Orchestrating Multi-Robot Collaboration: From Aerial Drones to Heavy Machinery

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Multi-robot coordination is becoming an important direction in robotics because many real-world tasks are too large, complex, or time-critical for a single robot to handle alone. By working as a team, multiple robots can share sensing and physical work, cover wider areas, and improve system efficiency and robustness [1, 2]. However, using many robots also raises an important question: how should their collaboration be orchestrated? Similar to human teams, robot teams need clear goals, role assignment, communication, conflict resolution, and safety rules [3]. This talk explores this question through two real-world cases from academic research and industry: multi-drone coordination for 3D reconstruction, and autonomous operation of multiple heavy construction machines.

As the first technical example, we will introduce work from the speaker's doctoral research on collaborative multi-drone systems for 3D map reconstruction [4, 5]. In this project, multiple drones observe an unknown environment from different viewpoints, aiming toward efficient and adaptive 3D mapping. The key idea is to coordinate where the drones look and move, while using feedback from the evolving reconstructed map to guide future observations. This example shows how multi-robot coordination can help robots better perceive and understand the physical world.

As the second case, we will explore an industrial application that DeepX, Inc. is addressing: autonomous operation and coordination systems for heavy construction machinery [6]. This work is motivated by challenges in Japan's construction industry, including labor shortages, an aging workforce, and the need safer and more efficient construction processes [7]. In constrained environments such as pneumatic caisson sites [8], multiple machines must operate safely and efficiently while sharing limited workspaces and supporting human operators [9]. This brings practical challenges beyond algorithms, including safety-aware planning, user interaction, system reliability, and deployment in real sites.

Through these examples, the talk will highlight that the future of robotics is not only about smarter individual robots, but also about effective collaboration among robots and humans. We hope to provide an accessible introduction to multi-robot collaboration, while sharing lessons from both academic research and industrial perspectives.

References

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Muhammad Hanif is currently a Robotics Control Engineer at DeepX, Inc., where he works on autonomous operation and coordination systems for heavy construction machinery. He received his Ph.D. in Systems and Control Engineering from Institute of Science Tokyo in 2025, under the supervision of Prof. Takeshi Hatanaka. His doctoral research focused on collaborative multi-drone systems for 3D map reconstruction, aiming toward efficient and adaptive 3D mapping of unknown environments. He has also been involved in various robotics projects across aerial, ground, and underwater robotic systems. His broader interests include multi-robot systems, safety-aware autonomy, and human–robot collaboration.