Challenges in the adoption of visualization system: a survey

Olusegun Folorunso and Oluwafemi Shawn Ogunseye
Department of Computer Science, University of Agriculture, Abeokuta, Nigeria

Abstract

Purpose – The need for maximum cognition from massive amounts of data is becoming explosive. Different visualization mechanisms are being introduced to achieve this aim. This paper aims to consider the state of organizations as regards being abreast with the recent visualization technologies.

Design/methodology/approach – In this paper, the authors look critically at the system adoption life cycle as it applied to visualization system. Also, the two forms of visualization; static and dynamic are looked at, considering the least applied and why. An evaluation of the visualization system was implemented in order to discern if it provides any benefit to organizations.

Findings – The study showed that the RT-DANGO tool when compared to result from Excel exposed some spikes at some points when visualized dynamically which are not observed using usual static graph as it exposed some unseen events. The mean time taken to finish analysis of 4,000 concurrent-related data were 168 s using RT-DANGO and 121 s with the MS-Excel. The difference was significant to $p < 0.05$ ($Z = -2.040$). This was considered a reasonable tradeoff for accuracy, clarity and completeness of information.

Originality/value – The paper shows the factors that are responsible for visualization's usage in organizations. The paper will thus serve as an eye opener to critical issues affecting the visualization industry to the benefit of all stakeholders. Some references are made to the challenges faced in Nigeria.

Keywords Cybernetics, Databases, Control, Programming and algorithm theory

Paper type Research paper

1. Introduction

Advancements in visualization system have led to the development of animated visualization tools from the traditional static ones. These are software that can mimic and to a large extent capture the processes of a dynamic system showing inherent parts of the system that would not be visible if static visualization techniques were employed. Static visualization enables the visualization of state and a suitable analogy would be the use of ordinary or still cameras to capture events as compared to the use of video cameras. Of course, video cameras would capture every instance of the event per time while ordinary cameras will capture the state of the event at a given time. Since business processes are dynamic there is therefore a need to take its dynamics into consideration when making analysis or important business decisions. This informs the use of dynamic visualization techniques worldwide.

With all these noticeable advantages, the big question this research tries to find an answer to is what are the possible challenges impeding the adoption of dynamic visualization techniques by enterprises/organizations.

The remainder of the paper is organized as follows: Section 2 describes the system adoption life cycle (TALC) of the visualization techniques. Section 3 lists some of the common challenges faced by organizations in adopting animated visualization. A very encouraging footpath for introduction of visualization to enterprises is drawn in Section 4. Section 5 describes the present state and future prospects of animated

Kybernetes
Vol. 37 No. 9/10, 2008
pp. 1530-1541

0368-492X
DOI 10.1108/03684920810907841

visualization looking at the possible areas of its applicability in the Nigerian context and the research is concluded in Section 6.

2. Visualization system

Visualization is a concept that has been around for a long time. It is usually divided into three major classes, these are: information visualization, scientific visualization and software visualization. The definition of scientific visualization as stated by Aref *et al.* (1994) is the use of computer graphics to manipulate data for the purpose of gaining insight, testing hypothesis, and general elucidation. Price *et al.* (1993) described software visualization as the use of typography, animation and cinematography with modern human-computer interaction system to facilitate the comprehension of computer software. Schonhage (2001) in his thesis on DIVA described information visualization as the process of transforming non-visual data to visual information. This is carried out because visualization helps humans understand large amounts of data. Some school of thought believe that there is no difference as such in the system (Tory and Moller, 2004). It has been employed in many fields and in different research works for varied reasons; some of these are mentioned here. Research has been carried out on visualization for the automobile industries (Marcus, 2002) to show prototypes and frameworks for advance vehicle display. It has also been used in many bioinformatics related disciplines like visualizing large phylogenetic trees (Hughes *et al.*, 2004), visualizing biological pathways (Saraiya *et al.*, 2005), in medicine; for liver cancer detection (Sammouda *et al.*, 2002), in stock marketing (Wattenberg, 1999), online auction (Shmueli and Jank, 2005), finance; (Kiem *et al.*, 2006) and many other innumerable visualization applications to make easy the understanding of complex data. As regards other visualization of data; there has been research on managing large datasets when it involves complex data structures (Meyer, 2000) there are also research works on integration and visualization of structural state data.

Visualization invariably uses the visual representations that help to amplify cognition.

Card *et al.* (1999) further described six major ways through which visualization amplifies cognition. These are by:

(1) increasing the memory and processing resources available to users;

(2) reducing the search for information;

(3) using visual representations to enhance the detection of patterns;

(4) enabling perceptual inference operation;

(5) using perceptual perception mechanisms for monitoring; and

(6) encoding information in a manipulability medium.

Visualization system's state can be static or dynamic. Some existing package such as MS-Excel displays graphical results statically while some make theirs dynamic. It has been argued that dynamical visualization exposes the unseen when implemented which makes it more suitable for monitoring events that change with respect to time.

2.1 Some application areas

2.1.1 Information visualization. Visualization system is applicable in geographic information systems (GIS). Large commercial GIS systems have long been used for regional planning, transportation planning and management, weather forecasting, and mapping. Simple GIS applications are becoming fairly common on the world wide web in the form of customized maps that are displayed to show the location of an address in response to a query to a search engine. Figure 1, for example, was returned by the MapQuest web site in response to a query that supplied a zip code for Chapel Hill, NC and a street intersection. MapQuest provides ten levels of zooming for displayed maps.

The SmartForest project uses an interactive modeling and visualization tool to simulate a 3D forest environment. Starting with standard data – ground surveys, aerial photographs, and sample plot data – detailed 3D visualizations are built, as shown in Figure 2. The SmartForest visualization provides both high-level overviews of a forest and detailed views of individual trees at ground level. The representation of each tree in the visualization is a result of multiple variables in the database; changes to the database are reflected in the next refreshed visualization.

HomeFinder enable users to more easily see trends in the data and pinpoint exceptional data. Research from the University of Maryland shows that users performed tasks significantly faster using the visual, dynamic query interface as compared to ones where queries to the database were input through fill-in forms with textual output (Ahlberg *et al.*, 1992). A number of subsequent applications have been developed with this framework of visualizing multi-dimensional data, such as films (Figure 3) and health statistics (Plaisant, 1993), and there is now a commercial product called Spotfire that provides users with more features and flexibility when working with their own multi-dimensional data.

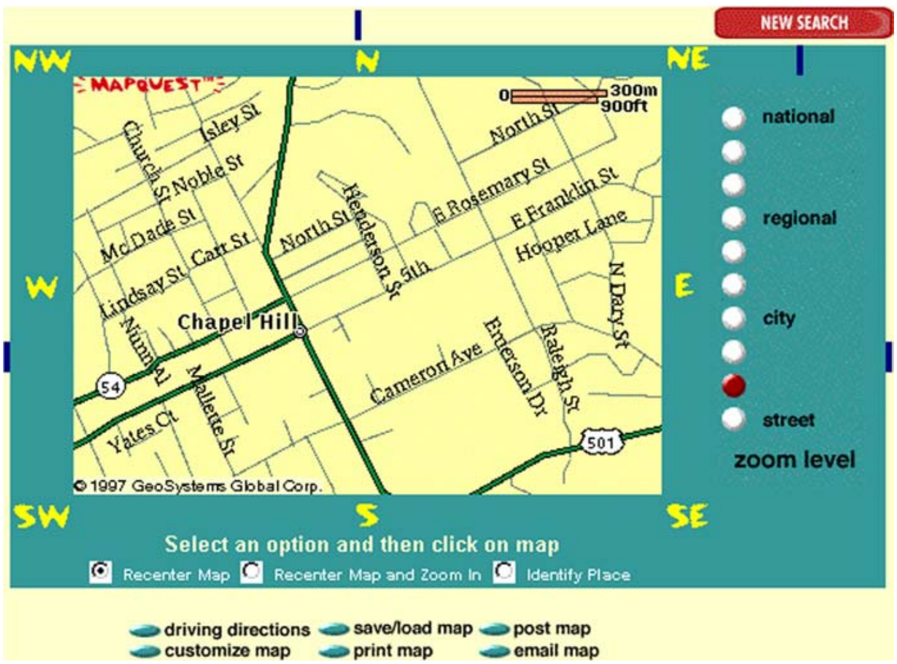
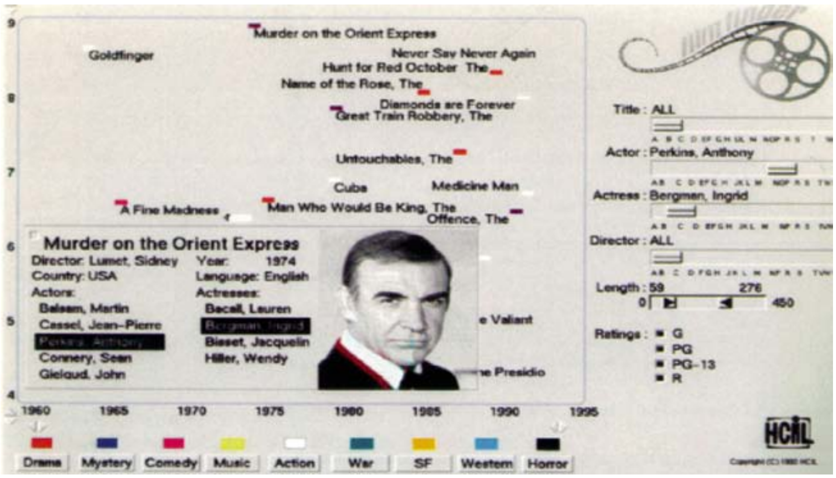


Figure 1.
MapQuest

Source: www.mapquest.com (accessed 23 November, 2006)

Source: www.imlab.uiuc.edu/smartforest/1.html (accessed 23 November, 2006)

Figure 2. SmartForest forest visualization



Source: www.cs.umd.edu/projects/hcil/ (accessed 23 November, 2006)

Figure 3. FilmFinder

2.1.2 Scientific visualization. Many applications in scientific visualization incorporate volume visualizations, because a primary purpose of scientific visualization is to represent real, 3D objects. These computer models have provided scientists with a way to perform manipulations and experiments to predict how real-world objects actually behave, but which are too expensive, difficult, dangerous, or simply impossible to perform with real-world objects.

In recent years, 3D visualization has been applied to a wider variety of areas, especially architectural and medical applications. The use of technologies such as QuickTime-VR, Virtual Reality Modeling Language, and digital imaging are used to create systems that realistically represent 3D data. These systems enable people to examine and explore 3D objects and spaces, in a way that is often more practical and efficient than going to the real thing.

For example, the National Library of Medicine's Visible Human Project provides a large digital library of anatomical images of the human body, based on precise, comprehensive images made from a male and a female cadaver at 1 mm intervals. These images include color photographs of cross-sections and MRI and CT scans. A number of projects have built interactive, visual systems based on the Visible Human Project database. Examples are shown in Figures 4 and 5.

2.1.3 Software visualization. The GraphVisualizer3D, developed at the University of New Brunswick, visualizes the complex relationship between the various components that make up a software program. In contrast to the one-dimensional representation of SeeSoft, GraphVisualizer3D uses network diagrams to illustrate how files, classes, variables, and functions (Figure 6) interrelate. By presenting a lot of complex relationships in a 3D visualization, network diagrams of the type used by GraphVisualizer3D can help users understand relationships and dependencies in a large system more quickly and easily while reducing the need to look up such information in the code or in reference tables.

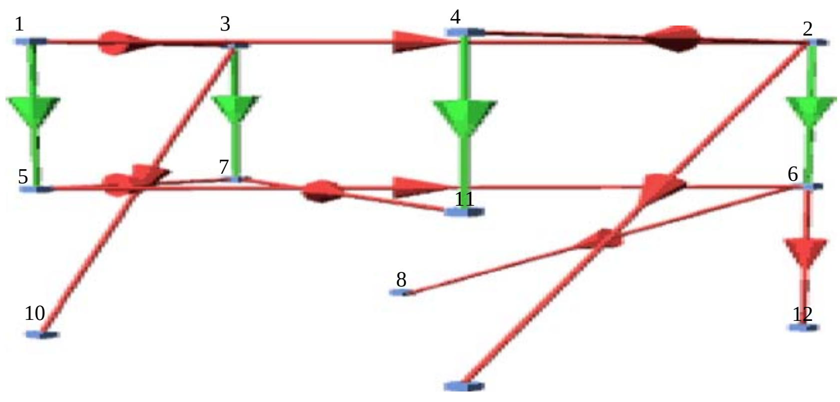
Obviously, visualization system is gradually having its effect on all fields of human endeavor. Therefore, its characteristics as regards adoptability need to be studied.

Source: www.dmsv.med.umich.edu/head.html (accessed November 23, 2006)

Figure 4.
A slice of human head

Source: www.dal.qut.edu.au/DALhome.html (accessed November 23, 2006)

Figure 5.
Animated skeleton



Source: www.omg.unb.ca/hci/projects (accessed November 23, 2006)

Figure 6. Visualizing software component relationship

2.2 Dynamic visualization adoption life cycle

From research in the social sciences, the path of a business adopting a new system can be depicted by TALC model proposed by Moore (2002) (Figure 7).

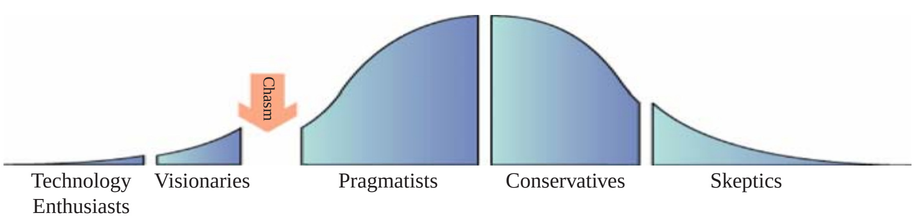
The TALC can be likened to a bell shaped curve divided into five phases through which every system is purported to pass through during its life cycle: system enthusiasts, visionaries, pragmatists, conservatives and sceptics:

(1) *System enthusiasts*. These are a category of people who acquire new system for its own sake. They are gatekeepers who allow entry of any new discontinuous system into the market. Any new system needs the approval of innovators for it to survive in the lifecycle.

(2) *Visionaries*. They are people who consider trying out a new system a bearable risk. This is probably because they assume it will afford them an edge over competition.

(3) *Pragmatists*. These set of people basically concern themselves with using tried and tested system for improving existing business processes.

(4) *Conservatives*. In this group, you find people who dislike discontinuous innovation and prefer tradition over progress. These people have a very low and nearly negligible probability of buying high-system products and are not expected to like it.



Source: Proposed by Moore (2002)

Figure 7. TALC

(5) *Skeptics.* These set out rightly reject new system. From the descriptions made above, a wide gap (chasm) exists between the visionaries and the pragmatists. The former appreciates the risk associated with creating groundbreaking technologies and accept them for varied reasons, while the later wants true and tested technologies. In Nigeria, since animated or dynamic visualization is still in its infancy it can be said to be in the late majority (conservatives) or laggard zone (skeptics). The next section discusses possible reasons for this.

3. Likely reasons for poor adoption rate

The common challenges often encountered in the adoption of visualization methods in a developing country like Nigeria are: serial thinking, closed mindedness, black and white mindset, fear of change, specialized skills, easy way out mentality, do-it-all-at-once attitude and office politics. All these issues are discussed in this section:

- *Serial thinking.* This basically implies being accustomed to a particular method and not willing to change. Many IT professionals are proficient in the use of static methods of visualizing data and find it difficult to appreciate the opportunities afforded by dynamic visualization methods. This might be attributed to the fact that there have not been any obvious major losses of precision in their data analyses in question.
- *Close mindedness.* We have long time IT professionals who have not taken the time to familiarize themselves with the new developments in the IT world as regards visualization and do not consider it worthwhile. They also do not see the need why others would want to adopt it and will therefore discourage them.
- *Office politics.* This is common in most organizations especially in this part of the world. Some people will prevent the use of visualization to save their power base. A top official that has no knowledge of visualization might actually kick against any junior officer trying to "outshine him."
- *Black and white mindset.* IT professionals usually are of the opinion that things are either black or white and cannot be any thing in between. What this mean is as far as some professionals are concerned there are no middle grounds. So it is either static or dynamic visualization and there cannot be a mixture of both to produce a great result.
- *Fear of change.* IT professionals are usually saddled with huge responsibilities which might include presenting important company information to top executives of the organization. It is therefore not too farfetched that they might be skeptic about employing considerably new system where the older ones have always performed.
- *Specialized skills.* When organizations parade staff who are specialists in static visualization methods and who possess very little or no knowledge of dynamic visualization methods it will not be too easy for such an organization to change its methods.
- *Do-it-all-at-once attitude.* It is usually an unfortunate situation when an attempt is made to integrate all visualization techniques possible into one business process

at once. The output will suffer and losses might be incurred. This might be a reason why some organizations have backed off dynamic visualization.

- *Easy way out mentality.* People tend to always want the easiest way out at all cost even if it will be detrimental to them or the task being performed. This also applies to the issue at hand; some IT professional will rather work with static methods at the expense of clarity, precision and detail than use the newer methods.

These are issues worth considering, and when handled cautiously then will visualization be more easily introduced to organizations.

In Section 4, we discuss issues pertinent to introducing visualization to organizations.

4. Introducing visualization to organizations

- *Obtain management support.* The upper and middle level management should be educated on the benefits of animated visualization. The grey areas in adopting dynamic visualization techniques should be clarified. They should also be made to see the financial implications of being able to view all the intricacies of data and the enhance cognition it avails.
- *Education and support.* The management and development team should be familiar with the principles, practices and framework of visualization before actually completely adopting it. Training and support should be available to tackle misconceptions and fears arising from the change.
- *Make the need obvious.* The need for dynamic visualization should be made obvious to all concerned. The management and staff of the organization should be made to appreciate the necessity of the system without any other more logical alternative.
- *Integrate to external processes.* It is important that new techniques are made to fit existing practices in organization.
- *Start pilot implementation phase.* It might be necessary to carry out a harmless trial of the new technique to see if it will fit well with the organization's policies or if her workers will be able to handle it.
- *Introduce champions.* Encourage the presence of a champion (or champions) of the system in that organization, somebody who has become knowledgeable in the field and is enthusiastic about its potentials.

5. Present state and future prospects of visualization system

Visualization system has been considered a good tool for pedagogy especially in teaching algorithm and program behavior to computer science students; it has been also employed by organizations. Section 2 above discusses some application areas of visualization system. Figure 1 employs a dynamic visualization to help monitor the movement of the vehicles. Apart from this very good example there are only a handful of others that might exist. Another example is the use of a Real Time Database ANimation GeneratOr (RT-DANGO) to effectively monitor the functioning of real-time database systems (RTDBS) (Folorunso, 2003).

A critical look at visualization shows that there exists a wide area of applicability, examples are:

- the real time monitoring and reporting of election and voting situations;
- the health sector; in diagnosing ailments and diseases;
- traffic monitoring for motorists, computer networks, network security; and
- teaching in universities.

The following are the issues leading to the preference of dynamic visualization technique over the usual static technique as stated in Folorunso *et al.* (2005):

- How can the users of visualization system be aware of the behavior of their algorithms or model?
- How can the users of visualization system determine the quality of the performance evaluation solution found by their algorithms or model?

The above questions are answered in the case study below.

5.1 Experiences from a case study: visualizing the behavior of concurrency control algorithms for RTDBS

Visualization assists in evaluating concurrency control (CC) for RTDBS performance by studying the characteristics involved. However, a snapshot of a representative of the output can be examined via a graphical user interface.

5.1.1 Interface design. This subsection describes the individual views and navigators available in CC-RTDBS. Figure 8 shows examples screen image taken from CC-RTDBS containing a coarse-grained miss ratio versus number of transactions, miss probability versus arrival rate (bottom), a fine-gained visualization (top right), a text boxes range selector (top left).

The design features of each component are described in the remainder of this subsection. The "augmented miss probability versus number of transaction graph"

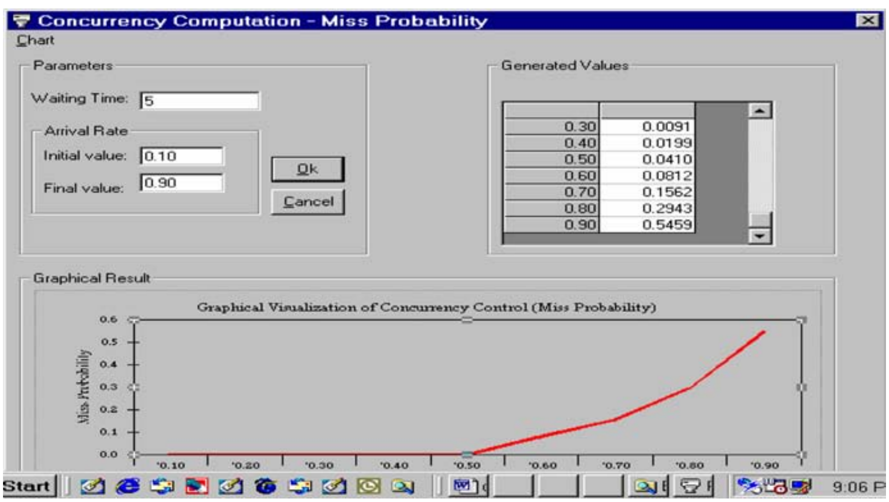


Figure 8.
Description of an interface design of visualizing miss probability

shows the result of the CC-RTDBS's run. The values of the miss ratio computed are plotted on a single line graph (Figure 8). CC-RTDBS is an algorithm visualization system primarily concerned with illustrating the algorithm's "high level" data structures. Visualizing the work of the algorithm presents the user with more direct view of the RTDBS behaviour than visualizations of the code or the "low-level" data values, this work may be a useful educational debugging aid used selectively as it presents so much fine-grained, detail of the CC-RTDBS runtime characteristics execution.

The "fine-grained view" presents the values of selected miss probability and their number of transactions values. This view is coupled to the visualization and supports the user's further investigation of the CC-RTDBS behaviour. When the view is displayed the user can monitor the behaviour as it happens.

5.1.2 Results from graphical package: MS-Excel. For comparative studies, Figure 9 shows the former method of displaying performance behaviour graphically through electronic spreadsheet program of which the features are not easily monitored dynamically.

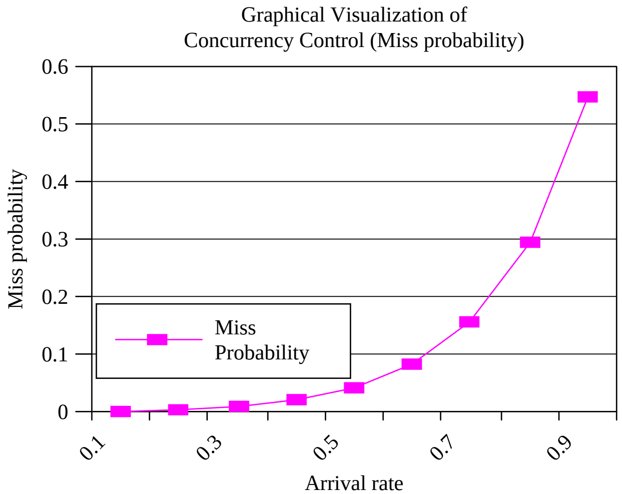
The inherent characteristics of the data being visualized are not visible.

Comparative studies of Figures 8 and 9 answer the questions raised earlier.

5.2 Discussions

To quantitatively analyze these different techniques above, two groups of 20 students each was formed. Group A used the RT-DANGO to study CC-RT-DANGO runtime characteristics while group B used the MS-Excel spreadsheet package to do these studies.

We judged based on three metrics: retrieval performance, recall and precision metrics, and a non-parametric statistical significant test, i.e. the Wilcox in test for related pairs (Howell, 1997).



Note: Miss probability

Figure 9.
Figure 9 Offline visualization of concurrency control

5.2.1 Retrieval performance results. The time taken to perform the goal-directed search for points and actions of the RTDBS was on average significantly longer than RT-DANGO group. The mean time taken to finish analysis of 4,000 concurrent-related data were 168 s using RT-DANGO and 121 s with the MS-Excel. The difference was significant to $p < 0.05$ ($Z = -2.040$).

The mean interactions precision and calculated value using expert judge relevance ratings show a significant difference between groups A and B performance 0.67 against 0.50 for precision $p > 0.1$, $Z = -0.756$, and 0.27 against 0.16 for $p > 0.1$, $Z = -0.471$. This performance was partially uniform. For example, subject scores had a standard deviation of 0.02 and accounted for 6 percent of total variation.

More time was spent in the analysis and presentation of results by the RT-DANGO. This was attributed to the attention to detail of the RT-DANGO and can be viewed as a reasonable trade-off for the clarity and completeness of information it provides.

6. Conclusions and future work

This research looks at a renowned system – dynamic visualization and attempts to see the possible issues impeding its widespread adoption. From the research it has become obvious through the exposed challenges facing it that if awareness is raised and good management principles are applied to the issue of adopting dynamic visualization it will go a long way in providing more force to the cause. An explorative study to find out the critical factors affecting the adoption of this system should be conducted with a view to solving them.

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About the authors

Olusegun Folorunso is a Senior Lecturer at the Department of Computer Science, University of Agriculture, Abeokuta. Nigeria. His areas of interest include adoption of information systems strategies, knowledge management, software visualization and database management. He has publications in reputable local and international journals. Olusegun Folorunso is the corresponding author and can be contacted at: folorunsolusegun@yahoo.com

Oluwafemi Shawn Ogunseye is a Research Student at the Department of Computer Science University of Agriculture, Abeokuta, Nigeria. His research interests include expert systems, knowledge management systems, extrusion detection, visualization and business intelligence. He has publications in reputable local and international journals.