Visualizing Perceived Safety in a Campus Environment

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Abstract: Past research has shown that the perception of the environment is caused by certain characteristics within that environment. The most commonly mentioned characteristic is visibility, which deals with lighting, immediate visibility, and the visibility of safety. In this study, multiple maps were developed in order to visualize perceived safety at a university based on these factors of visibility. This is part of my thesis research, a larger project that is still in progress. The maps shown in this paper are the preliminary results from my thesis. At the conclusion of my study, a focus group consisting of campus security and planning personnel will provide feedback on the nature and applicability of the findings and recommendations for continued or clarified research. The overarching goal of any work in this vein is the enhanced and quantifiable understanding of the terrain of local security and safety as inputs to informed security infrastructure design and pointed safety messaging.

Introduction

Over the years, research has suggested that there are certain environmental characteristics that could evoke an emotional response of fear in individuals, especially at nighttime (Fisher & May, 2009). Of these characteristics, visibility is most commonly discussed. Visibility deals with many different aspects of the environment, including the most predominant aspect that is lighting. Due to the human eye and our limits in night vision, it would be impossible to see in certain areas at nighttime without adequate lighting. Additionally, foliage and buildings can reflect or diffuse lighting, causing areas that have efficient lighting appear to be inefficient. These obstructions can also block views for individuals, which may make them feel trapped. Obstructions may also limit the ability of individuals to see areas of safety. By being able to visualize these different aspects of visibility, land use planners can make more informed decisions about potential changes in the environment, thus making individuals feel safer at nighttime.

The goal of this study is to visualize the different aspects of perceived safety in the environment. This is important as it helps in the understanding of the local security and safety for a given location. Representations of lighting, immediate visibility, and visibility of safety will be developed in order to achieve this goal. This project is part of my thesis research, a larger project which is still in progress. The preliminary results of my thesis are shown in this paper. At the conclusion of my research, the results will be presented to a focus group consisting of campus security and planning personal to get their feedback on my project. Their feedback will give me insight into whether visualizing these characteristics would be beneficial to them in their decision-making process.

Past Research

The widely accepted definition of cognitive maps is the transformations in which an individual stores, recalls, and decodes information about the environment that surrounds them (Downs & Stea, 1973a). Robert Kitchin breaks this definition down by stating that cognitive mapping can be thought of as a marriage between spatial and environmental cognition (1994). Spatial cognition is defined as the representation of structure, entities and relations of space, or simply the reconstruction of space in thought (Hart & Moore, 1973), while environmental cognition is thought of as the awareness, impressions, information, images, and beliefs that individuals have about the environment around them (Moore & Golledge, 1976). Hart and Conn also refer to this as place cognition, which they say involves the thinking, feeling, and acting in the environment (1991). It is then suggested that people use cognitive maps to help them make spatial decisions in their environment; it guides their behavior (Kitchen, 1994).

Researchers have found evidence to support that there is a significant association between specific features of the immediate physical environment and fear of crime (Fish & May, 2009). It is suggested that there is not just one characteristic that evokes fear within individuals, but rather a combination of multiple characteristics. The most common aspect deals with visibility in the environment and how it can affect the way individuals perceive their surroundings.

Lighting, of course, plays a major role in the visibility of the environment, as it allows individuals to see what awaits them (Fisher & May, 2009). A study looking into the perceived safety on campus claimed that individuals most often reported that lighting and hidden areas that people could hide in were factors that made areas appear unsafe (Kirk, 1988). Another study asked university students which characteristics in an environment make them feel protected from possible victimization (Loewen et al., 1993). The results show that an area high in lighting was the most common answer. The results of these studies show that illumination of the environment is strongly related to the way an individual perceives risk and fear (Fisher & May, 2009). Nevertheless, lighting depends on a variety of factors in the built environment. Obstructions, such as foliage and buildings, can greatly influence how individuals perceive the environment. Past research and literature shows that foliage can block visual views and also provide hiding places for possible predators (Fisher & May, 2009). Buildings can do this as well, and both can modify light by directing, reflecting, and absorbing it (Thibaud, 2001). In a study that looked at the connection between perceived danger and environmental features, it was reported that a significant predictor of danger was the amount of foliage in an area (Herzog & Chernick, 2000). Another study focused in on the physical cues of fear at a university, in which it was found that certain characteristics of the built environment were related to student's high fear levels since students felt the environments were concealed and difficult to escape (Fisher & Nasar, 1995). In the study by Loewen, the second most common answer that made individuals feel safe was areas of open space (1993). The results of these studies indicate that the immediate surroundings of an individual can greatly affect the way they perceive the environment.

The visibility of safety also plays an important role in how people view their surroundings. Fisher and May cite several sources that suggest an increase in police presence reduces fear levels in individuals. It has been proposed that the visibility of police can reduce the fear of crime in an area (Winkel, 1986). Winkel came to this conclusion after comparing the results of his study that compared the level of fear in two groups of participants: one group received surveys from police officers, and the other group received surveys from researchers not in a uniform (1986). Another study confirmed the notion that with the increased presence of police officers, fear levels were reduced (Cordner, 1986). Furthermore, a safe area that is easily accessible was also a common answer that made individuals feel safe in the Loewen et al. study

(1993). These areas show that individuals will feel safer if some form of safety is visible and nearby.

Study Area

The study area for this project is the main campus of Central Michigan University (CMU) in Mount Pleasant, Michigan. This campus is home to over 21,000 students during the academic year, and has seen many changes over the last couple of decades, including renovations, extensions, new buildings, and new pathways. The campus will likely continue growing as the years pass, making this a perfect location to visualize how potential changes may affect the way individuals perceive the environment.

Methodology & Results

Multiple variations of maps will be created that represent lighting, immediate visibility, and the visibility of safety on CMU's campus. This should provide the focus group a variety of ways to assess the current state of the campus and determine if any changes are needed. As mentioned earlier, this is part of my thesis research which is still being worked on; what is shown are the preliminary results.

For all of the maps, a cell size of 0.5 meters seemed most suitable. My committee and I came to this conclusion for two reasons. First off, a cell of this size would represent the average space an individual can take up while walking through the environment. Secondly, objects such as buildings, trees, and walls needed to be modeled. Using a cell size bigger than 0.5 meters would inaccurately represent some of these objects, while using a cell size smaller than 0.5 meters would require more processing time and power.

Manual data collection was used to represent lighting, while only processing time was needed to represent immediate visibility and the visibility of safety. In an effort to save time, my committee and I agreed that I would only collect data for a portion of the campus. Figure 1 displays the study area and the different locations used to represent visibility.

Figure 1. Study areas for the different visualizations.

Lighting Visualization

Since lighting is a major contributor of how people perceive their environment, it is important to visualize this. As mentioned, data was collected in order to achieve this. The

Geography Department at CMU provided me with the tools necessary to do this: Pasco Light Sensor, Trimble R8, and Trimble TSC3. The light sensor is capable of recording measurements ranging from 0 to 5249 lux within an accuracy of 2 lux. The Trimble R8 is a highly accurate, survey-grade GPS that is controlled with the TSC3.

Both the light sensor and GPS were set to collect points in continuous 1 second intervals. For 20 fair weather nights, data was acquired at nighttime throughout the summer. At the end of each night, the data was exported from the light sensor and the GPS. The resulting tables were joined based on time stamp outputted by each. These tables were then merged together and a point shapefile was created from the coordinates. A Natural Neighbor interpolation was used to create a surface that represented lux values on CMU's campus. It is important to note that campus was mostly empty while data was collection. The results do not reflect the impact individuals could have on lighting, such as parked cars and open windows, but rather the lighting infrastructure of CMU's campus. The resulting lighting map was layered over an aerial image of CMU's campus to help understand the different lighting patterns; this can be viewed in Figure 2.

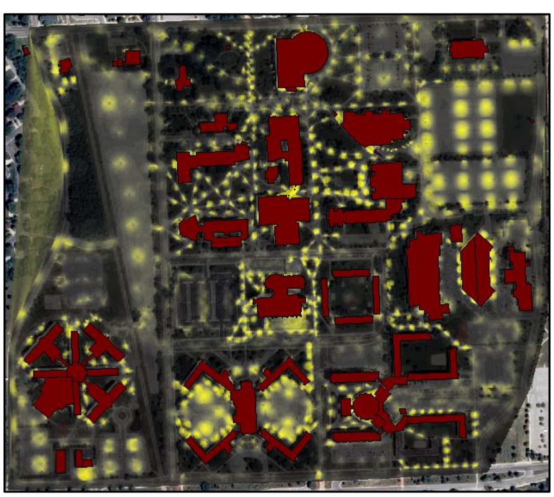

Figure 2. Lighting intensity on CMU's campus.

Immediate Visibility Visualization

Past research has indicated that open spaces made individuals feel safer, while areas that are concealed or difficult to escape made them more fearful. The main component used to represent this idea was a viewshed analysis. Viewsheds require a Digital Elevation Model (DEM) and observation points as the input. The resulting raster map represents the number of observation points for which a given cell is visible; the cells are known as the target points. There are a number of parameters that can be set for this type of analysis. For instance, a height value can be applied to both the observation and target points. Additionally, the viewshed can be limited to only calculate within a certain distance.

In this study, viewsheds were used to visualize the ability of one person to see another person within their immediate surroundings, thus making them feel safer in case they needed to call out for help. For this, observation points are defined as any outside space that an individual could be in, such as pathways or grassy areas. A height value of 1.5 meters was applied to both the observation and target points, which represents the average height of an individual. Adding this height limits the effect any small dips or bumps may have on the actual visibility of a location. There does not appear to be any research regarding what distance the immediate vicinity of an individual would be defined as. My committee and I decided that a distance of 100 meters seemed reasonable for someone to call out for help if needed. Anyone farther away than 100 meters may be too hard to reach, making them less helpful.

To complete this visualization, two layers needed to be created: A Digital Surface Model (DSM) and a grid of observation points. The DSM needed to represent CMU's campus in which buildings, trees, and any other obstructions were represented on top of the ground elevation. The universities Facilities Management (FM) provided me with most of the necessary data needed to do this. Data included shapefiles that represented buildings and surveyed elevation points. Trees needed to be digitized, which was completed with through the use of field observations and aerial imagery. Trees were represented as either a point or a polygon depending on the type of tree it was and how much space it took up.

A Natural Neighbor interpolation was used on the elevation points, resulting in a DEM of the study area. To create the DSM, both the building and tree layers were converted to raster format. This layer was then merged with the DEM using a conditional statement, in which buildings and trees were assigned arbitrary height values that were above the highest value in the DEM.

In order to represent immediate visibility, a viewshed was to be calculated for each observation point. The original idea was to make an observation point for each walkable cell. However, the study area contained 11,642,876 cells, of which 10,062,284 were defined as walkable. Clearly this would take too much processing time and space to complete. It was determined that creating a grid of observation points that were equally spaced out slightly more than 0.5 meters would reduce the processing time and space required to finish without losing much information. A grid was used to create observation points for every 2.5 meters rather than 0.5 meters; this reduced the amount of walkable points down to 403,566.

A script was generated in R that utilized the power and functions of GRASS GIS to iterate through the viewshed process. For each of the 403,566 observation points, a viewshed was calculated using the parameters mentioned earlier. The resulting raster maps contained values of 0 and 1, with zero representing not visible and 1 representing visible. Each map was then sequentially added on top of one another, creating a composite Immediate Visibility map. A black to white color ramp was used to display the cell values. Darker values represent areas where the immediate visibility is lower, while lighter values represent areas where the immediate visibility is higher. The result can be viewed in Figure 3.

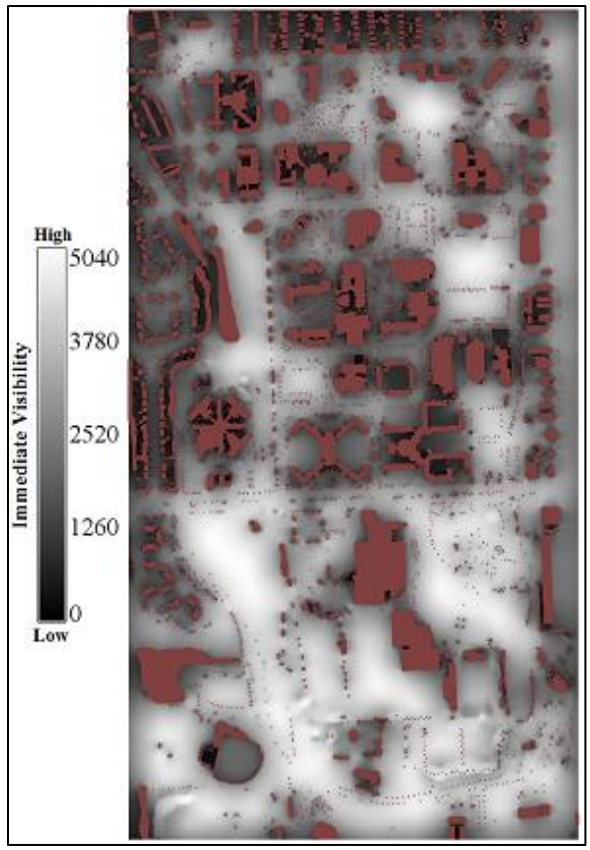

Figure 3. Immediate visibility for CMU's campus.

Visibility of Safety Visualization

Research has also shown that the visibility of safety and accessibility to that safety makes people feel more protected. Safety in this sense is a very broad term. It could mean doors, windows, or even roadways, in which someone has the ability to access or be seen from someone else. However, this can be difficult to estimate as they can be very complex. For instance, not all doors are unlocked at nighttime on CMU's campus. To represent safety, the university's blue light emergency phone system is used. This system allows for individuals to connect to the police dispatcher in case they need help. There are 26 blue lights located around campus, of which 25 fell within my study area.

This visualization was represented in multiple ways. First, it was important to understand where the blue lights are visible on campus. For this, a viewshed analysis was once again used. In order to represent where a blue light was visible to someone at eye level, a height was added to the observation and target points. In this case, the observation points were the blue light locations, which were estimated to be 3 meters high. The target points were any walkable location and a height value of 1.5 meters was added. It was not necessary to limit the calculation within a certain distance of the blue lights itself, since this should represent all locations where a blue light is visible.

Using the same DSM created earlier, a viewshed was calculated for each blue light. The resulting raster maps had values of 0 and 1, so an overlay was used to combine the raster maps based on the maximum value for each cell. This resulted in the comprehensive coverage of where the blue light emergency call boxes could be seen; Figure 4 displays this result. Another way to visualize this information is to see where blue light coverage overlaps. An overlay was created that summed the viewshed raster maps together, representing this thought. This result can be viewed in Figure 5.

Since the research suggested that an easily accessible safety zone made people feel more protected, it was important to visualize this. A cost layer was created in order to represent areas of the campus that are traversable, but may be difficult to get around or go through. Cells in

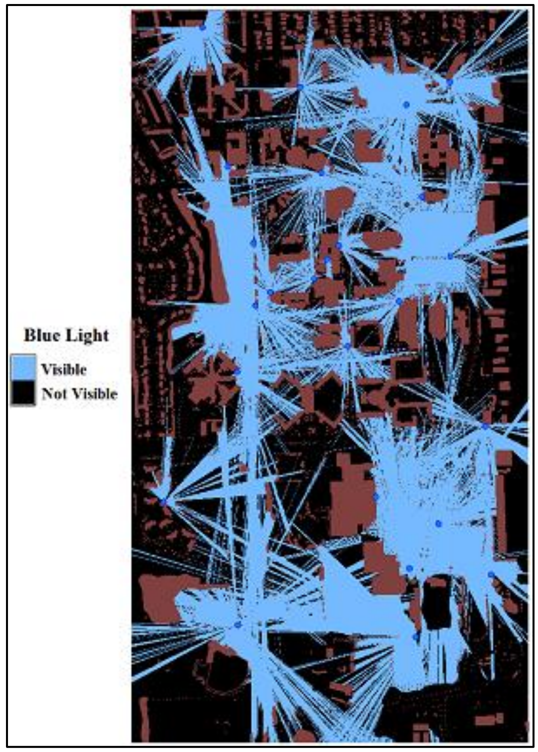

Figure 4. Locations where blue lights are visible

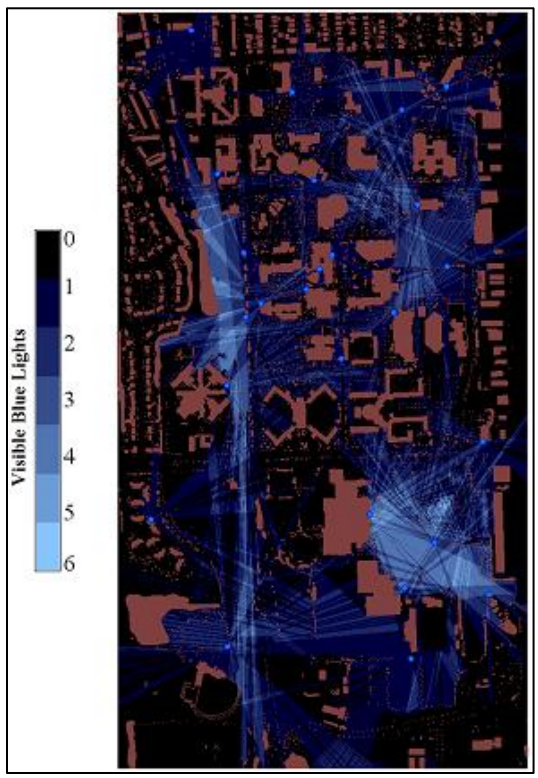

Figure 5. Locations where more than one blue light is visible

this layer are given a value of impedance. Higher values represent areas that are difficult to pass through such as ponds or fences. Lower valued cells represent areas that are easy to pass though, such as pathways or grassy areas. A Cost analysis was run to represent the ability to see a blue light and how easily accessible it is. In this process, a weighted value is assigned to the cells based on the accessibility of the blue light systems. For each blue light and its related viewshed, the cost layer was applied representing the distance to travel to a blue light. Cells further away or more difficult to traverse had higher values, while cells closer to the light had low values. The raster maps were then combined together using a minimum overlay function, which represents the easiest accessible blue light. A color ramp representing high to low cost was used to visualize this concept; it can be viewed in Figure 6.

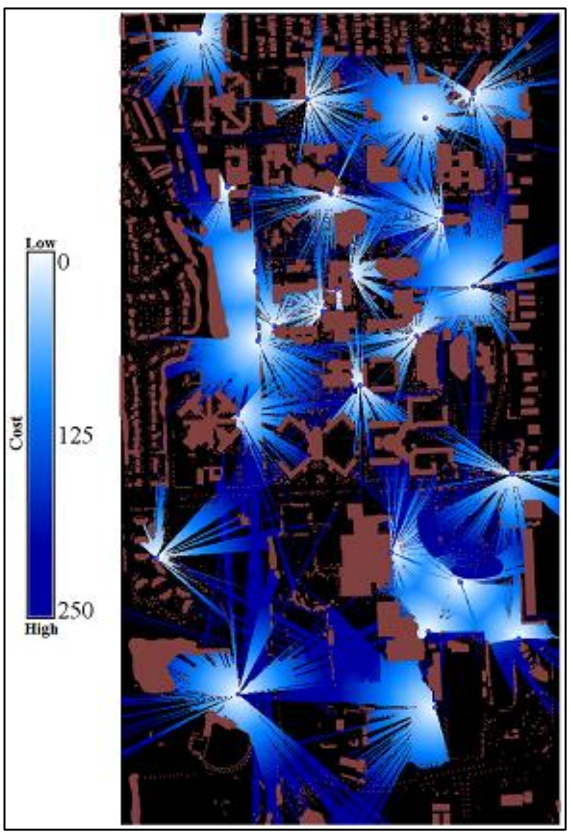

Figure 6. Representation of how easily accessible the blue lights are.

Discussion

The visualization of lighting intensity had a few different benefits that can help the people in my focus group. First, it clearly shows areas on campus where lighting is sufficient and insufficient. Secondly, it shows the distinct lighting patterns that the different lighting fixtures have. For instance, in some parking lots, the lighting is very uniform throughout. Though in other lots, the lighting is more inconsistent due to the lighting fixture impairing the ability for light to shine out. The same can be applied for pathways, in which some lights did well providing adequate coverage, but others did not depending on the quality of the light. This type of information can be provided to my focus group and allow them to make decisions on whether lighting should be altered; and, if so, a decision can be made to place a better, alternative fixture in its place.

Visualizing the immediate visibility indicates areas where the potential to see another individual, or be seen by another varies. For the most part, the campus appears to have a decent amount of visibility throughout. However, there are some dark spots which are located around buildings and other obstructions. Not only do this dark spots represent areas where an individual cannot see much, they also represent areas in which a potential predator can hide. This process allows the focus group to assess the current state of campus and for them to view how potential changes could affect the visibility and safety of campus.

The multiple visibilities of safety represent the infrastructure of the blue lights on campus. These visualizations show that there are a few areas in which no blue light can be visible. Though, it is important to remember that this is an estimation, so not all dark areas necessarily mean a blue light is not visible at that location. Instead, it can be thought of as there is potentially an obstruction preventing individuals from seeing the blue light. For most areas, only one or two blue lights were visible. Though, in some of the larger parking lots this number increased. Using the cost layer helped identify areas that could see a blue light, but may be actually difficult to reach based on distance or obstructions.

Future Work

As I continue working on my thesis, more maps will be created. For instance, the maps shown here represent the visibility in all walkable locations. However, individuals will typically stay on the pathways or in parking lots. It may be beneficial to view only these locations, since people will be there the most. To do this, a pathway and parking lot layer is being digitized so the information regarding these locations can be extracted from the other maps. Some campuses have a guideline for which pathways must be illuminated with a lux of a certain value. After determining what CMU's guideline is for lux levels is, locations where they do not meet this level could be easily identified. Additionally, it might also be beneficial to view where on pathways or in parking lots the blue lights are visible. Currently, the blue light map is showing there to be a decent amount of coverage throughout campus. However, we do not know what the coverage is for where individuals typically walk.

These maps also represent the current infrastructure of CMU's campus. However, moving objects, such as cars, could have a major impact on the ability of people to see around their immediate surroundings and access safety. To visualize how parked cars could affect these aspects of safety, the DSM will be altered on one of the larger CMU parking lots in order to represent cars. The Immediate Visibility and Visibility of Safety layers will then be recreated for this smaller area of campus.

At the conclusion of my study, I will meet with the focus group to get their input on my project. Their feedback will help me understand the nature and applicability of the findings and any potential recommendations for continued or clarified research.

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