CADAE*
(COMPUTER AIDED DESIGN & ENGINEERING)

Donald R. Johnston
Geographic Information Services
Gibbs & Hill, Inc.
393 Seventh Avenue
New York, New York

Introduction

Gibbs & Hill is a large engineering and design organization headquartered in New York City. Beginning at the turn of the century as a pioneer in electrical transportation systems the company now provides a complete range of engineering/architectural services. These activities include: the design of major power generation facilities (including nuclear, fossil, hydro and solar power) planning, development and construction of new communities, urban and regional systems, industrial facilities, transmission and transportation systems siting and environmental studies, water and waste treatment systems and constructions services.

CADAE

As with most engineering firms Gibbs & Hill was faced with an ever-higher level of demand for design output. This traditional problem coupled with the increasing complexity of projects and new requirements imposed by stringent environmental, government regulations, and siting demands posed an increasingly serious production question. In 1972 the development of the CADAE system was initiated as a possible solution to some of these more obvious problems.

*Illustrations available from the author.

CADAE was desinged as a completely interactive system that could be used by the whole engineering staff. It is based on descriptive geometry. Complex shapes are readily constructed from baseic elements: angular lines, rectilinear lines, points, circles, ellipses, and irregular curves are called up and manipulated by keyboard and light pen. Views can be manipulated in any direction. The designer sees the results of any action immediately. Design changes previously requiring days of redrafting effort may be made on CADAE in a matter of minutes.

Gibbs & Hill have now had an opportunity to test and refine this capability on a variety of projects over a period of many months and preliminary experience indicates that CADAE is a significant breakthrough in the methodology of designing and enineering of large projects. The system frees the designer of much of the mechanical burden, and enables the design and engineering team to solve many communications problems inherent in traditional design methods. It provides a designing tool that can keep pace with the increased requirements of today's engineers.

The fundamental architecture of the CADAE System is based on bounded numeric geometry and employs the methodology of classical descriptive geometry. All geometry elements in CADAE are two-dimensional. Each element lies in a "view" - a plane oriented arbitrarily in space. Internally, CADAE handles geometry using the techniques of modern linear algebra. The user constructs views by indicating lines-of-sight and base points. They are converted to the equivalent matrix form. Projection of elements between views is accomplished using edge lines, just as a draftsman would. The projection of elements between views always utilizes these matrices. The drawings are created on a cathode ray tube (CRT) graphic display screen sensitized to a light pen that is used to develop the drawings.

Views are displayed to the user as if they were located on a piece of paper. The user is free to move, rotate, and scale each view and to add, change, or remove elements from them. All of these operations merely change the image; none of them alters the three-dimensional relationship between views. Thus, the tedious work involved in orthogonal/isometric view construction and projection on the drafting board is eliminated when using CADAE, but the convenience and ease of visualization of objects attendant with the use of descriptive geometry techniques remains.

The system installed at the company's New York headquarters on an IBM 3033 C.P.U. permits the storage of an enormous inventory of engineering detail. With the large memory available, CADAE can store many thousands of typical engineering drawings ranging from the most simple elements to highly complex modules (Figure 1). Once stored, the drawings, geometry, and alphanumeric data may be shared among an unlimited number of users. This sharing of data among users not only eliminates the need to duplicate drawings within engineering disciplines, but greatly reduces the margin for error as an increasing number of drawings circulate. The designer is always assured of having available the latest version of any drawing. Computer response time to a user request is less than one-half second for normal operations.

The designer/draftsman has instantaneous access to standard details, symbols, and drawings stored in the CADAE System by simply depressing a key on the terminal keyboard. Changes to drawings, previously requiring days of redrafting effort, are made directly on the display screen in minutes. The System automatically accommodates all changes made to a drawing. Electrostatic hard copy reprodution that incoporates changes can be obrained at a scale defined by the user within 3 to 10 minutes after the drawing has been stored. Other reproduction options avilable with CADAE are wet ink on film plots (produced on a flatbed plotter) with a quality surpassing that of hand-drafted ink drawings (at a fraction of their cost) and the reproduction of drawings either on microfilm or with microfiche techniques (Figure 2).

In using CADAE, any drawing detail need be constructed only once. Thereafter, it can be positioned and replicated on a single drawing or a group of drawings as needed. The replicated item is sized automatically without distortion to suit the scale and unit of measurement of each drawing.

During the creative process CADAE logic inhibits human and construction errors. If a syntactic or geometrically impossible error is made, a message to that effect appears on the screen so that it may be corrected immediately.

CADAE's data base provides the capability of duplicating portions of drawings or entire drawings stored by the System, thus minimizing new drawing development from project to project or from discipline to discipline within any given project. Using the building block approach, a plant physical arrangement developed by one design discipline may then be displayed on several terminals simultaneously and independently. Other disciplines may then work with a copied version, as required, while remaining independent of the master drawing. The copied version may be used by each design discipline as a basis for that discipline's portion of design responsibility. Such a feature greatly reduces the time formerly required for individual background creation and ensures uniformity of all drawing development.

One feature which has a direct analogy in environmental/planning applications is the ability to composite a multiplicity of elements. In engineering, there are always various disciplines which must be accommodated within the same space. The structural detail relates to the piping which in turn must relate to electrical, mechanical and so on. All activities must be reconciled within a certain floor or structure space. CADAE permits the user to composite multi-layers of detail within the same drawing. If there is a conflict or interference between structural and piping this is quickly evident and the necessary revisions can be made with a light pen. Seperate engineering disciplines can continue to work independently on a large project and still resolve the interdisciplinary conflicts by compositing any two or more elements on the screen at the same time.

One simple but time consuming task in any engineering detail is the need to change scale or dimension. CADAE provides a user-defined unit-of-measure option including English or metric, scale, and displayed-size capability accommodating variations in any scale and size. Drawings may be developed in first- or third-angle projection (American or European). The system will automatically calculate and display dimensions simultaneously in English or metric units. Dimensions may also be displayed in feet, inches, and fractions of an inch to 1/64 or in excess of 6 decimal places. Geometry chosen in a given scale can be subsequently converted to any other scale or unit of measure as required.

An increasing number of analytical functions are available on the system including: calculations of volume, area and weight, beam analysis, structural sections and properties, hydraulic circuit properties, fluid line analysis, individual geometric element analysis, etc.

Use of CADAE

As an operational tool CADAE has been available since 1977 and has been used on a number of projects already underway. Based on these successes we are now initiating large projects on CADAE, where all drawings will be developed on the system. Preliminary experience has shown that the first and obvious advantage has been the time saving over conventional drafting and design methods. Design efficiencies appear to be at least 4 times as fast as an average designer and for tedious repetitive tasks the ratio has been as high as 20:1. As an increasing number of the design/engineering staff have gained experience with the system, efficiencies in a number of different areas have become evident: time spent in checking drawings has been reduced by 25%, errors in accuracy have been reduced by 90%. Interaction among various engineering disciplines is now a very simple procedure. Once the basic design standards and functions have been established for a project all users can operate from the same data base.

Various disciplines can composite their individual design units to ensure all components are compatible and that there are no conflicts. A complex project can go forward on several fronts simultaneously with complete control over the technical interrelationships. Improvements in project coordination is approximately 60%. Coordination is accomplished by providing General Arrangement drawings to all disciplines. Each layout has the same plotting reference and can be overlaid precisely on any discipline drawings of the same area. Although each designer is working from the same data base he has complete freedom to select any scale, or choose as required any number of symbols or details from the library. This freedom and flexibility greatly reduces research and production time and enhances the creativity of the operator.

Training

CADAE has been designed to be completely user-oriented so that a minimum of training time familiarizes all levels of the engineering staff with the system.

Training programs entail 10 periods of 3 hours each for a total of 30 hours training for new designer/engineer users. At the end of the 30 hours the trainee has a good working knowledge of the system and can begin using CADAE on regular production work. Levels of skill and sophistication increase quickly so that by the end of the first 30 days of user experience, the operator is competent in all facets of CADAE's application.

The Gibbs & Hill program has completed the training of over 200 of its staff on the use of the system and by the end of 1979 expects to have 60 terminals in use.

CADAE Future

During the 1980's the engineering profession will be facing an increasing shortage of engineers. Of the students entering college, less are entering engineering schools. Even today we are experiencing a shortfall of 11,000 engineering graduates. CADAE will aid in easing the burden of the existing engineers, reduce the tedium, and enable them to be more productive professionals. Recent experience with CADAE suggests that it will aid greatly in this task and indirectly assist in alleviating another persistent problem - paperwork. In recent years the flow of paper has increased exponentially. More regulations, more codes, increased standards, more people active in projects that were not previously involved. The result has been that the designer/engineer is awash in paper. He spends more of his time in "busy" work. Paper shuffling, forms, correspondence, and general communication between project participants consumes a significant portion of the creative time available. CADAE has proven to be a significant aid in reducing this problem. The alternative would be a substantial reduction in the companies productive efficiency in the next five years.

Now that the viability of CADAE has been established in the engineering field the company has expanded its efforts into the area of computer mapping to include urban and regional planning, environmental and economic considerations and the total field of spatial data analysis for resource and land planning projects.

Now that the viability of CADAE has been established in the engineering field the company has expanded its efforts into the area of computer mapping to include urban and regional planning, environmental and economic considerations and the total field of spatial data analysis for resource and land planning projects.

During the coming months Gibbs & Hill will expand their capabilities in this area as a logical complement to its engineering/design activities. The vehicle for this expansion is the newly formed department - Geographic Information Services (GIS). The primary focus of the new department will be the use of computer graphics as a supporting service for existing Gibbs & Hill applications in energy generation, natural resource development, mining, transportation, planning and real estate development.

The function of GIS is the development and management of project data bases and its most visible application as in CADAE, is in the storing, display and analysis of information.

As a purely graphic tool we see GIS as one of the most direct and effective means of communication with the client throughout the life of a project. As a management tool it provides a means of organizing data and aids in the simplification of the project methodology. Being involved in a large number of complex projects, both domestic and foreign, we are always aware of the need to maintain a high level of communication with the client and to ensure he has a full understanding of every facet of the project. The maxim: "a client would rather live with a problem he cannot solve than accept a solution he does not understand", is still very true. Gibbs & Hill views the GIS capability as a mechanism to expand client participation and thereby enhance his project perception.

The final contribution of the GIS will be in the broad range of analytical and modeling applications that are possible. As a computer based device it brings to the project manager the luxury of being able to explore all the "what if" options that might influence the project.

The R & D required to develop this new capability necessitates considerable committment, consequently a commercial enterprise such as Gibbs & Hill must weigh the implications of the R & D effort, and ensure that the development exercise does not lose sight of the eventual corporate requirement, that the effort results in a contribution to net earnings. To this end, the development is directed to facilitate as broad a system application as possible. The system will incorporate Fortran language in a mini/micro configuration that is as transportable as possible and also compatible with our IBM 3033 central processor.

With this type of configuration we hope to be able to develop large spatial data bases within the system and also use the increasing number of public sector digital inventories already available from such agencies as the Bureau of the Census and U.S.G.S.

There are two main reasons that have encouraged us to pursue the development of GIS: The near-miraculous advancements in hardware have reduced the cost of highly sophisticated components to a level which makes them available to a much larger segment of the user population. At the same time, both the hardware and software have become more familiar and user-friendly to all participants. The other component essential to the expansion of this new capability is the sharply inreased user awareness. We have growing evidence from departments within our own firm who, having seen some colorful output products on a project, suddenly become enthusiastic users of the system's graphic capabilities. The highest confirmation of our decision to expand in this area came when a young engineer said, upon receiving the first output from the plotter - "hey, this is okay!"