing by MATLAB and Photoshop will be explained in the discussion. Calculation of the area was conducted on the binary image, which means only the images that are worth 1 or white will be calculated. So that the output is the surface area of the Sun not covered by the Moon to determine time of maximum and end of solar eclipse.

3. **Discussion**

3.1. **Binary image processing**

Comprehensive calculation method used in this paper is by turning the data into a binary image (black and white). To change the image into a binary, MATLAB was used. However, because the cloudy conditions during observation, the results of binary image by MATLAB were poor. See an example of the conversion process for image at 6:59 a.m. in figure 1 and figure 2.

![Figure 1. Partial solar eclipse at 06.59 a.m.](image1.png)

![Figure 2. Binary image of partial solar eclipse at 06.59 a.m.](image2.png)

Based on the results of Photoshop processing as in figure 3, we determine area of eclipse using MATLAB.
Figure 3. Results of photoshop processing on partial solar eclipse at 06.59 a.m. (UT+7).

3.2. Determination of the area
Calculation has been performed from the surface area of the Sun that has not been covered Moon. The results would be compared to the whole surface area of the Sun when the Moon does not cover the Sun. Data were taken, during the observation, every 60 seconds, but approaching the maximum of the eclipse at 7:19 a.m. until 7:31 a.m, the data were retrieved every 30 seconds. Images were recorded till the end of the solar eclipse at 8:31 a.m..

Table 1. Results of the Sun area that was not covered by moon.

| Time (UT+7) | Area (Pixel Unit) |
|------------|------------------|
| 06:53:18   | $4.97 \times 10^5$ |
| 07:19:16   | $1.43 \times 10^5$ |
| 07:20:00   | $1.42 \times 10^5$ |
| 07:20:16   | $1.41 \times 10^5$ |
| 07:21:00   | $1.41 \times 10^5$ |
| 07:21:16   | $1.42 \times 10^5$ |
| 07:22:00   | $1.43 \times 10^5$ |
| 08:31:16   | $9.27 \times 10^5$ |

Table 1 shows the result of Sun area not covered by the Moon. To find out what percentage of the surface area of the Sun being covered by the Moon can used a simple equation.

$$A_E(\%) = 100\% - \left( \frac{A_i}{A_S} \times 100\% \right)$$

$A_E$ is area of eclipse that the Sun covered by the Moon, $A_i$ is area of data, and $A_S$ is area of the Sun. Covered area at 6:53 a.m. reached 46.34%. We found differences of area of the Moon covering the Sun between the data converted to black and white by Photoshop and MATLAB as seen in table 2.

Table 2. The results of area of the Moon covered the Sun

| Time (UT+7) | Area of The Moon Covered The Sun % (Photoshop) | Area of The Moon Covered The Sun % (MATLAB) |
|------------|-----------------------------------------------|---------------------------------------------|
| 07:19:16   | 84.60 %                                       | 87.34 %                                     |
| 07:20:00   | 84.64 %                                       | 87.36 %                                     |
| 07:20:16   | 84.78 %                                       | 87.43 %                                     |
| 07:21:00   | 84.81 %                                       | 87.49 %                                     |
| 07:21:16   | 84.68 %                                       | 87.59 %                                     |
| 07:22:00   | 84.60 %                                       | 87.50 %                                     |
The difference of percentage area in table 2 is due to differences in the edge detection method of the image area. Figure 4 shows the results of area calculations that processed by Photoshop (a) and MATLAB (b). It appears that the images edges processed by Photoshop are smoother than by MATLAB.

Figure 4. Calculation of Solar Eclipse by (a) Photoshop (b) MATLAB

Table 2 shows that the maximum area reached 84.81% at 7:21 a.m.. NASA predicted that the maximum area of the Moon covered the Sun was 85.86% at 00: 21: 44.8 UT or 07: 21: 44.8 a.m. (UT+7). A significant differences are in area calculation and time occurrence of maximum phase of partial solar eclipse. The differences of area and time occurrence between the calculation and the reference are 1.05% and 44.8 seconds. Respectively, differences may be caused by less subtle edge of the picture. Additionally, the timing method is important, because we recorded time sequence by the camera setting, instead of using GPS timing and images were stored in JPEG format.

4. Conclusion
Solar eclipse image obtained at 6:53 a.m. has percentage of the covered area of 46.34%. Data were taken every 60 seconds and approaching the maximum phase of the eclipse (at 7:19 a.m. until 7:31 a.m) the data were taken every 30 seconds. The time for the maximum contact by calculation was at 07:21:00 a.m. with percentage of 84.81%, while NASA predicted the time for maximum contact was at 07:21:44.8 a.m., with the percentage of 85.86% eclipse. The difference value is caused by the lack of precision of location and time during telescope setting because we did not use GPS to set right variables. Moreover, this difference is also due to the edge determination.

References
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