R&D Theme

Dynamic Collaboration System for Multiple Robots

Progress until FY2022

1. Outline of the project

To achieve "infrastructure construction adapted to diverse environments," it is crucial to adapt to changing surroundings dynamically. It is effective to incorporate collaboration among multiple robots and enable them to adjust their team composition to address unforeseen circumstances dynamically. However, until now, the architecture and algorithms required for such robots did not exist. Therefore, in this R&D project, titled "Dynamic Collaboration System for Multiple Robots," we aim to establish "Dynamic Collaboration System" that enables the reconfiguration of robot teams. Our initial focus will be on achieving a task involving the transportation of sediment, which is applicable to river channel blockage disasters. We strive to realize a dynamic collaboration AI that adaptively reconfigures the team composition in response to changing environmental conditions (refer to Figure 6). Furthermore, we will conduct verification of the dynamic collaboration AI using multiple construction robots in the 3-ton class.

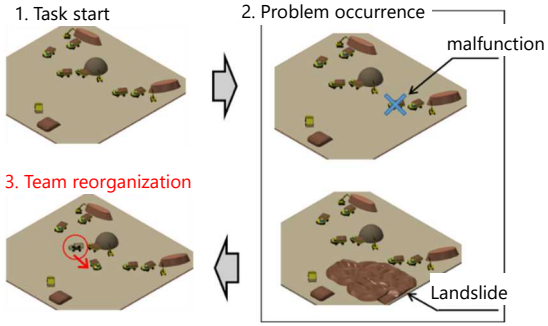

Fig.5 Team reconfiguration in dynamic environments.

2. Outcome so far

We have developed a "Self-Organization" algorithm that enables flexible team composition based on the current site conditions. Specifically, for the task of sediment transportation using excavators and dump trucks, as mentioned earlier, we have constructed an algorithm that reconfigures the team based on parameters such as the amount of sediment, the location of sediment piles and disposal sites, robot performance, and delivery deadlines. This algorithm utilizes the predicted performance (transportable sediment volume) and actual performance (sediment volume transported) to determine the team composition. To validate the above algorithm, we have developed a three-dimensional geotechnical simulator for multiple construction robots using the Vortex Studio simulator. Based on the Self-Organization algorithm, we implemented a motion simulation to achieve excavation and loading of sediment by the excavator and transportation by the dump truck (refer to Figure 6). As a result, we confirmed that this algorithm operates effectively, even in cases where the dump truck experiences a malfunction, by successfully demonstrating the reconfiguration of the team based on the site conditions.

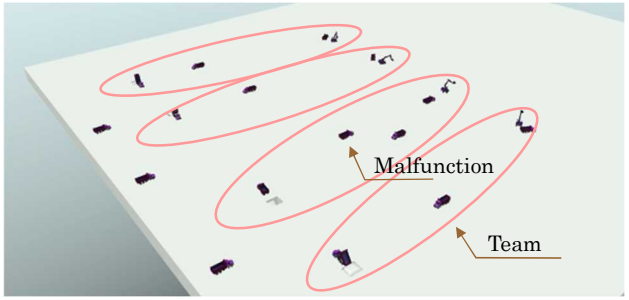

Fig.6 Multi-robots simulation based on self-organization.

Furthermore, to validate the algorithm on real machines, we have developed a simultaneous localization and mapping (SLAM) technique for small construction robots using multiple sensor pods. This position estimation technology for construction robots has several advantages. It can be used in environments where GNSS is unavailable and provides a real-time understanding of the surrounding environment. Additionally, we achieved the execution of sediment transportation tasks by multiple construction robots with the aid of this position estimation technology (refer to Figure 7).

Fig.7 Multi-robots for earth moving operations.

3. Future plans

This R&D project for 2025 aims to achieve the reconfiguration of teams by multiple small construction robots, enabling them to adapt to changing circumstances and successfully perform tasks. To accomplish this goal, we will continue advancing research and development on the "Self-Organization algorithm" until 2023. By the summer of 2023, we aim to demonstrate sediment transportation tasks by six operational construction robots equipped with the Self-Organization algorithm.