From luke%haydn.csg.uiuc.edu@uxc.cso.uiuc.edu Fri Mar 4 17:05:02 1988 Received: from uxc.cso.uiuc.edu by p.cs.uiuc.edu with SMTP (UIUC-5.52/9.7) id AA25325; Fri, 4 Mar 88 17:04:45 CST Received: from haydn.csg.uiuc.edu by uxc.cso.uiuc.edu with SMTP (UIUC-5.52/9.7) id AA10470; Fri, 4 Mar 88 17:04:15 CST Received: by haydn.csg.uiuc.edu (3.2/9.7) (hacked for broken IBM.COM mailer) id AA11056; Fri, 4 Mar 88 17:08:16 CST Date: Fri, 4 Mar 88 17:08:16 CST From: luke%haydn.csg.uiuc.edu@uxc.cso.uiuc.edu (Luke "Skywalker" Young) Message-Id: <8803042308.AA11056@haydn.csg.uiuc.edu> To: kurt@uxc.cso.uiuc.edu, mel@leopard.ccsr.uiuc.edu, om@complex.ccsr.uiuc.edu,

robison@b.cs.uiuc.edu, skiena@p.cs.uiuc.edu,

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Academic Computing in the Year 2000

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November 30, 1999

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1. Introduction

Computers today represent a powerful tool for education. The computer of the year 2000 will be an even more powerful tool. But it is not the tool that gets the job done - the person using it does. This essay discusses the task of education from the vantage point of *Tablet*, our vision of computing in the year 2000. While we are very optimistic about the potential of *Tablet*, it is not by itself a solution to the problems of education. No tool can be unless applied by proper craftsmen.

Any reasonable vision of the future must be bound by two distinct constraints. The first constraint is technological — what will we know and what will be be able to build at that particular moment in time? For computers, how powerful will they be and how much will they cost? Will they be bigger than a bread box? Can they be made portable? How can such a machine communicate with its world - both with its immediate environment as well as the global community? It is this aspect of our design which won us the Apple competition.

The second and more fundamental constraint is how this technology can be used meaningfully by people. A person's density does not double each year, the way VLSI circuitry does. There are only twelve years remaining before the year 2000, and for massive changes to happen in education in this time more people must get involved in an exciting way with the creation of this technology. We mean the educators, scholars and administrators; the people who are running the classrooms of today. Without significant and enlightened participation from this community, the computer of the year 2000 will be doing the same thing in the classroom that the computer of 1988 is doing: sitting there, running a few games, tabulating grades and filling out reports — inspiring only to a stray hacker wandering into the vicinity.

However, there is reason to hope that technical progress by the year 2000 will animate the human side of education. As computers become more powerful, it becomes reasonable to mold them in the image of people. The computer as a tool will fit naturally into the lives of the masses instead of being shoehorned in under the oxymoron of “computer literacy”. Only when educators need not strain to realize the potential of their classroom machines will computers revolutionize the way things are done. This will happen by the year 2000. Hypertext systems are already beginning to allow the structuring of knowledge with a flexibility that makes it accessible to both student and teacher.

In this essay, we give our vision of *Tablet*, a machine unquestionably feasible for twelve years from now. We present a brief look at how *Tablet* will change the life of both the professor and the student. Finally, we elaborate on the challenges education will have to meet for our vision to become reality.

2. Tablet: the Personal Computer of the Year 2000

Tablet will have the same dimensions as a standard notebook. This rectangular slab will look like an $8'' \times 11''$ monolith from the movie *2001*, and weigh but a few pounds. Having neither buttons nor knobs, the front surface will be a touch-sensitive display screen. One side will have a credit card sized slit, while the other three sides support ruby-colored ridges. Here, we describe our vision in terms of its components, leaving the rest of the essay to prove that the sum is greater than its parts.

2.1. The I/O Surface

The most important part of any computer is its user interface. The front surface of *Tablet* is a high-resolution touchscreen, which yields slightly to the touch. With this single input device, we get the tremendous flexibility of a soft interface: from the low-resolution but traditional means of pointing with your finger to the higher-resolution available using a stylus. The touchscreen can emulate a mouse, or a soft keyboard - customized to the user's finger size and taste.

But if we are holding a stylus, why bother with the keyboard? We can write and draw directly on the surface of the screen, integrating text and graphics. And, if we wish, handwriting recognition software will convert our scrawl to typed text. Finally, this color display is more than just an imitation notebook page, it will be fast enough to support video communications.

Without question this is technologically achievable. Liquid crystal displays are inherently pressure sensitive, and the density is increasing fast enough that by 2000 they will be of laser printer quality and in color. The touchscreen resolution will mimic the finest ball point. Cursive character recognition systems with training and spelling correction techniques can achieve nearly 100% accuracy. Of course, no human or silicon system will recognize all handwriting, particularly from the medical community, but what isn't recognized will be highlighted in a different color and reentered by the user.

It might seem surprising that voice is not a major interface. Science fiction seems to specialize in talking to computers and listening to what they have to say. However, in many of the contexts where *Tablet* will be used, such as the classroom, the airplane, or a shared office, talking out loud will not be appropriate. This is not to say that speech is not a viable form of input for our design. A microphone and speech recognition processor will allow a user to communicate via speech if he or she chooses. Although dictating letters and memoranda is a skill which takes time to master, a system allowing the user to alternate between a speech-to-text mode and a text editor could spare the user a great deal of time in preparing reports — especially when the words that are spoken match words already appearing somewhere on the screen. In addition, there are circumstances where speech may be the only way a physically handicapped user could communicate with our computer. Our design has the flexibility of allowing the user to communicate in whatever way is desired.

2.2. The *LaserCard* Mass Storage Unit

To replace classical rotating-disk/movable head media, we propose *LaserCard*. These credit card sized optical RAMs will be a convenient, inexpensive, and physically robust data storage medium. Through data compression techniques, a single one-gigabyte card will hold four hours of video or two thousand books from a personal library. People will carry them in their shirt pockets and trade them like baseball cards. The only moving part in the whole machine will be the lid which keeps the optics dry if we use it in the rain.

One gigabyte is a healthy chunk of memory. However, it is only twice the capacity of a compact disk. We will use *LaserCard* for convenience, but it is clear that the real databases of the world will have to be elsewhere but still easily accessible.

2.3. The *DataLink*

To get this easy access, we need communication capabilities. Thus, *Tablet* integrates a cellular telephone link. This will not only support voice but data communications as well. The

ISDN standard combined with compression techniques is sufficient to transmit video at conference quality rates today.

To use this link for voice communications, we will need a microphone and speaker built into the unit. These are inexpensive and justified by other applications. However for privacy, in most applications we will use a headset attachment clipped onto the infrared bar.

2.4. The Infrared Interface

Along three sides of *Tablet* will be an infrared bar interface, through which *Tablet* will talk to its local environment: printers and projectors, stereo headsets and video cameras, toasters and roasters, other *Tablets* and just about anything else. Every smart device in the world will have its own unique 256 bit key - so a simple protocol will enable devices to talk intelligently to each other. There are nowhere near 2^{256} atoms in the universe, so we need not worry about running out of keys. With infrared light, low bandwidth devices need not be physically connected while indoors. The infrared interface may be extended by repeaters stationed in large offices and clip-on optical cables to boost bandwidth to gigabaud rates.

What types of peripherals will people need? One of the most widely owned peripherals will be a tactile keyboard. The handwriting interface and simulated keyboard will suffice for portable applications, but for rapid text entry, nothing beats a good solid keyboard. Another extremely popular peripheral will be a lapel sized video camera. Charge-coupled devices (CCDs) make inexpensive and rugged solid-state cameras. The cameras will record meetings, electronic mail videos for instruction and personal communication, and digitize those printed documents which remain in the year 2000. The notion of digitizing documents is important, because a substantial number of printed documents will remain, such as old books and new contracts. After digitization, an image can be processed to cleanup and recognize the text to allow searching by keyword and context.

Tablet will have a GPS (Global Positioning System) receiver as a built-in component. GPS is an existing satellite-based system which enables objects to locate themselves in the world to within a few *meters*. By plugging in the *Rand McNally Road Atlas LaserCard* before a drive, it can provide us with the ideal route and parking place for that new French restaurant in the city. Its usefulness extends well beyond driving, however.

2.5. The Traditional Computer

That aspect of our vision which deals with what we today call the computer, i.e. the processor and its memory, is rather mundane. It is clear that there will be mega-MIPs and giga-bits available to work with, but whatever processor we have under the hood is irrelevant to the rest of the design. Thus we avoid the temptation to guess the exact number of MIPs, the memory size, or the degree of parallelism of our machine.

We expect microprocessors to converge on generic designs, coming in fast, extra fast, and economy sizes as do memory chips today. There will also be standardization among user interfaces, to the extent that all will be constructed in layers, where all but the highest layer will be a universal standard. Running on these generic processors might be a standard version of UNIX coming out of its shell into a PostScript interface.

All circuitry will sit on the same six-inch wafer of silicon. Though silicon may sound old fashioned, more exotic technologies such as optical computers, molecular or chemical computers, or superconductors will not mature by 2000. Improvements in semiconductor processing and design technology of our wafer will make room for large graphics processors, analog and digital hardware for image processing, and much more.

Perhaps the most interesting special purpose processor will be a data compressor sitting between the memory and the main processors. This will permit video to be stored on *LaserCard*s and transmitted over cellular phone links, because image expansion will occur at video rates. It is ironic that compression becomes even more important as memory capacity increases, because there is so much more to transmit and access.

Rechargeable lithium batteries will deliver all the power we will be able to use without running into heat dissipation problems.

3. A Day in the Life

Sexy technology is nice, but how will *Tablet* fit into the lives of the academic community? Here, we take a brief look into the future for the student and professor of the year 2000.

3.1. A Day in the Life of a Student

The date is October 5, 2000. Alexis Quezada is a freshman at a prestigious institution of higher learning. Her classes are typical for a freshman of the year 2000: Algorithmic Mathematics, Physical Science, Art History, English Composition, and Conversational Japanese. On her first day of classes she was given her own *Tablet*, the personal computer used at the university.

Today Alexis has three classes: Physical Science, Japanese, and Algorithmic Mathematics. It is a nice day, so Alexis rides her bike over to the park before the lecture starts. At 10 AM sharp *Tablet* informs her that the Physical Science lecture is about to start. She directs her attention toward the screen as the lecture begins. When lecture is over, she begins the laboratory experiment. It involves determining the equilibrium for a chemical reaction. She sets up the simulated experiment apparatus and starts it going. But it isn't working. She instructs *Tablet* to search today's lecture for "the stuff about setting up today's experiment." Within seconds the requested portion of the lecture is displayed on the screen.

Because of the problem with setting up the experiment, Alexis missed the beginning of her Japanese lecture. Instead of jumping into a lecture that has already started, Alexis's computer contacts the university's lecture database again and instructs the database to display the current lecture from the beginning. Time-shifting the start of the lecture by fifteen minutes has allowed her to see the lecture from the beginning, at the cost of not being able to ask the professor a question if she doesn't understand. Fortunately, the lecture is still in progress and should last another forty minutes, so Alexis invokes the "catch-up" facility. Over the next fifteen minutes, Alexis watches thirty minutes of lecture as *Tablet* squeezes out the times of slow movement and silence. Through signal processing, the lecture looks and sounds fast-paced but is otherwise normal. Now up to speed, she watches the rest of the lecture and participates in asking questions, performing an occasional "instant-replay / catch-up" sequence on material that she found confusing.

Once Japanese is over, Alexis heads back to the dormitory for lunch. Some things never change, and dorm food is one of them. Fortunately, the social aspects of lunch will still be important even in a world where one can communicate with friends by video email. Afterwards

Alexis returns to her room to start reading her *LaserCard* edition of G. B. Trudeau's *Republic*, complete with art, text, and extensive commentary. She scrawls notes directly on the simulated page, which she can search or hide at will.

In English Comp class at 2 PM, the professor indicates that she has finished grading the previous assignment and returns them. Instantly, the corner of the display contains a copy of Alexis' graded paper. B+, not too bad. Alexis pages through the paper by touching the screen. She touches the video-mail icon for comments about a particular page. Segments of her text become highlighted in color as they are discussed. Unfortunately, her teacher is pretty boring, and so she turns on her soap opera instead.

That evening, Alexis starts her math homework due the next day. She makes her computer plot a portion of the Riemann Zeta function to show that most of the zeros lie on a line and completes her assignment by including the counter example discovered in 1993. After finishing her math, she decides to have a look at the *Newsweek LaserCard* she got today. She reviews the headlines: "Last U.S. Nuclear Power Station Closes," "NeXT buys Apple Computer," "Air America announces new Boeing Spaceplane service between Chicago and Shanghai" — nothing exciting, so she checks the Sports. A fan of Debbie Gibson oldies, Alexis is pleased to learn that Ms. Gibson will be leading the opening ceremonies at the Third Annual Frisbee Olympics.

Now it's time to work on her art history term paper comparing Salvador Dali's surrealist images in his paintings and the images he developed for the movies *Un Chien Andalou* and *Spellbound*. Alexis tells *Tablet* to find the films in available film databases. It seems that there are three films with the title *Spellbound* - Alexis says to find "the one by Hitchcock." The scenes she is interested in analyzing are be copied directly into her paper — a hypertext document. Alexis expounds on the meaning of the images in the films and their importance with respect to Dali's symbolism until its time to call it a night.

3.2. A Day in the life of a Professor

We now concentrate our attention on Xiao-Lin Zhang, a professor of Complex Systems Science at the same university as Alexis. He starts the day at home by checking his electronic mail. There are a number of questions from his students and a request from a colleague to give a speech at an upcoming conference. He responds to the students' questions and checks his electronic calendar to see if he can attend the conference. It appears that there are no conflicts so he accepts the invitation. He then instructs the computer to make the travel arrangements. After a few seconds, *Tablet* responds that the airline and hotel reservations have been made and that he is registered for the conference. His calendar is automatically updated.

He heads to his office and prepares his Theoretical Economics lecture. He could work at home but he feels more comfortable working in his office. *Tablet* retrieves his version of the textbook. Apart from the handwritten marginal notes and solution sets, his copy is identical to the student's copy. These notes will be used with his lecture. An old fogy, he prefers lecturing from the classroom. Upon entering the classroom, the "electronic blackboard" recognizes his *Tablet* as an authorized host and links in. About a third of the students are physically present, but his *Tablet* shows that the rest are tuning in. A student calls in with a question about the rent control case study included in the textbook. Xiao-Lin illustrates the effect of rent control on the Campbell curve by plugging values for rent into the graph. As the value for rent is changed, the curve on the graph changes appropriately. The reasoning behind these changes is sufficient to clear up the misunderstanding.

With lecture over, it's time for some high-powered research. He needs to find some data about the effect of political turmoil on debt in fourth-world nations. A database search through *Tablet* comes up with three sources, one of which is useful but six years old. He needs data that is more up-to-date and contacts the author to see if anything is available. *Tablet* finds that Professor Moore is no longer at Oxford and has moved to Buckingham. After a few seconds, Professor Moore's face appears on the screen. Xiao-Lin introduces himself and learns his work is a dead end — an internal Buckingham technical report produced last year solved his very problem. Thank God he hadn't invested more time in this project.

It is now time to attend the Complex Systems Science department staff meeting. *Tablet* contacts the other members of the department and the meeting begins. The new budget is the current order of business. On the screen of every department member's computer appears the tentative budget. After a number of arguments and changes to the budget, it appears that a consensus has been reached. Each professor has their computer apply a digital signature to the budget acknowledging their final approval. There is no other business to cover, so the meeting ends and Xiao-Lin can now eat a late lunch.

After lunch it is time to head home and work on his car. Xiao-Lin prides himself on being able to handle himself under the hood and is confident that he will be able to fix whatever is wrong. Once he gets home he has his computer run diagnostic tests on the engine. The computer responds that there are two possibilities and diagrams of the engine appear on the screen with the possible faulty parts highlighted. Xiao-Lin checks the two parts and determines that both are broken. He then has the computer contact the parts stores in the area to see if they have any replacement parts in stock. There are five local stores with both parts in stock, and the store with the lowest prices is just a couple blocks away. He heads over to the store and picks up the parts.

4. Tablet in the Classroom

We have presented a vision of radical change in the structure of the classroom. Why have a physical classroom where you must go to learn when, with *Tablet*, you can take it with you? *Tablet* makes this vision possible, but what is not clear is to what extent this future is desirable. Do all the changes improve the quality of education, or do they simply change the set of problems?

The essence of education is interaction, and this does not mean canned programs and canned classes. This interaction will not come between a person and their computer, because it will take far more than ten years progress in artificial intelligence to create programs which will communicate with people in a meaningful way. This interaction will have to come from people. We hope that *Tablet* will remove enough of the drudgery associated with education to enable people to interact in a more powerful way.

Disclaimers aside, there is great merit in the idea of *The Tele-University*. Lectures need no longer be situated in auditoriums with an army of students facing a lone professor. Using the cellular DataLink and image processing capability of their *Tablet*, students will be able to take part in lectures from any point in the academic world. The class notes produced by the professor will automatically be transferred from their "electronic blackboard" to a window on the student's screen. These notes need not be limited to text. Why not multimedia class notes incorporating video, text, and audio? It is vital that these be two-way lectures — any student must be able to interrupt the professor with a question by simply raising the hand icon on the screen. If you happen to be in the hospital with a broken leg, there is no need to miss an important lecture. To go over a topic covered in lecture at a later date, simply access the file for that lecture in the university database and play back that portion at your own pace.

These days, if you want to be a major player in a particular research area, you have to go where the action (or advisor) is. The tele-university will enable the best teachers to lecture to thousands of students at dozens of universities simultaneously. However, the real advantage is that eminent researchers will be able to teach extremely specialized courses to small groups scattered around the globe. Perhaps there may not be enough people at Illinois to appreciate a Herbert Edelsbrunner course on "Combinatorial Geometry in E^3" to justify offering it. But by including stray graduate students from NYU and McGill, as well as a few others from here and there, a quorum can be made and maintained. This has exciting possibilities for breaking down the barriers between institutions — geographically and politically. Perhaps different branches of a state university will indeed start acting as members of a system - with faculty and students moving easily between them.

At the university level, most learning happens in front of an open textbook at home, instead of an open notebook at lecture. Because of the availability of *Tablet*, textbooks in the year 2000 will only partially resemble what is used at universities today. Most courses will have on-line multimedia textbooks available. For example, a "book" on Orson Welles could contain video excerpts from the movie *Citizen Kane* as well as audio from his "War of the Worlds" radio broadcast. A math textbook will include living formulae for the student to manipulate. For example, a student encountering Taylor series can specify their favorite function to be expanded, along with evaluating the first several terms to get a feel for the rate of convergence. A chemistry textbook discussion of the Belousov-Zhabotinskii reaction could include a simulation of the reaction with chemical parameters input by the student. The textbook would also include video of the actual reaction as viewed in a laboratory.

In addition to textbooks, other sources of information such as scholarly journals will be stored on-line. A current and inevitable trend in publishing is to submit articles via electronic means. Once display formats become standardized, it will also be possible for journals to be electronically published. This means more than just desktop publishing - it means the student from a university with a crippled library will be able to get the material they need on-line. The technology will not only speed the publication process, it will dramatically reduce the cost of publishing a journal. Reducing the cost threshold for starting a journal means more specialized journals will spring up like weeds - again, enhancing our ability to communicate. Doctoral theses and technical reports normally published by universities will also be available on-line. If a particular piece of information is in a language which you do not understand, your computer will make a rough translation for you to work with.

The organization of such vast amounts of information will dictate the extent to which it will be usable. Imagine a tremendous hypertext encyclopedia where every expert in every field maintains their knowledge on-line. Such a document can only keep growing and assimilating more and more information, pushing older and less popular information to lower levels while maintaining a hierarchical structure. A student can plunge deeply into superstring theory or skim the surface of modern physics by following different paths of links in the document. New links will be formed by remembering the path of previous searches. Thus every student becomes an explorer, blazing another trail for all to follow.

To efficiently search the available databases, automatic indexing programs will be used. These programs might map all English words and proper names into, say, 2^{16} different classes. A bit vector of this size can be prepended to each document, where a bit is set if a member of the corresponding word class appears in that document. Thus we can quickly identify the set of documents relevant to our query by comparing the document vector against a vector of all possible aspects, spellings, and synonyms for our search. Such a system can "infer" by analyzing the similarities between the vectors of related documents. Similar indexing techniques can be used for music and video, so we can search for songs similar to our favorite Beatles tune.

In addition to the ease of access for specific volumes of information, the computer will allow quick and simple searches for a particular item. You can search an art textbook for a painting by drawing a sketch of the painting on your screen. The computer would then try to match your sketch with one of the paintings in book.

Of course, there will exist problems for which the processing power available in a *Tablet* will not be great enough to solve a particular problem. In these situations, it will be necessary to tap into "computing power stations". By pulling the plug on the six billion dollar supercollider, we could build a thousand-processor Cray or a *billion*-processor Connection Machine. Students will be able to use a few processors whenever they need, and the entire machine can be set aside for one hour weekly to do the national weather forecast.

The way programming is done must change dramatically for educators to cash in on the computer revolution. Programs in low-level languages like C will die out like dinosaurs. Filling their ecological niche will be scripts for high-level interpretative systems. These programs will not be created by entering a sequence of lines of code, but rather by linking together operations using a graphical representation of the program's function. At the simplest level, a program will be just "replaying" a sequence of commands to a high level system. Thus, a classical literature major should have no more trouble programming the computer than an electrical engineering major.

5. The Effect on Curriculum and Coursework

When calculators entered the classroom in the 1970's, they resulted in a dramatic rethinking of the philosophy of education. Is it worthwhile for students to spend time learning long division when a calculator from a box of breakfast cereal will do the job better? Access to a tool like *Tablet* will have to cause an even greater revolution in what is considered worth knowing.

By the year 2000, computers will have forever become an integral part of doing science. Just as all arithmetic is done on portable calculators today, algebra, calculus, and all aspects of mathematical calculation will be relegated to computers. Yesterday's science followed one of two paths: hands-on physical experimentation or pure theory. Computers make possible a third path: computer experimentation, which will become the dominant method for investigating many kinds of systems. Such experimentation is the method by which one uses an algorithm to simulate a physical system and then finds out what happens by watching the program run. For many systems, this approach is not only fast and convenient, but fundamentally necessary. There will be very few scientists in 2000 who do not spend the majority of their time in front of their computer.

Because of the computational power available to students in their *Tablet*, the content of homework and exams cannot and should not include exercises requiring the brute force attack of a problem. More likely, exercises will involve describing how a problem is to be solved, instead of giving the mechanics of getting to the actual solution.

Word processors has revolutionized the way papers are written at the college level. This will inevitably filter down to the lower grades. We laughed at Mr. Dobko in eighth grade for telling us how important rough drafts were - but now that the technology makes iterative writing possible without excessive drudgery these styles must be emphasized from the beginning of school. It is not clear to what extent spelling and grammar will be taught in the primary grades - when *Tablet* can check them better than Mr. Dobko, what is the point?

Despite the interactive nature of current word processing programs, almost all writers print out a draft and scratch corrections upon it before pronouncing it ready. In the year 2000, editing papers will be a snap. With stylus in hand and a page of text on the display screen, corrections will be made the old-fashioned way, only faster. By drawing revision symbols directly over that offending participle or comma splice, editing will occur naturally and automatically. Graphs, images, tables and mathematical formulae will likewise be integrated into such editors.

Through on-line data bases, each student will have easy access to most of the world's words. Since it will be easy to obtain obscure references, the opportunities for plagiarism will naturally increase. To combat this problem, a professor will check each paper using an "originality analyzer." This system will compare a submitted work with related sources available to the student and will flag passages which appear to be copied or suspiciously unlike that student's previous style. Mencken said that "Conscience is the little voice inside of you that says someone may be watching." Without invoking images of Big Brother, *Tablet* will be watching.

One educational trend that is bound to continue is the emphasis on simulation. Through simulation, any student can get the feeling of being there. Historical simulations will enable high school students to run for president in 1920 and see why Harding would have beaten them, too. In economics classes, students can erect trade barriers and watch the effect of the ensuing depression. Laboratory science can also be effectively simulated. Ray traced graphics will enable anyone to dissect a frog without the frog minding. Many experiments which could not be performed because of cost or safety considerations can easily be done using the computer.

However, an important aspect of simulations is seldom given enough thought. No simulation is better than its underlying mathematical model of the world. Every model is biased by its designer, its politics, and its goals. Some simulations are just plain wrong - their underlying model is fundamentally flawed. Placing trust in the outcomes of simulations is misplacing trust. Students will have to be taught a critical eye for evaluating the results gleaned from simulation. Historical simulations are simply one man's theory, and despite the need to maintain student's interest scholarly ideals must be maintained. Further, it is self-defeating to simulate certain aspects of laboratory science. Learning laboratory technique is an important part of experimental science, and it is impossible to realistically model Murphy's Law.

Interactive simulation, treated with the proper reverence, does have its role in education. Exercises will more likely be done when they resemble a video game than a homework assignment. Integrating video, speech and text, these programs will adapt to a student's likes and dislikes. For example, an explanation of harmonic waves would be described to a musician via the analogy of the vibration of a guitar's strings. The same explanation would be made to an avid sailor using the waves of the sea as a metaphor. Ideally, the computer will be able to detect weaknesses in a students understanding of a particular area and will target problems to attack the weakness. However, it will remain the teacher's job to monitor their student's progress.

6. The Social Aspects of Education

The biggest flaw in many visions of the future is that they forget that people are social creatures. One of the negative aspects of increased use of computers is the corresponding reduction in human interaction. If it is not necessary to spend time in the library for research, one of the traditional gathering sites for students will be empty. The same can be said for open classrooms. The solution is that students will take their work to where other students are, instead of taking themselves to where the classes are. Students will not be limited to working in the library or at home. Why not do your calculus in the park, or at a museum or cafe?

Electronic mail will be a major communication medium for students in the year 2000. Unlike todays email, it will be possible to incorporate audio and video along with text in the mail message. Electronic mail is a wonderful medium for ideas and does not intrude the way a telephone does upon its recipient. It sits there quietly waiting to be read. The cellular telephone built into *Tablet* will allow students to converse with other students from any location. Using the infrared interface, a computer will be able to talk to other computers. A student's personal computer will be able to continually broadcast what the owner wishes the world to know about him or her: perhaps their name, face, interests, and sexual preference for openers. Setting your machine in "get-acquainted mode" will display the location of all machines in the vicinity and who their owners are. While sitting in a museum or restaurant you can find out about other people nearby, with the possibility of meeting a person with similar interests. Just imagine turning this loose in a singles bar!

Local computer bulletin boards will be constantly monitored by your computer looking for events you would be interested in. For example, a bulletin board listing upcoming concerts would try to find matches with your music collection. If you had a recording by an artist that was appearing locally, the computer would notify you of the event and present you with the opportunity to order tickets.

It is amusing to consider that the next generation of computer geeks is more likely to consist of artists than programmers! *Tablet* will be a creative medium which will lend itself to the creation of new art forms. Descendents of programs like today's hypertext system will lead to a redefinition of what exactly literature is. Initial efforts to create hypertext novels will no doubt be artistic failures, but with time legitimate hyperliterature will be created. The time will come, perhaps not by 2000, when the Nobel Prize for Literature will be awarded for hyper instead of linear text.

Using CCD cameras and ray traced graphics, home movies take on a new meaning. By digitally splicing home "footage" with simulated scenery, the amateur will be able to produce professional looking movies the way any author can now typeset his own material. As the technical and financial obstacles to entry for such arts fall, more and more people will participate.

The social aspect of this problem is who will appreciate all this new art? Some form of shareware video might arise. Other distribution channels will sprout up, but much of this art will be for private consumption only. An analogous situation already exists, as publishers have known for years that more people write poetry than read it. So it might be with shareware video.

Just having a studio available doesn't make everyone an artist!

7. Economic Impacts on Education

At no point in American history have sufficient resources been allocated to education. It doesn't take a visionary to know this will still be the case in the year 2000. Putting a price tag on *Tablet* is pure speculation, but 2000 dollars could be in the ballpark. We must find a way to get *Tablet* into the hands of the student. Who is going to pay for these computers and the software to run on them?

Some universities currently require their students to purchase a computer, in addition to the costs of books, tuition, and other items. The limited resources of students are strained enough that this additional cost is not often appreciated. Despite assurances that the naive freshman is buying is a "productivity tool for life", by senior year it will obsolete and suitable for use only as a planter. Something, either economic or technological, must happen to get us out of this rut.

What will happen is that in the university of the year 2000, a student will be given a computer on their first day. Over the years that he or she spends at the university, a fixed cost will be accessed each term. This cost will pay for the computer, tuition, access to a myriad of database services, and on-line textbooks. By the time a student leaves the university, *Tablet* will be theirs to keep. The reason this scenario is different from today is that by 2000, the technology will have reached saturation the way typewriter technology had reached saturation by World War II. *Tablet* is a complete tool which will integrate into people's lives and maintain its value. Manual typewriters maintained their value after electrical typewriters came around, finally meeting their match with the word-processor. It will take another product generation, several years down the road, to do in *Tablet*. We have difficulty imagining what *Tablet*'s successor will be able to do - but given time we will think of something.

Theft is a significant problem in an academic environment - anything valuable that isn't nailed down vanishes. And *Tablet* is valuable. However, with the Global Positioning System (GPS), the machine will know where it is and with the cellular phone DataLink, it will be able to communicate this information to the proper authorities. Try and fence merchandise this hot!

8. Conclusions

Tablet will have a tremendous impact on education by the year 2000, but it will require effort in many different directions to make it happen. Technologists will have to build the thing, but that is the easy part. The educational community will have to use its imagination to decide what is desirable and struggle with the technologists to make it work.

9. References

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