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Article

Improvement of UAV Based an Evaluation Approach to Mid-High Rise Buildings' Exterior Walls

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Abstract: This research will develop a set of assessment techniques and procedures for exterior wall deterioration detection. The proposed method is mainly based on equipped with high-resolution photographic equipment for unmanned aerial vehicle (UAV). To overcome the problems of visual inspection difficulties due to different angles and height, the proposed method provides a safer and more efficient detection way to get the buildings' exterior status. After using the proposed method to analyze the images taken from UAV, the size of the damaged area can be evaluated more accurately, and the accuracy rate of visual assessment will be significantly improved. The results of the proposed method can reduce the accidents caused by the inspection process in the critical environment and the costs incurred by the temporary facilities without sacrificing the quality of the inspection results. Then, the research will implement the existing visual assessment method because of the characteristics of rapid detection, however, the assessment results will be different from different inspectors due to subjectivity. Thus, the research will present an improved visual inspection method by using UAV and Forward Looking Infred Thermal technology (FLIR). The result will be presented by Condition Index (CI-Level) instead to improve the subjectivity of the personnel.

Keywords: Exterior walls; inspection; UAV

1 Introduction

Since buildings degrade, exterior wall tiles or attachments drop off, thus causing frequent injuries. Governments have established regular inspection mechanisms for the exterior walls of buildings that has a certain age. Currently, the inspection techniques for middle-high rise buildings are generally visual assessment. Inspectors create angles on buildings and inspect them through visual inspection, but this method is likely affected by subjective factors. The hanging detection should prevent inspectors from falling and also the establishment of eagle erection could also increase the price. Additionally, telescopes tend to be used regarding detection, however the effect is restricted by height and angle, and inspectors cannot illustrate the judgment when they look downwards standing atop the building. These methods for exterior wall detection have their respective benefits and drawbacks. If equipment costs and consideration for technology and safety are considered, several types of charges are added. Thus, this research builds up a low-cost and efficient assessment way of exterior wall assessment that is simple to acquire as well as traditionally used through having high-resolution photographic equipment on Unmanned Aerial Vehicle (UAV). Using the maturity of UAV technology and the capability of operation, Global Positioning System (GPS) can provide the location of detected points and also the setting of relevant height more efficiently. Its stability can improve the image recording of the detection process, and also the overall visual detection technology, and solve the present visual detection conditions inspectors cannot view from top to bottom at some certain angles or when there are actually shelters. Using UAV with high-resolution lens, coupled with additional image recording supplied by infrared thermal image detection technology, can improve the precision of visual inspection much since this technology can create pictures of temperature distinction in bumps or cracks. Therefore, using high-resolution photographic recording devices in creating parts can get over difficulties due to the top-down view, angle, temperature and height, and the price is fairly reduced. Within the subsequent handling of computer picture assessment as well as meaning, the appropriate CAD design drawings and rating can be used to help in meaning. This process can help to eliminate mishaps within function and also the cost deriving from temporary facilities in thought on open safety. The objective of this research is actually targeted in order to suggest a more efficient and low-cost recognition technology which increases the precision associated with present evaluation which effectively compares the outcomes of damage associated with exterior surfaces or supplementary structures to grasp the properties as well as tendencies as well as evaluate, detect as well as tackle difficulties correctly. When exterior walls are damaged or in routine maintenance, evaluation should be carried out as schedule quality evaluation and long-term follow-up inspection. Thus, the objectives of this research are the following:

1. A close-range detection approach according to visual detection, FLIR and UAV is proposed, and an assessment process is created on regardless if up-down assessment can be done when shelters occur.
2. Discussing infrared thermal imager could be put into UAV-based GPS positioning system to improve the temperature distinction rate of pictures to help in interpretation, improve the precision of visual detection and give a case study.
3. The picture comparing approach is proposed to check the original CAD layers of buildings with pictures for short-range detection from UAV, and to approximate the shape and range of defective styles and locations.
4. The detail identified by visual inspection and UAV high-resolution video is employed to build up a proper visual assessment procedure for exterior walls. With the test results of several cases, the abnormal state and needs for routine maintenance are considered based on the level of overall performance.

2 Literature Review

The objective of this research is to look into the literature relevant to exterior wall assessment and UAV's application to incorporate the techniques of application and maintenance, to know the existing research developments via literature discussion, and further incorporate the literature review relevant to this research to get theoretical assistance and reference.

2.1 Exterior Wall Inspection

The majority of the previous studies on inspection technologies relates to materials and non-destructive testing, and a few in Taiwan have similar research. Lee et al. [1] used infrared thermography to check connecting defects of exterior wall decorative tiles of structures and also to test the connecting quality of exterior wall decorative tiles, to be able to determine the limitations of empty drum, calculate the speed of empty drum and evaluate the influencing factors and maintenance schemes. Case study of pull-out make sure non-destructive testing approach to connecting strength of exterior wall decorative tiles by Chiao provides theoretical grounds for future engineering practice [2]. Tai [19] established the RC wall membrane, set different exterior wall tiles by different sticking methods, after which used seem-tapping approach to identify the sticking condition of tiles. The seem frequency measured by seem-tapping method was digitized and mapped through fast Fourier transform. Yen [3] suggested the frequency domain could be misjudged easily because of the poor material quality. Therefore, this research introduced the seem energy area way in which is dependent on time domain with no above limitations because the grounds for knowing the degeneration of tiles. Lin [4] applied ordinary exterior wall tiles to infrared thermal image recognition mainly to identify the debonding between surface tiles, connecting layer and bottom concrete, since air layer created by debonding helps make the temperature between normal and defective regions of exterior wall under sunshine. The main difference could be judged by real-time display of infrared thermal image. Huang et al. [5] applied the idea of D.E.R.U. visual inspection criteria, and built some "visual inspection and evaluation means of public safety of creating exterior walls" using the hierarchical analysis method (AHP) and also the questionnaire of experts and students that lead to produce the standards and weight for that public security inspection needed for building exterior walls [6].

2.2 UAV Application

The Unmanned Aerial Vehicle (UAV) means flying vehicle whose flight radius is beyond sight. The excellent enhancement produced from 1980 to 2010 makes the UAV today possible, especially in the following four areas:

1. GPS: In 1981, the first commercial-purpose GPS receiver weighed 50 pounds as well as price was up to USD 100,000. Currently GPS weighs only 0.3 grams and the chip price is under USD 5.
2. IMU: Inertial Measurement Unit (IMU) is employed to measure the speed, azimuth and acceleration of UAV. An IMU (consider Project Apollo) weighed 50 pounds and price millions of dollars in the1960s.
3. Digital camera: In 1976, Kodak launched the first digital camera with only 100,000 pixels, weighing 3.75 pounds and costed over USD 10,000. The digital camera today is notably different from that of 1976 (1,000 times higher resolution, 1,000 times smaller size and 100 times lower price).
4. Computer and wireless communication (Wi-Fi, Bluetooth): Undoubtedly, the cost-effectiveness ratio of computers and wireless communication continues to be basically (almost a billion times) superior to that in the 1980s.

UAV is used to:

1. Agriculture: UAV screens catastrophes and gathers real-time data on crop wellness yield.
2. Energy: Energy organizations utilize UAV to observe pipelines and rigs.
3. Real estate and architecture: UAV take pictures of sites such as courses and skyscrapers, prospect specific sites, informs property developers, and watches the progress of project.
4. Rapid response and emergency services: UAV utilizes infrared sensors to help in search and also save operations in a range of scenarios, like firefighting, ruins and avalanches.
5. News: UAV reports breaking news/disaster/war area situation in a quicker and safer way than humans perform [7].

Lately, due to a few well-known factors, such as the use of computer vision technology (motion structure), improvement the quality of digital cameras and the outstanding improvement, the close-range photogrammetry technology has made substantial advancement. Photogrammetry software [8,9]. Also, lightweight RPAS (Remote Pilot Systems) continues to be equipped with more and more advanced and dependable navigation systems [10–12]. A combination of the technological improvements has resulted in the rapid and widespread utilization of lightweight RPAS in photogrammetry, particularly for social history [13]. Thus, increasingly more professionals and experts from numerous areas which are not strictly in measurement have started to use the digital photogrammetry technology of RPAS. This pattern suggests the need for simple guidelines for that suitable utilization of low-cost photogrammetry performed from very light RPAS (less than 2 kg) to acquire a sufficiently precise three-dimensional model of the object being measured [14]. The emergence of UAV camera can compensate for the present drawbacks. This sort of camera captures a obvious picture and it has a large vision using the idea of gimbal that may be tracked back greater than two centuries ago. The gimbal technology was well-known within the 15th century, having a pivotal device that allows objects to rotate around just one axis without bias. Each three vertical pivot axes which are vertical with one another constitute a gimbal group, so the object within the innermost area of the frame can keep up with the position of spin axis unchanged. In the past, the gimbal was mainly utilized in navigation. The crew would put the compass around the gimbal so the compass wouldn't be affected when ships oscillated. Nowadays, the gimbal isn't just employed for navigation, but in addition for photography. When users take videos, the gimbal is bound around the camera to help keep the image stable, as proven in Fig. 1.

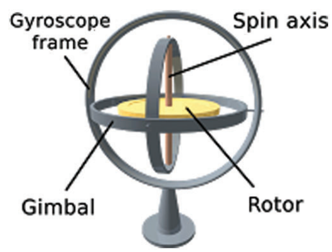

Figure 1: Structure of a Gimbal

The UAV gimbal is principally operated by the engine that controls each axis. When users are surfing within the sea or skiing, the camera lens instantly capture pictures as lengthy because the camera having a route set is a component of UAV. Additionally, once the camera moves, the computer program determines whether it's under user instruction or just oscillates, so the image could be maintained in a benchmark point and become avoided from trembling because of exterior forces. The drawback to UAV may be the huge power consumption that needs users to organize extra batteries anytime [15].

However, the standard operation mode of any UAV should include at least default route, autonomous driving and satellite navigation. That is to say, after taking off by remote control, the aircraft can automatically fly on the route input into the flight computer in advance, modify the flight route by verifying coordinates through the GPS on the aircraft, and transmit flight information back to the ground control center. After the UAV arrived at the target region, ground controllers perform scheduled tasks by remotely manipulating the equipment on UAV aircraft via radio. Engel et al. [13] used a monocular camera as the main transmitter, so no exterior tracking tool such as GPS or visual tags is required. The costly computing includes an exterior laptop and the four-axis UAV of wireless local area network [16]. The UAV research of Bošnak targets vehicle positioning that aims at achieving the self-control of the exterior transmitter of a fully automatic UAV. If the global positioning system (GPS) doesn't work, computerized vision is needed to enable a four-axis aircraft to stabilize its position through the visual system. This marks improvement data fusion algorithms for measuring and positioning by utilizing inertial sensors and visual systems. The four-axis UAV provides applications for aerial robots. Given the potential of hovering ability and the large dynamic platform, its high-speed flight dynamics are complex. Since the modeling has shown difficult, the charge of algorithms usually relies on simplified models to feedback, correct and make up for non-modeling effects, which may lead to significant tracking errors and repeated execution in high-performance flight. Tracking errors are mostly due to repetitive execution [17]. Data extraction from UASs is no longer utilized in visual purposes but designed to be interchangeable while continuously containing all important elements of the long-way procedure. Rapid 3D imaging discoveries uncover the gap of visual needs of the information. This perspective presents potential challenges to engage with tool integration as well as laser scanning, camera and RGBD camera as components to conduct assessments [18]. UAV relies on the built-in GNSS system as a guide to recognize location, position and coordinates. Circular flight pattern was deployed for the missions. Four control points were used as a reference for two difference missions due to image alignment to accomplish positive correlation between high-resolution images and stitching accuracy [19]. The SfM software will connects the detected features by comparing photos and constructs a 3D model towards accuracy assessment. Standard technique workflow was adopted to process the 3D image [20]. UAV-based monitoring to photogrammetry has long been developed and introduced to both commercial and professionals as a low-cost tool. This technology is one of a robust applicable methodology in many sectors, such as industrial sector, transportation, civil and construction, meteorological, environment, health, education, management and many more [21].

Thus, according to the progression of the entire architecture, this research presents the idea of visible examination picture assessment following UAV image shooting to the detection operation of exterior walls or ancillary structures, and the detection methods are discussed. The classification of detection and the level of detection results are recognized, and the appropriate maintenance techniques are selected to fix or renovate buildings, and then several new detection cases are selected for verification. The technique proposed in this study can enhance the safety and capability of inspection workforce at a lower price.

3 Research Method

This study implements the case study method given that it's primarily aims to develop a detection and assessment model of exterior wall that combines UAV with infrared thermal imaging recording, and to discover the practicality of the above-mentioned model. As a result, real cases are required to adjust the entire process, and expert interviews are carried out to improve the application of detection technology. Moreover, data and knowledge can be preserved and inherited by using computerized database, so the whole case database is capable of greater efficiency of query and inspection.

As discussed in the literature review, UASs-based Photogrammetry is critical components at early stages of this project, which can provide dataset with valued information and visualization, especially when the project offers various alternatives of integration and interoperability requirements. Improving the dataset with technology and smart tools is the main objective of this study. This methodology has been carefully selected to be an awareness among user to consider a sustainability methodology in construction industry. This section of this study proposes UASs-based Photogrammetry as a long-way methodology for the main components to data integration and interoperability management in practice.

This section describes the study area, control points, and survey parameters for research object in National Yunlin University of Science and Technology, Taiwan (Fig. 2). In this study, several constraints and factors were identified, such as: standard visual survey, according to the environments, conditions, and weather to conduct flying on January 10th, 2019.

Figure 2: Study area (Tower Cloud Building, National Yunlin University, Taiwan)

Founded in 1991, Tower Cloud Building become the landmark and considered as the famous civil structure in campus area. This building has 14 floors with a facade that looks similar on each side of the exterior (Fig. 3). In some parts of this building, there are some difficult areas to conduct maintenance because the position was not accessible. Weather impact was the biggest considerable variable in implementing this research in order to promote building inspection. Visually, this building does not have many decorative structures, only standard material mainly covered with red bricks, iron, cement, and reinforced concrete.

Figure 3: Yuntech tower cloud

In order to ensure image alignment during image collecting process, Control Points were used on places which easily seen by the UASs as a reference. In general, there were two reasons to use Control Points which are need of high degree of accuracy or to provide measurements within a certain range of accuracy. 4 CPs (Control Points) were placed as a guidance for reference to assure the measurement assessment in the data processing stage. They were placed on the ground on the open place with no sight barrier for the UAV during the mission. All these necessities must be considered during flight planning and control to ensure the precision and the final result before move to the next step [22]. Usually the objects that represent the Control Points are made colored and given a separate code at each location to facilitate the next process [23,24]. This is because there is a positive correlation between high-resolution images and stitching accuracy.

According to the reported survey data, the mission was possible measured on wind speed of $\leq$20 km/h in average, and weather forecast reported as normal and the sun visually bright to gather images. During this mission, the height of the objective was ±65 m above ground level. Conducted maximum altitude for this mission was set at 70.5 m. This would help to establish that the UAV would be within the operator's line of sight during the mission.

DJI phantom 3 Standard quadcopter which widely used commercial UASs was operated. This UASs camera setup consisted of a manually flown UASs and an independent camera was set to take photographs at a fixed interval. This UASs was suggested to fly manually by sight, equipped with waypoint programming or first person view with maximum control range of 1 km. This setup already equipped with 3-axis gimbal for the camera as an excellent device. The camera was deployed with 12 MP sensor up to 2.7K resolution video at up to 30 frames per second, carried at 40 Mbps Sony Exmor R BSI 1/2.3" CMOS, standard point and shoot cameras with FOV 94° 20 mm lens (35 mm format equivalent) and f/2.8 apertures at the wider view. Offered as single shot, burst mode, auto exposure, bracketed frames and time-lapse shooting (DJI 3 2005) (Fig. 4). The camera was attached to the UASs using a simple camera mount and the vibration from the UASs is quite stable and doesn't affect the quality while capturing images, just for a notice an effective camera mount must prevent transmission of vibration to the camera in advance [25] (Fig. 6).

Aircraft : Using DJI Phantom 3 Standard		
1.	*dimension < length X wide X height >*	*289.5mm x 289mm x 185mm*
2.	*GPS*	*Satellite navigation System*
3.	*Max. Flight time*	*±25 minutes*
4.	*Max. Flight Altitude*	*±6000 m*
Camera		
1.	*Sensor*	*1/2.3" Effective pixels : 12 M*
2.	*Lens*	*FOV (Field Of View) 94° 20mm (35mm format equivalent) f/2.8*
3.	*Image max. Size*	*4000 X 3000*

Figure 4: UAV Specification and Visualization used in this work as photogrammetric platform

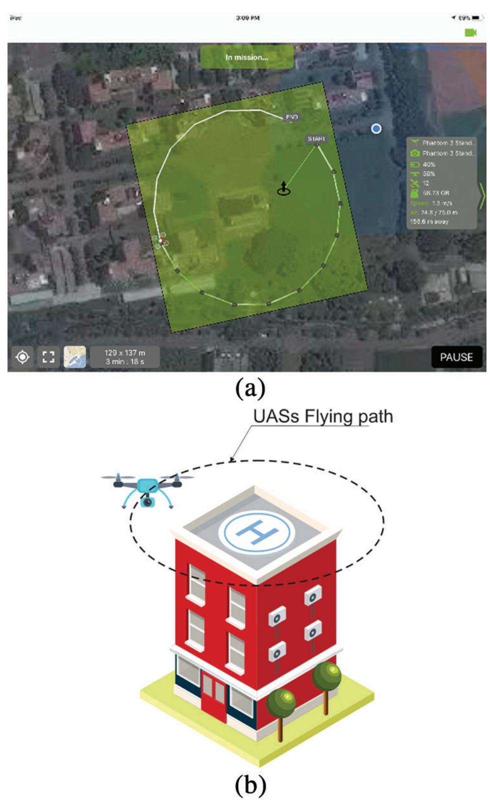

Figure 5: UASs Autonomous flying mission application (a) UASs flying mission on PIX4Dcapture application (b) UASs-based Photogrammetry flying pattern

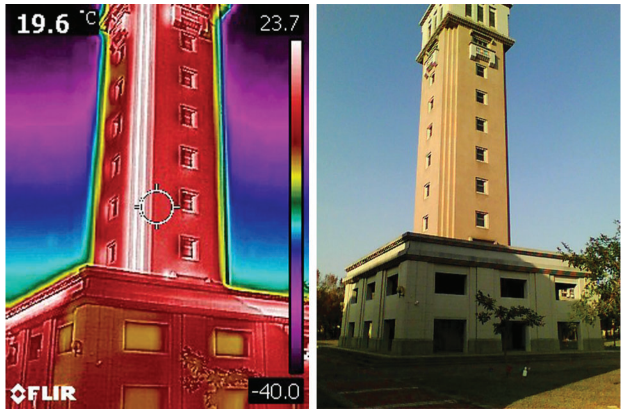

Figure 6: Infrared thermal imager detection case: detection of exterior wall peeling (infrared and visible images)

Figure 7: Image of overhead photography by UAV's camera

DJI Go was an open source application from DJI Phantom and combined with Pix4Dcapture as a support application to manually or automatically control the UASs to get better imagery acquisition, better quality and precision during the mission (Fig. 8). Some factors such as: sunlight illumination and water surface reflectance were also considered to influence the quality of images, but it was not necessary during flight mission. During this step, the GPS and the built-in function had been confirmed correctly set. The mission was deployed in circular flight pattern (elevation was reduced randomly of each layer). Maximum flying altitude was set at ±110 m. Area coverage was considered to be ±85 m × 85 m with 45°

Figure 8: Image of close-range horizontal photography by UAV's camera

of camera angle. Four batteries were used sequentially to anticipate power failure. Flight time duration was ±20 min per layer in this mission.

Autonomous flight mode for take-off, landing and waypoint flight and stabilized with GPS with no signal barrier were selected during a flight mission. As for the controlling system, DJI Go app was installed on IPAD model A1489 and combined with Pix4D capture App to collect image data. Selected tools on DJI Go app for ground point/home point GPS based for RTH (Return to Home) point of the drone was defined as a helpful function to enhance the position markup and drone image alignment for image processing. First preparation of this study was to measure the maximum altitude by flying the drone manually and check the optimal image coverage.

Above all condition, the mission must accomplish pre-designated virtual mission and flying pattern. In order to set up a required flight plan in the mission, third party application and built-in application were deployed. Third-party application was used to create a flight mission which enable operator to setup UASs altitude, flying pattern, UASs hovering speed, camera angle, image overlap, and area coverage. This application integrated with the UASs and remote controller. This mission also utilized built-in application from UASs to both manually control and integrate between third-party application and the UASs (Fig. 5). The information uploaded to UASs to autonomously start the Photogrammetry mission after mission setup.

Based on the literature so far, many applications have been improved in the mission planning process in the trends of UASs to this day. The technology built in the UASs and the remote controller is integrated with third-party applications with either a paid or free system. There are many applications that provide services both on a mobile and web basis that can be used for mission planning purposes. The GUI system provided greatly supports operators in planning and mission management information. This research also utilize DJI Go App and Pix4D App to implement the concept Photogrammetry due to research background. DJI Go App has integration with many types of DJI products and provide easy-to-operate system. As well as DJI Go App, Pix4D is used for the flight pattern and to conduct autonomous mission to integrate with DJI Phantom 3 Standard as a tool for UASs-based Photogrammetry.

3.1 Research Findings

About the detection methods developed in this study, UAV is used to carry image recording equipment, images are transmitted to mobile devices in a wireless and real-time manner and recorded in the memory card of the camera synchronously, and large-area images are recorded by infrared thermal imager, which are followed by high-resolution images for inspection and interpretation. After that exterior wall structure is inspected through image comparison to estimate the damage. In addition, the method developed in this case evaluates and records the current functions of exterior walls and adjacent structures, providing a reference for future maintenance use.

3.2 Application of Infrared Thermal Imager

The infrared thermal imager utilizes photoelectric technology to identify specific infrared band signals of thermal radiation of objects, which may be changed into picture patterns that may be visualized by individuals, and the temperature value can be further calculated. This technology can observe the temperature distribution on the outside of objects shown in Fig. 6. It features contact lessness, fast temperature measurement and direct visual observation. Thus, it can be used for non-destructive detection like building and bridge structure detection to detect problems in advance. Infrared thermal imager has a number of applications, such as the detection of cracks in buildings, fault parts of walls, leakage in walls and underground pipelines, the heat consumption and heating of buildings, and the maintenance and diagnosis of insulation and lighting systems and bridge structure [26].

3.3 Discussion on Effective Detection Distance of UAV Image Recording

The aerial picture detection and evaluation focus on near, fast and crucial detection. Moreover, the detection picture evaluation approach can assess the overall or structural fixed-point location and simplify the detection process. The crack beneath the exterior wall surface may only reflect what happens to a general location. When the inspection is in a close range, the aerial image evaluation can help in the inspection through image magnification, along with infrared thermal image detection and enhanced partial development to comprehend the status quo. Thus, the test is required to be performed in both static and dynamic way by using expert questionnaire to assess the pictures, among which the majority of the view can be used the scope and distance of image detection is determined.

If close-range detection is utilized substantially, lots of time and manpower might be consumed. Therefore, in the first stage, the infrared thermal imager is utilized, with the status of exterior walls or adjacent structures considered and the deterioration location recorded. Then this deterioration status of structures is known by close-range image inspection by having an aerial camera. Thus, the close-range inspection and documenting of problematic parts are performed by the UAV image transmission system, known as "image transmission." This technology acts for transmitting the aerial picture of UAV to the ground wireless image transmission receiving equipment instantly. Usually, the image transmission system consists of three parts: transmitter, receiver and display.

3.4 Effective Detection Distance of UAV Image Recording

This research is performed in static and dynamic approach through the number on the horizontal ruler and the word E as the test objects and using repetitive picture records to get the best detection range. The length in this research ranges from 1 to 8 m, each time adding 1 m for evaluation. What can be inspected is selected by a dozen of inspectors from the magnified original images. It is determined that the range of 1.5–3 m is 100% visible and the word cannot be verified when the distance is over 3 m. The range of 3.5–7 m registers the original image visibility of 75%, which increases to 85%–90% after the word is magnified. Therefore, it is suggested that the static visibility range be 1.5–7 m.

The dynamic test utilizes UAV to shoot the several pictures for the test. As the test goes on, the distance is increased by 1 m at a time and the object is lifted at a fixed point. The initial picture is recorded in the same manner. The magnified visual part is also the pictures chosen by inspectors. Although GPS system assists in the positioning and stabilization of the fuselage when the UAV flies at the altitude of 1.5 to 4 m in static condition, the drift caused by the changing wind speed should be considered. Additionally, if the distance from the inspected target is too close, there is a chance that the UAV falls. Therefore, pictures are not suggested to be obtained through inspection at under 5 m. This research tests the picture at 5 m. The results indicate that at the distance of 5 m the visible rate of original images exceeds 90%, so the rate can reach 100% after magnification; the visible rate of initial images at a distance of 6 m is 85% and reaches 100% after magnification; the visible rate of original images at a distance of 7 m is 80% and reaches 95% after magnification. The visible rate of original images at 8m starts to decrease, with roughly 75% for original images 90% after magnification. The visible rate of original images at 9 m is 70% and rises to 85% after magnification. The visible rate of original images at 10 m is 65% and increases to 80% after magnification but the images are unclear partially. Therefore, it is suggested that the distance for image detection be 5–9 m.

3.5 UAV in View of the Detection Height for Testing

In view of the detection height for testing, currently all cases are verified at the height of over 8 floors. The fuselage remains stably controlled and the sampled images can be taken through head-up photography and overhead photography. As shown in Fig. 7, the remote and timely inspection mode added with the high-resolution image can be used to obtain and magnify images as shown in Fig. 8. In addition, by comparing the side-shooting and the real-time UAV inspection as shown in Fig. 9, The detection program can also use infrared thermal imager to detect the difference in the image as shown in Fig. 10, and then use UAV image to increase the accuracy of detection position as shown in Fig. 11. By means of real case detection, images are obtained by the image transmission system and information screenshots can be made by smart phone or tablet to facilitate recording. Parameters such as height, GPS position and azimuth and real-time images are shown in Fig. 12. This study also integrates image comparison technology. By comparing 2D plane CAD image with actual detection images, annotation method in the CAD drawing system is adopted to obtain the size, which serves as a basis for estimating the size and range of damaged area and subsequently improving the accuracy and completeness of detection results as shown in Figs. 13-1 and 13-2.

Figure 9: Image of ground side-shot implementation process

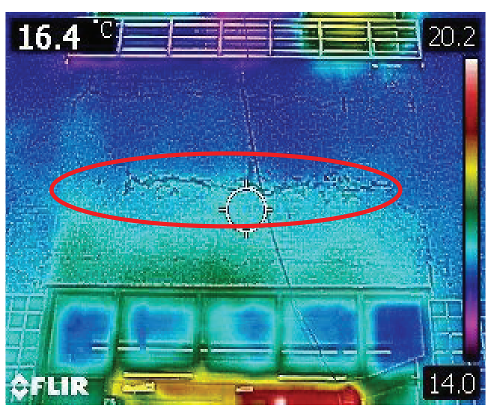

Figure 10: Imaging aided by infrared thermal image detection

3.6 Testing and Rating

The proposed detection method is to be divided into two phases. The evaluation of the first stage is conducted by infrared thermal imager detection. In the second phase, after UAV close-range image documenting, this research tested the deterioration degree defined as part D, added with high-resolution

Figure 11: UAV-acquired Image

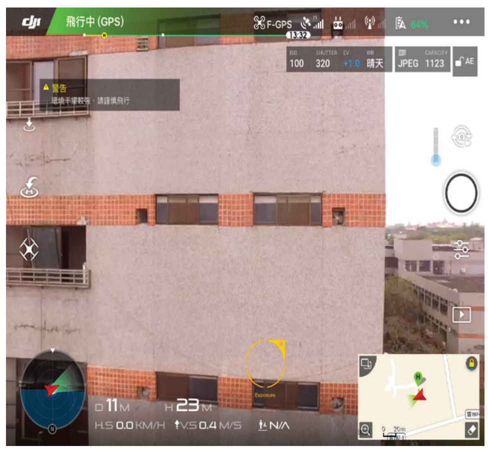

Figure 12: Image of obtaining information of inspection execution

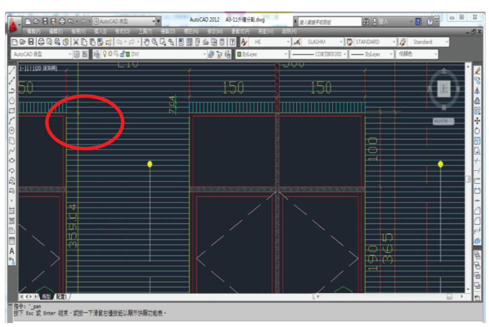

Figure 13-1: Original CAD image

pictures to calculate a ruined part of exterior wall space. Additionally, based on the deterioration of exterior walls or nearby structures, the primary causes for are shown in Tab. 1. The research additional discovered that whitening has slight impact on the structure, while cracks and spalling continue to be the primary assessment items for the structural safety. The deteriorated condition is graded in line with the pictures of damage. Grade A represents the slight damage, grade B means medium-level damage, grade C for that poor condition and grade D marks the severe damage. The grading clearly reflects the condition from the structure. The quality of damage is believed through image inspection for that problematic part, and so the structure is graded to

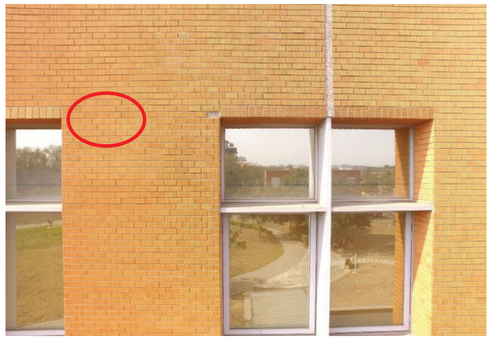

Figure 13-2: Actual aerial photography of inspection

Table 1: Types of exterior walls and causes for deterioration

Type of Exterior Walls	Cause for Deterioration
Metal curtain wall	The corrosion of metal sheets and the deterioration of sealants, such as pollution, discoloration, softness and fading.
Tiled exterior wall	Poor construction, internal and exterior drop, concrete crack, rusty window frame rust.
Whitening of red bricks	When the environment remains highly humid for a long time, these inorganic compounds can dissolve and re-precipitate out of the surface, resulting in whitening exterior.
Wall cancer	Preliminary judgment is made through visual inspection of concrete surface paint peeling or spalling powder of mortar layer partially adhered, and the addition of water seepage or whitening precipitation.

(Source: Compiled by this study)

exhibit its status. Tai provided the evaluation tables for every amount of degeneration in the article [19]. Proceeding from Tai's evaluation tables, this research increases the table featuring four levels as proven in Tab. 2 below. Within this study, the broken section of exterior walls is believed by evaluating the CAD layer using the pictures of exterior wall verification, which plays a role in evaluating the broken area and becoming actual reference basis. Overview of literature and questionnaire marks an ideal way to classify the degeneration and impact of exterior walls that is favorable towards the precision of future evaluation. This research offers an extensive evaluation approach to estimate the degeneration status of exterior walls based on the lots of degree and impact succumbed the evaluation. The outcomes of every classification can offer a reference grounds for subsequent maintenance.

3.7 Web Output Interface of the Proposed Method

In this research, webpages are utilized as the output interface to show the cases in the database. The web pages include info like case codes, date, items, materials and methods of main detection, description of deterioration position, and the evaluation of degree (D) and impact (R). The image information includes infrared thermal imager detection images and UAV close-up images as shown in Figs. 14 and 15.

Based on the test results of Case A, the exterior wall deterioration is primarily due to cracks in magnetic tiles. The apparent temperature difference could be detected by infrared obtained by UAV at close range. The image rating reveals that the structure has not been seriously impacted. Since mosaic tiles are small magnetic tiles, routine detection is suggested.

Table 2: Degree of deterioration status

Type of Deterioration	Degree of Deterioration
Stripping	A. Wall tiles
	B. Wall tiles and adhesive layers
	C. Composite stripping of substrates
	D. Large-area serious stripping
Cracking	A. Grey joints of wall tiles
	B. Cracks between wall tiles and adhesives
	C. Cracks in base materials, wall tiles and bonding materials
	D. Large-area severe cracks
Spalling	A. Wall tiles
	B. Wall tiles and adhesive layers
	C. Spalling in base materials, wall tiles and bonding materials
	D. Wall tiles

(Source: Compiled by this study)

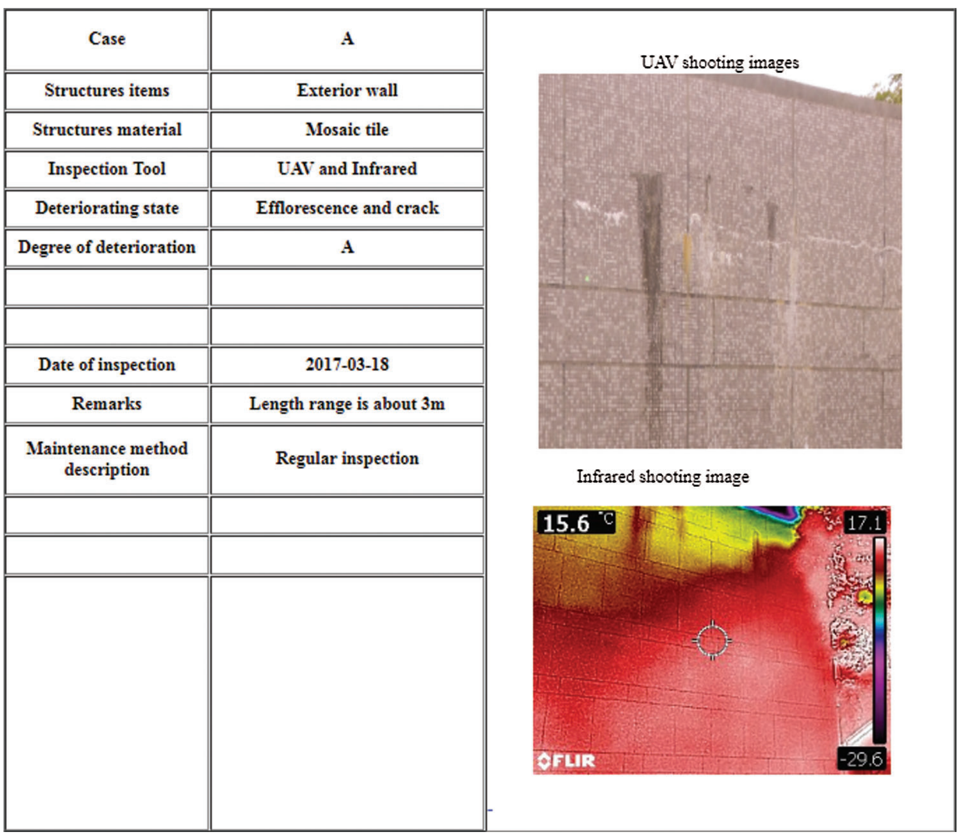

Figure 14: The test result output from the webpage display (Case A)

Case	B
Structures items	Exterior wall
Structures material	Mosaic tile
Inspection Tool	UAV and Infrared
Deteriorating state	Crack and peeling
Degree of deterioration	B
Date of inspection	2017-03-18
Remarks	Length range is about 1.5m
Maintenance method description	The degree of structural deterioration is safe. It is recommended to take regular inspections and repair and repair the peeling.

UAV shooting images

Infrared shooting image

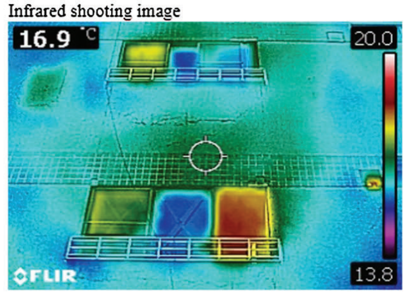

Figure 15: The test result output from the webpage display (Case B)

Case B test results behave like cracks but some of the tiles drop off. Utilizing infrared camera to obtain pictures, we can realize that there is a substantial temperature distinction around the hunting wind and the crack range may also be obviously observed. After that utilizing UAV to close-range flat-view pictures, we could find that only a few tiles have fallen off, the crack distribution is at least two, and compound deterioration occurs. Thus, the rating result is B grade. It's suggested that the mining components should be inferior. It's suggested that routine inspection and repair of spalling ought to be performed.

The study results described above might be summarized as the following:

1. In view of lacking safe, effective and quick assessment way of exterior walls of middle and high-rise buildings, this research combines the visual inspection technique nowadays used, infrared detection technology, UAV real-time detection, and particular picture making method. Such combination of inspection methods suggested has proven cost-effective and safe with case tests. Additionally, the incorporation of this method into GPS positioning and height recording leads to locating deteriorated positions and the subsequent reference locations for maintenance.
2. By way of literature review and expert questionnaire interviews, this research displays appropriate detection elements and evaluation indicators, and builds up image comparison and image capturing technology for damaged portions to offer reference indicators for the follow-up picture comparison to avoid the evaluation criteria of exterior wall status from subjective effect.

4 Conclusions and Suggestions

In this research, UAV comes with very accessible and popular high-resolution photographic devices, like high-quality image recorder. Using the maturity of UAV technology and also the ease of operation, the method proposed by this research may find detection points more effectively and set the appropriate height. It may also help record images within the detection process, enhance the total visual detection technology, and resolve the current difficulties of visual detection due to angle and shelters. The UAV high-resolution photography and stable UAV coupled with laser beam are utilized to enhance image recording because laser beam can establish uneven images if it encounters bumps or cracks. The comparison of two-dimensional CAD layer pictures considerably enhances the aesthetic meaning precision, overcoming problems due to top-down view, angle and height. Using this technique, the cost for professional devices are relatively low and the exterior wall assessment helps to reduce incidents and the cost derived from temporary construction facilities. Through expert questionnaires and regularity analysis, this research summarizes and establishes the present value index of exterior walls or ancillary structures, and the status quo evaluation mode of exterior walls or ancillary structures. The conclusions are listed below:

1. In line with the assessment criteria from the exterior wall status of middle and-rise structures described within this research and also the current value index of exterior wall or accessory structure, these studies produce the present value assessment type of exterior wall or ancillary structures.
2. These studies suggest improvement UAV recognition way of exterior walls or ancillary structures, as well as an improved approach to recognition, evaluation and recording, and offer the outcomes of UAV recognition by webpages that users have quick access.
3. Situation-based reasoning could be presented afterwards. Situation databases enables you to obtain installments of exterior walls or ancillary structures, and knowledge comparison enables you to help in using proper maintenance cycle and techniques for renovation. Recommendations for situation-based maintenance and techniques for renovation might be coded in an organized way.

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