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APPLICATION OF OPEN SOURCE HARDWARE AND SOFTWARE IN ASSESSING THE VARYING LEVELS OF PERCEIVED SAFETY IN CITIES

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Abstract:
Although planning is said to be done targeting the people, plan-making processes in most instances are dominated by top-down approaches, giving very little regard to how people perceive or feel about the cities they live in. The perceptions or 'emotions' urban areas trigger, and how these cause behavioural changes reflect the implications of planning and decision making upon them. Prior studies indicate that environmental factors are capable of triggering affective reactions in people. Thus, throughout the course of this study, it was attempted to understand how environmental factors affected University students' perceptions of safety, which were quantified on the basis of emotions, i.e. the calmness or stress felt, and walking speeds. Data on emotional states were captured in real-time by a technically-sound, low-cost device assembled using Free and Open Source Software and hardware. The study demarcated the areas perceived to be 'safe' and 'un-safe' by people, and ranked them based on their perceived safety. The reasons for this classification were then identified. The results concluded that the factors in the environment affected people's emotional states and walking speeds, as people walked faster in areas regarded as 'unsafe' and slower in areas regarded as 'safe'. The data also explained the difference between the behaviour of males and females, when perceived safety was concerned, during different times of the day. This study introduced the chance to identify unconscious emotional reactions of people, which can be served as useful inputs for urban planning. Furthermore, the study will confirm the value of the real-time sensing device as a tool beyond traditional methods in understanding feelings of safety in environmental settings.

Keywords: *Emotions, Free and Open Source Software (FOSS) and hardware, perceived safety, real-time sensing device*

1. Introduction

People, as users of cities encounter a vast array of environmental qualities belonging to environments of various sorts on a daily basis. These environmental qualities are what contribute to the experiences people undergo in these various environments. Certain environments or places may grab the attention of the users and leave them feeling pleased or delighted, while some others leave the users feeling fearful or unsafe (Nasar, 1998). These feelings instilled within city users can be wholly attributable to the qualities of the particular environments. However, these feelings also depend on a number of dynamic and static contextual factors such as time of the day, gender, age, whom they are with, familiarity of the environment etc. (Ratnayake, 2014)

Methods of quantifying the people's perceptions and feelings in urban areas last boomed in the 1960s with Kevin Lynch's concept of Mental Mapping. This was the closest the planning continuum has ever got to quantifying urban perceptions. However, there is still a scientific lack in the discussion of emotional aspects and their correlation with people's behaviour in planning. In the recent past however, scientific research has been done integrating technical and human sensors in combination with direct feedback from people via real-time participatory communication channels such as social media, to determine what areas give rise to various emotions (Raslan et. al., 2014). Despite such technological advancements, which are financially out-of-reach for third world countries, there still is a lack in the application of the emotional data layer in the field of town planning, particularly with regard to quantifying urban perceptions of areas on various grounds such as being wealthy, modern, safe, lively, active, unique, or family friendly. Although emotion extraction is being done in various other fields in many first world countries using the latest, high-end technologies, there is a lack in technologically sound, yet cost-effective technologies to measure and extract these data for countries like Sri Lanka. Therefore, a financially feasible and technologically accurate device is needed for the purpose of extracting people's perceptions and emotions.

2. Theoretical Background

Environments serve as habitats to many and are expected to fulfil the biological needs of those within it to a certain degree, besides its primary duty of providing refuge. Among the many biological needs of living beings particularly humans, the physiological needs, safety needs, belongingness and love, esteem needs, and self-actualization are eminent (Maslow, 1943). However, recent studies indicate that, out of the above needs, personal safety is a crucial factor of lifestyle options, and is said to be one of the main problems threatening the quality of urban life (Noll, 2000; Park et. al., 2001). This causes people to avoid places that they associate with personal risk. (Keane, 1998;

Riger and Gordon, 1981). Thus, perception of safety in any environment plays an important part in the human interactions with the particular urban environment.

How people perceive cities usually depend on a number of dynamic and static contextual factors. Methods of quantifying the people's perceptions and feelings in urban areas last boomed in the 1960s with Kevin Lynch's concept of Mental Mapping, which was the closest the planning continuum has ever got to quantifying urban perceptions. This approach, which reflects the subjective perception of a person in space, considers only the geometric and behavioural dimension, thereby leaving out the emotional dimension. Lynch's concept, along with several other contemporary concepts has influenced research to be carried out coupling modern and innovative tools with traditional techniques to explore the city in the recent past.

The first to combine data from Global Positioning Systems (GPS), with data from biometric human sensors was the artist Christian Nold (2008), who came up with the concept while working on his art project: Bio Mapping. To practically explore the subject, Nold invented a device that was portable and wearable, which recorded data from two technologies: a simple biometric sensor measuring the GSR (Galvanic Skin Response) and a GPS. The trained sample was then asked to walk around an area predetermined by Nold in order to test their emotional responses to the environments of the particular area. This technical method could be regarded as a sequel to and an automation of the work done by Lynch (1965), which overcame the most prominent drawback of mental mapping: the ability of participants to draw and express their imagination adequately.

Subsequently, several researches went on to attempt to better understand space using novel bottom-up approaches. The use of sensor technologies to understand people's perceptions was one such attempt by Resch et. al (2013). In an approach named "People as Sensors", Resch et. al utilized people as sensors following a previous claim made by Siegele (2010) which stated that that humans have turned out to be excellent sensors themselves. This "People as Sensors" approach represents a model in which not only electronic devices produce data sets, but also where people generate subjective measurements by recording their subjective, individual perceptions or observations (Resch et. al., 2013). The uniqueness of this concept is twofold: firstly, this research provides the first application for "ground-truthing" emotions in near real time in an urban context using the concept of "People as Sensors", and secondly, unlike other research efforts, this approach offers direct feedback to real-world processes in urban management and planning, and will help to detect previously unseen urban patterns. One clear limitation of this methodology in extracting emotions however is their over-reliance on Twitter Tweets, assuming that they are written in-situ (Resch et. al., 2013).

Further, affective perception of people's about their environments, in combination with crowdsourcing approaches was investigated by Klettner (2013). Though, in this approach, there is no real-time sensor technology, real-time visualisations of geo-social networks or social media like Flickr, Twitter, Foursquare, Facebook, etc. was made by Neuhaus (2011). The use of psycho-physiological measurements in urban space, for instance, to map emotions was made by Zeile et al. (2014) or with the help of smartphone data and social media data to get collective human behaviour patterns by Sagl et al. (2012). These new data and information layers can provide additional insights into the development of both the physical and social structures of inherently complex and dynamic urban environments (Resch et al. 2015b, p. 200). In research fields of security, aspects of perception of urban spaces and subjective felt security is getting more and more important. Salesses et al. (2013) examine, how the perception of safety of test persons changes during watching randomised Google Street View image pairs. The ratings were aggregated in a city map and compared with criminal statistics. The methods based on a subjective rating of a statistical situation and the test persons were not in situ. There was no embedding of people, thus, the situative urban context was also not considered.

Despite the success of the previous attempts, there were several inherent limitations of these studies: the methods followed and the equipment involved were extremely costly (Nold, 2008), and the data collection mechanisms were not in real time (Klettner, 2013), did not embed people (Salesses et. al., 2013) or excessively relied on social media posts assuming they were written in-situ (Resch et. al., 2013). As a result, the discussion of emotional dimension and their correlation with people's behaviour in planning, particularly has been essentially less researched.

3. Research Question

Accordingly, this research attempts to answer the following question: whether technically sound yet financially feasible anthropocentric methodologies, combining open source hardware and software are capable of assessing the temporal impacts environmental factors have on pedestrians' feelings of safety.

4. Methodology and Results

4.1. CASE STUDY AREA

A site located in close proximity to the University of Moratuwa (Figure 1) was selected to assess the impacts of environmental factors on pedestrian perception of safety and walking speed. The surrounding of the University has developed a particular notoriety in terms of safety over the past number of years and hence was ideal to assess the levels of safety. In the selected site, a continuous path which has varying environmental characteristics was chosen to observe the people's perception and behaviour as they walk along it.

Figure 1, Case study area (Source: Google Earth (DigitalGlobe image, imagery date 8/2/2015)

4.2. SAMPLE SELECTION

With the University of Moratuwa in the vicinity, it had a vibrant university student population that temporarily resided in the vicinity, who were homogeneous in their age categories, i.e. typically ranged within the ages of 20 to 27 years, the familiarity of their surrounding was relatively akin given their daily commutes from where they were boarded to the university, and with relatively alike ties with the environment, given the fact that all those who are boarded in the vicinity of the university are not from the area, hence perceive the area merely as their place of temporary residence. Thus, a sample size of 50 was selected with 50% of gender diversity.

4.3. METHODOLOGY

The purpose of this study is to assemble a cost effective, yet technically sound open source device, in order to examine the temporal impacts environmental factors have on people’s emotional states or perceptions, i.e. how the impacts of environmental factors differ based on the time of the day, particularly on the feeling of safety, and their walking behaviour, particularly, the walking speeds. As the first step, the environmental factors affecting people’s sense of safety needed to be determined. These vary from place to place and exist in uncountable numbers. For that, the path which spanned over 2.85kms was divided in to 28 segments, each segment spanning over a 100m. After identifying the 28 road segments, serial vision photographs were captured both during the day and night times for each of these road segments.

After capturing the photographs, a pairwise comparison was carried out for each of the 28 photographs, where a single photo was compared with each other on the basis of which photo the person felt reflected a safer environment than its counterpart. In addition to rating what photograph depicted the safer area, the reasons for their selection too were noted down. This process was carried out for the 378 photo combinations ($^{n}C_{r} = {}^{28}C_{2} = 378$) by using test persons, where each test person was to rate photo combinations and give reasons for their selection as to what factors made a photo look safer over the other. These reasons were then used as the basis for determining the environmental factors that existed in the area depicted by the photographs.

The complete list of reasons for selection of a photograph was then summarized, cut short and merged to produce the final list of environmental factors (shown below) that contributed towards an area being perceived as safe or unsafe.

1. Inter-visibility of road segment
2. Street-oriented buildings
3. Frequency of vehicular movements
4. Distribution of places attracting people (such as boutiques, bus halts, public institutions etc.)
5. Lighting conditions during the day and night
6. Dead spaces
7. Distribution of households
8. Frequency of pedestrian movements
9. Hierarchy of roads
10. Physical upkeep of the area

Based on the choices made by the test persons, a win ratio and a loss ratio were calculated for each photograph. A win ratio is a statistical rating that depicted the selection of one photo over the others in relation to its level of safety, whereas the loss ratio depicted the non-selection of a photo over the others in relation to its level of safety. The win (W) and loss (L) ratios of image i with respect to image u are as follows:

$$Q_{i,u} = \frac{10}{3}\left(W_{i,u} + \frac{1}{n_i{}^w}\sum_{j_1=1}^{n_i{}^w} W_{j_1,u} \; - \; \frac{1}{n_i{}^l}\sum_{j_2=1}^{n_i{}^l} L_{j_2,u} \; + 1 \right)$$

$$W_{i,u} = w_{i,u} / (w_{i,u} + l_{i,u} + t_{i,u}) \quad (1)$$

$$L_{i,u} = l_{i,u} / (w_{i,u} + l_{i,u} + t_{i,u}) \quad (2)$$

Here,

w- the number of times an image was selected over its paired image

l- the number of times that an image was not chosen over its paired image

t- the number of times when an image was chosen as equal to its paired image

(Salesses, Schechtner, & Hidalgo, 2013)

Using these ratios, the Q-score for each image pair i,u was computed as follows:

Here,

n^i_w- the total number of images i was preferred over

n^i_l- the total number of images i was not preferred over, and where the first sum extends over j1, the images that image i was preferred over and the second sum extends over j2, the images that were preferred over i.

(Salesses, Schechtner, & Hidalgo, 2013)

Q-scores, or Quotient Scores, are a statistical representation that determines how well-known or well-liked a specific subject is by surveying a group of respondents to determine their choice and gauge their opinions (Chruscinski, 2011). In the context of this study, Q-scores were used to quantify people’s choices of environments on grounds of perceived safety.

After each pair of photos was compared, then the win ratio, loss ratio and the Q-scores were computed for each of the 28 photos, as shown in table 1 below. A high Q-score meant that the area was perceived to be safe by the majority of the respondents, while a low Q-score meant that the area was perceived as unsafe. Each street segment was then ranked based on its Q score, where rank

1, representing the safest segment, was given to the segment with the highest Q score. Additionally, each street segment was concluded on its safety status: whether the segment was perceived to be 'safe' (if W > L) or 'unsafe' (if W < L).

The same process was then repeated for the data corresponding to the night time.

Then, the final list of environmental factors was evaluated using various methods and techniques (Table 1) in order to rate the factors for each road segment. The rating was done using a Likert scale spanning from 1 to 5, where 5 was given when a particular factor was largely existent and 1, when the factor was almost non-existent.
To monitor the actual behaviour of the users within the environment, with special regard to the 28 segments, the Galvanic Skin Response (GSR) and walking speeds were measured of the 50 test persons.

Table 1, Method of analysis, criteria and their corresponding ratings to rate the cues for each road segment

Factor	**Method of Analysis**	**Criterion**
Inter-visibility of road segment	Axial lines and Partial Isovist Analysis using UCL Depthmap 10	Number of axial lines drawn between two anchor points Lesser the number of lines, greater was the inter-visibility
Street-oriented buildings	Isovist Analysis using UCL Depthmap 10	Area visible along the sides of the road from each of the anchor points, also known as the Isovist Area
Frequency of vehicular movements	Based on author's observations	Observed frequency of vehicular movements
Distribution of places attracting people	Based on author's observations	Number of places attracting public users per road segment as a percentage of total buildings
Lighting conditions during the day	Based on author's observations	Hindrance of illumination by various means such as trees, walls etc.
Lighting conditions during the night	Buffer Analysis using ArcGIS and author's observations	Area illuminated by street lighting
Dead spaces	Based on author's observations	Percentage of road frontage taken up by dead spaces per segment
Distribution of households	Based on author's observations	Number of households as a percentage of total buildings per road segment

Frequency of pedestrian movements	Based on author's observations	Observed frequency of pedestrian movements
Hierarchy of roads	Based on the road class classification as per the National Road Master Plan 2007-2017	Class of the road to which the segment belongs
Physical upkeep of the area	Based on author's observations	Observed upkeep and maintenance of the road segment.

The GSR, which was aimed to capture people's perception of safety, is also known as electro-dermal activity, is a property of the human body that causes variations in the electrical characteristics of the skin. The GSR is said to be varying with the state of sweat glands in the skin. Sweating is controlled by the sympathetic nervous system and skin conductance is an indication of psychological or physiological arousal. Thus, the GSR can be used as a measure of emotional and sympathetic responses (Peuscher, 2012).

For the purpose of measuring the GSR of the test persons, a GSR sensor (Figure 2) was used by attaching the two electrodes of it to the index finger and the middle finger of the user's non-dominant hand. Each of the test persons were then asked to walk along the path, on one side of the road, during the day time and during late evening.

The sensor was then connected to a Dccduino UNO, which is a microcontroller board used for creating interactive electronic objects (Figure 3). The GSR sensor was configured to the Dccduino UNO board, and then personalized by coding in the Arduino.

Figure 2, the GSR Sensor
(Source: Grove – GSR Sensor)

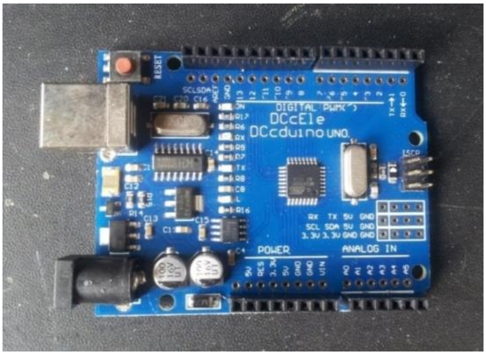

Figure 3, The Dccduino Microcontroller Board (Source: Captured by author)

The GSR sensor readings were captured every 0.2 seconds by the device (Figure 4). For the purpose of refining these readings, only the sensor readings of every second were taken in to account. Then the 'neutral level of arousal' was calculated based on the 'line of best fit'. The difference between the neutral level of arousal and the actual level of arousal was then determined and a conclusion was made as to whether the individual was calm (difference > 0) or stressed (difference < 0) during the particular time. Lastly, the aforementioned difference was averaged to obtain the mean level of arousal for each of the 28 road segments.

To measure the walking speeds of the test persons, a mobile application named Runtastic Pro was used. The main reason behind the selection of this particular mobile application is that this is one of the very few mobile applications in the market that displays the walking speed adjusted by the Naismith's rule. Walking speeds are greatly influenced by the variations in the terrain: people tend to walk slower when climbing a terrain with an upward slope and faster with a downward slope. For the purpose of this study, variations in walking speeds that were caused by the differences in the gradients could not be taken in to account and hence, the walking speeds needed to be adjusted to represent the equivalent speed the person would have travelled at if the terrain was flat. This is called the Naismith's rule. This adjustment was essential as the selected path had massive variations in the terrain.

Time	GSR Reading
1	0.017304
1.2	0.017113
1.4	0.017263
1.6	0.017284
1.8	0.017174
2	0.01669
2.2	0.016663
2.4	0.01782
2.6	0.01771
2.8	0.017179
3	0.017258
3.2	0.01717
3.4	0.017172
3.6	0.017019
3.8	0.017091
4	0.016652
4.2	0.017698
4.4	0.017684
4.6	0.017155
4.8	0.016919
5	0.016885

Time	GSR Reading	Neutral State	Difference	Conclusion	Average Difference
1	0.017303728	0.01670003	-0.0006036976	Stressed	
2	0.016689553	0.01670006	0.0000105071	Calm	
3	0.017258428	0.01670009	-0.0005583378	Stressed	0.0169576451
4	0.016651971	0.01670012	0.0000481494	Calm	
5	0.016884546	0.01670015	-0.0001843964	Stressed	

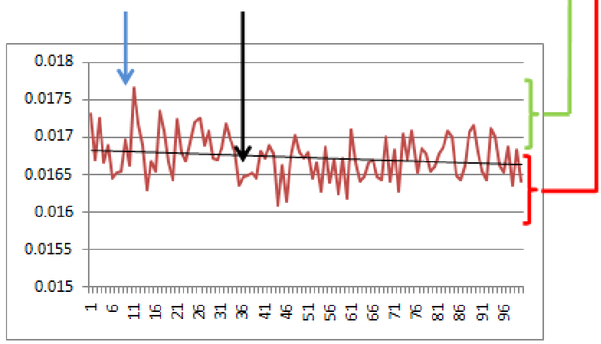

Figure 4, A snippet of the pre-processed sensor readings
(Source: Captured by author based on collected data)

First, the walking tracks of the individuals were exported in the GPX file format and visualized using the Google Earth application. Then, the time taken in seconds to travel from one anchor point to another was gathered. The average walking speed (km/h) too was determined by the GPX tracks and these were later converted to meters per second (m/s). These speeds have been adjusted by the Naismith's rule, as mentioned in the previous paragraph.
After gathering the GSRs and the walking speeds of each of those in the sample for both day and night times, the data were then analysed using various statistical techniques such as Linear Regression analyses, Chi-Squared tests, Independent Sample T Tests, Binary Logistic Regression analyses to infer meaningful conclusions.

5. Findings, Discussion and Conclusion

The study initially demarcated the areas perceived to be 'safe' and 'unsafe' by people, and ranked them based on their perceived safety. The reasons to regard some areas as 'safe' and some as 'unsafe' were then identified. The results of the analysis concluded that the cues in the environment affected people's emotional states and walking speeds, as people walked faster in areas regarded as 'unsafe' and slower in areas regarded as 'safe' (day: $\chi^2(9) = 83.933$, $p < 0.1$, night: χ^2 $(4) = 8.174$, $p < 0.1$). The data also explain the difference between the behaviour of males and females, when perceived safety was concerned, during different times of the day. Men appeared to walk faster than women during the day and the night (day: $t(48) = -7.041$, $p = .000$, night: $t(48) = -5.737$, $p = .000$). However, this does not indicate that the men's perceptions of safety were more significantly influenced by the cues in the environment than that of the women. Both men and women walked faster during the night than during the day (female: $t(48) = -2.555$, $p = .014$, male: $t(48) = -2.268$, $p = .028$). There were no significant differences in the changes in emotional states of males and females, both during the day and night (female: $t(48) = 1.248$, $p = .218$, male: $t(48) = -.784$, $p = .437$). Lastly, the environmental factors or cues affecting the perceived safety during the day ('inter-visibility of road segment' ($p = .101$) and 'physical upkeep' ($p = .118$)) and night ('distribution of places attracting people' ($p = .057$) and 'distribution of households' ($p = .063$)) were identified in order of the significance of their influence.

With the data collection methods widely used in practise at present, it was perceived to be impossible to gather intricate and personal human details such as emotions instantly by most professionals in the field. However, in an ever-so advancing world where technology seemed to have the upper hand, a technological solution seemed the only possibility. As a result, a technologically sound, yet financially feasible device was assembled for the purpose of capturing and recording human emotions, while a mobile phone application captured the changes in the walking speeds. In doing so, the study discarded some of the beliefs held as to the impossibility of quantifying human emotions.

The study initially demarcated the areas perceived to be 'safe' and 'unsafe' by people, and ranked them based on their perceived safety. The reasons to regard some areas as 'safe' and some as 'unsafe' were then identified. The results of the analysis concluded that the factors in the environment affected people's emotional states and walking speeds, as people walked faster in areas regarded as 'unsafe' and slower in areas regarded as 'safe'. The data also explain the difference between the behaviour of males and females, when perceived safety was concerned, during different times of the day. Men appeared to walk faster

than women during the day and the night. However, this does not indicate that the men's perceptions of safety were more significantly influenced by the factors in the environment than that of the women. Both men and women walked faster during the night than during the day. There were no significant differences in the changes in emotional states of males and females, both during the day and night. Lastly, the environmental factors affecting the perceived safety during the day ('inter-visibility of road segment' and 'physical upkeep') and night ('distribution of places attracting people' and 'distribution of households') were identified in order of the significance of their influence.
This study confirms the value of the real-time sensing device as a tool beyond traditional methods in understanding feelings of safety in environmental settings. Methodologies followed by similar preceding studies in detecting human perceptions were extremely costly (Nold, 2008), not in real time (Klettner, 2013), did not embed people (Salesses et. al., 2013) or excessively relied on social media posts assuming they were written in-situ (Resch et. al., 2013). The methodology followed in this study however eliminates all of these shortcomings. The device is open source, and can be assembled by anyone at a cost less than $20. The data on the test people's emotional states and walking speeds were monitored in real time while the test persons were out walking in the study area and embeds people, as the devices were physically attached to their bodies. Further, the study does not rely on social media posts, which can be easily manipulated and may not be posted in-situ by the participants.

Additionally, this study, and the methodology introduced by it offer the chance to identify and analyse unconscious emotional reactions of people, such as the stress caused by travelling through unsafe areas, traffic congestion, high densities of people etc. which can be served as useful inputs for urban planning in devising strategies for the betterment of places. Also, the identification of unconscious decisions, such as increased walking speeds and increased stress levels (indicating the possibility of unsafeness), provide insinuations for planners to understand the city and improve areas that appear to be problematic. Therefore, studying the emotional states and their corresponding behaviour of people in cities, not only provides a new perspective to planning, but also gives due recognition and enables the involvement of the single most important element planning is done for, and has been avoided for decades: the people.

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