VISUALIZING E-VOTING RESULTS

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ABSTRACT

Recently, the urge for e-voting has been described to be the inevitable future of electioneering in most countries of the world. Despite all its good features, like the other voting systems it has been seen to also be susceptible to rigging and fraud. Some of its undesirable features include not allowing recounting of votes after election in case of a protest like the others. Another issue is that of erroneous software which can greatly affect the result of the election. All these is further compounded by the fact that voting systems deals with very large amount of data that is collected from a distributed population source hence the raw data are extremely difficult to comprehend and therefore monitor. This paper attempts to solve this problem using a TreeMap based visualization technique to monitor in real-time the distributed balloting and voting processes. The paper proved that TreeMap algorithms can be configured and deployed on the central server to monitor effectively the voting transactions in real-time and hence enable transparency.

Keywords: *E-Voting, Treemap Algorithm, Visualization, Results, Real-Time, Balloting, Nigeria*

1. INTRODUCTION

Voting systems, regardless of the type basically involve the collection of usually widely distributed ballot data and transporting them to a central location/server where they are to be counted and interpreted for results.

E-voting is an example of election system that allows a voter to record his or her secure secret ballot electronically. Its implementation has been of major interest in countries around the world including Nigeria. Advocates of the technology have highlighted the major benefits obtainable from the technology some of these are its ability to reduce to an appreciable extent the cost of elections and if properly implemented; can invariably lead to a more trustworthy election process. They also posited that the electronic voting possesses the ability to increase civic participation in elections by making the voting process more convenient (IT Knowlegde Exchange ,2008). Worthy of note is the fact that the amount of dataset involved in e-voting is usually large depending on the population and the distribution of the area in question and it actually becomes impossible to adequately monitor the voting process. Although the situation (monitoring) is worse for paper voting, Critics of e-voting maintain that without a paper trail, recounts are more difficult and monitoring the system is almost impossible hence the probability of rigging is intolerably high and unacceptable (National Election Committee of Estonia , 2005).

To monitor e-voting systems large volumes of data (raw ballot data) will have to be deciphered in real-time. North (1999) proposed information visualization as an approach to making large quantity of complex information intelligible. In accordance with his proposition, the possibility of monitoring elections with information visualization techniques is explored herein.

The remainder of this paper is organized as follows. Section 2 describes the related works, and section 3 illustrates the methodology. The implementation process is discussed in section 4, and section 5 concludes the paper.

2. RELATED WORKS

The term "electronic voting" has been used for a large variety of system, ranging from hand-held infrared devices, kiosk systems with touch screens machines used in polling stations to remote voting via the internet. E-Voting is the preferred platform for future elections in the developed and developing nations of the world. It is a system that has modernized the electoral processes and electorates are able to cast their votes through an electronic device as against the traditional manual system (Ayo et al,2008).

The three types of e-Voting include: (a) Polling station : where voters cast their votes electronically on an electronic machine within the polling booth;(b) Kiosk e-Voting: where voters cast their votes at pre-selected stations through ATM-like terminals; and (c) Remote e-Voting: where voters cast their votes anywhere , and anytime , there is Internet access; as well as voting through mobile devices.

E-voting system has been subjected to practice and trials across several nations of the world but trailed by both success and failure stories. The experiences are recounted below:

The US experience
The US is referred to as mixed system because the types of e-Voting system adopted vary from one county to another Ansolabehere et al. Thus, it is a combination of the Punched Card Machine (Votomatic); Diebold Machine; Electronic System and Software (ES&S); Optical Scan System; Manual System etc. (Andrew & Paul ,2003; Steve, 2004).

The encountered problems include: over-voting; broadcast storms arising from simultaneous transmission of results from polling booths to the headquarters; equipments malfunction during elections and taken off-site for repairs; poorly implemented security measures; and election rigging through code manipulation from proprietary software developers among others.

The Brazil experience
Brazil was the first country in the world to have a complete e-Election through an indigenous technology called the Brazilian Voting Machine. The machine was developed through partnership among OMINITECH, Microbase and Unisys do Brazil (Whitney, 2000). The country had won a lot of accolades for its affordable and uniform electronic voting machine (EVM) called Urna Which was used by its 115 million voters (Leslie, 2004 & Luciano ,2004). The machine was used with printers in some elections to produce paper receipts for an adult trail, but in the last presidential election, printers were not used and the country was able to save over $100 million. There were a lot of savings through the use of indigenous technology, while Diebold costs $3000 in the US, Urna(non-touch screen) cost $420 on average (Leslie, 2004).

However, before its adoption, there was a series of road shows; it was setup in bus and train stations, and the other public places for all and sundry. The machine has been exported to other countries like Argentina, Mexico, and the Dominican Republic.

The India experience
India is the world's largest democracy, where most voters are poor rural dwellers. The country developed its electronic voting machines (EVM) through an indigenous technology. It was designed by Bharat Electronic Ltd, and the Electronics Corporation of India Ltd, with the microchip imported from Japan (Whitney, 2000 & Habib, 2004).

The country developed over 1 million EVM s for its 668 million voters. It would have cost them a great deal of money. The machine was able to cater for 64 candidates per election, in pages of 16 candidates each.

The technology was able to solve a lot of problems associated with the traditional voting system. However, before its adoption there were pilot schemes in five (5) states to familiarize the voters with the technology.

Developing nations, particularly Nigeria and Africa in general, have a lot of lessons to learn from Brazil and India.

The Nigeria experience
The heart of the matter within the context is about "election process" in Nigeria (Clinton, 2009) . The nation should address the critical mass of the major cause of electoral crisis cycle. The problems are about vote snatching, stuffing, hijacking, and outright vote stealing. Clinton (2009) further said Nigeria's electoral system and processes have been hunted by "Vote inflation, destruction, cancellation and Vote snatching or hijacking" for a very long time. This has eroded the confidence of Voters and established an endemic voters' apathy amongst

Nigerian. Indeed, the scenario constitutes the core challenge of Nigeria's electoral process – that is, the ability and capability to generate and deliver secured, authentic, transparent and generally accepted electoral result. The solution is automated election through e-voting."

However, from the experiences above, e-voting implementation all over the world is fraught with a number of problems begging for solutions. These include; a voter verifiable audit trail; multiple voting; over-voting (rigging); security and confidentiality. Paul Herrnson et al (2008) of University of Maryland, USA made the following recommendations for manufacturers of voting technology devices:

   a) "First and foremost, voting system designers and manufacturers should emphasize usability engineering in the development of their products," the report says.
   b) Systems should not provide too much information at once. The "full-faced" system showing the entire ballot in a single display overwhelmed voters.
   c) Voters need clear feedback on where they are in the voting process.
   d) Special care should be taken to make it clear when voting is complete.
   e) Review screens should display full information on a single screen, if possible, including races that the voter has skipped.

Despite all these, real-time monitoring of election results is also very essential in solving the problems mentioned above using treemap visualization technique.

We adopted some of the recommendations for manufacturers of voting technology proposed by Paul Hernson et al (2008) in the development of our work.

2.1 BACKGROUND TO VISUALIZATION

Visualization is the use of computer-supported interactive, visual representations of data to amplify cognition (Card et al, 1999). The purpose of visualization is to gain insight. There are various forms of visualization. The two major types are the scientific visualization and the information visualization. Information visualization is the use of computer-supported, interactive, visual representations of abstract data to amplify cognition. While scientific visualization is applied to scientific data, information visualization is applied to abstract data. The reason for the divergence is that scientific data are often physically based.

Work in data graphics dates back to the time of Playfair(1786) who seem to have been amongst the earliest to use abstract visual properties such as lines and area to represent (Tuft, 1983). Starting with Playfair the classical methods of plotting data were developed. In 1987 Bertin published his theory of graphics in the Semiology of Graphics. This theory identified the basic elements of diagrams and described a frame work for their design (Bertin,1977) . Tufte published a theory of data graphics that emphasized maximizing the density of useful information. Both Berlin's and Tufte's theory became well known and was instrumental to the formation of the information visualization discipline.

Also scientists were interested in statistics. Tukey, (1977) began a movement from within statistics with his work on Exploratory Data Analysis. The emphasis in his work was on the use of pictures to give statistical insight into data.

In 1985, NSF launched an important new initiative on scientific visualization (Mc Cormic, 1987). After a lot of other contributions and researchers, the user interface community saw advances in graphics hardware opening the possibility of a new generation of user interfaces. These interfaces focused on user interaction with large amount of data, such as multivariate databases or document collections. The first use of the word "Information visualization" to describe this new found use of visualization was in Card et al (1999).

2.2 HISTORY OF TREE-MAP RESEARCH

Ben Shneiderman can be said to be the father of Tree-Map. He started work on it in 1990 when he wanted to create a compact visualization of directory tree structures. He explored ways to show trees in a space constrained layout. He came up with an algorithm to the effect which was published in the first technical report in January 1992 in the ACM Transactions on graphics. Brian Johnson implemented the algorithms and refined the presentation strategies while preserving rapid performance even with 5,000 node hierarchies. Tree-Maps are a convenient representation that has unmatched utility for certain tasks. The capacity to see tens of thousands of nodes in a fixed space and find large areas or duplicate directories is very powerful.

Some features of Tree-Map, like the zooming and sound were added by a PhD student; Brian Johnson, other features he added are hue/saturation control, many border variations and labeling control. Other researchers have made adjustments to the original Tree-Map design and they have all been usually from the original framework.

2.3 WHY TREE-MAP IS PREFERRED TO OTHER HIERARCHICAL DATA VISUALIZATION TECHNIQUES?

Traditional methods for the presentation of hierarchically structured information can be roughly classified into three categories: listing, outlines, and tree diagrams. It is difficult for people to extract information from large hierarchical information structures using these methods, as the navigation of the structure is a great burden and content information is hidden within individual nodes (Kim et al, 1987).

Listings are capable of providing detailed content information, but are generally very poor at presenting structural information. Listing of the entire structure with explicit paths can provide structural information, but requires users to parser path information to arrive at a mental model of the structure. Alternatively user may list each internal node of the hierarchy independently, but this requires users to manually traverse the hierarchy to determine its structure. Outline method can provide both structure and content information, but since the structural indentation can only be viewed a few lines at a time it is often inadequate (Chimera et al, 1991) .

The number of display lines required to present a hierarchy with both the listing and the outline is linearly proportional to the number of nodes in the hierarchy. These methods are inadequate for structures containing more than a few hundred nodes. A great deal of effort is required to achieve a mental model of the structure in large hierarchies using these methods.

Tree diagrams have traditionally sought efficient and esthetically pleasing methods for the layout of node and link diagrams. These layouts are based on static presentation and are common in text dealing with graph theory and data structures. They are excellent visualization tools for small trees Bruggerman –Klian & Hood-D (1989), Tyson R.Henry & Scott E.Hudson(1990), Tomihissa Kamada(1988) . However, these traditional node and link trees make poor use of the available display space. In a typical tree drawing more than 50% of the pixels are used as background. For small trees this poor use of space is acceptable and traditional layout methods produce excellent results. But for large trees, traditional node and link diagrams cannot be drawn adequately in a limited display space. Attempts to provide zooming and panning have only been partially successful (Tyson & Scott ,1990).

Another problem with tree diagram is the lack of content information; typically each node has only a simple text label. This problem exists because presenting additional information with each node quickly overwhelms the display space fro trees with just one node.

The presentation of content information in all of these traditional methods has usually been text based. Although tree diagram are a graphical based method capable of making use of visualization techniques. Unfortunately, global views of large tree diagrams require the nodes to be so small that there is virtually no space to provide visual cues as to node content.

Tree-Maps efficiently utilize the designated display area and are capable of providing structural information implicitly, thereby eliminating the need to explicitly draw internal nodes. Thus much more space is available for the rendering of individual leaf nodes, and for providing visual cues related to content information.

Tree-Maps provide an overall view of the entire hierarchy, making the navigation of large hierarchies much easier. Displaying the entire structure at once allows user to move rapidly to any location in the space. As Beard states in his paper on navigating large two-dimensional spaces (Beard & Weaver,1990) , "if the two-dimensional informational space fits completely onto a display screen, there is no navigation problem …Users are never lost because they can see the complete information space."

2.4 Treemap Algorithm

Treemap algorithm is to draw treemap and to track cursor movement in the tree. The algorithms may be applied to any tree, regardless of its branching degree. Both algorithms appear below.

The basic drawing algorithm produces a series of nested boxes representing the structure of the tree. The cursor tracking algorithm facilitates interactive feedback about the tree. Every point in the drawing corresponds to node in the tree. While the current tracking point(from a mouse

or touch screen input device) is in a node, the node is selected and information about it is displayed(Card et al ,1999).

2.4.1 Drawing algorithm

The treemap can be drawn during one pre-order pass through the tree in O(n) time, assuming that node properties (weight, name, etc.) have previously been computed or assigned. The drawing algorithm proceeds as follows in c-language specification:

1.)The node draws itself within its rectangular bounds according to its display properties (weight, color, borders, etc.).

2.) The node sets new bounds and drawing properties for each of its children, and recursively sends each child a drawing command. The bounds of a node's children form either a vertical or horizontal partitioning of the display space allocated to the node.

DrawTree( ) The node get a message to draw itself
{donesize=0 ;
PaintDisplayRectangle();
  Switch (myOrientation) {
Case HORIZONTAL;
  StartSide=myBounds.left;
Case VERTICAL;
   startSide=myBounds.top;
}
If (myNodeType==Internal) {
   ForEach(childNode) Do {
childNode->SetBounds(startSide,doneSize, myOrientation);

ChildNode->SetVisual();
ChildNode->DrawTree ();
}}}
SetBounds(startSide,doneSize, parentOrientation)
{ doneSize=doneSize+mySize ;
Switch (parentOrientation) {
Case HORIZONTAL;
myOrientation=VERTICAL;
*endSide=parentWidth*doneSize/ parentSize;*
SetMyRect(startSide+offset,
parentBounds.top+offset,
parentBounds.left+endside-offset,
parentBounds.bottom-offset,
parentBounds.bottom-offset);
startSide=parentBounds.left+endSide;
case VERTICAL;
myOrientation=HORIZONTAL;
*endSide= parentHeight*doneSize /parentSize;*

SetThisRect(parentBounds.left+offset,
startSide+offset,
ParentBounds.right-offset,
parentBounds.top+endside-offset);
startSide=parentBounds.top+endSide;
}}

2.4.2 TRACKING ALGORITHM

The path from the root of the tree to the node associated with a given point in the display can be found in time proportional to the depth of the node.

In our implementation, when a node draws itself it stores its bounding box in an instance variable. Every point in the tree-map corresponds to a node in the hierarchy; in addition every node is contained in the bounding box of the root node. Recall that each node's bounding box completely encloses the bounding node containing a given point thus involves only a simple descent through one path in the tree, until the smallest enclosing bounding box is found.

FindPath(point thePoint)
{ if node encloses the Point then
   Foreach   child of thisNode do {
    Path=FindPath(thePoint);
      If (path!= NULL) then
   *Return(Insert List(thisNode, path));*
}return(NULL);
}

3.   DESIGN METHODOLOGY

The **T**ree-**M**ap **E**-voting **M**onitoring **S**ystem (TEMS) is made up of three primary sub-systems, these are:

(i) ***The e-voting devices/system:*** these refer to the appliances or techniques and technologies used to get a voters ballot into electronic form. These might be through normal computer systems as in online voting or through special appliances making use of some networking technology to transfer election data to a central location. This also includes The N-tier e-voting application which serves to provide business logic and a user interface for the e-voting system.

(ii) ***The networking facilities:*** these are the tools used to transfer the data to the TEMS. They can range from wireless internet connections, wired networks, to wireless sensor equipments.

(iii)***The central server/monitoring system:*** this is where the voting results is collected and been

monitored in real-time. It is where the TEMS resides.

The diagram showing the conceptual framework of the system is shown in figure 1 below.
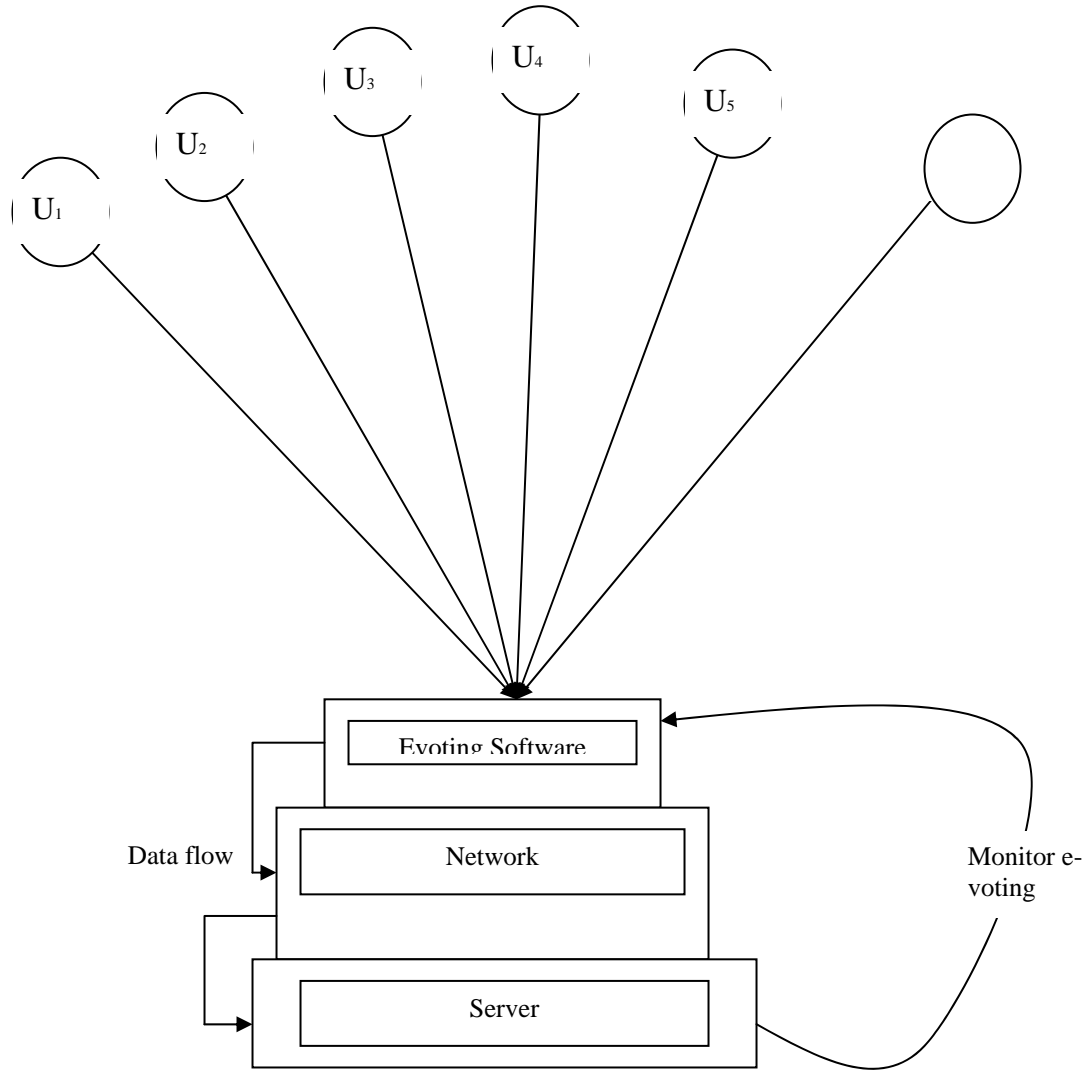
Figure 1: Showing a simple representation of interactions between the sub-systems.

In figure 1 above each of the users Ui represent a user set i.e either a single or multiple users using the system for voting. The data which is passed through a network is stored on the central server. The data in this case is purportedly coming from 20 local governments of Ogun state with 236 electoral wards in them altogether.

Figure 1 shows the low level interaction between the sub-systems. The TEMS enables the server monitor the balloting process.
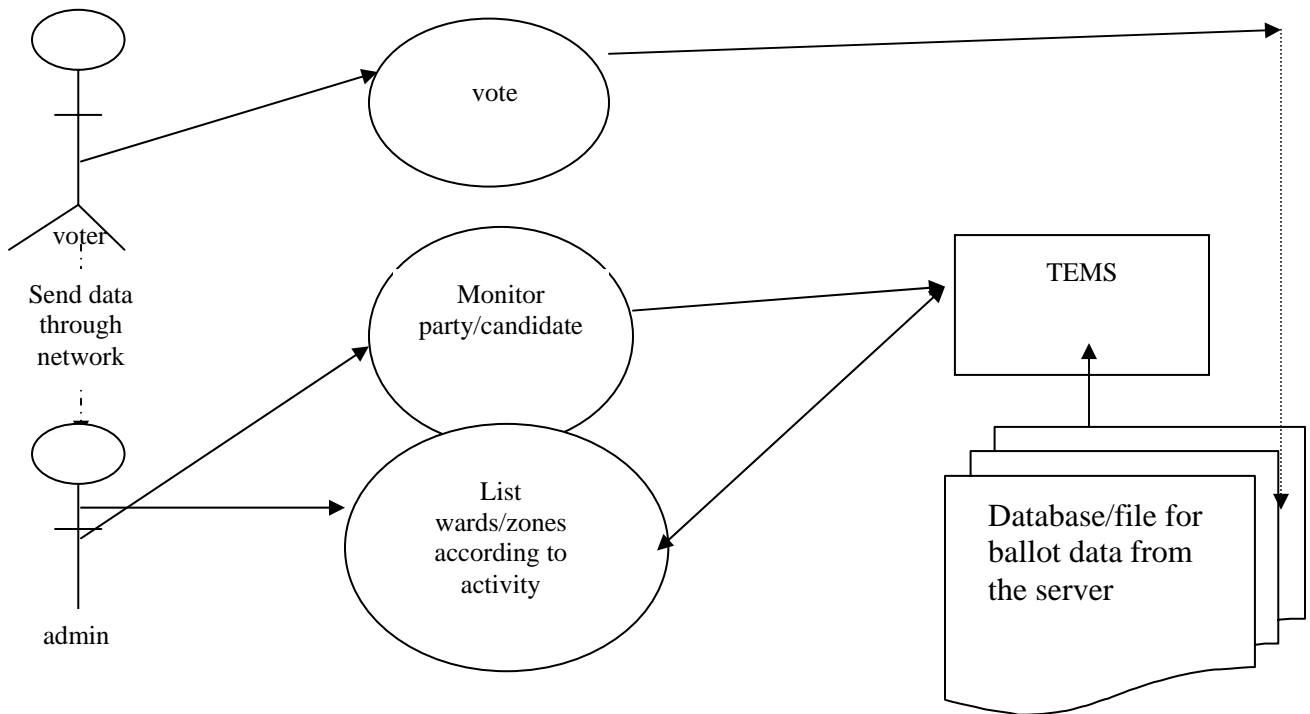
Figure 2: A use case diagram of the possible interactions between the user and TEMS.

From figure 2, the voter cast his vote which is sent to the central server' data store through a fast and reliable network.

The administrator on the other hand has different reasons and view to the system. He wants to see the activity in the nodes or wards and wants to be able in real time make useful and conclusive meaning from the millions of data rolling in from all the wards in the state.

The activities of the TEMS can be further explained using a simple task model to show the interaction of the administrator with the system. This as shown in figure 3 overleaf.
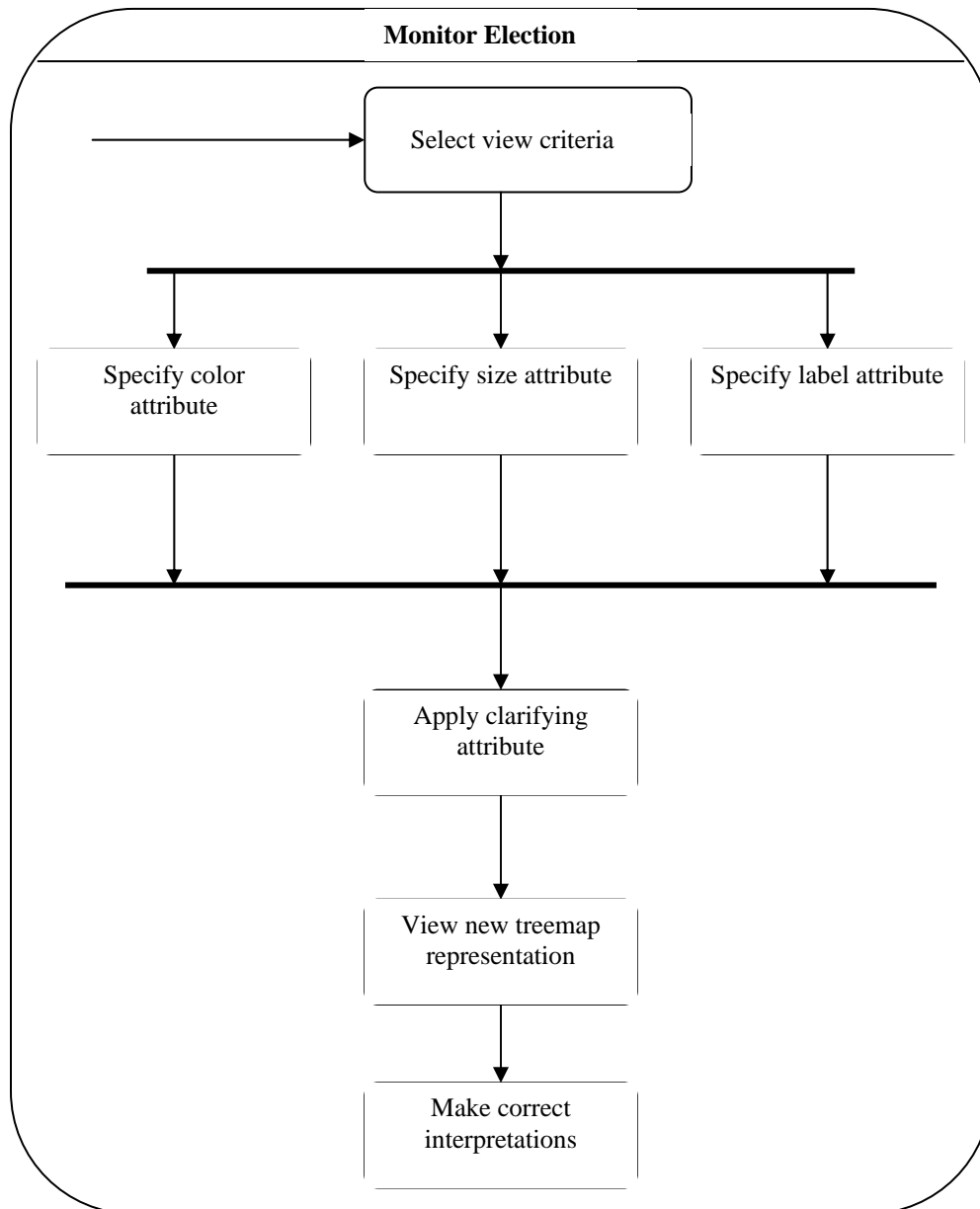
Figure 3: A partial view of the task model

Figure 3 shows some of the possible tasks that the TEMS administrator might want to perform. The complete e-voting system and the TEMS integrated therein are shown in figure 4.
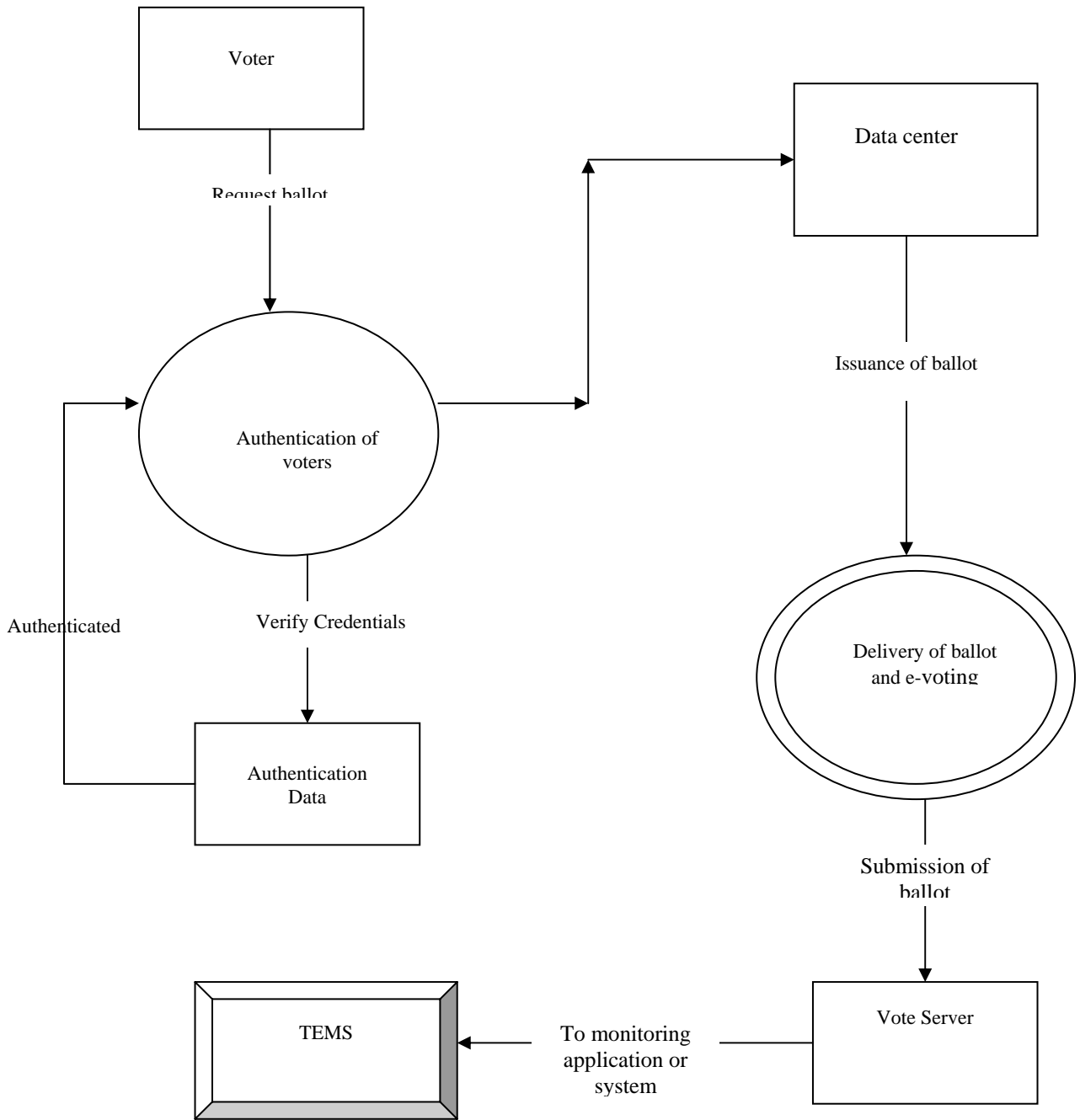
Figure 4: A modified data flow diagram for e-voting (modified from Ayo & Babajide, 2007)

Figure 4 shows the different stages involved in the e-voting and how the TEMS is going to be integrated into the e-voting system. This represents the proposed conceptual models.

The TEMS can be deployed by using any form of communication link or wireless sensor that the

designer of the network deems fit. The ballot data goes through the network to a data repository on the server where the TEMS pick the raw data and transform it into meaningful visual representations that can be easily interpreted.

4. IMPLEMENTATION PROCESS

Characteristics of the TEMS are:
(i) WEB BASED: The TEMS was designed to be web based to allow for easy access by online voting sites.
(ii) TREEMAP FRAMEWORK: it is built on the original treemap framework. The particular version used was designed by macroFocus and modified to be able to continually read and display graphical representations for ballot data in real-time.
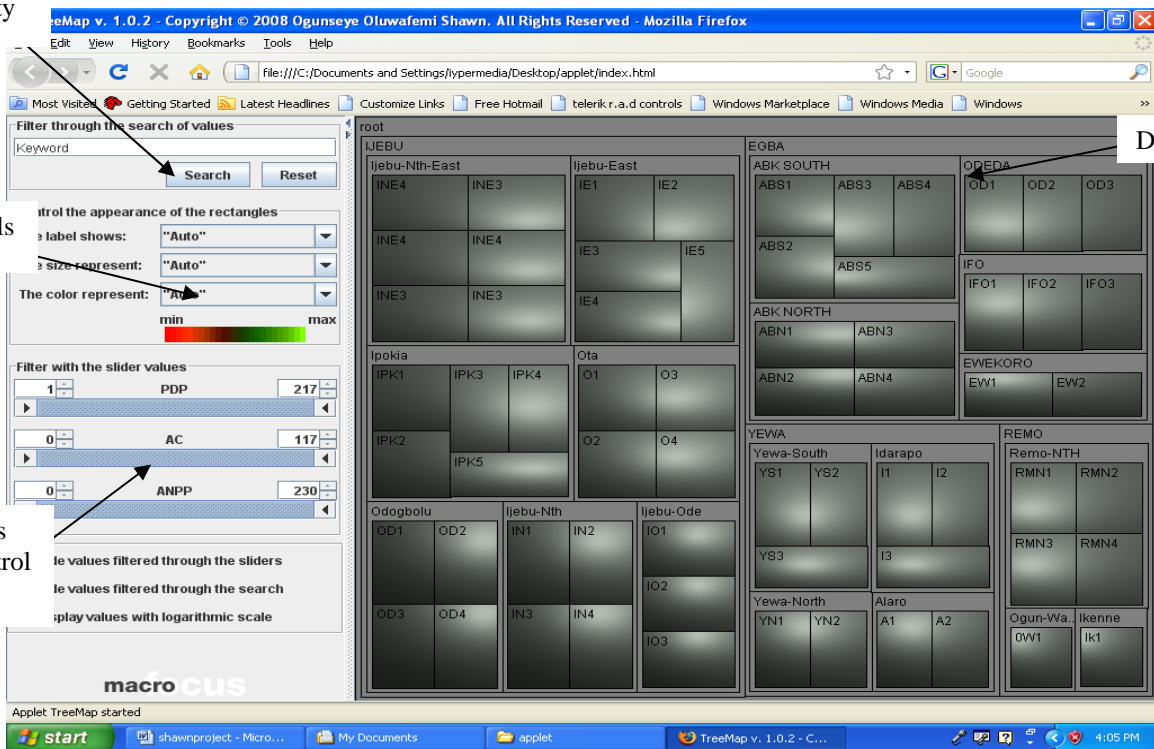
4.1 THE ZOOMABLE USER INTERFACE

The TEMS interface is atypical of any treemap system except for some particular features are that uses the metal interface of Java, making it more attractive. The other general features are discussed based on figures shown below.

Figure 5: the interface for the TEMS showing the different Divisions in Ogun state and their local governments

(i) ***The search facility*** added to the normal Tree-Map framework enables quick search for relevant data from the TEMS.

(ii) ***The labels*** show the property for which the Tree-Map should constraint or distinguish its nodes. An example is the use of color, or size.

(iii)***Gliders*** are used to set parameters for which nodes are to be outputted or shown on the Tree-Map.

(iv)***The Divisions*** on the TEMS are parent nodes to local government areas in Ogun state.

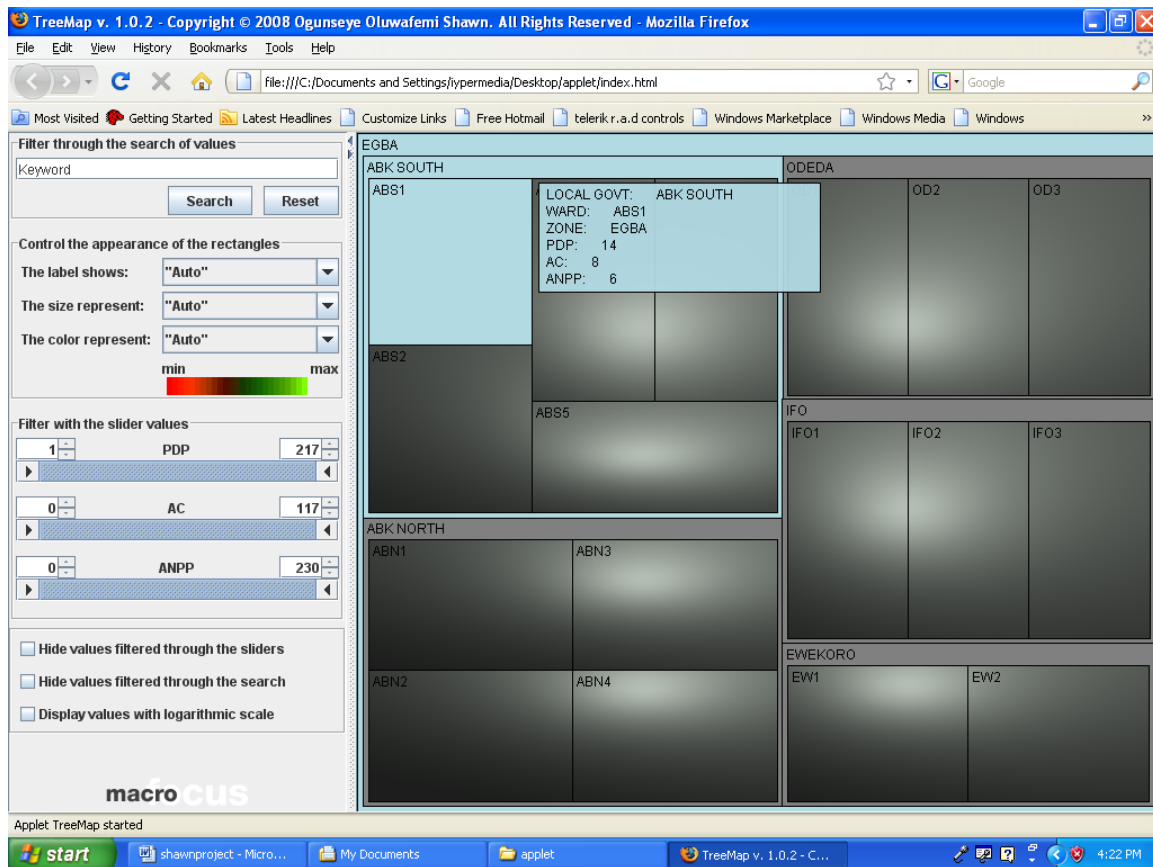The zones can be zoomed into to get data or focus. This is shown in figure 6 below.

Figure 6: screenshot showing a zoomed view to Egba zone.

The screenshot in the previous figure shows the zoomed view from the Tree-Map and also shows the ballot data for each local government at that particular instance. Figure 6 above shows results from Egba division of Ogun State , Nigeria with 6 local governments (political zones) in the division. The highlighted results above is for ward ABB1 of Abeokuta South Local government with   Wards: ={ ABB1, ABB2, ABB3, ABB4, ABB5}
ZONE: EGBA (ABB1)
POLITICAL PARTIES RESULTS
PDP (Peoples democratic Party)= 14
AC (Action Congress) = 8
ANPP (All Nigerians People Party) = 8

The TEMS updates itself by refreshing itself and continually reading the data in the data repository.

5   CONCLUSION

This work has attempted to alleviate the fear of critics of e-voting systems by adopting a form of information visualization – TreeMap to monitor events in the balloting process. Though the work recognizes that there are also challenges in the adoption of visualization technologies, research has shown that this can be easily circumvented (Folorunso & Ogunseye, 2008) .   From the implementation and design of the TEMS and its integration with e-voting systems, this paper has shown that the system is the implementation of a secure e-voting system that is not susceptible to unnoticed faults and fraud is achievable.

6   ACKNOWLEDGEMENT

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