Digital City, Smart City and Beyond

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ABSTRACT
This article revisited past digital cities, and discussed smart cities and the future. If we understand digital cities as *exploration of cyber space* and smart cities as *exploitation of physical space*, the next stage is to evolve networked society based on cyber physical systems. The current movements suggest two different directions, *socialization of commerce* and *commercialization of society*. We can predict the convergence of the two directions in the future.

CCS Concepts
Human-centered computing → Collaborative and social computing → Collaborative and social computing theory, concepts and paradigms.

Keywords
Digital city; smart city; cyber-physical system.

1. UNDERSTANDING TRENDS
From the 1990's to the 2000's, digital cities have been developed and become operational in Europe and Asia. At first glance, it seems natural to regard today's smart cities as the successor of digital cities. It is also natural to think that their differences are due to the technologies they use, i.e., digital cities are characterized by activities based on web services, while smart cities demonstrate sensory services. This interpretation is not wrong but not so persuasive, because some of digital cities have been developed to connect virtual and real cities.

Let us submit two keywords "digital city" and "smart city" to Google Trends on trial. We learn that smart cities evolved ten years after the termination of digital city activities. In the meantime, global optimization of resource usage was attracting increasing attention around the world. Though there certainly are technological advances from digital to smart cities, it is more meaningful to see the "digital city" as the *exploration of cyber space*, while the "smart city" is the *exploitation of physical space*. This approach makes it easier to discuss what lies beyond the digital and smart cities. In future cities, cyber and physical spaces will be more tightly connected and our attention will shift from exploration or exploitation to the evolution of systems and architectures of society.

2. DIGITAL CITY
Various approaches have been used to develop digital cities in Europe and Asia [1]. In the US, corresponding activities were called *community networks*. Those activities were collected and published in three books entitled "Digital Cities" in 2000, 2002 and 2003. Below, we classify their activities into three categories, *social interaction*, *virtual space*, and *connecting virtual and real spaces*, and introduce typical examples.

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2.1 Social Interaction
The European Digital Cities Conference has been held annually from 1994. The topics include telematics applications and car-free cities. A good example is Digital City Amsterdam [2]. This city was built as a platform for various community networks and thus focuses on social interaction among citizens.

Digital City Amsterdam was launched by a non-profit organization called DDS (De Digitale Stad) for communication between the municipal council and citizens. All communication was presented via text. Terminals were placed at public spaces such as libraries. The success of this experiment increased the interest of the citizens in the Internet. In the first ten weeks, 10,000 people registered with the digital city and 100,000 accesses were recorded. The system continued to grow, and in 1998, 80,000 users were registered with the digital city.

2.2 Virtual Space
Helsinki Arena 2000 Project started in 1996, under the initiative of the Helsinki telephone company (now Elisa) [3]. The goal of the project was building the next generation metropolitan network. This network enabled citizens to communicate with each other using live video in both directions: members of a classic car community can cooperate on repairs by using live video transfer.

In parallel to the development of high speed networks, an entire 3D city of Helsinki was built. As the 3D model became more accurate, more computational power and communication bandwidth were required to view the digital city at home. The virtual city was a face of the project, and provided a human interface for new broadband services. Though there was a big discussion on whether or not 3D virtual reality was useful, the 3D Helsinki was accepted by the Finnish people who always prefer new technologies.

2.3 Connecting Virtual and Real Spaces
Kyoto was the capital of Japan for more than a thousand years, and has been a cultural center of Japan for even longer. We started a digital city project for Kyoto in 1998 [4] with two design policies. The first was to make it *real* by establishing a strong connection to the physical Kyoto: The digital city complemented the corresponding physical city, and provided an information center for everyday life for actual urban communities. We thought "digital" and "physical" make things "real." The second policy was to make the digital city *live* by dynamically integrating web archives and real-time sensory information created in the city.

We proposed the three layer model as a system architecture suitable for digital cities. The first layer, called the *information layer*, integrates web archives and realtime sensory data and reorganizes them using the city metaphor. The second layer, called the *interface layer,* uses 2D maps and 3D virtual spaces to provide an intuitive view of digital cities. We developed FreeWalk and the scenario description language *Q* for 3D virtual spaces with social agents [5]. The animation of moving objects such as avatars, cars, busses, and trains demonstrated some of the dynamic activities in the cities. The

third layer was called the *interaction layer* where residents and tourists interact with each other. If an animation reflected a real activity, the moving object became a tool for social interaction: users could click the object to communicate with it.

In the Kyoto railway station, we installed a disaster evacuation system that tracks passengers to help them navigate [6]. As the sensors, we placed twenty eight cameras in Kyoto station, and captured the movements of passengers in real time. A 3D virtual city system was used to reproduce the passengers' behavior. A bird's-eye view of the real space was reproduced on the screen of the control center so that evacuation leaders in the center could easily monitor the station. The leader can point at particular passengers on the screen, and talk to them through their mobile phones. We also implemented a large-scale outdoor evacuation system. A simulation with three thousand agents controlled by evacuation scenarios was performed in parallel with an experiment in the real space. The leader could issue high level instructions to the evacuees, and precise navigation instructions were automatically generated by the agent for each evacuee.

3. SMART CITY AND BEYOND

3.1 Smart City

A large amount of literature has been published on smart cities. The definitions of smart cities and comparison to related concepts are found in [7, 8]. Though the conceptual relatives of the smart city include digital city, intelligent city, virtual city, ubiquitous city and information city, since the substantial volume of activities were under the name of digital city, we focus on comparing the concepts of digital city and smart city in this article. According to [8], digital cities provide innovative services based on broadband communication and service-oriented computing, while smart cities apply technologies of self-monitoring and self-response systems to complex social problems including scarcity of resource, inadequate and poor infrastructure, energy shortages and price instability, global environment, and human health.

The above definitions include two separate aspects. One is the technological aspect, which highlights the difference between digital cities with the rise of the Internet, and smart cities being challenged in the era of IoT. The other is the social aspect, which distinguishes roles in human society: digital cities *explore cyber space* while smart cities *exploit physical space*. Both digital and smart cities represent paradigms, which are the general approaches adopted by a community for carrying out research and development. If we take the former technological aspect, it will become difficult to discuss the next stage of smart cities, but the latter social aspect can trigger the broad discussion of future cities. The rest of the article outlines recent and future evolution in human societies.

3.2 Socialization of Commerce

One evolution is to network for-profit activities. A typical example is *Industrie 4.0* in Germany. The initiative aims at networking a large number of manufacturing companies to create a nation-wide supply chain. Large scale factories in developing countries for *mass production* are no longer necessary. Instead, a network of many companies for *mass customization* will appear regionally.

There are several related activities. Michael Porter proposed the concept of CSV (creating shared value) which could reshape capitalism and its relationship to society. A for-profit sector *Y Combinator* will conduct a trial in support of universal basic income in Silicon Valley. The design firm IDEO now has both for-profit (.com) and non-profit (.org) organizations and employees move from one to the other flexibly. In France, it is now illegal to waste food. Supermarkets must sign contracts with non-profit organizations to collect and distribute the food. Unfortunately, since the efficiency of for-profit and non-profit organizations are far different, the connection is not seamless at this moment. However, we can discover potential problems from their courageous challenge.

3.3 Commercialization of Society

Another evolution is the commercialization of citizens' ordinary life. Networking of unused resources in society can reveal profitable resources. A typical example is called the *sharing economy* such as Uber and Airbnb. Most cars in large cities are idled in parking lots. It is reasonable to share them to reduce environmental burden. Related non-profit activities called *sharing cities* have been launched in Seoul, Amsterdam, and so on. Although most of their activities are non-profit, sharing cities are creating substantial values by recycling resources. Similarly, newly created social innovation companies are viewing their market as a long tail investment.

We can expect the convergence of the two evolutions in the future, i.e., for-profit and non-profit activities will be connected seamlessly to sustain our society [9].

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