

## Development of a tracked mobile platform with adaptive locomotion capability for operations in nuclear power plants

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### 1. Introduction

Nowadays, unmanned monitoring and automatic responses using robots are widely attempted in various industrial facilities to protect human workers from harmful conditions such as noise, extremely high or low temperature, toxic environment, and radiation. Nuclear power plants are also one of the facilities that the human workers can be exposed to the harmful conditions. To utilize robots in the nuclear power plants, the mobile platform should be considered first to approach desired locations. Mobile platforms can be categorized by their configurations: wheeled, tracked, legged (biped or quadruped), and legged-wheeled. Legged or legged-wheeled types have advantages of climbing stairs and passing through uneven terrain environments, but they have very limited payload capability compared to other types of mobile mechanisms. Since the wheeled mobile mechanism is very limited to climb stairs, the tracked type of mobile platform can be a proper solution for the robots operated in nuclear power plants.

PackBot (Endeavor Robotics, USA) is one of the most representative robots of the tracked mobile platform, and it was implemented to damaged Fukushima nuclear power plant in 2012 [1]. Chiou *et al.* utilized Telemax (AeroVironment, USA) as a mobile manipulator to conduct operator-controlled emergency response activities [2]. Park *et al.* proposed a hydraulic-powered mobile manipulator for a nuclear disaster response robot named Armstrong, and a tracked mobile platform was integrated to carry heavy payloads stably in an irregular terrain environment [3]. However, conventional tracked mobile platforms were mainly focused on teleoperation that the operator manually controls every motion of the robots.

In this paper, we propose a novel tracked mobile platform named TALON for operations in nuclear power plants. It consists of a body, independently controlled four track arms, and perception sensors to recognize indoor structure and near terrain information. TALON can control the flipping angle between the ground and the track arm according to the obtained spatial information, including indoor structure and terrain information, so it can adaptively control its posture and increase locomotion stability. We designed, fabricated, and assembled a real prototype of TALON, and conducted an experiment to verify its locomotion



Fig. 1. Complex indoor environments with several narrow stairs and passages of HANARO which is a research reactor of KAERI.

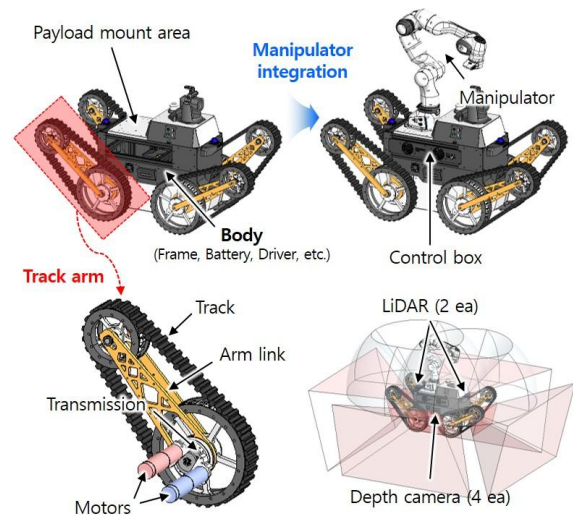


Fig. 2. Structure of TALON consists of a body, four track arms, payload mount area, and perception sensors (LiDAR and depth camera).

stability and maneuverability in multiple stair-included driving environments.

### 2. Tracked Mobile Platform with Adaptive Locomotion Capability

Proposed TALON was developed considering indoor structural characteristics of nuclear power plants. As shown in Fig. 1, the internal structure of a nuclear power plant consists of narrow passages and stairs, so the robot operating inside should be able to move and turn within these narrow pathways. Therefore, the total length and width of TALON were designed to be smaller than 650 mm and 850 mm, respectively, which



Fig. 3. Fabricated and assembled TALON.



Fig. 4. Sequential steps (STEP 1 to 4) of a stair climbing experiment with global and local view data

are very challenging limitations for a mobile platform. Also, required performance specifications for actuator-related components (motors, drivers, batteries, etc.) were selected considering the stair climbing conditions, which require relatively high torque on each motor.

Structure of TALON consists of a body and four track arms as shown in Fig. 2. Each track arm can independently rotate its arm link and drive its track using two motors and transmission mechanism. These independent control of track arms enable adaptive locomotion in irregular or complex terrain environments. Inside the body, electric components such as motor drivers, batteries, DC converters, and control computer are mounted to a frame, and payloads can be mounted to a payload mount area which is located upper rear of the platform. For an example, a manipulator and control box of Franka Research 3 (Franka Robotics, Germany)

can be integrated as upper right of Fig. 2. To recognize indoor structure and near terrain information, TALON utilizes two types of perception sensors: two LiDARs (MID-360, LIVOX, China) and four depth cameras (RealSense D435if, Intel, USA). Field of view (FOV) of each sensor are represented in lower right of Fig. 2. The point clouds gathered from the LiDARs can be utilized for mapping and localization, and the point clouds gathered from the depth cameras can be used to recognize dynamic or unexpected obstacles and near terrain information, including stairs and steps, to evaluate traversability.

To verify the concept and performance of TALON, the prototype was fabricated and assembled as shown in Fig. 3. The size and weight of TALON are 602 mm (W)  $\times$  825 mm (L)  $\times$  832 mm (H) and  $\approx$  110 kg, respectively. Figure 4 shows sequential steps (Step 1 to 4) of a stair climbing experiment conducted by the TALON prototype. Global view and local view (Front image, rear image, and point clouds) data were obtained for each step as shown in Fig. 4. As a result, TALON successfully approach a target stair (Step 1), climb first stair section (Step 2), turn direction at stair landing (Step 3), and climb second stair section (Step 4). The results show the developed TALON can operate within a complex environment including narrow passage and multiple stair sections using four independently controlled track arms and can simultaneously obtain spatial data using integrated perception sensors.

### 3. Conclusion

In this paper, we propose a novel tracked mobile platform, TALON, which can generate adaptive locomotion by utilizing its perception sensors and four independently controlled track arms. We designed, fabricated, and assembled a real prototype of TALON, then conducted an experiment to verify mobile capabilities of the developed platform. According to the results, TALON successfully moves through multiple stair-included pathways in stable motions by gathering spatial data. In future works, autonomous terrain adaptation and navigation of TALON will be developed for applications of automatic surveillance, monitoring, and response in nuclear power plants.

### REFERENCES

- [1] S. Kawatsuma, M. Fukushima, and T. Okada, "Emergency response by robots to Fukushima – Daiichi accident: summary and lessons learned," *Industrial Robot*, vol. 39, no. 5, 2012.
- [2] M. Chiou et al., "Robot-assisted nuclear disaster response: Report and insights from a field exercise," *2022 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, Oct. 23-27, 2022, Kyoto, Japan.
- [3] J. Park, J. Lee, and K. Im, "Development and field test of a nuclear disaster response robot, Armstrong," *Korean Nuclear Society Spring Meeting*, May 19-20, 2022, Jeju, Korea.