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# Small Unmanned Aerial System (SUAS) for Automating Concrete Crack Monitoring: Initial Development

Julian Kang[1] and B.C. Lho[2], J.W. Kim[3], and S.H. Nam[4]

***Abstract: Small Unmanned Aerial Systems (SUAS) have been gaining a special attention in the U.S. recently because it is capable of getting aerial footages conveniently and cost effectively, but also because of its potential threat to the safety of our society. Regarding the benefits, one can easily find successful cases. For example, remote controlled or pre-programmed unmanned aircraft help ranch owners monitor their livestocks or crop harvesting status cost-effectively without having to hire human pilots. The professionals in the construction industry also acknowledge the benefits they could gain from using SUAS. Some firms already use a small unmanned aircraft for monitoring their construction activities, which may help project managers figure out construction progress, resolve disputes in real time, and make proactive decisions for quality control. However, there are many technical challenges that my hinder the use of small unmanned aircraft in the construction industry. This paper explores opportunities and challenges in using unmanned aircraft to monitor concrete cracks on the surface of containment building in the nuclear power plant.***

***Keywords: SUAS, Monitoring Concrete Cracks***

## I. Introduction

The containment building of a nuclear power plant is one of the critical components preventing the radiation leakage in case of internal explosion or external attacks. Most containment buildings in S. Korea are concrete structures, and therefore monitoring the development of concrete cracks is a critically important procedure for preventive facilities management practices. Korea Electric Power Electric Corporation (KEPCO) has been making efforts to keep monitoring the surface of containment buildings at the regular basis, so that they can detect any cracks as quickly as they can and record the development of cracks in a way that anyone can see how cracks are getting developed over time at a certain location and make informed decisions to prevent those cracks from getting too much serious.

One of the challenges they had when monitoring the cracks on the surface of the containment building is caused by the location of cracks that prevents field crews from easily approaching to the cracks. In many cases, those cracks are getting developed in the middle of containment building, and field crews need to use a special crane to get closer to the spots where cracks are being developed. The need of using a special crane or a ladder can hinder those field crews from frequently monitoring those cracks on the surface of the containment building, and the KEPCO has been looking for a better method that could facilitate those field crews to monitor those cracks more frequently.

## II. Small Unmanned Aerial System

Small-size remote-controlled aircrafts, most likely with fixed wings and one or two routers, have been one of the popular items among those hobbyists who want to assemble the aircrafts and fly them for fun. While watching the U.S. Air Force using sophisticated remote-controlled aircrafts, also known as Drones, in recent operations against those terrorists in the Middle East, many civilians gained good understandings of the potential opportunity of remote-controlled aircrafts in terms of monitoring objects on the ground. However, controlling a fixed wing aircraft needs a significant amount of training, and therefore only a small population of enthusiastic hobbyists has been enjoying flying remote-controlled aircrafts.

What made it practically possible for ordinary people to use remote-controlled aircrafts for monitoring objects on the ground were small-size multi-router aircrafts integrated with GPS technology. Since those commercial multi-router aircrafts can lift and land vertically, users don't need to learn how to takeoff and touchdown the aircraft any more. In addition, those multi-router aircrafts combined with GPS technology can hover at the same position using the position information received from GPS satellites. Users don't need to keep controlling the aircrafts carefully to get them stay at the same position any more, which enables them to control the aircrafts easier than ever. Further more, some remote-controlled aircrafts get integrated with mobile computer and now they can automatically control the flight of those aircrafts through the waypoints defined in advance.

For the challenges that KEPCO has been experiencing, authors were wondering if the remote-controlled small aircrafts, which are now also known as Small Unmanned Aerial System (SUAS), can be used to monitor the cracks developed on the surface of the containment building in the nuclear power plant.

## III. Applications of SUAS

While evaluating the possibility of using SUAS for monitoring the concrete crack on the containment building, authors learned that remote-controlled aircrafts have been used for various industrial cases.

In the U.S., the Department of Homeland Security's Customs and Border Patrol (CBP) have been using unmanned fixed-wing aircraft to monitor the border between the U.S. and Mexico, which helped the agency arrest 4,766 people and seize 22,823 pounds of marijuana [1].

In Europe, monitoring 200,000 km natural gas transmission pipelines is critically important task to secure the value of the pipelines and protect them effectively against damage caused by third parties. Before using SUAS, the monitoring methods used were either foot patrols along the pipeline route or aerial surveillance using small planes or helicopters, which cost the agency significantly. To overcome this challenge, Hausamann et al [2] proposed two different types of UAS: 1) small and lightweight, low-altitude UAS with a limited sensor and weight capacity, and 2) medium-size, mid-altitude UAS with a weight capacity sufficient for multi-sensor applications. A small lightweight low altitude UAS can lift up to 25 kg and fly up to 5-6 hours. A typical medium altitude long endurance UAS can lift up to 200 kg and fly up to 30 hrs.

UAS are being used even for shooting the movie scene. For example, one of the chasing shots in the James Bond movie "Skyfall" was taken using Flying-Cam 3.0 SARAH. Using this Flying-Cam specialized for filming, the technical crew was able to take a shot of 007 dynamically from almost impossible positions as he chased a terrorist across the rooftops of the Istanbul's famous bazaar. The company who shot the scene won an Oscar in 2014 for their aerial imaging platform [3].

## IV. SUAS FOR MONITORING CONCRETE CRACKS

The use of SUAS for monitoring concrete cracks on the containment building bears unprecedented challenges. First of all, the remote-controlled aircraft needs to get close to the surface of the containment building to take photos that can be used to detect cracks. Since the size of cracks are tiny, a high-resolution camera needs to be used, and obviously one can get better photos as the remote-controlled aircraft gets closer to the surface. However, the aircraft should not collide against any adjacent buildings at all times. Either wise, it could damage the facilities, which could initiate a major catastrophe. To cover the entire surface of the containment building, the aircraft needs to fly around the building multiple times at different elevation.

In order to see if SUAS can meet the above-mentioned conditions, we tested a few different types of UAS and found some challenges that may hinder industry professionals from using it for monitoring cracks on the surface of a containment building in the nuclear power plant. First of all, we found that no remote-controlled aircraft could fly longer than 20 minutes. Unless someone is well trained for operating the aircraft, 20 minutes is not long enough to take photos showing cracks. Therefore, one may need to fly the aircraft multiple times to cover the entire containment surface. We also found that it became difficult for the aircraft operator to figure out the exact location of the aircraft once the aircraft is beyond 30 meters from the operator. If the aircraft flies in an open space, there is no need to pay attention to exact location of the aircraft because there is almost no chance that the aircraft gets collided against any obstacles. However, when someone tries to control the aircraft in a busy setup such as nuclear power plant, this issue could become very serious. Most likely, the operator may not be able to depend on the line-of-sight to control the aircraft precisely through busy facilities, because he or she cannot easily figure out the distance between the aircraft and nearby facilities from a distance. What makes the situation worse would happen when the aircraft flies behind the containment building. The operator will lose the line-of-sight and may have no idea how the aircraft flies behind the containment building, which can create a critically dangerous situation. Many remote-controlled multi-router aircrafts recently developed for commercial purposes are equipped with video camera and they can transmit the video footage picked up by the camera back to the operator in real time over 2.4GHz or 5.8GHz radio frequencies. Therefore, the operator now has a chance to see the target object through the camera mounted on the aircraft, but the field of view is still limited and it is challenging to figure out all surrounding objects from looking at the live video transmitted from the aircraft. Some SUAS was specifically developed to collect video footages, and does not support users to take photos while watching the live video footage transmitted from the aircraft.

## V. AUTOMATING THE FLIGHT OF SUAS

From the test flight, we learned that it would be challenging to control unmanned aircraft to take photos of the concrete cracks on the surface of the containment building. Unless we can have the unmanned aircraft to fly autonomously through the congested facilities in a nuclear power plant, it would not be possible to collect photos of the concrete cracks on the surface of containment building. Some commercial SUAS vendors already provide computer applications, which can me installed on mobile devices, to automate the flight of the aircraft. It facilitates users to define multiple waypoints, and then enforces the aircraft to fly through those waypoints. Some venders even provide Application Programming Interface (API) to add additional function to the exiting flight automation computer application.

Our research team has developed a computer application that controls the flight of unmanned aircraft automatically to take photos of the concrete cracks on the surface of containment building. Our application takes variables including the coordination of the containment building, the height and radius of the building, and intervals between elevations. With these variables, our application can determine the flight path of the aircraft and send this

information to the aircraft in real time through remote controller. We are currently testing this application to see how it controls the flight of aircraft. We measure differences between the pre-defined flight path and actual flight path in order to figure out what has to be improved.

## REFERENCES

Here are the examples of references format:

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