User Interfaces in Smart Cities

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Contents

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Abstract

What is smart? Smart is welcoming, in which objects and environments make one feel at home. Smart is being cared for, feeling appreciated, safe, and belonging. Smart is being able to access information when in need, no matter where the location is. Smart is being able to freely roam around, to visit parks and recreation easily. Smart is turning waiting time into quality time, connecting with family and friends. Smart is feeling refreshed and rejuvenated through work, rest, and play. Smart is having things that think, spaces that sense, and places that play. Smart is embracing technology that empowers people to raise the standard for quality of life. Smart is having friendly interfaces that take care of people and connect them with a digital infrastructure. Smart is having tools that enhance the lives of those living and working in the city by providing them with context-aware, safe, secure, and sound means to access and interact with each other, and the community resources in a smart city. The chapter presents hundreds of interface ideas and examples for enchanted objects, interactive spaces, and services designed or proposed for everyday life in smart cities.

Introduction

A Day in a Smart City

Jenny walks out of her apartment before dawn, as she needs to be at work early today. She notices the color beacon on the top of the office tower nearby is flashing white and blue light, signaling that the temperature is falling and snow is coming. She tells her watch to remember to turn up the heat before she gets home tonight. Meanwhile, the street lamps light up softly to illuminate her path toward the bus stop. One of the lamp posts displays that bus 22 will arrive in 7 min, and another one displays the current air quality and traffic conditions. Jenny blows a kiss to the lamp posts with a smile, thanking them for making her feel safe and informed. The traffic light senses her approaching the crosswalk and turns the signal green for her to pass. Arriving at the bus shelter, she is greeted by the smart display that plays her favorite sci-fi movie, powered by the solar panels above the roof. Jenny is glad that the bus shelter and the lamp posts are also Wi-Fi hot spots, so she can stay connected with all her devices. When Jenny boards the bus, the shelter display and lights turn off automatically, ready to be activated again when the next passenger arrives. Jenny notices an approaching siren sound, as an ambulance is approaching. She is pleased to see that the traffic lights automatically turn green to let the ambulance speed through all the intersections.

This is just a snapshot of how someone's everyday life could be enabled or augmented by the design of smart environments, from smart objects, smart sidewalks and street furniture, to smart traffic control and smart coordination in a smart city. Many people are already accustomed to smart watches, smart thermostats in smart homes, smart phones that track the user's schedule and physical activities, as well as the smart traffic lights activated through motion sensors. Some of the interactions or user experiences may be awkward at first for people who have never encountered them before. For example, lifting one's wrist to talk to a watch, being pleasantly surprised by activated lights when jogging at night, or the traffic light that turns green when someone approaches the crosswalk. Some of them were conventions of practice, such as recognizing the color red in a weather beacon (Color Kinetics 2013; Alexandru et al. 2018) to signify sunny weather. Increasingly, more public entities and private companies are teaming up to facilitate a wide spectrum of functionalities such as real-time digital signage, interaction with information (Corning 2013), vehicle navigation, schedule and transportation coordination, emergency alert and resource sharing, and public safety (AT&T 2013), for "City Brains" that ensure energy efficiency and infrastructure maintenance (Alibaba Cloud 2018) or a "Smart Nation" (Government Technology Agency of Singapore 2018) (Table 1).

Table 1 Covered topics in this chapter and how they relate to the different dimensions of smart city

	Dimensions of a smart city	Attributes
Sect. 1	Smart environment	Internet of Things (IoT) Information communications technology (ICT) System of systems (SoS)
Sect. 2	Smart living	Public utilities Mobility (e.g., public, private) Health (e.g., public safety) Communication (e.g., AMBER Alert) Quality of life (e.g., social, playful)
Sect. 3	Smart people	Tech literacy Ability Local versus global (e.g., between cities) Resident versus government Work versus leisure Digital democracy
Sect. 4	Smart interfaces	Tangible user interfaces Ambient interfaces In-environment interfaces (IEI) Environment scale interfaces Mobile/wearable Extended reality Smart materials Data analysis

How to Read This Chapter

As it is not possible to exhaustively cover all possible topics, this chapter, "Interfaces in Smart Cities," sets out to first examine existing guidelines for what a smart city is and how user interfaces relate to users in smart cities. It looks at guidelines on smart cities (ITU 2015; FabLab 2018; CEN 2019; IEC 2020; ISO 2020) and establishes terms and definitions. Section "Introduction" explains the interconnectedness of a smart city and section "Characteristics of a Smart City" covers the characteristics of a smart city. Section "People of a Smart City" discusses the people of a smart city and section "Interface Trends for Smart Cities" discusses the interface trends for smart cities, and finally, section "Conclusion" outlines the outlook and opportunities for the future of smart cities. Readers who are strictly interested in current interfaces and interface studies should skip to the section "Interface Trends for Smart Cities."

IoT, ICT, and a System of Systems

The Internet of Things – IoT (Atzori et al. 2010; Dave et al. 2011) shows the concept and vision of a network of "things," for example, the physical objects or devices with embedded sensors, software, and other technologies that connect, interact, and exchange data with other devices or systems over the Internet. Mark Weiser coined the term "ubiquitous computing" (Weiser 1996; Weiser et al. 1999) and many others also refer to the ideas of "smart objects" (Kortuem et al. 2009), "ambient intelligence" (Cook et al. 2009), or "everyware" (Greenfield 2006). The vision for ubiquitous computing is an intelligent system that monitors, informs, and controls the environment such that human to human, as well as human–computer interaction can become enhanced. Whether these systems are explicitly interacted with or are ambiently gauging the state of the environment, these devices bring a sense of enchantment (Rose 2014), they seem autonomous and benevolent, and likely inform and affect the everyday life of a smart city resident. Through ubiquitous sensing, actuation, and an increased propensity to collect better data, homes as well as cities will become connected, safer, more convenient, and overall increase the quality of life within the system.

The concept of a system of systems (SoS) (Cavalcante et al. 2017) is important because it differentiates from IoT and information communications technology (ICT), and also arguably best describes how IoT and ICT are incorporated in city systems. The SoS view describes relationships between the nested systems involved in IoT and ICT. This view also establishes the idea that these systems are independent, heterogeneously complex, and act in collaboration with one another to achieve the common goal of improving city life. It is also important to recognize population density as a critical design factor for data collection and system operation, where densely populated cities operate differently than cities that are smaller or more spread out. This view is adopted to best explain how "smart interfaces" are representative of a collaboration between independent systems that act together to bring context- and user-specific information for the various people and concerns of the smart city.

Characteristics of a Smart City

Public Utilities

Public utilities are a concern of most, if not all, smart cities. Public utilities, including water, waste, sustainability, energy, etc., need to be monitored carefully by city officials and the general population. Efficient means of monitoring public utilities lead to a reduction of waste, increase in safety, and reduction of frustration in the general population (IEC 2020). It has also been found that fine-grained energy consumption feedback for consumers can reduce waste when coupled with citywide use statistics and incentives (ITU 2015; ISO 2020), giving credence to the importance of interfaces for energy consumption. The interchange of information that flows from production to consumption of goods and services gives rise to many different types of interfaces that help access information appropriate for their use.

Mobility

Public

Intelligent transportation systems (ITS) are an essential component of a smart city. Inefficient transportation means can lead to excess vehicle emissions, road infrastructure wear, traffic jams, and an overall road network capacity decrease (ITU 2015; IEC 2020). Several methods are utilized to monitor public transportation systems, including, but not limited to, in-vehicle sensor monitoring, wireless communication technology, roadside sensors, and unmanned vehicles. This information is often collected in the interest of informing city planners, car manufacturers, insurance companies, and the general public.

Private

Private transportation and parking is a resource that is widely available in most cities. This is largely due to the taxi industry and smartphone application-driven transportation services. Private transportation systems come in the form of taxis, bicycles, powered scooters, and other devices (Cycling Matters 2017). These modalities of transportation can reduce overall energy consumption, the need for parking in densely populated areas, and increase safe travel.

Health and Safety

Health

Citizens depend on their city to provide access to medical facilities and services. The most advanced healthcare services also provide pervasive health monitoring, care, and security of medical information (David et al. 2011; Acampora et al. 2013). In the event of an emergency, city planners and hospital owners are concerned with the location that hospitals are constructed relative to population and ease of access for emergency medical vehicles. In addition to planning, data concerning diseases, type of injury, and care services are essential information to be communicated between hospitals and to necessary officials.

Public Safety Services

Introducing nascent technology into policing has the potential to exacerbate existing issues of bias, injustice, and community distrust. Instead of creating tools for predictive policing, which have the potential to reinforce bias and inequality in policing (Lum and Isaac 2016), technology and data science can be used to directly measure and address equity and bias in policing (Goff et al. 2016).

Introducing pervasive technologies that monitor and record behavior raises a number of ethical and privacy concerns. Cities should engage residents in dialogue around the benefits and drawbacks of new technologies, and ensure that appropriate measures are taken to protect the privacy of citizens (Martinez-Balleste et al. 2013).

Ubiquitous sensing provides large amounts of information from many scales and contexts. Being able to monitor and respond has increased alongside sensor technology, but is carefully designed to be used in emergency situations.

Communication and Amber Alert

A variety of situation awareness or alerts for safety and security have been implemented through software or mobile phone applications for situations such as weather alerts, family location, disaster readiness, location-based social network, gas station locator (Fisher 2020), or emergency alert (Red Cross 2020) or wearable safety app, with a digital or physical panic button in the networked objects such as phones (Jara et al. 2019) or necklaces, and bracelets (McGarry et al. 2000; Karusala and Kumar 2017; Ylizaliturri-Salcedo et al. 2018).

Alerts of missing children such as AMBER alerts (AMBER Alert 2020a) or the Police Expert Network on Missing Persons (PEN-MP) (AMBER Alert 2020b) are often displayed on electronic message signs, in the cities, or along the highways or transportation infrastructure, though there are traffic safety concerns (U.S. Department of Transportation 2020). Many of such alerts are sent through Wireless Emergency Alerts (WEA) to phones, but with inadvertent consequences of some people turning the WEA off (Hu and Goodman 2020), with such a situation, could a smart city enable further notification channels?

Quality of Life

Playful

A playable city is a concept that enhances the description of a smart city. Whereas, a smart city is often associated with the ability of the city to sense, actuate, accumulate data, and interact in an "intelligent" way with its residents, a playable city describes human behavior as being nodes in the IoT of a smart city – intelligent actors that shape the dynamic interactions among each other (Nijholt 2017, 2018a, b).

Playful, sometimes termed "gameful," cities are cities that incorporate play into their city infrastructure (Nijholt 2018a). Playful components of a city are often found in isolated or semi-isolated locations within the city, such as public parks, amusement parks, event centers, and businesses where patrons interact. The public spaces where city dwellers go apart from home and work are termed "third spaces" (Oldenburg 2002), and it is precisely these third spaces that determine the components of a playful city in the context of smart cities.

Social

The intentional design of public spaces for the purpose of interaction and shared experience can occur in many settings. A critical factor in the design of these spaces are the aspects that make these spaces attractive (Gaol et al. 2018). For example, the historical significance surrounding the space can be an important factor in what draws members of the city to explore them. Museums fall into the category of historical significance because historical items are often collected and held in these locations, to create this sense of significance. Carefully considering areas of interest and types of interactions found by viewing areas as nodes, generally found towards the center of the city, can inform city planning.

People of a Smart City

The residents, government officials, and people who find themselves in smart cities all have distinct roles that require their own support tools and interfaces. Industrial design considers the role of each person in this ecosystem and will tune interfaces present within the city to match the needs of the user. This section describes the various roles of a person in a smart city and interface design considerations that are crucial for smart operation.

Tech Literacy

Tech literacy is a term used to describe how fluent one is with technology. The factor contributing to the largest discrepancy in tech literacy is age (National Academy of Engineering and National Research Council 2006) and is often due to poor eyesight and diminished motor control (Müller et al. 2015). Another contributing factor is socioeconomic status which can manifest when education mediums are either not present or underfunded (National Academy of Engineering and National Research Council 2006). This can occur because tech tools are often cost-prohibitive and public funding for education may not provide enough to supply one with a technically literate foundation. Tech literacy is a necessary consideration for those expected to have some level of fluency with the interface.

Ability

The term “ability” refers to aspects, technological or otherwise, that afford one to be independently able to accomplish a task. In contrast, those who are able-bodied are able to easily complete a task in a category of tasks that others who are disabled would otherwise struggle with (IEC 2020). This term is flexible and can be assessed on many axes; however, the concept that underlies them all is often discrimination and hardship that comes with social exclusion based on ability. Many of these underlying factors can be mitigated with the appropriate use of technology and design, making the city a more inclusive place and a common concern among city residents.

Local Versus Global

Interfaces must be made for types of interactions within the city as well as between cities. Here, local and global interactions are explored from the perspective of the designer for smart city interfaces.

Local

Locality in terms of interaction refers to interfaces that are designed specifically for those in one’s city or close proximity. Interfaces that concern themselves with local interests often are built for goods and services that are utilized within the city.

Global

Interfaces that are designed to connect cities often deal with goods and services that are transported to another city or place. These types of interfaces are often built to monitor the movement of goods and e-commerce generally but are also known for connecting people around the world and monitoring intercity dynamics.

Resident Versus Government

Information that is designed for residents is different than information designed for those working in government. Government services are often concerned with the maintenance or tracking of the dynamics of the residents, whereas residents are often concerned with where they can receive goods and services.

Resident

Residents of the city are people living in the city limits and have access to the commodities a smart city has to offer. Residents often work within the city and provide goods and services to each other; however, smart cities differentiate themselves in how the residents access and manage them. Interfaces for smart city residents often provide faster and more efficient services powered by a network of shared information.

Government

Government employees are concerned specifically with the state of the smart city. Information provided to government employees pertains directly to the interconnectedness of the moving parts within the city and the well-being of the residents. These concerns can be local or global and pertain to a scope that is generally larger than those of its residents (ITU 2015; Chun and Noveck 2020).

Work Versus Leisure

Work

People working in a smart city are concerned with domain-specific technologies, which include many types of interfaces. Often these tools are used to manage workflow with respect to the industry in which they work, many of which overlap.

Leisure

People living in a smart city are concerned with many aspects of daily life within the smart city leading to needs that require different interfaces. For example, a city that provides transit schedules, real-time traffic, and event maps would enable citizens to become more engaged, while, a smart lighting lamppost, equipped with sensors and connectivity, would assist in remote monitoring for everything from air quality to public safety.

Interface Trends for Smart Cities

Interfaces in this section are supported by the information provided in the previous sections. The interfaces themselves are explained with respect to how this addresses a concern of a smart city, as well as the intended users.

Tangible User Interfaces (TUI)

Tangible objects can be designed to support retrieval of historical stories in a tourist spot, for example, the Navigational Blocks (Camarata et al. 2002) demonstrated a physical embodiment of digital information through tactile manipulation and haptic feedback that was easy to understand and easy to use to manipulate complex digital information. Electromagnets embedded in the Blocks and wireless communication encourage users to quickly rearrange the Blocks to form different database queries.

Tactile Internet Systems

Tactile Internet systems (Ateya et al. 2017) provide a means to produce motion in a robot at a distance in real-time. The actions on one end of the system are mimicked in real-time to corresponding actions on a robot. To produce actions in real time, network latency has to be reduced as much as possible. With the proposed system, network latency as low as 1 ms can be achieved when reducing the nodes of transmission using a 5G network. Though the benefits of a low-latency network are many, the ability to transmit motion data in real time has the capacity to engage people with a much more familiar sense of in-person interaction. Smart cities that have the infrastructure to support high bandwidth networks and deliver information at these speeds can drastically change the daily life of the resident of the smart city. Many may benefit from technology like this, but it is proposed for local use with residents of the smart city in everyday communication.

Urban Interaction Using TUI

Health/Global/Residents

"Who's There?", a publicly displayed tangible map can be used to connect people in distant cities using tangible interaction (Ventä-Olkkonen et al. 2013). The map contains every continent with a tangible object attached to various cities around the world. When residents interact with the tangible map by pulling a rope, residents in the other city watch as the motion is translated by receding into the map slightly. Though more interaction such as video chat or the ability to enter queries may be added, the tangible interaction between cities establishes the feeling of connection in another city and provides value to residents through simple connected interactions.

Geospatial Tangible Urban Planning

Local/City Planning

Geospatial tangible user interfaces (GTUI's) are used for interactive and collaborative city planning tasks (Maquil et al. 2018). GTUI's make a great interface for collaborative work because they are generally tabletop interfaces that are sized appropriately for small groups of people. The tabletop interfaces are projecting on the tabletop surface and are affected by interaction with objects on the table. Projections are run by a computer that has access to data regarding the state of the city, interactive maps, data visualizations, and other tools necessary for urban planning (Maquil et al. 2015). Tangible objects on the table can be differentiated by the computer and react according to how they are being used in context with the visual information on the table's surface. This method enables large amounts of data to be visualized and displayed to many people at once.

Participative Design

Public displays can also foster participative design and feedback regarding city planning. Survey information can be recorded using a series of buttons with smiley faces on them, enabling pedestrians to give instant feedback on their experience in the environment (Wouters et al. 2014). This affords city planners more data to work with and also connects the context of the environment to the survey, giving residents the opportunity to give feedback in a constructive, context-specific way.

These interfaces can be extended to include speakers that one presses for news, including context-specific news. This provides the context for the news and affords passersby the ability to engage with their environment in an informative and nonintrusive way. The other benefit is that the engagement provides the information immediately, whereas, using a personal device to access the same information is distracting, and may not be available in the location of interest.

Tangible Interfaces for Three-Dimensional Interaction

Tangible interfaces that physicalize interaction with computational devices push the limits of how one interacts with information as well as each other. Smart cities contain a plethora of tangible interfaces; however, robust three-dimensional actuation sets some systems apart from others. Aside from hardware and cost limitations, these interfaces demonstrate promise for a future of tangible interaction. Extending upon the tactile and connected Internet described in the section above, there are interfaces that can be programmed through deformation and physical manipulation (Follmer et al. 2012). This is very useful for programming repetitive tasks or conveying tactile sensations at a distance. Multiple kinds of actuation can be employed for this case, such as clay and other soft objects.

Additionally, tabletop interfaces that extend into physical space such as inFORM (a tabletop dynamic and physical user interface) can be used to react to the user and objects placed on the table (Follmer et al. 2013). A card game, for example, can be played with physical cards that are managed by the table itself. Other uses are available also, such as dynamic screen-like physicalization, which enables users to use the system as a complete interface for sensation as well as actuation. Similar to this interface for more modular use is Dynablock (Suzuki et al. 2018), a rapid 3D printing mechanism that can create many objects through the use of magnets and current. To use Dynablock, programs to render three-dimensional objects can be used to create a wide array of physical objects in a number of seconds.

Ambient Interfaces

Integral to the smart city is the concept of ambient interfaces. These interfaces are generally powered by a distributed network of sensors and actuators, aimed towards recognizing humans and subtly supplying them with their needs (David et al. 2011). These systems are often referred to as “context aware systems” and provide ambient and ubiquitous intelligence (Kjær 2007).

Ambient Intelligence

Ambient intelligence is a term used to describe a future where “intelligent” or “smart” systems react in an attentive, adaptive, and active way. Ambient intelligence is often accomplished through a system of sensors and actuators of many different types. These systems are generally running in the background, controlling environmental cues and assisting with the needs of daily human living and collaboration (Streitz 2011). The overarching goal of ambient intelligence is to be hidden from users, by providing unobtrusive interaction. Therefore, an increasing need for systems that are built with many different types of sensors (i.e., RFID and computer vision, running simultaneously to better inform the system), and intelligence informed by machine learning and human-centered research is imperative to ensure ambient intelligence systems act in a way that compliments the needs of human life (Streitz 2011).

Context-Aware Middleware for Ambient Intelligence

Resident Employee

Context-aware middleware encompasses the concept of passive data acquisition by personal devices that use this information to enhance the user's experience (David et al. 2011). In an example proposed by Bertrand, sensors are consistently gathering information about a person's whereabouts. This example utilizes an RFID card, a QR code, and a camera in order to gain all of the information necessary about where someone is located within a given area. This information is gathered via mostly passive, such as facial recognition, and some active interaction, such as swiping an ID card. With this information, personalized experiences can be made for the individual as they interact with their environment, and is designed for workplace and home environments (David et al. 2011).

The Smart Bus Stop

An example that involves many different people in a smart city is that of a hypothetical bus stop (David et al. 2011). The proposed interaction is controlled primarily by RFID used to differentiate between users and therefore their desires at the bus stop. The proposed system differentiates three types of interfaces for the differing needs of the smart city residents: in-environment interfaces (IEIs), environment-dependent interfaces (EDIs), and environment-independent interfaces (EIIs).

In-Environment Interface (IEI)

IEIs are included as part of the bus stop. This type of interface currently exists as large public screens that display information including expected bus arrival and departure times, station information, etc. This interface is included for any person who does not have a personal device or would like their information delivered in an ambient fashion. The display monitors would react based on the ID of the person in the vicinity of the board and provide individualized information for the desires of the reader.

Environment-Dependent Interfaces

EDIs can be a part of the smart bus station by affording the user to further customize their interface experience. A smartphone, running a specific application for the transportation services is included in this definition. Speculatively speaking, there could be another type of interface or device, such as goggles, or other portable technology that could extend the amount and type of information retrieved at the station. By managing transportation information on a personal device, users are able to maintain more confidentiality about who they are and what their preferences are, as well as enable multiple people to engage with the desired information simultaneously.

Environment-Independent Interfaces

EIIs are a more specific type of interface that is used for large amounts of information retrieval. The proposed technology for this type of interface is the Pico projector or a similar type of portable large-scale display. This type of interface is more likely to be used by maintenance or city planning government employees because of the need for a large amount of information to be accessible on-site.

Ambient Actuation Through ShapeBots

Looking to the future, a room that has highly contextually aware sensors may have actuators that take on a physical form. These actuators may look like tiny robots that take on functions such as moving furniture or tabletop items. RoomShift demonstrates the hardware and software implementation, applications in virtual tours, architectural design, and interaction techniques (Suzuki et al. 2020a). ShapeBots presents a solution whereby many tiny robots have the ability to complete a single action, such as extending and retracting an arm (Suzuki et al. 2019). By collectively applying the ShapeBots to accomplish certain tasks (i.e., tabletop data visualization, physical barriers, games like tangible chess, and safety applications) that contribute to a more tangible and accessible world.

Ambient Play

Meanwhile, mobile games become conduits for “ambient play” (Hjorth and Richardson 2014) in social and communicative aspects of everyday life. It is increasingly becoming the “time-killer,” the pastime event that individuals engage in when stuck in a place, waiting in line, between tasks, either alone or in company, in private rooms, or in public spaces. This interaction across digital, material, and social landscapes, different platforms and contexts, has become an important way to experience and navigate a digital world, to connect people, to seek information, and have emotional support.

The virtual space facilitates both face-to-face or networked collaborative play, either synchronously or asynchronously, in real-life experiences (e.g., restaurant reviews) (Kondamudi 2017), that is part of a complex cultural practice embedded into our contemporary ways of being, knowing, and communicating.

Ambient Surveillance

Unmanned aerial vehicles (UAVs) or drones are a technology that can be utilized for various purposes in a smart city including transportation of goods, as well as surveillance and data collection (Vattapparamban et al. 2016). Surveillance of this type is generally utilized for the purposes of the local government.

As recreational UAVs become more popular, residents may not be aware of how their activities might affect other civic safety or concerns. For example, in the case of forest fires, flying drones for surveillance may seem like a good idea; however, it is actually detrimental to firefighting activities (US Forest Service 2019). Ambient surveillance technology also comes in the form of "smart street lamps" that not only can learn about light or safety patterns, but also report aspects of the local environment like sound level, amount of humidity/moisture, or even provide the ability to reach emergency medical personnel (Nijholt 2018b).

Ambient Intelligence in Healthcare

Health/Ability/Residents

Ambient intelligence and distributed systems have the ability to process information related to health. Those who are disabled, experience health issues on a day-to-day basis, or experience a physical setback may be more amenable to ubiquitous sensor technology. In the context of the home environment, sensors that sense stress or other health concerns can be used to contact emergency responders or provide doctors and caretakers with the necessary information to keep the individual safe at home. The sensors can also be used in a personal setting by controlling home devices to dynamically respond to one's physiological states (Acampora et al. 2013). This promotes a happier and healthier lifestyle through ubiquitous and ambient intelligence.

Healthy Aging

One in six people in the world will be 65-year-old or over in 2050; the world population aging report by the United Nations in 2019 (United Nations 2019) projected a 16 percent increase. Preventive care and self-management health systems (SMHS) contribute to living longer and healthier, assisting aging-in-place. However, there are concerns about the unfamiliarity with new technology, data sharing, or the perceived value of the technology for healthy aging (ASSET) (D'haeseleer et al. 2019). Researchers have begun to understand how people construct, develop, and maintain their social circles, referred to as a "safety net" (Wang et al. 2018). These provide opportunities for smart city programs to be intergenerational urban communities with engagement scenarios, augmented with information technology to support interests and social practices by providing agency and community (Righi et al. 2015).

The ACTIVAGE project is building an IoT ecosystem across nine sites in seven European countries to provide interfaces and interoperability across different IoT platforms, technologies, and standards. The Active and Healthy Ageing IoT-based solutions and services are supporting the living environments and responding to the real needs of caregivers, service providers, and public authorities (ACTIVAGE Project 2019). Similarly, the City4Age services for active and healthy aging project aim to enable Ambient Assisted Cities or Age-friendly Cities. Services enhance early detection of risk related to frailty and mild cognitive impairments (MCI) and provide a personalized intervention that can help the elderly population to improve their daily life (CITY4AGE 2016).

Virtual Humans and Agents for an Aging Population

Technology can be valuable aids for aging adults, such as reminders for complicated medicine schedules, navigation for an ever-changing city landscape, and electronic memory aids. Yet, there is a potential for artificial intelligence (AI) agents and virtual humans (VH) to serve as more than digital assistants for an aging population (Kenny et al. 2008) in a smart city. An AI agent uses computer learning algorithms to perform a task to assist an aging adult at home, traveling, or in the city. A VH is a computer-generated graphic that appears human-like. A VH has active animations (waving) and idle animations (breathing, weight shifting, and blinking). A VH exhibits cues that make the AI agent feel more real and copresent (Slater et al. 1999) with a human user. Intelligent agents can adapt and change with an aging adult. A smart city should facilitate independence and other important factors for an aging adult (Thielke et al. 2012). VHs and avatars can improve physical and mental health through social interaction styles.

To age is human, but not all humans age the same. An aging adult may be best served by flexible interfaces, beyond using audio-based I/O for deteriorating eyesight or visual-based I/O for poor hearing. Consider an aging adult who spent their years drawing very precise blueprints, but Parkinson's has taken that joy. An intelligent agent can deliver independent capabilities back but interject if needed. When an interaction is affected by intermittent physical changes, such as a physical tremor, the agent could adjust for more effective use (Thielke et al. 2012). Behavior patterns may be analyzed to identify when an aging adult may seem lost or have a brief memory loss episode. Interfaces that enable aging adults to continue their passions to extend their livelihoods in a smart city.

Humanizing the smart interface. In a global economy where technology changes rapidly and new interfaces can be confusing, VHs can potentially bridge the gap between an aging population and smart resources. A VH may offer a more intuitive interface resembling human-to-human interaction. A VH can change appearances and dialect. A familiar VH could assist with memory-loss episodes. A virtual human or social-oriented digital assistant has been shown to provide aging users with enhanced perceptions of two-way interactivity and trust (Chattaraman et al. 2019). VH conversational style and interface type are important. Social VHs are better for aging adults who need less task-related assistance; however, users with low competency of technology benefit in reduced cognition load and self-efficacy from an agent with a task-oriented interaction style (Chattaraman et al. 2019).

Smart communities that connect aging adults as avatars. Avatars are computer-generated graphics resembling humans, but instead are controlled by real humans. Social activities help an aging population maintain physical and mental health. However, when an aging individual becomes ill or cares for an ill partner or sibling, then social activities diminish. They may not be able to physically travel or become concerned about appearances. Copresence (Slater et al. 1999) is the sense of "being with" another human even when physically apart. This is often facilitated through the use of computer-mediated technology. Virtual reality systems, such as IMRCE (Salimian et al. 2018), can connect and facilitate a higher sense of human copresence among aging communities (Casanueva and Blake 2001; Carrasco 2017). Tracking technology and avatars that represent these aging adults can provide a sense of natural movement and augment physical ailments.

Environment Scale Interfaces

Parks and Recreation

Parks and recreation are an integral component of a smarter, healthier city. The goal of public parks in a smart city often correlates with the use of technology, ease of accessibility, are efficient or self-sustaining, and generally promote health as well as social behavior among residents. The Luskin Center's SMART parks toolkit provides guidelines for making public parks smarter and better fit the needs of their communities (UCLA Lushkin School of Public Affairs 2019). Guidelines include environmental sustainability, integration of interactivity with technology, incorporation of energy generation through play, and creating creative digital landscapes.

Pervasive Games

Genres of pervasive games (Montola et al. 2009) include (i) treasure hunts, (ii) assassination games, (iii) pervasive live-action role-playing games, (iv) alternative reality games, (v) reality games, (vi) smart street sports, (vii) playful public performances, and (viii) urban adventure games. Specifically, the examples in the last three categories demonstrate how digital technology can make games challenging and engaging.

LiftTiles

LiftTiles is an example of a room-scale (or larger) interface (Suzuki et al. 2020b). The concept behind LiftTiles is to use the ground as an interface. The actuation mechanism for this interface is pneumatic and pumps air into a bag, quickly moving the tiles to their desired height. With sufficient complexity in the arrangement of the tiles, furniture can be spontaneously assembled from the ground up. It is possible to imagine a world in which furniture and household objects can always be moved and reconstructed. This can extend to public spaces where large recreational and aesthetic structures can be made spontaneously to support events with different functional needs.

City as a Playground

Augmented reality on personal devices has been used to gamify the city. As is the case with games like *Pokemon Go* and *You Got Tagged* (Vogiazou et al. 2004), an entire city can contain "hidden" objects that can be uncovered with the use of AR on a personal device. *You Got Tagged* is a citywide game that enables players to see who is playing a citywide game of tag. Simply, if one is "it" (touched by the hand of the person who was tagged last), the player is labeled within the application. Other residents playing the game can use their device to see if a player has been tagged and whether they should run away from another player – effectively playing a game with the city as the game environment.

Digitally Enhanced Communal Spaces

Digitally enhanced communal spaces can be used for many different purposes and are designed for the user and the type of device used to accomplish the enhancement. Examples of digitally enhanced communal spaces include interactive display installations indoors, such as the Wooden Mirror (Rozin 2000), and hundreds of elaborate shape-changing flora bots in an international flower expo (Tang 2018) that sense a visitor and respond with changing colors, shapes, and neighboring objects (Dejiki 2020). There are also many engaging examples outdoors, such as projection mapping on buildings (cathedral, clock tower) (The Denver Theatre District 2020), a park display of a large digital face (Plensa 2004), waves (Gross 2020), interactive circular pads (Lewin 2012), and "Digital Nature" that turns an ancient Japanese garden into living art on trees, rocks, and landscapes (teamLab 2020). Similarly, a large-scale solar system model (Bennett et al. 1991) on a neighborhood scale can be digitally enhanced to provide learning opportunities.

Interestingly, drone light shows have been presented as a sustainable fireworks alternative (Kuss 2019), with path-planning (Stuart 2018) for the swarm robots' behaviors to configure a wide variety of displays of colors and formations. Meanwhile, there is also a proposal for personal drone lighting for mobile safety accompanying foot travel at night (Deng et al. 2018).

Urban musical instruments (Janney et al. 2007) merge sound, art, architecture, light, and interactive technology. With projects like the Sound Stair (Janney 1979), parking garage music boxes, and rainbow passages in airport walkways, public spaces are transformed into places for creative interaction (Janney 2007). Meanwhile, collaborative musical experiences such as the Jam Station (Hopkins 2021), and the popular marketing campaign of Fun Theory's Piano Stairs (Josephmark Studio 2010), demonstrate how multimodal interactions can encourage behavior change (e.g., taking the stairs) and playfulness.

Mobile/Wearable

Mobile and wearable devices have the ability to collect information and to provide residents with customizable experiences. Since a smartphone is the most ubiquitous form of powerful computing held by many residents, the pervasiveness of the technology can be used to enhance public and personal experiences to inform everything from personal well-being to city-scale planning.

Smartphone as a Data Collection Mechanism for Security Resident

Residents can use their smartphones to connect with and input queries into a system for smart services (Liao et al. 2014). Using a relatively small amount of data, including location information, various sensing tasks, and the user answering a few questions, an algorithm can populate information about a city in regards to basic queries such as noise levels in a given region. Issues of cybersecurity and usability can be effectively explored as well.

Government Concerns

From the perspective of the local government, these types of collection mechanisms can greatly enhance the efficiency of citywide systems. Such a system could mitigate public issues like riots, fights, protests, demonstrations, fires, chemical leaks, stampedes, and high crowd levels in events. These issues could be mitigated with the given technology by routing people to a particular highway, going to other public places, and avoiding specific dangerous locations (Liao et al. 2014; Hu et al. 2016).

Digital Democracy

Many countries have engaged the use of "digital democracy" (Caetano et al. 2016) such as e-voting, e-participation in the municipality or federal levels (Macintosh et al. 2009; Hacker and van Dijk 2000; Nesta 2017), that crowdsource policies or laws (Horton 2018), or budgetary concerns (Decide Madrid 2020), transportation (Le Dantec et al. 2015). This can also be used to track the spread of a pandemic such as COVID-19 in the USA (Centers for Disease Control and Prevention 2020), in Europe (European Centre for Disease Prevention and Control 2020; Ireland Health Service Executive 2020), in East Asia (Huang et al. 2020), and how contact tracing with phones is an effective strategy to help stop the spread of the virus (BioSpace 2020; CSIS 2020; Ghaffary 2020).

There are various ways to increase resident engagement, for example, local communities could fabricate their own sensing tools, to monitor their environments and to address pressing environmental problems in air, water, soil, and sound pollution, smart citizen (FabLab 2018), and enable communications, including notifying repairs for potholes with tweets (Nudd 2015; Denver Department of Transportation and Infrastructure 2019). Some cities also exercised different measures to encourage picking up dog waste through rewards (e.g., lottery tickets) or punishment (e.g., fines) (Brulliard 2016).

Wearable Health Monitoring

Personal health records can be attained through wearable sensor technology. Wearable sensors are generally constructed with conductive threads that can seamlessly integrate into everyday clothing (Paradiso et al. 2005). These ubiquitous sensors can contribute to the integrated and networked systems of a smart city.

The benefits of wearable technology are many. The softer and more integrated sensors become, the more unnoticeable and prevalent in everyday items they will be. This could lead to sensor technology that collects better data and can contribute to people's well-being through ambient intelligence and actuation (Banos et al. 2014). For example, a hospital patient may have their vitals monitored through the hospital gown rather than connecting the individual to the various devices used by the care team. This could alleviate undue stress caused by the noises and attachment requirements of the technology (Majumder et al. 2017).

Bioinformatic data collected in everyday situations through wearable sensors or devices, such as a smartwatch, can be used to inform local health trends, contribute to intelligent ambient systems, and for emergencies. Such services range from data analysis applications that can report on the state of their health (i.e., if the heart rate drops below a certain level or blood pressure is consistently very high), to having near-instant access to emergency services (David et al. 2011). Monitoring the health of the residents of a smart city can be kept private while connecting those in need to health services.

Social Wearables

As wearables or e-textiles become common everyday objects, it is important to consider how interaction with wearables may be perceived in different cultures or contexts. For example, a speculative exploration of "Don't mind me touching my wrist" (Profita et al. 2013) tries to answer the question, what is a socially acceptable interaction with e-textiles? The study consists of a number of interfaces embedded in various garments and found that people from different cultures (e.g., the USA and South Korea) may have different preferences for on-body placements and interaction for social acceptance.

Co-creation Wearables

The techniques of co-designing (Sanders 2000) and context mapping (Scrivener et al. 2012) have been used to understand people's interactions with products. Researchers have engaged individuals through co-creation methodology to explore the reusing and repairing of textiles or discarded clothing. The qualitative visual interviews and creative workshops with women between 21 and 60 years old revealed everyday creativity in reusing and repairing apparel (Lapolla and Sanders 2015). Meanwhile, the pop-ups of Fix-it Clinics (Fixit Clinic 2018; Fixit 2020) have connected the global community of repairers to troubleshoot, disassemble, and repair broken furniture, appliances such as TVs or dishwashers, and even cars. How might interfaces of smart cities support the co-creative process to encourage reusing and repairing of broken things at home or in the neighborhood, whether they are e-textiles or street furniture through participants' ability to repair, reuse, and adapt to their current wardrobes or the civic infrastructure? How might the co-creation change our relationship to consumption and sustainability, as well as policy choices for society?

Wearable Interfaces for Ubiquitous Gaming

Wearables and e-textiles can be used for gaming and the promotion of social interaction. The Gauntlet (Martins et al. 2008) is a wearable arm sleeve that is connected to a mobile device to extend interaction and game-play. The wearable can be used independently and ubiquitously, therefore, making anywhere within the city part of the game environment. The Gauntlet wearable can also sense everyday objects in the environment and include them as game objects. Wearables in the smart city can be used in this way to extend interaction with the city in tangible and expressive ways.

Extended Reality

Extended reality (XR) is a blanket term used to describe the spectrum, or reality-virtuality continuum (Milgram and Kishino 1994), of the physical world versus digital content that is displayed in the user's field of view using augmented reality (AR) and virtual reality (VR) interfaces. XR systems display digital 3D content, either superimposed on the physical world (AR) or surrounding the user as an immersive environment (VR). The term mixed reality (MR) is sometimes used to describe technology that incorporates or switches between AR and VR, therefore our focus is on AR and VR technologies but those listed can also be extended to MR and XR.

Augmented Reality

AR interfaces (e.g., screens, glasses, head-mounted displays, projection) superimpose digital 3D content on the user's view of the physical world using image recognition or location tracking to overlay digital content in a real-world location in real-time. A smartphone or tablet can also extend the physical environment of the smart city with its back camera and incorporate a digital interface that can be explored in tandem with one's surroundings.

AR applications, such as Google Maps' Live View (Warren 2019), can provide walking directions for pedestrians (Lages 2018) by superimposing arrows, street names, and destination pins on top of a live view of the physical world streaming from the phone's camera. This communicates directions relative to their surroundings without requiring the user to translate between an abstract map and their own physical surroundings. It also enables real-time translation to signs, menus, and other printed text in a different language (Popular Science 2015). This allows the user to see the translation in its original context, which can increase understanding.

Another domain AR is useful for is in city planning and urban design. The Urp is a luminous-tangible workbench demonstrating the usage of projected simulation in urban planning and design (Underkoffler and Ishii 1999) to provide feedback (e.g., shadow casting, wind flow direction) in response to physical architectural models. DeepScope (Noyman and Larson 2020) is a platform for cityscape visualization that enables multiple designers, planners, and stakeholders to collaborate on designing cities. DeepScope's TUI is a 3D tabletop city model, composed of blocks that users can move around to change the city's design. A land-use diagram is projected onto the tabletop model to display information about land-use, density, etc. Similarly, Tangible CityScape (Tang et al. 2013) and Uplift (Ens et al. 2020) streamline the urban massing process involved in city planning by using AR to combine digital information projected onto the 3D TUI. All three work use AR to combine the physical and digital aspects of urban design to improve collaboration and communication among the different domain experts involved in the design process.

Virtual Reality

VR surrounds a user in an immersive virtual environment typically enabled with head-mounted displays (HMD), tracking, and handheld controllers. As a purely digital environment, VR can also provide a sense of presence (of being there) in a virtual environment as well as a sense of copresence with other people (Slater et al. 1999). Currently, gaming is the most widespread use of VR where players are immersed into virtual environments and have 3D user interactions, like slicing through blocks with a lightsaber (Beat Games 2020) or climbing a ladder by grabbing onto the rungs and pulling oneself up (Alyx 2020).

There are other VR applications beyond gaming. Supernatural is a VR workout application that has users hit balls with a bat and crouch to avoid obstacles to exercise while surrounded by scenes of nature (Supernatural 2020). Virtual Desktop allows users to work on their desktop computer using an HMD, providing the user multiple virtual monitors with variable sizes and positions. It also enables users to work in a variety of virtual locations (Virtual Desktop 2020). Spatial is an application that provides a collaborative workspace where users can get together as avatars in a virtual office space (Spatial 2020).

VR is also used in urban planning and design (Liu 2020). It enables users to see what buildings, streets, parks, etc., will look like at scale, and it gives designers a better sense of what it will be like for people to inhabit the environments they are designing. VR can also be used as a way to communicate urban design decisions to residents and engage stakeholders in the urban planning process.

Material Based

Sustainable Interfaces

Sustainability is a critical concern for smart cities. Materials used in goods and services will eventually be discarded. Therefore, creating interfaces from sustainable resources allows for smart cities to stay cleaner, cheaper, and more efficient. The concept of critical raw materials (CRMs) is useful because CRMs can provide cities with technology made from sustainable materials (Silva et al. 2018). Though there are environmental and health concerns associated with the primary extraction of CRMs, they can easily be recycled or reused, reducing overall waste within and outside of the city. Understanding how materials are harvested, manufactured, and recycled is necessary to maintain a clean and sustainable smart city.

Everyday Objects

As the number of computational devices increases, there is a corollary demand for powering them. To address this issue, along with making interfaces more accessible, making use of everyday materials to act as interfaces are increasing in popularity. By using technology such as computer vision or RFID tags, everyday objects can be tracked and used as interfaces within the environment (Li 2017). For example, printed paper markers enable users to interact with markers that can be easily printed from a home printer (Zheng et al. 2020). The printed ArUco markers can be tracked using a camera that is connected to a computer. Interacting with the paper interface by changing the marker's rotation and deformation can inform the computer and control actuation accordingly. Everyday objects can then be used as controllers and interfaces at home by attaching markers to them and can be generally supported within the smart city.

Smart Material Interfaces

Smart material interfaces (SMIs) are used to complement computational devices by using the affordances of smart materials to do work (Vyas et al. 2012). For example, polymers on the end of a vacuum can be synthesized to have properties whereby they change color when the dust level exceeds a certain amount. Smart materials can be developed such that they are controlled by stimuli like stress, moisture, temperature, light, magnetic fields, and pH. These materials respond intelligently to their environment and therefore do not need computational assistance. The benefits of this type of interface include a long lifespan, no power needed, and they can be easily formed into aesthetically pleasing shapes.

Data Representation and Physicalization

Today's society is more than ever in an era of dual citizenship to the physical and digital world (Ishii and Ullmer 1997). The abundance of data generated from online transactions, emails, videos, Bluetooth, videos, audios, image, clickstreams, logs, posts, search queries, health records, social networking interactions, science data, sensors, and mobile phones and their application has made data become a commodity (Zikopoulos et al. 2011; Patel and Sharma 2014; Berendsen 2020). Yet the way data is interacted and represented is still monotonous.

Data visualizations turn data (e.g., text, images, numbers) into visual representations that promote insight and discovery (Card 1999). But much of the analyzed data originates in and refers to the physical world (e.g., traffic, air pollution, population density) (Atzori et al. 2010). Yet, these visual representations are traditionally confined to a graphical user interface (GUI) on desktops or laptops that are far away from the original context (e.g., object, location) the data refers to. Consequently, this enforces non-situated analysis (i.e., data analysis without referring to the original context the data refers to). Various data-driven tasks – such as debugging an electrical grid, assessing the effectiveness of an in-store product display – can be greatly enriched by viewing data in its original context (Willett et al. 2016). Smart cities can provide this reality. The technology behind smart cities offers a rich potential to overlay or even embedded data on specific objects, buildings, or features in the surrounding environment, introducing new ways to engage with data.

For example, consider the scenario (Willett et al. 2016) discussed in the context of city life: a manager is interested in optimizing the product placement throughout a store. To accomplish this, she visualizes the sales data from the past 3 years on a computer screen, including the locations where each product was displayed. With the visualization, she analyzes the data to identify which products sell the best and see how this trend varies over time. However, because the data is non-situated, the sales manager must use abstract descriptions like aisle numbers to overlay the data on a map or 3D simulation of the store. This does not account for the physical world where the decline of certain products could have been due to variables in the physical environment (e.g., low lighting, smell). To account for the physical world, the store manager uses AR glasses to overlay sales information directly on top of products. This allows the manager to have a better understanding between the relationship of the physical placement of products in the store and sales.

Healthcare Applications

Data associated with healthcare has been a consistent issue in global as well as local healthcare. Privacy of data related to health and healthcare services is important to residents, though restrictions on this data in many cities have caused problems when access to medical histories is difficult to attain (Cook et al. 2018). In smart cities, healthcare data needs to be managed by providing privacy of the information between residents, but comprehensive medical histories need to be readily accessible to healthcare professionals. This is often accomplished through anonymization of personal data and local public health statistics being all that is accessible by local physicians and public health workers.

Resident Engagement and Resident Participation

The goal for resident engagement or resident participation is to increase the collaboration between residents and government to improve public services, resource management, and the decision-making process.

Government and Professionals

Electronic health records can also be accessed by public health professionals and epidemiologists to begin tracking health trends within the city. Data mining electronic health records can also be useful to physicians who use this information to track health issues within subpopulations of the city (Cook et al. 2018). This information can be used readily by general practitioners who are responsible for sending patients to more specialized physicians based on a diagnosis.

Nanotechnology for Health and Smart Cities

With color-changing "tech tattoos" (Bruns 2019) or shape-shifting molecular machines (Bruns 2019; Atreya et al. 2020), nanoscience enables new materials and technologies that can interface with the largest organ in the human body, the skin. These technologies can help protect the body by sensing overexposure to UV radiation, diagnosing medical conditions before they would otherwise appear, and detecting other physiological states such as low blood sugar or fever. Nanotechnology also has the ability to enhance and augment existing technology and smart networks or infrastructure, in biomedical, agricultural, and equipment industries. Nanomaterials could be used for smart textiles, healthcare, food, and smart living, for energy storage, smart building construction, for highways, water resources, and environmental remediation (Gupta et al. 2020).

Conclusion

Looking to the future, smart cities will become an essential part of global commerce and everyday living for the majority of the global population. As urban populations continue to increase, so does the need for cities that operate more efficiently and sustainably. Researchers have proposed designing smart cities for better living with human–computer interaction (HCI) and user experience (UX) approaches for learning, reusing, adapting, designing, developing, inventing, innovating, and sustaining smart cities and their inhabitants.

This chapter emphasizes the many opportunities to contribute in the area of interfaces for smart cities. The previous sections discussed a wide spectrum of user interface (UI) or user experience (UX) design that may have implications for everyday life, perhaps at the scale of object, furniture, or home, but that can be easily extended beyond the scale of smart homes to smart neighborhoods, smart cities, and smart nations.

Many interesting lessons have been learned from exploratory or experimental research projects, art installations, and commercial products, which can provide inspiration for future research and implementations. For example, researchers of the Neuro Network House (Mozer et al. 1995) found that the reasons why smart home technologies were not widely adopted are because (i) people are already accustomed to and reasonably satisfied with the current controls, and (ii) it is not easy to understand and use the new interfaces. This suggests that the new technology will be adopted only if the perceived return outweighs the effort required to understand or use it. Hence it is very important that the interfaces for any smart cities need to be designed to meet user's expectations and perceptions of benefit. Taking a human-centric approach, technology and interfaces could be designed to address mobility, housing, food production, responsive public spaces, economy sharing, shopping, play, work and learning, and relationships with each other, as well as with the technology or the smart city.

The term Omotenashi represents the Japanese way of hospitality that can be applicable to customer service. Omotenashi is the idea that the host pays close attention to detail and anticipates the needs of the guests with a welcoming spirit, warmth, understanding, and respect. The idea of the Digital Omotenashi could cover social digital service platforms and sensory augmentation with an all-encompassing service to provide happy and healthy environments in the realms of brand hospitality, tourism design (Lim et al. 2017), and proactive needs-serving.

With the advancement of the Internet of Things, artificial intelligence, and networks, people increasingly depend on cloud computing and data centers. Figure 1 shows the content of a "life cloud" that encompasses the different aspects of daily life that may depend on the on-demand availability of computer system resources. In a smart city, people use the Internet to maintain their family relationships, including the home, work, and leisure activities, with the use of smartphones

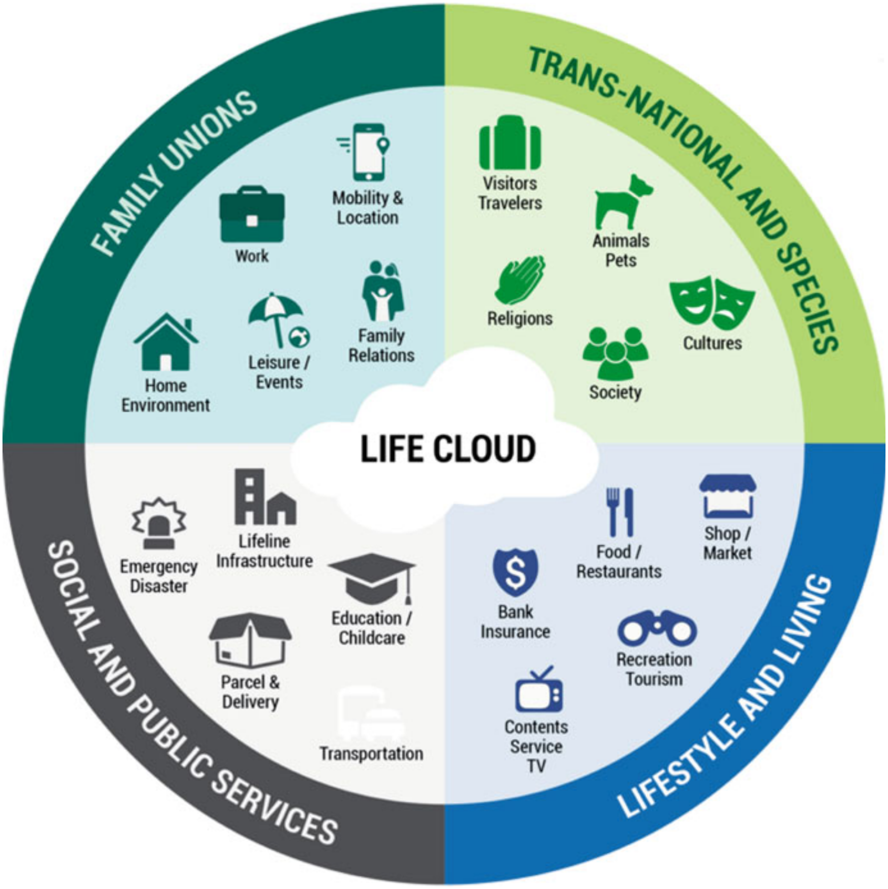

Fig. 1 Life Cloud supports daily living functions such as work, leisure, social interactions and public services

for mobility and location assistance. The trans-national and trans-species relationships with communities, societies, cultures, religions, travelers and visitors, animals, and pets are also managed through the life cloud. A smart city would support the lifestyle of its inhabitants through interfaces with banks, insurance companies, televisions, shopping, markets, restaurants, recreation, and tourism, all through the life cloud. Certainly, a smart city would support public services such as public transportation, education, childcare, delivery services, emergency rescue, and the lifeline infrastructure.

One may ponder the question, "How Smart Does Your Bed Have to Be Before You Are Afraid to Go to Sleep at Night?" (Gold 1995), and designers of smart cities should pay attention to ethical concerns (Kitchin 2016), because a city is more than a computer and one needs to watch out for the "coded bias" on the web or recommendation systems (Baeza-Yates 2018). This presents welcome opportunities and challenges to think about how to approach design and review of interfaces for smart cities with the 3 M's (Do 2018): Mind, Might, and Magic. Wisdom dictates one to "Mind" – to observe before acting, to be thoughtful, and open-minded; to "Might" – to consider the capacity, and competency of people and the technology; and, to "Magic" – to have technology wonderfully blended in everyday life activities. And yes, the best way to predict the future is to invent it (Kay 1971) and any sufficiently advanced technology is indistinguishable from magic (Clarke 2013).

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