Crawler Mechanism for Omni-Directional Movement Using Multiple Subcrawlers

Hiroaki Yamamoto\textsuperscript{1}, Geunho Lee\textsuperscript{2*}, and Kazuma Takemoto\textsuperscript{1}

\textsuperscript{1}Faculty of Engineering, University of Miyazaki, 1-1 Gakuen-Kibanadai-nishi, Miyazaki 8892192, Japan
\textsuperscript{2}geunho@cc.miyazaki-u.ac.jp

Introduction The recent advances of mobile robots allow to perform dangerous tasks in various rough terrains such as construction sites and/or disaster sites instead of human workers. Practically their locomotion mechanisms have been mainly used for the crawler devices. Generally, mobile robots equipped with the crawlers have high movement performance at rough sites with lot of rubble. However, accurate robot positioning such side movement is a difficult problem with the crawler mechanism. To overcome this limitation, there are several studies on crawler devices capable of multi-directional movements such as mechanism using active subcrawlers. From the positioning viewpoint, these devices differ from ordinary multi-directional mobile robots. For the reason, a special platform design is required. With the consideration in mind, a novel locomotion mechanism is developed, enabling an ordinary mobile robot to move in lateral directions. In detail, a proposed multi-directional movement crawler mechanism is based on synthesis of traveling vectors generated by using subcrawlers diagonally installed to the main crawler. In this paper, to compare the proposed mechanism with the existing multi-directional movement mechanisms, real robot experiments verified the usefulness of the multi-directional movements by the proposed crawler.

Model and Implementation of Multiple Subcrawlers
Fig. 1 shows our mobile platform and its kinematic illustration. Specifically, the platform is composed of four passive subcrawlers, four motors equipped with encoders, four motor drivers, and one motor controller. Each subcrawler is mounted underneath the base frame 45 degrees apart from it (see Fig. 1), allowing the mobile platform to move forward/backward, sideways movement, and turn right/left. Such omni-directionality provides an efficient means of direction control in highly cluttered environments.

Next, the first-order kinematics of the mobile platform is derived as follows:

\[
\begin{bmatrix}
\omega_1 \\
\omega_2 \\
\omega_3 \\
\omega_4
\end{bmatrix} = \frac{1}{r} \begin{bmatrix}
-1 & 1 & a_1 \\
1 & 1 & -a_1 \\
-1 & 1 & -a_2 \\
1 & 1 & a_2
\end{bmatrix} \begin{bmatrix}
V_x \\
V_y
\end{bmatrix}
\]

where \( V_x \) and \( V_y \) indicate \( \bar{x} \) and \( \bar{y} \) component of vector \( \bar{V} \) with respect to the body coordinate system \((V_x,V_y)\), respectively. Also, the angle of traveling direction vector is defined as \( \theta \).

Evaluation Results The right side in Fig. 1 shows our prototype of the mobile platform composed of four subcrawlers. By using the prototype, we demonstrated its basic performance of the straight-line and rotation motions according to forward/backward movement, turning left/right, and left/right sideways commands. Specifically, to evaluate its omni-directionality, the experiments are set to move left and right directions along straight paths, respectively. In Fig. 2, the blue solid lines show the prototype’s trajectories of left and right movements manually controlled by a human operator. Despite no use of feedback controllers, the motions of the prototype in the lateral directions resulted in a deviation of about 100 mm with respect to the movement of 4,000 mm. From the results, we confirmed that the proposed prototype could generate straight-line and rotation motions by using multiple subcrawlers.

Conclusions To enhance movement performance on rough terrain and easy system integration to mobile platforms, the omni-directional locomotion mechanism for multiple subcrawlers was proposed. To verify the validity and effectiveness of the proposed prototype, experiments were performed, and the results were analyzed. In contrast to existing crawler mechanism, our prototype features a simpler structure and more compact size, and can fit easily into everyday environments. Towards the more practical use of the prototype, we will need to devise a more enhanced feedback control scheme for a wide range of applications. Furthermore, a more reliable structure and more compact design will need to be incorporated into the next prototype.

References.