Abstract for the ICRA11 Space Robotics Workshop

Wheels, Tracks and Reciprocal Walking: Challenges to Loose and Steep Slopes

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Mobile robots (rovers) have shown successful mobility on the Martian surface for exploration tasks. However, rovers also showed limitation of traversability in difficult terrain, in particular, loose soil environment. The authors' research group in Tohoku University has been investigating the traction mechanics of wheels and tracks to answer the question: what is good design and smart control laws for future planetary and lunar exploration rovers. In the previous workshop at ICRA2010, we reported that tracks show better performance for loose and steep slopes in general although, wheels can also show good performance with bigger diameter. This year, in the ICRA2011, we will present three representative designs to challenge steeper slopes. Our indoor and outdoor field tests show that all the following designs can climb loose soil slopes up to very high inclination that is close to the critical angle of repose of each soil.

1. **Big Wheel Rover**
This rover has two big wheels with grousers (see Fig.1). The wheel diameter is 420 mm and the height of grousers 50 mm. Total mass is about 15 kg. The design looks similar to AXEL [1], but our Big Wheel Rover does not have tethers yet can negotiate steep slopes by own motors. We have been developing two wheel rovers for many years for students' design training [2][3]. Table 1 show the comparison of slope climbing performance with our previous four-wheel rover named El-Dorado-II [4]. Even though the load on each wheel is almost the same between Big Wheel Rover and El-Dorado-II, the Big Wheel Rover shows much better performance. The reason is the effect of large diameter of the wheel. The Big Wheel Rover shows successful climbing on 40 degrees slope of dry pebble (material is like pumice or scoria), which angle is very close to the critical angle of repose of the soil material.

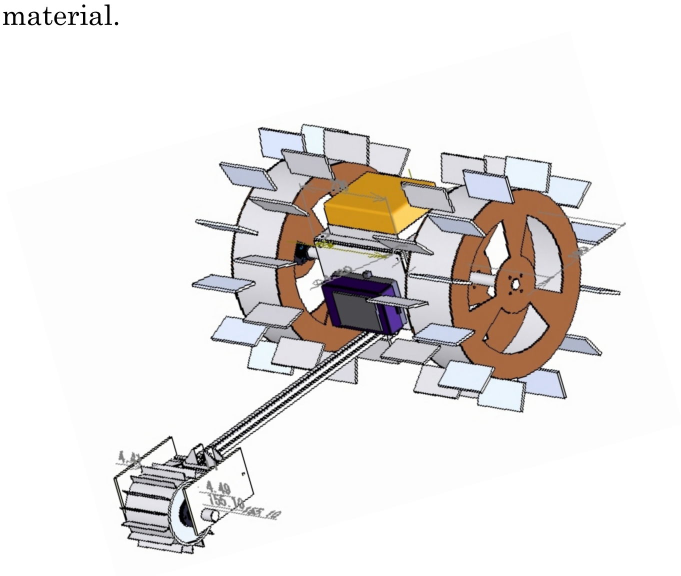
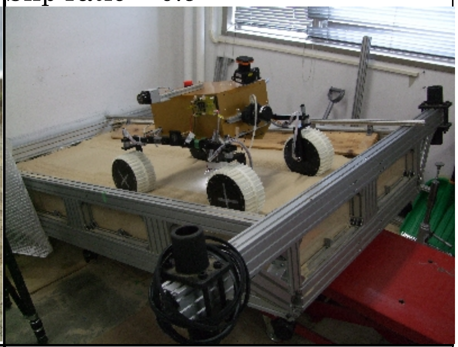
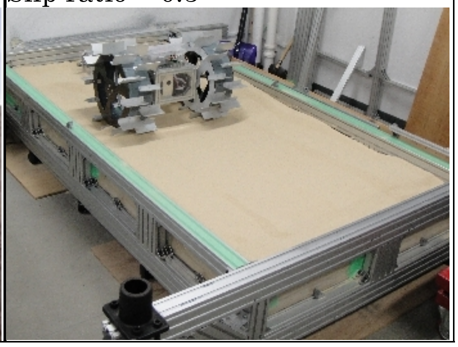


Fig.1 A design illustration of "Big Wheel Rover"

Table 1: Comparison of slope climbing performance between a traditional four-wheel rover and a novel dual-wheel rover with a large wheel diameter

	Outdoor testing (“Yuriage” beech, Sendai, Japan)	Indoor testing (“Toyoura” sand, a type of dry quartz sand)
El-Dorado-II (wheel diameter = 200 mm)	Slope angle = 20 deg Slip ratio = 0.7 	Slope angle = 16 deg Slip ratio = 0.9 
Big Wheel Rover (wheel diameter = 420 mm)	Slope angle = 20 deg Slip ratio = 0.1 	Slope angle = 20 deg Slip ratio = 0.3 

2. Blade Walker

Walking can show better performance in loose steep slopes in avoiding shear destruction of the soil that is usually observed under the wheels or tracks. A rover test bed named Blade Walker was developed to test the performance of walking type of traversal with a relative large area of foot print. As shown in Fig.2, it has a design of a pair of foot blades (flat shoes): two side shoes and one under the main body, connected by a simple crank and stepping on the surface reciprocally. The Blade Walker shows a nice slope climbing capability with 40 degrees of slopes in both sand dune (Fig. 3) and snowy-surface environment [5]. The reason of good performance is considered the effect of treading action (compaction) of the soil surface.

3. Track Walker

Another challenge is a combination of walking and track crawling. We developed a new machine named Track Walker by adding a crawler belt at each foot in Blade Walker (See Fig. 4). Most of field can be traveled by tracks. Obstacles can be stepped on and ridden over the crawlers. In addition, loose and steep slopes can be trod by the stepping action like Blade Walker. Now a various field testing are conducted in slopes of volcanic mountains, which could be a good analog of lunar or planetary surfaces.

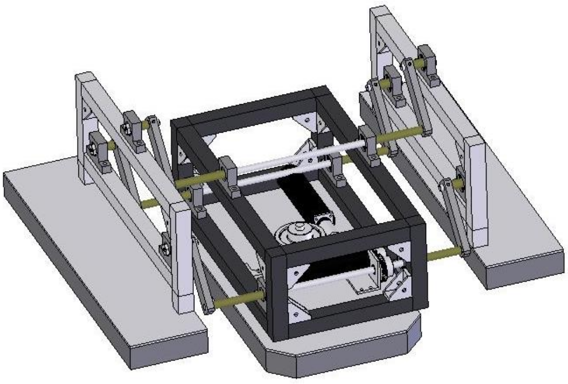


Fig.2: (left) A design illustration of "Blade Walker"
Fig. 3: (right) Field test of the Blade Walker in a sand dune

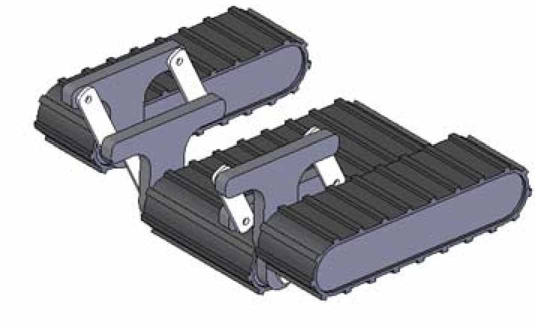


Fig.4: (left) A design illustration of "Track Walker"
Fig. 5: (right) Field test of the Track Walker in a volcanic mountain

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[2] Ishigami, G., Mizuno, N., Miwa, A., and Yoshida, K., "Long Range Navigation on Desert by a Dual-Wheel Micro Rover," The 24th International Symposium on Space Technology and Science, ISTS2004-k-07, 2004.

[3] Kazuya Yoshida, "ARLISS Comeback Competition: Six-year History of Autonomous Rover Challenge," The 26th International Symposium on Space Technology and Science, ISTS2008-u-20, 2008.

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[5] K. Yoshida, K. Nagatani, K. Tadakuma, H. Kinoshita, "Design and Development of Surface-contact-type Mobile Robot to Traverse on Weak Soils and Steep Slopes," ROBOMEC2009, 2P1-D17, 2009 (in Japanese).