A new intelligent outdoor street lightning system supporting universal design and accessibility features.

Swathi Papudesi [1]; Robert F. Erlandson [1,2]
Department of Biomedical Engineering
Department of Computer and Electrical Engineering
Wayne State University, College of Engineering, Detroit, MI, 48201.

INTRODUCTION

A new intelligent outdoor street lighting system provides urban designers a unique and powerful platform for the delivery of accessibility features within a universal design context. The system takes advantage of built in microprocessors and a wireless communication network to not only control LED lighting, but also address way finding, accessibility and safety concerns. While universal design has been widely used in indoor environments, for example in public buildings and homes, to provide better accessibility, safety and security, much less attention has been given to the application of universal design in outdoor urban environments. This paper introduces a new intelligent outdoor street lighting system, describing its capabilities and then exploring a variety of accessibility features that can be implemented within a universal design framework.

INTELLISTREETS TECHNOLGY

IntelliStreets® is a network of inter-communicating LED streetlights developed and brought to market by Illuminating Concepts. While providing cost-efficient, urban lighting, IntelliStreets' basic capabilities also afford opportunities to significantly improve accessibility for individuals with disabilities.

Existing streetlights consume around 20% of the world's electrical energy (Alexander Suzdalenko, 2010; Mullner & Riener, 2011). Introduction of LED streetlights can provide up to an 80% energy savings depending on the operating characteristics (Technology, 2011). An LED lightning system with other useful features, like wireless transceivers, digital LED signage, alert indicators, and speakers, can provide safety, security, emergency reporting, way finding options, and entertainment for people with various abilities in outdoor environments at relatively low cost.

Key elements of the IntelliStreets (IS) system are its process control microprocessor and wireless dual band mesh transceivers. Advantages of the wireless mesh network include low cost, self-configuring, self-healing, self-monitoring, and non-line of sight connectivity (IJIS institute, 2006).

If the wireless mesh network is interrupted the IS poles function independently (Illuminating Concepts, 2009). Most fundamentally, from an urban design perspective, these elements enable the creation and operation of the "Smart Grid" streetlight concept while concurrently providing the ability to provide a variety of universal design and accessibility features (Illuminating Concepts, 2011a, 2011b). These explicitly designed capabilities distinguish IntelliStreets from other Smart Grid street lighting systems that only target LED control, for example the Echelon and Relume systems (Echelon, 2011; Relume, 2009b).

Like all Smart Grid systems, the IS system uses long lasting LED's to provide illumination. The advantages of LED luminaries include improved night visibility, instant on, less hazardous (no mercury or metal), long life span, cost-efficient use, and reduced maintenance costs (Bergren, 2006; PG&E, 2009). The brightness of the light can be programmed and controlled for high intensity lightning during dark peak hours of pedestrian and vehicular traffic (evening, night, before dawn). Additionally, smart sensors allow the IS system to modulate lighting based on ambient light in the environment (Illuminating Concepts, 2009). Color changing options associated with the IS luminaries provide not only decorative options, but afford an opportunity for way finding assistance.

Public safety is associated with accessibility and universal design in that any lighting system must provide adequate illumination. Improved lightning increases visibility rendering travel easier and safer for pedestrians and drivers. A summary of 38 studies verified the beneficial effects of lightning on unlit streets (Wanvik, 2008). Severe accidents after darkness were reduced by 64%, injuries reduced by 28%, and property damage reduced by 17% (Wanvik, 2008). Another summary of 26 studies also showed a reduction in the number of accidents after darkness linked to improved lightning (Elvik, Hoye, Vaa, & Sonerson, 2009).

Studies draw conflicting conclusions as to whether or not improved lighting reduces crime, has no effect or actually increases crime (Farrington, Welsh, & Britain, 2002; Marchant, 2006; Pain, MacFarlane, Turner, & Gill, 2006). Certainly public opinion favors improved lighting and indicates that people feel safer in well lit environments (Farrington et al., 2002; Herbert & Davidson, 1994). Studies also show improved lightning helps to increase community involvement and investment (Farrington et al., 2002; Herbert & Davidson, 1994).

Each IS pole has a visible alert indicator, LEDs that can control color, intensity, and the on-off cycle. During emergencies, color LED indicators can mark evacuation routes for both vehicular and pedestrian traffic while a different color LED can identify access routes for emergency responders (Illuminating Concepts, 2009). The IS system can also be programmed to guide large crowds at sporting events and other public events.

The IS system supports an invisible speaker (as part of the Concealed Placement Speaker (CPS)) system, which provides clear, high quality 360 degree dispersion audio (Illuminating Concepts, 2009). This system has been operational for over five years in cities and theme parks across the world. The system can provide local (close to the pole) or wide area coverage. The system can be used to provide announcements during general and emergency situations and to play music for various events, and cultural activities. In places like parks, shopping malls and college campuses the CPS plays an important role announcing lost children or people, safety precautions around the park, and special events.

The IS system supports digital LED signage for both street signs as well as decorative and promotional banners. A thin, two sided LED display shows customized signs, text, pictures, and videos for directing the flow of traffic, way finding, and displaying upcoming events, advertising, or amber alerts. The size of the font, background color and font color can be customized. In a small 4-pole demonstration system IntelliStreets demonstrated the ability of a smart phone to communicate with the IS system via a text message that can then be displayed on the IntelliStreet LED banners and via text to voice to make simple announcements over the CPS (Illuminating Concepts, 2011a, 2011b).

An iPAD has been programmed to control the music and banner displays for a small collection of IntelliStreet poles in the demonstration system (Illuminating Concepts, 2011a). Such customizable message and communication capabilities can serve multiple purposes.

CURRENT AND POTENTIAL APPLICATIONS

Relume Technologies provides a smart grid LED street lighting system. Their case studies report that three Michigan cities with installed Relume LED systems have demonstrated reduced energy costs, reduced carbon emissions, reduced maintenance costs and significant decreases in light pollution (Relume, 2009a, 2009b, 2009c). However, the Relume system does not have the collection of features supported by the IS system.

The computer components and wireless communication capabilities of the IntelliStreets (IS) system create an opportunity for a variety of universally designed accessibility features using smart phones and related technologies. The IS system can localize a person with respect to a local environment. With localization information applications can be developed to help people navigate and communicate within this local environment. Such ideas are not new, but the integrated communication capabilities of the IS system render them feasible and cost-effective.

In 2007, the city of Dörentrup in Germany implemented the Dial4lights system with the aim of providing light on demand. This technology uses a special modem and software to light a path after sunset (Moore/ Berlin, 2009). The users must register online and provide their mobile phone number. To light a path of interest, users call the Dial4 light number to enter a six digit code to turn on the light for 15 minutes. The disadvantage of this system is that the user has to call before using the system and is required to call again if light is needed for more than 15 minutes.

Recently a team from Austria developed a smart street lightning (SSL) system with LED lamps that use GPS and smart phones to provide location based services in rural and urban areas (Mullner & Riener, 2011). Users can expand or diminish the path that is illuminated by using smart phone applications. However, objects like trees and buildings can interfere with wireless communications between the nodes of the two street lights. Also the ZigBee nodes do not have their own GPS location. In the IS System each pole has its own GPS location and knows the GPS location of all poles in the network. By using the GPS position data from a smart phone or (similar device) users can control illumination for individual needs.

Based on discussions with visually impaired individuals, mobility impaired individuals and mobility experts from *Leader Dogs for the Blind* (LDB) headquartered in Rochester, Michigan, it is clear that local navigation is a major concern. In addition to GPS way finding, local navigation also requires information about specific local conditions, such as sidewalk repairs, road construction, or other highly localized navigational barriers. GPS based navigation aids do not provide the detailed local level information necessary to avoid such barriers.

To illustrate this point, the Kapten Plus is a French-made–navigation aid for people with visual impairments (Kapsys, 2010) that LDB offers to its clients to assist mobility. Kapten Plus is GPS-based and provides a range of voice navigation and tactile (button) controlled features. While navigating the City of Rochester's mobility training course using the Kapten, we encountered a stretch of sidewalk and road repair. While we were able to simply walk around these barriers, such occurrences represent significant obstacles for people using a wheelchair or a walker and for people with visual impairments.

In an interview Mr. Christensen (Age 52), a wheelchair user who works at Children's Hospital of Michigan, he reported that finding a disabled parking spot has been difficult in the majority of the places he visits. By integrating an RFID tag reading system to the IS system Mr. Christensen could be informed of a suitable parking place (if one were available) and directed to its location.

Standard GPS way finding can determine a route from the current location to a destination, but the IS system can then add very specific information that enables a user to avoid local navigational barriers. If a user is registered with a localized IS system, say in a neighborhood or city, it is possible for the users to receive alerts regarding the inconvenience and instructions for the best alternative route. The users could also register their Smartphone for a variety of applications, such as restaurants, ATM's, and public parking and transportation.

UNIVERSAL DESIGN AND ACCESIBILTY

Common problems faced by all people in outdoor way finding include finding entrances and exits, difficulty reaching their destination due to lack of information, taking the wrong path or direction confused by large text or messages, difficulty seeing the text on the message boards, not being aware of English or other languages on message boards, lack of alternate forms of information displays (e.g., Braille), and lack of adequate lightning at signs or message boards. The IS system supports simple, easy, multi-modal information presentation and way finding options for all people to overcome the common problems mentioned above. Additionally, the IS system can provide customized communication and control capabilities to people with disabilities who require accessibility in excess of that provided by the base IS system configuration.

Erlandson addresses specific universal and accessible design principles at both the individual and process level (Erlandson, 2008). *Universal Design New York 2* (Levine, 2003) provides a compilation of strategies and examples that describe implementation of universal design and accessibility principles in urban settings. Tables 1 (a-c) provide a summary of universal and accessible design principles and how they can be addressed by the IS system.

Each table has the same layout. Column 1 refers to the universal design principles addressed, with respect to Erlandson's hierarchy (Erlandson, 2008). Column 2 provides universal and accessible design (UAD) implementation strategies for addressing the universal design principles as presented in *Universal Design New York 2* (Levine, 2003) and embodied in the IS system. Column 3 provides a summary of the needs addressed by the implementations described in column 2. The 4^{th} column suggests accessibility enhancements possible by integrating the IS system with a variety of other existing technologies.

CONCLUSIONS

Research is underway at the Enabling Technologies Laboratory (ETL), at Wayne State University, to design, implement, test, and evaluate the IS accessibility enhancement features presented in the tables. The IS system and Smart Grid street lighting systems are examples of what are being called ambient intelligence (Augusto & McCullagh, 2007), pervasive computing (Kourouthanassis, Giaglis, & Karaiskos, 2010), and intelligent environments (Macagnano, 2008). The IS system is part of the infrastructure of the urban environment and as such can function to help create intelligent environments that can in fact provide greater accessibility and participation in civic and public affairs for all people.

Table 1(a) LED luminaries.

Universal design principles (Erlandson 2008) **addressed by IntelliStreets**	**UAD Implementation using IntelliStreets** (Illuminating Concepts, 2011c; Levine, 2003)	**Functional issues addressed by IntelliStreets**	**IntelliStreets combined with other technologies**
Human Factors principle: Perception	**Provides illumination in any outdoor environment* **Avoids glare or hot spots* **Increases illumination at safe crossing areas* **Prevents glare on signage*	**Safety and way finding* Increases ability to see and recognize dangers, signage, and way finding devices (e.g., pavement texture & color)	**Individually customized illumination* (e.g. via a smart phone app or use of RFID integrated technology and GPS technology).

Table 1(b). CPS and alert indicators.

Universal design principles (Erlandson 2008) **addressed by IntelliStreets**	**UAD Implementation using IntelliStreets** (Illuminating Concepts, 2011c; Levine, 2003)	**Functional issues addressed by IntelliStreets**	**IntelliStreets combined with other technologies**
Human Factors principles: Perception Cognition Process principles: Error-proofing Efficiency Reduced variability	**Provides multi-modal alert capability by combining CPS, LED signage, and different colored alarm LEDs*	**Safety, navigation and information* Multi-modal capabilities address perceptual impairments as well as cognitive impairments. LED signage and CPS can alert and then serve to guide people to safety using specified routes for egress.	**Individually customized alerts & information* In addition to general multi-modal alarm capabilities the system can be configured to provide customized alerts and information to individuals depending on their needs and technology requirements.

Table 1(c) CPS & Digital LED signage

Universal design principles (Erlandson 2008) **addressed by IntelliStreets**	**UAD Implementation using IntelliStreets** (Illuminating Concepts, 2011c; Levine, 2003)	**Functional issues addressed by IntelliStreets**	**IntelliStreets combined with other technologies**
Human Factors principles: Perception Cognition Process principles: Error-proofing Flexibility Efficiency Reduced variability	**Provides multi-modal communications capabilities; sound, spoken language, & visual.* **Provides simple, easily identifiable & legible signage readable from sitting and standing position* **Varies information formats (organization & spacing)* **Provides information & scheduled events, signage showing availability of assistive listening devices and assistive facilities*	**Presents information in multi-modal formats* Variety of languages Visual information available in words, icons, symbols Various foreground & background colors and image and word size (within limits) Variety of alternatives in information pacing, spacing and organization	**Individually customized communication* Targeted communication can be customized for individuals (e.g., via a smart phone app or integrated use of RFID technology and GPS technology).

REFERENCES

Alexander Suzdalenko, I. G. (2010). Investigation of Power Supply Methods for Intelligent LED Luminary. *IEEEXplore*.

Augusto, J. C., & McCullagh, P. (2007). Ambient intelligence: Concepts and applications. *Computer Science and Information Systems, 4*(1), 228–250.

Bergren, M. (2006). ICLEI Climate Innovation Invitational: Ann Arbor's LED Streetlight Program. *http://www.ledcity.org/lib/resources/Ann%20Arbor%20LED%20Summary.pdf*.

Echelon. (2011). Managed Street Lighting Networks *http://www.echelon.com/solutions/streetlight/*.

Elvik, R., Hoye, A., Vaa, T., & Sonerson, M. (2009). *The handbook of Road Safety Measures* (2nd ed.).

Erlandson, R. F. (2008). *Universal and Accessible Design for Products, Services, and Processes*. Boca Raton, FL: CRC Press, Taylor & Francis Books, Inc.

Farrington, D. P., Welsh, B. C., & Britain, G. (2002). *Effects of improved street lighting on crime: a systematic review*: Home Office Research, Development and Statistics Directorate.

Herbert, D., & Davidson, N. (1994). Modifying the built environment: the impact of improved street lighting. *Geoforum, 25*(3), 339-350.

IJIS institute. (2006). Wireless Mesh Technology. *http://www.ijis.org/docs/WP/ijis_wp_wireless_mesh_20060124_final.pdf*.

Illuminating Concepts. (2009). IntelliStreets, by Illuminating concepts. Retrieved Nov 11th, 2009, from http://identitypr.com/pressrelease/illuminating-concepts/IntelliStreets-by-illuminating-concepts/

Illuminating Concepts. (2011a). Illuminating Concepts Debuts IntelliStreets Lights in Farmington Hills. Retrieved October 28, 2011, from http://macomb.patch.com/articles/illuminating-concepts-debuts-IntelliStreets-lights-in-farmington-hills#video-8264754

Illuminating Concepts. (2011b). Intelligent lights make up wireless network use for entertainment and safety. Retrieved October 28, 2011, from http://www.wxyz.com/dpp/news/region/oakland_county/intelligent-lights-make-up-wireless-network-used-for-entertainment-and-safety

Illuminating Concepts. (2011c). IntelliStreets home page. from http://IntelliStreets.com/videos.php

Kapsys. (2010). Kapten Plus: Voice-Controlled Mobility Assistant from http://www.kapsys.com/modules/movie/scenes/content/index.php?fuseAction=learnuse&rubric=learnuse&article=products_kapten&FUSEBOX_LANG=2

Kourouthanassis, P. E., Giaglis, G. M., & Karaiskos, D. C. (2010). Delineating 'pervasiveness' in pervasive information systems: a taxonomical framework and design implications. *Journal of Information Technology, 25*(3), 273-287.

Levine, D. (2003). *Universal design New York 2* (2 ed.). New York: Center for Inclusive Design and Environmental Access.

Macagnano, E. (2008). *Intelligent urban environments: towards e-inclusion of the disabled and the aged in the design of a sustainable city of the future. A South African example*. Paper presented at the 5th International Conference on Urban Regeneration and Sustainability: The Sustainable City 2008. .

Marchant, P. (2006). Investigating whether a crime reduction measure works. *Radical Statistics, 91*, 41.

Moore/ Berlin, T. (2009). Germany's Bright idea: Street Lightning on Demand. Retrieved July 1, 20099, from http://www.time.com/time/world/article/0,8599,1907182,00.html

Mullner, R., & Riener, A. (2011). An energy efficient pedestrian aware Smart Street Lightning system. *International Journal of Pervasive Computing and Communications, 7*(2), 147-161.

Pain, R., MacFarlane, R., Turner, K., & Gill, S. (2006). When, where, if, and but': qualifying GIS and the effect of streetlighting on crime and fear. *Environment and Planning A, 38*(11), 2055-2074.

PG&E. (2009). LED street lights. from http://www.pge.com/mybusiness/energysavingsrebates/rebatesincentives/ref/lighting/lightemittingdiodes/streetlightprogram.shtml

Relume. (2009a). 735 Forest, Birmingham, Michigan: Case study. 2009, from http://www.relume.com/docs/pdf/relume_casestudy_birmingham.pdf

Relume. (2009b). Ann Arbor Michigan: Case study. 2009, from http://www.relume.com/docs/pdf/relume_casestudy_annarbor.pdf

Relume. (2009c). Battle Creek Michigan: Case study. 2009, from http://www.relume.com/docs/pdf/relume_casestudy_battlecreek.pdf

Technology, D. U. o. (2011). Intelligent Lightning System Saves 80 Percent on Energy. 2011, from http://planetsave.com/2011/07/13/intelligent-street-lighting-saves-80-percent-on-energy/

Wanvik, P. O. (2008). Effects of road lightning: An analysis based on Dutch accident statistics 1987- 2006. *Elsevier: http://www.sciencedirect.com/science/article/pii/S0001457508001917*.