Orbit Determination for Space Debris Tracking using Laser Ranging and Angular Data from the Encoder for Geochang DLT system

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More accurate Orbit Determination (OD) for space debris are a challenging area due to the growing population of space debris in recent years. A Debris Laser Tracking (DLT) system for space debris has been considered as a new method for more accurate OD results. However, the uncertainty of space debris size and attitude can make imprecise measurement value which can make OD result degrade. In this study, we address novel idea to combine the laser ranging data with an encoder data (angular data; azimuth and elevation) for the OD process. Simulation result using AGI's Orbit Determination Tool Kit (ODTK) shows its improvement of OD results comparing with when only using laser range data for OD.

Keywords: Space Debris, Debris Laser Tracking (DLT), Orbit Determination (OD), Encoder

1. Introduction

Currently, most of the space environment from LEO to GEO has been congested and getting more clustered by these uncontrolled and ultra-speed space debris. Not only protecting assets themselves, but reducing their anti-collision maneuver, providing accurate orbital information of space debris is essential to protect our valuable space asset. For this, the Radar and electro-optical (EO) system have been used for space debris tracking with low tracking accuracy. Thus, An alternative system is needed which is like a laser system for space debris tracking. Korea Astronomy and Space Science Institute (KASI) has a plan to develop a Debris Laser Tracking (DLT) system in Geochang until 2020.

Orbit determination only using range measurement of DLT system brings limits in the achievable accuracy (Cordelli, Vananti et al, 2017). DLT can regard as a Satellite Laser Ranging (SLR) System for space debris. But the accuracy of measurement error is quite different. In case of SLR for satellites with retro-reflectors has about one centimeter or better. On the other hand, DLT for space debris has about 1 meter from some representative systems

(Graz : 0.7m, Shanghai : 0.6 ~ 0.8m, Mt. Stromlo : better than 1.5m RMS) (Zhang, Yang et al, 2012, Kirchner, Koidl et al, 2013). The uncertainty of debris size and attitude grow its range measurement error (Zhang, Yang et al, 2012). This inaccuracy of range measurement makes poor OD accuracy results.

To alleviate this issue, many related works are to combine additional data with the range data of DLT during the OD process (Li, Sang, Zhang et al, 2016, Bennett, Sang et al, 2015). Back to the basic principle, good measurement for OD might come from small measurement error, small noise condition, number of observation and geometry of observation (Cordelli, Vananti et al, 2017). Meaning of these factors are accurate, enough and dense data would help to make OD result accurately. Particularly, a geometry of observation such as angular data can help range data cover 3-dimensional orbit position; radial, in-track and cross-track. Thus, we address a novel idea for OD process to use angular data from the encoder with laser ranging data from Geochang DLT system. Look at Figure 1, All points of each range data have angular data from the encoder. We extract the angular data from encoder correspond to full-rate after data processing.

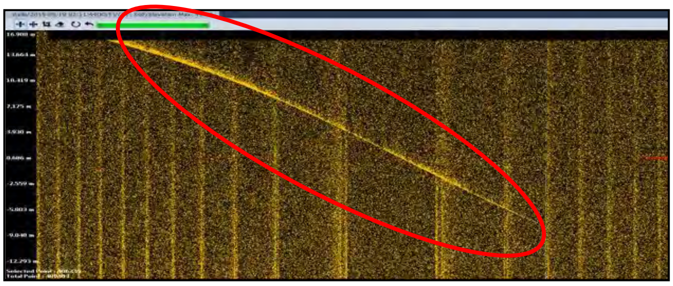

Fig. 1. Range data with angular data from the encoder

In this paper, this idea was investigated based on AGI's Orbit Determination Tool Kit (ODTK). Both range and angular data were generated with its measurement error value. Especially, the measurement error of encoder is analyzed and assumed.

2. Encoder and Measurement Error Analysis

Tracking Mount System (TMS) system is one of the main parts in Geochang system to track space object accurately. The high-resolution angular detecting sensor which called the encoder is needed to obtain good pointing and tracking accuracy. Cutting edge angle encoder made by HEIDENHAIN company in German has been selected to satisfy the requirement of TMS as the value of dynamic tracking accuracy below 2 arcseconds.

Applying for ODTK simulation, measurement errors of angular data from encoder should be analyzed. Remarkable factors of measurement errors of angular data from the encoder are C-SPAD field of view, pointing and tracking the accuracy of TMS for orbiting space object, not for stars and time synchronization error. However, setting up of the simulation environment would be good for assuming the worst case. We decided to give some additional value for assuming the worst case. In this study, C-SPAD field of view is regarded as 12 arcseconds from product specification. And pointing and tracking accuracy for orbiting space objects can be assumed as 10 arcseconds, which value is 5 times bigger than the calibration case which is pointing and tracking star. The value of time synchronization is negligible because the numerical number is so small. Lastly, for the worst case scenario takes additional values as 7 arcseconds. Thus, the total measurement error of angular data from the encoder which inserts to ODTK setting is 20 arcseconds.

3. ODTK simulation set up

We only considered Geochang DLT system with laser range and angular data from the encoder for simulation. Our simulation setup procedure was followed by ODTK guidelines (Vallado et al, 2010). We selected a period of measurement as 1 pass like Table 1. This period depicted short-arc and sparse data condition considering the difficulty of space debris acquisition.

Pass	Start Time (UTCG)	Stop Time (UTCG)	Duration (min)
1	29 May 2018 18:29:05.146	29 May 2018 18:31:05.146	2

Tab. 1. Period of measurement for Norad ID 43031 from Geochang DLT system

Earth gravitational effect was modeled using an EGM08 100 by 100 gravity model. And the density model used is the NRLMSISE 00 model. Target space debris is Norad ID 43031(CZ-2C R/B). Its expected mass and size is 5000kg and Radius 3.5m/length 8m, respectively. Its shape is cylinder type and area is 50 square meter. Measurement errors and time span are like below Table 2.

Measurement Type	Measurement Error	Time Span
Range	Range (1m)	1 sec
Angular (Encoder)	20 arcseconds ≈ 0.005 Deg	1 sec

Tab. 2. Measurement Errors and time span for simulation

4. Simulation Result of Orbit Determination

Two kinds of results can be analyzed from the simulation. The first one is position difference which means comparison between true orbit and determined orbit for presenting OD accuracy. The second one is position uncertainty that shows how much we can trust OD result. The result of OD is like below Table 3 and Figures 2, 3 and 4. Radial, In-Track and Cross-Track present R, I and C, respectively. And 3D means 3 Dimensional value.

Position Difference (m) - RMS -	OD Case	Data type	3D	R	I	C
	(1) DLT Only	Range	892.7	673.6	88.1	579.2
	(2) DLT + Encoder	Range + Angular	93.4	19.1	78.2	47.3

Position Uncertainty (m) - Mean Value -	OD Case	Data type	3D	R	I	C
	(1) DLT Only	Range	195.7	115.4	88.9	130.7
	(2) DLT + Encoder	Range + Angular	66.5	16.6	52.9	36.7

Tab. 3. Result of OD (Position Difference/Uncertainty)

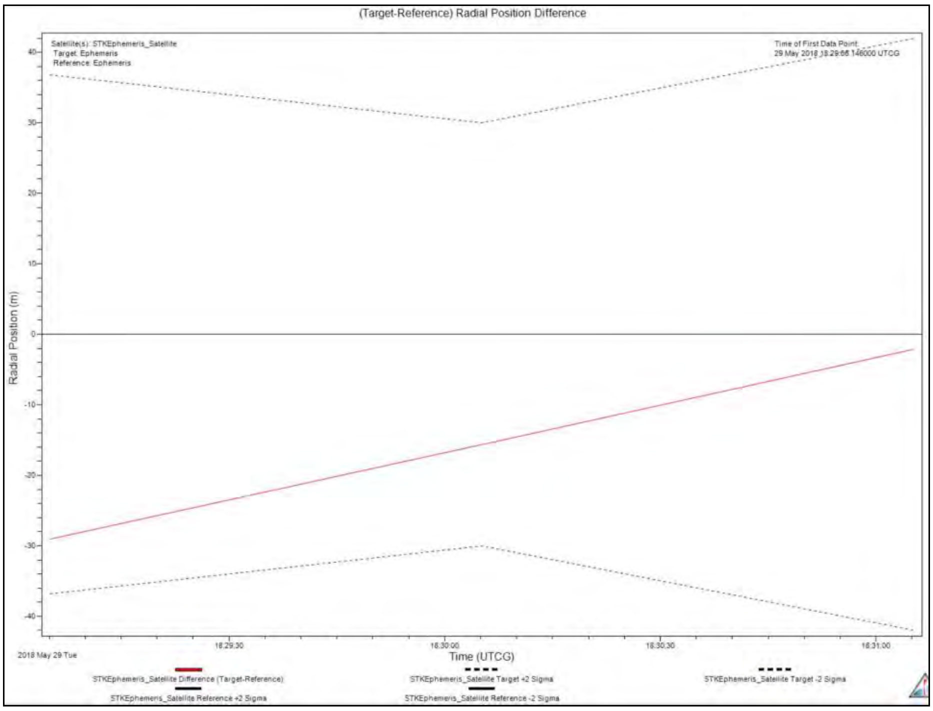

Figure. 2. Graph of DLT with Encoder (Position Difference Radial)

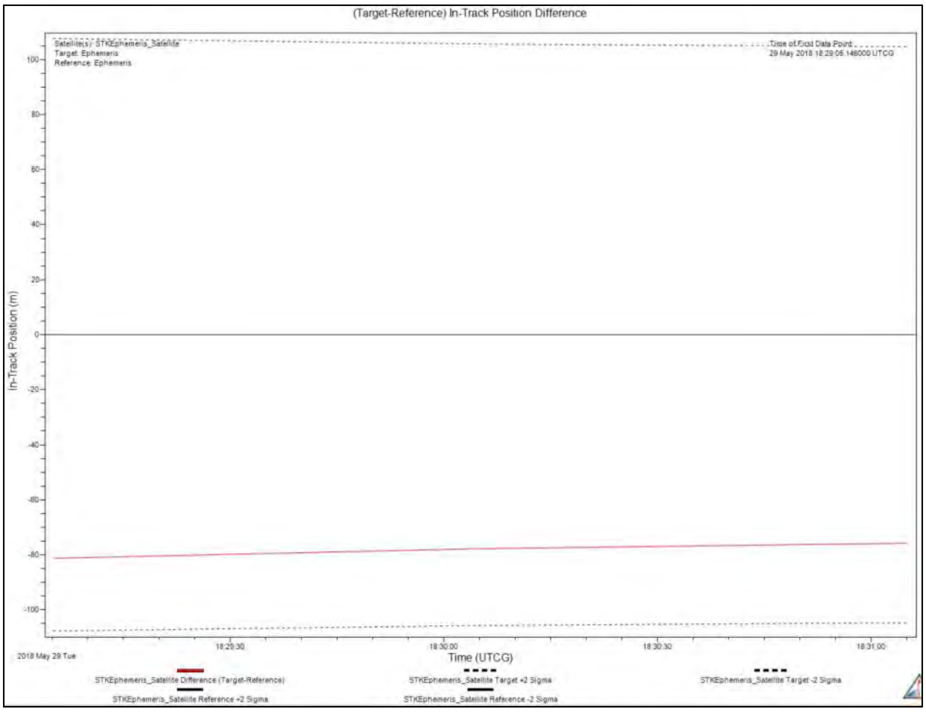

Figure. 3. Graph of DLT with Encoder (Position Difference Intrack)

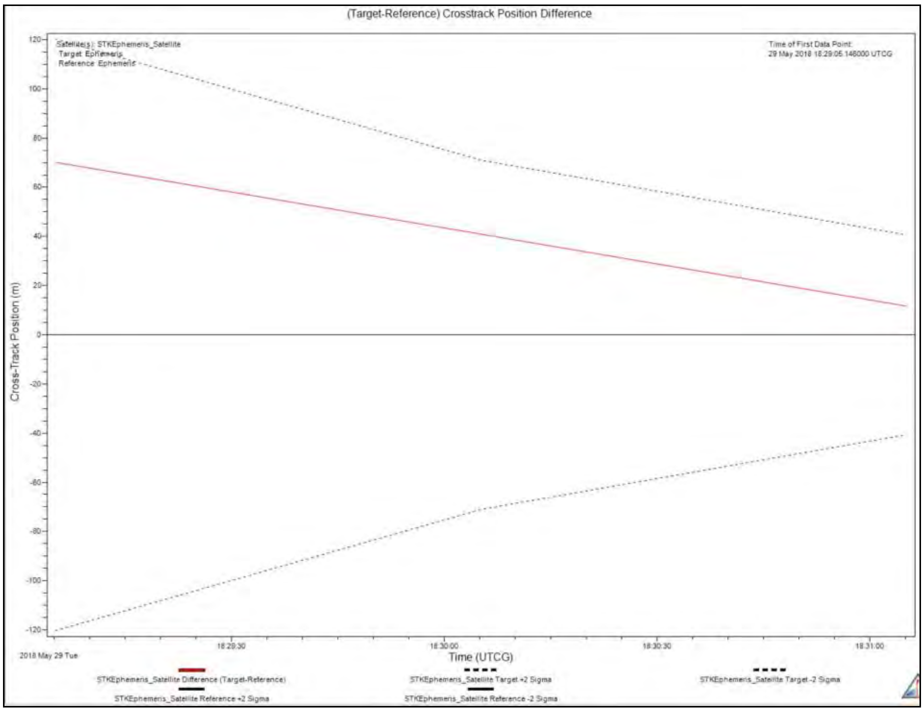

Figure. 4. Graph of DLT with Encoder (Position Difference Crosstrack)

4. Conclusion

The simulation result in this summary indicates that significant improvement of OD, when combining laser range data with encoder angular data. Looking to position difference result; DLT system only result (3D : 892.7m) and using DLT + encoder result (3D : 93.4m), Using DLT + encoder result shows 89.6% decreasing of position difference. And position uncertainty result; DLT system only result (3D : 195.7m) and using DLT + encoder result (3D : 66.5m), Using DLT + encoder result shows 66.1% decreasing of position uncertainty. Especially, a value of position difference (3D : 93.4m) might expect to enough small which can do unaided laser ranging when extending its OD result to predict until no sun-illuminated and visible time. Future works will be determined more; its possibility of unaided laser ranging for breaking terminator session when using laser ranging data with encoder data for Orbit Prediction (OP). System implementation to extract encoder value will be followed. And finally, the result of OD/OP using real observation data (Laser and encoder data) will be verified.

References

Zhong-Ping Zhang, Fu-Min Yang, Hai-Feng Zhang, Zhi-Bo Wu, Ju-Ping Chen, Pu Li and Wen-Dong Meng, The use of laser ranging to measure space debris, Research in Astron. Astrophys. 2012 Vol. 12 No. 2, 212–218

Georg Kirchner, Franz Koidla, Fabian Friederich, Ivo Buske, Uwe Völkerb, Wolfgang Riede, Laser measurements to space debris from Graz SLR station, Advanced Space Research, Volume 51, Issue 1, 1 January 2013, Pages 21-24

E. Cordelli, A. Vananti, and T. Schildknecht, Fusion Of Laser Ranges And Angular Measurements Data For LEO And GEO Space Debris Orbit Determination, Proc. 7th European Conference on Space Debris, Darmstadt, Germany, 18–21 April 2017

Li B, Sang J, Zhang Z, A Real-Time Orbit Determination Method for Smooth Transition from Optical Tracking to Laser Ranging of Debris, Sensors, 2016 Jun 24;16(7)

J.C. Bennetta, J. Sang, C. Smith, K. Zhang, An analysis of very short-arc orbit determination for low-Earthobjects using sparse optical and laser tracking data, Advances in Space Research 55(2) · January 2015

David A Vallado, Orbit Determination Using ODTK Version 6, Getting Started Processing SLR data with ODTK, May 2010

Degnan, J. J, Millimeter Accuracy Satellite Laser Ranging: A Review, Contributions of Space Geodesy to Geodynamics: Technology, Geodynamics Series, 25, 133-162, 1993.