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A COGNITIVE COMPUTING CONCEPTUAL MODEL FOR AGILE E-GOVERNMENT DESIGN

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Annotation. Studies have linked e-government failures (primarily its adoption and development) to factors such as design shortcomings and design-reality gaps. With the increased availability of big data and analytical techniques, government agencies must leverage data-driven models in the design and implementation of electronic government (e-government) or digital government solutions. By doing so, minimizing design-reality gap problems and design shortcomings is attainable. Backed by stakeholder theory and the Agile design methodology, this study proposes a cognitive computing framework as an efficient approach to the design of public sector electronic services (e-services) so as to obtain value. Cognitive computing was deemed appropriate for inclusion into the Agile methodology for e-government design because of its rapid frequency of expansion of data for which the human mind is limited in analytical ability as well as the desire by policy makers to reduce burdens and cost against the desire for more tailored solutions. With respect to research, cognitive computing models present a novel means of implementing human-centric and data-driven processes into practical domains of discourse and these models have yet to be integrated into the e-government sphere. By applying design thinking, the proposed model is built and tested in the UPPAAL model-checking software by applying the principle of finite state deterministic automatons. Theoretical and practical contributions are made to the fields of e-government, Agile methodology, and quality service delivery. Future research recommendations for expansion and building evaluation metrics are also indicated in the study.
Keywords: E-Government, Agile Design, Cognitive Computing, Data-Driven, Human-Centric, Stakeholder Theory, Finite State Automata.

INTRODUCTION

E-Government (Electronic Government) plays a vital role in the ecosystem of public service delivery in many nations today. It fosters national growth by creating business opportunities, increasing citizen satisfaction and trust in the government; improves Government agency to Government agency (G2G) interoperability. Governments which seek to enhance eService delivery constantly keep on integrating new social, economic or political aspects which affect the adoption process [1].

According to studies, bad design decisions could build up to a cataclysmic failure in e-service adoption because in their bid to satisfy identity assurance requirements, designers of e-services in many cases do not put citizen perspectives into consideration [2]. This generates hurdles for citizen/user adoption, negatively affecting the return on investment especially for public facing transactional e-services. Other studies have pointed out that e-government projects also fail due to reasons such as design-reality gaps and unrealistic planning [3].

In one scenario, due to the inefficiency of district courts in maintaining their own data-bases, the E-Government Act of 2002 was en-acted to provide online access to all written opinions, but

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the legislation after many years failed to be fruitful due to design strategies [4]. Also, it has been noted that failure of e-Government projects occurs right at the design stage and not the implementation stage [5].

With all the proof of e-government failure offered by past research, it is pertinent that design of e-government be highly considered by researchers in order to obtain effective electronic participation and return on investment.

The research question for this study is as follows: *How are agile methodology and cognitive computing integrated into the design of e-government systems?*

1. PURPOSE OF THE STUDY

1.1. Agile Design Methodology

The agile methodology or technique is an iterative method to make software development in shorter times with lightweight deliverables and cycles [6]. In software development, agile methods implement practices increase responsiveness and collaboration. The agile method has been widely adopted into many spheres such as software development, business process, innovation, etc. Within the context of e-government in the Philippines, research uses information systems benchmarking and agile methodology to propose a system design framework that develops a data management and analytics system [7]. The percentage of successful projects using agile methods is significantly higher than that of projects using traditional approaches which is due to the improvements that Agile techniques bring to project management (eg. "just-in-time" planning, iterative requirements gathering or frequent collaboration).

With regards to design, one major issue is design. Agile methods and practices have been known for more than a decade as an alternative for software development yet not quite popular in the public administration environment [8].

Researchers pointed out that the convergence of both e-government and agile methodology is a new area yet to be researched deeply into [9]. But, modern technology presents us with a solution to the existing challenge in e-government design. Agile software development methodologies can play a vital role here for cost effective and continuous development process [10]. According to the authors, it is important to produce a simple system quickly, and the small releases are necessary to gain feedback from the client

In light of this, this research seeks to answer the question: *How can cognitive computing be integrated into agile design of e-government?*

1.2. Cognitive Computing

Before diving into cognitive computing it is pertinent we understand the origin of the concept.

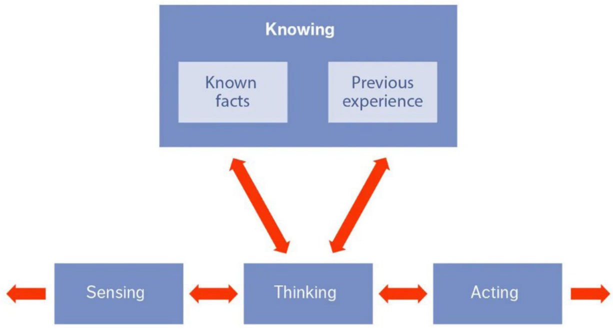

Fig. 1. The model of the mind (adopted from [11])

It has been pointed out that there is a tangible value to not knowing such as the loss of revenue and as such, cognitive computing helps enterprises discover the hidden patterns in data so as to create value [12].

Reasons for cognitive computing include the following: Massive Data (rapid frequency of expansion of data for which the human mind is

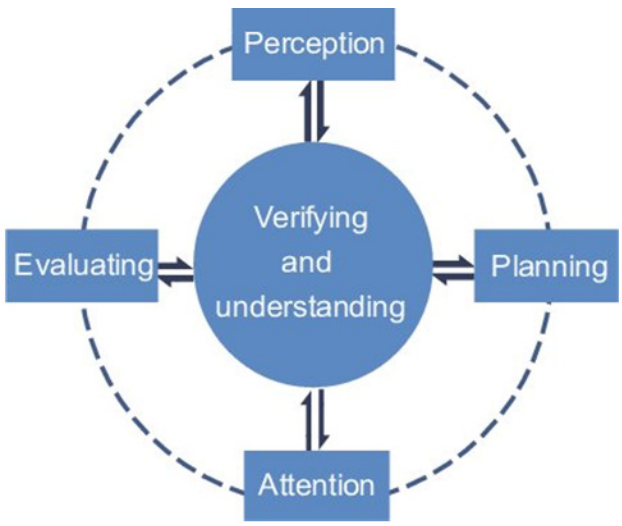

Fig. 2. Basic framework of cognitive computing (adapted from [13])

limited in analysing), Complexity of data and finding meaning in data, Competing Priorities (i.e. the desire by policy makers to reduce burdens and cost against the desire for more tailored solutions) [12].

Cognitive computing technologies are in the initial phase of adoption [14]. Cognitive computing is trained to process large unstructured datasets imposing machine learning techniques to adapt to different context and derive value from big data [15].

The major characteristics of cognitive computing are:

1. Capture — the collection of large volumes of data for storage to make it available for strategic analysis;

2. Connect — integrating varying data to obtain new information which is followed by the presentation of that new information in an easily understandable form;

3. Create — the creation of new knowledge, products, or services. The overarching characteristic of the three (3) main is change, i.e. the ability of the cognitive system to autonomously dynamically adjust or learn over time [12].

Studies have argued for the use cognitive systems to analyze big data to create a competitive advantage in healthcare by businesses as part of

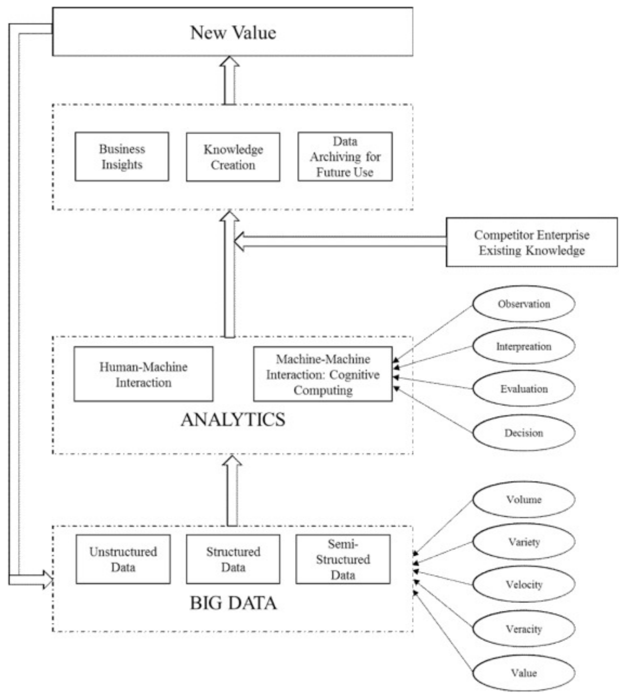

Fig. 3. Conceptual Model of Big Data and Cognitive Computing (adopted from [16])

a strategic process to create value. Figure 3 illustrates the process involved in extracting knowledge and creating value from big data. This is applicable in the realm of e-government.

It is being applied in areas such as healthcare, urban planning (i.e. smart cities) [17, 18]. Evidently, there is more demand for cognitive computing in healthcare due to the increasing health issues as well as the availability of computing power and data.

Cognitive computing helps the humans in decision making whereas AI based systems works on the concept that machines are capable of making better decisions on the human's behalf by examining a range of various types of data and its interpretation to generate rich insights. Cognitive computing is a sub-set of AI and anything that is cognitive is also AI. IBM Watson where the system is revolutionizing the healthcare industry by providing medical insights to doctors in better decision making [16].

Cognitive computing is a potential enabler for organizational ambidexterity which in turn enhances firm performance [14]. This is possible due to the fact that it facilitates enhanced data processing capabilities that can aid business decisions by means of providing a greater number of alternative solutions and enhanced data processing speed. Cognitive computing can have potential applications in analyzing consumer, financial and investment data along with analyzing socio-economic environmental data directly or indirectly affecting business operations.

Studies have suggested that cities are in need for more cognitive computing systems to facilitate effective and real-time communications among citizens [18]. Their study proposed an intelligent urban governance framework for a cognitive city that can impact citizens' collective behavior in regards to energy consumption by flow of information and learning processes.

A cognitive computing system framework was developed to meet the challenges in predicting judicial decisions comprising of a legal semantic understanding layer, a legal knowledge learning layer and a legal knowledge reasoning layer [19]. The researchers sought to meet the challenges of semantic understanding, knowledge learning and judicial reasoning in the Chinese legal domain. Using first logic base, a Markov Logic Network (MLN) model which consists of a series of $< F_i, w_i >$ pairs, where F_i is a first order formula and w_i is the weight of it. As a result, their technique, effectively predict the decisions for divorce cases with different expression styles as well as provide results can be easily understood by general public as applied induction rules are given.

Just like every major modern innovative solution, cognitive computing is also without challenges. Studies have pointed out a number of these challenges such as its inability to react swiftly to evolving environments in near-real time; the fear that cognitive systems taking away human jobs due to their automation capabilities; and also the invasion of personal privacy as well as defiance of privacy law [20]. Another huge challenge has to do with issues of trust in increased automation tied with the question of data quality and reliability [21]. This is because when garbage goes in, garbage comes out and as such the fear of bias and inaccurate data influencing the results for policy making presents a challenge.

From figure 4, a list of challenges in multimedia for decision making in a cognitive computing era. The authors indicate that despite the unique relevance of cognitive computing and its potential benefits, it presents several challenges as depicted in figure 4. Yet, these challenges can be overcome thanks to scientific advancement and research. As such, we encourage the use of cognitive computing models in e-government system design.

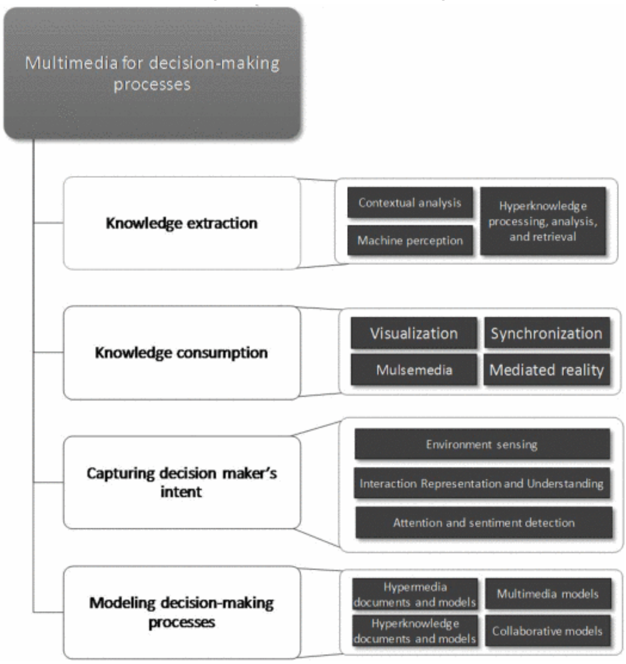

Fig. 4. Categories of Challenges in Multimedia for Decision Making in a Cognitive Computing Era (adopted from [22])

The next section discusses the proposed model.

2. MATERIALS AND METHODS

A study demonstrated the usefulness of the notion of "agent" or "actor" in designing, prototyping, and simulating sociotechnical systems. In other words, using Agent-Oriented Modelling (AOM) methodology for modelling, simulation, and prototyping of sociotechnical systems [23]. Agent-Oriented Modelling (AOM) offers software engineering processes and work products for agile design, simulation, and prototyping of distributed sociotechnical systems. As such, we propose our model by using AOM.

The goal of integrating cognitive computing into the agile development process is to build an all-inclusive model which aims at including modern technological techniques into the design process of e-government.

Cognitive computing is integrated in this model because it can tolerate data of mixed quality [21] which is an important feature required in designing of e-government due to the multifaceted nature of data sources (surveys, in-app logs, online social media sentiments, application review comments, user experience testing results, etc.). Research suggest that cognitive computing and big data will lower the cost of services incurred to the user in the long run as this system will reduce the human intervention [16].

In order to answer the posed research question, we employ the concept of design thinking in agile systems as a foundation for the proposed model. Design thinking methodology imbues the full spectrum of innovation activities with a human-centered design ethos [24]. It is the preferable method for this study because of its scalability and ability to be applied incrementally into already existing ideas thereby creating disruptive solutions while meeting human needs in an entirely new way [25]. An advantages of design thinking methodology is its potential of integrating technologies, innovative thinking, design process, and available resources into the human desire to build up new and innovative products [26]. As such, it is the preferred methodology for the proposed model due to the fact that the study aims at resolving how cognitive computing can be infused into the agile design methodology of e-government.

Upon integrating design thinking strategies and the cognitive computing framework into the agile methodology, we produced our final model. The model was built in the UPPAAL model checker software which is used in modelling, simulating and verifying models for real-time systems. Since the design process is in phases, all stages are treated as finite state automatons (FSA). Simulation and formal model-based testing of the proposed model were performed because researchers have indicated that they are capable of automatically detecting the hidden errors and the worst cases [27–28].

The method of formalization using finite state machines (FSM) is adopted for representation of key processes and concepts. Formalization with FSMs describe the sequence of states that an object experiences in its life cycle and how different states respond to various behaviors from the outside world [29]. FSMs are expressed mathematically as:

$$FSM = (Q, \sum \sigma, q_0, F) \quad (1)$$

Where q_0 is the initial state; Q is a set of finite states, i. e. $Q = \{q_0, ..., q_n\}$; Σ is a set of finite input characters, i.e. $\sum = \{\delta_1, ..., \delta_n\}$; and F is the set of finalized states.

The formalization and simulation of the proposed model is represented by the following formulae:

$$Q_{model} = Q_{agile} \times Q_{cognitive} \times Q_{sprint} \quad (2)$$

$$Q_{agile} = \begin{Bmatrix} Q_{specification}, Q_{design}, Q_{development}, \\ Q_{testing}, Q_{launch} \end{Bmatrix} \quad (3)$$

$$Q_{cognitive} = \{q_{bigData}, q_{analysis}, q_{newValue}\} \quad (4)$$

$$Q_{sprint} = \{q_{sprint1}, q_{sprint2}, q_{sprintEnd}\} \quad (5)$$

$$F = \{q_{launch}\} \quad (6)$$

$$\sum\nolimits_{agile} = \{\delta_{complete}, \delta_{phase}\} \quad (7)$$

$$\sum\nolimits_{cognitive} = \{\delta_{cognitive}, \delta_{reset}\} \quad (8)$$

$$\sum\nolimits_{sprint} = \{\delta_{one}, \delta_{two}, \delta_{end}\} \quad (9)$$

The algorithm for representing the simulated formalized model as:

Start Q_{model}
  Initiate q_{sprint} (δ_{one})
    Perform Q_{agile} process $(\delta_{reset} = 2)$
      Perform $Q_{cognitive}$ $(\delta_{cognitive})$
        Gather $q_{bigData}$
        Perform $q_{analysis}$
        Generate $q_{newValue}$
    Move to next Q_{agile} (while $Q_{agile} \le q_{testing}$)
    End Q_{agile}
    Update Q_{sprint} (δ_{two})
    End Sprint $q_{sprintEnd}$ (δ_{end})
    Move to q_{launch}
End Q_{model}

It must be noted that the algorithm presented does not include the synchrony, guards and update control parameters (i. e. $\delta_{cognitive}, \delta_{reset}, \delta_{complete}, \delta_{phase}$) though they are stated as input characters in the model's FSM definition. They are revealed in the visual representation of the model in the next section.

3. RESULTS AND DISCUSSION

The final results of the proposed model are presented in figures 5, 6, and 7 as formalized models.

Figure 5 illustrates the number of agile sprints we used in testing the proposed model. For the simulation phase, the total number of sprints chosen was two (2). Figure 6 depicts the main model of our research as a real-time transition system represented by finite state automatons. Using the agile model methodology with the cognitive computing framework integrated into it, each phase is executed when the necessary conditions (guard conditions) are satisfied. For example: the "cognitive?" guard condition instantiates the cognitive framework (i.e. figure 6) which runs as long as the condition reset <= 2, and upon completion the flag is reset to 1 (i.e. reset = 1).

Figure 6 illustrates the cognitive computing framework in a finite state transition system

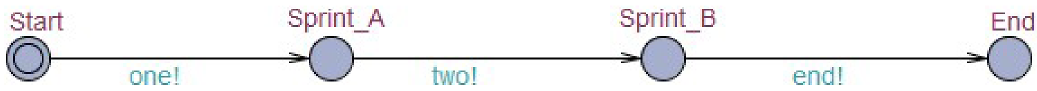

Fig. 5. Model Sprints (Simulation of Two Sprints)

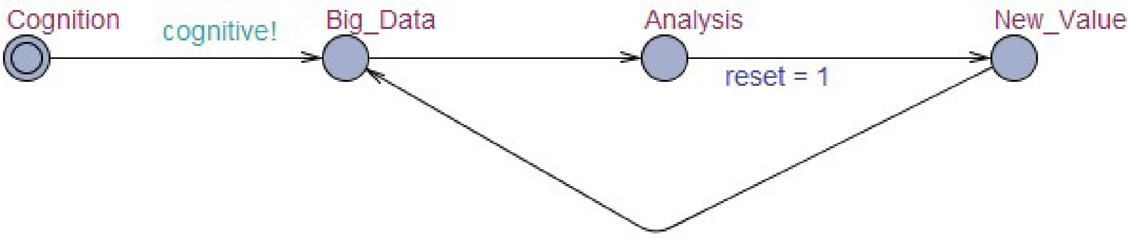

Fig. 6. Cognitive Computing Process

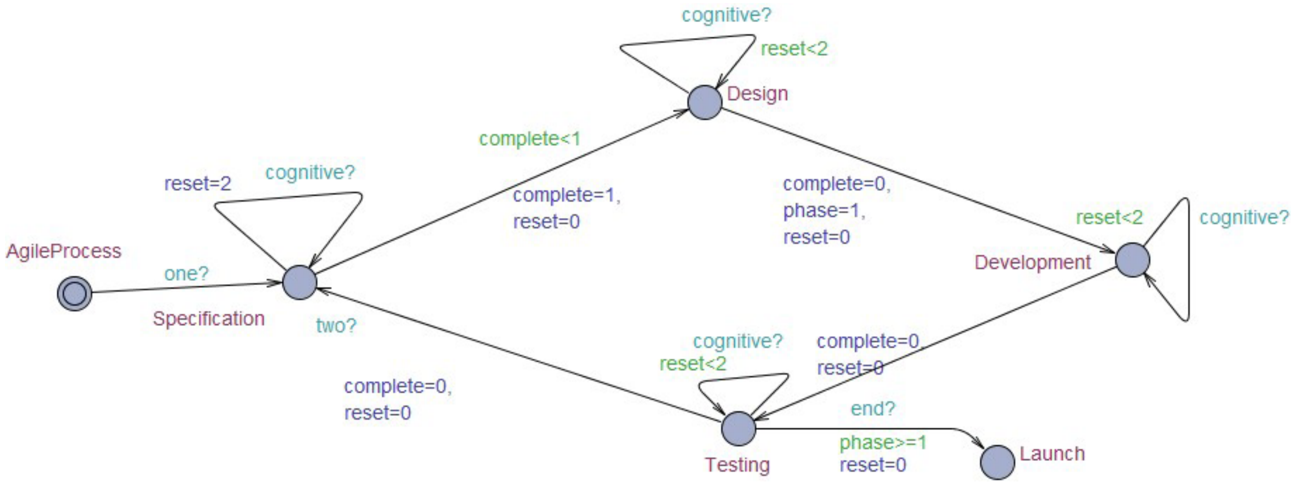

Fig. 7. Proposed Human-Centric Design Process with Cognitive Computing Model

where the method of cognition begins with the gathering of data, followed by analysis and then finally the new value is obtained. Upon obtaining new value the next phase is executed of the main model only when the cognition process for any current phase in figure 6 is complete. It is observed that the simulation was conducted twice before obtaining the final launch because according to studies, requirement engineering is the most challenging task in e-Government automation projects and should be an ongoing process as agile methodologies propose [30].

The final model's processes are mutually exclusive hence, when the cognitive computing process is being executed, all other processes come to a standstill. Figure 8, depicts the comprehensive framework's symbolic trace where mutual exclusivity occurs. A sequence diagram for the simulated conceptual model is generated by UPPAAL.s

To test the simulated model, the following queries (UPPAAL q-format [31]) were executed:

a. Query: ***E<>Agile_Process.Launch***

Description: Eventually the system is launched.

Outcome: ***Property is satisfied***.

b. Query: ***E<> not(Agile_Process.Launch and Simulation.End)***

Description: It should never be the case that sometimes when there's a launch, the simulation ends.

Outcome: ***Property is satisfied***.

c. Query: ***A[] Agile_Process.Launch imply Simulation.End***

Description: Always upon launching the system, the design process (whether iterative or not) must end.

Outcome: ***Property is satisfied***.

d. Query: ***E<> Simulation.End imply (Agile_Process.Design and Cognitive.New_Value)***

Description: There exists a path where Simulation ends when the agile design phase and new value from the cognitive model are satisfied.

Outcome: ***Property is satisfied***.

e. Query: ***A[] Agile_Process.Launch and Simulation.Start***

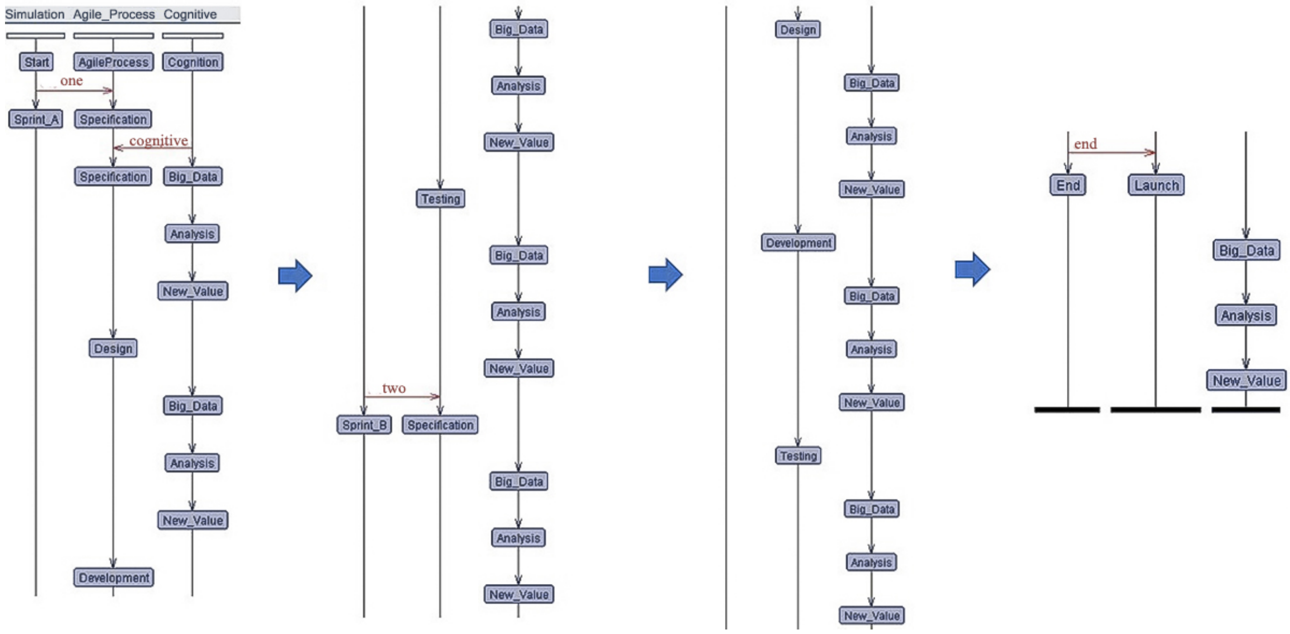

Fig. 8. Formalization of Proposed Conceptual Model – Sequence Diagram of Simulation

Description: The launch phase of the agile process must always be reached when the sprint process begins.

Outcome: ***Property is not satisfied***.

Through simulating and formal model-based testing of the model for two (2) iterative phases, it is evident that the model is feasible in a real-world scenario and has the potential of producing efficient e-government solutions. This is due to the fact that the design process integrates the agile methodology together with the principles of design thinking and the cognitive computing framework. During these processes, future end-users are involved in the design process (producing value-driven solutions) hence, producing the most efficient and cost-effective outcomes.

In order to back the veracity of the proposed model, a case for the development of a single window system for the clearance of imported goods at the ports of Ghana on a more specific level. The already existing GCNet system, which handles the clearance process, was set for replacement by Integrated Customs Management Systems (ICUMS) [30] and this caused shippers to raise various concerns. According to the Ghana Shippers' Authority, the goal of the existing service, GCNet, was to increase transparency and speed within the clearance process as well as ensuring that the right revenue is accrued [32]. Due to the lack of prior notice by authorities, the clearing agents, freight forwarders and importers were left stranded at the Tema port of Ghana [33]. In the first quarter of 2020, authorities temporarily suspended the transition from GCNET in order to prevent a loss of government revenue [34]. Also, end users commented on the problematic nature of the new system (i.e. ICUMS) [34].

It is evident that:

1. Stakeholders (primarily end users) were not involved in the design process of the system.

2. The abrupt transition led to a possible loss in government revenue

3. A wide design-reality gap was present since a new implementation was already on the verge of failure.

This picture solidifies the scientific fact that design-reality gaps, unrealistic planning and non-involvement of stakeholders in e-government leads to public mistrust and failure [3]. According to researchers, involvement of users has the capability of simplifying complexities in information systems [35].

Thus, our proposed model is a formidable solution for such a scenario. This is attainable by implementing deep learning and machine learning models, which are an embodiment of cognitive computing, to evaluate user experience from the past and compare with a selected pilot testing phases. During the pilot phase which is performed before general implementation, data must be gathered in the form of user satisfaction; user requirement evaluation; processing times (from requests to clearance); service provider (the employees of the ports) satisfaction with the ease of use of the system; and revenue. Post-implementation, a similar process can be adopted to comparatively evaluate user satisfaction over time. Also, end user perspectives and reviews may be solicited and the application of NLP (natural language processing), sentiment analysis and opinion mining techniques, could give providers a fair perspective of user experience as well as where changes need to be made. In doing so (adjusting the e-service to end user requirements while optimizing system benefit), value is realized, the gap between design and reality is minimized drastically, and government's return on investment is assured since the system will iteratively be improved upon through an agile data-driven methodology.

CONCLUSIONS

Research has revealed that e-government failure is triggered by a lack of design strategies. To avert the higher failure rate of e-government interventions, it is vital that effervescent e-government design be informed by context-aware conceptual frameworks and models [36]. Thus, this study aimed at developing a model that merges the modern concepts of agile methodology, cognitive computing frameworks and big data analytics in developing a human-centric data-driven design model. By building this model, we contribute to the scholarship in agile design methodology, e-government design and cognitive computing applications.

The outcome of our study reveals that by integrating a data-driven approach which collaborates with end-users in the design process, optimal user satisfaction is attainable.

Future studies will extend the model and develop metrics for evaluating and improving upon the model's performance.

CONFLICT OF INTEREST

The authors declare the absence of obvious and potential conflicts of interest related to the publication of this article.

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