From Smart To Cognitive: A Roadmap for Technologyin SmartCities

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Abstract:This conceptual paper discusses how we can consider a particular city as a smart one, drawing on recent practices to make cities smart. A set of the common multidimensional variables underlying the smart city concept and the core factors for a successful smart city initiative is identified by exploring current working definitions of smart city and a diversity of various conceptual relatives similar to smart city. The paper offers strategic principles aligning to the three main dimensions (technology, people, and institutions) of smart city: integration of infrastructures and technology-mediated services, social learning for strengthening human infrastructure, and governance for institutional improvement and citizen engagement through cognition

Key Word:Smart city, Cognitive city,Information communication technology, Smart infrastructure

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Introduction:

Providing adequate services to the megacities of the future requires a fundamental rethinking of urban governance. Leveraging information technology and imbedded intelligence, coupled with innovative service provision and governance structures, can allow cities to deal with the complexities of the fundamental shift from a nation-state mindset to cities as the centers of global competition and cooperation. This has resulted in an increasing interest in concepts such [8] as “wired city”, “smart city”, “intelligent city”, “digital city”) and, as we propose in this article, “cognitive city”.

We distinguish the term cognitive from all the other variants of information-centric cities by the fact that cognition also implies the existence of learning, memory creation and experience retrieval for continuously improving urban governance

Smart city is the essence of new age. The urbanization is pushing for organized development of the city. Since 2010, more than half of theworld’s populations live in urban areas. The UN estimates that by 2050, this numberwill jump to over 70 % [1].A Smart city is a city that uses ICT (Information and communication technology) to improve the efficiency of its services and meet the needs of the citizens. The services include transport and traffic management, education, health care, water supply, power supply, waste management, law enforcement and other community services. The aim of building smart city is to improve the quality of life, to optimize the use of resources, to improve the contact between city officials andthe citizens and to be better prepared to face challenges. Some of the important smart cities of the world are Barcelona (Spain), Vienna(Austria), London (U K) , Paris(France), Berlin (Germany), New York (USA) , Toronto(Canada), Tokyo (Japan) Honkong(China) and Singapore .

Under the ‘Smart City Mission’ the Indian government has announced a list of twenty cities which are to be developed as smart city.

While ensuring sustainable development and quality of life cities and urban areas are complex social ecosystems and are huge concern for stakeholders. In such urban environments, citizens, companies and local governments experience unique needs and demands regarding key themes such as sustainable development, business generation and population engagement, healthcare, education, energy and the environment, safety, and public services. Subsequently, these domains required to enable and facilitated by broadband networks, Internet-based applications and open platforms.City authorities increasingly understand that urban environments are complex, adaptive procedure of systems in which economic, social, spatial, environmental, and infrastructural grid must be managed in an integrated manner. Meeting the demand for enhanced outcomes in terms of quality of life on one hand and greater resilience (successful adaptation to fast and slow moving shocks and stressors) on the otherrequires smart governance. To tackle these urban challenges, technological solutions are being increasingly promoted under buzzwords such as ‘smart cities’, ‘digital cities’, ‘intelligent cities’, or the latest addition to the debate—‘cognitive cities’.

Because of radical economic and technological changes cities are facing growing competitionfor investors, tourists, qualified labor or international events over the last decades (Begg1999). Therefore, cities are challenged to introduce more strategic instruments in order toconcentrate relevant organizational capacities and to identify most relevant strategic projectssteering urban and metropolitan development in an effective and competitive way (Jessop et al.2000; Maier, 2000).

Cognition and urban systems Mitola (2000: 4) defines a cognitive system as follows: “Cognition centric systems, briefly, are systems with many richly interacting adaptive components that include human beings and other cognitive entities with sufficient awareness, reconfigurability, learning, language, autonomy, and cooperation capabilities at multiple scales to adaptively yet predictably synthesize the intended sustainable, responsible individual and collective behaviors”. This applies quite well to networked infrastructure systems such as transportation, energy, telecommunications, emergency services and utilities among others. Such networks, when enabled cognitively, “can perceive current network conditions, and then plan, decide and act on those conditions. The network can learn from these adaptations and use them to make future decisions, all while taking into account end-to-end goals.” (Thomas et al., 2006)

The cognitive ability of a system allows the system to deal with complex operational environments much more efficiently (Sheard and Mostashari, 2009) and allows past experience to be leveraged for improved responses to changes in the environment. A cognitive system can be defined as one that is able to behave in the following manner (Mostashari et al., 2011): • Sense individual internal and external changes • Perceive the overall picture that these changes represent • Associate the new situation with past experienced situations and identifying potential responses • Plan various alternatives in response to the change within a given response timeline • Choose a course of action that seems best suited to the situation • Take action by ad

Objective

1. To analyze the expected transition from smart to cognitive city spaces

2. Identification of ICT-based solution which can improve governance and/or delivery of public services

Aspects related to sensing in smart cities as well as efficient processing of data collected by these sensors is discussed in the remainder of this paper. It is organized as follows: Sections 2 Technologies for Smart Cities and 3 reviews the current state of sensing and enabling technologies. In Section 4 Cognition and intelligent urban governance for smart cities are discussed, and in Section 5 Technologies for Smart Cities. Applications of cognitive technology for smart city is discussed Section 6, Challenges in Section 7 and conclusion to the topic is in Section 8.

2. Technologies for Smart Cities

The Future Internet domain landscape comprises a great diversity of research streams and related topics for designing alternatives for the Internet of tomorrow. For example, the Internet of Things (IoT) is considered as a major research and innovation stream leading to plentyof opportunities for new services by interconnecting physical and virtual worlds with a huge amount of electronic devices distributed in houses, vehicles, streets, buildings and many other public domains. Hence, a massive amount of data will be flowing over the Internet that should not decrease the overall service performance and satisfaction. In [5] it is proposed to examine the four key components of a real time control system: entity to be controlled in an environment characterized by uncertainty; sensors able to acquire information about the entity's state in real-time; intelligence capable of evaluating system performance against desired outcomes; physical actuators able to act upon the system to realize the control strategy. This perspective corresponds to a new technology paradigm of "embedded spatial intelligence". The Institute for the Future [2], [9] has also identified some major trends of the future Internet technologies on smart cities, which emerge, among others, from cloud computing, smart sensors and devices, and open data.

3. Sensing the Evolution

Sensors are a crucial component of any intelligent control system. A process is improved based on its environment and for a control system to be aware of its environment, it is typically assembled with an array of sensors, from which it collects the required data. Technology advances not only drive the innovation behind sensors, they also enable sufficient processing power for small-scale devices to which these sensors can be interfaced to a low costprescription. From the perspective of the requirements for smart cities, wide availability of these technologies translates to a large number of opportunities in terms of sensing. However, smart metering implies a new generation of technologies [10]. As through mechanical solutions, they must be robust, cheap, easy to maintain and reliable, as theirreadings will be used to define billing. Electricity meter readings have evolved from the manual procedure of reading the mechanical meter, to automatic meter reading (AMR) which were deployed to reduce costs and improve the accuracy of meter readings, eventually to an advanced metering infrastructure (AMI) which differs from the AMR in that it enables two-way communications with the meter, driven by a growing understanding of the benefits of two-way interactions between system operators, consumers and their loads and resources.

More engineered sensors include accelerometers which can be used to calibrate acceleration and vibration. In the context of structural health monitoring (SHM),[22] for instance, sensors like corrosion rate sensors (working on the principle of an increase in electrical resistivity due to corrosion); acoustic emission sensors (used to detect propagation of sound waves); and magneto-strictive sensors (detects the change in magnetic induction in the material caused by strain or stress). An even later generation of sensors is based on semiconductor physics and nano-technology, and intelligent sensing devices include, amongst others, smart phones. Nano-technology, this technology will enable applications where not only an individual's surroundings can be sensed, but also the person's health, at high granularity, for instance, and linked to social networks [11]. The ever increasing number of smartphones opens up a totally new sensing scenario. Smartphones are geared with a variety of sensors such as GPS, gyroscopes, accelerometers and compasses, enabling a gamut of crowd sourcing applications, which will eventually be augmented by the Internet of Things.
A possible application for these sensors, as indicated in [9], is humidity monitoring, by embedding the sensors into construction materials, or environmental monitoring [11], an important capability for smart cities.

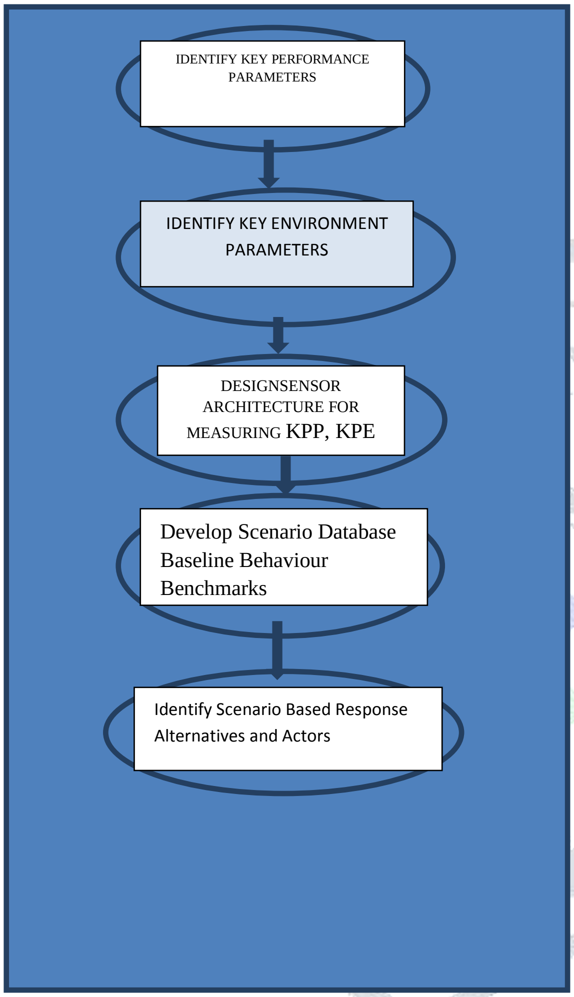
4. Cognition And Intelligent Urban Governance For Smart Cities

The cognitive ability of a system allows the system to deal with complex operational environments much more efficiently (13) and allows past experience to be leveraged for improved responses to changes in the environment. A cognitive system can be defined as one that is able to behave in the following manner (12):

- Sense individual internal and external changes
- Perceive the overall picture that these changes represent
- Associate the new situation with past experienced situations and identifying potential responses

- Plan various alternatives in response to the change within a given response timeline
- Choose a course of action that seems best suited to the situation
- Take action by adjusting resources and outcomes to meet new needs and requirements
- Monitor the behavior of the action taken and learn from its impact

Integrating cognition in urban service processes Mostashari et al (2011) developed a cognitive process architecture framework (CPAF) that allows individual system processes to become more cognitive. The framework was initially applied to a seaport, but can be applied to any large-scale infrastructure network. This processbased approach has the advantage that a city can gradually implement cognition by prioritizing its most important service processes. The CPAF framework is outlined in Figure 2 and includes a cognitive architecture (design) stage and a cognitive process (operational) stage that interact on a constant basis. In the cognitive architecture stage, the key performance parameters are agreed upon by a group of stakeholders and key environmental parameters (general contextual conditions that can be considered inputs to the



The CPAF Framework (Mostashari et al., 2011)

5. Institutional Changes for Intelligent Governance of Cities

The paramount need for citiesprogress towardsthe enabling of theprocess of cognition. [14] defines a cognitive system as follows: “Cognition centric systems, briefly, are systems with many richly interacting adaptive components that include human beings and other cognitive entities with sufficient awareness, reconfigurability, learning, language, autonomy, and cooperation capabilities at multiple scales to adaptively yet predictably synthesize the intended sustainable, responsible individual and collective behaviors”. Applying this definition to a city composed of networked infrastructure (such as transportation, emergency services, energy, water services) allows such systems to not only operate more efficiently, but also to learn to improve their service provisions over time and in the face of diverse operating conditions. A city with cognitive ability “can imbibe current network conditions and then plan, decide and act on those conditions. The network can learn from these adaptations and use them to make future resoluteness, all while taking into account end-to-end aims of development.” [15].

The CPAF Framework (Mostashari et al., 2011)

The new addition to this model can be Citizens as human sensor networks.Intelligent/smart cities have been touted as one of the solutions to the challenges of ever increasing complexities faced by present and future urban environments. Leveraging information technology to allow better demand and supply management of key urban infrastructure system offer immense opportunities for efficiency and quality of service improvements in urban services. Cognition is the ability of a system to learn from previous experiences and adapt its behavior based on them. A cognitive system is able to sense, perceive and respond to changes in the environment and can therefore improve a system's performance by increasing its adaptive capacity. This will collaborate the human with key performance indicators and accelerate the movement of smart city giving negligible space to errors. [21] With smartphones becoming increasingly more powerful in terms of resources, crowd sourcing[19] using smartphones phones has been thoroughly investigated[17]. For instance, as users regularly update their location status on social networks like Twitter and Facebook; based on this location information, it is possible to aggregate this data, enabling tasks to be dispatched to people in specific locations. Furthermore, by using sensor data on a smartphone,[18] it is possible to determine a person's state (i.e., whether the user is stationary or not), as well as environment. This data can be collaboratively used to obtain information regarding the weather with location information [90].Examples include MobSens [18], which combines four applications: PollutionSpy to monitor air pollution; NoiseSpy which captures noise levels; MobAsthma, a personalized asthma monitoring application; and Fresh, an application which provides a platform to let users discuss issues regarding their environment.Context, there would also be information flow from thecitizens (service users) to service providers on the consumption side of particular services.Although crowd sourcing is typically outsourcing work tasks to people, crowd sourcing can also be used for sensing, as described in [92]. Crowd reporting, as described in [21], consists of collecting information from sources such as mobile devices and social networks. The data reported can be in the form of messages which are aggregated and converted into a uniform format, for processing. The data is collected from Twitter as using a set of keywords to select relevant information. This data is then pre-processed, filtered and clustered so that event correlation can be determined.An important consideration for leveraging citizens asinformation providers in the urban environment is the issueof data privacy and security. This is an important areaof research and policy within the cognitive city context.However, if only 1-2% of the urban population is willingto play an active role in the cognitive grid in exchange forbetter information access on urban infrastructure services,the implications would be dramatic. The details of suchinformation exchanges have to be worked out in detail ineach case, but current research at our research group focuseson frameworks and tools that enable such discussionsbetween city governments and their constituents.Although sensing through crowd sourcing (i.e., pervasive sensing) is appealing to a number of promising applications, there are still a number of challenges, which are not necessarily of a technical nature. Privacy, in particular, is possibly the biggest challenge. Additionally, involving the not-so-evident risks related to large-scale data collection as well as legal issues such as data ownership, user protection [22] and trust needs to be insured as entities responsible for analyzing the collected data, can abuse the collected information or use it to harm the user.

6. Applications

The sectors in which these cognitive methods can catapult the mission of smart cities are

- Water Distribution Systems
- Electricity Distribution Systems
- Monitoring Bridges and Seismic Activity
- Environmental Monitoring

- Intelligent Transportation Systems
- Surveillance
- Public Services—Law Enforcement and Fire Fighting
- Health Care

7. Challenges for Cognitive Implementation
   - Addressing and coordination issues between sensor nodes for upgrading population is humongous task
   - Security: Enabling technologies for sensing applications have a number of issues which have to be considered within the context of smart cities. These networks will be prone to cyber-terrorism and cyber-vandalism.
   - Data ownership and privacy: Who will own the rights for all data collected by these sensing applications? For instance, if the electricity utility has access to an individual's energy consumption data, can that data be used without one's consent?
   - Social Issues: Residents have always been actively involved in a city. For instance, there are collaborative initiatives where people come together and help keeping the city clean by promoting no littering, etc. Will smart cities (with all the automated processes and sophisticated technology), create some sort of disconnect between the people and the city? Then there is the issue of education as well. Is the average person educated enough to use and understand all these systems?
   - Centralized control: A centralized control scheme, where all services are being progressively aggregated, to be managed by one core central system. This translates to complete control by the governing bodies, which can be used to illegally track people or invade someone's privacy. This is related to the trust and privacy issues previously mentioned.

8. Conclusions

The cognitive city is a paradigm that leverages information technology and artificial intelligence along with human cognition for improving decision-making and resource allocations in urban services delivery. A cognitive city is one that learns and adapts its behavior based on past experiences and is able to sense, understand and respond to changes in its environment. The role of the individual citizen in shaping a cognitive city is critical in the success of its governance processes, as is the integration of diverse performance measures that reflect the values of various stakeholders in the urban environment. There are numerous challenges to be solved before fully ubiquitous cities become a reality.

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