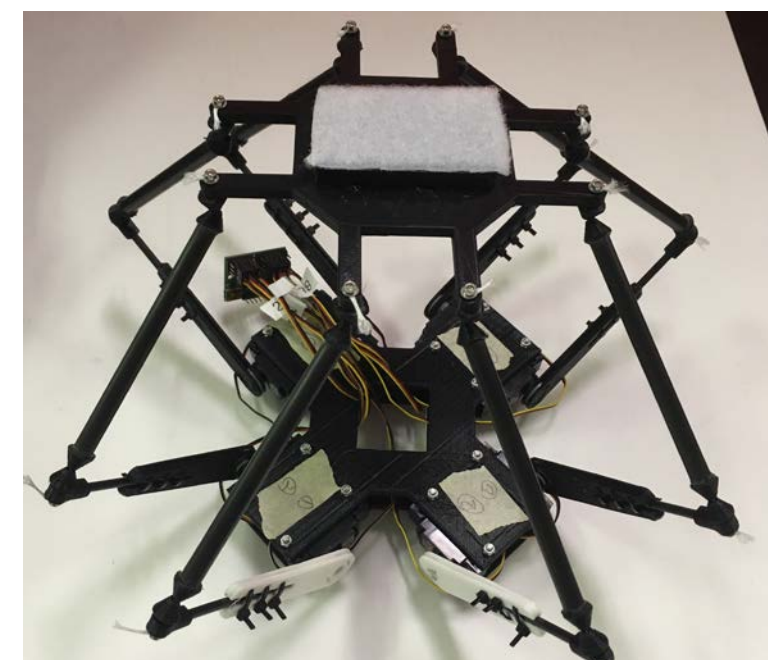


## INTRODUCTION

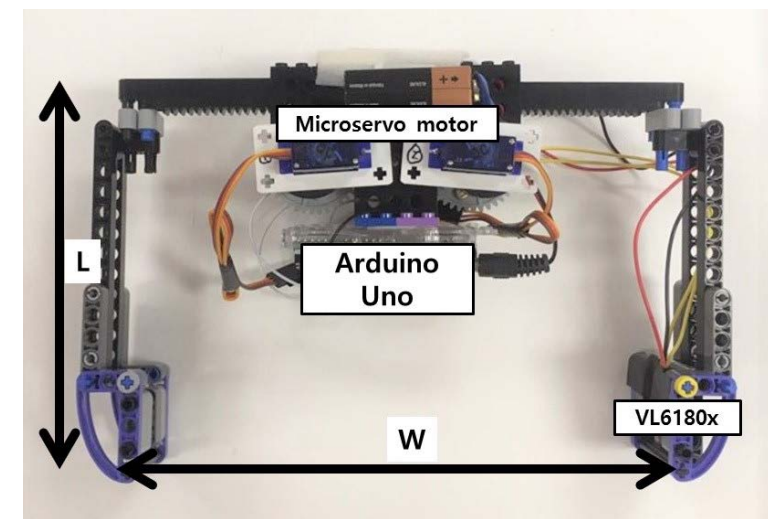
**Unmanned Aerial Vehicles (UAVs)** are originally developed for military, but have been developed over time to time for valuable roles in surveillance, work-assistant, and intelligence for both civilian and military operations.

The ability of UAVs that manipulate or carry objects can expand the type of tasks achieved by unmanned aerial systems. High degree of freedom robots with dexterous arm can lead to various applications. Most of manipulators are serial, each motor on each joint affects on stabilizing UAVs. Our lab, DASL, has presented parallel mechanism manipulator for UAVs. It results in less impact on center of gravity(CoG) of UAVs and high precise manipulation.

Thus, this work focuses on **6 degree-of-freedom parallel manipulator and gripper(PMG) concept** for unmanned aerial vehicles that can be used for multiple purposes. Depending on the purpose, the grasper module on the manipulator's end-effector changes. The design and mechanism is proposed, and the final results are also given.



(a) Parallel Manipulator-Gripper



(b) Parallel Sensorized Gripper



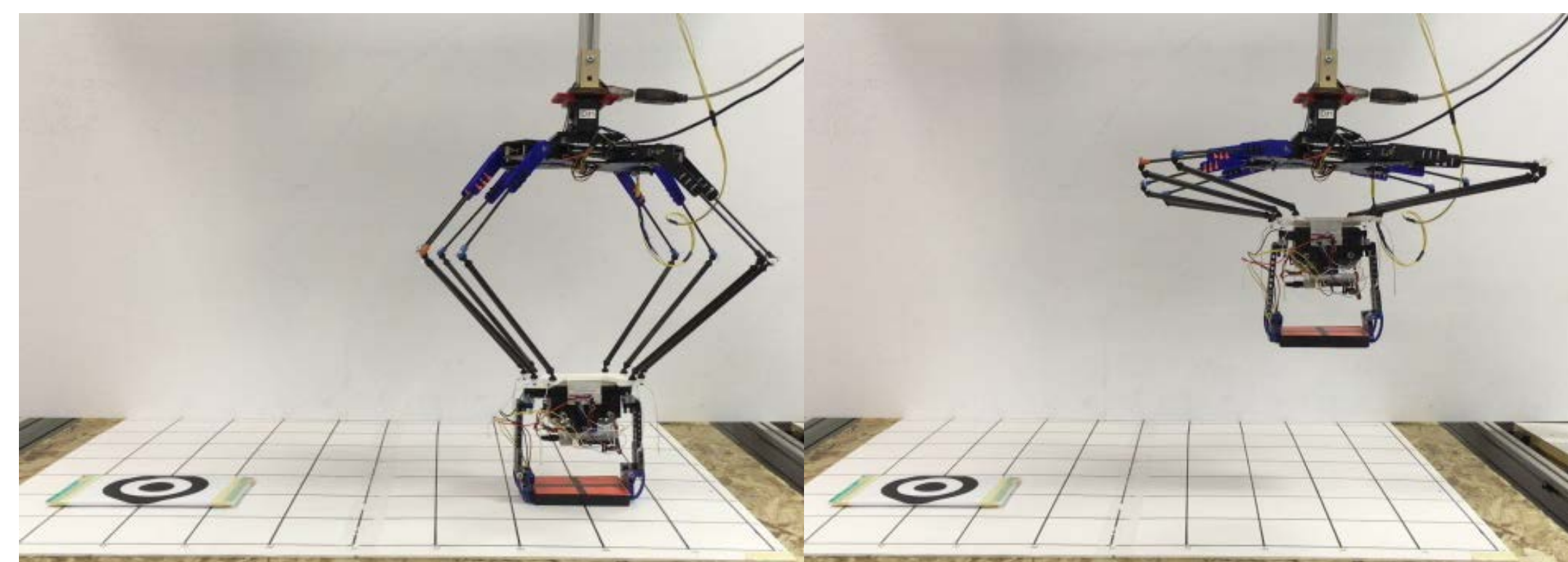
(C) Mobile Manipulating UAV Concept with Parallel Manipulator-Gripper

## METHODS

First, 6 degree of freedom parallel manipulator is designed and 3D-printed. The end-effector of manipulator is modified to attach any types of grippers in various grasping tasks

For test-and-evaluation, the gantry system is built to emulate UAVs motion in x, y, z, and yaw. The parallel manipulator-gripper is affixed and tested for angular and linear translation of the target object. The sensorized parallel gripper is built, then attached on the end-effector.

Lastly, UAV manual flight with PMG is implemented. The PMG is attached under the UAV for simple manipulation. Two tasks are given, air-hose carry and plate transportation. Different grippers are used for each task.



(a)



(b)

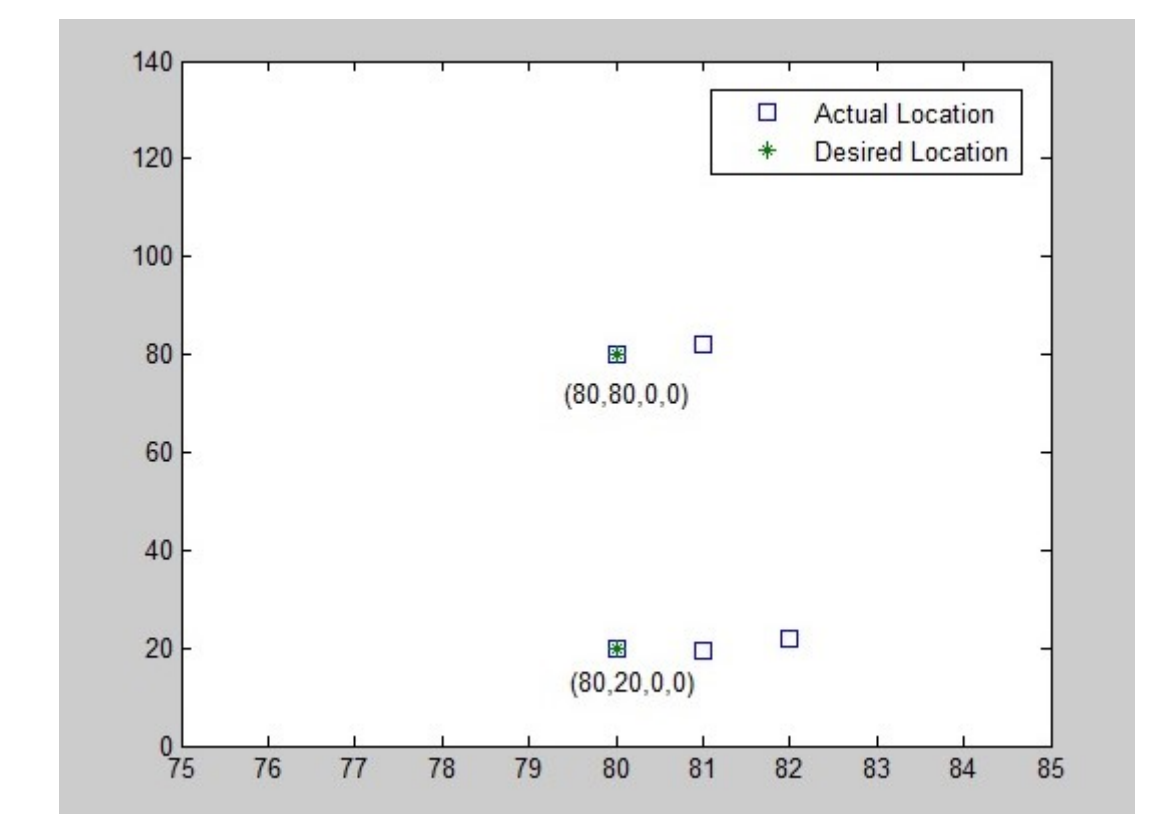
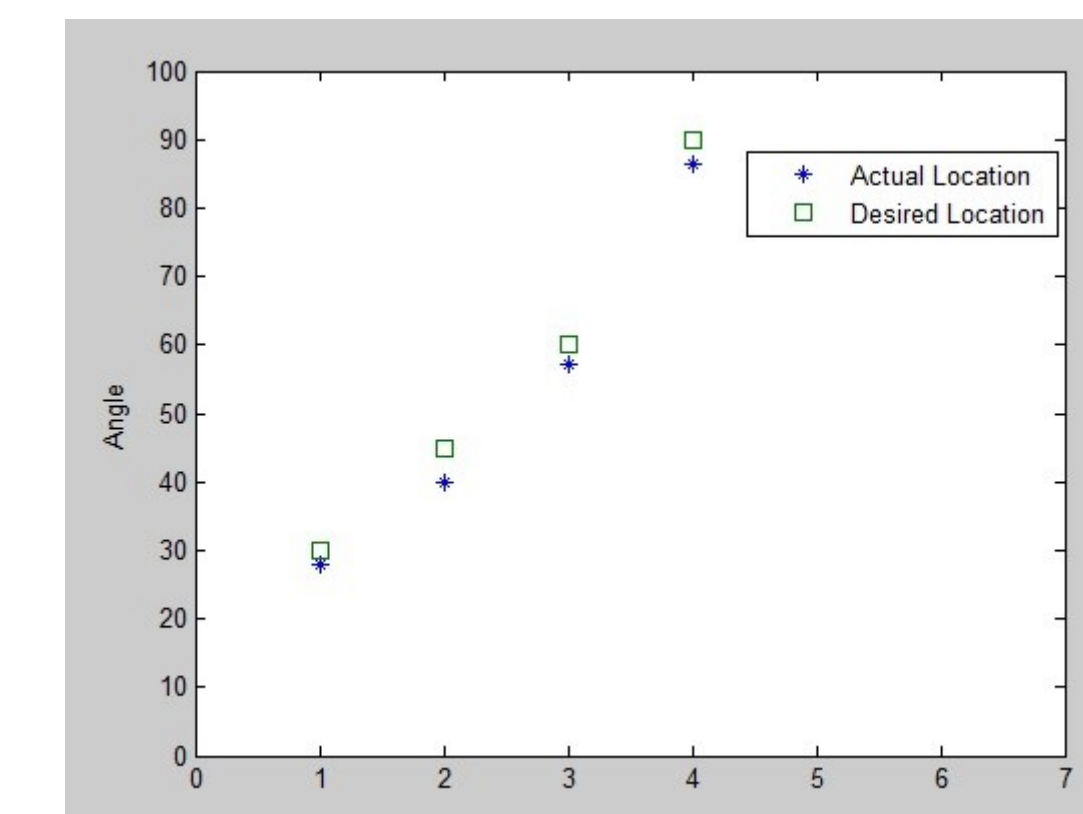


(c)

## RESULTS

From test-and-evaluation, the parallel manipulator gripper (PMG) itself shows around 95% precision in angular and linear translation on the gantry.

While in manual flight for air-hose handling and a plate transportation, the end-effector motion affected less on stabilization of UAVs. Also there are robust handlings for Air-hose and the plate



## CONCLUSIONS

In this work, the parallel manipulator-gripper concept design is proposed for Mobile Manipulating UAVs. A 4 degree of freedom gantry crane is built to emulate drones motions. The test-and-evaluation is implemented by affixing the PMG on the gantry and attaching on the UAV for a manual flight.

The results shows that the PMG can be used for UAVs in high precise manipulation tasks with different types of gripper.

Future work will consist of more testing and evaluation. The PMG concept will be upgraded and tested for other purposes such as bridge inspection, various types of object delivery.

## REFERENCE

DONGBIN KIM, Paul Y. Oh, "Parallel Manipulator-Gripper for Mobile Manipulating UAVs," 2018 INSPIRE UTC annual session meeting.

## Acknowledgement

Thank you to the department of transportation to support us in UAVs research.

### Methods and Results Description

- (a) Parallel Manipulator-Gripper(PMG) test on the gantry crane
- (b) Air-hose handling flight with the PMG
- (c) Plate transportation with the PMG