Test Phase of OWL-Net: Global Network of Robotic Telescopes (2017-2018)

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ABSTRACT

OWL, which was completed in 2016, has been in test operation for two years from 2017 to 2018. During that time, we focused on stabilizing the operation of five OWL observatories through software enhancements and hardware reinforcement work. As of the end of 2018, the average operation rate is more than 90%. We have performed calibration work using standards stars and satellites with known precise orbital elements. As a result, not only satellites but also near-Earth asteroids can be included in observations of OWL-Net. In this presentation, I would like to briefly present our works and results during the test period.

1. INTRODUCTION

OWL-Net (Optical Wide-field patroL Network) is an optical observation system of five stations with 0.5 meter telescopes connected to the Internet. These five observatories are spread across the northern hemisphere with as wide a longitude zone as possible, and the five countries are Mongolia, Morocco, Israel, the United States and Republic of Korea in the order of installation [1]. The headquarter for OWL-Net is at the Korea Astronomy and Space Science Institute. The OWL telescope is equipped with a 4K CCD camera, with a plate scale of 0.98 degrees and a viewing angle of 1.1 degrees x 1.1 degrees. It has five filters (Johnson *B, V, R, I* filters for astronomical use and *C* filters for satellite) and can observe fast-moving celestial bodies such as low-orbit satellites at a high speed of 20 degrees per second [2].
The OWL stations are operated automatically. When the observation schedule is created and sent from the headquarter using seven observation modes for satellite and astronomical targets, each observatory performs its own observations including necessary data processing at the site. For automatic operation, various sensors, including weather equipment, are installed at the stations, and the condition of observation equipment using these sensors as well as operation status are reported to the headquarter through the Internet in real time.
OWL-Net, which was installed in December 2016, began a two-year test phase from 2017. During the test period we set up identical electrical environment for all the stations for maintenance and equipment testing convenience. Various sensors and monitoring system were improved for the stable operation and user convenience. Test observation of artificial and natural objects was carried out to check the stability of the OWL-Net's hardware and software, and we performed the necessary updates based on the test results. This paper briefly introduces what we have done during the test phase.

2. ACTIVITIES FOR ROBOTIC OBSERVATORY

For stable unmanned automatic observation, the most important thing is the stable supply of electricity which can be achieved with frequency converter and UPS (Uninterruptible Power Supply). OWL stations are installed in different countries with different electrical environments. We use different frequency converters for each station. These converters are designed to have different inputs appropriate for the electric environments but the outputs are all the same. We installed the same type of UPS at all the stations. This allowed all stations to be in the same electrical environment.


Fig. 1. Frequency converter and UPS

Fig. 2. Insulators for dome and mount

Large power consumption occurs when the dome and telescope mount move. This can affect electronic equipment including UPS, which is connected to the same electrical circuit. To mitigate these electrical shocks, we installed the insulators. Insulators not only mitigate electrical shocks but also protect internal electric equipment from external electric shocks such as lightning.
Weather information is essential for automatic observation. OWL stations use four key weather information, Temperature, humidity, wind speed, and cloud. If any of the four key values is missing, automatic observation is stopped. We have installed at least three or more sensors to produce each key weather value.


Fig. 3. Multiple weather sensors for each key weather device at OWL station

OWL software for automatic observation run in the background so that we can monitor the status of the automatic operations at all times. The monitoring system was constantly upgraded to accommodate the updates and changes to the observing equipment. As a result, the monitoring system display currently provides the connection status, pointing information of the telescope, schedule information, observation results, and data processing status.

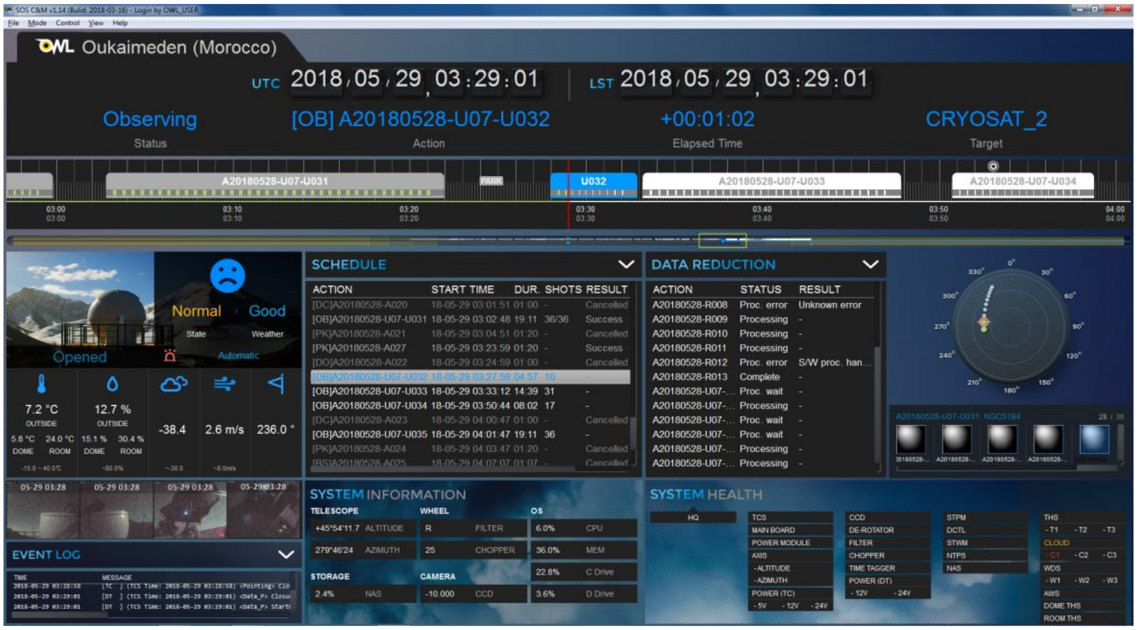

Fig. 4. OWL monitoring system. 1-hour expansion and 24-hour time line. White and blue color means normal or good weather. Yellow color means to be interested. Red color means abnormal conditions or bad weather.

For fast moving objects, OWL uses a chopper to convert the trajectory of the moving object into several line segments, and then obtains the position information of the moving object from the position of the line [3]. We found two main problems that the existing data processing programs create. The first is the double detection problem, which finds more than one point in a single line. Because the lines do not have the same brightness and exact endpoints, it is sometimes difficult to match one point for each. The other is the false detection problem, in which sources other than line segments are detected. We modified the existing data processing algorithm and resolved these problems to some extent. Since fast-moving low-orbit satellites require fast data processing, we are trying to ensure that data processing takes place in real time.

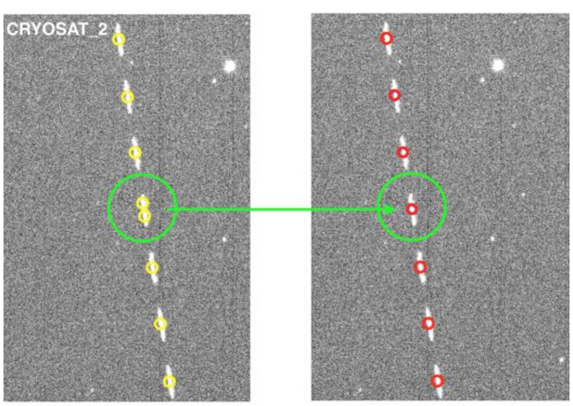

Fig. 5. Algorithm improvement for double detection

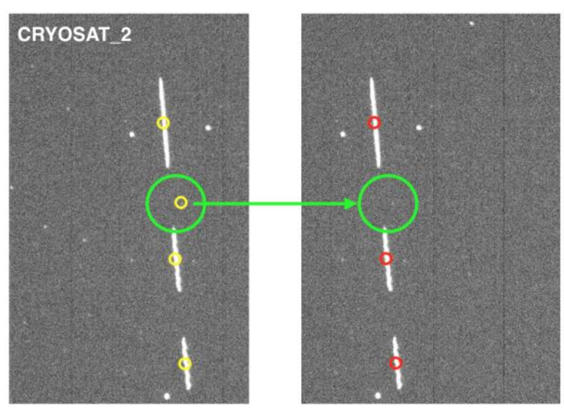

Fig. 6. Algorithm improvement for false detection

Some of the OWL observation time is used for our partners. We needed a way to deliver our partners' observation data after the end of observations. We installed data-sharing system at each OWL station. We call this OWL-NAS (OWL Network-Attached Storage). Upon completion of all observations made at the partner's request, the data are transferred to OWL-NAS along with calibration frames and a brief report file. Partners requesting observation can access OWL-NAS via FTP and take their observation data. Through these efforts for robotic observatory, the operation rate of OWL-Net reached 92.4% in the second half of 2018.

3. TEST OBSERVATIONS

During the test period, we conducted test observations of satellites and natural objects to check the performance of OWL-Net. In the case of satellites, we tested for orbits, confirmation of existence, change in brightness, etc. For natural objects, tests were carried out in terms of measuring brightness and determining orbit.
On May 4, 2017, Republic of Korea's communications satellite Koreasat-7 was launched. Observations were carried out to ensure that the geostationary satellite Koreasat-7 is in its normal position after entering the orbit. We also observed the Chinese space station Tiangong-1, which was nearing re-entry on March 28, 2018.

Fig. 7. Koreasat-7 (2017/05/21)


Fig. 8. Tiangong-1 (2018/03/28)

For PHA (Potentially Hazardous Asteroids) 2014 JO25, which was discovered in 2014 by the CSS (Catalina Sky Survey), OWL-Net was used to observe and measure brightness variations. We also observed PHA 1981 ET3 and NEA (Near Earth Asteroid) 2012TC4 for investigating the scheduling system and observation system for natural objects.


Fig. 9. PHA 2014 JO25 (2017/04/20)

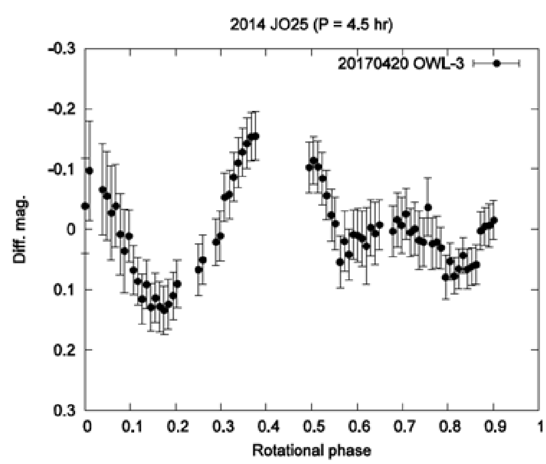

Fig. 10. Light curve of PHA 2014 JO25

4. OUR INTERESTS AND FUTURE WORK

OWL-Net started full-scale operation on January 1, 2019. The main targets to be observed are: (1) domestic satellites (2) re-entry satellites, and (3) NEAs which are of interest to OWL partners. We allocate most of the OWL-Net observation time to these targets. Through these observations, we are interested in the followings: (1) orbit and overall re-entry process (2) photometry of PHA, NEA (3) light variation study of mid- and high-orbit satellites (4) orbit calculation and estimation (5) follow up observation of NEAs (6) improvement of pipeline and image handling (7) observation of GTO satellites.

We continue to improve the pipeline and real-time data processing. Wet will also improve the scheduling system for various purposes. Based on these activities, we will develop automatic observation technique, study orbit calculations and prediction, and participate in the International SSA (Space Situational Awareness) program. In the near future, we hope to develop new OWL telescopes for mid- and high-orbit satellites and dedicated telescopes for NEAs.

5. REFERENCES

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