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Big Data analytics in government systems

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Abstract
Big Data can help improve the speed and accuracy of decision-making and improve the overall efficiency of government agencies. This paper introduces the benefits, impacts, and applications of Big Data in government as well as the methods and technologies related to Big Data. Challenges of Big Data applications in government systems are discussed. Some technology progress of Big Data in government is also presented.

Keywords: Big Data; Big Data analytics; government; systems engineering; data mining; knowledge discovery; Information quality; security; privacy; artificial intelligence; predictive analysis; cloud computing.

Introduction

From population figures to household income levels to commodity prices, data-driven decision-making has been the backbone of modern government economic policy. It is imperative that governments now adopt new technologies like Hadoop or NoSQL and develop advanced decision-making frameworks to transcend traditional data storage and analysis. It is crucial for the government to exploit Big Data technology and analytics to help with good governance and shape its public policy (Sanyal and Ranjan, 2015) [22].

Big data is data that exceeds the processing capacity of conventional database systems. The data is too big, moves too fast, or doesn't fit the structures of general database architectures. To gain value from this data, people must choose an alternative way to process it (Zdemir *et al*., 2013) [28]. Big data allows governments to improve public sector administration and assists global organizations in analyzing information to devise strategic planning. Big data furthers national goals such as optimization of natural resources, response to national disasters, and enhancement of critical information infrastructure (Tene and Polonetsky, 2013) [27]. Government has created initiatives to exploit Big Data in many areas such as science and engineering, healthcare, and national security (Chan, 2013) [16].

In March 2012, the Obama administration announced the Big Data Research and Development Initiative, a new, multi-agency big data research and development initiative aimed at advancing the core scientific and technological means of managing, analyzing, visualizing, and extracting information from large, diverse, distributed, and heterogeneous data sets (Tene and Polonetsky, 2013) [27]. Many federal agencies joined this effort, and approximately $200 million was invested in big data analytics to mine valuable information from the massive quantities of data that public agencies have collected (Krishnamurthy and Desouza, 2014) [18]. Since President Barack Obama announced the Big Data Initiative, the US government has been one of the leaders in government expenditure on Big Data. To launch this initiative, six departments and agencies of the US Federal Government announced additional budgets to improve Big Data tool and techniques. In the UK, the sectors with funding for Big Data research include the environmental sciences and arts and humanities (Sanyal and Ranjan, 2015) [22].

The advent of Big Data delivers the cost-effective prospect to improve decision-making in critical development areas such as health care, employment, economic productivity, crime and security, and natural disaster and resource management (Hilbert, 2013) [10]. Big Data can also be seen as a powerful tool to address various societal ills, offering the potential of new insights into areas as diverse as cancer research, terrorism, and climate change (McNeely and Hahm, 2014) [19]. IBM's most requested uses for analytics in government are in highly visible areas. Traffic management is most popular, followed by water management. After those, the top contenders are emergency response, energy consumption in buildings and public safety. Governments are gradually adopting big data tools and strategies, led by pioneering jurisdictions that are piecing together the standards, policy frameworks and leadership structures fundamental to effective analytics use (Shueh, 2014) [24].

Transformational government (t-government) is the seamless integration of businesses, citizens and other relevant stakeholders into the government value chain through the use of information and communication technologies (ICTs). T-government is also described as the ultimate evolutionary stage of electronic government (e-government). E-government refers to the adoption of ICTs by government institutions with a goal of improving public sector services. Early e-government projects were characterized by static web-pages that simply displayed information to website visitors. Overtime, e-government projects evolved into a more interactive environment with features such as message boards, e-mail, chat, downloadable forms and online transactions such as electronic tax filing. The adoption of e-government and ultimately t-government by public sector institutions are constrained by barriers such as security and privacy concerns; citizen access

and the digital divide; implementation and maintenance costs; and organizational inertia due to resistance to change. Competition is a driver for change and innovation in the public sector; Big Data analytics can be used as a tool for transformational government (t-government). In the government context, big data is generated from a variety of sources including transactions, web-interactions, audio, video, social media, and logs (Brown *et al*., 2014) [3].

The purpose of this paper is to introduce Big Data in government systems including benefits, impacts, applications, challenges, and technology and technology progress. The organization of this paper is as follows: the next section introduces government big data and technologies related to Big Data; Section 3 introduces the benefits, impacts, and applications of Big Data in government; Section 4 discusses the challenges of Big Data in government; Section 5 presents some technology progress of Big Data in government; and the final section is conclusions.

2. Government Big Data and Technologies Related to Big Data

Big data characteristics can be described by "6Vs". They are: Volume, Variety, Value, Velocity, Veracity and Variability (Bellini *et al*., 2013; Demchenko *et al*., 2013; Jean-François Lavignon, 2013; O'Leary, 2013; Jagadish *et al*., 2014) [1, 6, 14, 21, 13]:

- *Volume*: It refers to massive amounts of data. This makes it hard to store and manage.
- *Variety*: It refers to heterogeneity of data types, representation and semantic interpretation.
- *Value:* Value is an important feature of the data which is defined by the added-value that the collected data can bring to the intended process, activity or predictive analysis/hypothesis.
- *Velocity*: Data such as highly streaming data is generated at a rate that exceeds those of traditional systems.
- *Variability*: It refers to data changes during processing and lifecycle. Big data can be constantly changing (dynamic).
- *Veracity:* It includes two aspects: data consistency (or certainty) and data trustworthiness.

The types of big data in governments include records about citizens, businesses and transactions in core systems and data warehouses; text documents such as email, blogs, social media, and medical notes; and other data such as videos, broadcasts, images, sensors, and geospatial and weather information (IBM, 2013) [11]. Table 1 (Ha *et al*., 2014) [9] shows the summary of the standardization requirements for government-led big data.

Table 1 Standardization requirements for government big data

Type of Standardization	Requirements
Conceptual model and schema	• Metadata for big data • Data catalogue • Taxonomy for data & usability • Event description language • Workflow description language • Linage description
Interface & implementation specification	• Registry service interfaces • Event pattern query • Capability description for big data analysis services • SLA for infrastructure service • SQL-like language targeted at horizontally scalable data source
Guideline	• Security for big data • Privacy control • Guidelines for big data analysis and mash up

SLA: Service-Level Agreement
SQL: Structured Query Language

A number of government agencies are adopting cloud technologies. Big Data infrastructure service can be served as an instance of Infrastructure as a service (IaaS). The basic role of government big data provider is opening government big data. Government data shall be considered open if it is made public in a way that complies with the eight principles (complete, primary, timely, accessible, machine processable, non-discriminatory, non-proprietary, and license-free). In addition, several technology issues should be considered and they are listed as follows (Ha *et al*., 2014) [9]:

- Gathering the data and describing what they are.
- Supporting semantic search for consumer's ease of use.
- User's feedback about use of the data.
- Extract and send the imperatively necessary information from sensor stream data.
- Privacy and security of data.

Big Data require three key infrastructure ingredients: 1) a platform for organizing, storing, and making data accessible; 2) computing technology and power that can process large-scale datasets; and 3) data formats that are structured and usable (Bertota *et al*., 2014) [2]. Besides the general cloud base infrastructure services (storage, compute, infrastructure/VM management), the following specific applications, services, and technologies are required to support Big Data (Demchenko *et al*., 2013) [6]:

- Cluster services

- Hadoop related services and tools
- Databases/Servers SQL, NoSQL
- Big Data Management tools
- Massively Parallel Processing (MPP) databases
- Registries, indexing/search, semantics, namespaces
- Collaborative environment (groups management)
- Specialist data analytics tools (logs, events, and data mining, etc.)
- Security infrastructure (access control, policy enforcement, confidentiality, trust, availability, and privacy)

3. Benefits, Impacts and Applications of Big Data in Government

Businesses use big data to pursue profits, governments use it to promote the public good. Governments expect big data to enhance their ability to serve their citizens and address major national challenges involving the economy, health care, job creation, natural disasters, and terrorism. Governments of leading ICT (information and communications technology) countries have initiated big-data application projects to enhance operational efficiency, transparency, citizens' well-being and engagement in public affairs, economic growth, and national security (Kim *et al*., 2014) [17].

By harnessing big data, government agencies can perform a host of tasks, including responding to public safety or environmental events quickly, supporting decisions with both historical and real-time data analysis, and facilitating timely investigation of crimes, fraud and other incidents. Table 2 shows these kinds of tasks (IBM, 2013) [11].

Table 2: Harnessing big data for government

Agencies or Systems	Tasks
Surveillance systems	Analyze and classify streaming acoustic signals.
Cybersecurity systems	Analyze network traffic for anomalies.
Transportation departments	Use real-time traffic data to predict traffic patterns, update public transportation schedules.
Police departments	Analyze images from aerial cameras, news feeds, social networks to detect events, persons or items of interest.
Social program agencies	Gain a clearer understanding of beneficiaries and proper payments.
Tax agencies	Identify fraudsters and support investigation by analyzing complex identity information and tax returns.
Sensor systems in ocean buoys and river gauges	Collect data for faster, more accurate flood predictions.
Sensors streaming air, water, and temperature data	Support cleanup, fire prevention, and other programs.

Big data can help government agencies improve overall efficiency, boost the speed and accuracy of forecasting and decision making, identify more opportunities for savings, and better understand their own operations as well as constituents' needs (Informatica, 2013) [12]. From healthcare to defense and the all-important food security issue, Big Data Analytics can help reduce costs, provide insights and policy prescriptions, and help oversee the implementation of policy and assist in monitoring their effects. In fiscal revenues and expenses, if the government (like credit ratings agencies or banks) uses a broad based approach and utilizes Big Data to bring these various data points under a single umbrella, it will be able to significantly improve its tax net (Sanyal and Ranjan, 2015) [22].

Big data can help to facilitate social and civic empowerment and furthermore enhance and expand stakeholder participation in the policy and planning process. It can also be used to promote transparency and accountability. Big Data holds tremendous potential for policy analysis (Schintler and Kulkarni, 2014) [23]. Analysis of big data offers potentially to provide public sector policy makers with extensive new information that would inform policy at unprecedentedly detailed levels. Big Data can provide more information concerning populations served by public policy. Big data also allows governments to target their social services to those most in need (Stough and McBride, 2014) [26].

Big data analytics can deliver many benefits to government organizations—from increasing efficiencies through the delivery of online services and information to citizens, to ensuring a nation or region is protected from terrorist attacks. Key areas with initial success in big data analytics include the detection of fraud for social programs and tax collection, and the prevention and prediction of threats and crimes. Big data analytics can help to automatically identify hidden relationships and activities that may point to fraud or errors. Big data analytics can help tax agencies more accurately determine who should be investigated for fraud or denied refunds by detecting new deception tactics, uncovering multiple identities and identifying suspicious behavior. Big data analytics can help national security and law enforcement agencies improve intelligence by identifying threats and crimes before they occur, improving the accuracy of threat and crime analysis, protecting sensitive facilities from attack and thwarting growing cybersecurity risks (IBM, 2013) [11].

Some police departments, for example, already mine high-volume, high-variety, and high-velocity data sources to support predictive policing. Public officials also hope to deploy big data in public health, education, corrections, infrastructure management, citizen engagement and many other arenas (Douglas, 2013) [7]. Three of the most important developments in use of big data by the police are: crime prediction, mass surveillance, and DNA databanks (Joh, 2014) [15]. In crime prediction, the application of computer modeling to historical crime data is used to predict future criminal activity. While the police have long tried to find patterns of criminal activity on which to focus their resources, predictive policing permits the police to harness thousands of data points to forecast where crime is likely to happen. In mass surveillance, computer surveillance systems help police create a software-enhanced picture of the present, using thousands of data points from multiple sources within a city. As for genetic big data (DNA databanks), perhaps less obvious but not less important a big data matter is the collection of DNA for criminal justice databases. Police agencies around the country rely on CODIS—the shorthand for the system that links information among the different DNA databases around the country to match crime scene samples with offender or arrestee DNA profiles (Joh, 2014) [15].

The potential of big and open data are substantial for e-government services. Big and open data can foster collaboration; create real-time solutions to challenges in agriculture, health, and transportation, etc. Obama administration have involved big data – datasets that are

extremely large and/or complex, offering the possibilities of identifying previously impossible levels of insights, granularity of analysis, and relationships between elements in the dataset (Bertota *et al*., 2014) [2]. Business intelligence and analytics (BI&A) and the related field of Big Data analytics have become important in e-Government. Table 3 (Chen, 2012) [5] summarizes some features and capabilities of BI&A and Big Data in e-Government and Politics 2.0, including applications, data characteristics, analytics, and potential impacts.

Table 3: BI&A and Big Data in e-Government and Politics 2.0

Applications	• Ubiquitous government services • Equal access and public services • Citizen engagement and participation • Political campaign and e-polling
Data	• Government information and services • Rules and regulations • Citizen feedback and comments *Characteristics*: Fragmented information sources and legacy systems, rich textual content, unstructured informal citizen conversations
Analytics	• Information integration • Content and text analytics • Government information semantic services and ontologies • Social media monitoring and analysis • Social network analysis • Sentiment and affect analysis
Impacts	Transforming governments, empowering citizens, improving transparency, participation, and equality

4. Challenges of Big Data in Government

Agencies face difficulties in government data: (1) The U.S. PATRIOT Act, HIPAA, the Federal Data Center Consolidation Initiative, the Affordable Care Act, and many other regulations and initiatives require compliance with complex, stringent rules about data collection, storage, management, and security. (2) An average of 31 percent of government data is unstructured, complicating analysis and action as well as hindering interagency cooperation. (3) Only 6 percent of civilian agencies and 3 percent of defense agencies have the infrastructure and processes in place to successfully leverage big data. (4) IT spending across all major federal agencies has decreased by 2.4 percent annually from 2009 to 2013 (Informatica, 2013) [12].

Despite its potential, the adoption of big data and analytics faces challenges, particularly for central governments. of particular interest are the challenges regarding data ownership, data quality, privacy, civil liberties, and equality, as well as public sector's ability to attract big data analyst talent (Morobito, 2015) [20].

Governments that want to harness the power of big data face some serious obstacles. One challenge is collecting and storing data in many different formats. Much of the information that governments want to tap doesn't even reside in structured databases. Text documents, emails, photos, videos, and posts on social media sites all offer rich material for analysis (Douglas, 2013) [7]. One of main challenges of harnessing Big Data consists in bringing data from different sources together. Large parts of valuable data lurk in "data silos" of different departments, regional offices, and specialized agencies. Fragmentation impedes the massive and timely exploitation of data. Data interoperability standards are becoming a pressing issue for the Big Data paradigm (Hilbert, 2013) [10].

Collecting data is a big challenge for governments. The data not only comes from multiple channels (such as social networks, the Web, and crowdsourcing), but from different sources (such as countries, institutions, agencies, and departments). Sharing data and information between countries is another challenge, as shown by the terrorist bombing attack on the Boston Marathon in April 2013. National governments must be prepared and willing to share data and build systems for crime prevention and fighting. The Boston Marathon tragedy might have been prevented if the Russian secret services had shared critical information about the terror suspects with U.S. intelligence agencies. Sharing information across national boundaries involves language translation and interpretation of text semantics and sentiment so that the true meaning is not lost. Dealing with language requires sophisticated and costly tools. The challenge for sharing and organizing government data involves finding a cohesive format that would allow for analytics in the legacy systems of different agencies. There is the lack of standardized solutions, software, and cross-agency solutions for extracting useful information from discrete datasets in multiple government agencies. Data security is the primary attribute of government big data, as collecting, storing, and using it requires special care. However, most big-data technologies today, including Casandra and Hadoop, lack sufficient security tools, making security a challenge for governments (Kim *et al*., 2014) [17]. The enhancement of big data with interfaces for user interaction increases the number of access points and correspondingly elevates the risk of security breach and data leakage (Tene and Polonetsky, 2013) [27].

Another concern that is raised in relation to the collection and use of big data is privacy. A prime example of how big data potentially infringes on the privacy of individuals is Internet tracking (Schintler and Kulkarni, 2014) [23]. Privacy laws and policies can contradict the opportunities in big and open data; such data simultaneously can violate the privacy rights of individuals or communities (Bertota *et al*., 2014) [2]. A possible way to manage privacy invasion problems could be to strip all Big Data records or files of personal identifiable information before making them available for analysis. Research aimed at identifying a technology for stripping personally identifiable information is underway in several U.S. government agencies and universities (Stough and McBride, 2014) [26].

Government agencies are applying big data techniques internally, providing unprecedented access to their health data holdings both by granting researchers access, and by opening data sets to the public. However, the serious privacy and security considerations that arise from collection and use of sensitive health information pose a barrier to the realization of big data's benefits. Currently, health data privacy and security are addressed in a multitude of state and federal laws and regulations, which, in their very complexity, can seem to fail to offer comprehensive guidance on the ethical and responsible use of personal health information (Cdt, 2015) [4].

From the case of States Social Security Administration (SSA), challenges regarding big data projects in the public sphere are (Krishnamurthy and Desouza, 2014) [18]: First, issues related to privacy, ethics, and the unintended use of big data analytics. Second, agencies deploying big data projects must be aware of the potential of data analytics to create an unequal society and to discriminate against those who lack access to resources.

Third, analysis of big data requires new kinds of significance tests or other validation techniques that gauge the temporal variability to discover correlations and new patterns. In SSA big data governance, both challenges and opportunities ahead exist. It is critical for the SSA and other public agencies to pay attention to nine key dimensions: (1) developing systems architecture, (2) cultivating a culture of cross-agency collaboration, (3) consolidating databases, (4) adopting crowd-centric approaches, (5) managing issues of data security, (6) investing in employee training and capacity building, (7) developing collaborative leadership and management support, (8) creating resources to streamline service delivery to end-users, and (9) developing metrics to measure performance (Krishnamurthy and Desouza, 2014) [18].

As for data reuse, individuals need to be given clear guidelines as to which data use and reuse policies govern. As for data accuracy, data collected for single purpose use may not be fully compatible with other datasets; and this can lead to errors and a range of false findings. There is both a need to ensure data quality as well as to develop a verification system that validates reported findings. There is a need for a robust data sharing and interoperability framework. Big and open data initiatives that utilize collaborative analysis techniques require a seamless integration of data collection and reporting system (Bertota *et al*., 2014) [2].

Therefore, related challenges span the generation, collection, manipulation, analysis, and use of big data. The above main challenges and additional challenges are summarized as follows (McNeely and Hahm, 2014) [19]:

- Dealing with highly distributed data sources
- Working with variably formatted and structured data
- Enabling data sharing
- Protecting privacy
- Ensuring data integrity and security
- Tracking and validating data,
- Coping with sampling biases and heterogeneity
- Enabling data discovery and integration,
- Developing specialized analytical tools
- Developing appropriately scalable and incremental algorithms

5. Some Technology Progress of Big Data in Government

IBM has worked with governments on big data projects that have demonstrated very powerful return on investment (ROI). One example is South Bend, Ind., which installed sensors in its water system to collect data and helped the city avert potentially hazardous overflows of wastewater (Douglas, 2013) [7]. IBM has also developed a big data platform that offers a broad range of components. The components enable government organizations to harness the power of big data analytics, including (IBM, 2013) [11]:

- An enterprise-ready version of the Apache Hadoop engine to cost-effectively process and analyze massive volumes of structured or unstructured data.
- A streaming data platform that enables the application of analytics directly on data in motion in sub-millisecond response times to take action in real time.
- High-performance data warehouse appliances for complex analytic processing.
- Text and content analytics to uncover hidden meaning and insight in unstructured information such as case notes, social media, and more.
- A navigation tool to find, understand, and navigate big data while leaving that data in place high-volume information integration applications to ensure data is clean, trustworthy, protected and secure.

In defense and internal security, the US Department of Defense (DOD) has been 'placing a big bet on Big Data', investing USD 250 million annually across departments for internal and external defense. The ADAMS (Anomaly Detection at Multiple Scales) program is developing technologies for detecting data anomalies and cues in massive datasets, which DOD is exploiting it for insider threat detection (Sanyal and Ranjan, 2015) [22].

Public agencies are investing significant resources in big data analytics to mine valuable information, predict future outcomes, and make data-driven decisions. States Social Security Administration (SSA) collects, manages, and curates large volumes of data to provide Social Security services to US citizens and beneficiaries living abroad. The agency has made great strides in the burgeoning big data space to improve administration and delivery of services. Big data analytics has the potential to streamline services, reduce costs, and improve service delivery. However, the SSA is still in the early stages of developing capability in the domain of big data analytics (Krishnamurthy and Desouza, 2014) [18].

Differentiating between fraudulent and legitimate activities is difficult when vast amounts of information are buried within rows of numbers. Not every anomaly is fraud. A step that organizations can take to distinguish between fraudulent and legitimate activities and proactively identify and stop fraud before it happens, is to recognize whether any anomalies they uncover are from user error (such as processing a claim more than once by mistake) or from intentional misuse. By applying advanced analytics, organizations can quickly identify fraudulent activities while continuing to process legitimate transactions and keep business moving forward. To combat the fraudsters, more organizations are planning to use new approaches around Big Data to convert the volumes of information now available to them into useful insight and real action. Government tax agencies are using Big Data to fight fraud (Griffin, 2012) [8].

Bid Data has been used in tracking locations. Location-based services have obvious applications in private sector marketing, but can also be put to public service. In Stockholm, for example, a fleet of 2,000 GPS-equipped vehicles provide data in 30 - 60 seconds intervals in order to obtain a real-time picture of the current traffic situation. The system can successfully predict future traffic conditions, based on matching current to historical data, combining it with weather forecasts, and information from past traffic patterns, etc. Such traffic analysis does not only save time and gasoline for citizens and businesses, but is also useful for public transportation, police and fire departments (Hilbert, 2013) [10].

The concepts and features of Government 3.0 were described. Emerging Internet-based technologies and services were identified. Improvement plans for Government 3.0 were provided. As a result, ten issues to be brought together include: smart phone applications and service, mobile Internet computing and application, wireless and sensor network,

security & privacy in internet, energy-efficient computing & smart grid, multimedia & image processing, data mining and big data, software engineering, Internet business related policy, and management of Internet application (Song, 2014) [25]. Main features, emerging technologies, services, and policies of the newest type of e-Government (smart society) are described in Table 4 (Song, 2014) [25]. Big Data strongly supports e-Government.

Table 4: Characteristics of the newest type of e-Government (smart society)

Main Features	Accessibility	Service/Policy	Technology
• Government 3.0 • Real-World Web • Individual-centric	• My gov. (customized portal)	• Information collaboration • Real-time sharing of information • Seamless service • Intelligent service • ICT policy	• Wireless and sensor network • Mobile computing • Cloud computing • Big Data

6. Conclusions

Big Data helps improve the performances of government agencies such as social program agencies, tax agencies, transportation departments, police departments, cybersecurity systems, and health care systems, etc. It has achieved initial success and applications in social security services to US citizens and beneficiaries, fighting fraud in tax agencies, and security and public safety areas. Big Data analytics can be a useful tool for e-government and ultimate t-government. Data ownership, data quality, privacy, civil liberties, and equality are major challenges of Big Data applications in government.

All the challenges about Big Data in government can be further research topics. In addition, Big Data in opinion mining, sentiment analysis, social/political analysis, and text visualization also can be important research topics.

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