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# Inclusive Landmark based Pedestrian Wayfinding via Multi-modal Directions

by

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in partial fulfillment of the requirements

for the degree of

Master of Design

in

INCLUSIVE DESIGN

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## vi. Abstract

Navigational skills are fundamental to travelling from place to place, personal independence and community integration [2]. Current research in pedestrian wayfinding suggests that people vary significantly in their choice of navigation modalities [6, 7, 25]. In addition, pedestrians with learning disabilities find it difficult to recall routes travelled daily and stay oriented while enroute to unknown locations. This paper proposes a wayfinding interface that has 2 components: 1) temporary poly-coated cardboard signage along with imprinted information indicating a specific destination, minutes by foot, directional arrow and a QR code; 2) online interactive website to provide additional contextualized navigation instructions for pedestrians through various modalities. The University of Toronto Scarborough campus (UTSC) is being used as the physical environment to implement and test the proposed wayfinding interface. The QR code tags link the cardboard signage to the online interface and generate streaming of route instructions in the modes of panoramic video, photographs, aerial map, audio or text. The goal of the proposed wayfinding system is to aid UTSC pedestrians - especially those with learning disabilities - to orient themselves and navigate to their destination through multi-modal landmark-based, turn-by-turn directions.

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## vii. Introduction

Pedestrian navigation is an important domain that, if supported, can increase individual independence and community integration [2]. Recent research has addressed a range of issues concerning pedestrian navigation. Much empirical work has focused on the design of navigation aids for pedestrians with visual or cognitive impairments (e.g., [2, 5, 6, 8, 9, 12, 25]). Other research has focused explicitly on the provision of turn-by-turn instructions for pedestrians over mobile phones using GPS [1] and the multimodal nature of journeys [4, 7]. A trend in much of the recent research is the provision of turn-by-turn rather than map-based guidance [7, 8]. A key prerequisite to designing successful pedestrian services, and delivering these over web-based platforms, mobile devices or tablets - is to understand the nature of the navigation task, and the information requirements of the pedestrian. The nature of the navigation task for UTSC pedestrians is to orient themselves within a given location and navigate to their desired destination. Through quantitative and qualitative research outlined in the 'Experimental Research' section, UTSC pedestrians require landmark based turn-by-turn directions though multiple modes of delivery, e.g. signage, photographs, text directions, video, audio, aerial maps, etc.

Referencing several empirical studies, there are key factors to consider when designing wayfinding systems for pedestrians:

- The information used by pedestrians for navigation purposes shows that the main elements include: geometric and spatial relations, compass directions, distance units, time estimates, place names, descriptions of the nature of the route and landmarks. [2].
- Pedestrians are not strictly bound to linear routes, roads, paths and sidewalks in the same way as vehicles, but may walk over lawns, cross the middle of streets and use other shortcuts to reach their destination.

- Pedestrians not only travel outdoors but also use indoor environments where GPS signals may not be available.
- Pedestrians are a heterogeneous group and can be categorized by a variety of criteria reflecting abilities and personal preferences. Pedestrians navigating a route may have physical, learning, psychiatric and visual impairments. A user profile also depends on context: e.g., a person may become temporarily disabled when pushing a stroller, carrying an umbrella or a large number of books [10].

Based on this understanding of pedestrian navigation, route planning and navigation guidance should therefore cater to a variety of pedestrian navigational choices, needs and abilities. Depending on personal preferences and abilities, pedestrians use different modes of navigation assistance including physical aerial maps, online maps (e.g. Google or PDF maps), written/typed directions, verbal direction and GPS. For safety purposes, it becomes essential for pedestrians to focus their senses and attention on their physical, surrounding environment rather than the modes of navigation and their cues. Many pedestrian navigation systems rely heavily on visual and auditory senses while navigating, which inevitably excludes users with visual and auditory impairments [5]. As a result, pedestrians may not focus their visual and auditory attention on safety hazards such as traffic, obstacles and their immediate surroundings. In addition, pedestrians may not always have their hands free to hold navigation devices. Any navigational feedback provided should be easy to understand, unobtrusive and accessible when pedestrians are stopped at a safe location such as a sidewalk or pedestrian island [5]. It is also important to consider that navigational information provided prior to physically navigating a location should not place a high demand on working memory as pedestrians with learning disabilities may experience difficulty with their working memory and mental capacity. In addition, the use of landmarks are vitally important to pedestrian navigation:- landmarks are salient visible features which can be used for anchoring qualitative spatial actions for descriptions of route segments

[3], landmarks are either used at decision points, where reorientation may be required, or they serve as route markers for confirmation that a pedestrian is going the right way [5].

Taking these considerations into account, it becomes a complex task to design a system that is inclusive of all these requirements. However, it is an essential undertaking if a sustainable, inclusive and user friendly pedestrian navigation system is the goal. This paper proposes a wayfinding interface that implements temporary poly-coated signage along with information of destination, minutes by foot, directional arrow and QR code to provide more contextualized navigation instructions for pedestrians. The QR code tags generate streaming of route instructions in the modes of point of view panoramic videos, photographs, aerial maps, audio or text. The system is also unique because users can virtually experience the space online through the panoramic video, photograph and audio components before physically journeying through the space.

The University of Toronto Scarborough campus is being used as the physical environment to implement and test the proposed wayfinding interface. If this system is implemented by the University in the future, the temporary cardboard signage can later be replaced by materials used to create current UTSC signage. As the campus continues to expand in terms of its infrastructure and population, the abilities and requirements of the campus population will necessarily change as well. Therefore, it becomes essential to design a system that caters to pedestrians with varying abilities and preferences. Although the proposed prototype addresses the needs of the current campus population, the system is designed to be easily updated and expanded upon. The 'Future Recommendations' section defines solutions that include a broader audience, specifically those with visual, auditory or other physical disabilities, thus catering to the needs and abilities of an expanding campus population.

## viii. Rationale and Context

In recent years, GPS applications have become standard features with most new generation mobile devices. Many of these applications bring the interface used in car navigation or a web-based map application such as Google Maps to the mobile phone. However, the localization accuracy of satellite positioning systems of 5-30m is insufficient for pedestrians [3]. With the addition of Google Street View technology featured in Google Maps and Google Earth, it provides panoramic views from positions along many streets in the world through car mounted cameras [14]. This has since become a useful and convenient tool for car drivers and pedestrians to familiarize themselves virtually with a desired location before physically navigating through the space. Street View has provided people with the opportunity to virtually navigate their route from point A to B from the comfort of their homes. In October 2008, Google introduced the Street View Trike, a pedal tricycle with a 4th generation camera mounted to take images where cars cannot reach, including footpaths and dirt tracks [14]. This has especially aided pedestrians in navigating locations and estimating distance and time to their desired destination. In October 2012, Google used the Street View Trike to photograph some of the inner pathways of the UTSC campus. However, due to technical issues, the internal Campus Street View may not be launched until 2014. Without the availability of Street View for the Scarborough campus, the wayfinding mobile applications that use Google Maps are not useful to UTSC pedestrians as they cannot provide the user with directions within the campus. Therefore, pedestrian navigation within the UTSC environment can be quite different from other forms of pedestrian navigation that use major streets and pathways. Although pedestrians are able to see an aerial or bird's eye view of what the campus looks like, navigating from A to B within the campus is not yet an option.

The pedestrian environment within the U of T Scarborough campus setting can be better understood based on the “legibility” [13] of the campus (p. 3). Lynch [13] defined legibility of a city as “the ease with which its parts can be recognized and organized into a coherent pattern” (p. 3). He explored the relationship between a person and his/her environment and discovered that people understood their environment by building mental maps with five elements:

- paths: the streets, sidewalks, trails, and other channels in which people travel;
- edges: perceived boundaries such as walls, buildings, and shorelines;
- districts: relatively large sections of the city distinguished by some identity or character;
- nodes: focal points, intersections or loci;
- landmarks: readily identifiable objects which serve as external reference points.

**Figure 1a: UTSC graphic campus map**

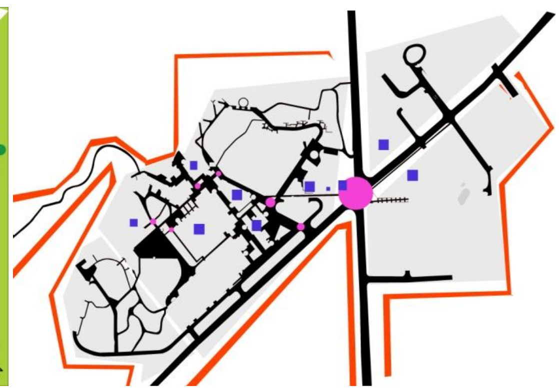

**Figure 1b: Lynch style graphic map with paths, edges, nodes, landmarks and districts**

In the figures above, Figure 1.a. provides a graphic map of the UTSC campus and Figure 1.b. provides a graphic representation of Lynch’s proposed elements of paths, edges, nodes, landmarks and districts.

As evident in Figure 1.b., the campus has two major paths or streets that converge at the intersection or node of Ellesmere and Military Trail. Beyond this, the rest of the paths are sidewalks or internal paths within the campus. Information or applications using Google maps are not useful for pedestrians who navigate the Scarborough campus because the inner streets within campus are not included within Google maps. Therefore, pedestrians hoping to get directions from point A to B have to use physical campus signage to find their way.

The existing physical signage on the campus has several inconsistencies in terms of branding and structure. Many visitors find it difficult to navigate on campus due to poor sign legibility or lack of signage altogether. Therefore, new students, staff, faculty or visitors unfamiliar with the campus have to constantly ask for directional support. Pedestrians with various disabilities, especially those with learning disabilities, find it all the more difficult to orient themselves.

Based on the lack of information from Google maps, mobile mapping applications and physical signage, a new method of providing wayfinding directions to pedestrians on the UTSC campus becomes essential. The qualitative research conducted within the framework of this project solidifies the need for an Inclusive Pedestrian Wayfinding System on the UTSC campus.

## ix. Target Audience

The target audience for this project includes students, staff, faculty and visitors of the UTSC campus that require customized directions around the campus. The target audience also includes people with learning disabilities. Within UTSC, close to half the population of students with disabilities have some form of learning disability. Kemp and Smith write that:

*Learning disabilities, or learning disorders, are an umbrella term for a wide variety of learning problems. Learning disabilities look very different from one person to another. One person may struggle with reading and spelling, while another may enjoy reading and cannot comprehend Math. Still another person may have difficulty understanding what others are saying or communicating out loud*[1] *[16].*

The problems are very different, but they are all learning disorders. As a result it becomes difficult to specify types of learning disabilities because of the wide variations and lack of a single symptom or profile. The data in figure below provides information related to common types of learning disabilities.

**Table 2: Common types of Learning Disabilities[2] [16]**

| Common Types of Learning Disabilities | | |
|---|---|---|
| **Dyslexia** | Difficulty reading | Problems reading, writing, spelling, speaking |
| **Dyscalculia** | Difficulty with math | Problems doing math problems, understanding time, using money |
| **Dysgraphia** | Difficulty with writing | Problems with handwriting, spelling, organizing ideas |
| **Dyspraxia (Sensory Integration Disorder)** | Difficulty with fine motor skills | Problems with hand–eye coordination, balance, manual dexterity |
| **Dysphasia/Aphasia** | Difficulty with language | Problems understanding spoken language, poor reading comprehension |
| **Auditory Processing Disorder** | Difficulty hearing differences between sounds | Problems with reading, comprehension, language |
| **Visual Processing Disorder** | Difficulty interpreting visual information | Problems with reading, math, maps, charts, symbols, pictures |

[1] Retrieved from Helpguide.org, an international non-profit 501(c)(3) charitable organization, based in Santa Monica, California.
[2] Table1: Authored by Gina Kemp, M.A., Melinda Smith, M.A., and Jeanne Segal, Ph.D, Last updated: June 2013.

Pedestrians often use maps or written directions as navigational tools for remaining oriented. However, people with learning disabilities are usually very sensitive to issues of abstraction (e.g., icons on maps or signage) [16]. Therefore, designers of wayfinding systems have a challenging task to tailor navigational information to each user and context.

A pedestrian who is familiar with a space is usually able to form a strong mental map of the space and, intuitively, estimate the distance or find the shortest route to a given location. A mental or cognitive map is the spatial representation of the environment that the person is navigating in and is an essential part of the wayfinding process [15]. However, when a pedestrian navigates through unfamiliar territory, a navigational aid becomes necessary to help with mental visualization of a space. Similarly, some pedestrians with severe learning disabilities may not be able to intuitively navigate through a given space even if they have navigated the space several times. This is because they are not able to form strong mental maps of their desired location. Therefore, the question for designers to consider is: how to create navigational aids to help pedestrians with learning disabilities form strong mental maps?

There are several cognitive processes involved in forming strong mental maps for pedestrian navigation [15]. Wayfinding is a cognitive process that produces a strategy and tactic for guiding a movement [15]. Wayfinding occurs not only before movement, but also during movement. Therefore, for people with learning disabilities, the navigational aid should be able to provide a useful strategy not only before navigating a space but also during navigation. An important information requirement of wayfinding is that travellers are aware of their location relative to their destination, and to other places or objects. Orientation is our awareness of the space around us, including the location of important objects in the surrounding environment [15].

Orientation is crucial for finding one's way from one location to another. People are oriented when they know their own location in relation to the surrounding environment. Therefore, signage with clear and concise contextual information about their current location can significantly aid pedestrians with learning disabilities in remaining oriented while navigating.

Several literary sources identify that people with learning difficulties use many different wayfinding techniques, and are not reliant on one method of wayfinding [7, 22]. There is also evidence that people with learning disabilities use both words and symbols on signs to help identify the information given [22]. This, along with the use of landmarks, is particularly useful to people with learning disabilities.

## x. Related Work

The growing recognition that inclusive wayfinding systems should be developed for pedestrians, has led several research groups in prototyping wayfinding systems (e.g., [3, 5, 15, 17, 19, 20, 21]). These prototypes fall into various categories based on their area of research focus, i.e.: landmarks, online and offline interfaces, augmented reality interfaces as well as visual and non-visual modalities.

### Landmarks

A common pedestrian wayfinding theme within the literature being investigated is the use of landmarks and its impact on the cognitive processes while navigating through a space. Landmarks are stationary, distinct, and salient objects which serve as cues for structuring and building mental representations [3]. The knowledge about landmarks contribute to the traveler’s orientation and localization within a spatial environment. However, the identification of landmarks can differ from person-to-person depending on environmental and cultural factors. Therefore Wolke [19] suggests that, since the concepts of landmarks have different definitions, local landmarks best fit the context of pedestrian navigation. Local landmarks are used at decision points where orientation is needed or they serve as route markers, as a confirmation that the pedestrian is going the right way [3]. Identifying a local landmark is dependent on the people that occupy the space and its surrounding area as well as people who navigate through the space. For the proposed prototype, the landmarks chosen are based on current students and staff navigating through the routes and identifying local landmarks. However, in order to reduce navigation errors with turn-by-turn directions, a landmark is required to be unique in relation to infrastructure or objects surrounding it. Millonig & Schechtner [3] propose that any object can be perceived as a landmark, if it is unique enough in comparison to the adjacent items. For example, a concrete building might serve as an important landmark if the surrounding area is populated by houses. Although the authors make a pertinent observation, even a building in a concrete jungle can be used as a landmark, provided the focus is on a unique feature of the building, which would allow the pedestrian to distinguish and identify the landmark with ease. Hausler et al. [1] claims that, where turn directions are slightly ambiguous in decision-making situations, adding landmark-anchored actions have a positive effect in terms of a decreased error rate while navigating to a desired location. Reducing error rate in wayfinding not only gives the pedestrian confidence while navigating but also reinforces positive perceptions about the space and people with whom they interact. However, solely using landmark knowledge is not sufficient to form strong mental maps; route and survey (map-based) knowledge is also required [5]. Landmark, route and survey knowledge can be acquired by consistent, inclusive and easy-to-read signage and navigational aids.

### Online & Offline Wayfinding interfaces

*Walk [Your City]* represents one of the fastest spreading Do It Yourself (DIY) civic engagement projects in the U.S., deemed “guerrilla wayfinding” by Atlantic Cities [18]. Within six months of its initiation in January 2012, their project has been replicated and adapted to more than 23 cities across the country and globe. [18]. *Walk [Your City]* began as a simple, unauthorized installation consisting of 27 plastic signs in downtown Raleigh. The signs depict how many "minutes by foot" it takes to travel from place to place [18]. Each sign is equipped with a QR code that provides Google Map based directions from the user's location to the destination indicated on the sign. The creator, Matt Tomasulo, wanted to shift the current perceptions that it took too long to walk to a certain destination. The temporary signage is the first part of Tamasulo's wayfinding system.

The second part links the offline sign to a web based system, allowing users to track sign usage, to create larger campaigns and to provide feedback to the city. The third part is a mobile application that acts as an on-the-go wayfinding sign. This participatory system is quite unique as it links all the offline signage components to a web-based system that allows users not only to create their own signage but also to understand their city better. The clear and concise signage can be extremely effective for people with learning disabilities. However, simply providing a Google map to receive directions may not aid users who may navigate more effectively using other modalities. In addition, people with learning disabilities would require more than route instructions to get to their desired location. Landmarks are significant elements in the communication of route directions and mental representations of space. Although contextual information about the pedestrian's location is not provided in the Walk [Your City] project, the expandability of the project allows designers to create signage that could not only provide time and landmark based instruction by foot to a certain destination, but also contextual information about the location of the pedestrian. These types of landmark and time based instructions along with contextual information about the locations of the pedestrians are considerations implemented within the proposed prototype, thereby aiding all pedestrians, including those with learning disabilities, to form strong spatial representations of their environment, which in turn helps them navigate to their desired location.

### Augmented Reality interfaces

Visual augmented reality (AR) interfaces have been emerging as the next important technology in the field of navigation interfaces as the popularity of smart phones equipped with a large display, video camera, GPS and a compass increases. A number of commercial programs are published for iPhone OS X and Google's Android operating systems, such as Layar and Acrossair's NY Subway.

AR interfaces in pedestrian navigation context have two main elements that define the nature of the interfaces: how the interface integrates virtual elements with actual reality, and the type of the navigation information it presents to the user [15]. An augmented reality mobile application employs the phone's camera, compass and GPS to display information about the user's surroundings.

Layar is an example of an AR application for iPhones or Android phones that adds content layers on top of the phone's video function that displays actual reality. [17].These layers display geo-spatial information, such as location and relevant information about nearby restaurants, real-estate value of nearby houses or the nearby hospitals. There are approximately more than 172 layers available, some of them location specific and some of them global [15]. Layar emerges to be a very promising technology if adopted by a community of developers willing to populate data about the location. It is important to keep in mind that each 'layar' is created by a 3rd party developer, also known as a Layar Service Provider, i.e., Flickr, Yelp, etc. [17]. The developers are provided with API documentation to build their 'layars' in unison with the Layar browser.

However, each Layar Service Provider could display their content and graphics differently in relation to the size, resolution, colour, interactivity: static vs. dynamic, etc. This would require the pedestrian to understand how each layar is designed as well as interact with the layar while navigating. The inconsistencies with each layar coupled with small display screens could pose a potential risk to pedestrians, especially those with learning disabilities, as their attention could be focused more on the device rather than their immediate surroundings, while navigating.

### Visual and Non-Visual Modalities

Several wayfinding systems using different visual modalities, such as images, audio, video and text to provide directions to users via handheld devices, have emerged [2, 7, 8, 9]. Many of these prototypes are designed primarily for people with cognitive disabilities. However, there are also several non-visual wayfinding systems that deliver non-speech auditory and tactile feedback to pedestrians while navigating to their destination.

Auditory display usually aims to improve accessibility in representing information to users who are blind or partially sighted, but can be very useful for the normally sighted users also, especially in situations where the pedestrian has to focus his or her visual attention on the surrounding environment. Holland, Morse & Gedenryd [20] created a prototype of a pedestrian navigation system entitled AudioGPS that relies on a virtual acoustic display as the user interface. By transforming an audio signal into a binaural signal to which the user listens through the headphones, the signal appears to emanate from a given environmental location and can assist the user to navigate towards his/her destination or to an intermediate waypoint. AudioGPS provides the user with two essential pieces of navigation information in non-speech audio: the distance as well as direction to the destination or an intermediate waypoint. [20]

A commercial tactile user interface, i.e., Braille cell, is almost entirely aimed at visually impaired people and requires special components to present navigation information. Using a tactile user interface to present navigation information for sighted people is a relatively new field of research. Lin et al. [21] introduce a pedestrian navigation system that uses tactons, i.e., abstract messages that can encode multidimensional information, to provide navigation information to the sighted user. The prototype of the system presents route guidance in the form of direction of travel and distance to next turn. The information is relayed by a vibrating alert on a mobile phone. Three different vibrotactile rhythms represent the direction of travel: seven short pulses for 'turn right', four longer pulses for 'turn left' and one short and one very long pulse for 'stop'. The use of different numbers of pulses in each rhythm helps to make the rhythms more distinguishable. The distance to a subsequent turn is conveyed by playing the rhythms in two distinct tempos: medium tempo (adagio) representing 'take action in the next block’, and high tempo (allegro) representing 'take action now' [21].

Pielot & Boll [24] report on a field study comparing a commercial pedestrian navigation system to a tactile navigation system called *Tactile Wayfinder*. The *Tactile Wayfinder* freed the participants' visual and auditory attention; however, participants made more errors in terms of navigation performance [24]. The opposite outcome occurred with the commercial navigation system as the participants’ visual and auditory attention focused less on their surroundings; however, they made significantly less navigation errors than the *Tactile Wayfinder* [24]. The report found no significant difference in the acquisition of spatial knowledge between the two navigation systems [24].

The auditory and tactile displays, such as those described above, would be suitable suitable for tourists as they provide navigation information without distracting the user's visual attention from his/her surroundings [15]. The auditory display can present information with spatial sound than the tactile display, as the meaning of the tactons used to provide information has to be learned. The auditory display uses non-speech audio to provide information, which makes it possible to alert the user without using words. However, the tactile display keeps both the visual and auditory channels open for other tasks. Attempting to replace the traditional audio-visual interfaces with tactile interfaces does not emerge as the most viable solution. Thus, further investigation in combining the superior navigation performance of visual and auditory interfaces with the hands-free advantages of tactile displays, is required.

## xi. Experimental Research

### Research study 1 (Students)

The first part of the study involved gathering data to understand the wayfinding needs of the student population on campus, as well as the requirements necessary to build the proposed prototype. Twenty (20) students participated in the study; thirteen (13) females and seven (7) males. The student participants were recruited from the U of T Scarborough campus and ranged from 18-22 years of age.

#### *Research Goal*

The goal of this part of the study was to understand:

- how students navigate around campus and what resources they use;
- how students provide directions to other people;
- what kinds of mobile technology do students use.

#### *Results:*

The participants were asked a series of questions related to the above research goals. The study revealed that 75% of the student participants used smart phones (25% Android, 5% Blackberry, 45% iPhone). 95% of these smart phones users accessed the internet on their phones. When asked how they navigate around campus, 55% indicated that they used a printed map and 30% used the online campus map. 65% of students indicated that lack of signage around campus was frustrating while trying to find a desired location. When asked how they provide directions to other pedestrians, 90% of the participants indicated that they point in a certain direction and use local landmarks on campus. From this initial scan of the student population, it was evident that students experience some frustration navigating through campus due to a lack of clear signage. In addition, a large margin of students accessed the internet on their smart phones. These phones became one of the requirements for building the prototype online.

## Research Study 2 (Visitors)

The second part of the study involved gathering data to assess the wayfinding needs of visitors who frequently visit the campus and those who have never visited the campus. 14 visitors consented to participate in the study; 8 males and 6 females. The participants were recruited as part of a networking event taking place on campus through the Co-operative Office. They ranged from 25-65 years of age.

### *Research Goal*

The goal of this section of the study was to assess:

- what resources visitors use to navigate to and around the campus;
- which types of directions people prefer, e.g., maps, video, photographs, text, etc.;
- the clarity and effectiveness of signage on campus.

### *Results:*

The participants were asked a series of questions relating to the above research goals. The study revealed that that 75% of the visitor participants used smart phones (45% Android, 0%

Blackberry, 55% iPhone). 92% of these smart phones users accessed the internet on their phones. When asked if the signage on campus was clear and effective, 64% of respondents indicated that the campus signage was hard to read. When asked how they navigate around campus, 79% indicated that they used some form of Google Maps which was street view, printed directions, map or application on their mobile phone. Only 14% used the campus map provided. Therefore, the majority of visitors chose a variety of different Google modes for navigation such as Streetview, online or printed map, printed text, mobile application, etc. This indicated that Google Maps was an essential tool that visitors used to navigate to and around our campus.

### Research Study 3 (Staff)

The third part of the study involved 5 staff members documenting wayfinding questions that students, staff and visitors asked for a period of 2 weeks. The staff members were chosen based on the location of their office as the first point of contact for pedestrians entering the building. They were also chosen based on the high traffic of student, staff and visitor populations around their office area. It is important to note that the research was conducted in January (Second Semester of the academic year). By that time, most pedestrians would be familiar with the important locations around campus.

#### *Goal:*

The goal of this study was to assess the areas on campus that elicited the most number of wayfinding questions from pedestrians. The purpose of this goal was to identify the top 2-3 locations that would be used as an example within the proposed prototype.

#### *Results:*

Based on Table 2, it is evident that students were constantly asking questions about getting to the Admission’s office and the Instructional Centre. Within the proposed prototype, in addition to the Admissions office and the Instructional Centre as location examples, the AccessAbility Services office was also used as a location example, as the prototype was also designed to include and assist pedestrians with disabilities, especially those with psychiatric and learning disabilities.

**Table 3: Number of Wayfinding Questions over two week period (January 7-11 & 14-18)**

| | Admissions Office | Registrar's Office | Instructional Centre | Parking Office |
|---|---|---|---|---|
| Week1 | 7 | 2 | 8 | 2 |
| Week 2 | 2 | 1 | 3 | 0 |

## xii. Designed Prototype & Benefits over previous prototypes

The design of this prototype is directly influenced by the literature review, qualitative research and several informal conversations with staff, faculty, students and new visitors, i.e. the stakeholders of this prototype. The intention of the designed prototype is not to replace Google maps, UTSC apps, Augmented Reality apps or existing signage, as each of these components have revealed their own strengths in aiding navigation. This prototype or solution is intended to complement these aids in order to provide pedestrians with an improved navigation experience. However, it is clear that implementing a new design or technology could have several positive or negative effects on the target audience, community and reception of new technology in the future. In terms of wayfinding, if components of the technology do not work or, worse, lead the pedestrian to the incorrect location, this could negatively affect the pedestrian's experience of the campus. This is extremely important for visitors to the campus as well as people with disabilities. The design of this prototype is a work in progress and a part of a larger campus goal to integrate all forms of wayfinding aids into a unified location to assist users with various abilities to experience the campus. Nevertheless, the design of this prototype is a new technology that has to be accepted and adopted into this unified wayfinding hub. It is evident in the literature sources that one of the major factors affecting people's attitude toward a new technology is the attributes of the technology itself [8]. Chang et al. [8] states that a new technology will increasingly be diffused if potential adopters perceive that the innovation:

i. is compatible with existing practices;
ii. has an advantage over previous innovations;
iii. is not complex to understand and use;
iv. can be experimented with on a limited basis before adoption;
v. shows observable results.

Consequently, keeping these considerations in mind, an explanation of how the design of this prototype meets these requirements is provided below.

### i. Compatible with existing practices

The prototype design has two components physical signage and an online web-based component. The offline signage is directly linked to the online component through the use of a QR code.

#### *The Offline Signage*

The offline signage is temporarily made of poly-coated cardboard normally used by real estate companies for marketing purposes. If the prototype is implemented in the future, it can be integrated with the existing signage on campus. The current UTSC logo has four colours (Figure 2.a.) and if the prototype signage is implemented in the future, it is a requirement that the logo be integrated with it. Therefore, the current colours within the offline signage are neutral with black and white to be com with the existing UTSC colours.

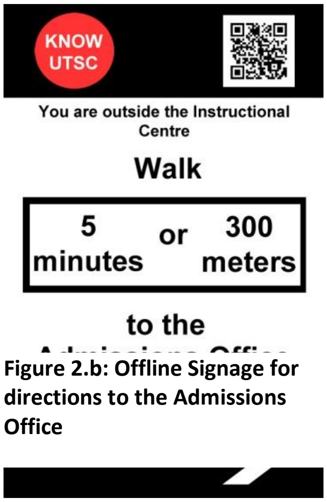

Figure 2.b: Offline Signage for directions to the Admissions Office

**Figure 2.a: UTSC Logo**

The offline signage is clear and concise in stating the location of the pedestrian e.g. 'You are outside the Instructional Centre'. The sign then gives the user information on how to get to key locations on campus, e.g.: Walk 5 minutes or 300 meters to the Admissions office [Fig. 2.b]. The sign also has a directional arrow pointing in the direction of the office location. This is similar to the existing Walk [Your City] project providing "Guerilla wayfinding" directions to pedestrians, which has proven to be an extremely effective for pedestrians. There is also a QR code present on the sign that links pedestrians to the online component. Although the QR code linking the offline and online components are similar to the Walk [Your City] project, it is quite different because the prototype online component has photograph and text, panoramic video, text-only, speech (audio) and map directions.

### *The Online System:*

The prototype is currently designed on a web-based platform rather than a mobile or tablet application, because the designer's current skill set in graphic and web design is more suited to a web-based platform. However, the intention is that the online prototype can be accessed via a mobile phone or a tablet. Therefore, the prototype is designed with an HTML 5 responsive design, addressing the ever-changing landscape of devices, browsers, screen sizes and orientations by creating flexible, fluid and adaptive web sites. The key feature is its adaptability to the user's needs and device capabilities. For example, for a mobile user viewing the prototype site on a small screen, taking the user's needs into account does not only mean adapting the website content to the screen size. It also means thinking about what that mobile user will require first when visiting the site and then laying out the content accordingly. The interaction areas need to respond better to a touch environment. For example, for the current design, the top menu collapses into a drop down menu when viewing the website content on a tablet or mobile device. Therefore, the prototype is designed in keeping with existing HTML 5 responsive web design practices. In addition, QR Codes are two dimensional bar codes used to store addresses and URLs that can appear in magazines, on signs, buses, business cards, signage or in almost any product that users might need information about. Many businesses are now adopting this code as a means of marketing and as an additional method of attracting customers to the internet for further information. Therefore, scanning the QR codes to direct pedestrians to the online component without searching for and typing in the URL falls in line with current practices of linking offline and online information.

### ii. Advantage over previous Innovations:

The online prototype design presents pedestrians with several navigation modalities based on user preferences. Previous innovations rely:

- on GPS to transmit information about the pedestrian's current location. This is not advantageous for pedestrians who rely on accuracy of positioning to get to their desired location and pedestrians who navigate indoors;
- solely on data or WiFi connection to present navigation information to pedestrians.
- solely on the assumption that the pedestrian owns a Smartphone, uses wifi or internet on their Smartphones;
- solely on Google Maps to acquire their data;
- on the assumption that all pedestrians navigate in the same way and use one or another modality to provide directions.

The proposed offline signage and online prototype design recognizes a number of issues:

- although GPS' provide accuracy of 5-30m, it may not be sufficient for pedestrians navigating through spaces that are closely situated to each other. In addition, GPS signals may not be available in indoor environments; the proposed prototype provides accurate pre-calculated indoor and outdoor directions to the location by providing contextual and landmark information about the space pedestrians are navigating;
- although data and Wifi may be required to access the online components, the offline physical signage is able to provide contextual information about the pedestrian's current location and a good amount of wayfinding information to navigate to their desired location;
- although a smart phone is required to get detailed directions, the proposed prototype allows users to explore the directions from the comfort of their own home without physically exploring the area. If pedestrians have a smart phone and may not use the internet or Wifi, the offline signage can aid them in getting to their destination.
- Although Google maps have proven extremely useful for providing an aerial map overview, Streetview (point of view) and directions from point A to B, it provides only an aerial map overview of the UTSC campus and lacks the provision of directions from point A to B or Streetview for pedestrians navigating on campus. The proposed prototype is able to provide point of view and aerial map directions from point A to B.
- It is evident through the literature review that pedestrians use different modalities to navigate or orient themselves. Some users navigate using a map, some require point of view (POV) directions and yet others navigate better viewing a video of the given space. Many users require specific landmark based directions to form strong mental maps of the location. Pedestrians with learning disabilities have the opportunity to choose directions based on their abilities. Pedestrians with low vision have the opportunity to hear directions prior to navigating the route or pause directions while enroute. Hence, the proposed prototype is able to provide landmark-based directions through the use of photographic, text, audio, video and map modalities.

### iii. Not complex to understand or use

The offline and online prototype design uses concise and clear information which aids in comprehension of directions for the pedestrian. Each modality of directional information has a clear graphic associated with it to allow users to know what type of directions they are receiving. This is in addition to the textual information available. The offline and online prototype provides the user with the number of minutes and meters needed to navigate to a location. Through informal interviews with pedestrians with learning disabilities, the amount of time required for navigation is indicated as extremely useful. The photographic directions provide a compass at the top right corner in case pedestrians want to know the North, South, East, West location to which they desire to navigate.

### iv. Can be experimented with on a limited basis before adoption

Currently the designed prototype has directions provided to only three locations for testing purposes. Although the formal testing of the prototype did not fit into the scope of the MRP, the intention is to test the prototype from May to August and expand the number of locations with the specified prototype directions. The intended deadline for adopting this prototype is September.

### v. Shows observable results

Through informal testing of the prototype design, some observable results have already begun to surface. The 'Skip to Content' link available at the top of every web page provides users using screen reader technology with the ability to skip to where the content begins in order to inhibit the screen reader from picking up unnecessary design elements when navigating through the page. The user also has the useful option of increasing the font size rather than an added step of navigating to the browser setting and zooming the web page. The evidence of the observable results are going to be presented when the user testing takes place between May and August 2013.

## xiii. Design Gaps

The current prototype design has several accessible features that set it apart from many previously implemented prototypes. However, there are a few additional personalization features that are not available in the current prototype. The online component of the prototype features multi-modal directions for a single route from one location to another. However, many pedestrians prefer having alternate personalized route instructions based on their preferences. Some pedestrians may prefer outdoor routes to explore the campus further. Others may prefer photographs and videos of the campus at night or during the winter. Some pedestrians with language barriers may prefer the directions to be available in a different language. In addition, the panoramic video options have a few issues related to resolution and file size. The section below describes possible solutions and future enhancements to the current prototype.

## xiv. Future Solutions and Recommendations

### Personalized directions

The proposed prototype currently does not provide alternate routes based on user preferences. However, by creating a login feature for the online prototype, each user could then set his/her preferences to indoor or outdoor routes, accessible routes, favourite routes, language options, etc. in order to receive personalized directions. Consequently, each QR code could then reveal a different set of directions to users based on their preselected preferences. This would prove extremely useful to all pedestrians, especially those with learning disabilities, as the system affords pre-planned routes based on personal preferences in order to alleviate stress that may be caused when navigating to unknown locations.

### Enhanced Panoramic Video

Panoramic video is made possible through an iPhone 4 or 4S attachment lens called the Kogeto Dot, which is the only commercial lens available to users at photography stores such as Henry's, in Toronto. Although the lens is able to capture panoramic video, there are several limitations. The output quality of the recorded video is fairly poor and the video can be viewed in its intended 'swipe' format only by uploading it to the Kogeto website and using Kogeto's panoramic flash web player. This web player allows the user to swipe across the screen, and the video rotates to provide a panoramic view. This web player cannot be viewed on tablets and cell phones that do not have a flash plugin. Since the release of this attachment lens in 2012, users continue to experience several technical issues in terms of editing and uploading. Unfortunately, when played on a user's desktop computer, the downloaded video cannot be edited and uploaded back to the Kogeto website as stated in the user manual. Therefore, for the purposes of illustrating the possibility of panoramic video, the raw footage is presented in this prototype. With the improvement of their web platform and lens, however, interesting features can be made possible; for example, by editing the raw footage, designers could increase or decrease the speed of the video, identify landmarks, provide arrows for change in directions, etc. Improvement of video quality would prove highly beneficial to pedestrians having a panoramic preview of the area they desire to navigate.

### Street view maps for UTSC

It is the campus' hope that in the near future Google street view will be available on Google Maps to provide point of view 360 images of the entire campus. Although the panoramic street view of the campus would be beneficial for pedestrians to virtually navigate from point A to B, the proposed prototype provides important contextual information, such as accessible entrances, and indoor and outdoor routes to several locations on campus.

## xv. Accessible Solutions based on Existing Systems

The online component of the prototype is designed with the assumption that a user can hold a smart phone in his/her hand while navigating. However, a user may become temporarily disabled if he/she holding an umbrella, carrying books and doing other activities that require the use of both hands. Some users, based on their limited dexterity or other physical disabilities may not be able to hold a smart phone in their hands. Based on studies of existing systems, the offline and online prototype may be expanded further to integrate some useful features.

### Talking Panel

The 'Talking Signs' system built in early 80's utilized audio speech signals presented via infrared transmission to a handheld receiver, in order to communicate navigational information to pedestrians, especially those with visual impairments [12]. A study was conducted to measure the efficacy and viability of the system [12]. The results of this study revealed that this navigational system significantly assisted blind travelers in finding specific locations [12]. In addition, this system worked better indoors as opposed to outdoors [12]. Therefore, a proposed adaptation of the *Talking Signs* system is the *Talking Panel* system. Since cell phones are currently ubiquitous, rather than having a receiver in addition to other hand-held devices, the mobile phone can now function as the receiver of these audio signals. The *Talking Panel* system can be implemented by installing a Bluetooth transmitter and recorder, preferably on a signage post to present on-location, pre-recorded speech prompts to a user's mobile phone when he/she is in the vicinity of the Bluetooth range. If a pedestrian travels with head phones or a Bluetooth headset, the audio signals could directly be transmitted to either mode. This could be extremely useful to users with low vision or complete blindness as they could be provided with contextual information about the space they are navigating. This could also be useful to pedestrians who prefer the hands-free option in bad weather conditions or bright sunlight causing screen glare. However, this requires users to pre-program their mobile devices to accept the Bluetooth signals. The software consists of a standard programming language compiler, boot loader and a microcontroller. The 'Talking Panel' system requires further investigation and prototyping; however, it emerges as a promising option not only to users with visual disabilities, but to all users that may not be able to view their screen due to the glare of the sun or other weather and environmental conditions. With the current availability of *Arduino* technology (single open source hardware motherboard) [23], it is now possible for designers to make the process of using electronics in multidisciplinary projects more accessible.

## xvi. Conclusion

Navigation and orientation are important factors required when attempting to find one's way to a desired location. Landmark based knowledge has proven to be useful for orientation and localization in spatial environments. Good navigation systems not only guide pedestrians to a destination, but also support them in understanding the environment, so they can ultimately reach the destination on their own. Research in pedestrian navigation also reveals that pedestrians vary significantly in their choice of navigation modalities [6, 7, 25]. The purpose of this MRP is to propose a system that aids UTSC pedestrians, especially those with learning disabilities to orient themselves and navigate to their destination through multi-modal landmark based, turn-by-turn directions. The prototype design is intended to complement Google Maps, mobile applications and physical signage in order to provide a comprehensive wayfinding experience for students, staff, faculty and visitors to the UTSC campus.

The prototype design features offline signage with clear and concise Time-based and metric cues while walking to a desired destination, in addition to a QR code that links the offline component to an online web based interface. Several sources in the literature review indicate that signage which is clear, simple, concise, consistent and easy to read helps people with learning disabilities orient themselves more effectively.

The online interface consists of photograph and text, panoramic video, map, text only and audio directions for users with varying abilities, especially those with learning disabilities. These multi-modal landmark based directions can be beneficial for users who require indoor and outdoor route information as well as those who prefer a specific type of modality in order to navigate.

The offline signage and the online prototype not only provide pedestrians with context about their current location, but also provide enroute landmarks to support them in understanding their environment as well as memorizing their routes. This is especially useful for people with learning disabilities who use landmarks to memorize their route. The proposed prototype allows users to explore the directions from the comfort of their own home without physically exploring the area. This increases the potential for inclusive navigation, as it allows people with learning disabilities to understand the routes through multiple modes, as well as plan their routes in advance before physically navigating through the campus. The online system is built using a responsive HTML5 wireframe to be compatible with multiple interfaces namely: laptops, mobiles phone and tablets. The online prototype complies with 'Web Content and Accessibility Guidelines' (WCAG) 2.0 in order to make the content accessible to people using screen readers and other assistive technology devices. The presented prototype can prove to be useful as it is easy to use, compatible with existing practices and has advantages over previous practices such as interfaces that solely rely on GPS, WiFi or Google Maps.

Although the proposed prototype demonstrates a multi-modal interface to communicate indoor and outdoor wayfinding information, it only features a single route from start to end point. However, with the addition of the personalized directions login feature, pedestrians may have the ability to plan alternate routes catered to their abilities and preferences. Therefore, a single QR code would be able to reveal alternate routes based on the user's saved preferences.

In addition to the personalized preferences, the proposed system is designed to cater to people with learning disabilities. It is also designed to be flexible and expandable based on the changing population's needs and requirements. Tactile wayfinding systems have proven to aid people with visual and auditory impairments, as well as those pedestrians who require their visual and auditory attention focused on their surroundings [23]. The system has the potential to be inclusive of a broader audience with the addition of hands-free modes, such as the *Tactile Wayfinder* or *Talking Panel* in order to aid pedestrians with visual and auditory disabilities. However, research suggests that pedestrians who utilize visual and auditory navigation systems have proven to make less navigational errors in comparison to tactile-wayfinding users [23]. Therefore, replacing the traditional audio-visual interfaces with tactile interfaces may not be the best solution. Further investigation, in combining the superior navigation performance of visual and auditory interfaces with the hands-free advantages of tactile displays, is required.

With the addition of personalized preferences for alternate route, language and media options, along with further user testing and research in the areas of tactile, visual and auditory systems, the designed interface has the potential to meet the needs and abilities of an ever-expanding campus population.

## xv. References


1. Rehrl, K., Hausler, E., & Leitinger, S. (2010). *Comparing the Effectiveness of GPS-Enhanced Voice Guidance for Pedestrians with Metric- and Landmark-Based Instruction Sets* (Salzburg Research). Jakob Haringer Straße, 5020 Salzburg, Austria.
2. Sohlberg, M. M., Fickas, S., Hung, P.-F., & Fortier, A. (2007). A comparison of four prompt modes for route finding for community travellers with severe cognitive impairments. *Brain Injury*, *21*(5), 531–538.
3. Millonig, A., & Schechtner, K. (2007). Developing Landmark-Based Pedestrian-Navigation Systems, 8(1), 43–49.
4. Chang, Y.-J., & Wang, T.-Y. (2010). Comparing picture and video prompting in autonomous indoor wayfinding for individuals with cognitive impairments. *Personal and Ubiquitous Computing*, *14*(8), 737–747.
5. Nordic Conference on Human-Computer Interaction, Gulz, A., SIGCHI (Group : U.S.), & ACM Digital Library. (2008). Tactile wayfinder: a non-visual support system for wayfinding. In *NordiCHI 2008 building bridges: proceedings of the 5th Nordic Conference on Human-Computer Interaction, Lund, Sweden, 20-22 October, 2008*. New York, N.Y.: ACM Press.
6. Liu, A. L., Hile, H., Borriello, G., Kautz, H., Brown, P. A., Harniss, M., & Johnson, K. (2009). Informing the design of an automated wayfinding system for individuals with cognitive impairments. ICST.
7. Liu, A. L., Hile, H., Kautz, H., Borriello, G., Brown, P. A., Harniss, M., & Johnson, K. (2008). Indoor wayfinding: developing a functional interface for individuals with cognitive impairments. *Disability and rehabilitation. Assistive technology*, *3*(1), 69–81.

8. Chang, Y.J., Wang, T.Y., Tsai, S.K. & Chu, Y.Y. (2007). Social Computing on Online Wayfinding Training for Individuals with Cognitive Impairments. In T. Bastiaens & S. Carliner (Eds.), *Proceedings of World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education 2007* (pp. 711-718).
9. Chang, Y.-J., Peng, S.-M., Wang, T.-Y., Chen, S.-F., Chen, Y.-R., & Chen, H.-C. (2010). Autonomous indoor wayfinding for individuals with cognitive impairments. *Journal of NeuroEngineering and Rehabilitation*, *7*(1),
10. Holone, H., Gunnar, M., & Holmstedt, H. (2007). *Users Are Doing It For Themselves: Pedestrian NavigationWith User Generated Content_*. Østfold University College, Halden, Norway.
11. Chen, B., Neubert, B., Ofek, E., Deussen, O., & Cohen, M. F. (2009). *Integrated Videos and Maps for Driving Directions*.
12. Brabyn, J. A., & Brabyn, L. A. (1984). An Evaluation of "Talking Signs" for the Blind. *Human Factors: The Journal of Human Factors and Ergonomics Society*, *28*, 649–652.
13. Lynch, K. (1964). *The Image of the City*. M.I.T. Press.
14. Google Street View - Wikipedia, the free encyclopedia. (n.d.). Retrieved April 26, 2013, from http://en.wikipedia.org/wiki/Google_Street_View
15. Pietilä, T. (2009, December). *Alternatives to map-based pedestrian navigation with location-aware mobile devices* (Media Programme Thesis). TAMK University of Applied Sciences
16. Kemp, G., & Smith, M. (2013, February). Learning Disabilities: Types of Disorders and Getting Help. Retrieved March 6, 2013, from http://www.helpguide.org/mental/learning_disabilities.htm
17. Layar. (n.d.). Retrieved April 2, 2013, from http://www.layar.com/

18. Walk [Your City] by CityFabric — Kickstarter. (n.d.). Retrieved January 17, 2013, from http://www.kickstarter.com/projects/cityfabric/walk-your-city
19. Wolke, L. (2010). Wayfinding in Your Pocket. *segdDESIGN*, (30). Retrieved from http://lesliewolke.wordpress.com/wayfinding-in-your-pocket/
20. Holland, S., Morse, D. R., & Gedenryd, H. (2002). AudioGPS: Spatial Audio Navigation with a Minimal Attention Interface. *Personal and Ubiquitous Computing*, *6*(4), 253–259.
21. Lin, M., Cheng, Y., and Yu, W. 2008. Using tactons to provide navigation cues in pedestrian situations. In Proceedings of the 5th Nordic Conference on Human-Computer interaction: Building Bridges (Lund, Sweden, October 20-22). NordiCHI '08, vol. 358. ACM, New York, NY, 507-510.
22. Walmsley J. and Johnson K. (2003). Inclusive Research with People with Learning Difficulties. Past, Present and Future. London: Jessica Kingsley Publishers.
23. Arduino. (n.d.). In Wikipedia. Retrieved March 22, 2013, from http://en.wikipedia.org/wiki/Arduino
24. Pielot, M., & Boll, S. (2010). Tactile Wayfinder: comparison of tactile waypoint navigation with commercial pedestrian navigation systems. In Pervasive computing (pp. 76-93). Springer Berlin Heidelberg.
25. Sohlberg, M. M., Fickas, S., Hung, P.-F., & Fortier, A. (2007). A comparison of four prompt modes for route finding for community travellers with severe cognitive impairments. Brain Injury, 21(5), 531–538. doi:10.1080/02699050701311000

# xv. Appendix A: Designed Online Prototype

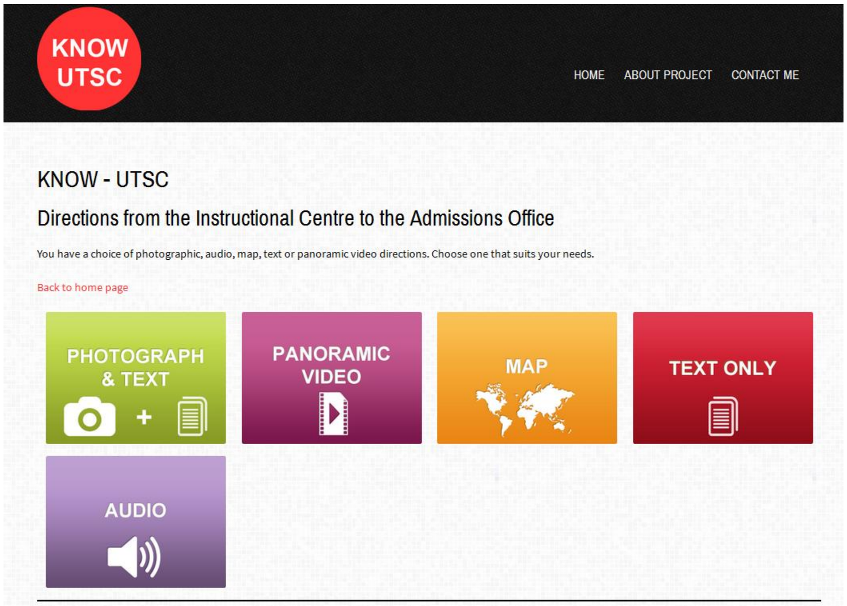


**Figure 3: Choose from Photograph & Text, Panoramic Video, Map, Text only or Audio Directions**

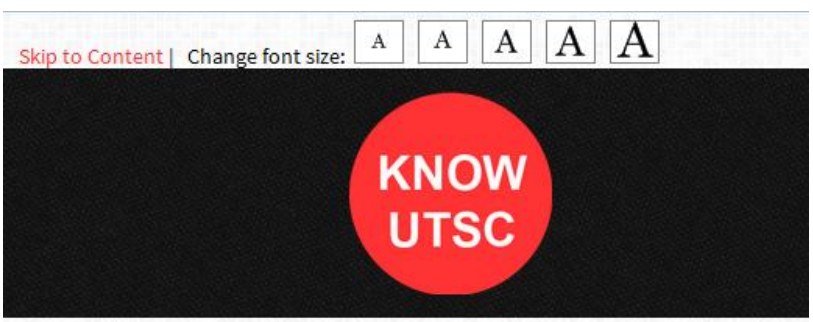


**Figure 4: 'Skip to Content' link for screen readers and 'Change Font' size to increase text size**

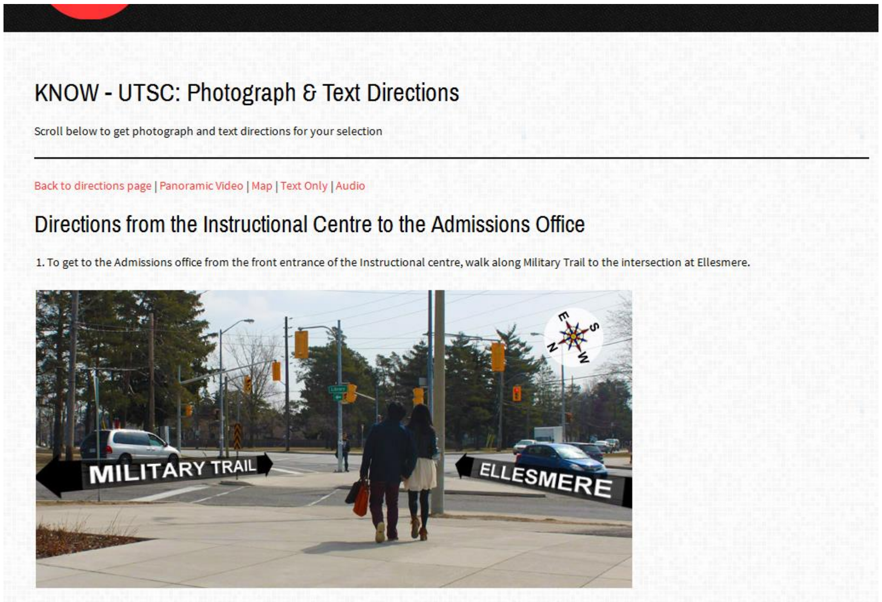


**Figure 5: Photograph & Text Directions from Instructional Centre to the Admissions Office**

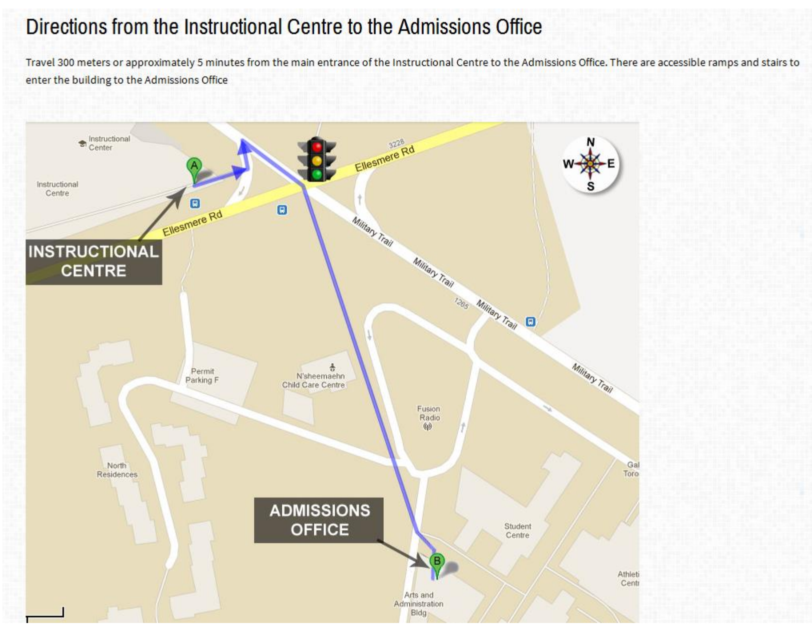


**Figure 6: Map Directions from Instructional Centre to the Admissions Office**

Figure 7: Panoramic Video from the Instructional Centre to the Admissions Office