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Industrial Crack Inspection Copter

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Abstract: The purpose of this paper is to present a study that aims to employ copters for the Inspection of Chimneys/ Industrial exhaust vents in high rise buildings where human intervention may prove risky. Concretes are popular material used for constructing Chimneys; concrete chimneys require routine observation and maintenance to ensure trouble-free operation. The frequent issues of chimneys are Hairline Cracks and Shrinkage cracks. Industries use Maintenance and Inspection Experts to inspect Chimneys by using various risky methods like Ladder climbing, rope access and many more, accessing such a dangerous environment can be overcome by using U.A.V's for this process. We have developed a system to overcome this issue and additionally we also have air samples collector which helps to collect air samples released from chimneys and send samples for QA assessments to know the consequences. In this paper, a novel method by which copters identify the Chimneys structural cracks and get air samples released from chimneys is tested.

Keywords: UAV, Stacks, Cracks, Air Sampling

1. INTRODUCTION

UAV multi rotors bear a potential of a great applications despite their limitations. One has to research on its capabilities and put to use to solve real world problems. Our research organization focuses on development of these drones for various applications in the industry. In this paper, we propose a method of how a drone can be used to solve problems encountered by industries/power plants bearing a stack/chimney. Industrial structures are subjected to inspection on a regular basis to ensure the safety of the workers and the people who stay nearby. For example, if a bridge has to be inspected, the entire bridge has to be shut down causing public inconvenience increase in traffic on the other routes, etc. This also involves a lot of manual labor and the method is risky, so deploying a UAV for this may prove to be an efficient method. Many UAV making companies are coming up with ideas such as aerial photography, photogrammetry but there were no special designs for inspection of buildings or structures until the recent past where Aibotix GmbH came up with power line inspections, quarry inspections.

Figure 1: Aibotix® inspection copter

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To inspect Cracks in structures a lot of concentration and patience is required. To understand the cause of cracks we need to know what material is the chimney/stack is made up of for e.g. Concrete or brick masonry. In this paper we focus on external structure of an industrial chimney. Usually Industrial chimneys are commonly referred to as flue gas stacks and are generally external structures, as opposed to those built into the wall of a building [2]. Brick was the initial structural component in these chimneys for many years and advances in material science and structural engineering has led to the use of reinforced concrete.

The paper is organized as follows: Initially we state the problem in the introduction followed by experimental setup where our setup is defined for experimenting a method for detection of cracks on the stack (by capturing images) followed by computing parameters for its analysis where we discuss our approach to detect cracks and design our algorithm. Later we discuss the efficiency of our experiment compared to the existing ones. Finally we conclude by portraying the results.

2. EXPERIMENTAL SETUP

1. A Quadrotor with avionics system to record flight data.
2. A 2.4 Ghz R/C transmitter and receiver
3. A camera with a good resolution
4. A Ground Station Setup for analysis of images using MATLAB.

Our Quadrotor has been designed by using Components of the shelf like Arduino, IMU, Brushless motors, Battery and ESC with a control system running PID with simple Complimentary filtering. The frame we chose was an X configuration so that maneuverability becomes easy.

Figure 2: Fabricated Quadrotor

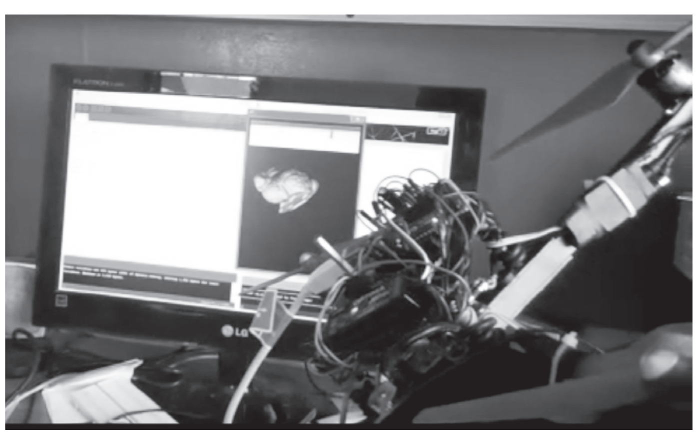

Figure 3: Ground Station Setup

3. APPROACH TO DETECT THE CRACKS

A UAV multi-rotor comprising of a camera as a payload is deployed and is controlled at the ground station via two different controllers one for maneuvering the drone and other for capturing the images of the desired subject which here is the industrial stack. Industrial stacks differ from the chimneys in fireplace of houses. These are huge concrete structures built very high (F.W. Thomas, 2012) for taking advantage of chimney/ stack effect and giving great buoyancy for the air to move out of the chimney. Therefore, these require meticulous examination of the finest details all around the structure. Hence, a good resolution images capable for examination is required.

It should be also taken care that since images are captured remotely from the ground station a large range is required. Thus a GoPro® camera is chosen with a range of nearly 600ft connected across a WLAN network. The Images with 12 Megapixels are collected for the analysis. A 3D camera developed by Intel called Realsense F200 can be used in capturing the images as it contains an inbuilt depth camera. Sometimes a 5 GHz wireless transceiver module can be used for the real time analysis where the Civil/ Structural Engineers are called for an inspection. Mostly these images are good enough to tell whether the structure can survive further years before having cured. Sometimes one has to know further details of the crack to analyze it before taking a decision. So, an Ultrasonic sensor can be used to capture the depth of the crack and predict how much damage has taken place. Although a depth measurement can be obtained by using an Ultrasonic sensor which is not as precise as achieved by Laser Range Finder. It was for the fact [1] that Laser Range finder fails to work in sunlight, we choose the Ultrasonic range finder instead. With these images we can easily identify the cracks developed in these stacks and understand what may have caused it and provide a method for its repair.

Table 1:

S.No	*Specifications of Depth Sensors*		
	Name/Make	*Range in meters*	*Accuracy*
1.	Ultrasonic Sensor HC-SR04	0.02-2m	3mm
2.	Intel Real Sense F200	0.2-1.2m	NA

Now that we have analyzed the material used in constructing these chimneys viz. bricks, concrete. We can account to the cracks occurring in these structures. In brick masonry chimneys cracks are caused by [3]

1. Improper construction: If there is no room left between the flue line and the masonry chimney sides, the heating up of the flue causes it to expand and sometimes crack up the surrounding brick.

Figure 4: Crack Resulted due to improper construction

2. Water leaks: Faulty chimney top seal/rain cap may cause the water to seep into the structure and result in cracks.
3. Chimney movements: Improper securing of the chimney to the building or defective foundation may lean; bend the structure. In tall stack structures, the high speed winds that exert pressure on one side of it may lead to varying stress. This may result in cracks at the mortar joints of brick masonry.
4. Thermal expansion: This is most common reason for cracks. It arises due to improper construction of the brick masonry where enough room is not left for the structure to expand or contract leading to variable stress and cracking.

Figure 5: Cracks caused due to seepage of water

5. Mechanical damage: A masonry chimney may crack due to stresses due to nearby site blasting stresses or earthquakes. Sometimes structures mounted on the chimney like lightning conductors/rod, antenna, etc. may cause damage leading to cracks.

   We can identify these causes just by careful examination of the images of the chimney stacks.

4. ALGORITHM AND PROCESSING

We initially converted the 3D RGB image into 2D black and white, and further thresholding it to obtain a simpler image.

1. B = rgb2gray (A);
2. C = graythresh (B);
3. BW = im2bw (B, C);

   The further analysis involves determining the connected neighborhood where we chose 4 nearest neighbors (K-NN algorithm). This gives us all connected objects in the image, hence exposing cracks easily.

4. D = bwconncomp(BW, 4)

Finally we used region props function to compute the area of the crack of the concrete structure.

5. Crakgraindata = regionprops (D, “basic”)

Though, this looked applicable to a quiet handful images, we weren’t able to process 100 percent of the images with accuracy because as a drone pilot it is very tough capturing the images with this stability without a gimbal. Efforts are made to further improvise the algorithm which suits all sorts of images even those with a lot of noise

During the first stage of testing images were acquired by an Intel Real Sense Depth camera and when these were subjected to post-processing the resulting images were as below:

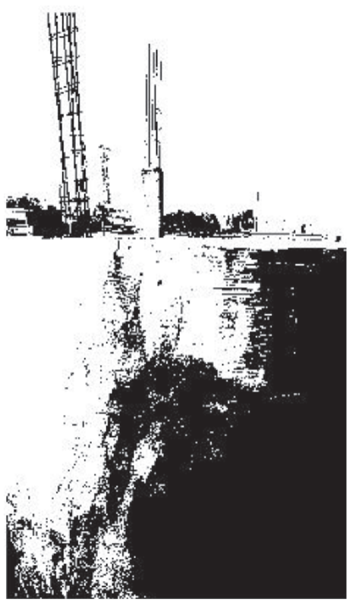

Figure 6: Captured image of a brick kiln made of RCC

Figure 7: Processed Image of the kiln

Figure 8: Boundaries in the processed Image

We also found that our algorithm couldn’t perform accurately in a few cases, especially where there is a varying intensity over the image.

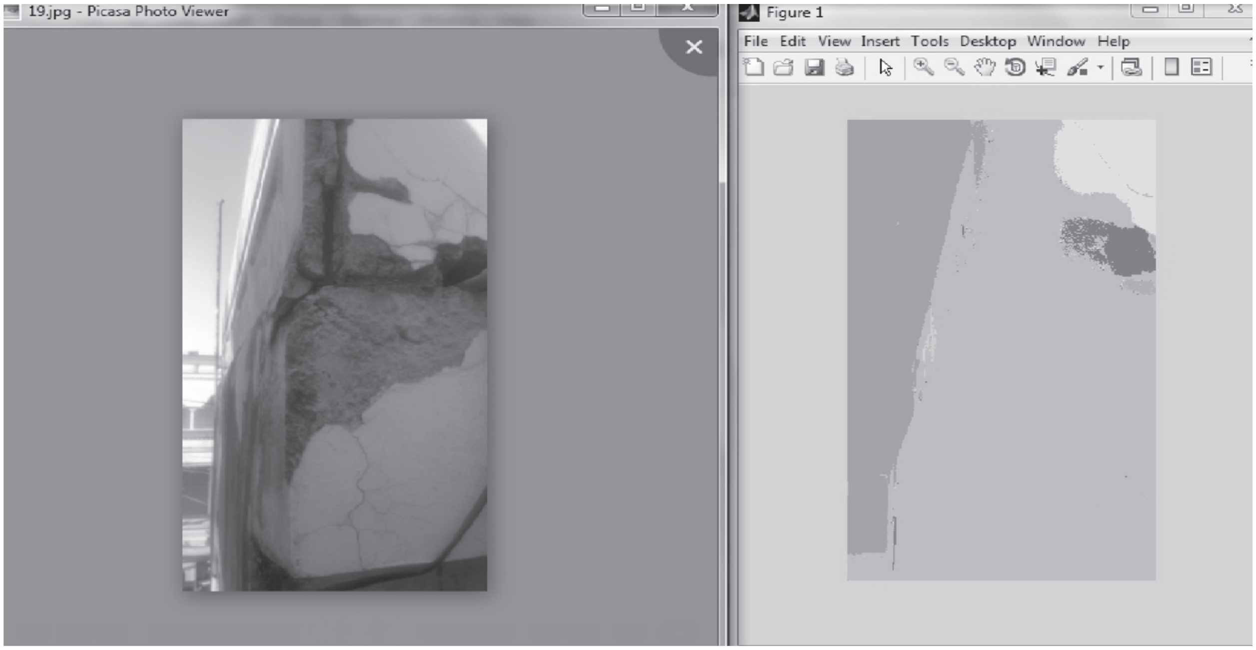

Figure 9: Image having variation in illumination fails to be accurate

5. EFFICIENCY

We have evaluated different types of structures and found the area of each type of crack. Most of the literature that was present on the crack detection using edge detection using Canny, Sobel, Roberts filters but in this paper we intend to use contours to detect the cracks. We find our method more efficient than the existing as our algorithm detects the cracks in the images which failed to be detected using the older ones.

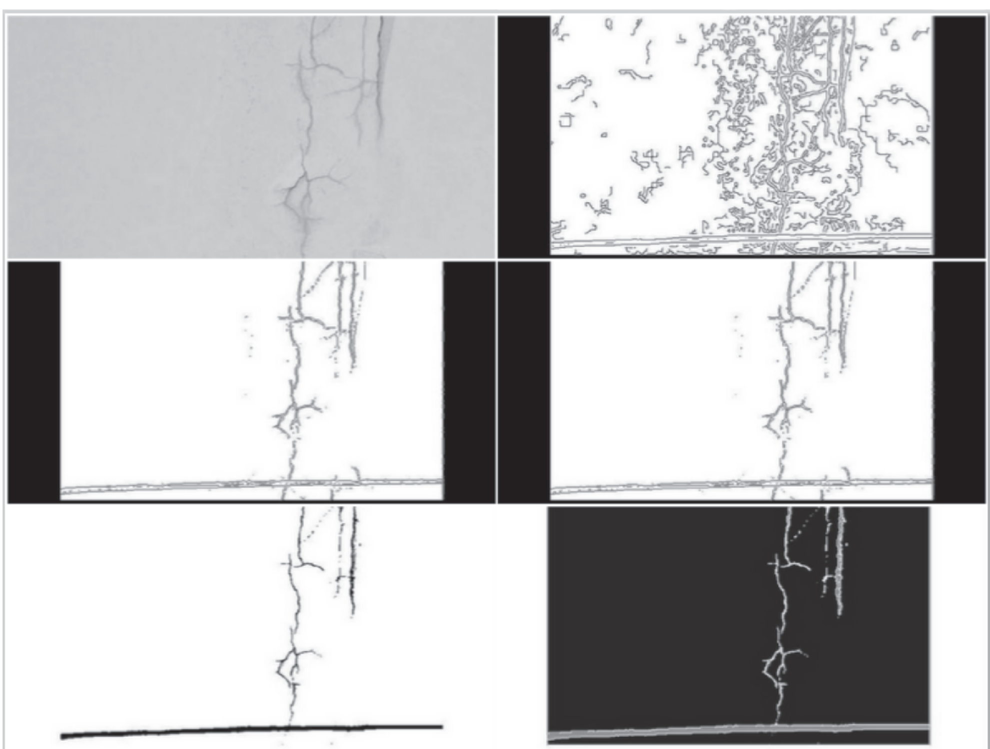

Figure 10: From the top left corner (a) original crack image (b) crack detection by edge detection using Sobel (c) edge detection using Robert's (d) edge detection using Prewitt's (e) crack detection using our algorithm (f) crack detection of our algorithm further optimized

The images shown in figure 11. are captured using Intel Realsense camera. These images are processed from the hardware and these also give depth information. The plain grey color is the normal grayscaled image and the pinkish overlay is the depth image. Both images are superimposed on each other by default. The tilt in the field of view is caused by the copters manuevrs while capturing these images. This camera has a range constrain which the pilot should be aware of, else the captured images shall contain a lot of noise.

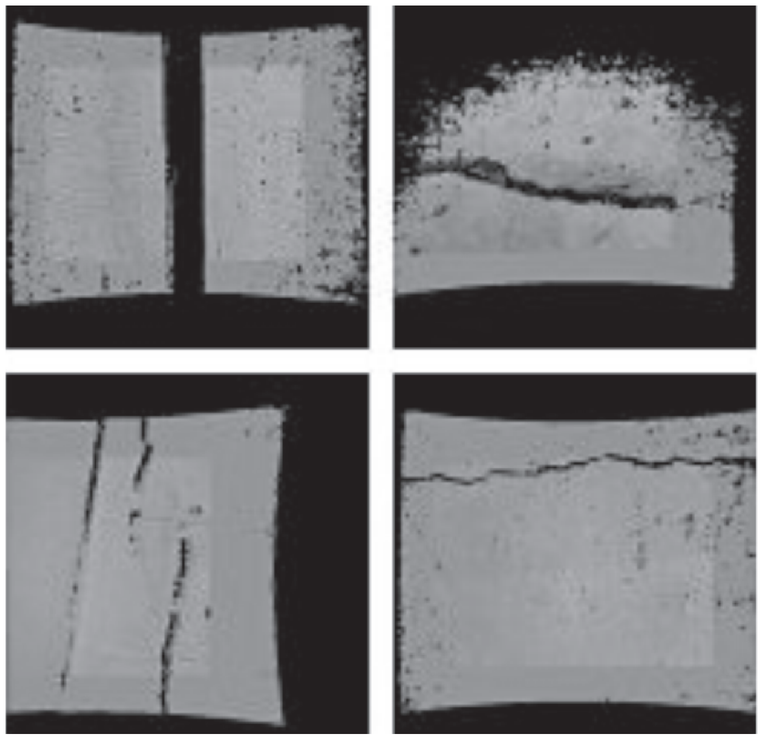

Figure 11: The images of cracks captured using Intel RealSense 3D camera F200

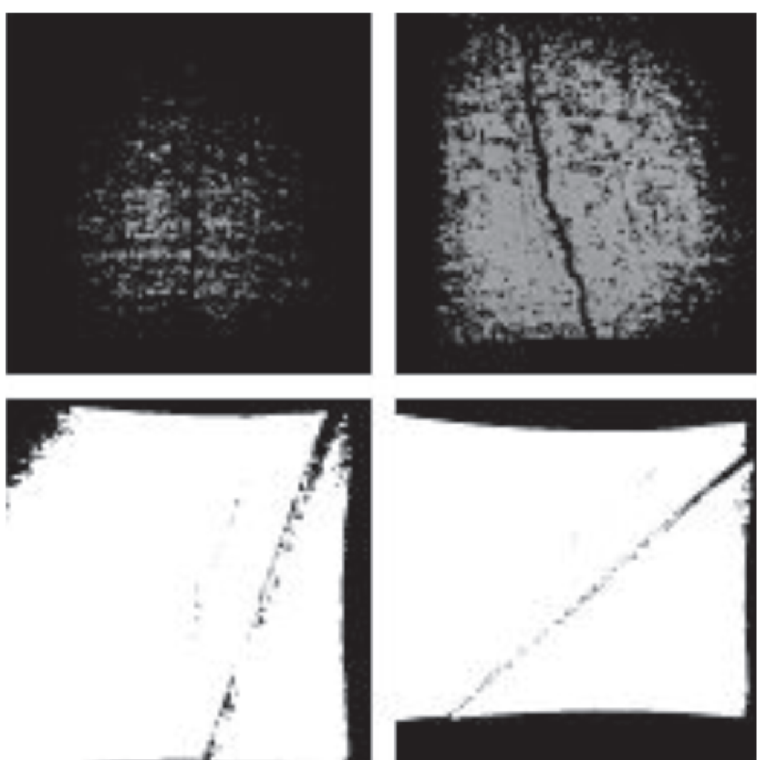

Figure 12: From top left corner images which failed to capture, due to lack of range

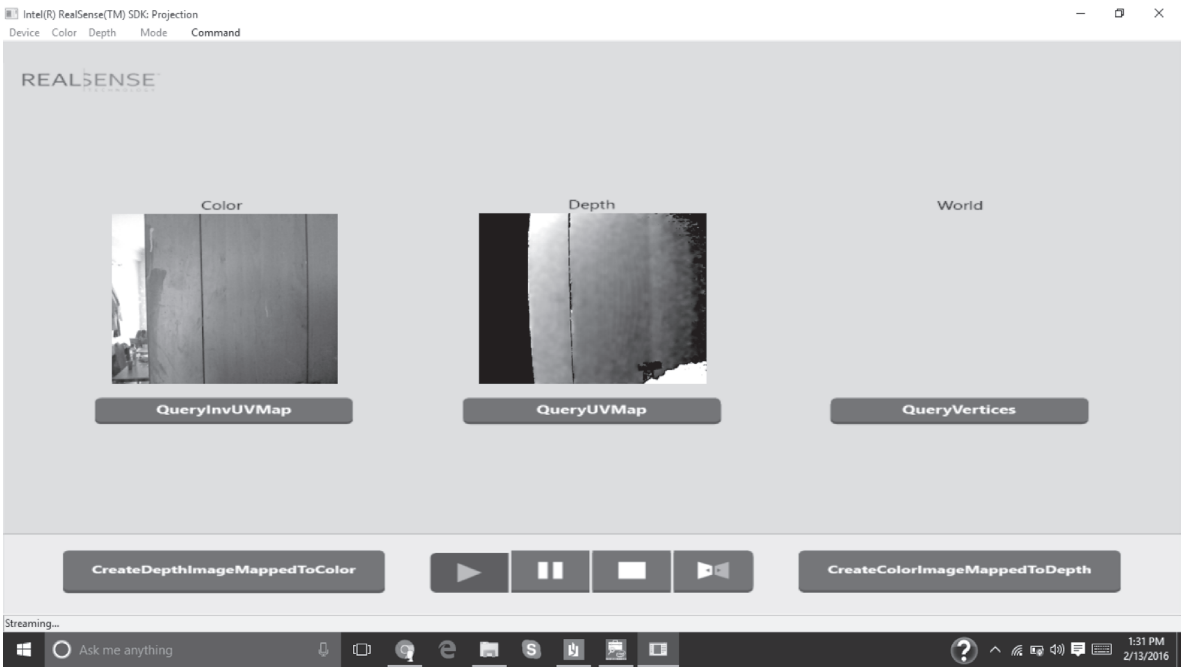

Figure 13: A Screen Capture from the SDK of RealSense Depth Camera

The efficiency of this method also involves the flight efficiency. To determine this we created a graph using t-chart package where the extracted data from the logger that is a part of onboard avionics is plotted against time. The purple plot represents energy consumed by GPS flight. Instantaneous power is represented by the green line where units are Watts/10. The black line on the graph is the distance efficiency or how many meters the Quadrotor is covering for every kiloWatt second of energy being used.

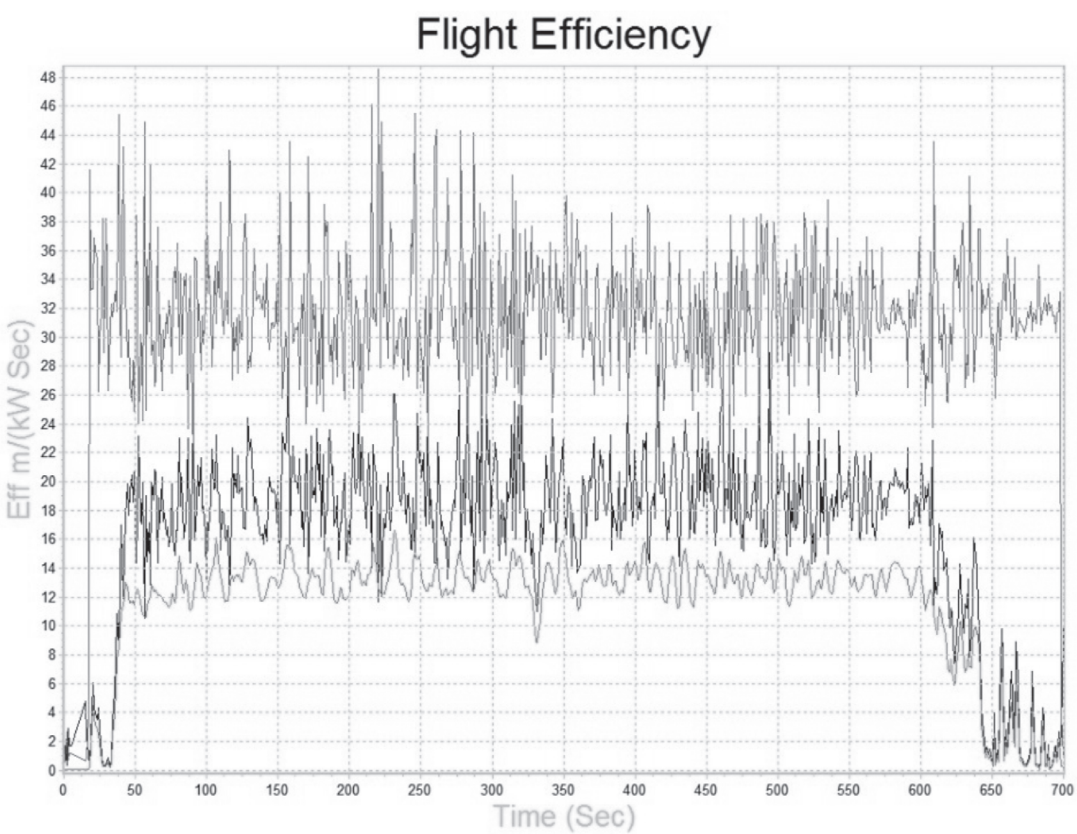

Figure 14: Efficiency of the flight tested during a headwind

6. CONCLUSION

A method proposed to determine cracks in industrial chimneys/stacks is tested and a novel approach in detection of cracks was derived. Our simple design employed in the construction of the Quadrotor was able to carry out the mission task successfully. We also achieved a greater altitude as well as greater flight time as compared to the normal design which includes a bunch of other sensors. However, this was at compensation of live telemetry. We were able to inspect an industrial stack made of RCC of about 300 meter high.

Proposed crack detection method was tested to be efficient and the method was economical. We were able to find out the area of a crack from the processed images using simple MATLAB code. This research led to a new set of applications of a UAV and further work is being carried out using onboard computer vision for the same. This method can be adopted by industries to save both money and time with almost no risk involved.

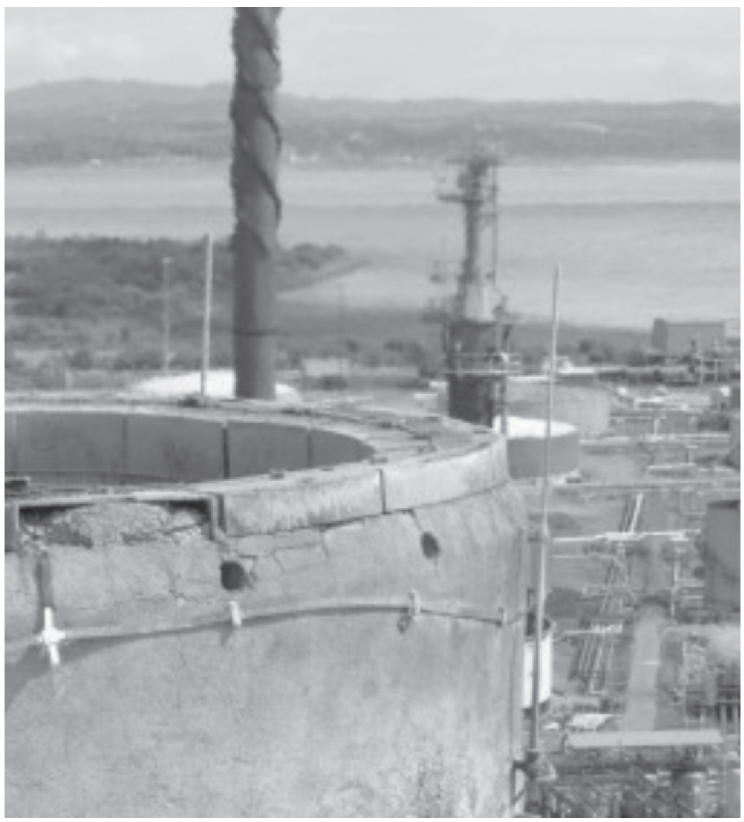

Figure 15: Copter inspecting a stack, about 300 meter high

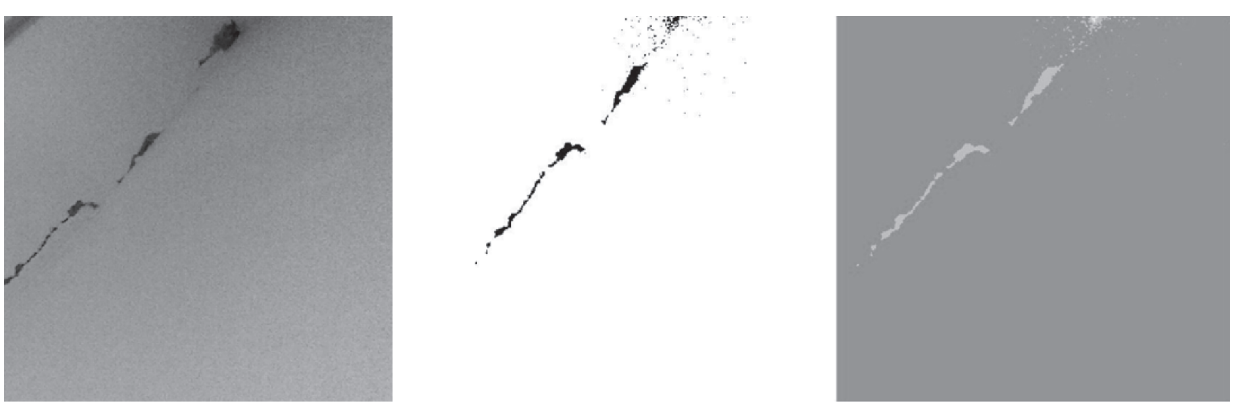

Figure 16: From left original image, processed image to black and white, connected components image

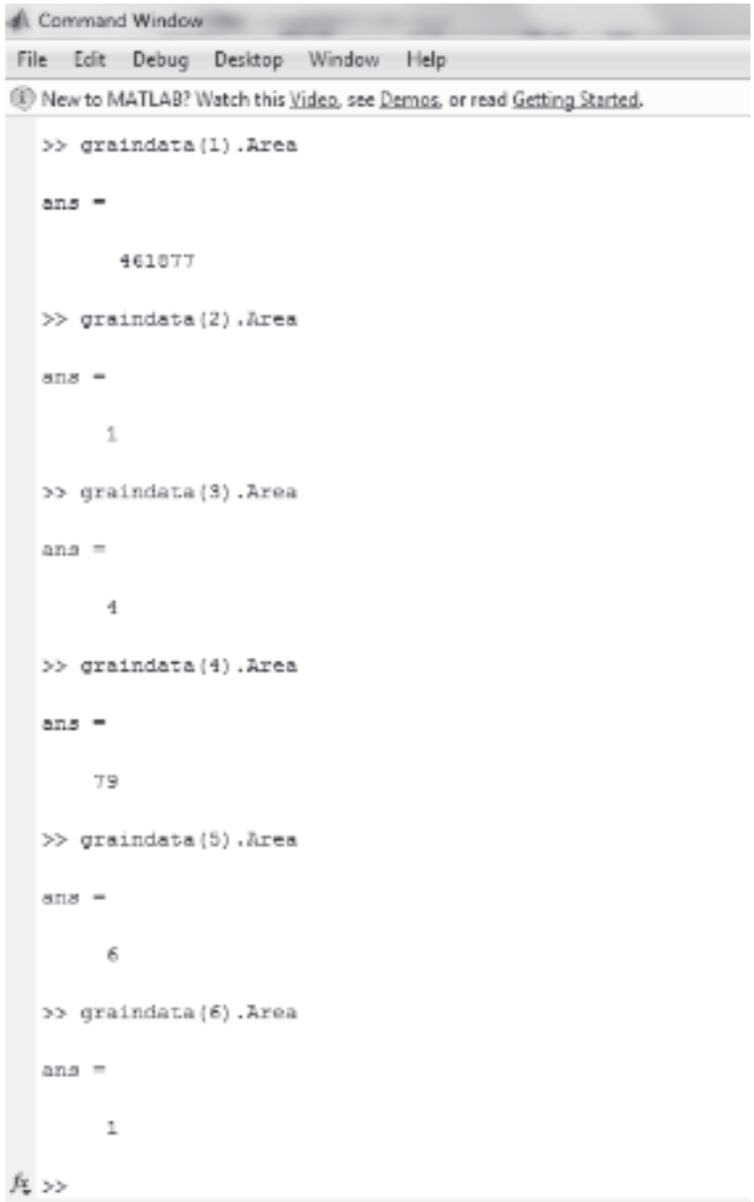

Figure 17: Result of our experiment for the above figure 16, the area of crack is determined in number of pixels

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