FROM MAD TO CAD: AUTOMATIC PRODUCTION OF ACCELERATOR LAYOUTS

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ABSTRACT

When building large installations such as particle accelerators, incorporating many interconnected systems in a confined environment, it is vital to keep track of the space occupation of individual components. The solution adopted for the LEP project links location data produced by the Methodical Accelerator Design program to the Computer Aided Design system library of components to produce automatically a variety of machine layouts and assemblies in 2D or 3D representation. The machine assemblies can be either visualized and manipulated interactively on a CAD workstation or plotted on paper.

INTRODUCTION

The decision to install a Computer Aided Design system in the technical divisions at CERN was made in 1981 and a year later, after a detailed technical evaluation, the EUCLID software supplied by MATRA-DATAVISION of France was installed on a Digital equipment Corporation VAX 780 (1).

Two of the principal reasons for its selection were its 3D modelling capabilities and its potential for user software development. Today the new version EUCLID-IS (2) runs on more than thirty dedicated work-station connected to two clustered VAX machines, a 8650 and a 6210.

One of the most powerful feature of EUCLID is the existence of a programming interface making it easy for users to develop extensions in the basic software. Extensions fall into two categories, being either additional tools for the interactive user or completely separate batch programs.

Batch programs have a number of advantages. They are well suited to perform pre-defined repetitive tasks based upon user supplied data. They can be executed overnight thereby giving interactive users of CAD the full use of computer resources during day-time, and they do not require the use of hard-coded workstations.

Two EUCLID extensions have been developed to produce the layouts of LEP. LECD (Layout d'Equipement Généré par Ordinaleur) is an interactive as well as batch application used for schematic layouts. ASMAC (Assembly of Machine) is a batch-only application producing detailed layouts. They have made it possible to follow closely the evolution of the machine at the design and installation stages with a major saving in manpower.

Two sources of data are exploited to produce layouts:

a) a set of component locations files:
   b) the CAD library of models.

THE COMPONENTS LOCATION FILES

The design and installation of a large accelerator is a dynamic process in which data is constantly modified and updated. Computing tools are necessary to deal with the large amounts of data involved. In the case of LEP the MAD (3) program is used by machine physicists to calculate the beam orbit and to place beam elements, magnets, accelerating cavities, beam instrumentation and vacuum tubes and valves.

The EDMMS ORACLE (4) is used by engineers in charge of cooling, electrical distribution and transport system. Wherever possible, use has been made of the source data to produce up-to-date layouts.

The link between MAD or ORACLE and layouts is established by a set of component location files, one file for each system. The intermediate files are useful for four reasons:

a) the coordinate system of MAD and EUCLID are different;

b) MAD is running on a different computer from CAD;

c) the data extracted from MAD and ORACLE is not sufficient for engineering purposes. Location number and geometric transformation code, taking into account the multiple orientations which a component may have in different part of the machine, have to be added;

d) they make it easy to freeze the layout in a given state.

The civil engineering, monorail and electrical distribution system not being defined in either MAD or ORACLE, their location files are created manually with a text editor.

The summary of LEP systems is given below. Altogether the layout applications deal with 55'000 components of 1'700 different types belonging to 34 systems.

THE CADD DATABASE

There are two types of EUCLID databases, project databases and standard databases.

The project databases contain all models, assemblies and drawings of machine components designed interactively. The contents of project databases is under the sole responsibility of the designer.

The standard databases contain all models of machine component used for assemblies and layouts. Before a model can become a standard, it has to be approved. It is then transferred from the project to the standard database and documented.

To keep drawings readable and to stay within FHCLID limitations on the complexity of models, up to four level of graphic representation are stored for a
component. For example, in schematic layouts, the model is a box whereas in detailed layouts, all geometric details down to the millimeter level are included.

**THE LEGO APPLICATION FOR SCHEMATIC LAYOUTS**

LEGO can be used interactively as well as in batch. Interactively, it allows the creation on the screen of the environment in a part of the tunnel when local modification or new implantation of components are studied.

The batch mode is used to produce two types of schematic layouts at scales of 1/250 and 1/50. Input parameters are read from text files prepared with the editor, one file per layout. Each file defines the drawing size and layout, the title block, the LEP systems to include and the part of the machine to draw in units of half-cells (39.5 m in most cases).

Features not found in earlier versions of EUCLID and therefore differs from LEGO in a number of ways:

- View arrangements on the drawings are predefined and stored in a library.
- An interactive interface is available for the input of parameters.
- The part of the machine to be assembled and drawn can have any size from millimeters to kilometers.
- A tree structure of the components in each view is built and stored in the database. These assemblies are then calculated in a combinatorial way by recalling the leaves two by two, computing and storing the intermediate results. The final results are then extracted from those partial results.

A structure of any complexity can be calculated this way, the only limitations being the available CPU and disk storage space.

![Fig. 1 Part of a schematic layout - Real scale 1/250](image1)

![Fig. 2 Part of a schematic layout - Real scale 1/50](image2)

**THE ASMAC APPLICATION FOR DETAILED LAYOUTS**

This application was developed in 1986 to provide the machine installation teams with detailed 3D views of the completely equipped tunnel. It makes use of

![Fig. 3 Part of a detailed layout - Scale 1/10](image3)

**LAYOUTS PRODUCTION**

Producing accurate layouts at the rate imposed by the machine installation teams, i.e. up to 25 schematic and 25 detailed layouts per week, has proved a major challenge for the CAD system and personnel.

Each detailed layout requires over one hour CPU (VAX 8650) to be calculated and plotted whereas 15 minutes are required for schematic layouts. Results have to be stored on disk until the layouts are checked and approved. Two 512 Mbytes disks were reserved for this temporary storage. Plotting high-density drawings can only be carried out on electrostatic plotters which means vector to raster conversion and transmission of large plot files. Managing the production checking the layouts and making the necessary modifications in the databases has occupied four designers for over a year. The following table lists some of the key production figures.

<table>
<thead>
<tr>
<th>Scale</th>
<th>LEGO</th>
<th>LEGO</th>
<th>ASMAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of layouts</td>
<td>24</td>
<td>800</td>
<td>800</td>
</tr>
<tr>
<td>Number of components per layout</td>
<td>200</td>
<td>100</td>
<td>500</td>
</tr>
<tr>
<td>Computing time (VAX 8650)</td>
<td>5 min.</td>
<td>15 min.</td>
<td>1 hour</td>
</tr>
<tr>
<td>Plot file size</td>
<td>0.2 Mb</td>
<td>0.5 Mb</td>
<td>1.5 Mb</td>
</tr>
<tr>
<td>Plotting time (including transfer)</td>
<td>3 min.</td>
<td>6 min.</td>
<td>20 min.</td>
</tr>
</tbody>
</table>

1964  PAC 1989
STORAGE AND RETRIEVAL OF DRAWINGS

At present CAD engineering drawings are stored in two forms:
- the CAD database representation,
- the computed drawings representation plotted on vellum paper.

Paper is still in use as the common archiving medium for CAD and manual drawings.

In future all drawing images, whether made with CAD or scanned from manual drawings will be stored on a large capacity magnetic storage device such as WORM (Write Once Read Many).

This drawing database, together with the Euclid-Oracle interface (5) under development will make it possible for all end-users such as workshops, maintenance teams and accelerator control-rooms to access engineering data, and drawings at remote locations via a graphic terminal.

CONCLUSIONS

Validating the machine layout with the help of a 3D CAD system has resulted in a smooth installation with few time consuming and costly corrections having to be carried out on site.

The quality, readability and reliability of the CAD layouts is a major improvement over the hand drawn layouts of the past and is achieved with a much reduced work force.

The computer memorisation of the whole LEP machine is a tremendous asset in view of the possible future installations foreseen in the same tunnel.

REFERENCES


(2) MATRA DATAVISION - EUCLID-IS Software

(3) F.C. Iselin and J. Niederer, the MAD program (Methodical Accelerator Design) User's Reference Manual - CERN/LEP-TH/87-33

(4) ORACLE Relational Database Management software.


Fig 4 The detailed layout at interaction point 3. The complete LEP detailed layout comprises 800 such drawings - Real scale 1/10 and 1/50