This paper examines the relationship between public displays and street-level users in the built environment. The research highlights ongoing prototype development for a new approach to identifying and presenting different interface modes for touchscreen pervasive displays. These displays provide a unique opportunity to function at two levels; 1) public communication device and 2) private interface platform. This research and the resulting paper seek to expose some of the challenges in a multifaceted interface and potential solutions currently being examined. At the core of this inquiry and resulting dissemination was a desire to evaluate how street-level interactive displays will play a role in the ever-expanding infrastructure of the ‘smart city’. In particularly, this work discusses some of the challenges that exist in deploying these displays in a sidewalk environment for the purpose of pedestrian tracking and engagement.

1. INTRODUCTION

Over the last 100 years the world population has been shifting from rural to urban environments. As of 2010, this transition from rural to urban tipped in the favor of cities which was marked by more than half the world’s population living in cities (World Health Organization 2014). At the core of this shift has been a change in economics and industries as well as improvements in managing shared resources and infrastructure. A new shift is occurring within these urban environments related to resources, infrastructure, optimization and community marked by the emergence of the ‘smart city’ (Shepard 2011). Growth is measured not only in population densities but the growth of data density and diversity within these new environments.

The ‘smart city’ brought on by improvements in sensing technology and the growth of information networks (Bowerman, et al. 2000) has been championed by mayors and municipalities as well as large corporate stakeholders as the answer to addressing many of the 21st centuries problems related to climate change, energy consumption, transportation, pollution, and economic growth. Brought on by improvements in sensing technology and the growth of information networks (Bowerman, et al. 2000), these intelligent landscapes and resulting systems are primarily positioned as instruments for large-scale planning and management by city administrators and consulting groups with the goal of optimization (Greenfield 2013). A situational awareness is presented to be acted upon, directed, or otherwise manipulated through the collection of city wide data and computational processing. Aside from this command and control view of the ‘smart city’ there is a growing component that involves other stakeholders – namely the inclusion of community and the individual citizen.

1.2 SCALE OF THE SMARTER CITY (MICRO VS. MACRO)

Smart urban systems, information networks, and city wide sensing may be considered a result of the growth of ubiquitous or pervasive computing (Weiser 1991) where by computational elements are integrated into everyday objects supported by ever expanding wired and wireless networks (Want 2010). The growth of this new era of computing has been marked by the expansion of mobile devices and a culture of continuous connectivity, resulting in the consumption and generation of data in ever-larger quantities.

Within the context of the city, ubiquitous computing has begun to present itself at two different scales when related to output, visualization, and action: 1) macro and 2) micro.

The first ‘macro’ scale described previously as the ‘sense’ of the city (Lynch 1960) is acquired for the purposes of aggregating large quantities of data to make planning decisions (Nabian, et al. 2013). Here stakeholders such as city planners, traffic engineers, and politicians can harness the vast array of collected data to identify patterns and
act on them with the goal of optimization. Other stakeholders such as individuals and communities may engage with this data and its resulting visualizations through websites and mobile applications to inform their own actions.

A second ‘micro’ scaled interaction is also emerging where the street-level user is engaged by and generating data. Aside from ambient sensing that collects information related to the behaviors, actions and movements of individuals there are an increasing number of situated interfaces such as kiosks that allow street-level users the ability to interact with contextually appropriate information.

2. NEW STREET LEVEL INTERACTIONS

Computational and analog street-level interfaces are deployed throughout the built environment, from crosswalk buttons at a pedestrian level to traffic signal loop detectors that identify a waiting car at a street intersection. These street-level interfaces have primarily evolved in response to the vehicular or the vehicular / pedestrian interplay; where by these interactions are used to control traffic flow in a more responsive way compared to the traditional timed or ‘planned’ systems.

In addition to traffic interactions other interfaces have expanded to support various product and service vending such as parking meters, ATMs, and transit kiosks (figure 1). The city is as much about service and commerce as it is about locomotion and it is no surprise to see an ever increasing number of these financial mediations. Although these interactive experiences have evolved and grown in response to traffic and commerce, there has also been a growth in the general presentation of information in the built environment. These elements of information guide and inform street-level users as they navigate the urban landscape.

![Figure 1. Street-level interface examples](image)

2.2 DISPLAYING URBAN INFORMATION

Urban street level displays of information are not new. In particular way finding signage has been a consistent part of modern cities for the last century and continues to grow. Wayfinding signage assists motorists, cyclists, and pedestrians alike as they navigate the complexities of the street and sidewalk. Aside from the traffic and pedestrian sign there are a plethora of commercial signs that cover the urban landscape. Each of these visual elements performs a communication task from identification and regulation to direction and orientation (Gibson 2009).

Although some of these commercial elements may support wayfinding many are also focused on advertisement. The common billboard is perhaps the most notable of these. As a means of promotion, these graphic displays have come to adorn every available structure and surface in the city and roadway. From the large scale public space they compete for driver’s attention on highways and buildings and at a smaller scale they are deployed on objects ranging in size from city buses to public benches. In the context of billboards, what once was a printed display was then illuminated in neon to capture the attention and charm of its audience during both the day and night. The illumination and self-illumination of facades and surfaces continues to grow not only in spaces like Times Square and the Las Vegas strip but in the average city sidewalk. This shift to screen based illumination with an emphasis on cycling information to the viewer presents unique challenges that a printed, static display does not provide. Although these ‘urban displays’ (Vande Moere and Hill 2014) may be positioned as attention grabbing or flexible in their application, it is this very flexibility that may confuse the observer.
2.3 ARRESTING ATTENTION AND DIRECT ENGAGEMENT – PUBLIC VS. PRIVATE

As the cost of LCD screens continues to decrease, one can imagine a world where every surface and façade in the artificial environment will provide opportunity for the designer, architect, and advertiser alike to manipulate messages that impact both structures and the spaces between them. Framed within glowing rectangles these new windows will continue to overtake print as the predominate street-level communication tool (McCullough, Ambient Commons 2013). As part of any ubiquitous scenario, where these displays continue to integrate onto any and all objects there remains unanswered questions regarding how designers might leverage these pervasive displays.

The term ‘display’ produces a particularly functional attribute; one focused on revealing content for a user to consume. Displays are typically one component in a user interface; providing the visualization of data so a user can act upon it, either directly or with other interface components such as keyboard, button, mouse, or direct touch. In its purist form, the ‘display’ as interface output provides a dynamic solution to many of the current print facades and signage in the urban space. Many of the LCD screens deployed at public locations act as their print predecessors with the key difference of having the ability to cycle or update the message. These ‘cyclical displays’ are most commonly positioned for public consumption and provide limited to no direct input or engagement from an individual or community. The challenge in designing street-level screens that act in a passive display manner is that they may also provide the opportunity for direct interactions as a touchscreen interface.

The communication of potential interactivity and differentiating public and passive between private and interactive will continue to pose a unique problem to interaction designers. Perhaps the most unique aspect of situated interfaces is that although they may be a singular piece of hardware, their behavior has the flexibility to change between the modes of display and interactive surface. Arresting street-level attention and providing affordances that promote direct user interaction are important issues that this research seeks to address.

2.4 SPATIAL INTERACTIONS

Researchers have examined the relationship between user and large format interactive display in an effort to identify common patterns. These researchers have sought to provide a framework for the spatial criteria of interactivity and how these spaces change the interaction patterns between user and interactive display (Michelis and Send 2009). These frameworks position spaces between user and screen as thresholds (Brignull and Rogers 2003), zones (Streitz, et al. 2003), and phases (Vogel and Balakrishnan 2004).

Location, Public and Private Interaction

One can consider the need to address not only general spatial patterns of interaction between display and user but the particular location of these public interfaces, as space or location is one of the predominate differentiations between situated technology and other mobile computing devices (McCullough, Digital Ground 2004). Constraints are exhibited by sidewalk displays versus those deployed in a pedestrian-only interior location such as a mall or private building. It becomes apparent that these interaction patterns will be heavily influenced by the very space they occupy. The research disseminated in this paper highlights early interface prototypes developed to better facilitate street-level interactions that promote private and direct engagement between user and public outdoor displays and address the particular issues for sidewalk situated displays.

3. INTERACTIVE STREET-LEVEL PROTOTYPE – PRELIMINARY RESEARCH

This research was initiated as a means of evaluating opportunities and challenges in deploying situated touchscreen interfaces at various street-level sites commonly found in the urban landscape. As previously described, one of the issues that was identified early on in the research was the potential challenges in initiating interactions between user and public display. In particular the development of a responsive interface that could capture behavior exhibited in its near environment to shift modes from public to private and initiate direct human interaction.

This issue has been addressed by other researchers in the field through the use of sensors deployed on or near a touchscreen display (Grace, et al. 2013) (Wang, Boring and Greenbery 2012). Common points of data collected by these sensor systems are the general movement near the display, the distance to the display, and facial...
attributes of the display observer(s). In each case these systems were utilized to identify behavior near the interface and thusly produce a response in the display. The objective of using our research prototype was to use similar sensing approaches to understand proximity and movement of users as they approached or passed by the display.

The primary difference or challenge unique to this prototype display and sensing system was the site-specific nature of its future deployment. In particular this prototype was in development to address street-level and more specifically sidewalk level interaction opportunities. The cross-section of the sidewalk (figure 2) has many actors and objects that vary greatly depending on location. Consider the standard US sidewalk and street cross-section show in figure 2. This diagram reveals that proximity and movement may vary depending on the actors at play. Pedestrians, cyclists, and vehicles present themselves at different scale, speed, and proximity to a situated interface. This early prototyping was directed at promoting engagement between pedestrian and touchscreen interface through the isolation of these actors.

Figure 2. Sidewalk cross-section

3.2 SITUATED SENSING AS INPUT

As part of the prototyping rig (figure 3), we examined the use of three main sensors systems in conjunction with a touchscreen display. The tests were primarily focused on the isolation of targets such as pedestrians within a larger field of objects in the street-level environment. As previously discussed, location and the sensing that occurs at a particular location produces unique challenges when compared to isolated tests in pedestrian only conditions. The urban streetscape is highly varied and no single sidewalk may resemble the next. With that variation in mind, this prototyping has utilized the generalized sidewalk cross-section highlighted in figure 2. Future work seeks to provide recommendations for a taxonomy of street-level constraints and how one may approach these conditions. Below is a brief summary of the sensor systems utilized in our initial prototyping:

- **Passive Infrared Motion Detector**
  These sensors monitor and collect data on motion only. A common use for these sensors is for automatic doors, where the sensor produces a simple binary signal of motion and thus initiates a door opening sequence. Within the viewable field, these sensors examine infrared heat energy and can identify changes in that field. As this sensor was not able to produce discreet data about speed, direction, or distance; the passive infrared detector was abandoned as a viable sensing solution.

- **Ultrasonic Rangefinder**
  Ultrasonic rangefinders (transducers) have been used for everything from measuring wind speed to autonomous navigation. Through the production and collection of sound waves, these sensors can measure distance (proximity) and speed quite effectively. Utilizing a MaxSonar-EZ1 in conjunction with an Arduino Uno processing board, we successfully tracked and responded to pedestrian movement within a 10’ range. However, it did not
have the capacity to differential individuals or successfully separate other non-pedestrian movement (vehicles, bikes, etc.).

- RGB-D sensor

Lastly, we shifted our testing to utilize a Microsoft Kinect (generation 1) commonly referred to as RGB-D range camera. The benefit of this motion sensing device is that it has the ability to track and isolate individual targets in the field of view. Although this has currently proved to be the best initial solution, the infrared laser on the sensor array shows a high level of sensitivity to ambient light conditions that vary at exterior and street-level sites.

Figure 3. Test rig with touchscreen display and individual sensor test rigs

3.3 ISOLATING ACTION IN MOVEMENT CORRIDORS

In addition to the actual sensor systems that are currently being examined, there is a need to better identify how these potential systems are deployed in relation to actual movement corridors. As highlighted in figure 2, the city at street-level exhibits a diverse range of movements and actions that may be monitored. To effectively and efficiently approach this problem one must isolate the corridors to develop a strategy for the use of sensors systems in the collection of these ambient conditions. This is particularly important when the actions of one actor such as a cyclist may affect the sensor system that seeks to collect data on a different actor such as a pedestrian. As traffic has been isolated into standardized paths in most cities, our current strategy seeks to examine opportunities for sensor fields deployed in either parallel or perpendicular path monitoring (figure 4). Future tests will examine how the relationship of these fields of sensing will better collect, isolate, and identify actor’s movement as well as present touchscreen based responses that promote direct interactions between street-level users and situated technology.
4. CONCLUSION

Most of the world’s projected growth of two billion people over the next 30 years will occur in cities (United Nations 2003). Along with this growth in population, there will be a continued growth in the use of computing to both manage and manipulate the complex infrastructures that arise to meet these populations. Increasingly, these computational elements will reach beyond the top level goal of optimization towards a personal and potentially private interaction at street-level. These spatially oriented interfaces will differ from mobile devices in their ability to connect the virtual to contextually relevant information about place. As part of this new and emerging interface type, there will be challenges in resolving the difference between public and private interactions. In particular, the interactions that will come to develop around pervasive street-level displays. At its current state, our research has focused on promoting more intuitive interactions between user and display through the exploration of sensor prototyping for sidewalk specific deployment. Additional user quantitative testing is schedule for late spring 2014 and aims to reveal not only the opportunities for sensing pedestrian traffic but also understanding the most appropriate screen-based response to promote direct user interaction and engagement.

5. REFERENCES


