INTERACTIVE COMPUTER GRAPHIC TECHNOLOGIES FOR REPRESENTING SYSTEM DYNAMICS MODEL STRUCTURE AND BEHAVIOR

New Tools for Marketing and Teaching System Dynamics

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ABSTRACT

Several interactive computer graphics technologies are now available that can provide powerful tools which enhance our ability to conceptualize, implement, and communicate complicated system dynamics model structure and behavior thereby giving us opportunities to improve our effectiveness as researchers, consultants, and educators. This paper gives an overview of several projects utilizing interactive computer graphics and evaluates their significance for system dynamics . Included in this discussion are: 1) computer aided design systems for "automagic" design and updating of overview, policy-structure, flow, and causal loop diagrams, 2) computer teaching games and self-paced interactive computer aided instruction packages designed for personal computers; 3) review of the new Micro-DYNAMO and Hewlett-Packard plotting software from Pugh-Roberts, 4) computer networks, computer conference based academic programs for the general public, and network indexed video cassette extension libraries of system dynamics presentations and seminars; 5) interactive computer driven video disk processors with touch sensitive screens allowing a modeller multimodal access to overview, subsytem, policy-structure, causal loop and flow diagrams, table functions, documentors, and DYNAMO equations on the same system; and 6) two- and three-dimensional representations and animations of model behavior on multicolor dynamic displays driven by computer and video disks.

These developments are assessed with respect to their possible contribution to the growth of system dynamics as a field, dissemination of system dynamics methodologies and to the implementation of policy recommendations. Because of falling prices for software and hardware, the explosion in interest in personal computers, the exponential growth in their functionality, and the current state of the field, we believe the the next two decades will be the phase of most rapid growth for system dynamics.

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INTRODUCTION

Well-conceived, graphical representations of system dynamics models can be powerful organizing tools that enhance communication and conceptualization of model structure and behavior. Visual representations of models and behaviors are crucial to every stage of a system dynamics project including conceptualization, model building, communicating with clients and staff about project purpose, and dissemination of results to clients and the general public for the purposes of policy debate. Causal-loop diagrams, overview diagrams, policy-structure diagrams, and system flow diagrams have become standard methods of portraying model structure. System behavior traditionally has been represented on plots with line printers, by hand sketched diagrams, and more recently with color plotters and color monitors.

Several additional computer graphics technologies are now available and inexpensive enough to offer opportunities to substantially improve our ability to create and to communicate visual representations of model structure and behavior. Such advances allow us to improve our effectiveness as researchers, consultants, and educators. This paper dicusses some of these new technologies and evaluates their application or potential application in system dynamics.

Computer graphics have been an important aspect of the field of system dynamics from its origin. Plots from line printers have been the principle means by which system dynamacists have studied system behavior. It is interesting to note that two of the first major developments in computer graphics can be traced back to projects directed by Jay Forrester. The first use of a computer driven CRT (cathode-ray tube) display occured as part of the Whirlwind Computer project in the early 1950s. The first use of CRT's as command and control processors was with the SAGE air-defense program where a light pen could be used to touch a radar image on the screen directing a computer to track the represented object as it moved across a territory. [1]

THE GROWTH OF SYSTEM DYNAMICS AS A FIELD

Forrester asserts that one of the factors leading to the birth of system dynamics as a field was the advent of low cost computing in the late 1950s and early 1960s. While this is undoubtably true it is

probably also true that one of the factors that has held back the growth of system dynamics as a field has been the lack of low cost computing hardware and software. While the cost of computers were low enough in the 60s for major universities and large corporations to buy computers or time-sharing, it has only been in the last couple of years that the cost of computer hardware and software has fallen sufficiently to allow computing to spread widely into colleges, businesses, high schools and homes. Even now software and hardware are too expensive for widespread use of computer simulation by the general public or students. Only a few universities can afford a professional quality DYNAMO compiler even with educational discounts. Most system dynamacists can undertake a system dynamics project only with sponsorship. We frequently see the enthusiasm of students, visitors, senior executives etc. involved in our programs diminished as they realize that they will not be able to continue modeling because of the high cost of software and hardware. The computer time-sharing budget alone for our National Model Project runs in the neighborhood of $30,000 to $50,000 a year. In order to write a professional quality book to convey research results it is neccesary to add the costs of the technical staff, graphic artists, word processors, administrators and secretaries to the budget.

The growth of system dynamics as a field and in terms of impact will probably continue to accelerate exponentially in the next two decades as the cost of computing continues to drop. Falling costs and new applications will provide current practitioners with far more extensive resources and will allow wider more people to take advantage of old and new technologies. Within the next two decades the home personal computer should be powerful enough to support all the functions of our current top of the line professional compiler and documentor in addition to word processing and automated flow charting systems. There will also be new capabilites such as computer driven video disks and video tapes, computer based instruction, teaching games, and computer conferencing. Already Pugh-Roberts supports a desktop color plotter that provides book quality DYNAMO plots. It is conceivable that a single modeler of the next decade, with his home computer (with access to all publicly available previous system dynamics models including the National Model on his own storage system) and no support staff, will be able to have more impact on public, corporate, and personal policy than previous major system dynamics projects with large support staffs, have had over several years. This seems more plausible when you remember that our modeler of the future will be addressing his modeling results to a general public that will consist of several million people who will possess not only the hardware and software capabilities but also the computer and modeling sophistication neccessary to understand, resimulate, and debate policy recommendations. Imagine the impact that some of our top people would have had if they were just starting their careers with the resources now or soon to be available.

BENEFITS OF COMPUTER GRAPHICS

The benefits of computer graphics can be summed up as increasing accessability and improving powers of communication. But these can be

broken up into into two general categories. The first is improvement and cost reductions of the current research methods. Examples of this are automatic flow diagramming, the desktop color plotter, and Micro-DYNAMO on the personal computer. Flow diagrams and computer plots have always been used in the field but because of the time or cost it takes to get professional quality plots and diagrams far fewer papers are written using graphics, and those that are have often been of lower quality. Now students in classes can produce plots and graphics of similar quality to those produced by those who can afford graphic artists [2][3]. This will probably lead to wider distribution of their papers. Other advantages of easily updatable, complete flow and policy structure diagrams are improved model conceptualization, improved client-modeler interaction, and more efficient research organazation. The advantages of low cost computing have already been mentioned. The second category of benefits of computer graphics, includes new applications such as computer based instruction, computer based learning games, computer video disks, computer networks and conferencing and academic programs and video cassette lending libraries of system dynamics presentations and classes based on them. Many of these applications give us new opportunities for disseminating the methodology of system dynamics and the results of modeling projects.

Despite our enthusiam for some of these new approaches a note of caution is in order. Converting to a new computer system can take much longer than one might expect. There are many possible serious mistakes to be avoided. We will describe some of the pitfalls one can encounter when developing or converting to a new technology.

COMPUTER AIDED FLOW DIAGRAMMING

Over the last three years the technical staff of the System Dynamics National Model Project has been using, developing, and pursuing a number of new computer graphics packages for designing and updating system dynamics flow diagrams and policy-structure diagrams. In the past, National Model flow diagrams have been produced by searching through 200 to 300 pages of documentation and drawing the symbols and connections by hand. A number of our group's diagramming conventions such as complete description, and smooth arcs that are consistent with the underlying feedback structure make producing a complete set of National Model flow diagrams a lengthy process. Flow diagrams are frequently obsolete before they can be finished. One new computer system that we have used has reduced the time required for a revision of one flow diagram from ten hours to ten minutes, thereby making up-to-date flow diagrams possible.

CADDS4 (Computer Aided Design and Drafting System Version 4) is a highly sophisticated, three-dimensional modeling software package implemented on Computervision's Designer System computer. The system consists of the main minicomputer, a tape drive, a video terminal, a dot matrix printer (for text), a light pen, a tablet, an image control unit, and an attached Calcomp plotter (for graphics).

It has several features which make it useful to our flow diagramming effort. Diagrams can be created on the video screen by touching the light pen to the tablet which sits in front of the screen. The tablet can be "programmed" to issue complete sets of commands when activated by touching the light pen to certain areas of the tablet. This capablility is extremely useful to us when we need to repeatedly create rates, levels, and auxiliaries. By touching the light pen to the area of the tablet which is "programmed" to create a level, and then touching the light pen to the area which corresponds to the video screen, a level will appear on the screen. From this step, rates and auxiliaries are added to the screen, then arcs are used to indicate the correct flows, and text is added where necessary. As the diagram becomes too large for the screen area, the image control unit allows us to zoom the screen away from us to cause the screen workable area to be increased. There is no need for us to be concerned about the correct dimensions of what we are viewing, because we have already programmed the computer to produce symbols, text, and arcs of a specific size. We have the ability to zoom a diagram so far out that it appears to be the size of a dot. We can rotate the diagram, invert it, or zoom in for a closeup view of a specific area.

Once a set of diagrams has been completed on the system, it is very easy to make additional changes by editing the document on the video screen. If a change in structure is required, the diagram can be considered to be made of separate entities (e.g. a level and associated rate as well as the text inside them). These entities can then be moved from one part of a diagram to another, or deleted completely. If any type of editing change is requested, it can be done by changing the text, "redrawing" an arc, reshaping a cloud, etc. These capablilites allow us to "fine tune" the diagram for presentations or for publishable material. When drawing such complicated flow diagrams by hand, there is a limit to how accurate we can make them when the error generation rate equals the error correction rate between sets. Because we do not have to redraw the correct portion of the diagrams on the automated system, we no longer generate as many new errors. Theoretically at least, our diagrams should now start approaching perfection. Figures 1 and 2 show a traditional hand drawn flow diagram and a computer aided flow diagrams. It is actually one of the lest complex diagrams of the complete set. Notice that the number key which has to repeated 40 times for each set and redrawn for every revision using the traditional method, can now be drawn once and inserted wherever we like with one touch of a button. Starting with a documentor describing the equations, it takes several hours to do even this simple diagram by hand. Some of the more complicated diagrams can take a whole day. Figure 2 was revised to represent the next model configuration in 10 minutes.

The computervision system has the ability to create three-dimensional images with different views from a number of separate planes. The software capabilities of the system far exceed what is necessary for the current standard system dynamics flow diagram. In the future we may be interested in producing three-dimensional multi-colored (the Calcomp plotter prints in many

colors) diagrams for the most modern client presentations.

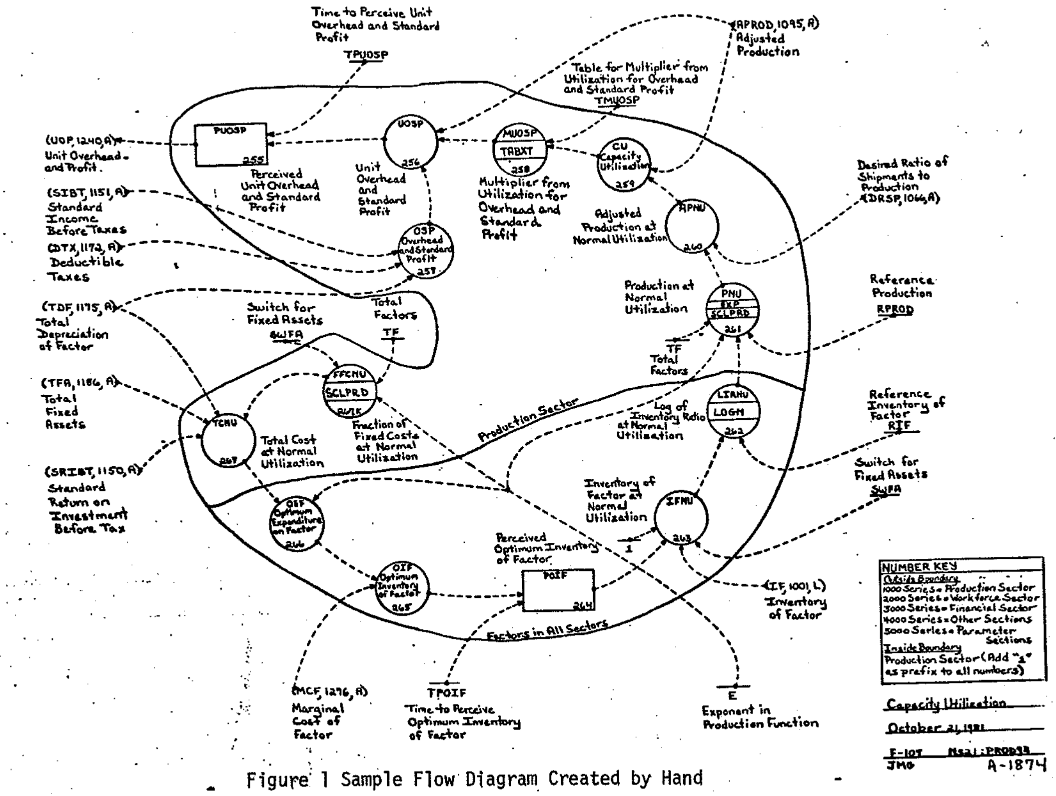


Figure 1 Sample Flow Diagram Created by Hand

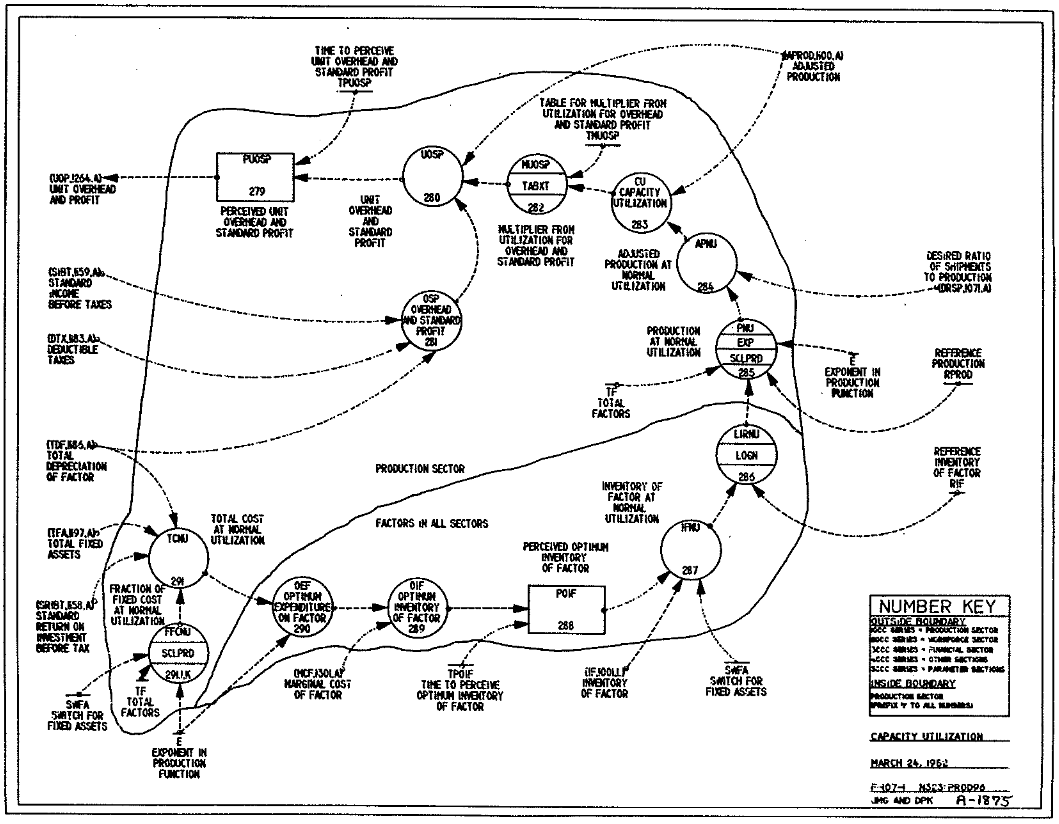


Figure 2 Example of New Computer Aided Flow Diagram

EASY UPDATING OF DIAGRAMS ENHANCES CLIENT INTERACTION, MODEL CONCEPTUALIZATION, AND RESEARCH ORGANIZATION

On another project, the ability to create policy-structure diagrams of many different versions of a sponsored model made it possible for clients to understand the week by week progress of the research and made it easier for us to elicit ideas for model improvement. These diagrams were also produced on the Computervision System. Figures 3 and 4 show an overview diagram and policy structure diagram used with a graphic arts consulting firm that sponsored a student program through John Morecroft's Corporate Research Program. The project is described more fully in "Strategies for Investing in New Technologies" also presented at this conference. [4] Because we were able to interact with the sponsors repeatedly over a period of several weeks with diagrams representing the lastest model changes and proposed changes from the last discussion, the project team was able to keep the research effort very tigtly focused. The bulk of the model was developed over a period of several weeks.

Figure 3. Overview Diagram

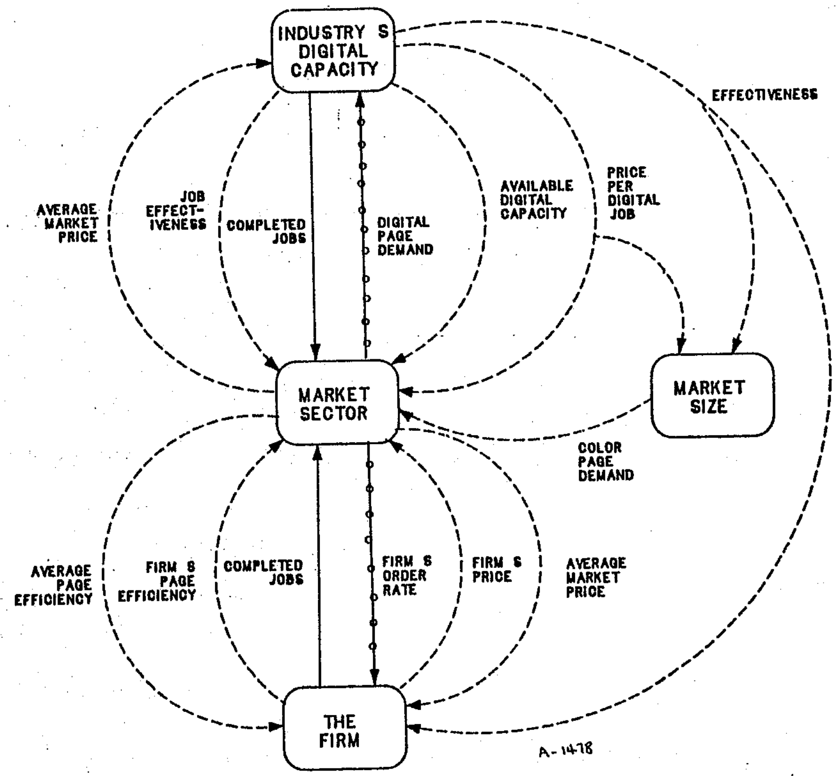
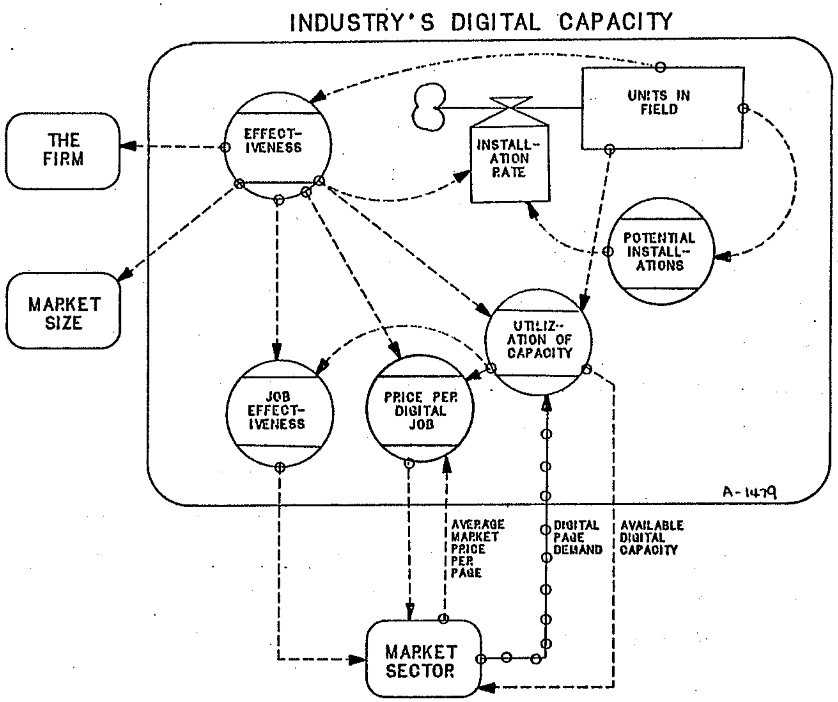


Figure 4. Policy Structure Diagram



CONVERTING TO A NEW GRAPHICS SYSTEM: A NOTE OF CAUTION

Although, there are many advantages to the Computervision system, there are two main disadvantages. The primary one being the prohibitive cost of purchasing a system. Unfortunately its high cost of $300,000 limits its availability. This problem may already be solved, though. There now exist several two-dimensional, black and white computer aided drafting systems based around some of the new micro-computers. The other major disadvantage to the system is the long learning curve. The ability to use the machine to one's best advantage takes many hours of training.

Converting to a new computer graphics system can take much longer than one might expect. There are many possible serious mistakes to be avoided. The easiest mistake is to get the wrong system. Fortunately, we were able to try out many different systems at no cost at MIT before finding a workable system. It was surprising to us to discover how many systems that at first seemed quite good turned out to be useless after we had worked on them for some time. Consider the following examples.

Our first attempt to implement flow diagrams on a computer system was at M.I.T. was with the architecture machine group which teaches students to program in PL/1 on the Perkins-Elmer computer using Magic Six software and an AED display processing terminal with a 480 by 640 pixel display. To the novice this seemed to be an appropriate system, although hours of programming would be necessary to set up the specific primitives used for system dynamics flow diagrams (rates, levels, clouds, etc.). After being exposed to the system for a few weeks, it became clear that the resolution of the screen was by no means sufficient to even view one small flow diagram completely. Solving this problem would require us to write elaborate programs for zooming, paning, scrolling etc. Also, their were only two ways to get hardcopy from this system. The first used a dot matrix printer that had poor resolution, and only printed on thermal paper. The alternative was to photograph the screen and splice each picture together. This would not be the system on which we would be able to create quick flow diagrams of the national model.

The next challenge came when we were able to use a Tektronix terminal located at M.I.T.'s Information Processing Service. The terminal is driven by PLOT 10 software commands programmed in FORTRAN on the same system that our main research is on. Unfortunately, it turned out that the graphics language and the plotter control languages were incompatable until an elaborate interface could be designed and implemented. We encountered similar difficulties with many other systems. The few systems we found that suited our needs were not available on campus and were too expensive for us to purchase. Finally, we learned that Computervision had donated a Designer System to a section of the Mechanical Engineering department. Professor David Gossard and Scott Ewing generously allowed us to use the system and taught us many of its functions. Contrary to our

expectations, even with this system, the first set of flow diagrams took longer than they would have taken by hand.

DISSEMINATING SYSTEM DYNAMICS AND SYSTEM DYNAMICS MODEL RESULTS

There are also a number of new ways computer graphics technologies can facilitate the communication of large and complicated simulation models. The System Dynamics National Model at M.I.T. provides an excellent testing ground for these assertions. It represents ten years of research by some of the top scientists and policy analysts in the field. The model is yielding results of great importance and relevence to current economic debates about reindustrialization, inflation, unemployment, energy shortages, prices, and tax burdens. However, it has a large and complicated structure. Introducing a model this size into general policy discussion could prove to be challenging. If a simulation model is to be useful in policy debates, it must be possible to communicate enough about its basic structure to the decision makers for them to have confidence in the model and to understand the reasons for the behavior presented in the conclusions. In a recent lecture to the French National Assembly in Paris called "Computer Models and the Public Policy" [1980], Professor Jay Forrester had this to say about the importance of communicating model structure to decision makers:

> A computer model should be understandable by anyone who wishes to take time to examine its structure and its underlying assumptions. If results from a computer model are presented as an argument in the political process, each person to whom the argrument is made should expect to be able to understand how the particular model represents the real world that it purports to explain [5].

What is the best way to communicate the basic structure or research results of a model as large as the National Model to a policy maker, student, or fellow scientist? For smaller models, system flow diagrams augmented by equation listings and descriptions introduce model structure explicitly. However, the system flow diagrams for the latest fully documented National Model span 26 pages. An average page contains 20 to 30 equation structures. Each equation structure has many equation inputs and associated constants. The basic equation listing without any documentation or definitions is 42 pages long, and this is in DYNAMO III which allows condensed expressions due to arrays. The documentation neccessary for the uninititated to understand the equation symbols in their condensed array form is 154 pages with 50 additional pages of listing and indexes. The latest draft of equation descriptions for one production sector is an additional 154 pages long. The serious student of the model will desire to puruse these materials carefully. However, the interested policy maker or the general public may not have the time or the need for such detail. In "Policy-Structure Diagrams of Selected Subsystems of the System Dynamics National Model," David Kreutzer supports Morecroft's assertion that subsystem and policy-structure diagrams may be a way of introducing model structure in an abbreviated fashion [2][6]. This kind of introduction may be more effective not only because it is more concise than introducing the model with flow diagrams but also because policy-structure and overview diagrams are conceptually closer in form to the mental models of the typical decision maker than are system flow diagrams or equations listings.

A similar argument can be extended to support the use of many of the new computer graphics technologies. Because of the incredible surge of interest and purchasing of personal computers by the general public, we have available to us both a new market for system dynamics and a new channel of access. The general public is undergoing a transformation of their mental models based on their experiences with personal computers and video games. In order to take advantage of this interest we need to address it directly. Many in the field are already doing this. There has been much discussion recently, about developing small models, teaching curriculum, computer based instruction packages, learning games, networks, and computer conferences for personal computers.

MICROCOMPUTERS AND DESKTOP COLOR PLOTTERS

The System Dynamics Group at M.I.T. has been using Micro-DYNAMO for personal computers (on the Apple and IBM PC) and the software for the Hewlett-Packard 7470A desktop plotter developed by Pugh-Roberts. We have found both to be useful developments and hope to see more such efforts.

The IBM Personal Computer has become a useful tool for communicating the graphics results of policy testing with small models. The IBM PC has been used by the System Dynamics group in association with our work with the Sloan School of Management's Senior Executive Program, Summer Session classes, and our own Sponsors' Meetings. We have found that the simulation runs created on a color monitor to be a clear visual representation of model results. Audiences seem to be more intrigued by output on a color monitor than output represented on a blackboard or 35 mm slide. Unfortunately Micro-DYNAMO software is only available for Apple and IBM micros which limits its availability to many audiences. Two other drawbacks that seem to limit the usefulness and sales of Micro-DYNAMO are its relative slowness and its inability to store plots as separate files that do not come from the same run. The combination of these two makes it virtually impossible to do policy testing with the color monitor. Fortunately Jack Pugh assures us that both of these latter two problems will be worked out soon.

The Hewlett-Packard desktop plotter is driven by Dynamo III and costs only about $1500. This is another example of an old computer graphics technology that is now inexpensive enough to give students and researchers access to professional quality plots that previously were avialable only to the wealthy sponsored programs that could afford a graphic artist. Most researchers would be embarassed to present the traditional line printer plots shown in Figure 5 in a publication or paper. Also Figure 5, is not an effective graphic in terms of communicating a point. Figure 6, on the other hand shows exactly the same plot done with the Hewlett-Packard plotter. We can also plot directly onto transparency film for use on overhead projectors. Although, Micro-DYNAMO does not yet drive this plotter, the plotter itself is compatible with most of the popular personal computers.

Figure 5. Dynamo Output on Traditional Line Printer Plot

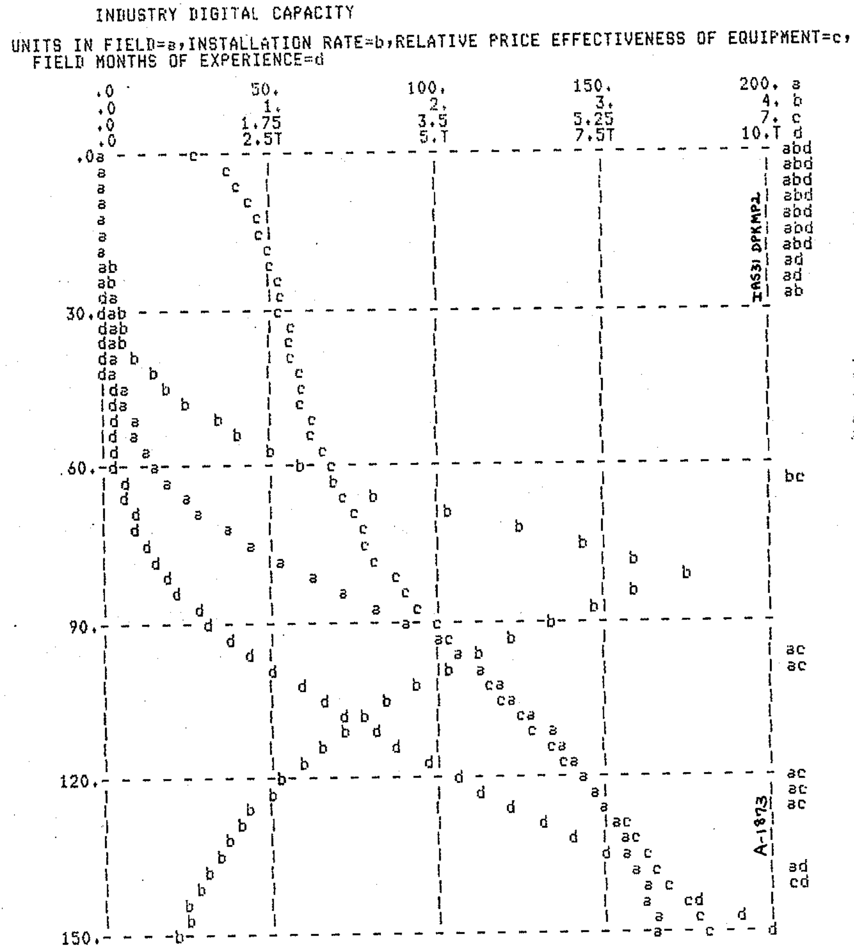
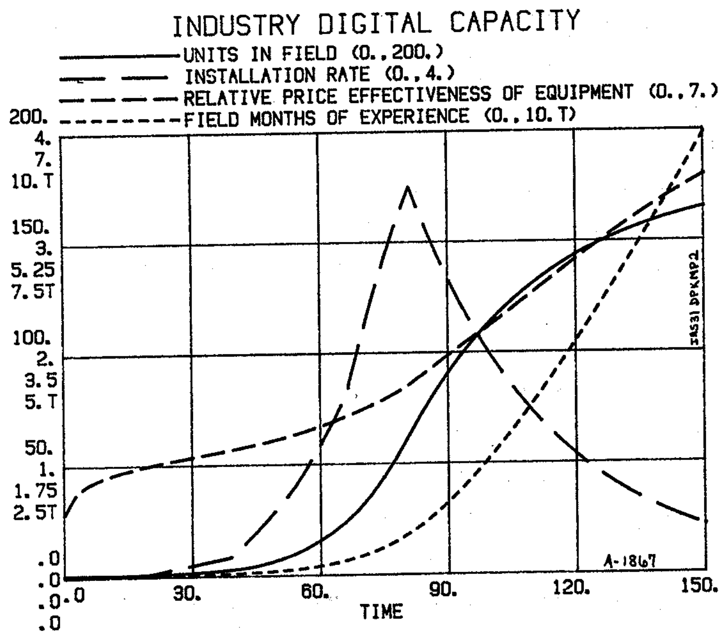


Figure 6. Dynamo Output on Hewlett-Packard Plot



LEARNING GAMES AND SELF-PACED INTSTRUCTION

Recent work by Nancy Roberts, George Richardson, and Jack Puch is encouraging in this area. Introduction to Computer Simulation A System Dynamics Modeling Approach has a companion manual used to explain the use of Micro-DYNAMO on the Apple Computer (now also available on the IBM Personal Computer). The colored output on the monitors available for the Apple and IBM computers help users to gain a more rapid understanding of their elementary models. This is a first step towards making system dynamics and its companion DYNAMO software, available to the general public. Professors John Sterman and Peter Senge design their Economic Dynamics course so that the model arising from student projects would be small enough to be used with micro-DYNAMO.

We, the authors, have also been developing a series of games based on personal computers that teach system principles or illustrate model results in the process of playing the game. One game under development allows the user to control the price of a company's product during the game with a button. The structure of the model, the incoming order rates, backlog, and the company's profits are displayed on the screen throughout the game. The goal during the play of the game is to make as much money as you can by controlling price. The lesson you learn by playing the game is one we have seen Forrester articulate many times. When you are gearing up production of a new product it is more profitable to constrain orders with a high price than with a high delivery delay. Even though he has demonstrated this quite well in many presentations, we have seen very intelligent senior executives who have not been able to fully understand this point even after several intensive seminars with Forrester. We believe that this game will be able to make the point very quickly. The impact of the game will be even greater if we let them pay an amount equal to the average profits most game players achieve and let them keep profits above that amount (scaled of course to practical limits.) This game would have the powerful effect of focusing attention on the key lesson and would provide immediate feedback on the consequences of pricing policies. This is the kind of interaction people are spending several billion dollars a year in quarters at arcades to achieve. Video games have an appeal that we should analyze and emulate for examples of certain types of curriculum development.

VIDEO-DISKS AND MULTIMODE USER INTERACTION

Interactive computer driven video disk processors with touch sensitive screens will allow a modeler to access subsystem overview diagrams, policy-structure diagrams, flow diagrams, table functions, documentors, and DYNAMO equations on the same system. The hierarchy can be traversed from one level to another by touching a finger to the structure of interest on the current screen. Loops can be traced from one diagram to another in the same way. This makes possible to create an interactive book-movie-game-simulation all in one. Unfortunately, the enormous amount of support work that must be done for this type of application severely limits its usefulness. It will be many years, at

the very least, before these types of output can be generated automatically from the Dynamo equations.

THREE DIMENSIONAL ANIMATIONS ON COMPUTER DRIVEN VIDEODISKS

Computer graphics also offers new possibilities for portraying system behavior. Two- and three-dimensional representations of model behavior on multicolor dynamic displays driven by computer and video disks may improve our ability to convey model insights to wider audiences. One current project will allow output from a DYNAMO simulation of urban growth to be viewed as an animation of the buildings of a three dimensional city, growing and shrinking in height, over time.

COMPUTER NETWORKS, CONFERENCES, AND VIDEO AND MODEL EXTENSION LIBRARIES

We should be amassing video tape libraries of the best system dynamics presentations and class lectures. Taking a longer term view of what would make the greatest contribution over the next 10 to 100 years of system dynamics, I can't think of a single $1000 block from our last years budget that wouldn't have been better spent videotaping 50 hours of the best presentations and discussions of Jay Forrester and our other top people.

It should be possible to establish an extension degree in system dynamics with an extensive video library and computer network, available to anyone in the country who has access to computer networking capabilities. A program such as this would allow a new dimension of accessibility and could be done in conjunction with a computer conference. In fact, such a program could solve one of the major difficulties with computer conferencing. Often, people become quite excited about computer conferencing until they get on a system and discover that they don't have anything to say to each other. A structured educational program would provide the context, purpose, and selectivity lacking in many current conferences. If there is any doubt about interest in such a program one should look at the explosive growth of night school adult education programs in the Boston Area during the last decade. These are people who after working a complete day at their regular jobs, defer dinner, drive to congested areas, search for parking, to spend several hours in a classroom. A program that allowed them to study potentially higher quality programs without having to leave their living rooms has a large growth potential.

CONCLUSIONS

There are some among us who question the growth rate of system dynamics and wonder whether we have what it takes to become a major field. It is too early to speculate about system dynamics ability to diffuse through the public as a methodology because it hasn't been adequately tried yet. Recent work by Nancy Roberts, George Richardson, and Jack Pugh is encouraging. The emergence of Micro-DYNAMO and personal computers should give us a striking base.

But we need to go beyond this. During the next decade we should utilize many new resources that are now available. As it is, we seem to have a decade or so delay in incorporating new technologies. We believe that much of the success of Visicalc on personal computers was only partially due to a burning need to do financial projections by the general public. It was also partially due to that fact that people were buying personal computers and needed something to do with them. There was very little software available at the time. Had Micro-DYNAMO been ready there might have had an explosion of interest in our work. Visicalc hit that "window of opportunity" and Micro-DYNAMO was late. A far greater "window of opportunity" is still opening with the upcoming long-wave transition: innovations and new paradigms centered around them will develop. The field seem to be in a strong position to grow into this opportunity.

The growth of system dynamics as a field and in terms of impact will probably continue to accelerate exponentially in the next two decades as the cost of computing continues to drop. Falling costs and new applications will provide current practitioners with more extensive resources and will allow more people to take advantage of old and new technologies. Within the next two decades the home personal computer should be powerful enough to support all the functions of our current top of the line professional compiler and documentor in addition to a word processer, and automated flow diagramming systems. There will also be new capabilites such as computer driven video disks and video tapes, and computer conferencing. Clever use of computer instruction games, self-paced instruction packages, video extension libraries and computer conferences could push the field to new levels of accessability and appeal.

In Jay Forrester's classic corporate growth presentation he asserts that the real problem faced by corporate executives is not how to increase orders but how to limit them. If you limit orders with delivery delay rather than price you are not realizing the full potential of your resources and therefore limit your corporation's growth. In fact, Forrester asserts that in such a corportion growth can cease as the system reaches a balance where high-delivery delay discourages orders to the extent that the company sees no need to expand so therefore has no way to bring down its delivery delay. He suggests that all that is needed to break a company out of a stagnation is an arbitrary expansion such as hiring more people or buying more capital plant. While we are not at all suggesting and do not believe that system dynamics is stagnating, we do think that it is possible for a field to unnecessarily constrain its growth just as a corporation can. Some of the existing or emerging computer graphics technologies present opportunities to accelerate the growth of system dynamic by enhancing our abililty to conceptualize and communicate model structure, behavior, and results and also by making the field appear more attractive to client, potential students, and the general public.

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