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G. Rani
Netaji Subhas Institute of Technology, Dwarka, Sector 3, New Delhi, geetachhikara@gmail.com

S. Chakraverty
Netaji Subhas Institute of Technology, Dwarka, Sector 3, New Delhi, apmahs@rediffmail.com

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Survey of E-Governance Systems with focus on Development Approaches and Interface Quality

G. Rani & S. Chakraverty

Division of Computer Engineering, Netaji Subhas Institute of Technology,
Dwarka, Sector 3, New Delhi-110078, India
E-mail: geetachhikara@gmail.com, apmahs@rediffmail.com

Abstract - There has been a significant growth of e-governance systems in general and online voting systems in particular. Various models have been proposed to conceptualise and develop these systems. Attention is currently on developing adaptive interfaces that respond intelligently to changes in user profiles. These models differ in many aspects, but no formal classification or comparative study is available as yet which may be used as a reference for researchers engaged in this area. This paper surveys the plethora of existing approaches and models for e-governance and presents a comparative evaluation based on certain qualitative parameters. These parameters have been selected based upon their criticality in e-governance applications. They include security, interoperability, authentication, flexibility, extensibility, privacy, adaptability, transparency, verifiability and robustness. The classification provides a common platform to glean knowledge about the strengths and weaknesses of different models, gain a quality-based comparative evaluation and build upon specific research directions.

I. INTRODUCTION

Electronic governance is a growing phenomenon within public sector institutions around the world. It provides an easy, fast, economical and transparent way of disbursing government services to public, government employees and businesses alike. It is the mandate of *Governments-online* to deliver their services and programs efficiently, provide governmental information and interact with citizens, all electronically [1,2]. Some of the successful applications of e-governance are rural banking for loans disbursement [3], grass-roots level online education, e-democracy [4,5,6], disaster management for distribution of medical and financial aid [8,9] and transport system for ticketing and crew management [10].

In the next section, we present the background for e-governance. Here we will outline different types of e-governance delivery systems, applications and take up e-voting as a case to mull the critical quality parameters. In section 3, we review the various existing e-governance models by classifying them along three dimensions; online and offline systems, development approaches and quality of user interface. In section 4, we present a comparative evaluation of these models based on the quality parameters discussed in section 2. Finally we conclude in section 5.

II. BACKGROUND

2.1 Delivery models

E-Governance delivery systems [11,12,13] adopted by different countries can be classified broadly as below:

Intra Governmental systems (G2G): These systems allow different governmental departments to interact with each other seamlessly. It improves efficiency as well as transparency of operations.

Government and Business (G2B and B2G): These solutions enable the government to deal effectively with a gamut of commercial transactions and e-commerce such as tendering, licensing, and infrastructure project management etc.

Governmental services to citizen (G2C & C2G): These delivery systems are based on the premise that the government-citizen relationship is a business-customer relationship. It implements various Customer-Relations-Management (CRM) processes. Services such as filing tax returns, issue of passports, registration of property, birth, marriage and death and providing driving licenses have been rendered smooth and transparent due to their online implementation. .

Government and foreign affairs (G2X): Various functions related to foreign trade, tourism and cultural/academic exchange programs are executed online, thus boosting international cooperation. These include repatriation of foreign earnings, foreign investments, work permits, hotel bookings and organizing international events.

2.2 Applications

Countries all over the world have adopted e-governance policies[14,15] to great advantage. Some success stories are listed below:

- Online voting was first allowed in the small Baltic republic of Estonia in their 2005 committee elections[16]. Since then, Estonia carried out online voting in further parliamentary elections and European parliament elections [17]. Norway and Switzerland will run online e-voting pilots in September 2011 and October 2011 respectively. It is expected that many countries will follow in the same direction.
- Launching of Citizen Facilitation Centres (CFCs) [18] has increased revenue collection from Rs 38.63 crore in 2003 to Rs 54 crore in 2005.
- The *pilot* project offered a corruption online reporting facility in six towns and two remote locations in Kenya[19].

In India, the government provides IT-enabled services [20] to citizens in several areas such as agriculture[21], education, banking, democratic processes, health services and tax payment. We review some sample applications below.

- *Karnataka*: The Karnataka government's 'Bhoomi' project has led to computerisation of centuries-old system of handwritten rural land records, thus systematising the revenue department's land records of Right, Tenancy and Cultivation (RTC) [22].
- *Gujarat*: Gujarat has launched websites for all major departments where citizens log on and get access to data and issues related to the concerned government department as land water and taxes [23].
- *Andhra Pradesh*: The 'e-Seva' portal of Andhra Pradesh facilitates citizens to pay water, electricity, telephone bills and municipal taxes online [24]. It also provides the facility of online birth and death registration, passport applications, permits, licences, transport department services and reservation.
- *Madhya Pradesh*: The District Council of Dhar in the state of Madhya Pradesh put up an intranet under a project named "Gyandoot" to help farmers and villagers transact their services online with the government of the province and district councils [25,26].

The above examples indicate some dominant features of e-governance applications. Several applications share data and communicate with each other. Interoperability and standardization are thus indispensable. The different stake-holders such as governments, businesses and citizens span different regions and languages. Therefore these applications need a flexible, user friendly and adaptable interface. We next take up online voting as a sample system to understand the quality parameters relevant to e-governance systems.

2.3 Quality parameters

Let us now consider the various quality parameters that influence the design of e-governance systems. Since a wide gamut of applications exist, we shall take up e-voting as a sample application and investigate the critical quality factors involved therein. Online voting entails the ability to vote from any location by using the internet [27]. It can increase voter participation without people having to join queues, allow voting from remote areas by military personnel and people living abroad, avoid postal delays and human errors in vote counting and bring faster results.

2.1.1 Protection issues

Insecure communication channels can provide unauthorised access to e-governance systems. An active fraudulent agent can detect the identity of voter when he/she is sending information through the network, thereby compromising his/her privacy[27]. E-governance systems must protect the site from illegal access and also protect sensitive user information. Protection relates to the following issues:

- **Security:** Security ensures that the data transferred between sender and receiver is not leaked or tampered with anywhere in between. Encryption and decryption algorithms and digital signatures allow secure transmission of cipher text.
- **Anonymity:** In some applications like e-voting, the identity of an online voter must be hidden even from the system administrator.
- **Verifiability**: The voter must be able to verify that her vote has been correctly stored in memory against her digitized entity. Anonymity and verifiability are often mutually conflicting issues that cannot be resolved simultaneously.
- **Authentication**: To ensure only valid votes, voters must be authenticated before the voting stage by digital signatures, smart cards or unique Personal Identification Number (PIN).
- **Fraud detection:** Access by fraudulent agents is a major issue as it decreases reliability and trust of people in the system. One way of tackling this issue is by monitoring the behaviour of users and storing the regular expected behaviour in the database. Unexpected behaviour shows that the user is fraudulent.

2.3.2 Democratization issues[28]

One of the objectives of online voting is to encourage wider participation in the democratic process.

- **Information systems for elections:** So far, online voting models dealt with different phases of voting such as registration phase, voting phase and counting phase. Newer online voting systems can enhance democratization by providing a complete information system on the election process by including an intelligent query response system, dynamic updates, visualization of results and online training for system operators and the public.
- **Transparency:** As more software is used, its trustworthiness becomes a major concern. All components of the software, including the code, compiler, installation mechanism and delivery should be validated and open to public scrutiny.
- **Adaptive interfaces:** Online voting systems must cater to a very large population with diverse educational and economic backgrounds. The digital divide is also of concern. Therefore, the interface design is a key issue. The system should be able to provide an appropriate interface according to the category of users. The interface must be flexible so that it is able to take inputs from various sources and work with different standards.

2.3.3 System design issues

Adopting excellent design principles cull out costly errors that may otherwise be hard to rectify at later stages. The following parameters must be kept in mind during system design.

- **Reusability[28]:** Since e-governance is an emerging area, it is expected that newer and more sophisticated applications will continue to be developed. It is beneficial to utilize past developmental efforts and learn from past experiences. Therefore, development methods that enhance reusability must be adopted. Design patterns based frameworks is a good approach towards development of e-governance systems.
- **Interoperability and standardization:** Online voting systems employ several servers that manage various types of data and services. It is important to maintain interoperability[29] among these components. Well-defined quality standards[30] for different e-voting processes facilitate cooperative services, allow data sharing and free customers from dependence on specific vendors.
- **Reliable design[31]:** Reliability entails that the hardware and software subsystems are functioning properly and correct outputs are generated every time. Fault tolerant design employing hardware and/or software redundancy increases reliability albeit at a higher cost. Votes already committed to memory must be protected under any cost and any attempts at tampering must be immediately detectable. Thus, online error-detection techniques must be incorporated at the design stage.
- **Scalability**:[32] The system should be scalable with an increase in number of users and requirements.
- **System data integrity[33]**: In online voting system various servers are used for different purposes like registration server, voting server, counting server. It is necessary to maintain database integrity among all the servers as a complete system.

The quality attributes discussed above affect the system globally and are generic in nature. Therefore, they can be easily extended to other e-governance applications.

III. CLASSIFICATION AND REVIEW OF E-GOVERNANCE MODELS

Classification of various e-governance models is important as it provides a common comparative platform for researchers and developers. We undertake three approaches for classification of e-governance models: Online versus offline approaches for e-voting, development methods adopted in e-governance systems and approaches based on the interface quality.

3.1 Online versus offline approaches for e-voting

Offline systems, historically developed first, still enjoy users' trust as they are free from cyber attacks unlike online systems [34,35]that can compromise privacy of users and cause unauthorized access of data and malicious attacks. Nevertheless, online systems are in great demand due to their interactivity and location independence.

3.1.1 The Offline Electronic Voting Machine [36, 37]:

The offline EVM e-voting systems are currently used for voting in India. Its software has been programmed in assembly language. It consists of two interconnected parts; the *Ballot unit* allows voters to input their votes by pressing a button and the *Control unit* maintains reliability of the system and displays results after closing of election.

3.1.2 Online approaches[38,39,40]:

Most of the current e-governance systems are online. We review some of the online models below:

Tamper evident storage for e-voting [41]:The authors have used reusable formal design methods like Event-B, Manchester encoding for PROM technology and write once data technology to maintain the accuracy of online vote-storage. These methods ensure tamper evident storage of votes to prevent addition of unauthorised votes after the election and change or deletion of already

validated votes. The "*correct by construction refinement technique"* along with its proof tool is used to make the system transparent and open. However detection of tampering is possible only after end of the election.

Rijnland Internet Election System[42]:The RIES system proposed integration of e-voting with ordinary mail voting system by including voter's feedback system, keyless hashes, technical votes and shadow system. This makes the RIES highly transparent and verifiable. However, security can be compromised due to possible hacking of domain name server while voting and modification of the java script in which cryptographic computations are done in the web browser downloaded in the voter's computer.

A Robust Electronic Voting System [43,44]: The REVS protocol includes mutually exclusive phases such as ballot distribution, ballot signing, ballot submission and counting phases to maintain privacy of the voter. Use of a blinding factor, the election's public key, a randomly generated symmetric session key and the election's private key support the removal of redundant and invalid votes after the election and counting of only valid votes. The system also provides the facility to resume a previous state the voter saved in a checkpoint in case of communication failure while voting. However, the system is sensitive to external and internal attacks which may corrupt the operating system or network stack to allow submission of invalid votes and resubmission of valid votes.

Fujioka approach [45]: The voting system proposed in [45] consists of three central facilities: registrar, validator and tallier, and seven election phases: registration, preparation, authorisation, voting, collecting, opening and counting. The separation of concerns thereby implement privacy and fairness by ensuring no way to find the relation between a vote *vi* and its voter *Vi*. The system may however compromise security because it assumes that the communication channel is anonymous. Besides, the counters may overflow with invalid votes without being detected during the election hours as they are detected only at the end of the election.

Sensus approach [46]: Inclusion of an extra central facility the *pollster* to the Fujioka approach supports the simultaneous casting and counting of votes. Invalid votes can be detected during the election hours. Once again, security may be compromised due to assumption of anonymous communication channel and use of blind signatures on a large scale. In [47] the tallier can replace some of the votes in case of selection of same random keys and votes by two or more voters.

Improved Sensus approach [46]: In a bid to remove the anomalies of the Fjioka and Sensus approaches and increase security, this approach employs six central facilities *viz.* registrar, counter, distributor, authenticator, matcher and verifier. A high degree of security and system integrity is maintained by prescribing well-defined roles for each entity and ensuring that none encroaches upon sanctified information with another. It also maintains the anonymity of the voter by using secure communication channel like HTTPS in Netscape for each transaction.

3.2 Classification based on development approaches

A variety of development approaches have been tried out by different researchers leading to specific benefits like extensibility, interoperability and ability to change the system with changing requirements. Here we examine the main approaches.

3.2.1 A UML based 4-Step Rule Set approach [47,48]

In 4-SRS method, the author proposes step-wise transformation of the informal requirements gathered from domain experts and users into an abstract model of system requirements. Object creation, object deletion, object aggregation/packaging and object association are the four steps employed to transform UML architecture to a semantically consistent object oriented architecture. The object model is further transformed into logical model to capture functional requirements, non functional requirements and support design decision. This approach is useful in designing service oriented e-governance systems. But it requires unfolding of use case hierarchy which increases the time complexity.

3.2.2Architectural and design patterns based approaches

E-governance frameworks[49]: Based on the observation that different countries implement their e-governance solutions using the same basic concepts under different contexts, the authors employed commonality analysis to investigate *e-government ontology and reusable knowledge*. Knowledge mapping, pattern recognition and mind mapping techniques are used to identify the boundaries of e-governance systems. These systems use architectural and framework patterns, governance patterns to design the structure of e-governance systems and implementation patterns to solve problems beyond design phase like portal content creation and management.

Frameworks such as E-governance Interoperability Framework (e-GIF) [50], Estonian IT Interoperability Framework (EE-GIF) in Estonia[51] and New Zealand's e-Governance Interoperability Framework (NZ e-GIF)[52]are used to maintain data integrity, interoperability in heterogeneous data, to define technical policies and for content management. Differences in culture and administration of various countries are still

wide enough to make the generalization of e-governance systems difficult.

Layered Software approach [53]: In [53] the authors propose four interdependent contextual layers to handle their specific assigned functions. The business process layer implements high level business rules, the data architecture layer handles data types and formats, the application architecture layer deals with performance requirements and technology infrastructure deals with hardware and software resources. Well defined protocols such as JDO, EJB and DAO for business layer, RDBMS, ODBMS, XML and ERP for data architecture layer and VPN, SSL and PKI for security govern inter layer communication. The layered approach is excellent for designing transparent and flexible e-governance systems.

In [53] technical and data format open standards such as XML have been used to allow seamless integration of new services to an existing e-governance system. Digital signatures, encryption password and access control systems are used to maintain security. Single-point Sign On (SSO) provides a single point of entry to all users while using National Gateway to interconnects different states. Of course, the high degree of interoperability incurs high cost of implementation and greater system complexity.

Using Design patterns [53,54,55,56,57]: In [54] Case Based Reasoning (CBR) and Formal Concept Analysis (FCA) based design pattern retrieval tools have been used to automatically extract suitable design patterns and thus reduce development efforts. CBR analyses problems mathematically and does not utilize knowledge from previously solved problems. FCA is used to find the conceptual relation between analysed data sets. FCA generates a concept lattice to show knowledge dependence between all the knowledge cases. In the relational database, knowledge cases or Objects(G) are rows and design patterns used by them are their attributes (M). Incidence(I) is a subset of G X M. This approach is user interactive and refines the problem on the basis of user feedback. However, it is not useful for retrieval of design patterns if no related solved problem is available in the knowledge case database.

In [55, 56] the authors make use of decorator, observer and chain of responsibility design patterns in combination, to design a common framework for e-governance applications. An abstract class is defined for defining the basic functions of an e-governance system and concert classes are defined to describe the functionality which varies from application to application. Decorator pattern is used to assign dynamic responsibilities. Chain of responsibility pattern is used to keep privacy and enforce indirect communication. Observer pattern is used to provide flexible communication between sets of publishers and subscribers.

WebML based approach[58]: The paper uses WebML, a model driven approach assisted by visual design aids in the CASE tool Web Ratio is used to resolve the problems of joint design and developmental procedures of e-governance systems. Pre existing design patterns are mined from XML specifications of the WebML conceptual schema using XSL and graph mining techniques, thus enhancing code reusability.

3.2.3 Agile and eXtreme programming approach[59]

Countries that are new entrants to the e-governance arena employ agile and eXtreme Programming (XP) for fast development cycles and to efficiently incorporate continuous changes in requirements. The idea is to develop small service oriented modules and get continuous feedback from users. The SOMF (Service Oriented Modelling Framework) is used for successful implementation of Service Oriented Architecture.

3.3 Classification based on Interface Quality

Given the much increased participation of users in e-governance systems, a classification based on interface quality merits attention. Very few of them have static interfaces and almost all have dynamic features for user interactivity. Now, the focus is on designing user adaptive interfaces.

3.3.1 Non adaptive interface [60]

The paper [60] uses Lowest Common Denominator (LCD), Most Popular Interface (MPI) and Negotiated (N/A) behavioural design patterns to develop a common interface by normalizing them in terms of data model and extracting common methods from them to wrap the functionalities in common interface. The design pattern interface system cannot display large amounts of content in limited area.

The approach in [60] uses a model based interface development using ASP.NET. It creates a complex interface by customising and defining the UIDP *<data set, property set, action set , present set>[60]*. Thus the approach is successful in designing customised complex interface. However, it does not support target code generation based on different platforms.

3.3.2 Adaptive interface[61,62,63]

Biclustering algorithm [61,62]: The main theme here is the analysis of the online behaviour of users and presenting information accordingly. The activities of online users are stored in log files and the proposed biclustering algorithm is applied to analyse them by mining navigation patterns, activities performed and time taken. The knowledge extracted is used to design an adaptive online application having better usability.

Apache servers and database servers are used to store the filtered daily activities of online users which may be collected from e-mails sent by online users to communicate with each-other. The data collected is divided into clusters containing similar information by using mining and clustering algorithms. The main problem here is the increased time complexity due to large, complex and heterogeneous data sets.

IV. COMPARATIVE EVALUATION

Based on our discussion of critical parameters in the previous section 2, we use them to present our comparative evaluation as summarized in Table 1.

V. CONCLUSION

We classified existing work along three important dimensions, *viz* offline-online approaches for e-voting systems, development approaches and interface quality. We presented a comparative evaluation of models of e-governance systems based on critical quality parameters. Our analysis in table I and II shows that historical offline models of e-voting are being replaced by online models. Architectural and design patterns for software development allow reuse of existing code and enhanced scope for future extensions. More significantly, new e-governance systems are being quickly developed by agile and eXtreme programming that also allow user feedback to be quickly converted to new requirements and duly incorporated into the system. Interface designs have graduated from static to dynamic and now adaptive interfaces. Interface design attempt to bind legacy systems and also support smooth display of complex, voluminous information.

Table I
E-Voting models

Title of Model used	Parameters				
	Transparenc-y	**Security**	**Verifiability**	**Privacy of user**	**Authent-ication of user**
Fujioka (1992) [46]	High, Voter can check status of his vote	Low(communication channel is assumed anonymous)	High(voter can verify the result)	Low(may be compromised in case of anonymous communication channel)	High (authentic-ator and registrar authenticate valid voters only)
Sensus (1999) [47]	High (possibility of vote checking by voter)	Low(communication channel is assumed anonymous)	High(voter can verify the result at end of the election)	Low	High [Fujioka]
Improved sensus (1999) [47]	High(user can check whether his/her vote has been added or not).	High(use of secure communication channel like HTTP in Netscape)	High(voter can verify the result even during the election)	High (only registrar get the name of voters in encrypted form who has no key to decrypt it)	High [Fujioka]
REVS (2003) [43,44]	High(the voter can verify that his/her vote is added or not)	Low (sensitive to internal as well as external attacks. Invalid vote casting is also possible)	High(result verification is possible)	High(use of digital signatures)	High (use of digital signatures)
RIES (2005)	High	Low(possible hacking of domain name server)	High(use of keyless hashes supports verification)	High	High(use of multifunc-tion smart cards)
Tamper evident (2007)	High(result can be verified at the end of election)	High(resistant to vote tampering)	High	High	High

Table II
E-Governance models

Title of Model used	Parameters			
	Adaptability	**Interoperability**	**Flexibility**	**Extensibility**
Layered software approach[53]	Not adaptable	High, use of single point sign on and national gateway	High(use of XML)	High(use of XML to integrate new services)
Biclustering algo(2004)[61,62]	High(supports user's behavior prediction)	High(applicable for various types of users)	High	High(New parameters can be added for user profiling)
Knowledge mapping based (2008)[49]	High (user profile based systems can be designed by suitable pattern combination)	High	High	High(use of design patterns)
WebML based approach(2008)[58]	High(pattern mining supports adaptable system designing)	High(use of interoperability frameworks)	High	High(use of Web ML and design patterns)
CBR and FCA based approach(2009)[54]	High(based on pattern mining)	Low	High	High(use of pattern mining)
eXtreme prog based(2010)[59]	High(use of pattern mining)	High	High (design patterns develop flexible systems)	High(reusability of design pattern based systems)

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