A fuzzy logic model for evaluating the standard performance of a prototype online voting system

Matthew O. Odighi [a], Adetokunbo M. John-Otumu [b,*], Ceindrick C. Egbon [c], Obi C. Nwokonkwo [d]

[a] Department of Computer Science, Federal Polytechnic, Auchi, Nigeria
[b, d] Department of Information Technology, Federal University of Technology, Owerri, Nigeria
[c] Department of Computer Science, Delta State College of Education, Mosogar, Nigeria

ARTICLE INFO

ABSTRACT

This paper described the major challenges associated with existing methods of voting; hence a prototype online voting system was developed and proposed for credible election in Edo state with a mind set to trash out the various problems identified with the existing system. In order to determine if the prototype online voting system developed is of standard performance a fuzzy clustering means (FCM) was designed to evaluate and ascertain its performance based on certain criteria gathered using questionnaire designed. The FCM model was simulated and tested for evaluation taking into consideration stakeholders of election that were drawn from twelve (12) local government areas, out of the Eighteen (18) local government areas of Edo state. Opinions of stakeholders of the election concerning the wished-for model were arbitrarily sampled and analyzed for the use of assessment in particular when compared to the present system of selection. In addition, other factors that can promise an open and just election were also discussed and place into consideration throughout the implementation of the developed prototype online voting system. The result from the evaluation revealed that the seven (7) local government areas which formed about (58.33%) of the beyond least standard cluster and the five (5) local government areas, which also formed about (41.66%) of the regular standard cluster of the entire population of (12) local government areas were both above the average acceptable benchmark for elections, which is a key indicator that the developed prototype online voting software meets more than the standard for a credible election process and it is therefore proficient as a verdict announcer for a transparent electoral process when fully implemented and deployed for usage.

1. Introduction

Election is the process, which enable individual to decide freely and fairly, who should lead them at every level of government and take decisions that will shape the socio-economic and political destiny [1]. It is assumed to be the popular means for peaceful change of government in a particular time frame. Election is a basic instrument of democracy, as it enable individuals to enjoy the freedom of making choice or being voted for. In a general term, election serves as the

---

* Corresponding author.

Adetokunbo M. John-Otumu https://orcid.org/0000-0002-3138-4639 e-mail: adetokunbo.johnotumu@futo.edu.ng

major instrument for the recruitment of political leadership in a democratic society.

Election is the key to participation in democracy and the way of giving consent to government, and allowing the governed to choose and pass judgment on office holders who theoretically represent the governed [2]. Voting is a vital component of election. Voting is very important to election because it allows individuals cast their ballot for those they feel will give the adequate representation.

The advent of Internet technologies, have made it possible for electorates to vote online [3]. Online voting system or remote voting is a web based application that can be used to vote from any computer system or communication medium connected to the Internet from any part of a country [4]. The improvement of information and communication technology will permit in favor of a fully computerized online voting process in which election results are counted in real-time at the conclusion of each election, the outcome be automatically tallied and released. Online voting system has been used in conducting elections in some countries by using the personal computers connected to the Internet or a private network [5].

The existing system of voting in Edo state is based on modified open ballot voting system, which allows voters to carry out their voting in an open polling booth. Fig. 1 shows a general view of the manual voting system. This voting system is the actual process of casting ballots, and qualified voter goes to the polling station where his or her name is registered and shows his or her voter's identification card to the Polling Official (PO) for inspection before voting can take place based on the voter registration number (unique) on the card [6]. The PO looks up the name of the intended voter from the voter's register, and ensures that no vote has been initially cast by that voter before issuing a ballot paper and his left thumb is marked with an indelible ink to note that he/she has cast his/her vote in an enclosed space. The voter then selects a preferred candidate on the ballot paper and thumb prints in the allotted space for that candidate. The voter can then carefully fold the ballot paper in order to avoid the fingerprint soiling other parts of the ballot paper, and then deposits it into the ballot box provided. Thereafter, he/she is expected to leave the polling center. Ballot counting process is prepared by hand, with outcome collated from end to end using a bottom-up process. This means that counting is first executed at the lowest echelon, which is the polling station level. The outcome collated from that level upwards to the constituency level and finally to the topmost level which is the state. At the uppermost level, all the votes of the various candidates are certified. After this, the Independent National Electoral Commission (INEC) publishes the final results.
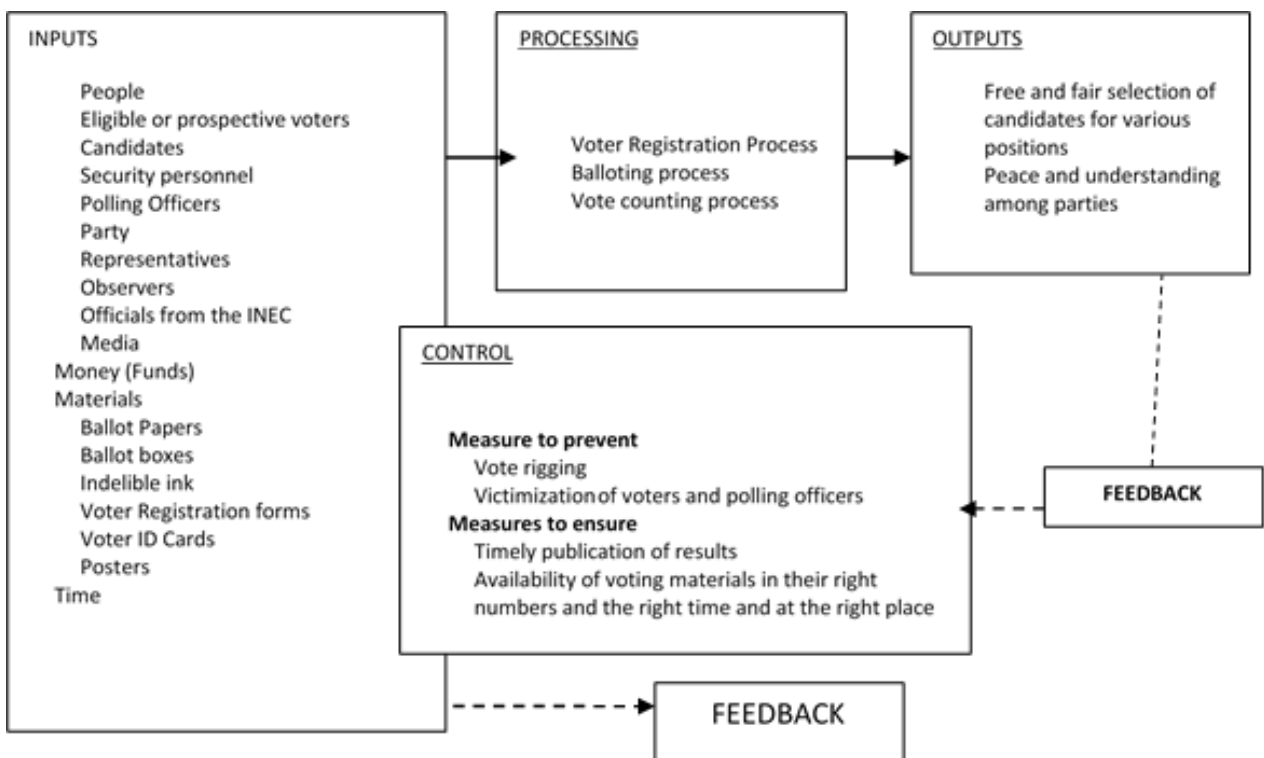

Fig. 1 shows a systemic view of a manual voting system [6]

The existing manual system involves methods like paper based voting, punch card, lever voting machine as well as optical voting machine using users' password as the only security measure. The main setback in this system is the fact that a user can gain access to the voting system easily without security restrictions and cast their vote using the identification cards of other persons. Other challenges and concerns that needed to be overcome included stuffing of ballot box with ballot papers, absconding with ballot boxes, falsification of election results and mutilation of election result sheets [7]. These challenges and concern can be resolved by integrating the usage of fingerprint reader in online voting system.

The main objective of this paper is the development of a general prototype system, which provides security measure and trusted online voting system for credible election in Edo State using Rapid Application Development (RAD) methodology. The RAD is a software development approach, which centers on building applications in a very short amount of time and encourages constant feedback from users throughout the software development life cycle [8]. The objective behind the development of this type of system is to simplify the process of organizing elections and to make it easy for voters to vote remotely from their computers while taking into consideration better security, anonymity and providing auditing capabilities [9]. Most web-based system provides for interfaces that are user-friendly and soft tools which can enable voting easy and interestingly pleasurable, because of their security feature that ranges from the application design to re-alization, administration and monitoring [10].

2. Literature Review

2.1. Overview

Fuzzy logic was first presented by Zadeh in 1965 [11]. Fuzzy provides an amazingly uncomplicated way to depict specific conclusion from unclear, uncertain or wooly information [3], [12]. In a sense, fuzzy logic mimics human decision making with its ability to work from approximate data and find exact solution [13]. Fuzzy set is an expansion of the notion of a normal set typically referred to as a crisp set. For example, in a crisp set X, an element either belongs to X, which could be equated by logic 1, or does not and could be equated by logic 0. This model will utilize the Fuzzy Clustering Means (FCM) and the fuzzy linguistic information standard developed will be in five (5) categories, which are as follows:

under least standard (uls), least standard (ls), beyond least standard (bls), regular standard (rs) and top standard (ts). Each of these categories is called a linguistic modifier. This modifier is associated to a numeric significance on a scale ranging from 0 to 7.

The fuzzy sets are used to portray the software application in terms of performance standard. It should be noted that a real number at closed intervals between 0 and 1 is used to form the linguistic modifier. The fuzzy linguistic information "standard" denotes the online voting system standard. This standard depicts a common way of constructing fuzzy sets for linguistic information or variables [14] in which five fuzzy sets are utilized in evaluating the standardization of the prototype online voting system proposed for credible election in Edo state. A fuzzy set can be referred to as a class of objects with a gamut of grades of membership; such set can be characterized by a membership function assigned to each object in a rank of membership sandwiched from (0 to 1).

To understand a fuzzy set, let X be a space of points with a generic element denoted by x, as:

$$Z = \{x, \ \mu_A(x)/x \in X\} \tag{1}$$

Where $\mu_A(x)$ represents the rank of membership function of element x of X in fuzzy set Z. Element x possibly will show a complete, incomplete or no relationship in Z. Its membership rank would be well thought-out to be complete if $\mu_A(x) = 1$; incomplete if $\mu_A(x)$ is sandwiched between 0 and 1; and there is no relationship if $\mu_A(x) = 0$.

2.2. Related Studies

Electronic voting was utilized for parliamentary elections in Australia in 2001 and for student union elections in Austria in 2003 [15]. Also, in 2003, electronic voting was used for municipal elections in Canada as well as for both the general and local elections in India [16]. Brazil, United Kingdom, America, among others are also leading examples of countries where e-voting has enhanced electoral process and eased the way voting were conducted [17].

Since the development of information technologies in modern times; community opinion polls, and national elections can be realized more rapidly and more successfully on electronic platforms. Though certain types of electronic voting have been utilized productively in a number of countries during their local and general elections, such a system is yet to take full blown effect in Nigeria [18].

Online voting had never been used in the USA pending March 2000 when the Arizona Democratic Party held its primary election online. Other countries that have implemented online voting are France election in 2003 and Estonia election in 2006. Estonia is believed to have held the globe's first ever successful online voting election [19].

In the western world, Nikhil and Viraj [20] stated many countries have made significant steps to assess and review existing electoral procedures with recommendations that pilot schemes of innovative and automated electoral procedures have been adopted. A good number of them, have since decided that electronic voting be made available to a voting population as a supplementary form of voting to guarantee their citizens the freedom to vote, secrecy of the vote, non-modification of the expressed intention of the vote and lack of intimidation during the voting operation [21].

Ashok and Ummal [22] reported that Americans living overseas are able to vote electronically by means of the Internet, from anywhere in the world. However, the widespread reports of electronic voting terminal breakdowns, and the rising concerns about the security of these voting systems, have given rise to numerous debates over how to safeguard the integrity of nation-wide elections [23].

The in-depth study by Mugisha [24] showed that online voting system, if thoroughly designed and implemented, can enhance polling and vote's security, sincerity, confidentiality and can lead to cost reduction. Electronic voting will foster enhanced accuracy of all valid votes and final outcome; permit voting once for only eligible voters; allow independent verification of all voters; also, it can expand voter turnaround and voter can vote from any polling station [25].

Therefore, online based voting technologies would expand the reach and range of the potential voting population. Consequently, research projects by [3], [4] reported that developed countries like the USA, France, Belgium, Germany, UK and Estonia are experimenting with, or even legalizing, online voting. As for France, 2007 another presidential elections was held using online voting technologies [26].

Lakshmi et al. [27] developed an web-based online voting system for conducting elections remotely using the basic functionality of the different web development tools/platform such as Hypertext preprocessor (PHP), HTML, JavaScript, MYSQL, WAMP Server. Results revealed that users were able to carry out voting activities successfully via web browser after being authenticated using the username and password. Anand and Divya [28] also a proposed the development of a secure web-based online voting system for Indian Election Commission using web programming languages such as Servlet, CSS, HTML, JDBC, JavaScript, JSP, MYSQL, ORACLE, and WAMP Server. The proposed software is online voting system was tested on Ethernet platform. Results revealed that the online voting system was secured using simple username and password and also increases the voting percentage and reduces false votes.

Rura et al. [29] executed a secured web-based online voting system using image steganography and visual cryptography techniques. The developed system was implemented using Java 2 Enterprise on the web based interface, Glassfish application and MySQL relational database server as the back-end. Waterfall methodology was adopted as the software development life cycle. Questionnaire investigation was used in collecting data with regards the user acceptance testing, and a simple percentage rating was used in carrying out the analysis. Finally, a simple comparative analysis was done against five (5) different online voting system using nine (9) key criteria index. Results showed slight improvement in terms of security enhancement. An online voting system (OVS) for eradicating the challenges as identifies by [30] was developed with fingerprint and face recognition system integration. The immediate release of results from the developed system showed some level of improvement over the existing ballot paper system of voting.

In [31], a mobile-based online voting application was developed to meaningfully reduce the direct and physical human intervention and control associated with student election matters at the University of Mauritius with an understanding of creating a positive point in the process but in same vein presents an entirely new scope of concern. The proposed system was built using operating system and android development tools such as Windows 10 Home 64bit, Microsoft Visio 2013, Notepad++ 6.8.8, IDE Eclipse Kepler 4.3.2, Android SDK and LATEX. Results showed that there was real enhancement in the ease of voting with the application. While in [32] an application that can offer online voters registration for student's delegates on Kirinyaga University campus, Kenya was developed using

JavaScript, HTML, PHP and MySQL as the web development tools. The system adopted the Waterfall process model in its development life cycle. Results revealed that the proposed system offered interactive interfaces to its users, and the voting results were represented graphically in percentage format for the candidate with the highest votes.

Ayo and Babajide [33] developed a secured internet voting application using HTML, JavaSript, PHP, MySQL database, Apache web server, and audio sound integration using SWiSHmax software to simplify election voting processes. Security features were also fused into the application using bi-modal authentication techniques (fingerprint and password authentication). Results also revealed that the proposed system helped to reduced multiple registrations, thereby increasing the voters' confidence rate.

The advancement of mobile technologies has necessitated [34] to propose a secure mobile voting system to deliver a suitable, stress-free and well-organized way of voting in order to remove the inadequacies associated with the old-fashioned method of voting using One Time Password (OTP) code generation as a means of authentication for voting on mobile phones. Results showed that the propose system offered a useful, relaxed and resourceful way of voting and most of the security inadequacies of the outdated approach was eradicated as people could vote from the comfort of their homes using their smart phones.

In Ghadi and Shelar [35], a safe and easy online voting application to resolve voting critical challenges was developed with fingerprint and aadhaar card integration in order to deliver efficient performance with high level of security to the online voting system. The proposed system was implemented using NetBeans IDE 7.1.2 and MySQL database management system. Results revealed that voters could cast their votes easily and the biometric fingerprint integrated reduces dummy and multiple votes.

3. Methods

In this paper, the Rapid Application Development (RAD) Methodology was utilized in developmental life cycle of the software, and was built using web programming languages such as Hypertext Preprocessor (PHP), JavaScript, Java programming language, Hypertext Markup Language and MySQL. Biometric fingerprint reader was integrated to the software to handle the security aspect in terms of intended multiple voters, and an intelligent software agent was also embedded to monitor the results separately from the voting application.

For the evaluation part; a questionnaire was designed and used for gathering relevant data regarding the evaluation metrics, which includes: security compliance, user friendliness, dependability, robustness timeliness, voter's privacy, navigational test, Compatibility and authentication. The questionnaires were administered to selected respondents and stakeholders of election in the selected Local Government Area; and were retrieved back from respondents for further analysis using the fuzzy logic.

The Fuzzy Clustering Means (FCM) was used to evaluate the questionnaire in order to determine the minimum acceptable standard of the developed proposed software. The fuzzy linguistic variable standard in this research work represents the proposed software application standard developed. The researchers are actually interested in the standard of the developed online voting system for credible election; hence, the respondents rating on the standard, which is in a five (5) point scale i.e. under least standard (uls), least standard (ls), beyond least standard (bls), regular standard (rs) and top standard (ts) is of utmost essence. The five fuzzy sets are interpreted as equations (1)–(5).

$$uls = \{0|0.3,1|0.4,2|0.7,3|0.0,4|0.0,5|0.0,6|0.0,7|0.0\} \quad (1)$$

$$ls = \{0|0.0,1|0.5,2|0.4,3|0.6,4|0.0,5|0.0,6|0.0,7|0.0\} \quad (2)$$

$$bls = \{0|0.0,1|0.0,2|0.3,3|0.7,4|0.5,5|0.2,6|0.0.7|0.0\} \quad (3)$$

$$rs = \{0|0.0,1|0.0,2|0.0,3|0.0,4|0.3,5|0.6,6|0.7,7|0.8\} \quad (4)$$

$$ts = \{0|0.0,1 |0.0,2|0.0,3|0.0,4|0.0,5|0.0,6|1.0,7|0.8\} \quad (5)$$

Each of these linguistic modifiers is linked to a numerical value on a scale from 0 to 7, which represents the standardization of the online voting system developed. One of the four standard fuzzy sets (intersection, union, complement and implication) operations can be used to manipulate a fuzzy set. For instance, let $\mu_A(x)$ and $\mu_B(y)$ represents two fuzzy sets with membership functions, then $\mu_A(x)$={1, 3, 4, 6, 8}and $\mu_B(y)$={1, 2, 5, 8, 9}.

The two fuzzy sets $\mu_A(x)$ and $\mu_B(y)$ are equal written as $\mu_A(x) = \mu_B(y)$, if and only if $\mu_A(x)$=$\mu_B(y)$, for all x in X. In an example $\mu_A(x) \neq \mu_B(y)$ for all x in X.

The union of $\mu_A(x)$ and $\mu_B(y)$ with respective membership function $\mu_A(x)$ and $\mu_B(y)$ is a fuzzy set, written as C = $A \cup B$. A fuzzy sets union operation is performed by the application of the maximum function to the elements of the two sets.

$\mu_C(z) = [\mu_A(x) = \{1,3,4,6,8\} \cup \mu_B(y) = \{1,2,5,8,9\}]$

$\mu_C(z) = \{0, 3, 5, 8, 9\}$ (6)

The intersection is performed by applying the minimum function to the element of the fuzzy sets.

$\mu_C(z) = [\mu_A(x) = \{1,3,4,6,8\} \cap \mu_B(y) = \{1,2,5,8,9\}]$

$\mu_C(z) = \{0, 2, 4, 6, 8\}$ (7)

Complement of a set can be calculated by subtracting each element of the set from its maximum probable value.

$\mu_a(x) = \{8 - \mu_A(x) = \{7,5,4,2,0\}\}$ (8)

In Table 1, the evaluation metric is assigned a membership grade between 0 and 1. Each evaluation metric is assigned a qualitative judgment to determine the degree of the standard and performances for the selected metric category.

These qualitative judgments are called linguistic variables and are shown in Table 2. The linguistic information or variables are symbolized with two or more letters shown in Table 3, each variable is giving a numerical significance within a close interval of 0 to 1.

These linguistic information or variables therefore formed another fuzzy set Z, which takes values in a universe of discourse W in the interval of (0, 1), such that:

$Z = \{W/fZ\,(w), w \in W$ (9)

$fZ\,(w) = \{0.2, 0.4, 0.6, 0.7, 1.0\}$ (10)

Table 2 Fuzzy linguistic information and membership grades

Evaluation metrics	Representation (w)	Membership grade fY(w)
Security conformity	F1	1.0
User responsiveness	F2	0.2
Navigation testing	F3	0.3
Robustness	F4	0.4
Timely, voter privacy	F5	0.5
Authentication	F6	0.6
Screen interfaces	F7	0.7
User identification	F8	0.8
Compatibility testing	F9	0.9

Table 3 Linguistic variables employed for the qualitative judgments

Linguistic Variables	Fuzzy Values
Under least standard	0<= x <=2.0
Least standard	1 <=x <=3.0
Beyond least standard	2 <=x =5.0
Regular standard	4 <=x <=7.0
Top standard	6 <=x <=7.0

The next step is to evaluate the standard of each local Government by each evaluation metric, which is based on the fuzzy opinion of the evaluator or decision maker. The results of these decisions however constitute the twelve (12) different fuzzy sets: $Z_1, Z_2, Z_3, \ldots Z_{12}$; with membership functions: $fz_1(w), fz_2(w), fz_3(w), \ldots fz_{12}(w)$. For instance, in Table 4, the fuzzy set and membership function of the first local government, B/City (Benin City) and the second local government, Ehor, are:

$fg_1(\text{w}) = \{0.6, 0.7, 0.7, 0.6, 0.7, 0.6, 1.0, 0.6, 0.6\}$ (11)

$fg_2(\text{w}) = \{0.7, 0.4, 0.6, 0.7, 0.7, 0.7, 0.6, 1.0, 0.7\}$ (12)

The numerical value was used to replace the linguistic variable symbols. Table 5 shows the absolute significance of the metrics from 1 to 9 across the twelve (12) local government areas where the opinion was sampled.

Table 1 Evaluation metrics and their membership grade

Membership grade	Symbols	Linguistic variable
0.2	uls	Under least standard
0.4	ls	Least standard
0.6	bls	Beyond least standard
0.7	rs	Regular standard
1.0	ts	Top standard

Table 4 Software standard rating codes across the selected local government area

	B/City	Ehor	Uselu	Abudu	Irrua	Ubiaja	Ekpoma	Uromi	Igarra	Auchi	Fugar	S/Ora
F1	bls	rs	ts	Ts	bls	bls	ts	bls	rs	rs	rs	rs
F2	rs	ls	rs	bls	rs	bls	ls	rs	ts	bls	rs	ts
F3	rs	bls	rs	ts	rs	ls	bls	ls	ts	bls	ls	rs
F4	bls	rs	bls	ts	bls	ls	ts	rs	rs	rs	ts	ts
F5	rs	rs	ts	rs	bls	ts	ts	ts	ts	bls	rs	bls
F6	bls	bls	ts	ts	bls	ts	rs	bls	rs	ts	rs	bls
F7	ts	rs	bls	rs	rs	bls	ts	bls	rs	bls	rs	ts
F8	bls	ts	rs	rs	rs	ts	rs	rs	ts	ts	ts	rs
F9	bls	rs	ts	rs	bls	ts	rs	ts	rs	bls	rs	bls

Table 5 Software standard rating in actual values across the selected local government area

	B/City	Ehor	Uselu	Abudu	Irrua	Ubiaja	Ekpoma	Uromi	Igarra	Auchi	Fugar	S/Ora
F1	0.6	0.7	1.0	1.0	0.7	0.6	1.0	0.4	0.7	0.7	0.7	0.7
F2	0.7	0.4	0.7	0.6	0.7	0.6	0.4	0.7	1.0	0.6	0.6	1.0
F3	0.7	0.6	0.7	1.0	0.7	0.4	0.6	0.4	1.0	0.6	0.4	0.7
F4	0.6	0.7	0.6	1.0	0.6	0.4	1.0	0.7	0.7	0.7	1.0	1.0
F5	0.7	0.7	1.0	0.7	0.6	1.0	1.0	1.0	1.0	0.6	0.7	0.6
F6	0.6	0.7	1.0	1.0	0.6	1.0	0.7	0.6	0.7	1.0	0.7	0.6
F7	1.0	0.6	0.6	0.7	0.7	0.6	1.0	0.7	0.7	0.6	0.7	1.0
F8	0.6	1.0	0.7	0.7	0.7	1.0	0.7	0.7	1.0	1.0	1.0	0.7
F9	0.6	0.7	1.0	0.7	0.6	1.0	0.6	1.0	0.7	0.6	0.7	0.6

$FY(w) = \{1.0, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9,\}$

$\overline{FY}(w) = \{0.0, 0.8, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2, 0.1\}$

$\overline{FY}\, Z_1(w) = \{0.0, 0.8, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2, 0.1\} \cup \{0.6, 0.7, 0.7, 0.6, 0.7, 0.6, 1.0, 0.6, 0.6\}$

$\qquad = 0.6, 0.8, 0.7, 0.6, 0.0, 0.6, 1.0, 0.6, 0.6 = 0.6$ (13)

$\overline{FY}\, Z_2(w) = \{0.0, 0.8, 0.7, 0.6, 0.3, 0.4, 0.3, 0.2, 0.1,\} \cup \{0.6, 0.4. 0.6, 0.7, 0.7, 0.7, 0.6, 1.0, 0.7\}$

$\qquad = 0.6, 0.8, 0.7, 0.7, 0.7, 0.7, 0.6, 1.0, 0.7 = 0.6$ (14)

$\overline{FY}\, Z_3(w) = \{0.0, 0.8, 0.7, 0.6, 0.5, 0.3, 0.2, 0.1,\} \cup \{1.0, 0.7, 0.7, 0.6, 1.0, 1.0, 0.6, 0.7, 1.0\}$

$\qquad = 1.0, 0.8, 0.7, 0.6, 1.0, 1.0, 0.6, 0.7\ 1.0 = 0.6$ (15)

$\overline{FY}\, Z_4(w) = \{0.0, 0.8, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2, 0.1\} \cup \{1.0, 0.6, 1.0, 1.0, 0.7, 0.10, 0.7, 0.7, 0.7\}$

$\qquad = 1.0, 0.8, 1.0, 0.7, 0.6, 0.7, 0.6, 0.7 = 0.7$ (16)

$\overline{FY}\, Z_5(w) = \{0.0, 0.8, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2, 0.1\} \cup \{0.7, 0.7, 0.7, 0.6, 0.6, 0.6, 0.7, 0.7, 0.6\}$

$\qquad = 0.7, 0.8, 0.7, 0.6, 0.6, 0.7, 0.6, 0.7, 0.6 = 0.6$ (17)

$\overline{FY}\, Z_6(w) = \{0.0, 0.8, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2, 0.1\} \cup \{0.6, 0.6, 0.4, 0.4, 1.0, 1.0, 0.6, 1.0, 1.0,\}$

$\qquad = 0.6, 0.8, 0.7, 0.6, 1.0, 1.0, 0.6, 1.0, 1.0 = 0.6$ (18)

$\overline{FY}\, Z_7(w) = \{0.0, 0.8, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2, 0.1\} \cup \{1.0, 0.4, 0.6, 1.0, 1.0, 0.7, 1.0, 0.7, 0.7,\}$

$\qquad = 1.0, 0.8, 0.7, 1.0, 1.0, 0.7, 1.0, 0.7, 0.7 = 0.7$ (19)

$\overline{FY}\, Z_8(w) = \{0.0, 0.8, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2, 0.1\} \cup \{0.7, 1.0, 0.4, 0.7, 1.0, 1.0, 0.7, 0.7, 1.0\}$

$\qquad = 0.7, 1.0, 0.7, 0.7, 1.0, 1.0, 0.7, 0.7, 1.0 = 0.7$ (20)

$\overline{FY}\, Z_9(w) = \{0.0, 0.8, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2, 0.1\} \cup \{0.7, 1.0, 1.0, 0.7, 1.0, 0.7, 0.7, 1.0, 0.7\}$

$\qquad = 0.7, 1.0, 1.0, 0.7, 10, 0.7, 0.7, 1.0, 0.7, = 0.7$ (21)

$\overline{FY}\, Z_{10}(w) = \{0.0, 0.8, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2, 0.1\} \cup \{0.7, 0.6, 0.6, 0.7, 0.6, 1.0, 0.6, 1.0, 0.6,\}$

$\qquad = 0.7, 0.8, 0.7, 0.7, 0.6, 1.0, 0.6, 1.0, 0.6, = 0.6$ (22)

$\overline{FY}\, Z_{11}(w) = \{0.0, 0.8, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2, 0.1\} \cup \{0.7, 0.6, 0.6, 1.0, 0.7, 0.7, 0.7, 1.0, 0.7\}$

$\qquad = 0.7, 0.8, 0.7, 1.0, 0.7, 0.7, 0.7, 1.0, 0.7, = 0.7$ (23)

$\overline{FY}\, Z_{12}(w) = \{0.0, 0.8, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2, 0.1\} \cup \{0.7, 1.0, 0.7, 1.0, 0.6, 0.6, 1.0, 0.7, 0.6\}$

$\qquad = 0.7, 0.8, 0.7, 1.0, 0.6, 0.6, 1.0, 0.7, 0.6, = 0.6$ (24)

Here, the goal is to establish a fuzzy implication relationship between a specific voter metric and voter's in each local government area. According to [5], the fuzzy implication relation was instituted by taking the complement of the software from the local government area. The complements of the evaluation metric set shown in the third column was applied to each proposed software standard rating across the selected local government areas. The Max function is then applied to each local government area and the complement of the evaluation metric set as revealed in Table 6. The final step combines the various performance standard of each local government in order to arrive at the final evaluation. This is achieved by utilizing the Min function to the set derived (see equations (13)-(24)) for each local government in the fuzzy set union operation.

4. Results and Discussion

The general outcome of voter's evaluation for the proposed online voting system standard across the selected local government areas (LGAs) showed that the application is user's friend and Figs. 3 – 7 showed some of the user's interfaces developed.

Table 6 showed that the scores value is tantamount to absolute significance of each linguistic variable. The ranking reflects the sampled judgment of voters' across the selected twelve (12) LGAs in Edo State. Table 6 also implied that voters from seven (7) out of the twelve (12) LGAs, which comprises Benin city (B/City), Ehor, Uselu, Irrua, Ubiaja, Auchi, and Sabogida-Ora (S/Ora) were clustered into the view that the prototype online voting software developed is beyond the least acceptable standard while the remaining five (5) LGAs, which consist of
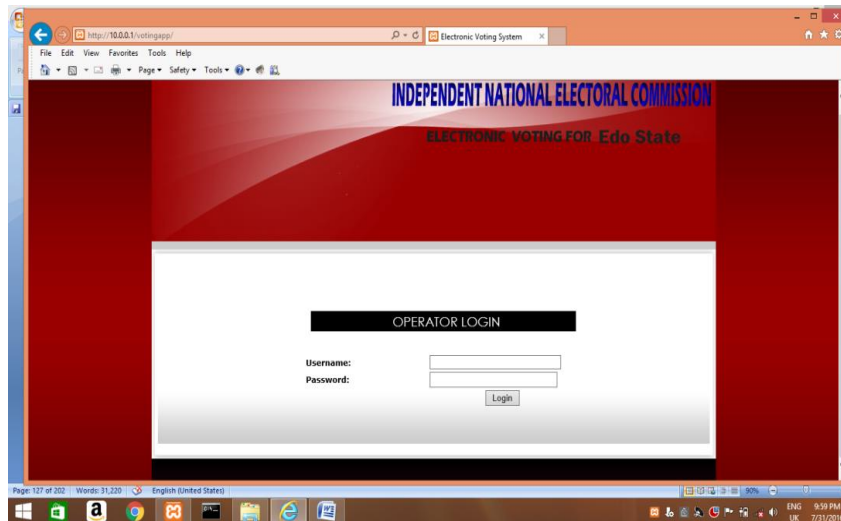
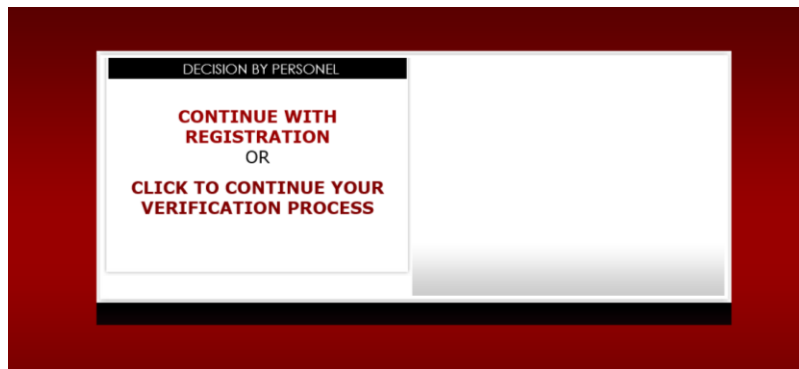**Fig. 3** The screen shot of operator login home page
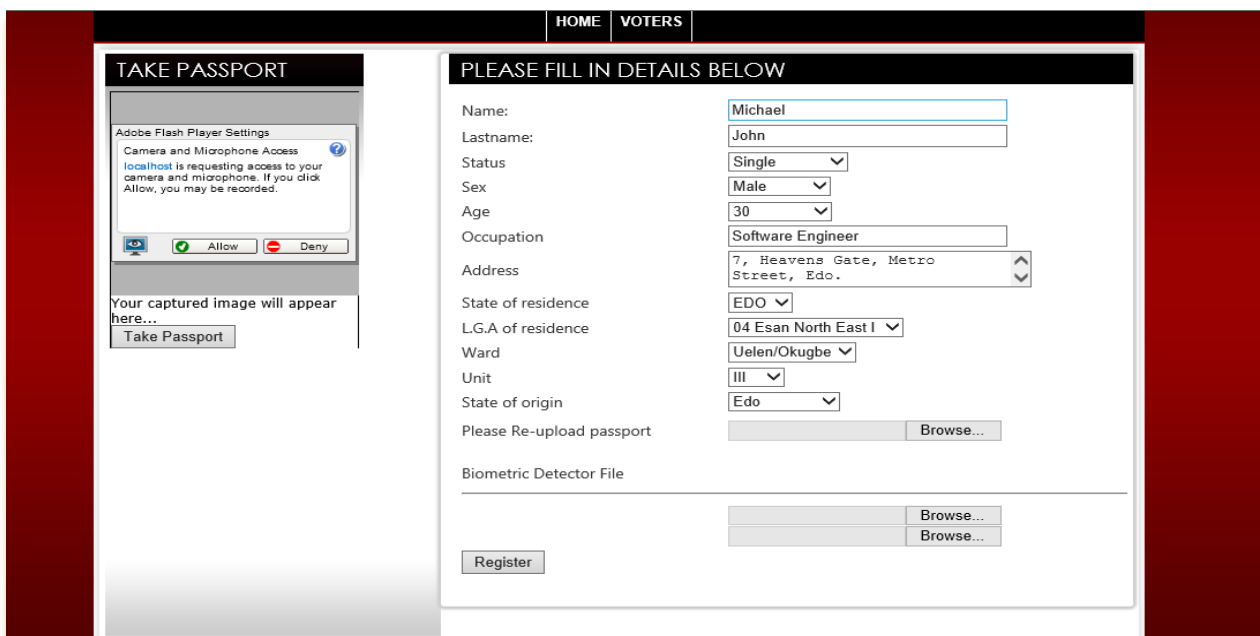

Fig. 4 Screen shot of the decision panel

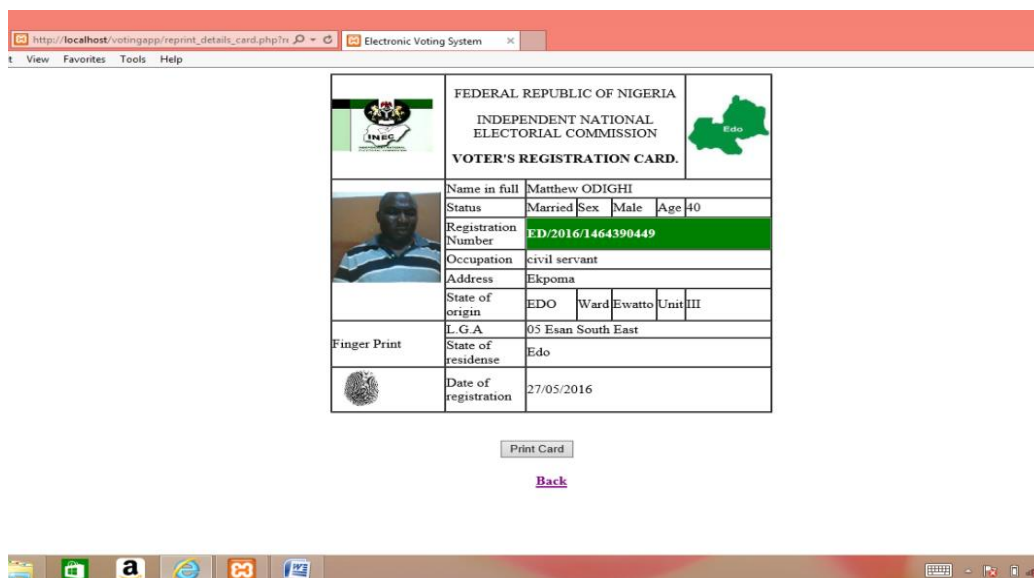**Fig. 5** Screen shot of detailed registration form
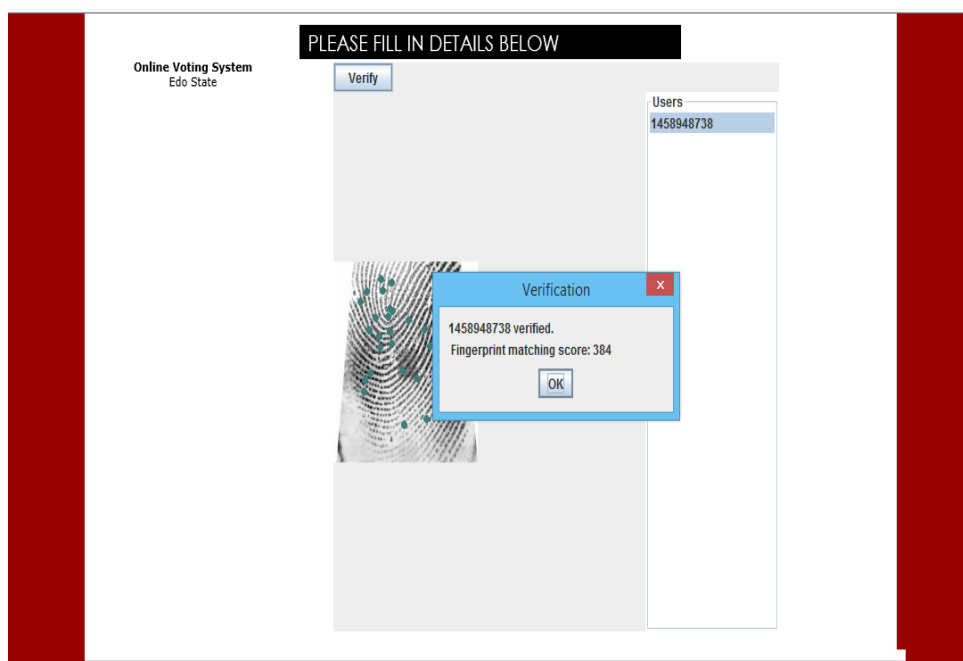
Fig. 6 Screen shot of voter's slip

Fig. 7 Screen shot verification dialog panel using fingerprint

Table 6 Overall rating across the selected LGAs

LGAs	Software standard rating
B/City	0.6
Ehor	0.6
Uselu	0.6
Abudu	0.7
Irrua	0.6
Ubiaja	0.6
Ekpoma	0.7
Uromi	0.7
Igarra	0.7
Auchi	0.6
Fugar	0.7
S/Ora	0.6

Abudu, Ekpoma, Uromi, Igarra, and Fugar were clustered into the view that the prototype online voting software developed is of regular standard in terms of performance.

Result further showed that the seven (7) local government areas, which forms about (58.33%) of the beyond least standard cluster and the five (5) LGAs, which also forms about (41.66%) of the regular standard cluster of the entire population of (12) LGAs are both above average acceptable benchmark that is a key indicator for fair and credible elections as compared to the different online voting system developed by [24], [27]–[35] that were not truly evaluated for performance standard of this nature, and therefore their standards cannot be really ascertained.

Finally, the FCM approach used has proven to be a very potent tool for evaluating performance standard for general software acceptability and has also showed that the

elasticity of the model allows a decision maker to initiate vagueness, and prejudice into the performance evaluation system. It is for that reason, a near perfect system for a decision-maker when confronted with chains of decisions to make.

5. Conclusion

This research paper extensively discussed the evaluation of the standard performance of the prototype online voting system developed for carrying out credible elections in Edo state using FCM model. The result showed that the prototype online voting system meets above the least acceptable standard and very proficient in helping the decision maker in evaluating software standard where the available data to be evaluated is based on indecision. However, the evaluation sheds more insight on the need to make some more enhancements. This technique is hereby recommended for evaluating the top standard of any application software to be adopted for online voting based on the principle of excellent improvement and the adoption of the prototype online system developed.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

References

[1] R. Blerim, N. Vehbi, and D. Ramadam, "Improving authentication and transparency of e-voting system–Kosovo case", *Int. J Comp. Communicat.,* vol. 6, no. 1, 2012.

[2] A. A. Araba, J. O. Braimah, "Comparative study of 2011 and 2015 presidential elections in Nigeria", *Global J Human Soc. Sci.*, vol. 15., no. 7, 47-54.

[3] L. Raja and N. Meenakshi, "Student online voting system", *Int. J Trend Res. Dev.,* vol. 2, no. 5, pp. 1 – 8, 2018.

[4] M. O. Odighi, "Software agent for monitoring and evaluating election results in real time voting system", Ph.D. thesis, Ambrose Alli University, Ekpoma, Nigeria, 2019

[5] E. El-Qawasmeh, and S. Uwais, "E-democracy in Middle East: hard to approach", *J Theor. Applica. Inform. Technol.*, vol. 21, no. 1, pp. 57–63, 2010

[6] D. Ofori and E. Paatey, "The design of an electronic voting system", *Res. J. Inform. Technol.*, vol. 3, no. 2, pp. 91-98, 2011.

[7] L. H. Nestas, "Building trust in remote internet voting", M.Sc. thesis, University of Bergen, Canada, 2019.

[8] R. Mercuri, "Electronic vote tabulation checks and balances", Ph.D. thesis, University of Pennsylvania, Philadelphia, PA, October 2000.

[9] A. Prosser, R. Kofler, and R. Krimmer, Deploying electronic, in proceedings of 2nd Int. Conference, EGOV 2003, September 1-5, Prague, Czech Republic, vol. 2739, pp. 234-239, 2003.

[10] F. Iyayi, "The conduct of elections and electoral practices in Nigeria", being paper delivered at the 2004 NBA Conference, Abuja on 24th August, 2004.

[11] G. J. Klir and Y. Bo, *Fuzzy sets, fuzzy logic, and fuzzy systems: selected papers by Lotfi A. Zadeh*, World Scientific Publishing Co., Inc., pp. 394–432, 1996.

[12] V. C. Ossai, H. C. Okafor, and A. O. Agbonghae, "An improved model of e-voting system based on biometric key binding", *Int. J Eng. Comp. Sci.*, vol. 2, no. 6, pp. 1704-1726, 2013.

[13] A. M. John-Otumu, G. U. Ogba, and O. C. Nwokonkwo, "A survey on artificial intelligence based techniques for diagnosis of hepatitis variants", *J Adv. Sci. Eng.*, vol. 3, no. 1, pp. 43-56, 2020.

[14] H. M. Beheshti, and J. G. Lollar, "Fuzzy logic and performance evaluation: discussion and application", *Int. J Producti. Perform. Manage.*, vol. 57 no. 3, pp. 237-246, 2008

[15] N. Gorla, "A survey of rural e-government projects in India: status and benefits", *Inform. Technol. Dev.*, vol. 15, no. 1, pp. 52 – 58, 2009.

[16] O. Philippe, "Making a faster cryptanalytic time-memory trade-off", Lecture Notes in Computer Science, In Dan Boneh, editor, CRYPTO, vol. 2729, pp. 617–630, 2003

[17] B. Simon and F. Ray, "Object-oriented systems analysis and design using UML", Computers and Communications, (3rd ed.), Mc-Graw Hill, vol. 6, no. 1, 2004.

[18] Y. Mahmood, "The use of biometric voter authentication system: experiences, issues and way forward," Independent National Electoral Commission, Nigeria, Windhoek, Namibia, pp. 26 – 28, April, 2018.

[19] G. Babu and M. Padmavathamma, "Optimally efficient multi authority secret Ballot e-election scheme", *J Theor. Applica. Inform. Technol.*, vol. 2, no. 1, pp. 1 – 6, 2006.

[20] L. K. Nikhil and A. B. Viraj, "Online voting system", *Int. J Adv. Res. Comp. Eng. Technol.,* vol. 5, no. 6, 2017.

[21] O. O. Okediran, "Mobile phones: a panacea for the implementation of e-voting in Nigeria", *Asian J. Res. Comp. Sc*i., vol. 4, no. 1, pp. 1-15, 2019.

[22] D. Ashok and S. Ummal, "A novel design of electronic voting system using fingerprint", *Int. J Innov. Technol. Creative Eng.*, vol. 1, no.1, pp. 12–19, 2011.

[23] D. S. Alan, and S. C. John, "Revolutionalizing the voting process through online strategies", *USA J Online Voting*, vol. 29, no. 5, pp. 513-530, 2005.

[24] B. Mugisha, "A secure internet-based voting system for low ict resource countries", M.Sc. thesis, Makerere University, 2005.

[25] O. O. Okediran, E. O. Omidiora, S. O. Olabiyisi, and R. A. Ganiyu, "A review of the underlying concepts of electronic voting", *Inform. Knowled. Manage.,* vol. 2, no. 1, pp. 8-20, 2012.

[26] P. A. Irabor, "Counseling for social adjustment: antidote to Nigeria political culture", paper presented at the Counseling Association of Nigeria, Enugu Chapter, Held at school hall, National Grammar School, Nike, Enugu State, 16th to 17th of April, 2012.

[27] R. Lakshmi, M. Nivya, and K. S. Selvanayaki, "Student online voting system", *Int. J Trend Res. Dev*., vol. 2, no. 5, pp. 438 – 440, 2015.

[28] A. Anand, and P. Divya, "An efficient online voting system", *Int. J Modern Eng. Res*., vol. 2, no. 4, pp. 2631–2634, 2012.

[29] L. Rura, B. Issac, and M. K. Haldar, "Online voting system based on image steganography and visual cryptography", *J Comput. Info. Technol*., vol. 25, no. 1, pp. 47–61, 2017.

[30] N. L. Kshemkalyani and V. A. Bandekar, "Online voting system", *Int. J Adv. Res. Comp. Eng. Technol*., vol. 5, no. 6, pp. 1773-1775, 2016.

[31] M. A. Hosany, and N. Chedembrun, "Design and implementation of an online voting system for the election of students of the University of Mauritius", *Int. J Adv. Res. Comp. Eng. Technol*., vol. 4, no. 7, pp. 4321–4327, 2017

[32] C. Makungu, R. M. Munyao, and J. K. Mwai, "Student online voting system", *Int. J Social Sci. Inf. Technol*., vol. 4, no. 5, pp. 175–196, 2018.

[33] C. K. Ayo and D. O. Babajide, "Design and implementation of a secure i-voting system", *J Comp. Sci. Applica.,* vol. 14, no. 2, pp. 38–51, 2007.

[34] P. Ahlawat, and R. Nandal, "Performance improvement using pseudorandom one time password in online voting system", *IOSR J Comp. Eng*., vol. 17, no. 5, pp. 31–38, 2015.

[35] R. M. Ghadi, and P. S. Shelar, "Online voting system", *Int. Res. J Eng. Technol.,* vol. 4, no. 12, pp. 1411–1413, 2017.