Evaluating Whether to Enter a Building During a Fire

ND EPSCoR Lesson Plan

Lesson Title: Evaluating Whether to Enter a Building During a Fire

Lesson Overview: Analyze and evaluate how UAVs can be used to determine a buildings safety and stability during a fire.

Lesson Objectives:
Students understand how to use UAVs for building surveying.
Students learn how to fly UAVs and map UAVs path.
Students understand how to use UAVs to analysis for building stability and safety.

NSF Subject Classification: Engineering

National Next Gen Standards:
HS-ET1-3: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

North Dakota Standards:
HS-ET1-3: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

Grade or Grade Band: 9-12

Time Needed (estimate)

Lesson Author: Allie Kollman

Author Bio:
Allie Kollman is a high school physical science and biology teacher at Davies High School in Fargo, ND. Kollman is currently a course captain for Physical Science in Fargo Public Schools. Her focus area this past year has been on developing Evidence-Based curriculum and Evidence-Based Grading.

Scientist/K12 Collaborator & University: Mijia Yang and Xin Bai

Scientist Bio: Dr. Mijia Yang is an associate professor at NDSU, who has worked in structural health monitoring and sensor development for many years. Dr. Yang has successfully managed dozens of projects and published more than 100 papers and project reports. He previously led and participated in more than 3 project involved in the structural health monitoring of composite laminates and bridges, which included (a) The development of An Over-Height Collision Protection System of Sandwich Polymer Composites Integrated with Remote

Monitoring for Concrete Bridge Girders; (b) An Integrated Real-Time Health Monitoring and Impact/Collision Detection System for Bridges in Cold Remote Regions; (c) Drone Assisted Drive-by Inspection of Bridges. Dr. Yang also worked in smart painting sensors through two projects, such as Automatic highway marking revealing through self-heating geopolymer concrete and A Novel Durable, Healable and Conveniently Removable Pavement Marking Material Suitable for Both Permanent and Temporary Marking Uses funded by the NCHRP IDEA program. Through these past projects, Dr. Yang has accumulated enough experience on drive-by and UAV bridge inspection, bridge condition assessment, as well as sensor development.

Summary of Research and/or Problem Being Studied: One of the major challenges in the structural engineering profession is timely post-disaster evaluations (FEMA 2000). From the past experiences, the first 24 hours are critical in an event like fire. In fact, it has been shown that UAVs can be used for post disaster surveillance of structures (Panda et al. 2019). In addition, it has been observed that a number of structures resting on spread footings responded better to seismic excitation and kept high integrity, after some earthquakes in China and Japan (Mergos and Kawashima 2005). However, the concerns about risk level of these structures due to fractures and disjoint that could possibly lead to tipping-over failure and collapse of the structure.

Recently many researchers have conducted image based structural health monitoring on bridges (e.g., Moller, 2008, Hiasa et al. 2018). Their major findings reveal that image based structural health monitoring possesses many desirable characteristics such as noncontact, convenient, prompt, and accurate. However, most of these researches focus on bridges, instead of buildings. Compared with bridges, configurations of building structures are more complex and load paths are more versatile.

Therefore, this project will summarize imaged based health monitoring techniques, enhance the autopilot tool for building surveillance purposes, and develop an on-time and onsite assessment tool for risk evaluation of post disaster buildings. The integrated stress analysis with updated structural configuration and image analysis will provide an accurate risk predication for immediate rescues. The research outcome will benefit the structural engineering field with a robust and economic post disaster surveillance and assessment methodology and provide a platform to integrate the stress and image analysis.

Preparation/Materials

Background knowledge students must have to be successful:
Students should have a background in technology and engineering solutions. Students should understand that new technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. When evaluating technology solutions, it is important to consider cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.

Essential Terminology:
Unmanned Aerial Vehicle (UAV)- an aircraft piloted by remote control or onboard computer.

Thermal imaging- a method of improving visibility of objects in a dark environment by detecting the objects' infrared radiation and creating an image based on that information.

Infrared radiation- portion of electromagnetic spectrum that extends from the long wavelength to the end of the visible-light range to the microwave range.

Resources:
Enter or Not Enter a Building After a Fire PowerPoint
Evaluating Whether to Enter a Building During a Fire Handout

Websites:
- https://www.youtube.com/watch?v=LkUtw1LV4ic

Materials needed:
Lesson 1:
- UAV (Drones)
- Whiteboard

Lesson 2:
- Enter or Not Enter a Building During a Fire

PowerPoint – found as separate attachment

Procedure/Activities

Lesson 1: Fundamentals of UAVs and Flying UAVs (50 min)

1. Introduce UAVs. UAVs are an unmanned aerial vehicle (an aircraft piloted by remote control or onboard computers) like drones. UAVs are used for quickest data collection, better performance, and extendable platforms (PPT Slide 4).
2. Watch the video https://www.youtube.com/watch?v=LkUtw1LV4ic (PPT Slide 5).
3. Ask students the question, "What are ways that UAVs help with building and roof inspection?" Have students discuss with their shoulder partners or lab groups. When they are finished have students write one answer on the board or discuss as a large group. In large group discuss highlight fire safety and building stability (e.g., without technology like thermal imaging and UAVs firefighters would not be able to see damaged of buildings before going in. Using these technologies can help create opportunities to see within a building where the fire is located and see damage pathways to make search and rescue safer for fire crews).
4. Discuss with students that UAVs can follow a designed path on consoles to fly over some targets. UAVs can scan a building according to a designed route. UAV uses features to capture images of buildings this can be done with feature extractions, attaching specialty hardware to the UAV, or image processing methods like edge detection, template matching, assisted structural surveying, or image-based integrated structural assessment (PPT Slides 6-12). (Optional): On PPT Slides 14 – 29 showcase the engineering research conducted by Mijia Yang and Xin Bai at North Dakota State University.
5. Instructor leads students through **either** a UAV demonstration of how UAVs can be programmed to follow a designed path **OR** have lab groups (3-4 students) follow the specific brand of UAVs directions to allow them to design a path within the instructors designated area.
6. Whether instructor chooses to perform demonstration or have students program their own flight path, instructor will walk students through the software of choosing a flight path and flying the UAV. Note that many UAV software has the option to have pre-made paths. For time purposes, instructor can make 2-5 pre-made paths and students groups can then choose from one of the pre-made path options in the software to perform.
7. Direct students to the designated fly area for either the demonstration or for student groups to have the UAV fly its designed fly path.
8. Instructor allows clean up time to get drones packaged up correctly and neatly.
9. Optional: If instructors choose the option for the demonstration and has time left over, instructor can ask the question to students, "What do you think are some current challenges of flying UAVs and using UAVs to survey buildings for damage?" Have students discuss with shoulder partner or lab partners then discuss student answers in large group (PPT Slide 13).

Lesson 2: Evaluating Stability and Safety of Buildings (50 min)

1. Instructor passes out the Evaluating Whether to Enter a Building During a Fire handout.
2. Watch the video **https://www.youtube.com/watch?v=ydn2x5ima8o** and have students take notes found on the Evaluating Whether to Enter a Building During a Fire handout.
3. After the video, discuss the answers to the video notes to ensure all students have the appropriate answers.

4. Explain to students that by using UAVs and thermal imaging, fire crews can monitor and diagnose the condition of a structure or building. Thermal imaging relies on collecting data of different temperatures. This data uses specific temperatures to show how these differences in temperature can determine where a specific point of damage is in a structure or building. Thermal imaging does not just show damage of a building but also helps crew to locate the specific location of the fire or see through smoke (FLIR website).
5. Put students in groups (2-4 students) and direct them to do Part 2 of the Evaluating Whether to Enter a Building During a Fire Handout.
6. After students have finished Part 2, have student groups share answers. Students should understand from Part 2 that the thermal imaging colors represent different temperatures of the fire. That red indicates the hottest location of the fire and that the images show that the fire is on the second floor of the building only.
7. Explain to students that they now understand how to read a thermal image indicating the location and difference in temperatures, they will now do Part 3 on the Evaluating Whether to Enter a Building During a Fire Handout.
8. Instructor walks around room, helping, redirecting, or answering questions when necessary.

Extensions for above average students:

Discuss:

1. How are UVA thermal images used in wildfires and wet lines?
2. How are UVA thermal images used in determining water damage of roofs?

Watch the following videos for further ideas:

1. **https://www.youtube.com/watch?v=x5bt-SCYWmc (Lesson 1)**
2. **https://www.youtube.com/watch?v=Ih_ayi318X0 (Lesson 2)**

Websites to explore and research topics:

https://www.flir.com/discover/instruments/manufacturing/thermal-imaging-cameras-for-warehouse-asset-protection/ (Lesson 1)

- What are different thermal imaging cameras used for in warehouse asset protection?

https://www.whsv.com/content/news/Staunton-Fire-Department-demonstrates-of-thermal-imaging-cameras-help-in-emergency-situations-568053171.html (Lesson 2)

- Explain how thermal images help in emergency situations with smoke and rescue operations.

Mediation/Support for students that need it:

- List the vocab words with definitions on the front board or hand out vocab that is listed on a piece of paper for students to reference.
- A color code for lesson 2 handout of the correlation between temperatures and colors for thermal images.

Standards Alignment

ND Science Standard(s):
HS-ET1-4: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

Disciplinary Core Idea: Physical Science
ET1.B: Developing Possible Solutions

- When evaluating solutions, it is important to consider a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.

North Dakota DPI Standards:
HS-ET1-4: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

Next Gen Standards:
HS-ET1-4: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

Science and Engineering Practices
SEP6: Constructing explanations and designing solutions

Cross Cutting Concepts
Connections to Engineering, Technology, and Applications of Science Influence of Science, Engineering, and Technology on Society and the Natural World

- New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits in a critical aspect of decisions about technology.

Unit Objectives

- Students will be able to analyze and evaluate how UAVs can be used to determine a buildings safety and stability during a fire.

Assessment

- Students can construct an explanation (CER) that evaluates UAV thermal images to determine a buildings safety and stability during a fire.

Daily Plans and Assessments

Learning Target for each day/activity

- Students understand how to use UAVs for building surveying (Lesson 1).
- Students learn how to fly UAVs and map UAVs path (Lesson 1).
- Students understand how to use UAVs to analysis for building stability and safety (Lesson 2).

Criteria for Success/Assessment for each activity

- Students can identify different methods of building surveying used by UAVs and program flight paths used by UVAs (Lesson 1).
- Students can analyze and evaluate thermal images taken from UVAs to analysis for building stability and safety (Lesson 2).

Additional Lesson Resources / Materials

References:

- "Delta Episode 10- Using Thermal Drones to Assist Fire Fighting Operations." *FLIR*, January 2019, https://www.flir.com/suas/delta/delta-episode-10/
- Jakubowski, Greg. "Thermal Imaging Cameras Help Firefighters See Through Smoke." *Fire Rescue Magazine*, 1 Nov. 2010, firerescuemagazine.firefighternation.com/2010/11/01/thermal-imaging-cameras-help-firefighters-see-through-smoke/#gref.
- Lufkin, Bryan. "These Drones Can Fight Fires Using Thermal Imaging." Gizmodo, 11 Dec. 2015, https://www.gizmodo.com.au/2015/12/these-drones-can-fight-fires-using-thermal-imaging/
- "Thermal Imaging Cameras (TICs) High-Rise Fire Fighting." *HIGH-RISE Fire Fighting*, June 2013, www.highrisefirefighting.co.uk/tic.html.

Websites for purchasing materials

Lesson 1:

- UAV/Drone
    - https://www.homedepot.com/p/CONTIXO-RC-Drone-with-Camera-Foldable-Quadcopter-Drone-Gimbal-1080P-HD-Wide-Angle-Lens-WiFi-GPS-Best-Drone-for-Beginners-F22/310006327