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CAM

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NCS Headquarters Office:
44 Nassau Street
Princeton, New Jersey 08
609-924-4780

EXECUTIVE DIRECTOR
William H. White

ADVERTISING COORDI
Judith Grisham

Editorial and Advertising
183 Loudon Road
Concord, New Hampshire
603-225-2631

EDITOR AND PUBLISHE
Mary A. De Vries

CONTRIBUTING EDITOR
James J. Childs
William M. Rynack

CHAPTER REPORTERS
Carl Natoni
Peter Budzilovich

ADVERTISING MANAGE
Virginia D. Scott

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NUMERICAL CONTROL IN INDIA

WILLIAM M. RYNACK
Contributing Editor

Education Editor Rynack reports on NSF-US-AID assignments in India.

PSG–COLLEGE OF TECHNOLOGY AND POLYTECHNIC

The January 1972 *NC Scene* carried the first report pertaining to this editor's NSF-US-AID assignments in India last year, but before detailing the two assignments concerned, the reader should keep in mind the following:

(1) India's recent indepence as a nation and her desire to prove and maintain this independence–philosophically, politically, and *industrially*.

(2) An extremely heterogeneous complexity of religion, ideologies, and languages (although fortunately English is the common language).

(3) An extremely high import duty (self-imposed) on all items–in particular, on machine tools, spare parts, and most industrial items, creating both purchasing and maintenance problems.

(4) A very *unfavorable* dollar exchange rate–even the *NC Scene* subscription rates and NCS dues are prohibitive.

(5) The inherent problem and the proximity to both China and Russia, and the unfortunate partitioning of what was West and East Pakistan (Bangladesh).

(6) A thirst for knowledge, which makes the engineering undergraduate an ideal student, and makes the teacher a dedicated and concerned individual who imparts this knowledge.

(7) Present relative scarcity of industrial positions and therefore low labor mobility, and a large, general labor market.

(8) The past ten years as a period of voluntary industrial aid and collaboration to India by most nations regardless of political and other ideologies–this has been a great stride toward industrialization but a complete neglect of standardization.

(9) Not new to industry–India recently celebrated its

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NC PANORAMA

CAD/CAM A COMPATIBILITY GAP?

JAMES J. CHILDS
Contributing Editor

Where we stand in bridging the CAD/CAM compatibility gap.

The terms CAD (Computer-Aided Design) and CAM (Computer-Aided Manufacturing) are becoming increasingly popular. And it would seem that CAD and CAM are practically inseparable–like bees and honey or beer and pretzels, with the only ostensible separation being a slash mark. It is pleasant to think that we may be on the threshold of a completely automatic design/manufacturing operation in which the purchase order goes in at one end and the engineered product comes out the other. Like it or not, however, this goal appears to be a long way off, although progress is accelerating.

CAD is nothing terribly novel. Computers have been used to assist the design engineer with calculations since computers were invented. If there is a growing distinction, it may be in the fact that the computer is being used increasingly as a *design tool* rather than as a calculator. There are any number of computer programs that accept design parameters and generate partial design solutions. There are far fewer programs that may be considered *automatic* in which the designed product is generated without interaction of the designer. And even in those cases where interaction is required, 10 devices such as CRTs and typewriter terminals are a reasonably convenient solution. The key restriction, however, is that the engineering computer programs are geared to peculiar types of designs, and there is no common denominator connecting them.[1] There are *special* programs for designing certain types of cams, special programs for types of parts in the automotive and aerospace industries; and the Navy, for example, has a series of programs for automating the design of ships. Nor are these programs inexpensive. The Navy's program, for one, has already cost several millions of dollars and still has a ways to go.

CAM may be considered to take up where CAD leaves off and is that function which assists in turning the engineering design into a working product. This involves the fabrication of the parts and the system, material handling and storage, planning and shop loading, and all forms of management reporting. Just as the designs of parts differ, so does the design of a manufacturing system and, as with CAD, there is also no common denominator. Every

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[1] The AED (Automated Engineering Design) system, developed at MIT under Air Force sponsorship, has been of help in this area.

THE STRUCTURE OF FUNCTIONS AND ITS APPLICATION TO

CAM PLANNING

By SHIZUO HORI

An international group of companies plans to establish Computer-Aided Manufacturing–International, Incorporated (CAM-I) this year. Its purpose: to improve manufacturing productivity through application of computers.

CAM-I derives from the former APT Long Range Program, but extends technical scope beyond the single product APT, to encompass the whole new technology of computer-aided manufacturing (CAM).

CAM-I intends to stimulate development of CAM subsystems software and other related goods and services, and to encourage achievement of compatibility among these many components. Successful pursuit of these objectives would not only accelerate advancement of computer-aided manufacturing, but would yield incalculable savings in time and costs for companies assembling these components to create their individual CAM systems.

CAM-I would conduct planning, standards, technology advancing studies, and other activities to specify common needs of member companies, and to formulate recommendations for standardization of key communication interfaces of CAM systems. It would place all outputs in the public domain to encourage responses from independent vendors in the development and implementation of components.

The uniqueness of operating CAM systems, stemming from the individuality of company organizations, requires that CAM-I's system designs focus on underlying functions, *as opposed to organizational operations, and on common patterns of functions, i.e., on the "logic of manufacturing."*

CAM-I planning, therefore, needs a common method of describing any *and* all *functions comprising manufacturing: functions of men, machines, computers, processes, etc. The method should permit function descriptions at any level, from macroscopic to microscopic; it should include a way of specifying interrelationships among all interrelated functions, including a mixture of levels; it should constitute a common framework for structuring data from diverse sources, including all cooperating companies as well as all relevant organizational units within a company; and finally, the method should be susceptible to computerization to handle the inevitable volume of data.*

A method meeting these requirements has been devised. It characterizes the structure of functions, and is represented by a "cell model"

The second law of thermodynamics states that closed systems change in time from a state of relative order to a state of relative disorder, i.e., from a relatively improbable state to a more probable state. The entropy of the system increases. Mathematically:

$S = k_1 \ln p.$

where S is entrophy,

k_1 is a constant,

ln is the natural logarithm,

p is the probability of state.

In contrast, man brings order out of disorder. To do this, he uses information. Mathematically:

$I = -k_2 \ln p,$[1]

where I is information,

k_2 is a constant,

ln is the natural logarithm,

p is the probability of symbols.

Man's action increases *negative* entropy. The identity of the mathematical expressions for information and negative entropy represents a corresponding interrelationship between information and energy in physical actions.

Conceptually, a given natural state could have originated from any one of a set of different less probable states. A human-directed activity can be considered as one in which a specific less probable state is selected out of the set, and appropriate action taken to bring it about. Maxwell's Demon exemplifies the process.

An insulated box is filled with gas, and allowed to attain the most probable state, i.e., uniform temperature throughout. A partition, containing a trap door, divides the box into two compartments. Maxwell's Demon,

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[1] Special case of equal probabilities.

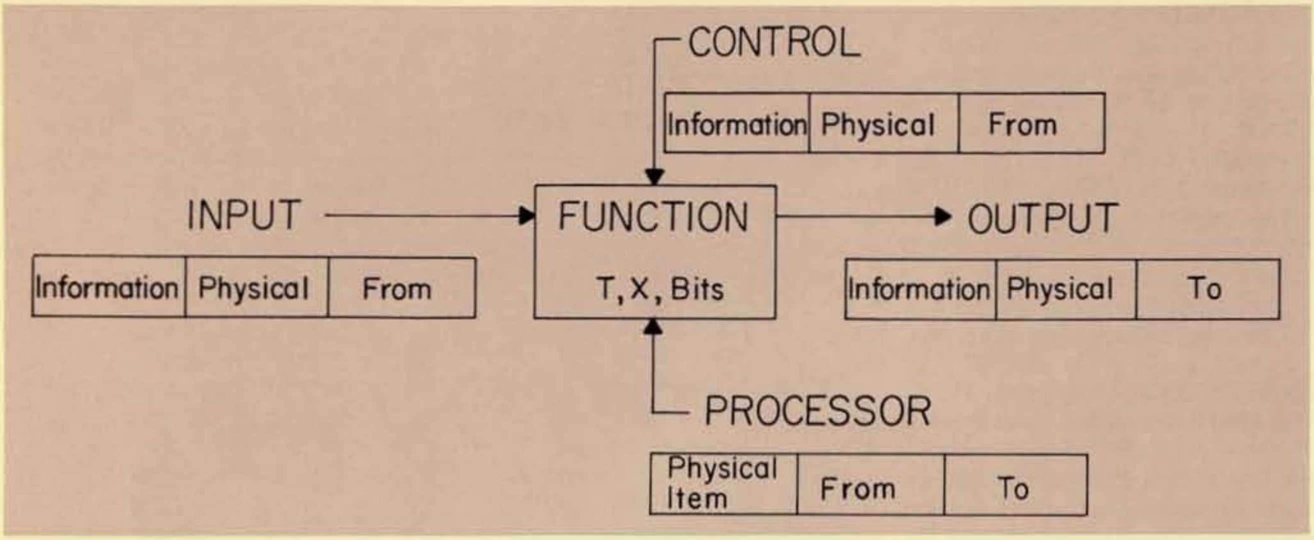


Figure 1. Cell Model

placed inside, observes the positions and velocities of molecules. By appropriately operating the trap door he allows high velocity molecules to collect in the right compartment and low velocity molecules in the left, thus increasing the temperature on the right and decreasing it on the left. This, of course, violates the second law of thermodynamics; the process as described is impossible.

Man emulates the Demon, but introduces external energy and information to avoid violation of the second law. Imagine a machine which captures molecules, measures their velocities, and reimparts the measured velocities to the molecules as they are released into the appropriate compartments. The machine requires external energy to operate it and information to control it; the controlling information manifests itself in a different form in the final result, namely, the distribution of molecules.

Generalization from this example leads to a model of any function, i.e., any human-directed activity.

Cell Model

The cell model representation of the structure of function consists of five elements, all structurally interrelated (figure 1).

The FUNCTION box represents an unspeakable physical process in which information "channels" energy and the "channeled" energy produces information. It consumes time, occurs in space, and yields increased negative entropy.

Channeling of energy requires a physical entity (man, machine, computer, etc.), which is here called PROCESSOR. CONTROL information controls the PROCESSOR in the channeling process.

The channeled energy acts on an item of the INPUT to produce an item of the OUTPUT. The INPUT represents a "universe of possibles"; the OUTPUT represents the result of a specific selection from the "universe of possibles." The CONTROL represents the symbolic equivalent of the OUTPUT.

The CONTROL, INPUT, and OUTPUT elements each have both informational and physical components. For a given element in a given situation the informational component may be of primary interest; but information must always be represented in some physical form.

Alternatively, where the physical component may be of primary interest, only certain (information) aspects of the physical item are relevant to the given situation.

Finally, items of CONTROL, INPUT, and PROCESSOR must come FROM someplace, and items of OUTPUT and PROCESSOR must go TO someplace. The FROMs and the TOs provide the connectivities among cells representing interrelated functions. Thus, a task consisting of many functions could be represented by a cell network.

Cell Network Boundary

Since the cell model can be used to represent any and all functions, there is no need for any other type of cell. But the FROMs and TOs of any cell imply the existence of other cells. Therefore, a natural boundary does not exist for any cell network. This is not inconsistent with reality, as ecologists will testify.

In practice, cell networks are arbitrarily terminated for convenience. Thus, a cell network representation of the functions of a factory could be terminated "horizontally" at the factory gate and "vertically" at the chairman of the board.

Such terminations serve as a first step in the structuring of a cell network.

Semantic Structure

The relationship between symbols and things provides another basis for structuring cell networks. A set of symbols conveys meaning only insofar as a mental connection can be made between it and some aspect of physical reality (figure 2). The meaning lies in physical reality, not in the symbols.

To produce physical *action* requires the intermediary of signals. In a management context, the alternate terms of *planning, control,* and *operations* may be more familiar.

This characteristically human method of operating provides a natural structure for cell networks.

ILLUSTRATIVE EXAMPLES

The OUTPUT of a machining func-

continued next page

tion is a part; the informational aspect of interest is its dimensions. The INPUT is material, representing all possible parts which could be machined from it. The CONTROL information consists of NC Controller commands, which take the physical form of a punched tape.

The output from machining may go to assembly directly or via inspection. The part would go to the INPUT of assembly, but to the CONTROL of inspection. Although the part is physically the same in both situations, the informational aspects of interest are different: the position and orientation of the part relative to other parts for assembly; the dimensions for inspection.

Figure 3 details the inspection process into three functions for the simple case of a bar whose length is specified as 10 ± 0.1 inch.

For the measuring function, a set of standard measuring rods comprise the "universe of possibles." Successive placement of the bar between pairs of standard rods enables selection of one rod whose length comes closest to that of the bar.

The length of the selected rod controls the evaluation function. The

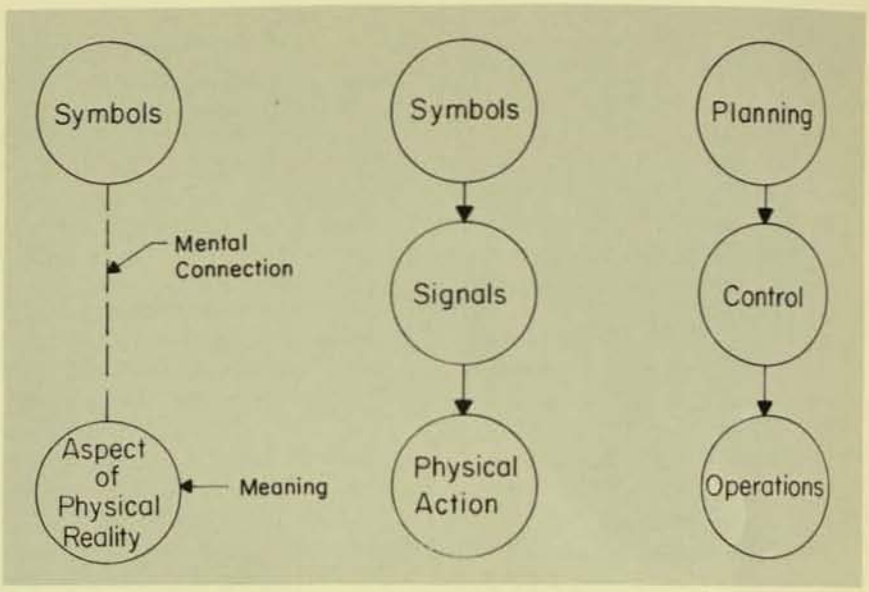
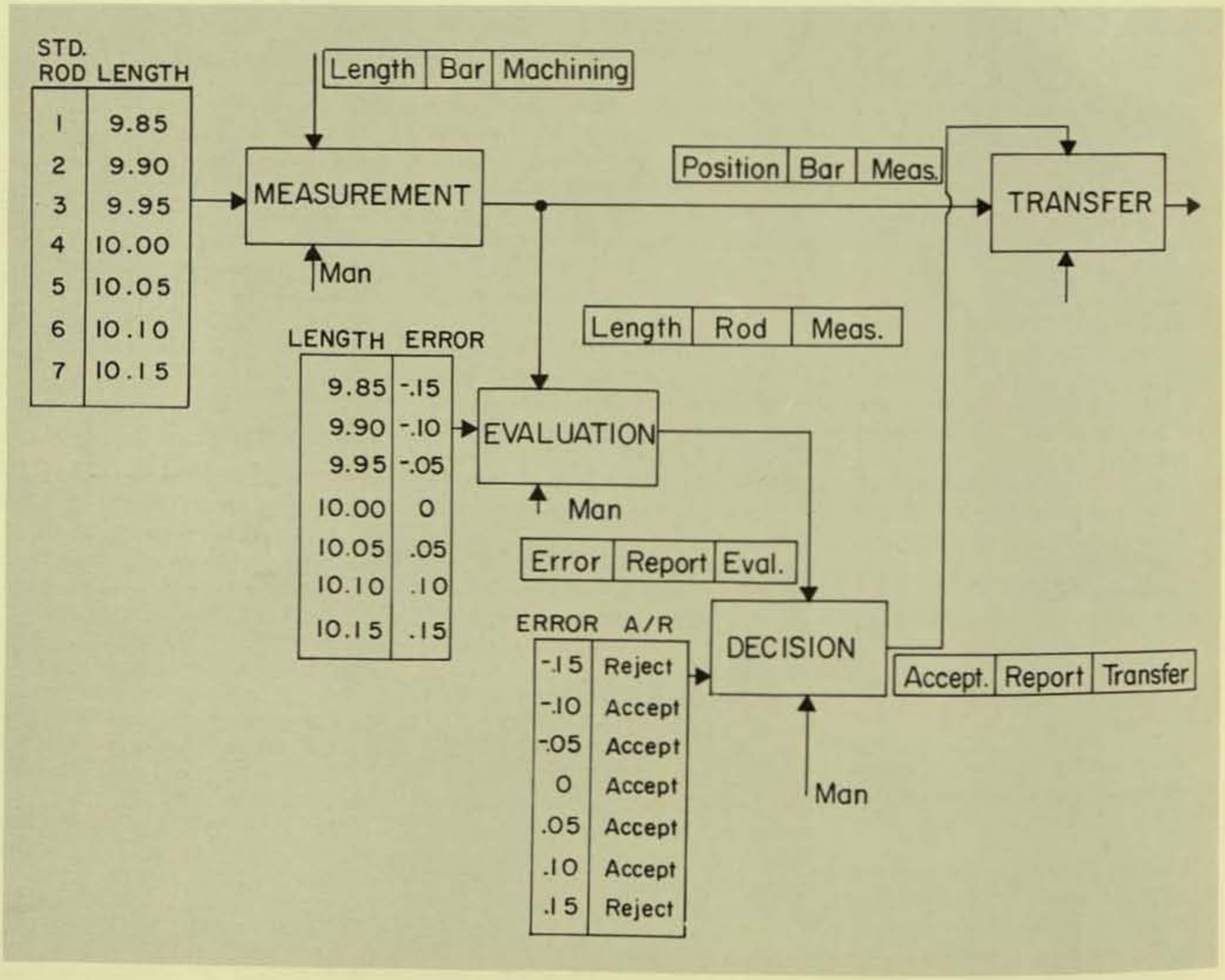


Figure 2. Semantic Structure



STD.	ROD LENGTH
1	9.85
2	9.90
3	9.95
4	10.00
5	10.05
6	10.10
7	10.15

LENGTH	ERROR
9.85	-.15
9.90	-.10
9.95	-.05
10.00	0
10.05	.05
10.10	.10
10.15	.15

ERROR	A/R
-.15	Reject
-.10	Accept
-.05	Accept
0	Accept
.05	Accept
.10	Accept
.15	Reject

Figure 3. Inspection

table of information shown at the INPUT of evaluation specifies the "universe of possibles." The left column is scanned until a match with the CONTROL information is found, and the corresponding data in the right column is recorded in a report. A similar procedure for the decision function yields an acceptance or rejection report. Assuming acceptance, this information becomes the control for transfer of the bar to assembly.

Figure 4 illustrates development of a cell network for manufacturing. Semantic structure elements of Operations, Control, and Planning provide a network framework. "Interfaces" provides space for specifying relevant termination points.

For simplicity, the example limits the Operations level function of interest to machining. However, three additional Operations level functions are introduced to clarify the FROMs and TOs of machining.

Machining CONTROL requires:

(a) part definition,
(b) operations required,
(c) sequence of operations required,
(d) work order.

The first three comprise technical information, and the fourth timing information. The other three functions require precisely the same categories of CONTROL information.

This knowledge identifies two Control level functions: "Generate and Store Technical Signals" and "Initiate Control". These two are related by a third, "Transfer and Apply Signal," which transfers the appropriate technical signal to the appropriate Operations level function at the time specified by the OUTPUT of "Initiate Control," resulting in the proper sequencing of the four Operations level functions.

Planning level functions control preparation of the Control level signals. Operations Planning determines the technical signals; Production Planning and Scheduling determine the timing signals. Further upstream, technical information comes from Engineering, and delivery dates for products from Sales.

This example, though grossly simplified, illustrates the systematic approach which can be used in describing manufacturing, and therefore in laying out ideas for computer-aided manufacturing.

CONCLUSIONS

The cell model concept needs further development; and computerization would greatly increase its utility. But even in its present form it provides a useful tool for planning. The author has introduced it to four manufacturing firms; their successful application confirms its practicality.□

Author Shiz Hori first presented this paper on April 18, 1972 at the NCS Ninth Annual Meeting and Technical Conference.

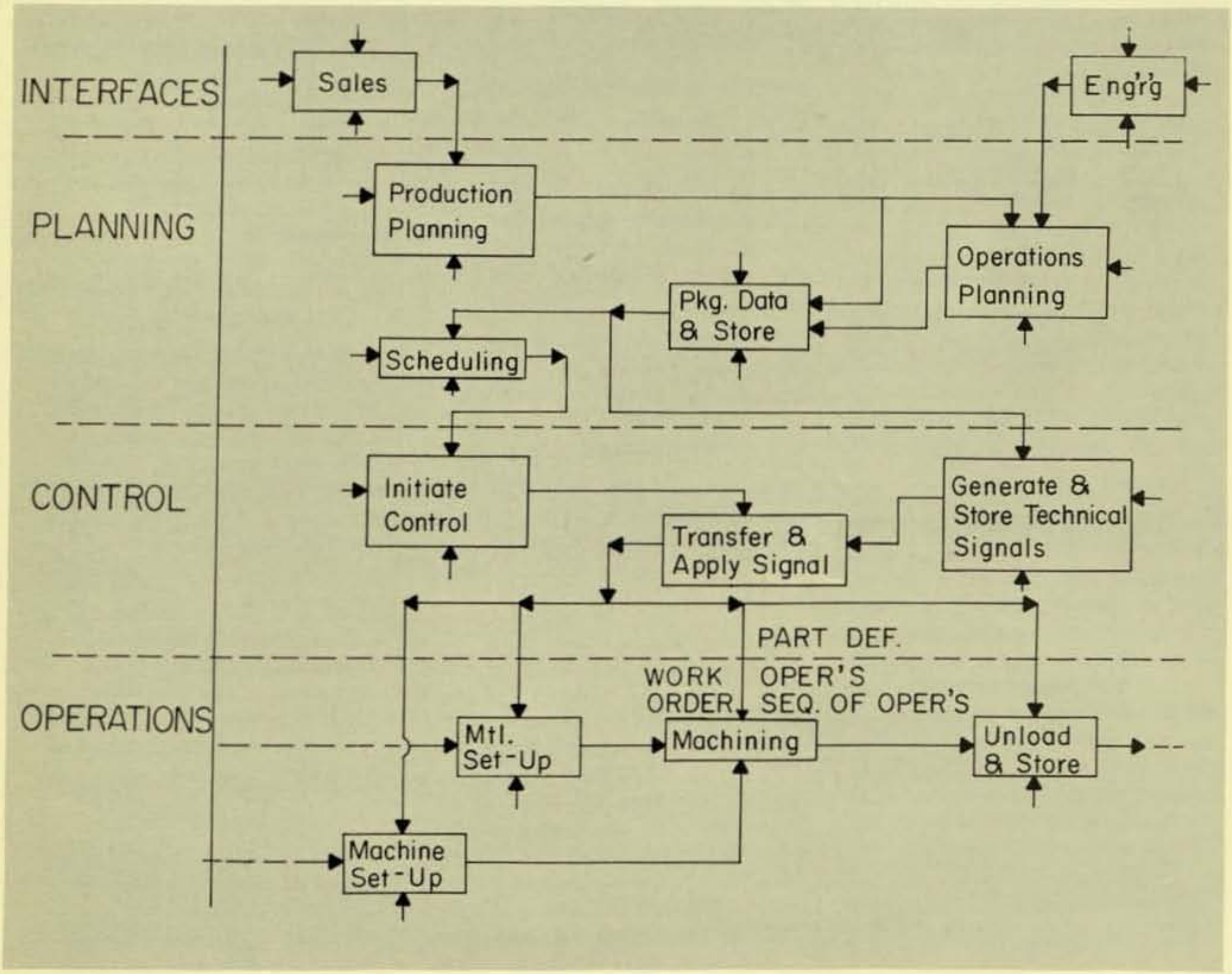


Figure 4. Manufacturing

NC SHIPMENTS FOURTH QUARTER 1971

from Series: MQ-35W(71)-4, Current Industrial Reports, Metalworking Machinery, U. S. Department of Commerce

During the fourth quarter of 1971, the value of factory shipments of numerically-controlled metalworking machine tools totaled $39.9 million, an increase of 20 per cent from the $33.3 million shipped during the third quarter 1971. Numerically-controlled machine tools accounted for 14 per cent of the total value of industrial type metalworking machine tool shipments during the fourth quarter 1971 and 14 per cent of the value of products shipped in the third quarter 1971.

A large percentage of the value of all numerically-controlled machine tool shipments during the fourth quarter 1971 were for cutting-type machine tools, predominantly represented by machining centers, 33 per cent; lathes, 28 per cent; milling machines, 11 per cent; boring machines, 12 per cent. The corresponding percentages for the preceding quarter were: machining centers, 43 per cent; lathes, 29 per cent; milling machines, 5 per cent; and boring machines, 10 per cent.

TABLE 2.--TOTAL SHIPMENTS AND UNFILLED ORDERS
OF NUMERICALLY CONTROLLED AND AUTOMATIC MECHANICAL METALWORKING MACHINERY
BY TYPE OF CONTROL AND TYPE OF MACHINE

SIC CODE	ITEM	QUANTITY SHIPPED - NUMBER MACHINES	PRODUCT SHIPMENTS MACHINES AND CONTROLS THOUSAND DOLLARS	PRODUCT SHIPMENTS CONTROLS ONLY THOUSAND DOLLARS	UNFILLED ORDERS END OF QUARTER NUMBER MACHINES	VALUE OF UNFILLED ORDERS MACHINES CONTROLS THOUSAND DOLLARS	VALUE OF UNFILLED ORDERS CONTROLS ONLY THOUSAND DOLLARS
		FOURTH QUARTER 1971					
	METALWORKING MACHINERY, TOTAL.	342	39 919	9 072	579	107 680	23 310
	BY TYPE OF NUMERICAL CONTROL:						
	POINT-TO-POINT POSITIONING.	108	10 921	2 161	150	30 732	6 332
	CONTINUOUS PATH ACTIVATED BY TAPE OR PUNCH CARD	223	28 125	6 735	419	76 176	16 807
	DIAL OR PLUGBOARD TYPE OF PRERECORDED MOTION PROGRAM CONTROL	11	873	176	10	772	171
	BY TYPE OF MACHINES:						
3541100	BORING MACHINES	24	4 899	1 142	74	23 729	4 981
3541200	DRILLING MACHINES	37	2 782	513	37	3 204	588
3541500	LATHES.	111	11 266	3 298	245	37 530	9 916
3541600	MILLING MACHINES.	32	4 450	932	27	8 787	1 221
35418PT	MACHINING CENTERS	105	13 303	2 756	171	30 684	6 123
354****	ALL OTHER METAL CUTTING AND METAL FORMING	33	3 219	431	25	3 746	481
		THIRD QUARTER 1971					
	METALWORKING MACHINERY, TOTAL.	270	33 359	7 648	593	110 694	23 412
	BY TYPE OF NUMERICAL CONTROL:						
	POINT-TO-POINT POSITIONING.	108	10 160	2 281	139	27 076	5 431
	CONTINUOUS PATH ACTIVATED BY TAPE OR PUNCH CARD	148	22 009	5 103	442	82 645	17 802
	DIAL OR PLUGBOARD TYPE OF PRERECORDED MOTION PROGRAM CONTROL	14	1 190	264	12	973	179
	BY TYPE OF MACHINES:						
3541100	BORING MACHINES	16	3 297	950	71	19 752	4 255
3541200	DRILLING MACHINES	24	2 069	373	34	4 213	779
3541500	LATHES.	87	9 558	2 903	253	38 873	10 175
3541600	MILLING MACHINES.	25	1 538	250	33	10 467	1 499
35418PT	MACHINING CENTERS	89	14 489	2 778	176	32 934	6 243
354****	ALL OTHER METAL CUTTING AND METAL FORMING	29	2 408	394	26	4 455	461
		FOURTH QUARTER 1970					
	METALWORKING MACHINERY, TOTAL.	374	43 776	11 054	683	121 778	26 296
	BY TYPE OF NUMERICAL CONTROL:						
	POINT-TO-POINT POSITIONING.	165	14 891	3 467	222	38 274	7 684
	CONTINUOUS PATH ACTIVATED BY TAPE OR PUNCH CARD	194	27 389	7 370	423	78 376	17 872
	DIAL OR PLUGBOARD TYPE OF PRERECORDED MOTION PROGRAM CONTROL	15	1 496	217	38	5 128	740
	BY TYPE OF MACHINES:						
3541100	BORING MACHINES	34	4 709	1 093	74	15 621	3 529
3541200	DRILLING MACHINES	39	3 417	628	48	5 849	1 019
3541500	LATHES.	136	15 539	5 253	273	37 370	10 910
3541600	MILLING MACHINES.	21	3 414	485	38	12 957	2 041
35418PT	MACHINING CENTERS	94	10 777	2 589	169	29 947	6 417
354****	ALL OTHER METAL CUTTING AND METAL FORMING	50	5 920	1 006	81	20 034	2 380

* REPRESENTS A COMBINATION OF CODES.

INCREASING PRODUCTIVITY THROUGH

AUTOMATED INSPECTION

By Peter Budzilovich

From a New York Metropolitan Chapter meeting, presentation by Frank Schings, quality control manager, Monarch Die Corporation.

Automated inspection can play a key role in increasing the over-all productivity of an NC or non-NC shop. While in many plants inspection is considered as an overhead expense, in actuality it should be accepted as a part of the manufacturing process. Indeed, a part or an assembly is not really finished until it passes inspection.

The most valuable tool that made automated inspection a reality is the modern coordinate measuring machine (CMM), which permits very accurate (and repeatable) measurements in all three axes. These are among the CMM's advantages over manual inspection:

(1) Speed–time savings of ten to one are not uncommon.

(2) Simplicity–a modern CMM having a data print-out and electronic display permits an *unskilled* operator to do a highly competent inspection job. All that the operator is required to do is to place the probe at the specified part points.

(3) Versatility–a CMM is a device capable of displaying and/or printing out three-dimensional coordinates within its measuring envelope in digital form. This means that:

  (a) It can inspect parts or assemblies.

  (b) It can produce detailed measurements of a part with unknown dimensions in terms of x, y, z coordinates that can be converted into an NC tape.

  (c) It can be used as a fast and *very accurate* layout tool. That is, it can scribe and/or centerpunch by putting a corresponding tool in its probe holder.

  (d) It can produce data for an NC tape for drilling printed circuit boards directly from the artwork.

The print-out capability of a CMM is important for at least two major reasons:

(1) It saves time for the operator and it also *eliminates* errors, both in taking the data and in the subsequent data transcribing.

(2) On many precision jobs, especially for the government, the automatic CMM print-out is accepted as the official QC (quality control) record.

In selecting a CMM for your needs, there are quite a few points to watch for. The major ones, however, are these:

(1) accuracy

(2) repeatability

(3) capacity

(4) construction

In the case of accuracy, pay very close attention to how the manufacturer specifies accuracy. From a user's point of view, the accuracy figure (say, ±0.0003") should be valid throughout the useful measuring volume of the CMM (say, 20 x 14 x 12 inches). Furthermore, an accuracy figure should be for the over-all CMM system, i. e., for the machine itself, plus its position sensors, plus its electronic display and/or its data print-out.

Many manufacturers, however, specify accuracy in a variety of ways. Some, for instance, specify accuracy *per foot of probe travel.* This means that your operator will have to do a bit of figuring trying to calculate what his accuracy will be. Another way (just as bad) is to specify the CMM accuracy for a small portion of the over-all measuring volume. This, of course, is also unsatisfactory–what if none of your parts has datum point within that space?

An example of a good (from a user's point of view) specification is the data listed for a family of CMMs built by Shelton Metrology Laboratory, Inc., Paducah, Kentucky, and called CHEK-MATE Series 400. The smallest Series 400 CMM is 20 x 14 x 12 inches (x, y, and z axes, respectively), while the largest has the measuring capacity of 56 x 38 x 12 inches (x, y, z). Accuracy for each type (ranging from ±0.0003" to ±0.0005") is given for the *over-all measuring* CMM volume. In other words, the specified accuracy figures are the *worst case* numbers, for the data as it gets displayed on the three-axis electronic readout.

A final point about accuracy is this: accuracy is expensive. Buy only what you *actually need*; don't overspecify. Here it is good to keep in mind that the so-called "rule of ten" does not have to be adhered to blindly. For instance, using the "rule of ten" to check parts to ±0.001" tolerances you would need a CMM with accuracies of ±0.0001"! Experience shows that a

continued next page

AUTOMATED INSPECTION *continued from page 7*

well-built CMM can be used with confidence applying a rule of 2, i.e., in the above example a CMM with ±0.0005" is completely adequate.

CMM capacity must be selected on the basis of the present and *possible future* need (CMM capacity means the CMM measuring volume in terms of x, y, and z travel). If a certain CMM can handle 80 to 90 per cent of your shop's output, that's the one to buy. Here it is well to keep in mind that there are certain tricks that can greatly extend a given CMM capacity. For instance, parts longer than the CMM travel along the corresponding axis can be checked by checking one end of the part, then sliding the part within the CMM reach, then positioning it in accordance with the previous measurements and continuing the inspection. A CMM feature that helps here is the ability to preset a given number into the CMM display, so that dimensions on the second part will be displayed as they actually are given on the print.

CMM construction, in a word, must be such that it will provide *long-term* accuracy. That is, it must be sturdily built, capable of effortless motion in all three axes, have hardened probes.

In justifying a CMM purchase, inspection time saving is among the prime considerations. As a rule of thumb, one CMM and one inspector are about equivalent (in capability) to a five-man inspection team. Add to this associated overhead costs, extra space, various measuring equipment to accomodate the manual inspection, nonuniform inspection quality, record-keeping headaches, etc.

As a typical example, there was one job that paid for a $12,000 CMM. The job called for stamping over a million precision parts (four types) using presses capable of turning out about 1,000 parts per hour. While many people think that stamped parts are inspected only once, to prove the die, in actuality in precision stamping the job *must* be monitored continuously for die breakage, die wear, die shifting, etc. Manually, it would take over an hour to inspect each part, meaning that if something went wrong the press would turn out 1,000 rejects before the error would be caught. With a CMM, about eight minutes were required to do the complete inspection.

In the case of NC, the most obvious CMM saving is in the first-piece inspection, because the prevailing practice is to hold the NC machine idle while checking out the first part. Depending on the NC machine tool and the part complexity, the CMM can save from $50 to $1,000 per first-piece inspection.□

CLASSIFIED ADVERTISING

RATES: Rate for classified announcements in the *NC SCENE* is $1.00 per word per insertion. Cash must accompany order. Minimum, 10 words; maximum, 25 words. Box number $3 extra. Prices net, no discount or agency commission.

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ORDERS: Send orders with payment to Advertising Manager, *NC SCENE*, 183 Loudon Road, Concord, N. H. 03301.

REPLIES: Address replies to ads with box numbers to Box____, NCS, 44 Nassau Street, Princeton, N. J. 08540.

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NC BULLETINS

BIAS TO FEATURE AUTOMATED FACTORY

The International Biennal of Automation and Instrumentation (BIAS) will hold its twelfth international exhibition from November 22 to 28, 1972, in Milan. "The automated integrated factory in corporate development—theoretical, technological, and informational aspects" will be the conference theme.

Details are available from FAST, Piazzale Morandi 2, 20121 Milano, Italy.

CAD/CAM SYSTEM FOR SHOE, APPAREL INDUSTRIES

USM Corporation has introduced a CAD/CAM system for the shoe and apparel manufacturing industries. Its prime purpose is to reduce the lead-time required to tool high-fashion shoes and garments from many weeks to only a few hours.

The basic problem is pattern grading—redrawing the style pattern for each part in all the different sizes to be manufactured. For example, to grade one typical shoe style, one must prepare an average of 6 pieces per shoe, and 60 combinations of width and length, giving a staggering total of 360 pieces to be tooled before the style can go into production. By traditional methods this takes several weeks. The new USM system takes less than two work days.

While computerized pattern grading has been used for a few years, especially in the garment industry, it is usually on a batched, job-shop basis. No upstream automation of data collection, nor downstream generation of actual tooling has been available. The new USM Information Generator System (IGS) does all these jobs.

The system consists of three key elements: a digitizing table, a computer control system, and a specially designed NC nibbling press. In application, key design points are entered on the digitizer table; the interpolation and grading functions are then performed and stored in the computer. Finally, each size pattern is generated on the NC nibbling punch press, in fiber board or metal, to form the basis for tooling for the part.

The control system, built by Icon Corporation (subsidiary of USM), contains a minicomputer (Sp-65 or DEC PDP-11) with 8 K of memory. In one mode, input signals corresponding to design grade points are accepted. In a second mode, the parts are graded according to data supplied in table and functional form. In the third mode, pulses are sent to stepping motors (USM Responsyn type) connected to ball lead screws, producing the coordinated X-Y movements of the nibbling machine. Operator control is maintained via an alphanumeric keyboard (Teletype ASR-33).

A secondary but potentially very significant role for the IGS system is collection and preparation of data for downstream automation of subsequent operations, such as NC stitching. This is accomplished via a digital tape cassette unit, available on the system. Thus, the IGS system will provide a data base for the factory as it gradually becomes more fully automated. This is of immediate significance, as numerically-controlled sewing systems have already been introduced in both the garment and shoe industries.

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NC EDUCATION

continued from page 1

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The next issue of the *NC Scene* will detail and show pictures of this and other equipment, and P.S.G.☐

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NC PANORAMA

continued from page 1

manufacturing facility has its own unique operating characteristics and CAM systems must be designed to satisfy the peculiar requirements. DNC is expected to help this cause considerably–however, not without a good deal of software effort.

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NC LEXICON

NC GUIDE (Numerical Control Handbook), by R. Shah, 1971, 240 pp., $15.00, trilingual text (English, German, and French) with over 50 pp. of tables and 300 illustrations. Written for the production engineer and plant manager, as well as for machine tool and control equipment specialists, this self-contained reference book provides concise information on all production aspects of numerical control, including planning, selection criteria, economics, programming and operation. The directory section contains 44 pages of tables listing detailed specifications on nearly 1000 machine tool and control system models produced by 300 manufacturers in Europe (including Czechoslovakia, East Germany and Hungary), Japan, and the United States. Part 1 of the book treats in detail selection criteria, manual programming, automatic programming in general, and the APT and EXAPT programming systems in particular.

NC LEXICON, by Y. H. Attiyate, 1971, pocket-size, 526 pp., flexible plastic cover, $12.00, dictionary and explanations in English, German, and French; over 100 diagrams and tables. This handy trilingual book has detailed, illustrated explanations of the majority of NC terms, including those used in programming and computer techniques, with roughly 2500 terms and nearly 400 explanations.

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