学位論文の要旨

題　目　A Study on Mechanisms for Multicopter Consisting of Passive Joints Capable of Plane Perching and Rough Terrain Landing

（不整地への着陸および平面へのパーチング動作ができる受動関節で構成されたマルチコプターのための着陸機構の研究）

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Multicopters are now utilized frequently in the field owing to their outstanding advantages, such as low weight and low cost. Occasionally, multicopters perform tasks that humans cannot realize with high precision, such as rescue, inspection, and express delivery. Multicopters equipped with different devices will play different roles in various applications. For example, multicopters carrying monitors are utilized in the fields of rescue and aerial photography; multicopter carrying pesticide spraying devices are utilized in agriculture. However, perching or landing are inevitable challenges regardless of the type of outdoor mission multicopter utilized. On the one hand, when a multicopter is performing surveillance or aerial photography missions at a fixed position with a certain height, it needs to perch there firmly like a bird; on the other hand, when the multicopter needs to land at a disaster site, such as the site of an earthquake, mudslide or tsunami, to transport medical equipment or necessary supplies, a device that can make the multicopter land on a rough terrain is particularly important. Additionally, when performing the aforementioned tasks, the devices attached to the multicopter that consume less power, are light weight, and require less manipulation, will be the optimal choice.

An unteractuated parallel-link gripper is suitable for achieving perching on a planar object. It has a purely mechanical structure; therefore, it does not consume any additional electrical energy. In particular, under the action of the parallel-link mechanism and the principle of leverage, the entire device, including the gripper and multicopter body, can always maintain a horizontal posture while perching, which can be a necessary feature for the subsequent takeoff of the multicopter.

Although I successfully developed this underactuated parallel-link gripper in an earlier study, the discussion on perching was insufficient. Previously, to simplify the calculation, it was assumed that the contact point of the upper side of the gripper was at the innermost position. However, in the real world, cases in which the contact point of the gripper is at an arbitrary position should be considered, which is one of the focus areas of my doctoral study. Therefore, to enable perching on planar target with different thicknesses and embedded at different depths, I analyzed the available perching range and limitations based on the friction cone theory. Additionally, I considered the relationship between the position of the center of gravity and the possibility of perching. Through a detailed categorized discussion, I summarized the feasible range in different situations for perching.

In addition to occasions where the multicopter perches at a certain position like a bird, landing on a rough terrain is a problem it may face during missions. Under such situations, the parallel-link gripper utilized for planar perching has difficulty performing its function. To cope with this problem, I developed a passive skid that facilitates the landing of multicopters on a rough terrain or uneven ground. However, most of the previous studies have focused on electrical skids. Therefore, based on the robot arm attached multicopter, the idea of substituting an underactuated skid with an electrical skid for landing on a rough terrain is performed. The combined structure of the robot arm and underactuated skid can maximize the functionality of the multicopter. While the multicopter retains its catching or grasping function through the robot arm, it can also achieve smooth landing on uneven ground.

As the initial step, the mechanical structure of the underactuated skid was proposed, and the entire device can be considered a three-legged mechanism consisting of a passive joint and two feet. Then the non-tilting condition of the entire device was analyzed, and a judgment method was proposed to determine the possibility of landing on a rough terrain. To simplify the complex environment, I simulated a rough terrain with slopes with different inclination angles. By analyzing the positional relationship between the contact point and the inclined plane, and the contact points and the center of gravity, the possibility of landing the multicopter on different inclined planes can be concluded. According to the analysis and conclusion, the judgment regarding whether smooth landing can be successfully achieved is also feasible.