A ROVER SIMULATION TOOL FOR SMALL BODY EXPLORATION. T. Harada[1], K. Kitazato[2], N. Hirata[1, 2], H. Demura[1, 2], and N. Asada[1], [1]Department of Computer Science and Engineering, University of Aizu, Aizu-Wakamatsu City, Fukushima 965-8580, Japan, [2]Center for Advanced Information Science and Technology, University of Aizu, Aizu-Wakamatsu City, Fukushima 965-8580, Japan.

Introduction: Planetary rovers play an important role in detailed surface explorations of mission targets. In the Japanese Hayabusa-2 mission, which is planned to be launched in 2014 toward sample return from a C-type asteroid (162173) 1999 JU3, a small rover called Minerva-2 will be equipped. The Minerva-2 is a replica of the Hayabusa's rover Minerva carrying a pair of stereoscopic imaging cameras, one short focal length camera and thermal probes [1]. Because of the micro-gravity environment on the asteroid surface, hopping motion has been applied to the rover's mobility system. That is achieved by a turntable for orientation and a torque wheel device for reaction forces against the asteroid surface. In general, small bodies have an irregular shape so that the trajectory of a hopping rover would be complex. Thus, a simulator that accurately estimates the rover motion is required for the reliable and efficient rover operation. Such a simulator, however, has not been developed although there are several simulation tools targeting wheel-type rovers for lunar and martian surface explorations [2,3]. We have developed a simulation tool of the hopping rover for small body exploration.

System architecture: A primary requirement on the rover simulator is to implement physics-based computing of the rover motion and its visualization. Given a gravitational field and the rotational state of the target body, the equations of motion in a body-fixed coordinate system can be written [4]. We developed a function to compute the rover trajectory by solving those equations of motion with a fourth order Runge-Kutta numerical integrator. Here we use a polygon shape approximation to derive the gravitational field of irregularly-shaped body with a constant density [5]. This approach enable to determine the rover collision with polygon surfaces, but requires the computational time because every time the gravitational potential are evaluated. We consider a simple model that ignore the friction fource for the rover's rebound on the surface. In this simulator, computations of the rover trajectory are carried out through the input of parameters of the rover's initial position and velocity vectors, and of a polygon shape model of the target body. The computational result is output to a text file and users can display it in a 3D viewer and 2D graph window (Figure 1). In addition, a function to produce synthesize images of the onboard camera view was also developed.

Our simulator basically has been implemented with the Java technologies. That graphics rendering engine uses JOGL, the OpenGL 3D graphics API for Java programming language.

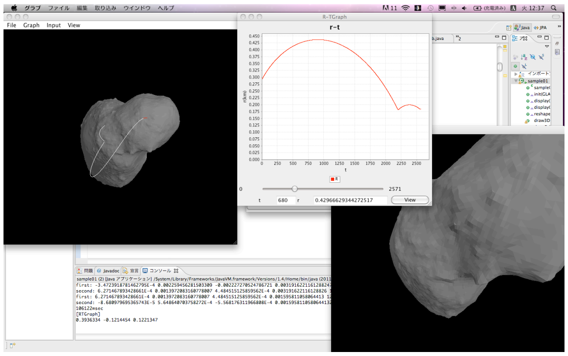

Figure 1. Graphical user interface of the hopping rover simulator developed in this study.

Experimental results: The lifetime of Minerva on the asteroid surface depends on the battery power, that is, its long-term operation requires a long stay on the daytime region where the solar panels are illuminated by sunlight. Such an effective operation of the rover may be derived from the trajectory cumputations with this simulator. Then, we carried out experiments with a shape model of asteroid Itokawa to assess the performance of this simulator. In this experiment, we used two types of shape models; a low-resolution model of 3,072 facets and a middle-resolution model of 49,152 facets. The average runtime to process a computation of rover trajectory resulted in 106 seconds for the low-resolution model and 1857 seconds for the middle-resolution model.

Conclusion and future works: We have developed a hopping rover simulator for small body exploration. It would be useful for the rover's operational testing. To date, only gravitational force has been considered in the rover's dynamical model so that radiation pressure and electric force should be added for more accurate computation of the rover trajectory. In addition, we will refine the model of rover's rebound on the surface in future work.

References: [1] Yoshimitsu, T., et al. (1999) *ESA SP-440*, 83. [2] Yen, J. et al (1999) *EAS SP-440*, 249. [3] Yang, Y-C., et al. (2008) *Int'l Journal ARS* 5, 2, 201-208. [4] Scheeres, D. J., et al. (1996) *Icarus* 121, 67-87. [5] Werner, R. A., and Scheeres, D. J. (1997) *Celestial Mech. Dynam. Astron.* 65, 313-344.