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Artificial Intelligence in e-Government: A Computational Perspective Review

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Abstract
e-Government is a field that has been significantly impacted by the ubiquity of Artificial Intelligence (AI). Specifically, Knowledge Graph (KG), a constituent technology of AI, is having a significant impact in e-Government. e-Government is defined as the application of information technology in government, and KG is a directed, labelled, multi-relational graph with some form of semantics. KG is used in advancing the e-Government objectives of effective and efficient service delivery and citizens engagement, given the increasing complexities of e-Government instances. Focus of AI in e-Government has evolved from the logic-based approaches to addressing the e-Government challenges, to the data-centric approaches. The logic-based approaches are driven mainly by the work done in the semantic web field, and the data-centric approaches are driven by work done in the machine learning field. Research activities have evolved from the logic-based to the data-centric approaches, and lately to the combination of both approaches. The AI in e-Government field could use a review of research trend in this niche research field, as a way to provide an indicative research outlook. This article attempts to provide such a review. First, it provides an overview of previous work carried-out in AI in e-Government, and then examines the different strands of research in the field including data management, intelligent web services and machine learning. Then it attempts to make a coherent statement of research direction in the field.

1. Introduction

In an era of digital technology, governments around the world are embracing this technology to enhance their services and improve the lives of their citizens. This has led to the rise of the e-Government domain over the years and the attendant increased complexity of the domain, which has made it a natural testbed for the ubiquitous influence of Artificial Intelligence (AI). e-Government and AI have become the means, both strategic and tactical, through which governments around the world seek to deliver public services in a more efficient, effective and transparent way.

In order to reason and solve problems associated with the increasing complexities of e-Government, researchers have developed several models, frameworks, and architectures to reason and analyse the complexity problems of e-Government. There has been proposals for e-Government adoption [1]; quality evaluation of e-Government services [2]; monitoring and evaluation of e-Government projects in developing countries [3]. Researchers have also attempted to use the power and ubiquity of AI to address the challenges of e-Government; earlier attempts at this include work done within the Semantic Web (SW) field – modeling e-Government with ontologies [4], [5]; meta-models for public services [5], [6]. Extensive use of AI in e-Government was well advanced in the early 2000s with several European Union (EU) sponsored projects in the AI in e-Government space. These include the SmartGov project, which used an ontology domain map for knowledge management [7]; the TerreGov project that is an Europe-wide semantic interoperability project which seeks to enable collaboration amongst public sector workers and facilitate semantic interoperability [8]; the OntoGov project is an ontology-based change management approach for e-Government [9]; and the General Government Architecture (GEA) model project of e-Government ontology [4], [10]. Most of these SW solution to e-Government is based on the Life Event Ontology [11].

The SW approach to AI in e-Government is a logic-based (also called symbolic AI) approach of the use of AI to solving the problems of e-Government. In recent years, the AI approach to the e-Government problem has been data-centric, with Machine Learning (ML) and its subfield – Deep Learning (DL), at the core of this approach. This has given rise to the proliferation of an array of new AI applications – e.g., prediction solutions, recommendation systems, facial recognition systems, chatbots and personalization solutions. This shift in focus of AI research and practice has been largely driven by increased availability of high-performance compute resources, advances in ML algorithms, the big data phenomenon. In addition, the sociological challenges of building semantics into, and getting semantics from, the web, has been a drag on the SW approach, and have given an advantage to the data-centric approach of extracting models and meanings from the web, which is the largest ever corpus [12].

Different governments have varying degrees of the use of technology in its operations and citizens engagement; hence researchers have adopted various staged maturity models for characterizing the capability and guiding the development of an e-Government instance. Most of these staged models are based on the Software Engineering Institute (SEI) Capability Maturity Model Integration (CMMI) [13]. CMMI is a 5-stage maturity model – Initial, Managed, Defined, Quantitatively Managed, and Optimizing - and was created for the development, maintenance, and acquisition of software products and services, but has been adapted for use in other areas, such as e-Government. One of the widely cited work on e-Government maturity model is the work by Layne and Lee [14], whose work identified 4 stages – cataloguing, transaction, vertical integration and horizontal integration; these stages are based on the complexity involved and different levels of integration. The staged maturity model has also been extended as open government maturity model, using heritage institutions as case study [15]. The focus of an open government maturity model is the evolution from proprietary data silos to a commonly shared data infrastructure that facilitates data sharing and reuse across government departments and outside the confines government. Staged maturity models have also been applied in the adoption and use of AI in the public sector, following the success of its use in the private sector. Different AI maturity models have be developed to guide industry practitioner in adopting and using AI [16], [17]. Providing guidance for adoption and use of AI in the public sector comes with it unique challenges arising from the peculiarities of government [18]. A combination of the maturity models in e-Government and AI in the public sector, gives a wholistic roadmap to guide the development in the AI in e-Government field.

The goal of this article is to provide a review of the research activities within the AI in e-Government field over the years, from a computational perspective. This article is not a systematic review in the sense described by [19], [20] mainly because of the paucity of literature available in the field, but rather a selective review of existing literature found in the field, with a view to providing an indicative research outlook for AI in e-Government. This review focuses both on the research and practitioners' applications of AI in e-Government and serves two purposes – a meta-review of e-Government generally and a survey of work done in the AI in e-Government field. A meta-review of the e-Government field, in the spirit of similar meta-reviews done in the computer science[21], social sciences [22] and management sciences [23], affords an opportunity to synthesize the reviews into a coherent statement of research direction in the field.

The remainder of this review is organized as follows. Related work is described in section 2. Section 3 gives a review of the different strands of research and practice in the AI in e-Government field, including aspects that relate to data management, intelligent web services, and machine learning. An indicative research outlook is given in section 4. The review is concluded in section 5.

2. Related Work

AI in e-Government, in its present form – beyond the use of SW technologies in e-Government, is a relatively recent domain in terms of both research and practice. As a result, there appears to be a lack of comprehensive overview, across the breadth and depth, of the field [24]. Nevertheless, this review builds on work that have been done in the field and the fields of the underlying technology areas that contribute to the AI in e-Government field. Quite a few of the these reviews address the field from a non-computational perspective – political, socio-economic, legal, and public administration [25]–[27]. This review is done from a computational perspective. A relatively recent and fairly comprehensive work on e-Government is the survey by [24]. The authors carried out a systematic literature review and organized the literature using a novel literature classification schema into model type, model focus, collaborative schemas, and interoperability levels. This survey was done on collaborative e-Government processes to answer the following research questions – what kind of representations, in the form of architectures, framework, ontology, meta-model, model or process, are used to model these processes; which concern – cost, value, citizen, technology, organization, do they focus on; how do they address collaborative processes concepts (interoperability and collaboration). While the survey comes up with finding that addresses its research questions, it also identifies some research challenges including use of new technologies, the use of ontology with AI to achieve the interoperability and integration objectives of e-Government, incorporating linked data, as well as development of meta-models for e-Government. A contrasting, yet comprehensive and recent perspective of e-Government survey was carried by [28]. The article describes a review of work done on digital government architecture over the years and identifies the main characteristics and components for the establishment of a digital government infrastructure. The review takes an architectural approach to conceptualizing e-Government and identifies common characteristics such as interoperability and integration, reusability, scaling, citizen-centric, and adaptability; as well as technology standards such as

XML, SOAP, WSDL, REST, and OWL-S. The review also aims to provide the basis for the development of a reference architecture for e-Government application is any context.

3. Strands of Research in AI in e-Government

3.1 Data Management

Early research activities in AI applications in e-Government was largely driven by research in the Semantic Web (SW) field, in the 2000s. The focus of research in the SW field has shifted from Ontologies in the early 2000s to Linked data(LD) in the mid-2000s, and lately to Knowledge Graph (KG) in 2012 [29]. The shift in focus of AI in e-Government research has followed this trend.

The Semantic Web is a vision of the web as a web based on machine-processible data, in addition to a web of human-only readable pages with texts and pictures, which is the case currently. This vision of the web was started or popularized by the seminal article by Tim Berners-Lee [30]. In order to achieve the vision of the SW, a data-oriented architecture - where data is decoupled from one application for reuse by other by other applications [31], needed to be adopted. In addition, a data-oriented architecture needs a data model (metadata, schema, vocabulary). These models are generally in the form of ontologies. Ontology has its roots in the field of philosophy that is concerned with the study of being and existence. In computer science, a definition of ontology that is widely cited is given by[32] as “a formal explicit specification of a shared conceptualization”. Ontologies sit on one end of a spectrum of Knowledge Organization Systems (KOS) [33] such as folksonomy[34], controlled vocabulary [35], taxonomy [36], thesauri [37], and then ontology, as shown in figure 1.

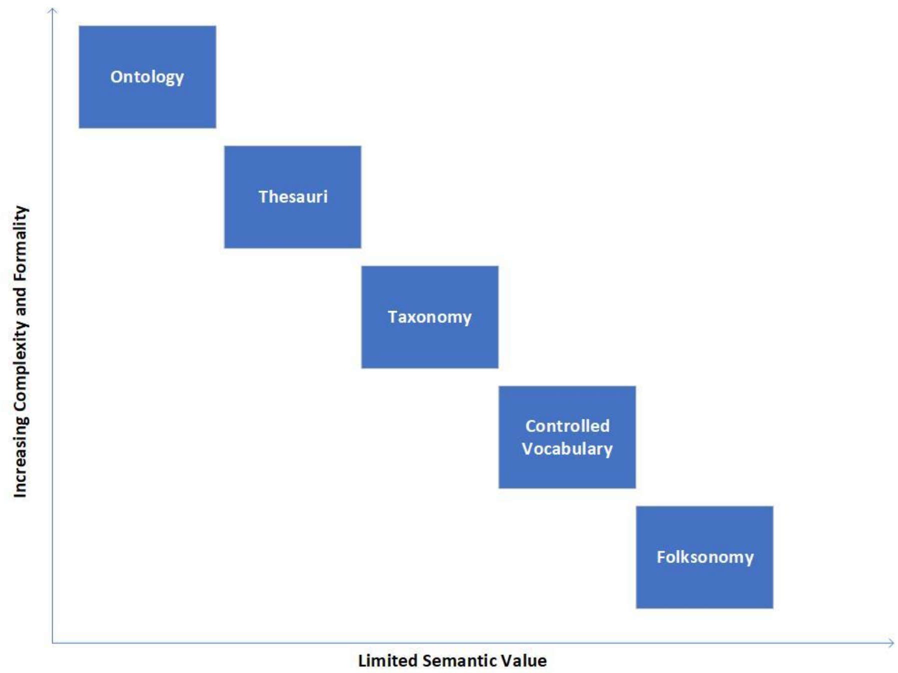

Figure 1. Knowledge Organization System (KOS) spectrum

A basic ontology has two classes of elements – entities and the relationships between the entities (e.g., ***life event*** – such as marriage, is a concept around which a ***citizen*** organizes her engagement with ***public services*** provided by ***public organizations***). In order for this knowledge to be machine-processible, ontologies are normally expressed in a language with a formal semantics and an inference mechanism[38]. The Web Ontology Language (OWL) is a W3C standard and is generally used to express ontologies [39]. OWL is based on description logic which in turn is based on decidable fragments of first-order logic [40]. OWL is also built on a W3C standard for objects called the Resource Description Framework (RDF)[41]. RDF is essentially a directed graph comprised of a triple statement – a subject node, an object node, and a directed arc for the predicate connecting both nodes. Many RDF graphs can be combined to form a larger graph as shown in figure 2. There are six triples in figure 2, with each triple appearing as a labeled edge. The child_birth313 node represents an instance of a child birth life event, and everything we know about that life event can be represented at that single node, which is both a subject and a predicate. This same information appears on 4 different rows in Table 1, which is tabular representation of the graph data in figure 2. Unless stated otherwise, all nodes and edges are identified by IRI shown on birth_registration121 node, which is the domain IRI. The nodes in this domain can link to nodes in other nodes outside the domain – i.e., Bidere in the *geonames.org* domain and *DateTime* data type in the XSD domain.

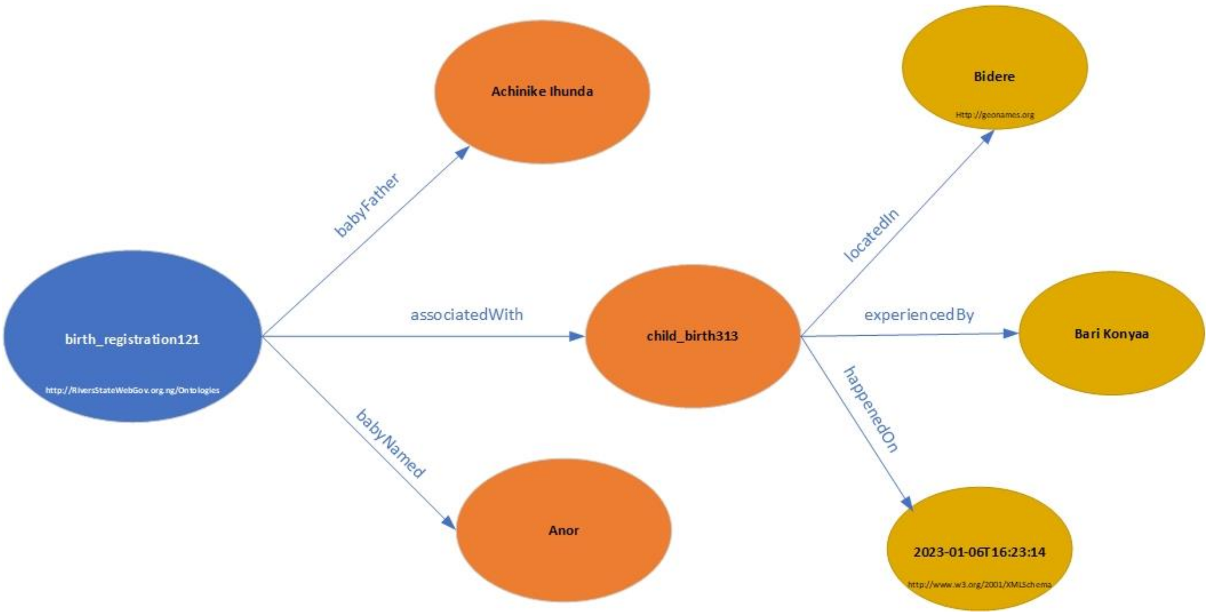

Figure 2. An RDF graph representation of triples describing birth registration and child birth

An RDF dataset is a collection of RDF graphs that comprise a default graph and zero or more named graphs associated with an IRI or a blank node. This dataset – the tabular form of which is shown in Table 1 - can be stored in an RDF database (or triplestore), and queried using SPARQL [42], which is based on graph pattern matching.

Table 1. RDF dataset derived from the graph in figure 2

Subject	Predicate	Object
:birth_registration121	:babyFather	:Achinike Ihunda
:birth_registration121	:associatedWith	:child_birth313
:birth_registration	:babyNamed	:Anor
:child_birth313	:experiencedBy	:Bari Konyaa
:child_birth313	:locatedIn	geo:Bidere
:child_birth313	:happenedOn	xsd:2023-01-06T16:23:14

RDF is used as a general method for description and exchange of graph data serialization formats, including Turtle, N-Triples, JSON-LD, and RDF/XML. Figure 3 shows a fragment of the serialization, in RDF/XML format, of the birth_registration121 and child_birth313 nodes shown in figure 2. Here the subjects(birth_registration121 and child_birth313) are referenced using the XML attribute rdf:about; the triples, with each of these as subjects, appear as sub-elements within these definitions.

```xml
-<owl:NamedIndividual rdf:about="http://WebGov.RiversState.gov.ng/Ontologies#birth_registration121">
    <rdf:type rdf:resource="http://WebGov.RiversState.gov.ng/Ontologies#Birth_Registration"/>
    <Ontologies:associatedWith rdf:resource="http://WebGov.RiversState.gov.ng/Ontologies#child_birth313"/>
    <Ontologies:babyFather rdf:resource="http://WebGov.RiversState.gov.ng/Ontologies#Achinike_Ihunda"/>
    <Ontologies:babyNamed rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Anor</Ontologies:babyNamed>
 </owl:NamedIndividual>
-<owl:NamedIndividual rdf:about="http://WebGov.RiversState.gov.ng/Ontologies#child_birth313">
    <rdf:type rdf:resource="http://WebGov.RiversState.gov.ng/Ontologies#Child_Birth"/>
    <Ontologies:experiencedBy rdf:resource="http://WebGov.RiversState.gov.ng/Ontologies#Bari_Konyaa"/>
    <Ontologies:locatedIn rdf:resource="http://WebGov.RiversState.gov.ng/Ontologies#Bidere"/>
    <Ontologies:happenedOn rdf:datatype="http://www.w3.org/2001/XMLSchema#dateTime">2023-01-06T16:23:14</Ontologies:happenedOn>
 </owl:NamedIndividual>
```

Figure 3. Fragment of the RDF/XML serialization of the birth_registration121 and child_birth313 nodes

Beyond the e-Government domain, ontologies have also found notable large-scale applications in other fields such as the Gene Ontology [43] in life science, the SNOMED CT [44] in healthcare management, and DBpedia [45] – a large scale general knowledge base extracted from Wikipedia. While ontologies are formal and heavyweight schemes (or vocabularies) for organizing distributed data across the web, the other KOS schemes, in figure 1, are informal and lightweight. These informal vocabularies are not amenable to being shared and reused across the web, due to their limited or no semantics, which limits their value. However, they have existed for a long time, well before the formal ontologies, and there is a large number of these vocabularies, mainly from the field of information and library science. Simple Knowledge Organization System (SKOS) [46] is a W3C standard designed for representing these informal vocabularies in a distributed and linkable way across the web, and making them semi-formal as a result.

Research and practice in the AI in e-Government field during this period have taken two forms - a whole-of-government ontology-based projects and ontology-based projects in specific government departments or domain applications. In addition to the whole-of-government projects mentioned in the previous section – SmartGov [7], TerreGov [8], OntoGov [9], GEA [4], [10], which are all based on the Life Event Ontology [11], there were specific domain ontology-based projects that addresses specific domain application for a government department. The "Hybrid Refining Approach of PrOnto Ontology" [47] describes one such application. The work describes research aimed at validating and refining legal ontology – PrOnto, using the General Data Protection Regulation (GDPR), privacy documents, and open information extraction tools. PrOnto builds on other foundational ontologies.

Linked Data(LD) is created when the components of an RDF triple – subject, object and predicate, are each represented by an Internationalized Resource Identifier(IRI), and each IRI (referencing the same individual) can appear in multiple graphs, thus creating links between the graphs [48]. A key difference between the RDF dataset and a LD dataset is that while a pure RDF dataset allows only limited inter-dataset linkages since RDF does not support owl:sameAs construct, LD can have inter-dataset linkage with owl:sameAs [49]. In addition, there is a shift of emphasis to shallow and simple ontologies in Linked Data [29]. Linked Open Government

Data(LOGD) was the fastest evolving part of the linked-data web, when the focus of the SW field was on LD [31]. Key benefits of the Open Government Data (OGD) paradigm align with the e-Government objectives of transparency and citizen engagement in addition to facilitating reuse of government data, opening up new business opportunities, and distributing the cost of government data processing to user communities. The LOGD initiative was the catalyst for many OGD projects around the world. The first official report from the world's largest open government project – Data.gov, operated by the United States government was made, where it described the background of Data.gov, and the current and future use of linked data for organizing knowledge and vocabularies in an OGD portal [50]. The experience of deploying a public data catalog – Data.gov.uk was also describe by [51], to illustrate important research challenges in integrating OGD into the linked-data web, and highlights the lessons for governments, technical communities and citizens. The importance of data provenance is highlighted in an LOGD project – "Record-keeping and Linking Government Data in Canada", which also describes the requirement for sound record-keeping while identifying the challenges to LOGD based on the experiences in record-keeping within the government of Canada [52]. Again, some of these OGD projects were specific domain application areas such as environment management. One such domain specific OGD project is the EU Environmental Information and Service Harmonization and Interoperability, which seeks to build an infrastructure for spatial information in the European community project, the goal of which is to develop a highly interoperable cross-border e-environment framework for the European Union [53]. The need for commonly agreed RDF schemas in enabling data links and mashups is again reemphasized in the work describing the Brazilian OGD portal [54], while the Australian government took a needs-based approach in building Australian National Data Services [55] which describes the architecture and experience involved in the "Making Research Data Available in Australia" project, and states lessons learned from linking government-funded research data. Following the same paradigm, an information science community-based solution for provenance tracking in LOGD; this solution uses a well-established conceptual model – Functional Requirements for Bibliographic Records.

Focus in the SW field shifted to Knowledge Graph (KG) when Google announced its KG with the release of the "Things not Strings" article by Amit Singhal [56]. Unlike the LOD initiative, which was largely driven by governments and other public organizations, KG was driven by, and finds large scale use in industry [57]. Normally, private organizations do not show as much commitment to openness as public organizations, mainly because of the need to protect their intellectual property, which may be a basis for competitive advantage in the market. While there are challenges to building a web-scale infrastructure for LD [58], this situation did not obviate the need for data management using LD technologies for specific domain applications, where the data is much more consistent and more tightly controlled to ensure quality [29]. Attracted by the data sharing, discovery, integration and reuse properties of KGs, governments around the world found a need to develop KG solutions as a way to manage their data and services. Many governments around the world, including national, sub-national, and local governments have sought to take advantage of the data management capabilities of KG. One such use case is the Zaragoza city council KG, which was done in response to open-data regulation, policies, and trends, to build an information system that facilitates open-data for citizens and organizations [59]. This work has led to the generation of the Zaragoza KG, which constitutes a key piece of its data management system. This system is based on open-data standards with shared data model designed to ensure interoperability and efficient data reuse.

3.2 Intelligent Web Services

The essence of e-Government is in improving internal operations of government and its engagement with citizens. Government operations and citizens engagement is carried-out under 3 broad operating models namely Government-to-Government (G2G), Government-to-Citizen (G2C), and Government-to-Business (G2B). Web Services Composition (WSC) [60] is used as a means to realize these operating models by enabling interoperation among different government departments and ensuring integration between them. The web emerged as a human-readable collection of static pages, containing a huge amount of information, which is not in a form that can be processed by computers. Even when the web evolved to include software applications with user-generated content, these applications were designed mainly to interact with humans. While part of the web could be processed by machines, the processing done were mainly syntactic, with no semantics involved. Currently, there is interoperation of services on the web in such areas as B2B, ecommerce (B2C) and public sector (G2C) applications, and these models of operation are widespread and based on standards such as Universal Description, Discovery, and Integration (UDDI) [61], Web Services Description Language (WSDL) [62], Business Process Execution Language for Web Services (BPEL4WS) [63], and Web Services Choreography Interface (WSCI) [64] [65]. Traditional Web Services(WS) infrastructure uses XML to describe multiple layers of abstraction from the transport mechanism, including message description – Simple Object Access Protocol (SOAP) [66], a mapping from messages to operations performed by the WS (WSDL), abstract process representation (BPEL4WS and WSCI), and discovery (UDDI). However, these interoperations are achieved through Application Programming Interfaces (APIs), which are hand-coded means of exchanging information between any two or more services, using programs. APIs are specifications for program interaction, and when these specifications change, the programs will need to be updated to accommodate the changes. This is a manual procedure, and can be almost impossible to accomplish when a large number of services is involved.

Traditionally, WSC is a highly complex process due to the high number of available services (millions in some domains), the dynamic nature of WS, and the different concept models used in developing the WS by different organizations [67]. Addressing these challenges had led to the use of automated means for WSC. These automated means are broadly classified, depending on the degree of automation, into workflow based and AI planning approaches. The workflow methods are mainly use in situations where the process model is known a priori - a dominant example in this category is BPEL4WS - while the AI planning methods are used in situations where the process model needs to be developed at runtime, and these methods offer more promise of meeting the WSC challenges. Some examples of AI planning methods include Situation Calculus [68], Planning Domain Definition Language (PDDL) [69], and Rule-based Planning [70].

The vision of the Semantic Web is to move the web from a web of pages designed for humans, with texts and pictures, to that more accessible by computers by making the web full of machine processible data [71]. Semantic description of the Web is a necessary requirement to have a relatively higher automated interaction of software systems (agents) across the web. This richer semantic description of the Web, with a semantic-aware software agent, enables the automated discovery, invocation, composition, and interoperability of WS [72]. As stated earlier, locating, invoking, and composing WS to meet a user request is a complex process, not amenable to be done manually; one reason that makes this process complicated is that, in addition to the complexities of finding and combining services to meet a user request, the user request can be fulfilled by more than one combination of services. So, one challenge in this area is to find an optimal combination of services that meets a user specified request. Researchers have investigated the use of SW technologies to address the WSC challenge. One approach that employed SW technologies is the DARPA Agent Markup Language (DAML) project described by [73]. DAML is a family of semantic markup language designed to facilitate and realize the vision of the SW – a machine processible web - and enable Semantic Web Services (SWS). DAML-S is a subset of the language focused on enabling WS to be developed using semantically grounded and rich representation of the web services that various agents can interact with [72]. DAML-S evolved into OWL-S [74] due, in part, to the more expressive power of OWL. OWL-S is a subset of OWL designed specifically for the semantic enrichment of WS, and has 3 components – service profile, process model, and service grounding [75]. In addition to these 3 components, OWL-S also uses an Input, Output, Precondition and Effect (IOPE) model to characterize a WS in order to reason about, enact, and compose the service. [75] also show that OWL-S can be integrated with existing WS standards – WSDL, UDDI, BPEL; enable automation and dynamism in WS for both providers and users; engender an ecosystem of powerful methods and tools; and advance the use of semantically well-funded reasoning about services. While OWL-S was funded by the United States government, an alternative approach to SWS – Web Service Modeling Ontology (WSMO) [76], was funded and driven by the European Union. Conceptually, WMSO is based on the Web Services Modeling Framework (WSMF) [77], has focused goals, specific application domains and has no compulsory ontology requirement. OWL-S on the other hand is based on OWL, has wider goals and not focused on concrete application domains. WSMO define four major components to describe WS – ontologies, goals, mediators and web services descriptions.

Many SWS frameworks have resulted from the many works undertaken to bring the world of SW technologies and Web services. In addition to the two dominant frameworks, there are numerous extensions to these and alternative approaches that exhibit significant differences with respect to the technological standards, languages, and underlying formalism that are used, despite sharing some similarities. These approaches to SWS are compared on the basis of how they are compliant and integrate core design principles of the Web, Semantic Web, distributed computing, and services-oriented computing [78]. Fensel et al also identified the criteria for comparison, reflecting these principles as: web compliance, ontological foundation, strict decoupling, centrality of mediation, ontological role separation, description independent implementation, execution semantics, and separation of service vs Web service. Semantic Web Services Framework (SWSF) [79] is an extension to OWL-S designed to overcome the restricted expressivity of its description logic base and provide formal definition of the dynamic aspects of SWS based on the Process Specification Language (PSL) [80]. Reasoning support for SWSF is provided based on its OWL-DL variant, which lacks the expressivity to define all parts of the user model – e.g., defining conditions within the process model. This gas in expressivity is augmented by a rules language such as the Semantic Web Rule Language (SWRL) [81]. Reasoner such as KAON2 [82] are capable of dealing with both OWL-DL and the rule language that augment it. Web service discovery in SWSF is achieved by comparing the ontological relationship between the input/output template of a user request and a candidate service. Such match-maker has been proposed and implemented by Klusch et al as OWLS-MX

[83], which matches based on semantic and syntactic properties. Service Composition is mainly achieved by AI planning based techniques and some tools have implemented this approach [84]–[86]. In contrast to the approaches promoted by WSMO and OWL-S, METEOR-S [87] adopts a bottoms-up approach to semantically enabling Web services technology. METEOR-S relies on existing Web services standards such as WSDL and its semantically enriched variant – Semantic Annotations for WSDL (SAWSDL) [88], [89]. The METEOR-S project has different elements that addresses the different aspects of the semantic Web processes life cycle including annotation, discovery, composition and enactment of web services. The METEOR-S Web Services Annotation Framework (MWSAF) [90] is a framework for the semi-automatic annotation of Web services. These annotations address four different aspects of Web services semantics - input/output, functional definition of semantics, execution semantics, and QoS semantics. A realization of the MWSAF is SAWSDL, which is a lightweight approach to associate semantic annotations with Web services using existing Web services standards – i.e., WSDL. For Web service discovery, the METEOR-S Web Service Discovery Infrastructure (MWSDI) [91] leverages semantics to enhance existing Web services discovery infrastructure. The METEOR-S Web Services Composition Framework (MWSCF) [92] is a framework used to accomplish semantic composition of Web services in METEOR-S. The essence of the framework is generating executable processes by binding semantically defined activities to concrete Web services that conform to the activity's specification.

Lightweight approaches to distributed services computing have become the mainstay of Web services, in recent years, and has given rise to an architectural design pattern – Microservices Architecture (MSA) [93]. Microservices are loosely coupled, independent, highly specialized applications that aligns better with the stateless and resource identification nature of the Web and its communications protocols – HTTP, URI [94]. The stateless service is delivered as a Representational State Transfer (REST) services, which uses URI to identify resources which are manipulated using a fixed set of operations – GET, DELETE, POST, and PUT [95]. Many mechanisms have been used to describe RESTful services, for the purpose of making those descriptions machine-readable, in the same way that WSDL is for traditional SOC. These standards include WADL [96] and Open API [97]. WSMO-Lite [98] and MicroWSMO [99] are two related lightweight approaches to semantic Web service description, based on the WSMO framework. WSMO-Lite defines an annotation ontology used in SAWSDL; and MicroWSMO and hREST [99], [100] are used to provide semantic annotation support for unstructured HTML description of RESTful services.

Several research and practitioner-oriented work have been carried-out in the field of e-Government SWS, spanning the complete life-cycle of semantic Web processes - annotation, discovery, composition and enactment of Web services - with a view to realizing the various e-Government objectives. A noteworthy work on ontology based composition of e-Government services using AI planning was done by [101]. This work describes a novel approach for SWS composition based on AI planning and multi-agent technology applied to the e-Government domain. The objective of this approach is to enhance interoperability and integration in the e-Government domain, by semantically enriching WS with metadata that enables agents to process the WS and automatically compose a service to meet a citizen's service request. Another work on e-Government service composition is the one carried out by Elmaghraoui et al [102], which describes an approach for optimization of WSC in e-Government based on graph theory. This approach relies on the Floyd-Warshall algorithm to compute the shortest path and hence the optimum path between any two services in a service composition graph. The service composition graph is a graph whose nodes represents e-Government Web services, and the directed edges between the nodes represents a semantic similarity value and a value represented by a non-functional property (i.e., cost, service execution time, reliability, and availability). The optimized service composition path is computed at the time of service publication rather than at the time of service request, to reduce the computational resource requirement. The semantic component of the service composition graph is based on the description of the input and output parameters of the services, and the service modeling is based on OWL-S. This work builds on semantic WSC based on graph search, such as the one done by [103], which describes the development of an algorithm that solves the WSC challenge in significantly improved time. The algorithm is polynomial time based on graph search, combined with a heuristic to reduce the number of services included in the composition. Another cornerstone of the work is the work on semantic matching done by [104], which describes a novel work done to move the Web along in the quest to achieve autonomous Web service interaction. This is achieved by performing a semantic match between the Web service request and advertisement, to achieve one component of automated Web service interaction – service discovery. In addition to the use of OWL-S to express the capabilities of the Web service, a matching algorithm is specified to be used on that OWL-S service representation. Semantic based composition is extended by Zhang et al [105] to include QoS attributes. The authors describe a novel Web service search engine that searches for Web services across the Web based both on functional and non-functional QoS characteristics of the Web services. This work goes beyond the keyword-based characterization of the Web services and uses a representation of the functionalities of the Web services to capture the semantics of the Web services. The QoS characteristics are added to distinguish cases in which the functional characteristics are identical. The QoS characteristics are based on such factors as penalty rate, price, response time, availability and reliability; and the functional criteria is based on a similarity model where the Keyword-Input-Output vector of a user query is compared with the Keyword-Input-Output vector of an advertised service.

3.3 Machine Learning

In recent years, AI in e-Government has been more in the form of data-intensive cognitive systems underpinned by ML. AI solutions based on ML is being used to solve problems in public services domain such as language translation, augmenting human decision making, improving the effectiveness of service delivery through citizens service personalization using data in citizens' profile and previous service interaction, and use of chatbots to answer service enquiries. A combination of factors has contributed to the adoption of data-centric AI in many domains, including e-Government. These factors include the big data phenomenon, increased availability of more powerful compute resources and advances in data-analysis algorithm.

Researchers and practitioners have used ML-based systems to automate e-Government services in both departmental and whole-of-government contexts. A proposal for a novel approach for the use of DL for Arabic letter and numbers recognition, and Arabic sentiment analysis has been put forward by [106]. Contained within this approach are 3 components that define it – a framework for the management of government resources, an end-to-end view of the e-

Government life-cycle, and a smart platform for the development and implementation of AI in e-Government. In the area of the use of ML to augment and aid human decision making, "RIGOR: A New Proposal for Predicting Infant Mortality in Government" describes the development of a method for predicting the mortality rate of newborn babies, using dataset from the Brazilian government, focusing on two key features – APCAR score and gestation weeks, from the dataset [107]. Others researchers have used DL to develop a referral system for patients with Retinopathy [108]. Here, the authors work used techniques that addresses screening diabetic retinopathy for the reduction of vision loss and blindness risk in patients. This approach seeks to solve the problems of clinical integration and the lack of optometrists in the specific region of the project.

Data-centric AI has also been applied in solving problems associated with the Web services life-cycle processes – annotation, discovery, composition, enactment and interoperability. One area in which this has be applied is schema matching using ML. The schema matching approach in use in the MWSAF [90] is replaced with enhanced ML approach using a Naïve Bayes Classifier [109], to predict the domain a particular Web service belongs. This ML approach used provided significant performance improvement over the schema matching approach.

4. Future Direction

e-Government is a large, heterogenous, dynamic, large and shared domain, and brings many technologies together in one place. This situation affords researchers and practitioners an opportunity to explore these technologies individually and the synergies between them. In today's world, AI and its underlying technologies – SW, KG, ML, DL, MAS - have become a key component of e-Government. Although, a lot of progress have been made in advancing the cause of AI in e-Government, many challenges remain, and the research outlook, in the next half-decade or so, will be driven by these challenges.

One prominent challenge in this domain is the problem of data management. Although this problem is not peculiar to the e-Government domain, it has taken on a more significant position in the strategic dashboard of many research communities, and even more so in an era of big data and open data. Even though the vison of the SW – a web of machine processible data, is yet to be realized, the field has led the development of methods and tools for data sharing, discovery, integration and reuse, in its quest for efficient data management [29]. Researchers are asking more fundamental and scientific questions about how data is represented and structured to better reflect the real world; and practical and technological questions about how to manage and exploit all the data collected by government [110]. These questions have driven research effort in areas such as KG and the different strands of research within its various communities.

Another area with promising research outlook is in service computing within the e-Government domain. Automated service composition has been driven largely by SW technologies using traditional web services standards – e.g., SOA, SOAP. Nowadays, researchers and practitioners are shifting their focus to achieving web services automation using newer standards such as microservices architecture, REpresentational State Transfer (REST) API, and JavaScript Object Notation for Linked Data (JSON-LD). Research in this area dates back to more than a decade ago [111], and it is taking a more prominent position is web services research due to the maturity of the newer standards.

A third area of research outlook is in the area of augmentation of ML in e-Government using data from SW technologies. This research area looks promising due to the benefit SW technologies offer as a primary and secondary data source for ML solution in e-Government. A crucial factor in the effectiveness of ML models is the quality of the data. The problem of data quality is particularly acute in the e-Government domain due to the ongoing problem of biased, discriminatory, and incorrect data used in ML. The basing of public policy decisions on these types of data leads to disastrous consequences for governments, citizens, and businesses alike. This fact is underscored by [112] – "Every AI project starts from the same point: data", highlighting the fact that government should ensure that they have access to sufficient unbiased data quality and quantity before taking advantage of AI techniques. Research effort has been directed at improving the effectiveness of ML models by the use of logic-based AI models such as KG to provide the data ingredient for ML models. This helps to address the problems of data quality, quantity and result interpretation [113]–[115] . However, problems remain in the areas of commonsense reasoning, quality and paucity of data, and interpretation of results of ML models

5. Conclusion

Semantic Web technologies drove research effort and practice in the AI in e-Government field in the early years of the field, and it was mainly used for government data management and e-Government service composition. The focus shifted to ML-based AI approaches to addressing the problems of e-Government. Research effort that combines both approaches are beginning to emerge and are likely to drive activities in the field for the next half-decade.

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