# Design Smart City Based on 3S, Internet of Things, Grid Computing and Cloud Computing Technology*

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**Abstract.** With High-technology and society being developed rapidly, there is a trend which is from digital earth to smart earth. Moreover, smart city is one of most important work in smart earth. Therefore, how to realize or design smart city leaves much to be desired. This paper puts forward some strategies and architectures for designing smart city based on geo-spatial information science and technology (GPS, GIS and RS), IT, communication technology, network technology (smart sensor web and ubiquitous sensor network), spatial data mining, high performance computing (grid computing and cloud computing), GPU, artificial intelligence and pattern recognition. The link and elements of smart city as well as applied key technologies in the future are outlined with some typical application instances, which will meet the versatile requirements of smart city service better.

**Keywords:** digital earth, smart earth, geo-spatial information, 3S(GPS,GIS and RS), GPU, grid computing, cloud computing.

## 1 Introduction

Digital earth is the name given to a visionary concept by former US vice president Al Gore in 1998, describing a virtual representation of the earth that is spatially referenced and interconnected with the world's digital knowledge archives [1]. With Digital Earth improved, a new concept that is Smart Earth is presented by IBM. Smart earth is the first virtual earth website to aggregate renewable energy, sustainable living, new clean technologies and green products/services from around the world into one location [2]. Smart city extended by smart earth is looking for new economic

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growth point after the financial crisis, so it become the world's largest cities' major strategic to propel economic development approaches to change, promote industrial upgrade and revitalize the economy. The concept of the smart city as the next stage in the process of urbanisation has been quite fashionable in the policy arena in recent years, with the aim of drawing a distinction from the terms digital city or intelligent city [3]. In this paper, we focus on the role and key problems of ICT (Information and Communication Technologies) infrastructure, so as to carry out on the role of human capital/education, social and relational capital and environmental interest as important drivers of urban growth.

We design smart city by following main parts: 1) generalized smart sensor networks; 2) data transmission; 3) spatial data processing; 4) spatial data management; 5) spatial data mining; 6) spatial data analysis; 7) user query. The flow chart can be seen in Fig1. In these parts, 3S, internet of things, grid computing, cloud computing, artificial intelligence and pattern recognition can be used to realize smart city.

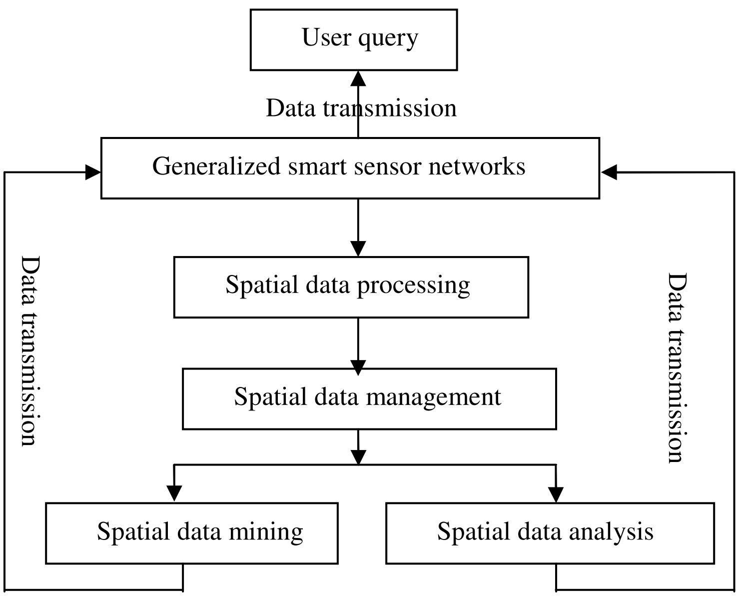


**Fig. 1.** The flow chart for realizing smart city

Prof. LI Deren stated that "smart earth" can be formed by combining "digital earth" with "internet of things"[4]. Therefore, the organization of the paper is as follows. In section 2, Geo-spatial information science and technology will be discussed for 3D city reconstruction or modeling, which is very important for implementing cyber city. Internet of things technology integrated for digital city is presented in section 3. Section 4 will give the conclusion and state the future work.

## 2 Introduction the Key Technology of Digital City

**1) Multi-platform and sensor networks**

Prof. Tong Qingxi said that Geo-spatial information science and technology is one of the most emerging fields of the progress of science and technology [5]. 3S technology is the key of Geo-spatial information science and technology, which is composed of remote sensing technology (RS), Geography Information Systems (GIS) and Global Positioning System (GPS). And it is the technology of highly combining integrated multi-disciplinary space information's collection, processing, management, analysis, expression, dissemination and application of modern information. Three-dimensional interactive environments offer intuitive and user-friendly ways to view location-based information, such as 3D city models. A 3D city model is usually composed of descriptions of terrain, streets, buildings, other man-made objects and vegetation [6]. In this paper, 3S technology is used for 3D modeling that is the core of cyber city.

The usage of integrated multi-platform, such as aerospace (satellite), aerial (airborne) and ground (vehicle), is a significant trend. Moreover, Professor Gong Peng said that it has the potential of supporting truely integrated ground—space—sky observation of the earth [7]. On the platform aspect. a trend is from emphasizing satellites and airborne platforms to sensor networks on ground that can achieve continuous observation (In this paper, we call these as generalized sensor networks). The development of sensor networks on ground has great importance to remote sensing and geoscientific studies [7]. For example, MMS (Mobile Mapping System) is the process of collecting geospatial data from a mobile vehicle typically fitted with a range of photographic, radar, laser, LiDAR or any number of remote sensing systems. Such systems are composed of an integrated array of time synchronised navigation sensors and imaging sensors mounted on a mobile platform. The primary output from such systems includes GIS data, digital maps, and georeferenced images and video. The development of direct reading georeferencing technologies opened the way for mobile mapping systems. GPS and INS (Inertial Navigation Systems), have allowed rapid and accurate determination of position and attitude of remote sensing equipment, effectively leading to direct mapping of features of interest without the need for complex post-processing of observed data.

**2) City 3D renconstruction and modeling**

Three-dimensional (3D) reconstruction and texture mapping of buildings or other man-made objects are key aspects for 3D city landscapes. In order to realize cyber city, on the ground, we do a lot of researches on 3D-reconstruction for street elevation by means of line matching、solving orientation elements by vanishing point、auto-rectifying and auto-mosaiking large obliquity-angle close-range sequential images、auto-recognizing concavo-convex edge of street elevation [8][9][10][11].

On the sky and space, an effective coarseto-fine approach for 3D building model generation and texture mapping based on digital photogrammetric techniques is proposed. Three video image sequences, two oblique views of building walls and one vertical view of building roofs, acquired by a digital video camera mounted on a helicopter, are used as input images. Lidar data and a coarse two-dimensional (2D) digital vector map used for car navigation are also used as information sources. Automatic aerial triangulation (AAT) suitable for a high overlap image sequence is used to give initial values of camera parameters of each image. To obtain accurate image lines, the correspondence between outlines of the building and their line features in the image sequences is determined with a coarse-to-fine strategy. A hybrid point/line bundle adjustment is used to ensure the stability and accuracy of reconstruction. Reconstructed buildings with fine textures superimposed on a digital elevation model (DEM) and ortho-image are realistically visualised. Experimental results show that the proposed approach of 3D city model generation has a promising future in many applications [6].

**3) Real-time processing—parallel computing**

With the continuous development of sensor technology, to obtain the surface information needs more quickly. Facing diverse data sources and doubling data quantity, many conventional algorithms could not well meet the challenge of the high-speed computing of large-scale data. How to improve efficiency and speed is urgent.Parallel computing is a form of computation in which many calculations are carried out simultaneously, operating on the principle that large problems can often be divided into smaller ones, which are then solved concurrently ("in parallel")[12].

Prof. ZHANG Zuxun presented parallel computing for remote sensing based on blade computer that is called digital photogrammetry grid (DPGrid). Combining the progress of digital photogrammetry hardware and theory, the ideal, that DPW to DPGrid, is educed. The structure and function of a DPGrid are explained, including cluster processing system based on blade computer, fully seam-less mapping system based on network and their features [13][14].

GPU (Graphics Processing Unit) is another method for real-time processing. GPU is a specialized circuit designed to rapidly manipulate and alter memory in such a way so as to accelerate the building of images in a frame buffer intended for output to a display. Modern GPUs are very efficient at manipulating computer graphics, and their highly parallel structure makes them more effective than general-purpose CPUs for algorithms where processing of large blocks of data is done in parallel [15]. The increasing programmability and high performance computational power of GPU present in modern graphics hardware provides great scope for acceleration of photogrammetry and remote sensing algorithms which can be parallelized. With the help of the strong computing ability of CPU + GPU and the parallel computing architecture of CUDA (Compute Unified Device Architecture), CPU + GPU that is used for mass spatial-data real-processing is the direction of future 3S development.

## 3 Internet of Things for City Intelligence

The Internet of Things refers to uniquely identifiable objects (Things) and their virtual representations in an Internet-like structure. The term Internet of Things has first been used by Kevin Ashton in 1999 [16]. The concept of the Internet of Things has become popular through the Auto-ID Center. Radio-frequency identification (RFID) is often seen as a prerequisite for the Internet of Things. If all objects of daily life were equipped with radio tags, they could be identified and inventoried by computers [17][18]. However, unique identification of things may be achieved through other means such barcodes or 2D-codes as well. Although the idea is simple, its application is difficult. If all objects in the world were equipped with minuscule identifying devices, daily life on our planet could undergo a transformation [19].

**1) Sensor web**

The concept of the "sensor web" is a type of sensor network that is especially well suited for environmental monitoring [20][21][22]. The phrase the "sensor web" is also associated with a sensing system which heavily utilizes the World Wide Web. OGC's Sensor Web Enablement (SWE) framework defines a suite of web service interfaces and communication protocols abstracting from the heterogeneity of sensor (network) communication [23].

**2) Smart city geospatial management**

The GIS operational platform will be the base for managing the infrastructure development components with the systems interoperability for the available city infrastructure related systems. The research will develop Service Oriented Architecture (SOA) in order to geospatially manage the available city infrastructure networks. The concentration will be on the available utility networks in order to develop a comprehensive, common, standardized geospatial data models. The construction operations for the utility networks such as electricity, water, Gas, district cooling, irrigation, sewerage and communication networks, need to be fully monitored on daily basis, in order to utilize the involved huge resources and man power where the SOA will significant value [24]. These resources are allocated only to convey the operational status for the construction and execution sections that used to do the required maintenance. The need for a system that serving the decision makers for following up these activities with a proper geographical representation will definitely reduce the operational cost for the long term.

**3) Smart city spatial information mining and discovery**

In the future, the Internet of Things must be a non-deterministic and open network in which auto-organized or intelligent entities (Web services, SOA components), virtual objects (avatars) will be interoperable and able to act independently (pursuing their own objectives or shared ones) depending on the context, circumstances or environments. In the future the Internet of Things may be a non-deterministic and open network in which auto-organized or intelligent entities (Web services, SOA components), virtual objects (avatars) will be interoperable and able to act independently (pursuing their own objectives or shared ones) depending on the context, circumstances or environments. Smart city should integrate the physical world with data social, semantic and access networks. Self-organizing networks in a Smart City includes small world overlays with load balancing, semantic gossiping, peer-to-peer reputation-based trust management. There are different forms of self-organization In this Internet of Things, made of billions of parallel and simultaneous events, time will no more be used as a common and linear dimension but will depend on each entity (object, process, information system, etc.). This Internet of Things will be accordingly based on massive parallel IT systems (Parallel computing) such as grid computing and cloud computing which refers to the use and access of multiple server-based computational resources via a digital network (WAN, Internet connection using the World Wide Web, etc.

## 4 Conclusion and Future Work

In an Internet of Things, the precise geographic location of a thing—and also the precise geographic dimensions of a thing—will be critical, so we discuss how to obtain city's 3D spatial information by diverse integrated technologies. Smart city needs that wireless sensor networks, when connected to the Internet, make observation data accessible anywhere and anytime. Therefore parallel computing (grid computing and cloud computing) should be taken into account. However, there are many directions that need to be studied deeply in future, as follows: 1) accurate, reliable and real-time geo-spatial data processing, management, mining and analysis; 2) smart sensor networks (under image condition: CPU + GPU) for internet of things.

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