Connected Healthy Living for Smart Cities

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As the Baby Boomers generation enters into their 60s, the healthcare system is under great challenge to respond to the needs of this rapidly increasing elderly population. A more innovative, preventive, proactive, evidence-based, person-centered and wellness driven approach is needed to transform the health delivery model. A framework for healthy living in Kansas City, as a prototypical smart city for connected health, proposes to integrate the information collected at multiple levels.

INTRODUCTION

American cities are undergoing a physical and technological transformation, with the increase in the population living in urban areas, and the proliferation of connectivity and sensing technologies to make cities smart. As architects, social scientists, and urban researchers focus on the connections of human health to Smart Cities, a framework is needed to integrate the necessary components to create lifelong neighborhoods, in which residents can thrive at all stages of life, including the integration of information and communication technologies to support the autonomy and health of aging adults. At the University of Kansas, the New Cities Research Initiative explored how the built environment would need to change in order to accommodate the exploding demographic of aging Baby Boomers in America (Domer 2011). This paper outlines a framework for healthy living in Kansas City, a prototypical smart city for connected health. The objective is to integrate heterogeneous sets of data to support user-level behavior monitoring in the home and the neighborhood, and the modifications needed, at the building-level and neighborhood-level, to enhance the quality of life of these smart city inhabitants.

CHANGING HEALTH MODELS IN SMART CITIES

As the Baby Boomer generation enters their 60s, the United States healthcare system is under great challenge to respond to the needs of this rapidly increasing elderly population and expand its scope to include preventive care, and finding alternatives to long term care (Rice 2004, Forti 2000, Redfoot 2013). These aging adults look for personalized medicine and health social networks to access and share information. Research in improving the current health delivery models, point to the need for a more innovative, preventive, proactive, evidence-based, person-centered and wellness driven approach (Knickman 2002, Johnson 2007, Swan 2009). In the context of smart cities, there are two important aspects in the reconsideration of healthcare models: preventive care in the home and health promotion in the neighborhood.

HEALTH PREVENTION IN THE SMART HOME

Researchers have looked at the modifications needed in existing residences to support aging in place and the impact and challenges in home maintenance to support preventive care strategies (Holm 1998, Koch 2006, Hwang 2011). The spectrum of home modifications to support aging in place ranges from design modifications of the physical space to facilitate access and remove barriers for elderly with mobility problems, to digital enhancement to provide greater connectivity and assistive care for elderly with sensory or cognitive impairments (Cheek 2005, Noury 2000). The effectiveness of home modifications has been evaluated based on the degree of independence they provide to the elderly person (Lawton 1990). However, the level of home customization needed to support the daily physical, personal, and social activities is often very costly (Pynoos 2003).

HEALTH PROMOTION IN THE BUILT ENVIRONMENT

The elderly population is one of the most vulnerable groups impacted by the lack of access to healthy food in many urban neighborhoods in American cities (Thomas 2010, Lee 2001). In addition, older adults are among the most sedentary groups in the United States, spending 60% of waking time in sedentary activities (Matthews 2008, Evenson 2012). Studies have also shown the importance of retrofitting the urban infrastructure to promote health (Sallis 2012, Dannenberg 2003, Tzoulas 2007). For smart cities, information and communication technologies can support neighborhood enhancements to help promote healthy activities and engage vulnerable groups such as the aging population (Lupton 2015). The literature also shows the growing number of grassroots initiatives to improve access to food through urban farming and low-income food markets (Armstrong 2000, Broadway 2009, Thomaier 2015, Brown 2008). These physical enhancements are often promoted with digital tools and apps for mobile devices.

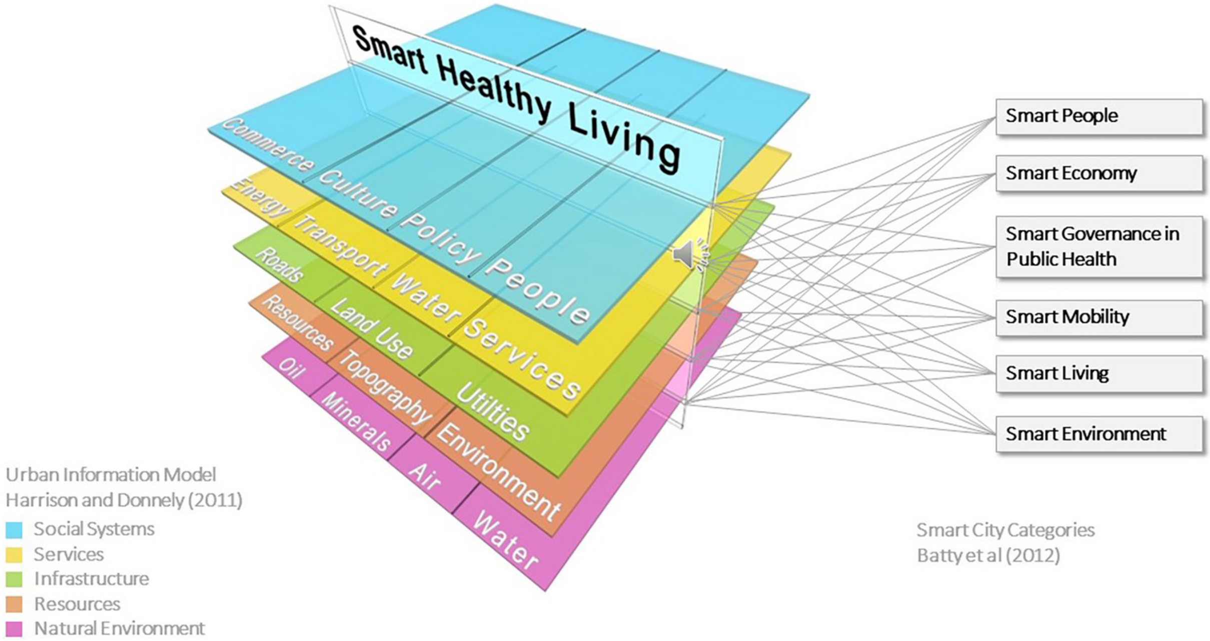

Figure 1: Framework for Smart Connected Healthy Living

Health prevention and promotion and strategies rely on connectivity and access to data at multiple scales and levels of detail. The next sections describer a multi-layered approach to integrate health prevention and promotion in the smart city.

INTEGRATED FRAMEWORK FOR CONNECTED HEALTHY LIVING

A smart city can be defined as a system of systems where a ubiquitous digital infrastructure supports the system connectivity in the built environment. Our research team builds on the smart city framework proposed by the research group led by Batty (Batty et al., 2012) and expands the Urban Information Model framework developed by Harrison and Donnely (2011) where Smart Healthy Living intersects and connects social, natural, infrastructural, resource and service systems. Figure 1 shows the proposed framework for smart and connected living in the smart city.

TOWARDS CONNECTED HEALTHY LIVING IN KANSAS CITY

Kansas City was selected because its development pattern is typical of many medium-sized American cities. It is unique, however, in its early adoption of gigabit technology. The first city in the US to receive a gigabit internet network installed by Google Fiber, the technological infrastructure allows one to speculate on how the future of housing may be influenced by almost unlimited bandwidth in the context of a Smart City. The smart street car system will connect multiple neighborhoods. Kansas City is an emerging smart city focused on tackling big challenges such as unemployment, quality of living, and sustainability. Private companies like Google and Cisco have invested in improving Kansas City's connectivity. Proactive government agencies are working together to build an integrated health system, and academic institution are exploring ways to improve various aspects of healthy living, and sustain energy and water systems.

The following sections present the research conducted at 3 scales focusing on the development of an integrated platform for smart city data analytics, studies on healthy living at the neighborhood scale, and the fabrication and construction of building components for a smart living unit.

SMART AND CONNECTED SENIOR LIVING UNIT AS A LIVING LAB

It is proposed that technology-rich senior housing units send biometric data to an on-site Living Lab which can be operated by local healthcare researchers. A Smart Cities housing prototype has been designed to collect vast amounts of data for more affordable, efficient, and effective healthcare deployment (Figure 2). Motion sensors provide fall detection and prevention, gait analysis detects issues with balance and can be used in determining early onset neuromusculature diseases (Huisinga 2013). Bed sensors collect data on heart rate, respiration, sleep apnea, and restlessness (Jiao 2016). Smart mirrors monitor skin and teeth irregularities, eye-tracking dysfunction, and advanced facial recognition software can provide warning signs of stroke (Chiarugi 2013). The mirror can also meter the amount of yellowing that occurs in the lenses of our eyes as we age. This yellowing partially blocks the blue light from our brain and inhibits the production of melatonin that helps us rest at night cortisol that allows us to wake in the morning. This imbalance in circadian rhythms can be attributed to many of the ailments associated with aging: sleepiness, lack of alertness, slow reaction time, and even depression (Mainster 2013). This can be corrected with custom color spectrum LED lighting. Finally, a smart toilet can monitor vital signs as well as hydration (Huang 2012). Not only is dehydration a leading cause of falls in seniors, data from the smart toilet can be coupled

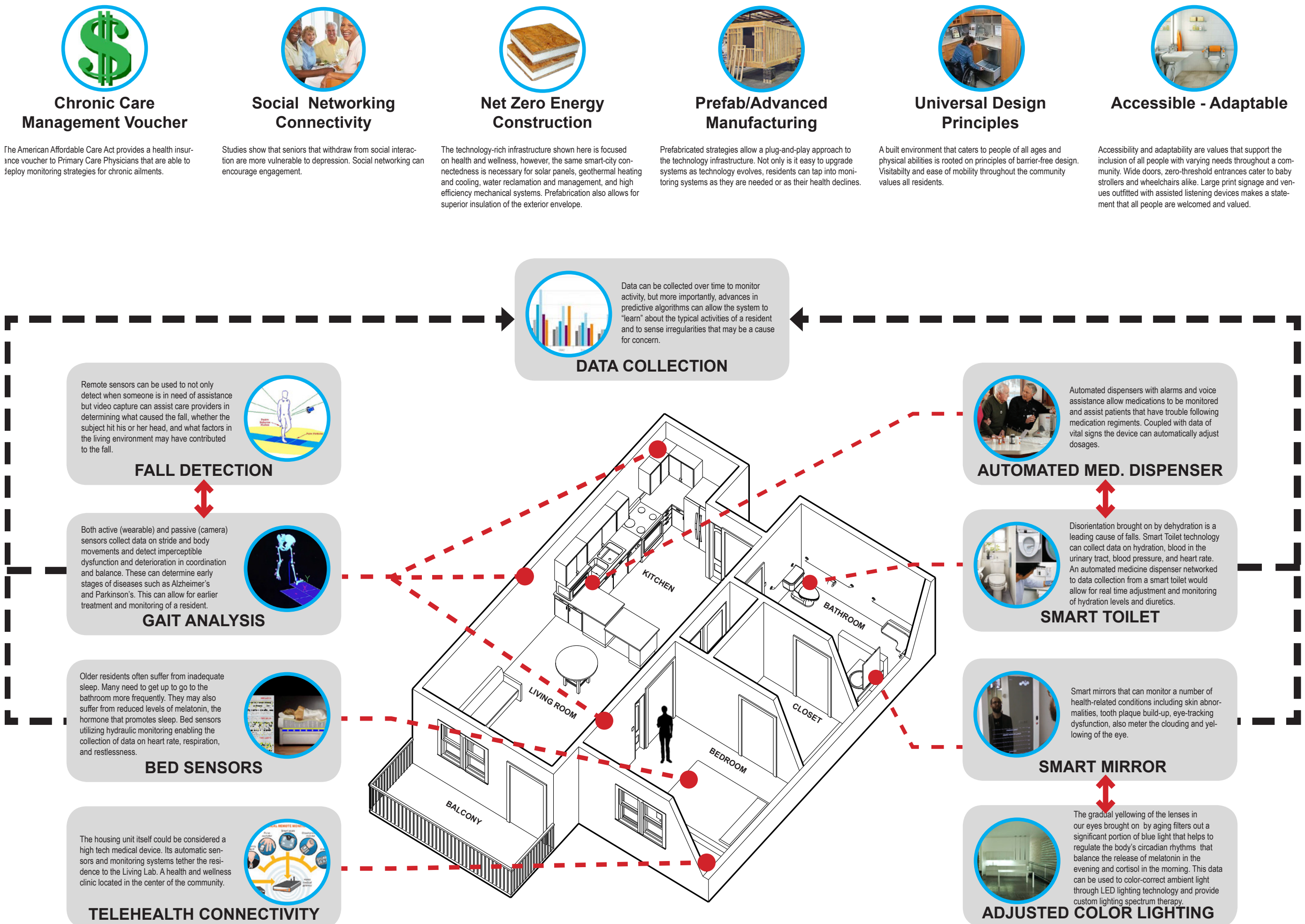

Figure 2: Smart Cities Housing Prototype.

with an automatic medicine dispenser to regulate diuretic dosages in heart medication.

We believe prefabrication is one of the keys to bringing these solutions to scale. We are working with industry partners to explore prefabricated wood wall panels (SMART 2016). These Passive House-certified wood wall panels arrive to site with engineered-wood framing, insulation, fluid applied vapor barrier, and high-performance windows and doors. We are exploring optimized manufacturing processes in order to determine the most efficient fabrication technique such as using an automated framing table to expedite the prefabrication and customization process.

We are also working with the University of Kansas School of Engineering to develop a lightweight modular steel floor/ceiling system has been developed for rapidly constructible and reconfigurable buildings. The system is currently envisioned as a two-way lattice-like structure comprised of slotted C-channels. We are exploring the possibility of utilizing robotics to plasma cut the slots and weld together the members. When used in conjunction with data-collecting sensors, these assemblies can leverage smart city networks to collect data on structural stability. These are used for routine performance inspections and maintenance plans. They can also be employed in the event of an emergency to alert first responders of danger zones and to prioritize rescue efforts. We are also investigating whether this type of sensor can track heel strike in order to provide fall detection and activity tracking.

INTEGRATED DATA PLATFORM

In order to support the aging population that lives in a smart city, we propose the comprehensive integration of a wide range of IT systems. As an integrated data environment, the Smart City Information Model (SCIM) will be capable of supporting interoperability among the multiple layers involved in the research. The following data types need to be effectively integrated by the SCIM digital platform: housing unit sensors, Building information modelling (BIM) data, neighborhood level space syntax analysis, and Geographic Information Systems (GIS) data. SCIM is in development as a software prototype to support the development of a variety of data translators.

We are still in the early development of this software prototype, fine tuning performance metrics at the building and neighborhood level. For the next steps involve calibrating the SCIM software prototype; testing data collection protocols in a Smart and Connected Senior

Living Unit; and aggregating building and user data with neighborhood level data in the context of healthy urban network. The goal is to better understand the correlation between these types of data. This approach for interoperability between the aging smart city inhabitant and the built environment traverses across scales to connect data: within the interior environment, to address the needs of the smart city dweller aging in place; and in the exterior environment, to improve mobility and walkability, and access to healthy food.

NEIGHBORHOOD DESIGN AND WALKABILITY FOR ELDERLY

Older adults are among the most sedentary groups in the United States, spending 60% of waking time in sedentary Activities (Caspersen, Pereira, and Curran 2000, Matthews et al. 2008). Walking is a relatively safe form of activity even for older adults with impaired cognitive and physical function (Lautenschlager et al. 2008, Murtagh, Murphy, and Boone-Heinonen 2010). Walking most frequently occurs in one's own neighborhood and is highly influenced by characteristics of the physical environment (Van Cauwenberg et al. 2011). Walking for exercise and transportation purposes is associated with a number of neighborhood characteristics including availability of sidewalks, accessibility of desirable destinations, aesthetic attributes, and perceptions of safety from traffic or crime (Owen et al. 2004). In a study of 64 older adults with and without mild Alzheimer's disease (AD), we evaluated neighborhood integration and connectivity using geographical information systems and space syntax analysis. In multiple regression analyses, we used these characteristics to predict 2-year declines in factor analytically derived cognitive scores (attention, verbal memory, mental status) adjusting for age, sex, education, and self-reported walking.

Neighborhood characteristics may be an important determinant of cognitive function and decline in older adults. Neighborhood integration is a measure of the number of turns required to travel between two points. The more direct a path is between two points (e.g., the fewer choice points), the less cognitive complexity required to navigate the route. Connectivity is associated with the availability of potential walkable destinations. High intersection densities and connectivity provide more potential routes for walking and greater accessibility. Neighborhoods with greater connectivity, that is, number of paths, streets, homes, and businesses were associated with maintained cognitive function among older adults without cognitive impairment. Neighborhood characteristics may influence health by other mechanisms than walking behaviors, such as social behaviors, driving behaviors, and cognitive complexity of navigating the environment. The study findings have implications for design and maintenance of living spaces for older adults with and without cognitive impairment and may be helpful in eliminating barriers to physical activity in sedentary older adults.

HEALTHY FOOD ACCESS AND HEALTHY COMMUNITY

In the United States (U.S.), there is a growing public health concern about "food deserts" on residents' diet-related health outcomes, such as an increase in obesity (Auchincloss et al. 2012, Kegler et al. 2014, Osei-Assibey et al. 2012), diabetes and a higher risk of heart-disease (Astell-Burt and Feng 2015, White 2007, Schafft, Jensen, and Hinrichs 2009, Salois 2012). The Kansas Health Foundation's (KHF) Healthy Communities Initiative funded 20 communities across Kansas, including Johnson County to "promote policy, systems and environmental changes that support healthy eating and active living." We have worked closely with Johnson County in a multilevel effort of healthy food assessment that synthesized a wide array of data using Geographic Information System (GIS) mapping. Multiple data sources were combined, including Automated Information Mapping Systems (AIMS) Department (Johnson County), Mid-America Regional Council's (MARC) Data & Economy division, Environmental Systems Research Institute's (ESRI) Community Analyst data and Google Maps.

These distribution of food resources were further analyzed using ArcGIS metrics including density, buffer area, and network distance. The results were overlaid with demographics, social economic status, and public transportation system. The resulted visual profiles can aid the Johnson County Food Policy Council in the detection of local food access needs to identify catchment areas and strategies for additional targeted investigation. The maps were built into an online web app to allow community stake holders to self- evaluate community needs for healthy food access, develop recommendations for policy changes for improving food environment, and track the changes of local food environment.

The study revealed that besides poverty, the vulnerable groups of population, especially elderly, confront substantial physical barriers in geographical food accessibility. We are currently working in linking the quantitative data on distance to food outlets with the survey results on food shopping behavior to further understand the impact of food environment on diet and diet related health outcomes, with a specific focus on senior population.

DISCUSSION AND CONCLUSION

An integrated framework is presented to outline the type of information needed to support older adults aging in place in smart cities. One of the goals is to advance the understanding of how the aging population make connections with their surroundings and neighborhoods, how to better address their needs, how to guide the decisions that impact the quality of life of these smart city dwellers. The research focused on Kansas City as a prototype for this approach to smart and connected health. To support data exchanges for health prevention and monitoring in the home, a streamlined construction method using modular construction with embedded sensors can reduce the cost of a smart living unit. A Smart City Information Model is proposed as a repository and processor for the data collected within the home, as well as a platform to exchange information at the neighborhood and smart city level. The results show that to support health promotion in a smart city neighborhood, the infrastructure needs to be retrofitted to achieve a level of physical connectivity that can support physical activities and access to healthy food. A multi-level approach to the data exchanges between the smart city inhabitant, the home and the neighborhood also points to the emerging challenge of access to personal information and privacy issues when dealing with digital health prevention and promotion.

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