Infrared Technology Pinpoints Energy Loss in Buildings

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ABSTRACT
In this paper we present an undergraduate project where we use an infrared camera to survey our campus buildings in order to find areas of energy loss. We surveyed the buildings of our campus using infrared (IR) technology then assessed for faults and cavities. We extend our study and claim that by sealing these faults and cavities, buildings with highly sensitive data and/or government personal will have an additional layer of protection around them against terrorist attacks. These energy leaks can be used as prime points in which terrorists inject lethal chemicals into the buildings. Also if a terrorist is biologically raiding an area and using IR technology, they will have the knowledge of which buildings are vulnerable to the attacks. Pictures taken by an IR camera were textured mapped onto 3D buildings within Google Earth. Using Google Earth as our main visualization platform allowed us to easily analyze in 3D the entire campus giving us a better perspective of the buildings and their faults compared to looking at flat two-dimensional images.

Keywords- Infrared technology; Google Earth

1. INTRODUCTION

Infrared Technology is used in many areas by the government as well as by professionals. It is used to find the temperatures of surfaces. It is an easy, non-invasive, technique to detect energy waste, moisture, construction, electrical, and many other problems related to heat energy [13]. It does not require a lighting source. It works in the dark and from a distance, which makes it an attractive technology to inspect hazardous locations that are difficult to reach [7]. It measures the amount of radiation emitted by a surface then it creates a 2-dimensional thermo-graphic image related to the temperature distribution [3]. It's instantaneous when reading temperatures. In the context for speed in diagnostics "it took the user 30 seconds to find the source of moisture, while it would have taken an engineer 45 minutes without a camera" [8]. For our study, we were able to expose exterior heat leaks.

Its applications range from heat loss [13], finding mold [5], water damage [5], plumbing, mechanical and electrical problems [5][9], air conditioning [4] and moisture condensation problems, as well as missing or non-performing insulation in buildings[10]. IR technology can also help us improve concrete structures [15] by pinpointing areas of high stress [12], and even design better wall material for buildings and houses [1].

IR technology could also be used to prevent terrorist attacks [16]. Biological threat agents such as anthrax and smallpox and chemical threat agents such as tabun and arsine could all potentially be used in attacks [14]. These could all seep through crevices and faults of a building not properly insulated. By surveying the exterior infrastructure with an IR camera, points of interests in heat leaks can be properly addressed and would prevent against these chemical threats. For example, a terrorist with access to the outside of

buildings could place chemical agents, airborne or in liquid form that can evaporate, to enter the buildings via pathways that air enters or escapes from the buildings.

2. INFRASTRUCTURE AND STANDARDS TO PREVENT TERRORIST ATTACKS

As a direct reaction from 9/11, federal agencies and standards increased their concerns for building protection. American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) addressed that ventilation systems could be used to contaminate buildings [11]. A key suggestion by the ASHRAE Presidential Ad Hoc Committee on Homeland Security on how to protect buildings is that "air intakes should be located as high as possible" [2]. This would prevent ground level people from tampering with the airflow of the buildings. Using IR technology on the inside would allow fixing any insulation problems. So in the event that chemical or biological lethal agents enter a building it could all be isolated. As for the outside, finding construction faults could prevent further propagation, prolonging the life of the building as well as sealing entrances to lethal chemicals [6].

The ways that terrorists could strike could be through poorly insulated windows or construction faults. These openings could allow anthrax, tabun and other threats to enter a building [14]. Protection of US Embassies on foreign soil and even buildings with sensitive data should be constantly checked on the exterior to keep the buildings' safety up to date. Ideally the buildings' exterior would be monitored 24/7, but that would become too costly in resources. It is more realistic to have a yearly check-up. If a region was bombed by chemicals, buildings with poor infrastructure would be at risk at being exposed inside. Terrorists on land using an IR camera could find vulnerable places on buildings such as windows that don't seal well, holes, etc. where the heat escapes. They would then use that point of interest to contaminate the building's air. Depending on the wind direction, chemical and biological threats can enter inside a building from the same pathways that air enters and escapes from a building.

3. IMPLEMENTATION

Wentworth Institute of Technology buildings were surveyed for heat leaks. Lack of insulation around windows was a common theme when surveying the buildings as shown in figures 1 and 2.

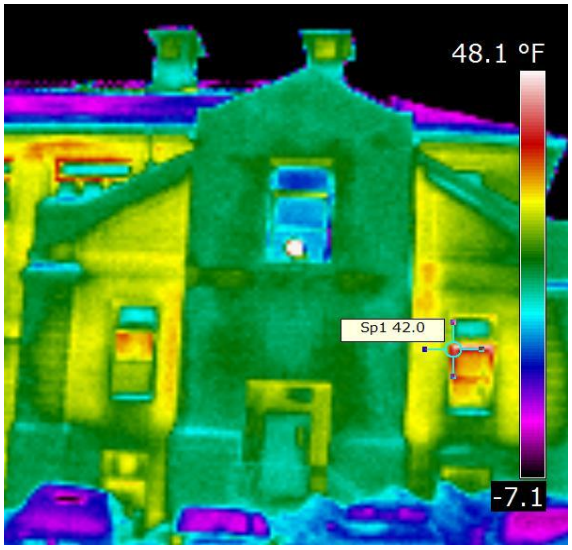

Figure 1. Heat escaping around the window on the right due to broken seal

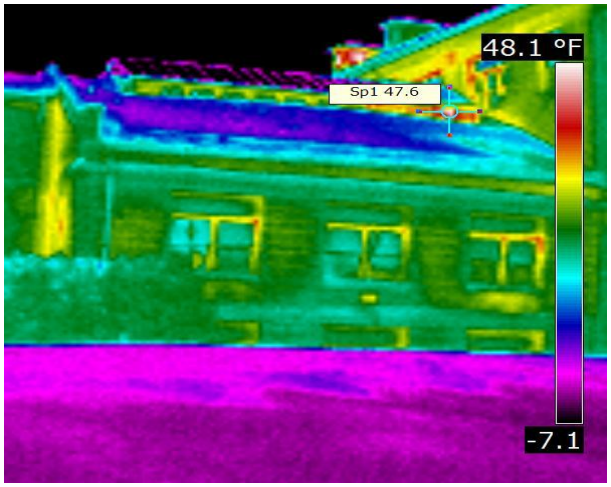

Figure 2. Heat escaping from the top window on the right due to lack of proper insulation

We utilized Google Earth as our visualization platform. We loaded the default 3D models of the campus that were part of the Google Earth's repository, which we downloaded and used as a template. We then went around the campus with our FLIR IR camera and took pictures of every side of all the buildings of our campus. The default temperature range was from -7 to 48 degrees Fahrenheit; the IR pictures were taken in the month of January. Creating the 3D models with the infrared faces was implemented using Google's Sketch-

Up tool. Every picture was resized and adjusted geometrically to line up with the corresponding building face.

After all the models with the IR imagery mapped onto the buildings were created, they were exported as a single KMZ file which could be loaded by Google Earth, as shown in figure 3.

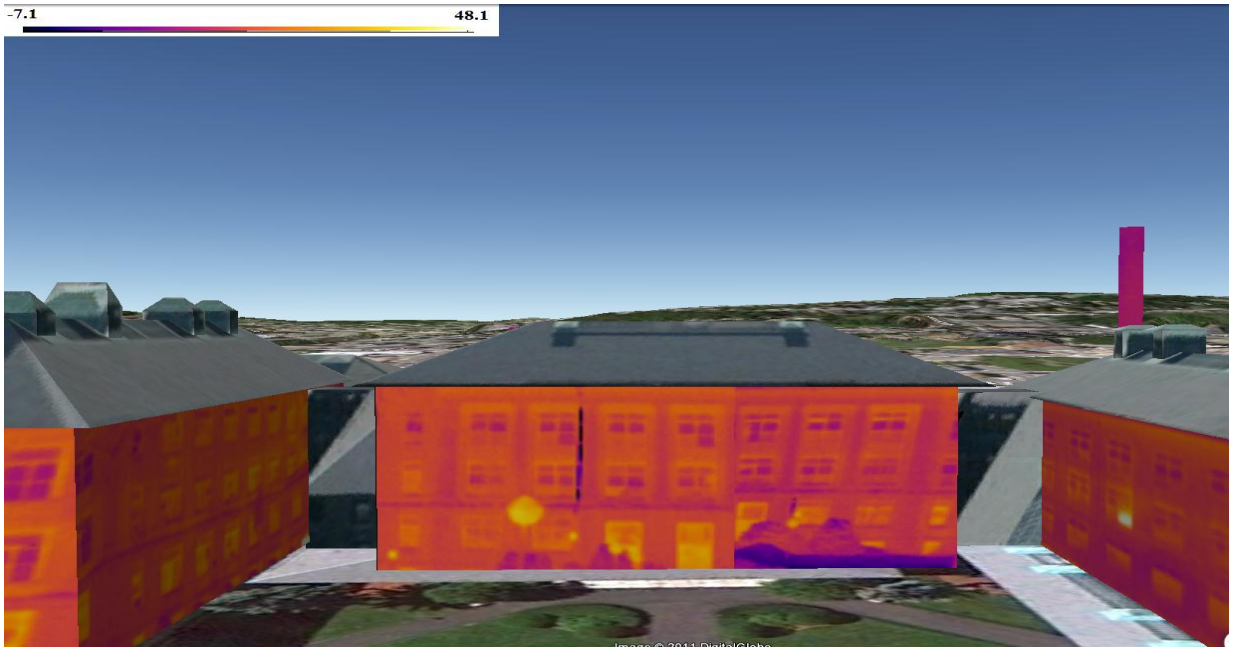

Figure 3. Main campus view within Google Earth. The user can switch between real and IR imagery by clicking a single button within Google Earth's navigation pane.

Figure 4. Wentworth's main campus with IR imagery (left) and without IR imagery (right)

Figure 4 shows a snapshot of the campus with IR imagery (left) and without IR imagery (right).

Every model contains the longitude and latitude of their current real-world position and a user can switch between the real and the IR imagery by clicking a single button on Google Earth's navigation pane.

To add the screen overlay (the scale - shown in figure 3 at the top left corner), the KMZ file was unzipped, creating a KML file and an image directory. The desired image logo was placed inside the "files" directory and the KML was modified through a text-editor. This code was added inside the 'Document' and 'kml' attributes:

```
<ScreenOverlay>
        <name>Infrared Wentworth</name>
        <Icon>
           <href>files/scale.png</href> //scale.png overlay image
```

```
        </Icon>
        <overlayXY x="0" y="1" xunits="fraction"
yunits="fraction"/>
        <screenXY x="0" y="1" xunits="fraction"
yunits="fraction"/>
</ScreenOverlay>
```

A virtual tour was set up using Google Earth's built-in tour functionality. A complete campus tour was created, switching from regular models to IR models autonomously. Free 3D virtual roaming is also possible through the use of the mouse and scroll-wheel.
Both Google Earth and Sketch-Up are freely available from google.com. Images were converted to the rain palette using the FLIR QuickReport 1.2 SP1 application that came with the FLIR Camera. When choosing a color scheme for analyzing pictures, the rain palette was used over the iron palette because the rain palette has more color gradients.

4. DISCUSSION AND CONCLUSION

The practical uses of using Google Earth alongside IR imagery mapped onto 3D building models, is that it gives users a good space visualization of where they need to go to address heat escaping as well as potential vulnerable places for terrorist attacks. If there were only 2D IR images to view, it would take a considerable amount of time to index through the images of a certain building. Then once you found the images regarding a building you would have to guess what face of the building it was, if it was on the first floor or second, and if it was accessible from the outside. These problems are solved using 3D models.
Without the use of IR cameras, poor insulation and heat leaks would not be found as easily. IR technology has made it possible to pin-point the location where the heat is escaping. And in turn, these locations could be used to prevent biological and chemical attacks from terrorists. Google Earth has made it possible to effectively analyze buildings in 3D space. The benefits of this are indexing through buildings is easy and perspective is enhanced. ASHRAE made appropriate changes in standards in response to 9/11. These standards made safer and more protected buildings, and with the integration of IR technology we could potentially make buildings even safer.

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