Web-Compatible Graphics Visualization Framework for Online Instruction and Assessment of Hardware Concepts

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Abstract

This paper explains the design of a graphics-based virtual environment for instructing computer hardware concepts to students, especially those at the beginner level. Photorealistic visualizations and simulations are designed and programmed with interactive features allowing students to practice, explore, and test themselves on computer hardware and architecture concepts. Despite the essential lab-oriented nature of hardware courses, theoretical knowledge is still a significant aspect of hardware and computer architecture courses. The use of a visual framework serves to reduce the cognitive load and also facilitates bridging the gap between lab and theory components. The framework includes virtual demonstrations that help students get familiarized with and understand the hardware concepts, practice the exercises for as long as required, and also finally take self-assessment to evaluate mastery of the concepts. This framework greatly reduces the restrictions experienced in educational institutions in terms of limited hardware, space and time limitations (of laboratories), as well as costs associated with installation, operation, and maintenance. Besides, there is a reduced risk while using a visual framework as opposed to an electrical equipment. Hence, on the whole, this framework offers an easy-to-access and use modality for users to get trained on computer hardware and architecture costs and also can serve as a valuable tool for educational institutions in supplementing hardware courses.

Introduction and Background

Computer hardware and architecture courses are offered in various disciplines such as Information Technology, Computer Science, Electrical and Computer Engineering, and several other departments as well. Driven by numerous aspects including technological developments in hardware as well as software and market demands, the materials covered in computer hardware courses have been constantly evolving over the past several years (Calazans & Moraes, 2001, Djordjevic, Milenkovic, & Grbanovic, 2000, Yehezkel, Yurcik, & Pearson, 2001). Even though different departments and disciplines have their own program objectives and course learning objectives for the specific hardware and computer architecture courses offered, there are some common aspects covered by the hardware courses such as basic architecture and hardware organization, I/O systems, memory hierarchy, Random Access Memory (RAM), device drivers, and peripheral devices, etc. Calazans and Moraes (2011) also point to a level of abstraction involved in the instruction of computer organization and architecture. Hence, the complexity and the diversity of the topics covered in addition to the abstraction involved makes this a difficult area to teach, especially for students at the beginner level. While numerous opportunities are available for students in the area of hardware and computer architecture, higher-educational institutions are faced with the challenge of preparing students to take advantage of these opportunities. One of the important problems that needs to be addressed in this area is the over-reliance on conventional approaches that are ill-suited and outdated, which has in turn adversely affected students' attitude towards learning hardware concepts. There is an imminent need to transform this attitude and hence, the design approach to teaching and learning

hardware concepts. To stimulate students' interest, an interactive platform that can facilitate a fun-learning environment is proposed in this study. As is evident from the above discussion, besides serving to enhance the geospatial skills of students, this research will also contribute to the development of an innovative design paradigm that can serve various other related academic disciplines. This research can result in notable impacts in the following areas: enhancing Geospatial Information Systems (GIS) curricula by contributing to increased Critical Thinking/Problem Solving (CT/PS) skills, training students with superior skills, improving student employability, enhancing mode of instruction, and increasing student graduation success. GIS education is interrelated to numerous other disciplines and GIS knowledge and skills can promote a student's ability to understand spatial concepts, facilitate critical thinking, and learn class subject matter (Chandramouli & Heffron, 2015). In addition to the above mentioned factors, teaching practices involving virtual models and visualization enable instructional environments concentrate on dissemination of materials, hence missing interaction and problem solving components. Computer hardware structure and construction can be a potentially troublesome subject both to teach and learn for plenty of reasons, such as the ever-changing nature of computer technology resulting in the constant increase in the pertinent material. Various different approaches have been employed by different earlier studies in this area of hardware instruction (Verplaetse, Campenhout, & Neers, 1999, Eisenberg & Johnson, 2002, Djordjevic, Nikolic, Borozan, & Milenkovic, 2008).

The proposed framework offers a significant advancement of the work done by the authors earlier involving a prototype graphics framework for interactive instruction of computer hardware concepts (Chandramouli & Chittamuru, 2016). This new framework is specifically built for online and web-based instruction of hardware concepts using some elements from the earlier framework and all the modules have been designed for online interaction through common web tools and browsers. From the assessment point of view, this framework helps realize the goal of instructing beginner-level students with hardware skills through interactive delivery of modules. The 'interactive' nature of the framework allows the transition from conventional methods that are passive and uni-directional to active learning through involvement driven by the event-response mechanism. This paper delineates some of the common examples employed in hardware education and elaborates with visualizations how the proposed framework can be used for the generation of static and dynamic virtual environments. Finally, the results are discussed from the points of view of the desktop virtual reality mode as well as the web-based visualization.

Related Work

Computer literacy is defined as one's ability in learning and assessing the complete computer from software and hardware perspective (Rose and Dugger, 2002). Job seekers in Europe can demonstrate their capability in fundamental computer abilities by presenting employers a "Computer driving License" (Csapo, 2002). The European/International Computer Driving License (ECDL/ICDL) is a universally perceived computer hardware training and accredited certification program. Due to its

success in Europe, the ICDL is presently offered in the United States also. The ECDL/ICDL has about 2 million enrolled members out of which more than 1 million members are already certified. This certification has helped employers to analyze and accept the computer hardware and architecture skills of job seekers. Another recognized certification program is the Internet and Computing Core Certification(IC3) available from Certiport (2017) for training in fundamental computer hardware, software and Internet skills. To be certified in IC3 a candidate has to go through three exams in the above mentioned three computer concepts: hardware, software, and internet. The hardware exam requires knowledge on basic computer components and troubleshooting issues. Zhao and Alexander (2005) stated,

> With the growth of the computer hardware and Web advancements from static data applications to interactive and dynamic interpretations, U.S. organizations and business sectors have been modifying their corporate computer hardware to incorporate and run these advances to keep up an aggressive edge with their competitors. (p. 175)

Zhao and Alexander (2005) led a survey review of Fortune 500 companies to figure out what computer skills they want in students they employ upon graduation. Their survey results showed an increment from 11 skills required only five years ago, to 28 skills emphatically recommended today. These include:
  • Hardware: using keyboard, microcomputer, and mouse; troubleshooting internal hardware if the computer stops running abruptly, so as to save the data.
  • Operating system: using Windows.
  • Productivity skills: Microsoft Office was strongly recommended as a productive application suit for creating and editing documents, presentations and spreadsheets. The IC3 certification (IC3, 2017) program has earned credit recommendation for college education on computer skills by American Council on Education (ACE).

The International Society for Technology in Education (ISTE) has joined forces with Certiport to construct the new 2005 version of the IC3 exams. IC3 aligns with the National Education Technology Standards for Students (IC3, 2017). Such type of certification programs must be made aware to students which will make them ready to face the market after graduation. There are various key terms, definitions, and conceptual abstract topics in computer hardware courses that students are required to learn and remember to pass the exam. In this manner, it is immensely hard to inspire students to learn the course as a majority of students seem to deem the subject rather technical, boring, and exhausting. Instructors likewise discover it somewhat hard to measure student's improvement in their classes. These difficulties continue to create a negative impact on student's attitude in studying the course leading to increase in the number of dropouts. In order to facilitate enhanced instruction, the author earlier created a graphics-intensive online textbook that had a significant impact on student learning and also corroborated the positive impact of suitable graphics in a web-based learning environment (Chandramouli, Reid, & Zywicki, 2016). Graphics have become an increasingly popular tool to convey technical information. Used in an engineering setting, graphics have a long history, as accounts date engineering graphics work

anywhere from several decades to thousands of years old (Barr & Juricic, 1994; Miller, 1996). These drawings have become stepping stones for the emerging 3-Dimensional representations. 3D graphics have been used extensively across the globe for the past decade. These 3D graphics, if used in educational institutions, will become the best assistive instructional tool for teachers. Hence 3D graphics have been used in this research to teach entry level engineering students on computer hardware and assembly. The advantage of graphics visualization is that such representations are not plain illustrations, but also interactive settings equipped for animation and simulation.

The various advantages of the use graphics-based visualizations and virtual worlds in instruction are summarized as follows (Chandramouli & Chittamuru, 2016, Chandramouli & Heffron, 2015, Chandramouli, Huang, & Xue, 2009, Chandramouli, Narayanan, & Bertoline, 2009):
• Teaching can be augmented through the demonstration of interactive visual setups, which can be used by students for repeated training till a particular level of proficiency is acquired.
• Visualization is not only extremely time-saving, but also important to universities from the space perspective, especially when built spaces are becoming expensive.
• Point of view from perspectives are not practically possible in the real-world. It may not be possible even within the real world to view some buildings from their top or from some sides due to the constraints in getting to that point in the real world. However, within the 3D virtual world, users can choose multiple viewpoints.
• Enabling different levels of detail (LOD) within the virtual worlds.

Methodology

After evaluating a number of software tools and techniques, the researchers have used Swift 3D and Adobe Flash for importing the developed models and hosting them on the web. The purpose of this research is to promote the teaching of basic computer hardware components and concepts for a better understanding in entry-level engineering and technology students. Figure 1 illustrates the proposed research framework involving three tiers.
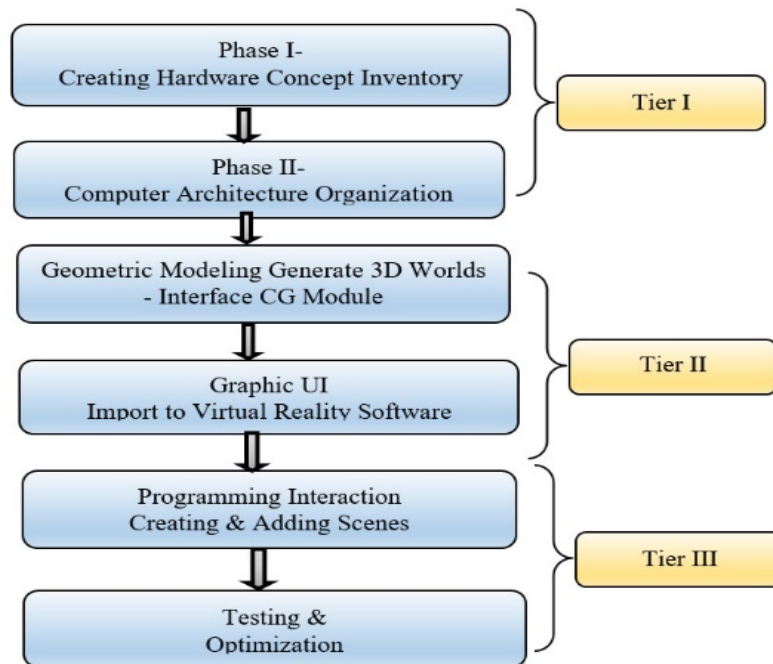
Figure 1.   Three-tiered framework for graphics-based hardware instruction

Adobe© Flash Professional CC deals with 2D animation but the 2D pictures can be given a 3D feel when many pictures are taken of the model at different angles and imported. These pictures are imported as frames and are played frame by frame to create motion and 3D animation feel. The models imported with frames are called sprites, and these sprites can be loaded into a bitmap image called a sprite sheet. Generation of sprites can be a tedious and time consuming task if it has to be done manually. Swift 3D uses the RAViX technology which automatically generates one sprite per frame within seconds by tracing the objects in the stage and shading them appropriately based upon the light and camera angles and exports it as small web file format (SWF), an Adobe Flash file format used for multimedia, vector graphics and ActionScript. The main graphical primitive in SWF is the path, which is a chain of segments of primitive types, ranging from lines to splines or Bezier curves. Additional primitives like rectangles, ellipses, and even text can be built from these. The graphical elements in SWF are thus fairly similar to Scalable Vector Graphics (SVG) and Moving Picture Experts Group 4- Binary Format for Scenes (MPEG-4 BIFS.) SWF also uses display lists and allows naming and reusing previously defined components. Adobe Flash is chosen for its popularity and ease of use. Based on an independent study conducted by Millward Brown (2009), over 99% of desktop web browsers in the "mature markets" (defined as United States, Canada, United Kingdom, France, Germany, Japan, Australia, and New Zealand) had a SWF plugin installed, with around 90% having the latest version of the Flash Player. The basic interface presented to the user is illustrated in Figure 2. Figure 3 illustrates the components of the motherboard
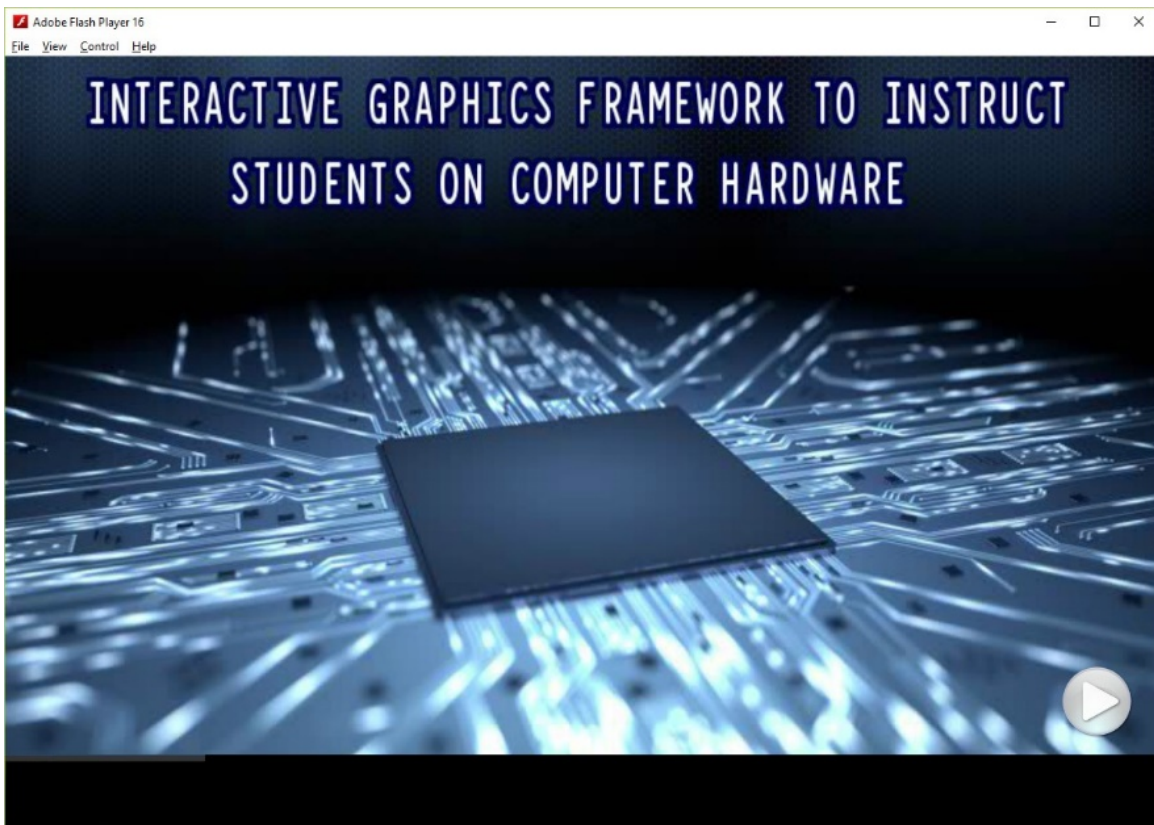
Figure 2. Interactive graphics interface presented to students

assembled in the virtual scene. Every virtual scene object is defined using parameters (attributes) governing the appearance characteristics and geometric characteristics. While modeling a larger component for the virtual-world scene visualization scene, the actual construction is made by assembling smaller objects.
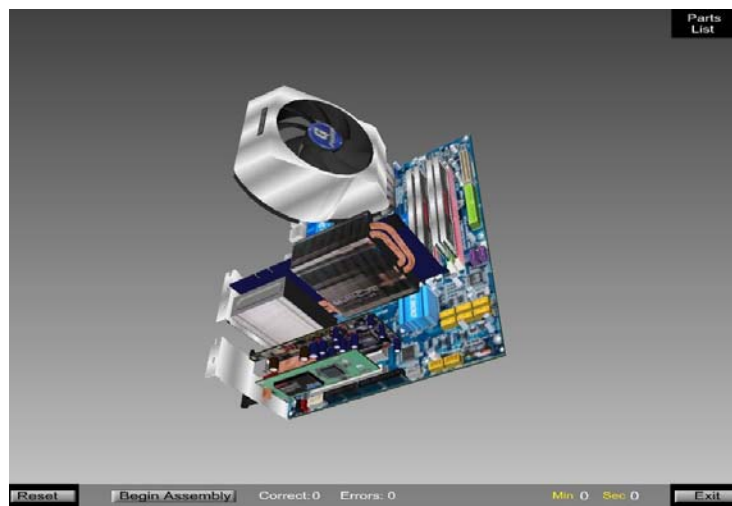

Figure 3. Assembled motherboard

Figure 4 shows the division of the concepts into five modules. The 3D virtual scene is built using nodes, which are the fundamental building blocks that are used to define the parameters (properties) of the scene objects. The scene objects created using nodes can be reused as, and when needed using a feature called "inline." Also, customizable objects can be built using a functionality called PROTO nodes and these can be reused again later by calling the EXTERNPROTO node. This ability to build once and be able to reuse the objects is an extremely time-saving and efficient way to construct scenes with 3D objects. Considering a sample scene, if the scene is further broken down into smaller fragments, the elements that result will also include much smaller components, which are of a particular material, color, and dimensions. All these are the attributes of the various components. Thus a scene is actually made up of a set of elements or objects, each of which has its own properties or attributes. A parent object can include any number of children, which can be grouped or assembled to function as one single entity. One of the primary advantages of this sort of parent-child grouping within a 3D scene manifests itself in the ability to perform "transformations". After creating the 3D objects and scene representations, modules are created to organize these in a way to teach the hardware concepts incrementally (Figure 4) in a web-based environment.
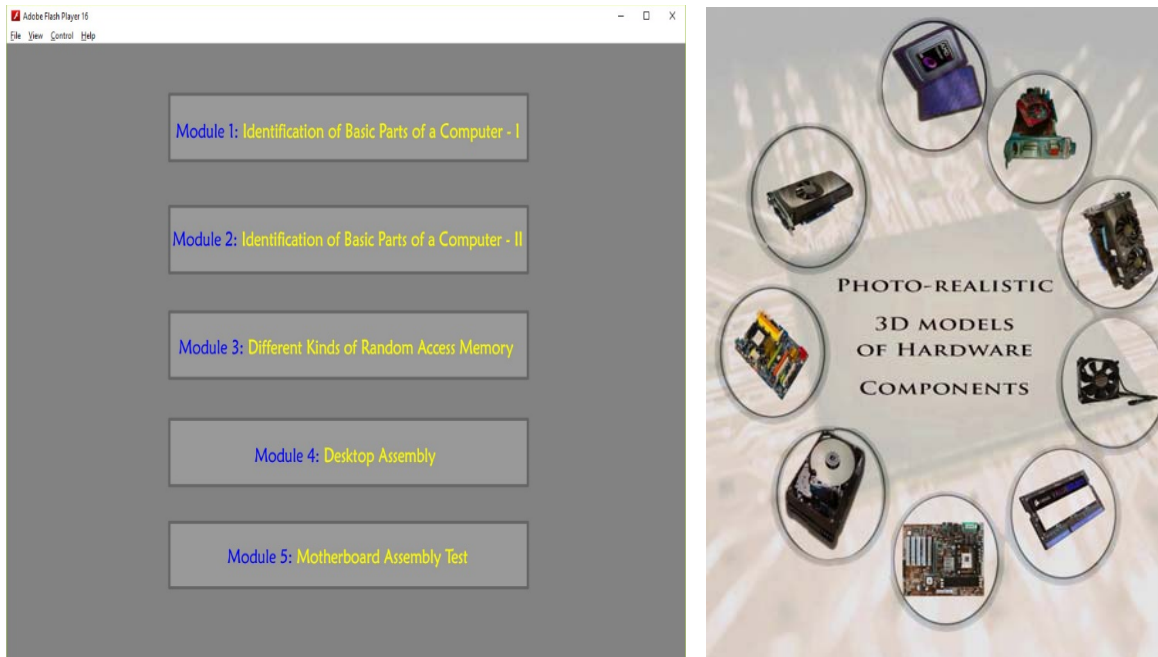

Figure 4. Web-based hardware modules using photorealistic 3D models

Results and Discussion

Besides serving to facilitate instruction in four-year degree programs, the framework can also be used in short-term courses and for training skilled workforce in the areas of Information Technology. Figure 5 demonstrates the portal to test the compatibility of the developed modules on a website. To aid the evaluation, currently, we are working on

demonstrating the Desktop VR part that can be accessed via an Open Source plugin for viewing 3D worlds on the internet.
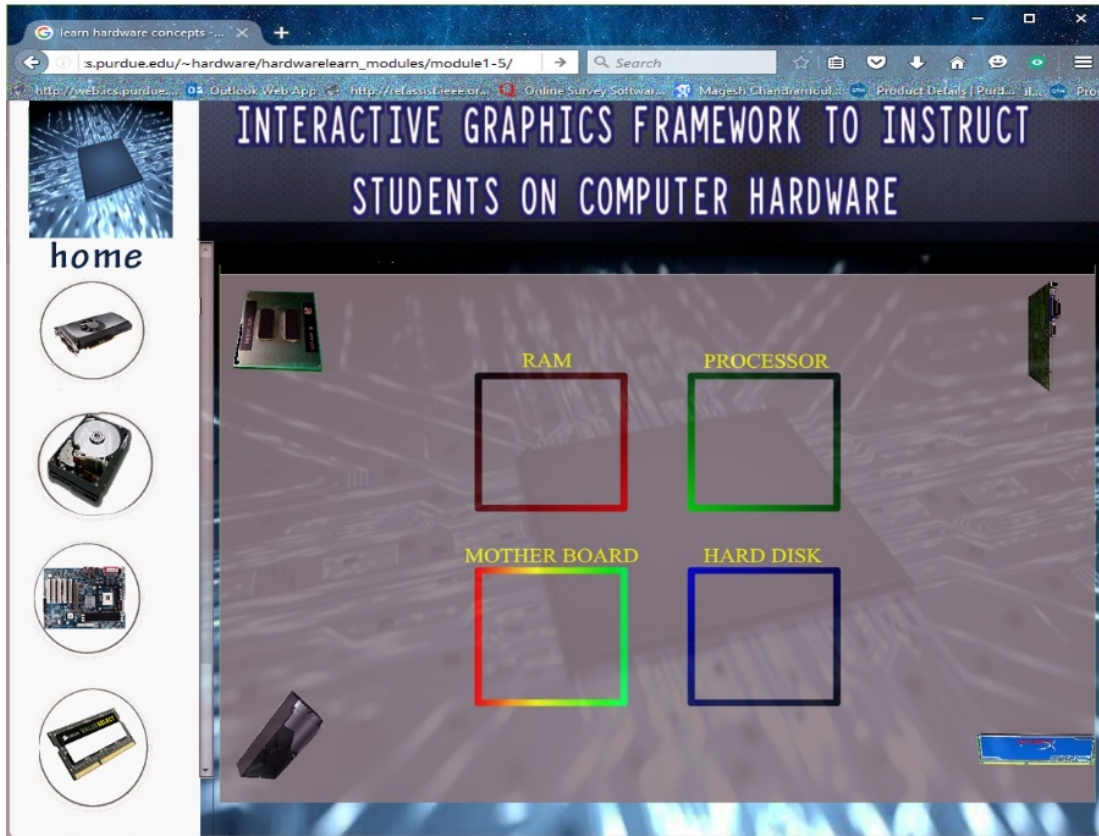

Figure 5. Website: Testing web-compatibility of framework

ActionScript is an object-oriented programming language and it is a superset of the syntax and semantics of the language more widely known as JavaScript. ActionScript supports primitive data types like Boolean, int, null, and void which makes it easy to add user defined functions and to call them easily. Also Adobe Flash consists of complex data types like MovieClip, Button, EventListener and MovieClipLoader which allows the easy usage of visual objects, in this case the models. The model is imported to Adobe Flash, to make it accessible to ActionScript, it is converted to MovieClip data type and given an instance name. The MovieClip is called in ActionScript using the instance name and can be programmed for interactivity. An event listener function is created for Mouse click and Mouse drag and applied to the desired MovieClip. This makes the models interactive to the user by responding to their actions. Esperient Creator can import files from popular 3D content creation tools like Autodesk 3Ds Max, Maya, and Google SketchUp. About 30 2D file formats and over 50 leading 3D file formats are supported by Esperient Creator. Esperient Creator is marked as an exceptionally robust tool for developing interactive real time 3D applications and most of the people who have worked on Esperient Creator name it as a true What You See Is What You Get

(WYSIWYG) editor. Esperient Creator has been designed to increase productivity, while decreasing development time with easy tools embedded (developer can achieve amazing visual effect with least amount codes. Lisp and CScript are the two languages supported by this editor. While CScript is familiar to everyone who has little bit of knowledge in Java and JavaScript, Lisp on the other hand is known to CAD students. Esperient Creator, with a friendly interface backed by a powerful scripting language, was employed in the development of one of the important and most complex module of this framework that is interactive motherboard assembly test. Figure 6 illustrates an event handler for a mouse click event.

```
/* Mouse Click Event
Clicking on the specified symbol instance executes a function with required
*/
Object_Instance_Name.addEventListener(MouseEvent.CLICK, MouseClickHandler);
function MouseClickHandler(event:MouseEvent):void
{    // Start custom code
     // End custom code
}
/* Mouse Over Event
Mousing over the symbol instance executes a function required custom code.
*/
Object_Instance_Name.addEventListener(MouseEvent.MOUSE_OVER, MouseOverHandle
function MouseOverHandler(event:MouseEvent):void
{
     // Start custom code
     // End custom code
}
/* Mouse Out Event
Mouse out of the symbol instance executes a function required custom code.
*/
Object_Instance_Name.addEventListener(MouseEvent.MOUSE_OUT, MouseOutHandler)
function MouseOutHandler(event:MouseEvent):void
{
     // Start custom code
     // End custom code
}
/* Key Pressed Event
Executes the function KeyboardDownHandler defined below when any keyboard ke
*/
stage.addEventListener(KeyboardEvent.KEY_DOWN, KeyboardDownHandler);
function KeyboardDownHandler(event:KeyboardEvent):void
{
     // Start your custom code
     // End your custom code
}
```

Figure 6. Event handler: code snippet

The Sprite sheet images of a processor, switching mode power supply, dual inline package (DIP) RAM, and complementary metal oxide semi-conductor (CMOS) BIOS battery are shown in Figure 7, respectively (clockwise from top-left).
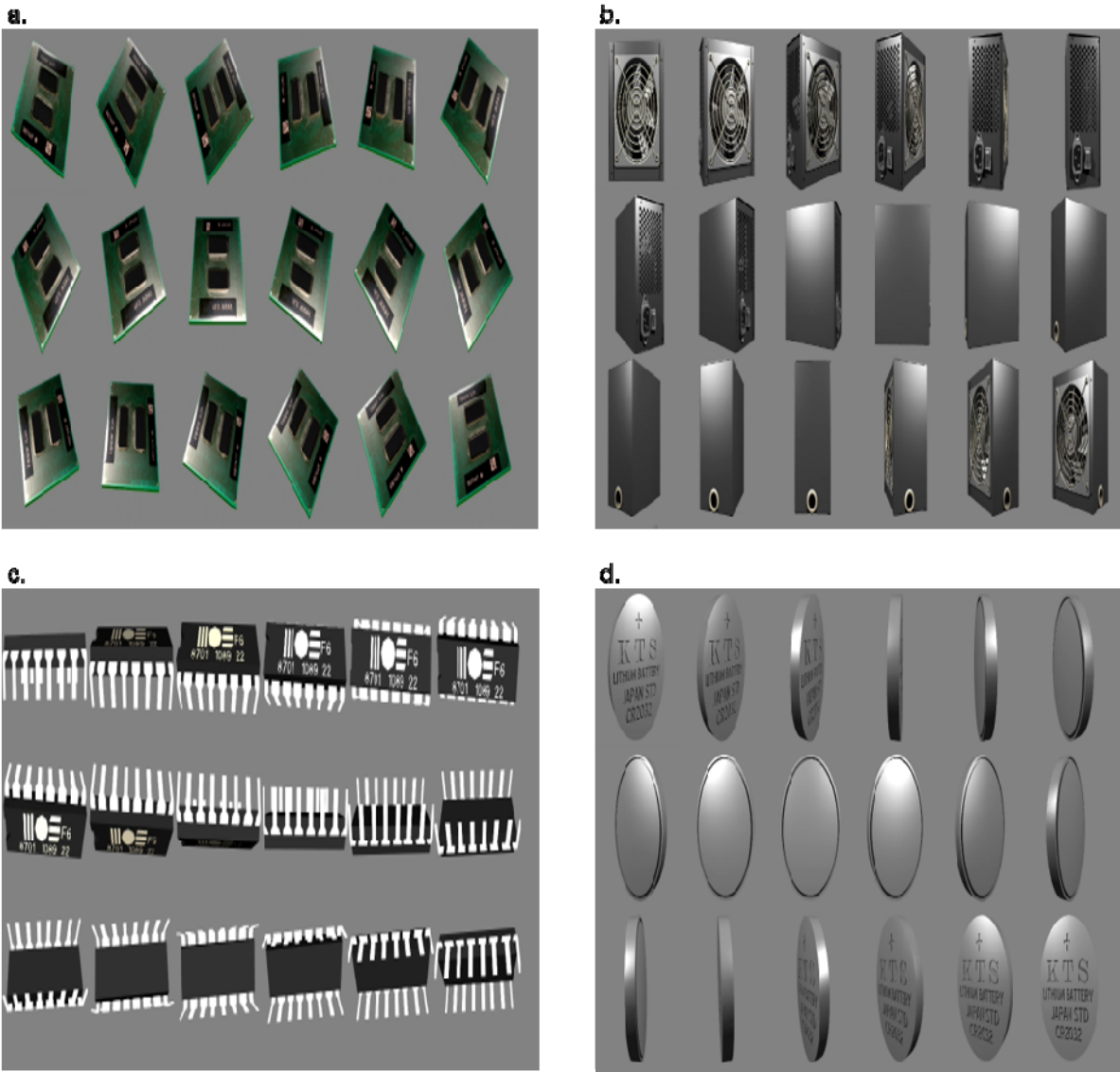

Figure 7. Sprite sheet images of a) processor, b) switching mode power supply (Type: CR2032), c) dual inline package, and d) complementary metal oxide semi-conductor BIOS Battery (Type CR2032).

Online/ Web-Based Guided Self-Assessment Component

The guided self-assessment component helps students test their level of expertise or the mastery of the concepts learned. Using the guided framework, students can interactively position components within the framework and clues are provided to those who need practice. Figure 8 demonstrates a task involving assembling the components on a mother board. The

structural layout and organization of the framework was initially created for the earlier prototype framework (Chandramouli & Chittamuru, 2016) and was then modified and customized for adaptation for web-based visualization and interaction.

Figure 8. Web-based guided self-assessment: hardware components

Reset and exit buttons are present in this module and are programmed to restart the assembly again or exit the application. After successful completion of this module a student will have gained knowledge on hardware components and will be well versed with the complex task of desktop assembly. Students have to identify the hardware components and manually assemble them onto the motherboard by dragging them to correct positions, this requires the knowledge gained from Module 4. If the component is placed in the exact position the component assembles to the motherboard and the student can proceed to assemble the next component. If the component is dragged and left on a wrong place it returns back to its original

position. The trial and error method cannot be practiced on a real time environment as it can lead to fatal injuries and also severe damage to the hardware. To make this module more interesting, sounds have been incorporated. If the student assembles the component correctly a bell tone will be heard and a buzzer sound will be activated when a wrong match is made.

Conclusion

The proposed framework offers a significant advancement of the work done by the authors earlier involving a prototype graphics framework for interactive instruction of computer hardware concepts (Chandramouli & Chittamuru, 2016). This new framework is specifically built for online and web-based instruction of hardware concepts using some elements from the earlier framework and all the modules have been designed for online interaction through common web tools and browsers. Lastly, a course in computer hardware and architecture is only the beginning of a large system. The design of the information systems, networking design and other subjects of the Pre-IT program are still to come. It is believed that principles incorporated into the design of this computer hardware research will act as stepping stones to effectively understand those other courses as they are interconnected to each other. The range of materials included in computer hardware and architecture has been evolving over the past decades and of late, the developments in this domain has been occurring at a phenomenal rate. This research also notes that the technology defined in this framework may change due to the rapid growth in technology and may this happen, it is designed in a way to still help students to learn about most common issues arising in a computer. Hence, the real challenge, though, will be changing the way our mainstream entry level student courses are taught, to make them more effectively taught by the use of interactive 3D graphical tools – responsive to the needs of course curriculum and interest of the students, making the course fascinating and engaging to prepare them for careers in Information Technology in the years to come. The main objective of this research is to develop an interactive 3D graphics framework to effectively instruct students on computer hardware course. There are obviously many other approaches to develop an assistive instructional tool which could have been adopted. However, the results from literature review prove that the use of 3D graphics clearly yields better results. From the literature review it is also clear that the instructors have problems teaching the course to students effectively. This research is believed to have tremendous potential in solving this problem of instructors by employing close to real interactive and animated 3D models, however literature review also suggests that instructors need to be aware of the computer skills required by industry and train their students accordingly. It is hoped that this research and its graphics framework will help empower more students and educate them to face the issues with computers and their hardware components.

Limitations

There are several important limitations that the authors would like the readers to note:
1. Even though this proposed framework offers notable advantages over the earlier framework developed by the authors, several problems were experienced while designing and implementing the online web-based framework. While the prior framework was not designed for web-based visualization, this framework did allow online tutorials and step-

by-step instruction and learning. However, challenges pertained to web-based interaction and animation components were encountered. Future work will focus on reducing problems related to animation and interaction in online and web-based frameworks.

2. Computer hardware and architecture concepts include various aspects such as system design, assembly-programming, digital logic and electronic circuits, etc. This paper focuses especially on and restricts itself to the web-based instruction of physical components of common PCs and their assembly.

3. Even though there is an assessment component included within the virtual environment itself, a comprehensive evaluation of the overall framework is not presented here yet. The version shown here is a prototype version and enhancements are being made to make it more user-friendly and some minor programming bugs are still being handled. Once this is complete, a detailed user survey will be carried out. However, the general informal feedback received from students thus far has been satisfactory and some students from non-IT backgrounds also have found this framework to be useful in understanding computer hardware concepts.

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