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Research paper

New approach of Cultural Property Fire Fighting System with Building Information Modeling (BIM) and Drone

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Abstract

Background/Objectives: Preventing the fire of cultural properties is a very important issue, but it is difficult to suppress the fire early due to the wooden structure of cultural properties.
Methods/Statistical analysis: The research team proposed a monitoring system using Building Information Modeling (BIM) and a fire suppression system using drone. It is constructed a cultural information integration model (BIM) which is constructed by including attribute and physical information based on laser scanning information, so could obtain the object's attributes information into BIM data to respond to cultural assets fire response system.
Findings: From literature review, there is no fire prevention standard considering its special nature based on the Cultural Properties Protection Act and the possibility of fire due to the deterioration of electric facilities. Therefore, the research team proposed a fire monitoring system with a drone that was connected with the fire detection system that is described as development of internet of things (IoT) converged real-time fire monitoring system based on the integrated building information model (BIM) with infrared heat-seeking sensor camera and development of robotic fire fighting device and/or drone fire system that enables optimal fire response by XYZ coordinate of fire point that is linked to real-time fire monitoring system. Through this, the research team could get an advantage that fire can be extinguished in early by integrating fire position information received from a fire monitoring system connected with fire detection sensor based on drone.
Improvements/Applications: The proposed system could lead overall facility layout plan with virtual simulation system, reduce damages by hydraulic pressure. Finally, precise fire response and minimal damages were expected in the event of a cultural property fire.

Keywords: *Cultural property, Building Information Modeling, Drone, Fire fighting, Fire response system*

1. Introduction

Korea has remained cultural heritage in various forms for 2,000 years. In particular, Sungnyemun gate, designated as Korean national treasure no.1, was built in 1396 and served as the main gate to the former capital. However, the fire broke out in 2008 and caused lots of damages and many people to feel uneasy. There are various cultural assets throughout the country, and these buildings are also constantly exposed to various disasters such as earthquake, flood, thunder, and fire risks. Among those risks, fire should be controlled, because most of fire accidents have been caused by carelessness and human. In this paper, the research team focused on fire risks, therefore, intends to prepare for the fire risks by using two aspects;

1) Development of internet of things (IoT) converged real-time fire monitoring system based on the integrated building information model (BIM) with infrared heat-seeking sensor camera

2) Development of robotic fire fighting device and/or drone fire system that enables optimal fire response by XYZ coordinate of fire point that is linked to real-time fire monitoring system

2. Literature Review

2.1. Understand the Fires of Wooden Cultural Assets

2.1.1. Characteristics of Wooden Cultural Assets

Buddhist temple cultural properties consist of a column, beam, girder, lead, and stone make up of wooden structures, which are weak at fire disaster, usually seem water content of under 15%. Inside the building, temple is consists of highly flammable heritages, such as buldan(temple room), tangwha(painting). Buddhist temples are always open to fire, and all temples, structural members, and surrounding accessory parts of the compound are constructed of wood[1].If the fire is failed to extinguish before the five-to-ten peak minutes (flash-over explosive combustion), the cultural assets could be completely lost. And Even if the fire is put out before the peak, the first, second and third damages are carried out due to cultural assets properties, so the importance of fire prevention and prevention system is very important.

2.1.2. Fire Analysis of Wooden Cultural Properties

The fire proceeds as a process of flare-free ignition, discharge ignition, ignition, peak, combustion, and extinguish depending on

the cause of fire as like below figure 1. The fire rapidly progresses as it moves from ignition to the peak stage. At peak stage, the temperature of the room increases to 800-900 ℃, flammable gas stored near the ceiling explodes, causing the entire space to burst into flames, and producing a three-dimensional flash over flame[2].

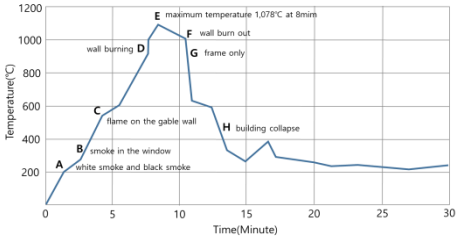


Figure 1: Fire process on wooden structure

Due to the nature of the wooden building, the fire damage is progressing in three stages. 1st Damage; damage by fire, increasing damage due to a lack of responsive systems and occurring damage of cultural assets and structural reinforcement issues. 2nd Damage; damage caused by hydraulic pressure during fire suppression. In case of severe secondary damage, excessive restoration costs expected. 3rdDamage;damage occurs as time has elapsed since the outbreak of fire, constant crack in joint due to hydraulic pressure[3].

2.2. Analysis of Fire Cases on Sungnyemun

2.2.1. An Analysis of Fire Diffusion Route on Sungnyemun

The fire spread path in the case of Sungnyemun Fire is as follows; 1)Formation of hot plume due to intense flame and instantaneous heat release in a short time, 2) Hot heat continues to work inside the ceiling due to high temperature flame and heat pillar, and then easily reach the flash point (253 ℃) and the ignition point (450 ℃) by flare, cellulite, convection, radiation, conduction, etc. 3) Start of heat decomposition on wood (around 180°C), then hydrocarbon and flammable gases, such as H2CH4CO are generated. 4) Ignition on the red core woods inside of the roof (wood chips, etc.) and fire up. Heat accumulates and proceeds to flame burning inside the ceiling, and spread fire rapidly through the ceiling[2].

2.2.2. An Analysis of Fire Fighting Planning By Roof Structure of Sungryemun

1) Red core: A pile of lumber more than 30cm long and higher, with the installation of pannel, rafters, and crossbars on the upper and lower part. Structure that cannot penetrate fire extinguishing agents even on concentrated water (≒ sandwich panel)

2)Combined lime layer: A rigid combined lime layer (which is located under evaporation) which is like 12~15cm concrete is not crashed, therefore, even if high hydraulic pressure is attempted to extinguish fire, it will be useless.

3) Inside: Long term completion of flames, heat and smoke stations may cause a building to collapse, only a ladder truck, anti-refraction ladder truck, and tarp can be operated.

2.3. Fire Prevention Status of Cultural Properties

2.3.1. Fire Prevention of Cultural Properties (Inspection) In Korea

There are no detailed fire prevention standards according to the Cultural Properties Protection Act, so it is not mandatory to install fire prevention system on wooden cultural assets of temples, so most temples provide fire extinguishers only. Only 16.2 % of cultural assets owned by fire hydrants are installed by fire stations and 407 temples that have local designated cultural assets are equipped with almost no fire hydrants. It is problem when installing a new electric facility due to the deterioration of an electrical facility, a new electric facility is installed in addition to an existing old electric wire, thus providing a cause for fire. Also due to the implementation of the forest recording policy, a large number of combustion substances were not screened out after planting trees. If forest fire spreads due to the absence of fire protection lines and fire prevention forests, the fire extinguishers currently installed and the fire hydrant alone are unsuitable as a large fire prevention facility[4].

2.3.2. New Fire Fighting Facility Guidelines for Wooden Cultural Properties

Cultural Heritage Administration of Korea published ‘New Fire Fighting facility Guidelines for Wooden Cultural Properties in 2013 as follows[4];

- Integrated installation criteria such as automatic fire detection system, automatic information broadcast system, and outdoor fire hydrant system

- Application of fire extinguishers (quantity, layout, etc.)

- Water supply to pressurized water supply system

- Install the pump starting method to operate normally even if the receiver loses power

- Change the radius of protection and application pressure of outdoor fire hydrant facility, and manage it regularly

- Install redundant wiring of automatic fire detection equipment receiver and repeater

-Install fire fighting facilities suitable for other wooden construction properties

- Wooden Cultural Properties Fire fighting facility consists of fire protection systems, such as water-proof guns, outdoor fire hydrants, CCTVs, smoke and flame detectors

2.4. Fire Prevention Status of Overseas Cultural Properties

2.4.1. Chinese Cultural Assets Fire Prevention Case

- Firefighting units consisting of 40 employees, patrolling and monitoring palace buildings 24 hours a day

- Use only incandescent bulbs (less than 60W), no smoking in all areas

- Install surveillance cameras and state-of-the-art smoke detectors in all buildings & - 162 hydrant and 1,300 fire extinguishers in the air

- All workers carry fire extinguishers

- Establish a roadmap to arrive on-site in the event of a fire within 2 minutes, and provide detailed response techniques for all employees.

- If it is difficult to use or to extinguish the powder fire extinguisher first, use a high-pressure fire hydrant but can adjust the pressure and size of water cannon depending on the characteristics of the fire.

2.4.2. Japanese Cultural Assets Fire Prevention Case

- For prevention of fire in Japanese cultural assets, fire-supported facilities such as early detection, initial fire fighting, and lightning prevention are maintained as shown in figure 2.

Figure2:. Fire Prevention water screen utility in Japan

2.4.3. Prevention of Fires on Cultural Assets in Europe (Norway)

- Sprinklers were installed in most wooden churches from the 1960s until the 1980s.

- Foggy fire extinguishing system and dry sprinkler

- Install heat detectors and video surveillance to prevent arson.

- Measure the distance between cultural assets and fire stations accurately to prepare a comprehensive fire system, including the emergency fire measures needed by passers-by to get firefighters to work after detecting fires

2.5. Summary in Literature Review

2.5.1. Problems of Fire Fighting Facility for Wooden Cultural Properties

- There is no fire prevention standard considering its special nature based on the Cultural Properties Protection Act

- The possibility of fire due to the deterioration of electric facilities

- Damage to cultural assets by viewing them, convenience, and indiscriminate installation for fire fighting or fire prevention purposes

2.5.2. The Necessity of Prevention System of Wooden Cultural Properties

- In the event of a fire on wooden cultural assets, damages do not stop at the pre-finishing stage but cause primary, secondary or tertiary damage.

- Considering the characteristics of wooden structures, it is crucial to anticipate, prevent, and focus disaster prevention systems to eliminate hazards in advance and protect them from early stage hazards.

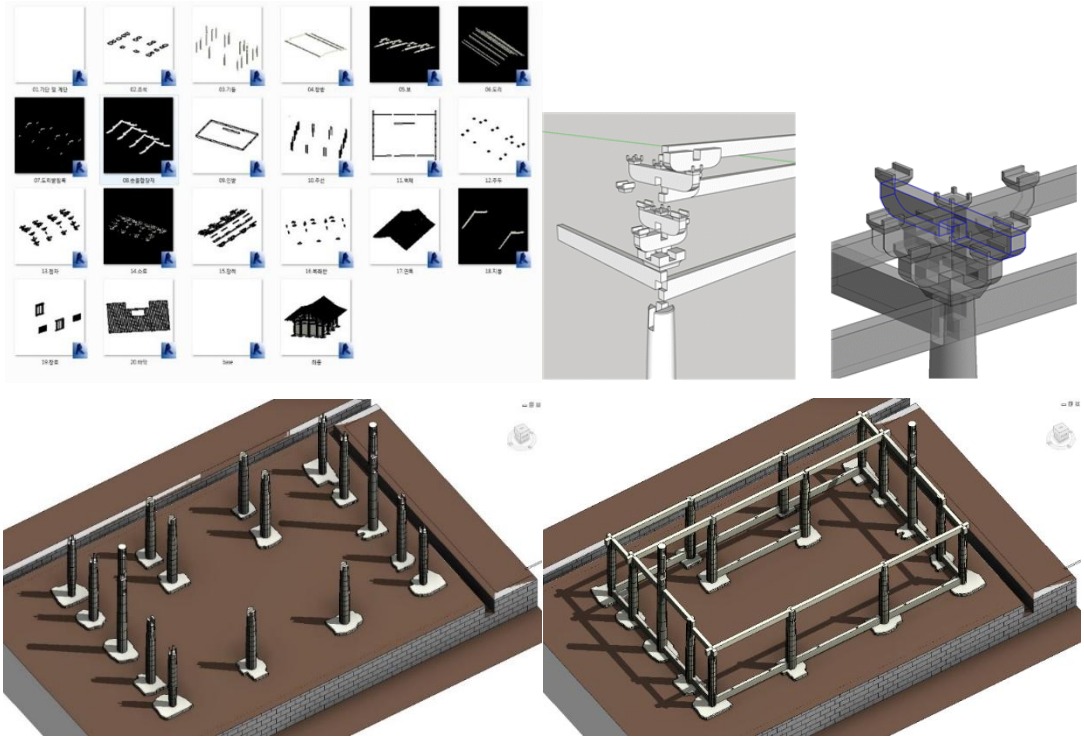
- This research is aimed at establishing a predictive fire prevention / disaster prevention system by installing a structure that can minimize damage and planning through accurate measurement data of cultural assets.

3. System Architecture

3.1. Fire Response System with Cultural Properties BIM Data

3.1.1. Construction of BIM Data to Bongjeongsa (Bongjeong Temple)

- To build fire response system, the research team obtained 3D laser scanning data to the Bongjeongsa project, and proceeded with 3D object modeling as shown in figure 3



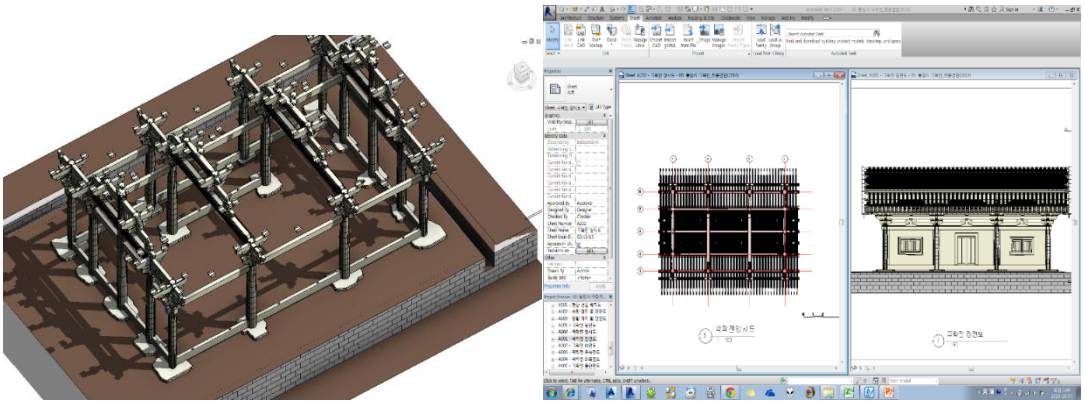


Figure3: BIM generation process in Bongjeongsa

3.1.2. Development of Fire Response System Simulator

- Existing cultural property modeling is intended to help users understanding of the concepts of simple shapes. However, this research used laser scanning to build the object's attributes information into BIM data to respond to cultural assets fire response system[5]

- 3D scanning information measuring each element of a building cultural asset was matched to the BIM, so that the information for subsequent repair/reinforcement/restore could be utilized.

- Predict vulnerabilities to other external forces (fire or natural damage) with deployed data

The below figure 4 can show development of fire response system process.

Literature review / Existing drawing analysis / Field investigation
Obtaining literature review and making Database
Field investigation

Making element data and dataset for Existing element
Mash information
Establishing database
Building shape element

BIM
Revit / AutoCAD / Shetchup

Comparing a existing drawing to BIM
Each element
Building template
Checking design error

Figure4:. Developmentof Fire Response System

3.2. Real-Time Drone Fire System

3.2.1. Definition and Current Usage of Drones

(1) Definition: A drone is an unmanned aircraft that enables a person to pilot remotely from the ground via radio propagation

(2) The benefits of drone

- Unmanned cars or robots have significant limitations in going up and down stairs

- Drones can fly, making them more free to move than any other device

- Approach complex building structures easily

- High speed, ultra-precision cameras, various sensors, communication systems, and other modern scientific accessories can be easily removed and attached[6]

(3) Benefits of using drones in the fire system

- Surveillance cameras and other equipment have accessibility problem, however, drone can overcome through flying

- Without any fire issues, drone can easily access wooden structures

- Monitor fire at different heights and angles to quickly identify the source of fire

3.2.2. Function of Drones in Fireproof Systems

(1) Monitoring cultural assets through real-time imaging

- Real-time video surveillance with drone enables high-efficiency fire-resistant system

- Proper approach to any design, installation and maintenance of wooden-based structures

- Real-time monitoring enables immediate action to remove hazards, prevent fires, and locate exact fire sources to minimize cultural property damage.

(2) Interworking of drone to BIM

- Even if real-time hazards are discovered by drones, it is difficult to identify the exact coordinates, materials in them, and the surrounding hazards at once [7]

- Korea's unique cultural property structure (especially, roof) has parts that cannot be penetrated by fire extinguishing agents[8,9], thus the importance of monitoring inside the building is emphasized more as shown in figure 5

- The biggest problem in drone is when the drone is inside. Drone uses GPS navigation system, so it is easy to use in outdoor not inside.

- BIM design will be applied to all structures (including cultural assets) starting from 2016 (5th Construction Technology Promotion Master Plan, Land, Transport and Maritime Affairs Ministry), enabling low-cost monitoring and precise coordinates in inside.

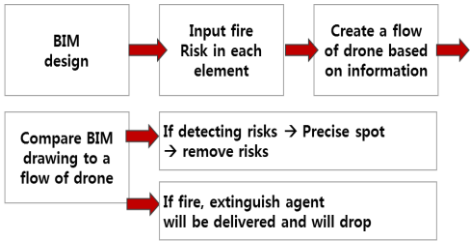


Figure 5:. Integration between BIM and Drone

(3) Reduced malfunction

- The risk of inspection or malfunction is very high in the case of a detection system or fire fighting facility

- If using drones, the probability of inspection or malfunction falls to a lower degree, reducing unnecessary fire fighting personnel and costs[10].

3.3. Real-Time Drone Fire System through Fire Response System Deployment

- Using the corresponding coordinate values extracted from laser scanning BIM information, an accurate location for the fire fighting system with an infrared fire sensor for the calculation of the location of the fire source X, Y, and Z locations of the fire as shown in figure 6.

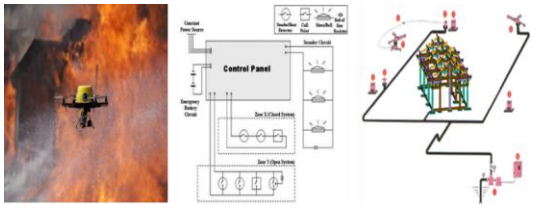


Figure6: Mimetic Diagram of Real-Time Drone Fire System

Cultural Properties have caused a lot of difficulties in extinguishing due to the complicated structure of a cultural asset, but by utilizing the pre-building data via the drone fire system, 2nd damage will be reduced from hydraulic pressure[4].

4. Conclusion

Preventing the fire of cultural properties is a very important issue, but it is difficult to suppress the fire early due to the wooden structure of cultural properties. The structure of cultural properties have a pile of lumber more than 30cm long and higher, a rigid combined stone layer (which is located under evaporation) which is like 12~15cm concrete is not crashed, and if long term completion of flames, heat and smoke stations may cause a building to collapse, therefore, only a ladder truck, anti-refraction ladder truck, and tarp can be operated.

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Acknowledgment

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