Testing the traversability of a ground vehicle transportable by UAV at the foot of a volcano

KOKUSAI-KOGYO,co,ltd ○Yukino Hiroki, Toru Shimada, Mina Kobayashi
University of Tsukuba Keiji Nagatani
Swiss Federal Institute of Technology in Lausanne Nana Obayashi, Kieran Gilday, Max Polzin, Josie Hughes

1. Introduction

During a volcanic eruption, access to the area around the crater is restricted, making it difficult for people to visually assess the damage and volcanic activity. One method to examine the situation within the restricted area is to deploy a remotely operated autonomous vehicle equipped with a camera. However, because the area around a volcano is often rugged due to eruptions, a vehicle capable of smoothly traversing rough terrain is required. Additionally, as the vehicle will operate in areas inaccessible to humans, it must be sized and weighted for transport by a UAV (drone).

A research team at the Swiss Federal Institute of Technology in Lausanne (EPFL) developed and designed a vehicle to meet these requirements. Given the lack of prior driving experiments in Japan, we conducted driving and UAV transport experiments on rough terrain near Mount Asama.

This presentation reports on the driving experiments of a foldable ground vehicle, transportable by UAV, on rough terrain, confirming its operability and performance.

2. Vehicle Characteristics

The characteristics of the ground vehicle used in the experiment are as follows:

- It has four wheels with radially arranged wires that firmly grip the ground, allowing it to overcome obstacles up to the radius of the wheels on rough terrain and steep slopes (Photo 1).
- The wheels come in various sizes and can be changed according to the driving environment.
- The vehicle's frame is flexible and capable of significant elastic deformation. By twisting or rounding, the vehicle can escape obstacles or depressions during driving (Photo 2).
- The vehicle is very light and floats on water. The wheels act as paddles, enabling water travel (Photo 3).
- The wheels are attached to the center of the vehicle's height, making it indistinguishable between top and bottom. Therefore, even if the vehicle flips over, it can continue driving.
- The center of the vehicle houses a palm-sized control device and a small camera.
- The camera's footage is transmitted to the operator's head-mounted display (HMD), allowing for remote operation while viewing the camera feed. When operating the vehicle nearby, the operator can also control it visually using a handheld remote control, without relying on the HMD.

3. Experiment Overview

The trial experiment was conducted from August 26 to 27, 2024, at the Katafuta River construction site and upstream site on the east side of Mount Koasama, where the Katafuta No. 1 dam is located. These locations are composed of pumice from the eruption of Mount Asama, with natural undulations and erosion grooves (gullies). The experiment mainly involved

Table 1: Vehicle Characteristics

Total length	0.75m
Height	Equivalent to the wheel diameter
Weight	1.2kg
Diameter of each wheel type	20cm、30cm、36cm
Maximum speed	1.1m/s at 12V (In the case of the 20cm diameter wheel)
Wire specifications and features	4mm diameter fiber glass rods
Battery capacity	Voltage：11.1V Capacity ：1600mAh

Table 2: Types of Experiments

	Location	Conditions
①	A gentle slope with patches of rocks and grass	Slope: Less than 30°
②	Steep slopes	Slope: More than 40°
③	Gully terrain	Gully: Width 2m Height 3m
④	Driving after UAV transportation	Transportation distance: 140m

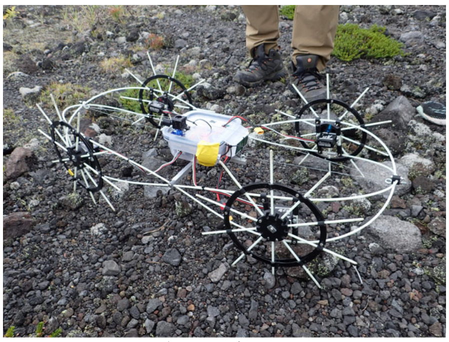

Photo 1: Vehicle used

Photo 2: Wires contracted

Photo 3: Driving on water

four types of driving tests (Table 2). In tests ① to ③, the operator stood near the vehicle and visually confirmed it while driving. In test ④, the vehicle was transported by UAV, and remote operation was performed based on the camera footage transmitted from the vehicle.

4. Experiment Results

The experiment results are described according to the experiment overview numbers.

① A gentle slope with patches of rocks and grass

The vehicle's wheels gripped the ground's undulations, allowing smooth driving. The gentle slope ensured that the wheels did not slip even in areas with many pebbles, and stable speed was maintained both uphill and downhill. In areas with grass taller than the vehicle's height, grass occasionally tangled in the wheels, but the vehicle could escape by moving back and forth.

② Steep slopes

When attempting to climb steep slopes vertically, the wheels often rolled the pebbles downward, causing slippage. Therefore, it was confirmed that climbing slopes as high as 1.5 meters was difficult. Horizontal movement on steep slopes also did not show smooth driving. Generally, the steeper the slope, the more the wheels slipped or the robot flipped over midway, requiring about ten attempts to climb the slope.

③ Gully terrain

Driving in artificially created gullies about 2 meters wide often resulted in the vehicle getting stuck in the grooves and unable to proceed. In such cases, the robot was able to escape by utilizing its flexible wires to round itself. Additionally, stones up to 40 cm in size were present, which the vehicle could not climb over, requiring it to go around them. Various wheel sizes were tested, and successful climbs were achieved at times.

④ Driving after UAV transportation

Assuming driving in areas where people cannot enter, the vehicle was lifted by UAV and transported approximately 140 meters within the experimental site. A winch was attached to the UAV for lifting and lowering the vehicle, and a mechanism (using the hook on the electric winch) was used to detach the vehicle upon landing. Remote operation was performed with the vehicle and operator up to 100 meters apart using the HMD. The detachment from the UAV was smooth, and the vehicle could start driving immediately after landing. The route included slopes up to 30° and tall grass, but communication from the operator was smooth, and the vehicle successfully traveled about 100 meters.

5. Conclusion

During a volcanic eruption, it is necessary to install equipment to monitor volcanic activity, collect ejecta and volcanic ash, etc. Before transporting equipment, it is essential to understand the local situation as part of initial response measures. The vehicle used in this experiment is not suitable for equipment transportation, but it is expected to be useful for confirming disaster situations in restricted areas during volcanic disasters, utilizing the traversability confirmed in this experiment.

Acknowledgments: This work was supported by JST [Moonshot R&D Project] Grant Number [JPMJMS2032]. We would like to thank the Ministry of Land, Infrastructure, Transport and Tourism's Tone River System Sabo Office for providing the test field for the field experiments.

REFERENCES

Max Polzin, Qinghua Guan, Josie Hughes, Robotic locomotion through active and passive morphological adaptation in extreme outdoor environments (Science Robotics, 2025)

【Photos for Each Type of Driving Experiment】

Photo 4: Driving in areas with scattered pebbles and grass

Photo 5: Driving on steep slopes

Photo 6: Driving in gully terrain

Photo 7: UAV transportation