Microcontroller Animation

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Abstract

Students in a typical Associates level technology curriculum go from studying relatively simple sequential logic circuits like counters and registers, to trying to understand and apply a microprocessor. As a result many students have great difficulty visualizing and truly understanding the flow of data inside a computer system. Verbal descriptions accompanying diagrams are adequate for some learners to grasp the operation, but many students need more. By animating the operation of a simple 8-bit microcontroller throughout the execution of a program, it is believed that the more visually oriented and mechanically minded students can be helped to see the big picture. Development of software to graphically animate this operation is currently under way. This paper attempts to justify the need of this method of instruction as well as describe the current progress toward the intended end.

Background

Try to recall a subject that you learned in school that involved a complicated sequence of operations, As an example this author recalls eighth grade shop class and the study of the internal combustion engine. What were the key elements in presenting this subject that caused a reasonably deep understanding to take root in the mind of a 13 year old boy. Was it the verbal description of the characteristics of piston rings? Or the play by play description of the four cycles; intake, compression, power and exhaust? I am sure that these elements contributed to my understanding but when I recall that lesson, the picture in my mind is not of the teacher talking or the overhead slides but rather of seeing an actual engine block with the crank rotating, the piston moving, etc. This is what defined the elements of the system in my mind. And yet memorizing the motion of each element was worth little without understanding the relationship to the other elements in the mechanical wonder. What was it that embedded that understanding of relationships and purpose? The animated film that was presented showing the relationship between piston motion, valve position, cylinder pressure and ignition timing comes instantly to mind and I can still play it back today in my mind's eye.

Is this because I am a visual learner? Felder [1,2, 3] has written extensively regarding the role of learning styles in classroom teaching. But I am convinced that most if not all students benefit from seeing such a process operate. If I were assigned today to teach the internal combustion engine, I would be looking for a model engine or cut up Briggs and Stratton and searching the archives for a 16mm film from the late 60s. (Perhaps now on video!) Unfortunately, I don't teach engines. I teach microprocessors,,, Introduction to Microprocessors... to sophomores.

These students have had two prerequisite courses in digital logic. They studied gates, decoders, flip flops, counters, memory devices, tri-state busses . . . . all the elements of complex digital machines, They have memorized names, analysis and design techniques and have been exposed to simple examples that give them a hint of what is possible in a digital system. Now I have the opportunity to help them understand how a truly complex digital system works that they will need to use in the future, the microprocessor. Of course, in my early years teaching I tried to teach as I had been taught. I stood up and reviewed for them how each basic element works, much as my shop teacher described the rings, bearings, pistons, spark plug, etc. Then I gave them a play by play description of the fetch/ execute cycle. I even showed them a circuit board that had all the constituent components. Then I woke then up and let them observe this marvel of digital genius as it actually ran! For the most part they were greatly underwhelmed.

You see, a working microprocessor looks pretty much like any other electronic circuit board (working or not). The only thing they could see was the end result of outputs responding to inputs. This would be similar to my shop teacher demonstrating that by opening the throttle on a lawn mower and pushing it that cut grass comes out the chute and then concluding that we understand how an internal combustion engine works. The fallacy of this conclusion has become obvious to me as I watch students near graduation trying to apply a microprocessor to their senior design project. Many of them simply don't know (and maybe never did) how a microprocessor works, They say, "That was a long time ago" and "I've slept since then, " But 8th grade was longer ago for me than they have lived and I still know how an engine works,

So what am I not providing for my students that was provided for me in 8th grade shop class? I believe there are two missing ingredients. The first involves a subject all in itself You see, I had a reason to want to know how an engine works because engines were in go carts and (planning for the future) sports cars, If we could only make 19 year olds as interested in micros as 13 year olds are in cars our j ob would be much easier. The second vital link to embedding an understanding was the animated video. It allowed me to see the relationships that simply could not be grasped by looking at drawings, hearing descriptions, manipulating a model engine, etc.

There is some evidence of even greater need for this approach due to the influence of video games, television, and the proliferation of video instruction. To further consider this need on behalf of the students an attempt at animation of a microcontroller's operation is underway in the Purdue University EET Dept.

Animating Microcontrollers

Although films and videos are available which serve the purpose of relating various generic blocks of a computer, we have available today a number of new options which offer advantages over films and videos. The software that is now available at reasonable prices allows development of interactive learning tools that run on the PC. Hypertext is one such tool which allows key words in a text to be defined and amplified by clicking on them [4]. The disadvantage of this approach is that the student with weak verbal skills or a preference for visual presentation still is limited to dealing with text. Other options include various forms of multi-media employing sound, still photography, video and graphic animation. [5], Software tutorials that use multi-media have been developed for basic DC circuits and digital fundamentals and are currently being marketed. The unique needs of a microprocessor tutorial have not been met by those things currently available, resulting in the current development project. The software that has been chosen for this experiment is Authorware by Macromedia. It allows easy development of Windows based interactive software that combines text, graphics and animation capabilities to create tutorials or presentations.

The animated tutorial that is currently under development allows the student to view a block diagram of a microcomputer system. Areas of the screen are capable of activating textual explanations of the funct ions or features by clicking on a part of the drawing. Each block of the diagram is presented in sequence with text to explain its purpose. Animation can be added to describe visual] y the operation of each part of the system.

After each part is described and the entire diagram is developed, the user can then explore the operation of the basic bus cycles; “code fetch, data read, and data write. Finally, a simple program is shown loaded into the program memory and the execution is demonstrated in animation, visually depicting the flow of information - on address, data, and control busses.

The current plans are to use this tool next semester in class and lab in the early phases of the microprocessor course. Students will be graded on their lab understanding and exam proficiency soon after the material is presented. At the end of the course, some of the same questions will be repeated to ascertain if the material was retained.

In order to determine if the tool is of value, an experiment is being designed to answer the following question: Does a hypertext/animation method of presenting microcontroller hardware operation produce superior understanding and retention of knowledge as compared to traditional methods of lecture, reading assignments and lab experiments?

To formulate the experiment the class as a whole is initially treated as students from past semesters have been, by verbal description of the system’s operation along with overhead drawings and definitions. Each student then performs the lab experiment that has been used for several years to demonstrate machine timing and bus operation by using a logic analyzer to study timing diagrams of a functioning system, Each student is then administered a short test. After completing the test, they are instructed to run a self paced, interactive, animated tutorial which relates the flow of information on the bus with the timing diagrams that describe the operation. When they have finished the tutorial, the same exam is once again administered. The two scores (one before and one after the tutorial) are used as data samples to measure improved understanding in a matched sample T test as described by Neter et al. [6]

Thirty one students participated in the experiment with the alpha level set at 10%. The hypothesis to be tested is:

HO: $\mu_2 - \mu_1 \leq 0$ where test average μ_1 is for the scores before the tutorial and μ_2 is for the scores after the tutorial.

Hl: $\mu_2 - \mu_1 > 0$

The results of this experiment showed a significant improvement in the overall score even at an alpha level of .025. The decision rule ($\alpha = 0.1$) states that if the sample of differences had a mean value of greater than 1.71, then we conclude H1. The actual value of the mean was 3.97 giving excellent support for the conclusion that the animated tutorial did improve the students’ comprehension as measured by this exam. In analyzing the scores of specific questions, it did show an improvement in every question’s average score with one exception. Those questions which were considered of greatest importance showed a statistically significant improvement. In the cases of questions that showed improvement that was not statistically significant, it was primarily because most students had already mastered that subject without the animated tutorial, leaving little room for improvement.

Conclusions

The experiment has shown significant improvement in understanding this subject. Given that the animated methods do improve the learning process there are some distinct advantages to this approach. The software will be available to students to run on their own computers, making it an interactive handout for home study. For those who do not own a computer capable of running this software, it can be placed on the laboratory computers which are available after normal operating hours. In lecture it provides the visual stimulus and relates the topics for those students that are not as adept at learning from lectures and reading assignments. Overall, it is believed that the results from this experiment show not only that preference for multi-media instruction exists but also demonstrates that understanding is improved by this mode of delivery.

References

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Neal S. Widmer graduated from Purdue with a BSET in 1979. He worked in two hospitals over the next six years, specializing in cardiac diagnostics and 2-D ultrasound imaging systems. In 1985, he began teaching full time as an instructor in the EET department of Purdue. In 1989, Prof. Widmer completed his M, S. in Industrial Engineering. In 1992 he was promoted to Associate Professor at the main campus where he teaches digital and microprocessor courses. Along with numerous conference papers, Prof Widmer has published articles in professional journals "Robotics", "Behavior Research", and "Computers in Industrial Engineering" , as well as co-authoring a text "Electronic Troubleshooting" and contributing a chapter on PLDs to Ron Tocci's "Digital Systems", 6th edition.