OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

FAIR USE POLICY

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

We regret that some of the pages in the microfiche copy of this report may not be up to the proper legibility standards, even though the best possible copy was used for preparing the master fiche

07564

Distr.
LIMITED

ID/WG.254/2
18 July 1977

ENGLISH

United Nations Industrial Development Organization

Interregional Expert Group Meeting on Computer Applications and Modern Engineering in Machine Manufacturing Industry

Warsaw, Poland, 19 - 29 September 1977

A COMPUTER AIDED MANUFACTURING SYSTEM APPLIED TO BATCH MANUFACTURING[1]

by

G.P. Putnam*

* Manufacturing Technology Advisor, IIT Research Institute, 10 West 35th Street, Chicago, Illinois 60616. U.S.A.

1/ The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the secretariat of UNIDO. This document has been reproduced without formal editing.

id.77-4833

SUMMARY

Recently a Computer Aided Manufacturing (CAM) System was developed for a United States Government Manufacturing Facility at Rock Island, Illinois. The system augmented an existing Direct Numerical Control (DNC) system under the control of a PDP 11/20 mini-computer.

This development project involved additions to existing hardware and software as well as the development of new software.

Additional hardware was added to:

- permit the PDP 11/20 to function as a terminal to interface with a large scale computer which processed APT part programs.
- provide added storage for storing part programs and newly developed system programs,

The software developments involved the design, development, and implementation of:

- Revisions to the existing PDP 11/20 operating system.
- A SCHEDULER - to develop a time table for routing parts through a machine shop.
- A LOADER - to dynamically construct and manage the work queue for each of the systems DNC machines.
- A UTILIZATION REPORTER - to monitor work performed on the DNC machines.
- An OPERATIONS HISTORY REPORTER - to compare actual performance with planned performance.
- Software which integrated the above software packages with one another and the DNC part programs used to manufacture parts.

INTRODUCTION

Computer Aided Manufacturing (CAM) has existed in a practical form for about 20 years. In its most popular form CAM has been most manifest during this time period as N/C (Numerical Control).

About a decade ago other CAM concepts such as DNC (Direct Numerical Control), CNC (Computerized Numerical Control) began to surface. More recently significant attention has been focused on other CAM elements and elements related to CAM. Group Technology, Process Planning, Scheduling, Loading, Simulation and Data Base Design and Management represent a partial list of such elements.

Combining groups of these elements has led to the emergence of what has come to be known as CAM Systems. As we begin to develop a jargon related to CAM it is important to begin to define the jargon as best we can as we develop it so that CAM technology, as it evolves, will be retarded minimally by the "braking" effect of confused terminology.

Therefore, let us draw a distinction between the terms CAM and CAM System as they will be used in this paper.

When computer technology is combined with manufacturing technology, the result is Computer Aided Manufacturing (CAM). In view of this statement, it is apparent that almost any use of a computer in the manufacturing environment falls within the scope of CAM. Some CAM Applications involve manufacturing support functions such as cost control, inventory control, production control, quality control, and the like. Other CAM applications deal directly with the manufacturing processes themselves -- for example, those related to numerically controlled (NC) machining and, later, direct numerically controlled (DNC) machining.

EXAMPLES OF CAM SYSTEMS

There are many excellent examples of computer applications to manufacturing activities -- some of them associated with significant savings. It is only recently, however, that the application of computer technology to the manufacturing system, as a whole, has begun to take place in a coordinated manner. A partial list of these examples include:

- The U.S. Air Force Integrated Computer Aided Manufacturing (ICAM) Plan.[1] Initially ICAM will be a collection of subsystems related to sheet metal forming at the manufacturing level - but only a part of the general support, management, and control systems at other levels of manufacturing. The total ICAM budget over the next 5 years is approximately 75 million dollars.

- The Fujitsu Fanuc Ltd. DNC System[2] which is in actual operation at Hino, Japan. Since this system produces parts for Fanuc N/C Control Systems, the manufacturing output of this factory is materially dependent on the reliability of this system.

- The Methodology for Unmanned Metalworking (MUM)[3,4] project is perhaps the largest and most ambitious undertaking in the CAM area to date. Organized by the Japanese Government with the active cooperation of Japanese Industrial and Academic communities, this project is budgeted at the 183 million dollar level. Its objective is to produce a totally automated factory utilizing CAM systems. Ultimately the maintenance function will be self-diagnostic and self-correcting to an extent.

- One of the most significant development projects in the area of computer aided process planning is being conducted by United Technologies Research Center[5] in the U.S. This project is directed at enabling a manufacturing organization to incorporate within a computer a decision making rationale for generating process plans. The approach to generating a process plan is "generative" rather than "variant". This means that a process plan may be developed using the part design as the system input rather than editing an existing process plan for a part similar to the one to be manufactured.

CAM SYSTEM DEFINITION

A CAM system (as distinguished from a CAM application) is a manufacturing system in which computer technology is utilized as an integral component. The key words are system, computer, and integral.

Manufacturing system often means different things to different people. The diagram in Figure 1 illustrates a simple yet general model of a manufacturing function structured along a systems approach. Using this type of schematic, any manufacturing function can be defined in terms of the following:

- Input to the function -- product designs, statements of product demand, shipping destinations and quantities, etc.

- Output of the function -- item or group of items produced in conformance with the input information and constraints.

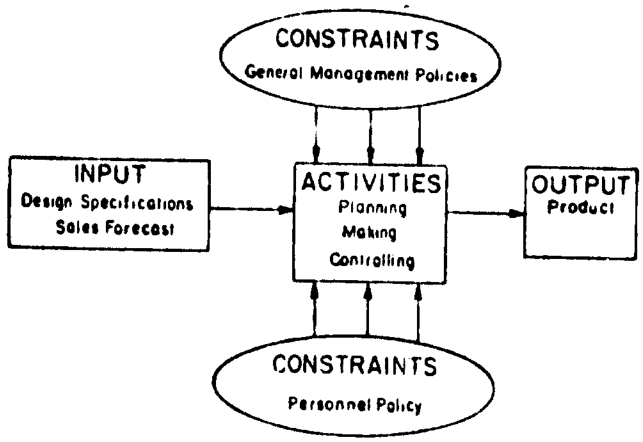
- Activities represented by the function -- in manufacturing these can generally be grouped into the following categories:

- Planning -- make/buy decisions, process/ methods planning, scheduling, materials specification, resource allocation, etc.

- Making -- material removal/displacement/ addition/processing/movement, assembly, packaging, etc.

- Controlling -- production control quality control, cost control, inventory control, etc.

* Constraints under which the function operates -- policies related to personnel, finance, quality, general management, etc.



MANUFACTURI"G SYSTEM

Figure 1

When a manufacturing system as described above includes the functional use of computer technology, the result is a CAM system. The computerization can be either partial or total; however, the only requirement is that it must be organized to fit into the scheme of the manufacturing system and function as a part of it. Its relationships cannot be haphazard or disjointed -- it must be carefully planned and coordinated towards the achievement of the specific objectives related to the system.

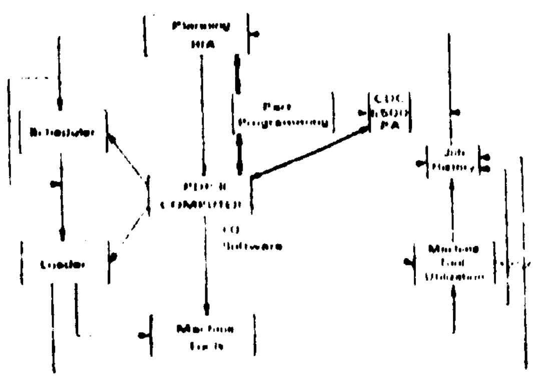
The chief difference between a conventional manufacturing system and a CAM system is the way in which the information is processed. In a non-computerized system, manual record keeping and communication is employed with most decisions being made after laboriously assembling, digesting, and analyzing data. In contrast, a CAM system utilizes computer hardware and software to assemble, organize, and analyze the data involved in the manufacturing system. In some cases, it can even process the data in a way that routine decisions can be made automatically. Further, it can greatly simplify the interfaces between activities within the manufacturing function as well as its interface with external functions.

RECENTLY DEVELOPED CAM SYSTEM

IIT Research Institute (IITRI), Chicago, Illinois has recently developed a CAM System which has been implemented in a U.S. Government manufacturing facility in Rock Island, Illinois. It is called the RIA DNC/CAM System.

SYSTEM STRUCTURE

The system was developed by adding certain hardware elements and computer software to an existing operational DNC system. The system structure is depicted in Figure 2.



CAM SYSTEM BLOCK DIAGRAM

Figure 2

Five DNC machine tools are incorporated in the system. Included are two machining centers and a lathe built by Sundstrand, an American Challenger turret lathe, and a machining center built by Kearney & Trecker.

The basic computer hardware configuration consists of:

- A Digital Equipment Corporation (DEC) PDP 11/20 computer system which controls the DNC/CAM components.
- Cathode Ray Tube (CRT) terminals located at the computer site and adjacent to each of the DNC machine tools.
- Different items of input/output (I/O) equipment to permit various types of input (card, disc, tape, and keyboard), output (printer, CRT), and the remote processing of APT part programs.

The software elements associated with the system include the following:

- An Executive System designed and supplied by Sundstrand Corporation to operate in connection with its Omnicontrol DNC System. In addition, the RIA DNC System software collection contains an extensive array of packages and routines (obtained from Sundstrand and other sources) related to part programming, editing of part programs, driving and operating the DNC machines, etc. The original Executive System was modified by IITRI to permit the PDP 11/20 to control the CAM software additions also.
- A Communications Package to permit the remote processing of APT part programs on a CDC 6500 computer located approximately 1000 miles away.
- A Scheduler (JOB SCHED) -- an Interactive Job Scheduling Module for establishing the estimated start and completion times for each operation to be performed on the DNC machines. This program has the added advantage of also being able to accommodate non-DNC operations. In fact, any operation performed within the manufacturing facility can be scheduled with this package.
- A Loader (MG LOADING) -- a Sequenced Machine Group Work Loading Module, which establishes a precise sequence or queue for jobs to be run on each DNC machine.
- Machine Tool Utilization (MT UTIL) -- a Machine Tool Operation and Utilization Module which accumulates and summarizes data on the operation and non-operation of each DNC machine.
- Operation History (OP HISTORY) -- Current Operation File and History Report Programs which serve to make a comparison of the "actual" versus "planned" performance for each operation by job on each DNC machine tool.

SYSTEM OPERATION

With reference to Figure 2, the block titled "Planning RIA" represents the logical starting point for the DNC/CAM System under consideration. Planning covers the traditional roles associated with order processing, resource procurement and allocation, determination of objectives, etc. Information flow from the planning function goes in two basic directions

- preparing/editing/proving/finalizing and storing the various part programs required, and
- scheduling and loading (sequencing) the operation of the machine tools.

The part programming/editing/proving/finalizing is typically an iterative procedure that can be performed either using only the hardware/software available on site at RIA or, in the case of more complex parts, by utilizing a remotely located CDC 6500 computer. In the latter case, the RIA PDP 11/20 computer serves as a remote terminal for the CDC 6500.

The component scheduler (JOB SCHED) permits pre-planning by assigning start and completion dates to each operation. Working from a start date or a projected completion date or both, this program accounts for engineered standard operations, process operations, inspection operations, move times, and efficiency against standards. This is a significant addition to the RIA DNC/CAM System because, prior to the implementation of this package, RIA had no scheduling capability -- a rough due date for each component was all that was known and no pre-planning on an operation level basis was possible.

Input to the Scheduler (JOB SCHED) consists of:

- Job data -- job/lot/part identification, lot quantity, start and/or due date, priority, etc.
- Data on each operation to be performed -- operation number, setup time, hours per piece, type of operation, machine group, cost center, etc.
- Certain parametric information on move times between departments, inspection times, etc.

The output from this program essentially indicates when each operation should start and end. As noted earlier, the use of this program is not restricted to DNC operations only -- it can and is being used for all operations associated with any job scheduled.

The Scheduler first processes the input in the background mode, producing hardcopy results for review. Interactive adjustments can then be made by the user via a CRT. He can attempt to re-schedule jobs with indicated conflicts and/or produce revised schedules for any selected jobs by changing rules pertaining to the distribution of slack (difference between the time available for a job and the time required, overlaps between successive operations, and work time available.

Schedule information relating to the DNC operations for each job processed is passed on to the Loader (MG LOADING). This module not only receives various data handled/processed/produced by the Scheduler, but also directly obtains from the user the availability status of the parts to be machined, the part program, and related tooling.

All input and output functions of the Loader are completely interactive in nature using a CRT.

When a DNC operation is available from the Scheduler, the Loader places it in an Unavailable Queue. As soon as the material, part program, and tooling are on hand, the operation is placed in the Available Queue and definite start and stop times are posted according to a priority algorithm incorporated in the software. When a particular operation is physically loaded into the appropriate DNC machine, the part program is called and supplied via the PDP 11-20 computer.

In summary, the outputs produced by MG LOADING provide answers to questions such as:

- What work is available to be run on a particular machine?
- What is the relative priority of this work?
- When will each of the available operations be completed?
- What future workload exists that has not yet reached the machine?
- When is this future workload expected to reach the machine?
- What is the projected workload by week for a (each) machine?
- What is the daily workload for a selected week on a (each) machine?
- What effect would 2 or 3 shift operations have on the workload picture?

This program was inserted in the system to provide answers that were not readily available before. In operating complex and expensive equipment, fast information feedback is necessary to allow effective corrective action when required, and to permit the system to function in a "quick response" mode.

The Machine Tool Utilization Program (MT UTIL) in the RIA DNC/CAM System fulfills both the role of an instantaneous monitor as well as a recorder/reporter of past DNC machine activity. Data input to this program is triggered by either sensor based devices or by means of 20 operator-activated switches mounted on a CRT adjacent to each DNC machine.

Using MT UTIL, the current status of each machine can be interrogated at any time by means of a CRT display. The different status modes covered include RUN, IDLE, CONV (Conversational), MAINT (Maintenance), and STOP. The STOP status is further defined by 22 possible reasons such as: NO OPERATOR, NO JOB, NO SETUP, NO TOOLING, PERSONAL, etc.

On request, MT UTIL can also provide a print-out of the utilization by status category and STOP reasons for each DNC machine for the previous day. An identical report summarizing machine activity for the previous month is also available on demand.

In summary, MT UTIL provides quick answers to questions such as:

- How much time does each DNC machine run on a daily and monthly basis?
- How much time is each DNC machine stopped and why?
- How much time is each DNC machine idle?
- How much time is spent in less significant categories such as CONV and MAINT?

The information generated by MT UTIL can give a more accurate picture of the actual availability of each machine under practical conditions. This by itself can help guide planning policies for better scheduling. Furthermore, when management can get a feel for the specific reasons why a machine is non-operational, more effective short and long term remedial measures can be taken.

Data from the Scheduler (JOB SCHED) and Loader (MG LOADING) modules and from the MT UTIL are captured by the Operation History Program (OP HISTORY); the total information is organized to make a historical comparison between the "planned" and "actual" performance on each operation.

Upon request, OP HISTORY will print out a report for any specified Operation number (uniquely identified by the Job number and Lot number) detailing items such as:

- Scheduled start and completion times (from JOB SCHED and MG LOADING) versus the actual recorded start and completion times (from MT UTIL).
- Planned versus recorded elapsed operation time together with the appropriate variance.

- Expected number of parts produced versus actual production.

Good records on planning versus actual performance are the most effective tools for improving cost estimates on repeat orders. This "adjustment" capability is specially useful in a job-shop environment and can be effectively used to make policy decisions that result in more realistic schedules.

CLOSED LOOP DESIGN

The RIA DNC/CAM System described in this section closely fits the CAM system definition described earlier.

It is apparent from the preceding paragraphs that the basic DNC System at a manufacturing facility is, by itself, a completely self-supporting manufacturing system. Even before the CAM augmentation, the PDP 11/20 computer served as an integral part of the operational scheme: it was used for the making activity (driving the machine tools) as well as for certain indirect planning elements such as parts programming. With the addition of the CAM software modules, primary planning functions are now covered by computer technology -- production scheduling and sequenced machine group work loading. Finally, and perhaps most important of all, the control activity (represented by MT UTIL and OP HISTORY) has been brought to a great extent under computer coverage.

The RIA DNC/CAM System comes very close to the idea of a "closed-loop" system discussed by Fox[6]. Work is planned -- part programs are finalized and schedules established and revised if necessary. Next, the actual operations are carried out. The system feedback loop is completed for control because the outputs from the MT UTIL and OP HISTORY are made available to the starting point -- the RIA planning function. As a result of reviewing the feedback information, the planning group can adjust scheduling, loading, resource allocation, maintenance plans, and other operational procedures and policies in order to achieve objectives such as:

- Make actual performance agree more closely with the planned performance.

- Improve/increase system productivity.

- Maintain machine utilization at a level commensurate with an acceptable rate of return on investment. This is particularly important when investment costs are high.

CONCLUSION

The control functions incorporated in the RIA DNC/CAM System are certainly not the ultimate solution to manufacturing problems. At present, manufacturing is too complex an activity for "total" answers. The number of variables involved is typically very large and it is next to impossible to exercise effective and simultaneous control over all of them. However, in any collection of variables, there are always some that are more readily identifiable, cost/effective, and more important than others. Some of these are amenable to control. This system is based upon that precise philosophy -- control what is important and can be controlled and only when it is cost/effective to do so.

REFERENCES

1. Wisnosky, D. E., Planning for Integrated Computer Aided Manufacturing, Society of Manufacturing Engineers, MS76-748, November, 1976.

2. Inaba, S., Direct Numerical Control System with Robot, Annals of the CIRP, Volume 23/2 1974.

3. Honda, F., Methodology for Unmanned Metal Working Factory, Bulletin of Mechanical Engineering Laboratory, Japan, 1974.

4. Putnam, G. P., Japan Plans the Automated Factory, N/C Commline, Volume 5, No. 2, 1976.

5. Putnam, G. P., Interview with W. S. Mann, N/C Commline, Volume 5, No. 3, 1976.

6. Fox, J., NC Processes Pay Off, Ordnance, July/August, 1972.

C-671

78. 11. 09