For task 3, we used two types of UAVs for the task. The general UAV called "hawk" as shown in Fig.**??**, which is similar to the one used in task 1, and the transformable multilink aerial robot, which is called "Hydrus" (Fig.**??**). As described in Fig.**??**, the hardware platform of "Hydrus" involves the controller for the joints, which enables stable aerial transformation.

[clip, bb=115 4 666 535, width=]sections/task3/images/task3-tarrot810.pdf

Figure 1: Image of task3 Hawk

[clip, bb=0 105 720 535, width=]sections/task3/images/task3-hydrus.pdf

Figure 2: Image of Hydrus

[clip, bb=0 0 720 540, width=]sections/task3/images/hydrus-platform.pdf

Figure 3: Hardware platform of task3 Hawk

Although the flight control algorithms between "Hawk" and "Hydrus" are fundamentally different, we use the same flight controller board which is build by ourselves. For "Hawk", we additionally designed another PCB board for controlling an electromagnet module that can generate attractive forces up to 20[N]. We equipped 5 electromagnets to the UAV and build the attachment with tactile sensors as shown in Fig.**??**(c). The electromagnet module control board is connected to the flight controller board unit through CAN bus.

For the transformable UAV, we introduce the prototype which contains four links and three servo joints. The modularization of the whole platform is achieved by distributing the power and control system to each link with exception to the flight controller and sensors. Therefore, it becomes easier to the change the speed of the rotors for controlling flight.

0.2 Aerial Manipulation Strategy

For each type of UAV, we develop a different picking method. For "Hawk" type UAV, we apply magnetic force to attract the ferrous object as shown in Fig.**??**. When contact between the bottom of the landing gear and the object is detected by the tactile sensors, the electromagnet module is activated. We successfully picked and carried the object in an indoor environment with the use of a motion capture system, validating the electromagnet based manipulation strategy.

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width=]sections/task3/images/task3-tarrot810-manipulation.pdf

Figure 4: Aerial manipulation method of Hawk

On the other hand, the object transporation based on the whole-body-manipulation strategy using "Hydrus" is also acheived as shown in Fig.**??**. The grasping control is developped based on the torque feedback from each joint.

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width=]sections/task3/images/task3-hydrus-manipulation.pdf

Figure 5: Aerial manipulation method of Hydrus

0.3 Software

As with other tasks the software are build using ROS and some functionalities are shared with task 1. Point Cloud and OpenCV libraries are used for visual perception.

0.4 General Approach

0.4.1 Overall Strategy

We divide the task into three states: Search, Pick, and Place. The UAVs are always in one of these three states and the states automatically transition into the next one if the certain conditions are satisfied as illustrated in Fig. 1A. In the "Search" state, the drone will traverse to the center of the arena and randomly generate a search end-point, the treasure detector will run while the drone is searching. Once the object is detected and locked, a pick motion will be generated in the "Pick" state, the UAV will turn on the electromagnet and approach the treasure (for the *Hawk*) or enclose its body around the treasure (for the *Snake*). The state transition is signalled by the trigger of the tactile sensor. Once the electromagnet of the *Hawk* has caught the treasure or the

0.1 Platforms