International Journal of Engineering & Technology, 7 (2.33) (2018) 1184-1187

SPC

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

A Study on Appearance Checks for Structures with UAV-Based Spatial Imagery Information

Dong-Moon Kim*

**Department of Spatial Information Engineering, Namseoul University, 91, Daehak-ro, Seonghwan-eup, Seobuk-gu, Cheonan-si, Chungcheongnam-do, 31020, Republic of Korea*
**Corresponding author E-mail: david@nsu.ac.kr*

Abstract

Background/Objectives: It is difficult to do visual inspections and checks for safety assessment in structures with low accessibility. This study, thus, set out to explore the possibilities of inspecting structure appearances with a UAV(Unmanned Aerial Vehicle)-based image information acquisition system.

Methods/Statistical analysis: Aerial photogrammetry was done with a UAV equipped datum point survey and image photography functions to produce spatial imagery information. The imagery information that was acquired was produced into ortho-photos and compiled as spatial imagery information based on the datum point information. Preprocessing and image analysis (edge extraction) techniques were applied to spatial imagery information to extract cracks in a structure.

Findings: In the survey of ground control points, which have the biggest impacts on the spatial accuracy of spatial imagery information, location accuracy was very good at 0.027m, 0.051m, and 0.106m on the X, Y, and H coordinates, respectively. As an image analysis technique for spatial imagery information, the Canny Image Detection technique was applied to extract 13 risk elements. Compared with on-site visual inspection, it succeeded in detecting 100% of the scaling and wire & cable except for micro-cracks and white rusts, which have no influence on the structural damage of general structures. The geometric forms of cracks detected under the category of cracks were defined with diagonal and perpendicular lines. The cracks were an average of 0.6mm in width and an average of 569mm in length, recording the minimum 301mm and maximum 739mm in length.

Improvements/Applications: The findings show that the UAV-based imagery information acquisition system helped to check and evaluate cracked parts in structures with low accessibility and was expected to serve effectively in the compilation of 3D spatial information as well as the inspection of structural appearance.

Keywords: *UAV (Unmanned Aerial Vehicle), Ortho-photos, Aerial photogrammetry, Spatial imagery information, Canny Image Detection technique, 3D spatial information*

1. Introduction

In recent years, natural disasters, such as earthquakes, have increased in frequency both domestically and globally. Such disasters are not restricted to small areas, and it is difficult to predict their forms and sizes. Most of all, disasters, such as floods and earthquakes, do not end as a one-time event, but happen in complex ways involving flooding and liquefaction. Given the recent trend of expanding disasters in damage size and scope, it is urgent to establish measures to figure out and prevent damage to all kinds of structures, which provide space for citizens to live and do activities in. Appearance checks are essential for the protection of human life and prevention of economic loss due to disasters by identifying risk elements in structures in advance and ensuring the stability of structures after a disaster, along with close inspection and safety diagnosis based on field study, precision survey, and non-destructive inspection[1,2]. It is, however, impossible to do appearance checks based on precision diagnosis and a naked eye in large-scale structures or structures with low accessibility due to the limited access to them. Thus, it is needed to acquire and utilize spatial imagery information that has a high utilization rate for non-contact appearance checks. The present study aimed to review the possibilities of checking the appearance of structures as a safety assessment by acquiring its imagery information and investigating image analysis techniques with a UAV-based imagery information acquisition system, which is capable of increasing access to structures and doing a non-contact diagnosis of them[3-6].

2. Techniques for Safety Diagnosis and Spatial Imagery Information Analysis

2.1. Safety Diagnosis Techniques for Structures

General structures are diagnosed and assessed for their safety through the precise safety diagnosis of structures and the interpretation of field study results in a static structure. Precise safety diagnosis methods mainly include a contact/non-contact diagnosis techniques using safety diagnosis equipment such as rebound hardness, ultrasonic and electromagnetic waves as well as the neutralization testing technique. A field study usually uses a naked eye to detect signs such as sagging, rupture, crack, and structural abnormality in a structure. The behavior level of structures is evaluated through strength and performance in static structure interpretations. A field study is essential to the conventional approach to the safety diagnosis of structures since it is very difficult to figure out their behavior by setting the entire structure as a unit of analysis. There should be measures to assess the entire structure in such signs as sagging and structural abnormality rather than parts of the structure in behavior. In addition, an inspection of connecting parts in a building for cracks is extremely important, which makes field study essential. The inspection of a structure surface for cracks is also very important[7]. Micro-cracks and diagonal cracks on the finishing materials or surfaces of structures are highly likely to facilitate the corrosion of reinforcing bars and lower their structural stability in the long term. In Figure 1, diagonal cracks are, in particular, caused by loads such as uneven settlement and characterized by cracks in a diagonal line.

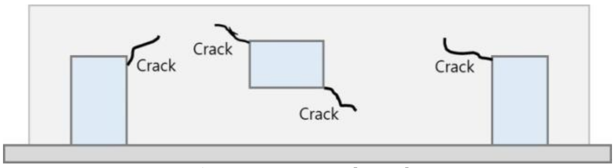


Figure 1:. Diagonal Cracks

A field study is of great importance in the safety diagnosis of structures, but it is not easy to examine objects with low accessibility with a naked eye. In recent years, unmanned aerial vehicles (UAVs) are used to obtain spatial imagery information about structures, interpret their images, and replace field studies for structures. A UAV positioning system can compile spatial imagery information by acquiring horizontal and vertical images of objects. It has the advantage of higher spatial resolution over the old aerial photogrammetry method; thus, being applicable to the field of structure safety diagnosis effectively. Acquired imagery information can be used to make ortho-photos, DSM, Point Cloud, and 3D models[8-12]. As seen in Figure 2, one should go through a series of processes from making a work plan and doing aerial photogrammetry through producing ortho-photos and spatial imagery information to analyze images and check the appearance in order to examine structure appearance with spatial imagery information.

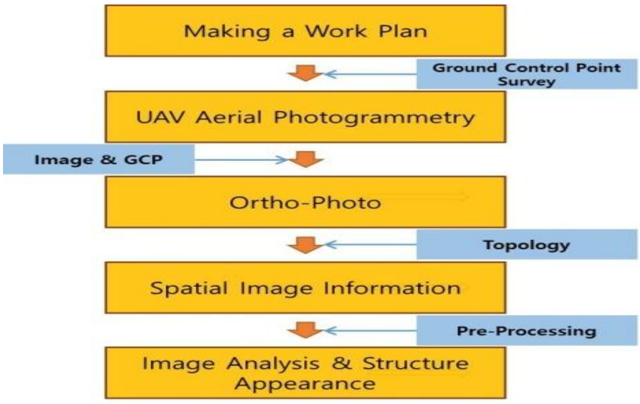


Figure 2.: Process of Making and Analyzing Spatial Imagery Information

2.2. Analysis Techniques for Spatial Imagery Information

Image preprocessing and analysis techniques should be applied to analyze spatial imagery information. That is, one can detect edges where cracks are predicted in an image preprocessing and analysis process. Edges are found in parts where the brightness of images turns from a lower value to a higher value, and the parts with a certain distribution appear as boundaries. Thus, it is possible to detect boundaries based on differences in brightness value changes.

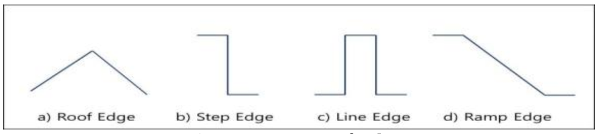


Figure 3:. Types of Edges

As seen in Figure 3, there are various types of edges including roofs, steps, lines, and ramps, but most of them are in the form of ramp edges. There are also various ways to detect edges including first-order differential, Sobel, Prewitt, Roberts, Compass, second-order differential, Laplacian, LoG, Canny, and Line edge detection techniques. Sobel is one of the representative edge detection techniques using a first-order differential operator (Formulas 1 and 2). As seen in Figure 4, it can detect edges in all directions with a mask in the horizontal and vertical direction and levels off protruding pixel values to eliminate noises. Most of all, it has a more sensitive reaction to edge detection in a diagonal direction. Formula 1 is used in a differential operation in the horizontal and vertical direction, and Formula 2 is used to detect an edge with first-order differential.

$$G(x) = f(x-1, y) - f(x+1, y),\ G(y) = f(x, y-1) - f(x, y+1) \quad (1)$$

$$\nabla G \approx |G_x| + |G_y| \quad (2)$$

-1	0	1
-2	0	2
-1	0	1

a) Vertical Mask

1	2	1
0	0	0
-1	-2	-1

b) Horizontal Mask

Figure 4:. Sobel Masks

Most edge detection techniques, including Sobel, are, however, sensitive to noises, regarding even small noises as edges and detecting them in many cases. Canny can detect strong edges not sensitive to noises to supplement this disadvantage. It meets the criteria of good detection, good localization, and clear response and detects an edge basically in the stages of Gaussian smoothing filtering, gradient computation on the x and y axis, gradient strength computation, non-maximum suppression, and hysteresis.

3. Acquisition of Spatial Imagery Information and Appearance Checks for Structures

3.1. The Subjects and Data Acquisition

The subjects included structures in the representative form of concrete structures seen in Figure 5. The investigator targeted roofs, which had relatively low accessibility for appearance checks rather than outer walls of buildings.

a) UAV Images **b)** General Aerial Photograph

Figure 5.: Aerial Photograph of the Subject

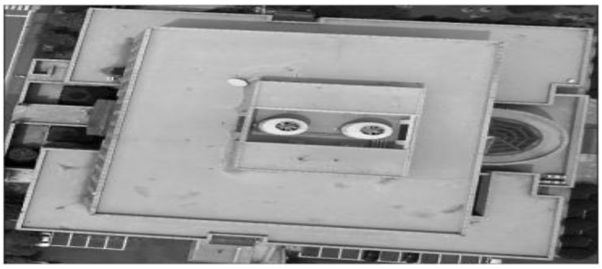
The imagery information that was used in the present study was obtained in the procedure depicted in Figure 2: making a filming plan, surveying ground control points, doing aerial photogrammetry with a UAV, and generating ortho-photos. VRS equipment in the Network-RTK style was used to obtain ground control points (GCPs) and survey five ground control points and four check points. In aerial photogrammetry, a UAV (Phantom 4) was used along with the fuselage of Phantom 4 model by DJI. Phantom 4 can fly for 30 minutes at the maximum speed of 72km/h. Mounted onto the aircraft, the camera has field of view (FOV) of 84°, focal distance of 35mm, and resolution of 4K. Ortho-photos were created with photos that were taken, GNSS data, and survey results of ground control points. DEM was generated with point cloud data made along with ortho-photos. The plane positions and altitude errors of check points were calculated to analyze the accuracy of ortho-photos, and the results show in Table 1 that RMSE was 0.027m, 0.051m, and 0.106 on the X coordinate, Y coordinate, and altitude, respectively. The final imagery information provided spatial imagery information, including coordinate system information (Korea Geodetic Datum). In other words, spatial imagery information provides information about length, area, and form, which are spatial features in images based on the Korea Geodetic Datum.

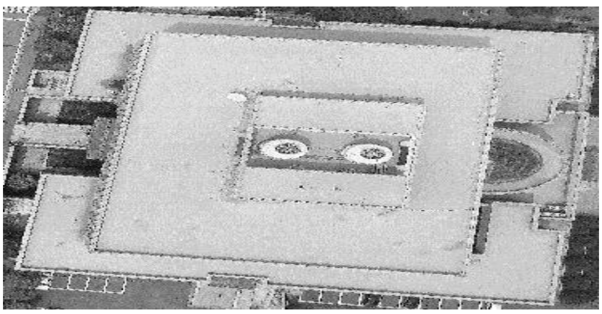
Table 1: Analysis results of check points in location accuracy

Point No.	X(m)	Y(m)	H(m)
1	0.025	0.035	0.156
2	0.008	0.057	0.117
3	-0.035	-0.058	0.074
4	0.015	0.036	-0.086
RMSE	0.027	0.051	0.106

3.2 Analysis of Spatial Imagery Information and Detection of Cracks

An edge detection technique was applied to detect damaged parts in appearance including cracks with spatial imagery information. For the application of an edge detection technique, cracks were detected through image binarization, sharpening, contour search (edge detection), and noise elimination. Figure 6 shows the outcomes of image binarization; Figure 7 shows the results of sharpening to increase the efficiency of feature search in binary images; Figure 8 shows edge detection by applying an edge detection technique called Canny; and Figure 9 shows the detection of crack parks by getting rid of noises from the edge detection images.





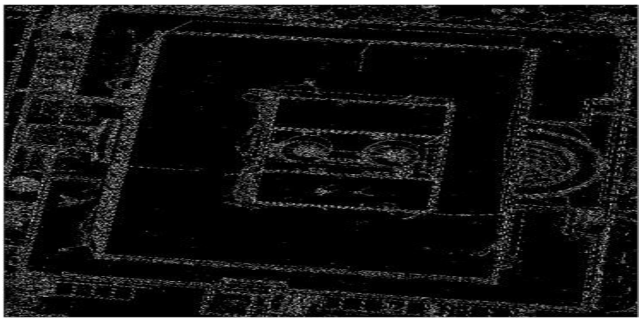


Figure 6:. Binary Image **Figure 7.** Sharpening Image **Figure 8**. Edge Detection Image

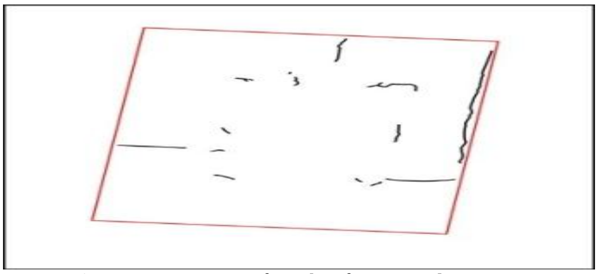


Figure 9:. Detection of cracks after noise elimination

Figure 10 shows the locations of cracks detected in Figure 9 with an examination done with a naked eye to present the damage on the concerned part in a quantitative manner. Table 2 shows the measurements of cracks in width and length with steel tape and the arrangement of each section type. Detected in images, the types found in each section included cracks, white rust, scaling, and wire & cable. There were three cracks, two spots of white rust, six spots of scaling, and two spots of wire & cable.

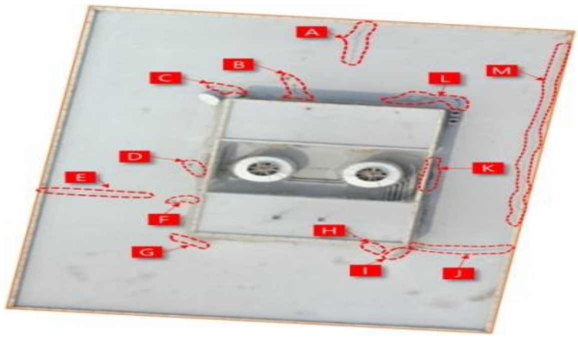


Figure 10:. The locations of detected cracks

Table 2: Measurements of Cracks

Section	Width (mm)	Length (mm)	Type
A	0.5	669	Crack
B	0.8	301	Crack
C	15	277	White rust
D	11	192	Scaling
E	0.5	739	Crack
F	5	149	White rust
G	7	251	Scaling
H	6	127	Scaling
I	10	156	Scaling
J	9	744	Wire & cable
K	20	501	Scaling
L	0.4	675	Scaling
M	9	3217	Wire & cable

An on-site inspection with a naked eye detected 100% of scaling and wire & cable spots, but some micro-cracks and white rust spots were not detected as seen in Figure 11. These micro-cracks and white rust spots were created within the depth of 1mm or less from the building surface, being in the scope of having no impact to the structural damage of buildings. As seen in Figure 12, the shapes of detected cracks were diagonal (B) or perpendicular (A and E) to the joints with outer walls or walls in buildings.

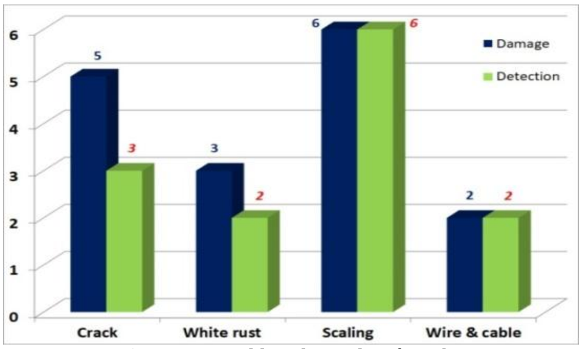


Figure 11:. Field study results of cracks

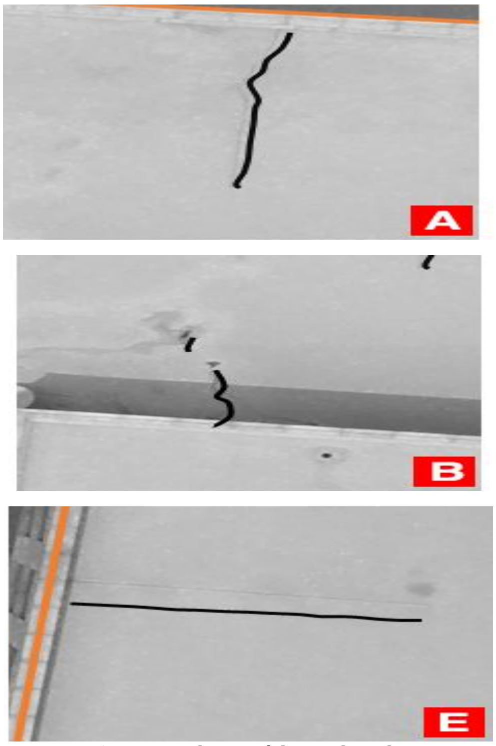


Figure 12: Shapes of detected cracks

The cracks recorded mean was 0.6mm in width and 569mm in length, measuring a minimum 301mm and maximum 739mm in length. As for the location of cracks, there were two cracks at the half point of the outer wall length and one crack at the one-third point of the wall length from the joint with the inner wall. These findings confirm the possibility that UAV-based spatial imagery information can be used as basic data to figure out cracks in buildings and serve various purposes in appearance checks to assess buildings for stability.

4. Conclusion

The present study reviewed the possibility and utilization of UAV images to check the appearance of structures as part of safety inspections. Spatial imagery information was obtained with a UAV and image photographing equipment to check the appearance of structures, and image analysis techniques, including edge detection techniques, were applied to detect cracks in the damaged parts of structures. The image analysis results show that cracks with an average width of 0.6mm and an average length of 569mm were detected. This approach, however, had its limitations in the detection of damage caused by exfoliation and white rust. There is a need to introduce cameras capable of capturing images of higher resolution and do additional research on analysis techniques by crack type in order to detect all types of cracks. The findings of the present study can replace an inspection with a naked eye for structures with low or no accessibility and are expected to be applicable to the compilation and utilization of 3D spatial information in various forms including DSM. In the future, there should be more research on filming equipment of higher accuracy and UAV photography techniques, and most of all, additional research to improve image analysis techniques for various types of cracks.

Acknowledgment

Funding for this paper was provided by Namseoul university.

References

[1] Kim, D. (2015). Integration of Near Infrared Image and Probabilistic Classifier to Increase the Classification Accuracy of Point Clouds. Indian Journal of Science and Technology, 8(20), 1-6.

[2] Kim, D., Shin, E. (2014). Vegetation Community Extraction through a Fusion of Multi-Spectral Images and Terrestrial LiDAR Data. International Journal of Applied Engineering Research, 9(22), 14597-14608.

[3] Um, D. Y., Song, Y. H. (2016). 3D Reality Model Creation and Positioning Accuracy Analysis Using Images Obtained with a Low-cost Rotary Wing Drone. Asia-pacific Journal of Multimedia Services Convergent with Art, Humanities, and Sociology,6(9), 235-246. doi :http://doi.org/10.14257/AJMAHS.2016.09.57.

[4] Kim, M. K., Jung, K. Y. (2016). Applicability Analysis of Drone Photogrammetry for Updating Digital Maps. Asia-pacific Journal of Multimedia Services Convergent with Art, Humanities, and Sociology, 6(8), 603-610. doi :http://doi.org/10.14257/AJMAHS.2016.08.60.

[5] Chan, B., Guan, H., Jo, J., Blumenstein, M. (2015). Towards UAV-based bridge inspection systems: a review and an application perspective. Structural Monitoring andMaintenance,2(3), 283-300.doi :http://doi.org/10.12989/smm.2015.2.3.283.

[6] Ali, G., Suraj, M., Bal, G.(2016). Prediction of Sewer Pipe Main Condition Using the Linear Regression Approach. Journal of geo science and environment protection, 4(5), 97-104. doi: http://dx.doi.org/10.4236/gep.2016.45010.

[7] Lee, H. B., Kim, J. W., Jang, I. Y. (2012). Development of Automatic Crack Detection System for Concrete Structure Using Image Processing Method. Journal of the Korea institute for structural maintenance and inspection, 16(1), 64-77. doi : http://dx.doi.org/10.11112/jksmi.2012.16.1.064.

[8] Brown, L. G. (1992). A Survey of image Registration Techniques. ACM computing surveys, 24(4), 325-376. doi : http://dx.doi.org/10.1145/146370.146374.

[9] Zitova, B., Flusser, J. (2003). Image registration methods: a survey. Image and Vision Computing, 21(11), 977-1000. doi : http://doi.org/10.1016/S0262-8856(03)00137-9.

[10] Lee, D. G., Yu, Y. G., Ru, J. H., Lee, H. J. (2016). Change Monitoring in Ecological Restoration Area of Open-Pit Mine Using Drone Photogrammetry. Journal of the Korean Society for Geo-spatial Information Science,24(4), 97-104. doi : http://doi.org/10.7319/kogsis.2016.24.4.097.

[11] Snavely, N., Seitz, S, and Szeliski, R. (2008).Modeling the World from Internet Photo Collections. International Journal of Computer Vision, 80(1), 189-210.

[12] Singh S., Chutia, D., and Sudhakar,S.(2012). Development of a Web Based GIS Application for Spatial Natural Resources Information System Using Effective Open Source Software and Standards. Journal of Geographic Information System, 4(3), 261-266.