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Interactive Cutting Path Analysis Programs

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PREFACE

The work described in this report was performed by the Space Sciences Division of the Jet Propulsion Laboratory.

CONTENTS

ABSTRACT

The operation of numerically controlled machine tools is interactively simulated. Four programs were developed to graphically display the cutting paths for a Monarch lathe, Cintimatic mill, Strippit sheet metal punch, and the wiring path for a Standard wire wrap machine. These programs are run on an IMLAC PDS-1D graphic display system under the DOS-III disk operating system. The cutting path analysis programs accept input via both paper tape and disk file.

I. INTRODUCTION

A. PROBLEM DESCRIPTION

Numerically controlled (N/C) machine tool tapes (8-level paper tape) must be monitored for accuracy throughout their development. Errors may result from improper part specification, data transmission, tape preparation, or tape duplication. These errors can ruin several hours of machining as well as waste materials. The use of numeric listings to check machine tapes is a very time consuming and tedious task, and as a result often fails both in identifying all erroneous characters and in permitting an error-free tape to be produced. A faster and more accurate checking technique utilizing lower cost methods is needed.

B. SOLUTION

A graphic display of machine actions is interactively generated from the commands on the input tape and user instructions via the keyboard. The following simulation programs were developed:

(1) Lathe - For the Superior Electric Slo-Syn model NCCR 25 series control applied to a Monarch lathe (Ref. 5).

(2) Mill - For the Acramatic 5 control applied to a Cintimatic horizontal milling machine (Ref. 1).

(3) Punch - For the Superior Electric Slo-Syn Model ENC control applied to a Strippit sheet metal punch (Ref. 6).

(4) WWM - For the Standard Logic models 300 and 600 wire wrap machines (Ref. 4).

These cutting path analysis programs display the center line of each tool pass on the CRT. Normally all tool passes between each tool or depth change are simulated. Operator messages supplying information on the tool, cam, and simulation states (including error conditions) are also provided. Through use of the keyboard, the user maintains control over the rate of the machine simulation by instructing the program to step through the N/C tape from cut to cut, or from depth/tool change to depth/tool change. By alternating between the continuous run and stepping display modes, errors are quickly isolated. (A correcting and editing method for N/C tapes is described in Ref. 7.)

The user is able to control the amount of graphics being displayed by having the option of deleting the entire screen contents whenever specific machine commands are encountered. The simulation programs also generate a numerical display at the top of the CRT informing the user of the current tool pass number, position, and control data for each pass. Tolerance checks may require a more conventional method than simple visual examination as the cutting area of each tool is not displayed. Input data and commands are checked for proper format and syntax. All violations are displayed on the screen with appropriate error messages. Continuation after an error has been detected is usually not permitted. The cutting path analysis programs accept both ASCII and EIA coded input data.

C. LANGUAGE AND PROCESSOR

The programs are written in assembly language for the IMLAC PDS-1D graphic display system (Ref. 2). They are run under IMLAC DOS-III (IMLAC's disk operating system) (Ref. 3). The programs could be run on a properly configured IMLAC PDS-1G; some program modifications would be required for implementation on an IMLAC PDS-4. Additional changes would be needed to allow the simulation programs to be run without the DOS-III (loaded via paper tape or cassette).

The minimum processor configuration includes an IMLAC PDS-1D graphic display system with 8192 words of core memory along with the following options:

(1) Photoelectric paper tape reader.

(2) Paper tape reader interface.

(3) Long vector generation hardware.

(4) Eight-level display subroutine hardware.

(5) Fast X-Y vector generator.

These options are specified for the cutting path analysis programs where input via paper tape is to be simulated. Circle interpolation is accomplished through software. Other options are needed for system maintenance, program modification, and program debugging.

D. OPERATING PROCEDURE

The four simulation programs have been designed to accept input from resident (ASCII) IMLAC disk files in addition to the paper tape reader. As a result the user must specify upon program start-up from which device the cutting path analysis program will access data.

The following procedures apply to all four cutting path analysis programs. Special characteristics of each program are deliniated later.

1. Load Program

This procedure is input-medium/system dependent. Loading instructions pertaining to paper tape, cassette, or disk input may be found in the IMLAC DOS manual (Ref. 3) or the IMLAC "Loading the PDS" writeup. Under the IMLAC DOS III system, the user must log in to the monitor and then select the program (MILL, LATHE, PUNCH, or WWM) to be executed. For data input via paper tape, enter the name of the program and strike carriage return (CR). For input via an IMLAC disk file, enter the name of the program followed by a slash (/), the name of the disk file, and a carriage return (CR).

2. Work Area Specification

The user is prompted for a working domain in terms of X and Y coordinate values. Default travel ranges are displayed. An example for the "MILL" program is shown in Fig. 1. These machining ranges are specified in the same units as used on the N/C tape. The format for "MILL" is +nnnnnn with an implied decimal point after the second digit (+nn.nnnn). Specific formats vary with the individual programs and are included in later discussion. After this data is entered, the input tape can be processed. Commands on the tape which generate tool travel outside this user specified work area produce incorrect displays. Cursor control functions for the specification of the work area are as follows:

+, -, 0 to 9	Numeric data entry
"Space Bar"	Move cursor one space right (skip)
"Right Arrow"	Move cursor to next field

"Left Arrow"   Move cursor one space left (backspace)

"Carriage Return"   Exit work area specification

3.   Mount N/C Tape in Reader (For Data Input Via Paper Tape Only)

This procedure is dependent upon the paper tape reader model used. For the Digitronics reader, the following steps are taken:

(1)   Turn the reader power switch to "ON"

(2)   Open the reader gate (turn gate handle clockwise)

(3)   Insert the paper tape to the back guide

(4)   Position the tape so that blank leader lies on the read head

(5)   Close the reader gate (turn gate handle counterclockwise) insuring that the tape is in proper position so that the gate will not produce a tear

The blank leader will be skipped over by the program. An incorrectly positioned tape (not aligned with feed holes or first character on the read head) generates a read error which halts execution of the simulation.

4.   Initial Processing

Strike any key to continue. When using paper tape input, the user is requested to indicate the code of the input tape. Strike the "Y" key for an EIA tape, any other key for an ASCII tape. The simulation program will start reading the input tape. The beginning conditions and environment implemented by each program, as well as the meanings of the symbols displayed, are discussed in the sections dealing with each individual cutting path analysis program.

5.   Program Execution

The program begins simulation in a continuous mode. The "TAB" key permits the user to step through each cut. The "FORM" key switches back to continuous mode. The mode can be switched at any time. Initial simulation is shown in Fig. 2.

6. Restart

The simulation can be restarted, and the work area can be respecified if necessary at any time by striking "R". If paper tape is being used for input, it must be repositioned to the beginning of the job.

7. Exit

The simulation can be terminated at any time by striking "Q".

8. Halts

The simulation programs stop reading the input tape when errors are detected or programmed halts occur on the tape. (Halt for cam change is shown in Fig. 3 and at end of program in Fig. 4). After a programmed halt, strike "TAB" or "FORM" to continue in a stepping or continuous mode. After an error, strike "Q" or "R" to return to the monitor or to restart the simulation. Error messages are displayed for the user. Specific error conditions are discussed for each program.

II. LATHE SIMULATION PROGRAM

This cutting path program simulates the operation of the Monarch (continuous path contouring) lathe. By means of paper tape or disk input, "LATHE" interprets commands for the Superior Electric Slo-Syn model NCCR 25 series control and represents the center line of each tool pass on the display screen. The lathe machine operates in a tab sequential manner, where cutting positions are defined by relative rather than absolute tool movements. The Slo-Syn control uses numeric codes as opposed to alpha-numeric codes (as used by the other three simulation programs) to represent the machining commands.

A. OPERATING PROCEDURE

The operating procedure for "LATHE" is as follows:

(1) Start the program by typing "LATHE" and striking carriage return (CR) for paper tape input, or by typing "Lathe/⟨File Name⟩" and striking carriage return (CR) where ⟨File Name⟩ is the name of an IMLAC disk dataset for disk file input.

(2) Specify work area as previously described. The format for the travel ranges is +nnnnnnn with an implied decimal point after the third digit (+nnn.nnnn).

(3) Specify EIA or ASCII coded input as requested (for paper tape input only).

(4) Mount N/C tape in paper tape reader as requested (for paper tape input only).

(5) Strike "TAB" or "FORM" to begin simulation.

B. PROGRAM EXECUTION

The program starts with a "+" displayed at the origin. The "TAB" and "FORM" keys place the simulation in step by step and continuous modes respectively, as previously described. The program stops reading the N/C input tape when:

(1) Tool change (06) is specified by input
   - Strike "Q" to exit to monitor
   - Strike "R" to restart simulation
   - Strike "TAB" or "FORM" to continue

(2) End of program (02) is specified by input
   - Strike "Q" to exit to monitor
   - Strike "R" to restart simulation

(3) Errors are detected
   Parity - Input tape probably is not aligned in paper tape reader, or wrong code (EIA or ASCII) was specified by user
   - Strike "Q" to exit to monitor
   - Strike "R" to restart simulation
   - Strike "TAB" or "FORM" to continue
   Arc Quadrant Error - Desired curve cannot be drawn due to computation overflow
   - Strike "Q" to exit to monitor
   - Strike "R" to restart simulation
   - Strike "TAB" or "FORM" to continue

Undefined Letter - A letter has appeared in the input string for which there is no corresponding machine command code
- Unrecoverable

Number Missing - Incomplete machine command input
- Unrecoverable

Undefined "M" Code - Improper machine function command-valid ones include tape rewind, and tool and feed rate changes (actual letter "M" does not appear on input tape as code is numeric)
- Unrecoverable

Number too Large - Number out of bounds
- Unrecoverable

When unrecoverable errors are encountered, the user may strike "Q" to exit to the monitor. If the user wishes to restart the simulation program at any time from the point at which the work area has already been specified, he can do so by striking "R".

The command codes in addition to the relative and absolute X and Y cutting positions and operator messages are provided as the cutting path is simulated on the display screen. The I and J values used in circle interpolation are also provided to aid in input tape debugging and error isolation. This information appears at the top of the IMLAC CRT.

III. MILL SIMULATION PROGRAM

This cutting path program simulates the operation of the Cintimatic horizontal milling machine. By means of paper tape or disk input, "MILL" interprets commands for the Acramatic 5 control and creates a display on the IMLAC CRT.

The center line of each tool pass is represented on the display screen. Internal positional computations are carried out to the accuracy of the milling machine, but the graphic display (consisting of a 1024 by 1024 point addressable matrix) has a lower resolution. The actual cutting area of the tool is not displayed.

"MILL" as opposed to "LATHE" does not utilize tab sequential (relative) positioning. Absolute coordinate values are provided by the N/C input tape along with the alphanumeric command sequences.

A. OPERATING PROCEDURE

The operating procedure for "MILL" is as follows:

(1) Start the program by typing "MILL" and striking carriage return (CR) for paper tape input, or by typing "MILL/⟨FILE NAME⟩" and striking carriage return (CR) where ⟨FILE NAME⟩ is the name of an IMLAC disk dataset for disk file input.

(2) Specify work area as previously described. The format for the travel ranges is +nnnnnn with an implied decimal point after the second digit (+nn.nnnn).

(3) Specify EIA or ASCII coded input as requested (for paper tape input only).

(4) Mount N/C tape in paper tape reader as requested (for paper tape input only).

(5) Strike "TAB" or "FORM" to begin simulation.

B. PROGRAM EXECUTION

The program starts with cam 00 (manual). The "TAB" and "FORM" keys place the simulation in step by step and continuous modes respectively, as previously described. The program stops reading input when:

(1) New cam (depth) is specified by input
   - Strike "D" to delete current display paths and continue
   - Strike "Q" to exit to monitor
   - Strike "R" to restart simulation
   - Strike "TAB" or "FORM" to continue and overlay current screen contents

(2) Tool change (M06) is specified by input
   - Strike "Q" to exit to monitor
   - Strike "R" to restart simulation
   - Strike "TAB" or "FORM" to continue

(3) Stop (M00, M04) is specified by input (operator significance)
   - Strike "Q" to exit to monitor
   - Strike "R" to restart simulation
   - Strike "TAB" or "FORM" to continue

(4) End of job is specified by input
- Strike "N" to begin next job simulation in input stream
- Strike "Y" or "Q" to exit to monitor
- Strike "R" to restart previous simulation

(5) Errors are detected

Parity - Input tape probably is not aligned in paper tape reader, or wrong code (EIA or ASCII) was specified by user
- Strike "Q" to exit to monitor
- Strike "R" to restart simulation
- Strike "TAB" or "FORM" to continue

Arc Quadrant Error - Desired curve cannot be drawn due to computation overflow
- Strike "Q" to exit to monitor
- Strike "R" to restart simulation
- Strike "TAB" or "FORM" to continue

Undefined Letter - A letter has appeared in the input string for which there is no corresponding machine command code
- Unrecoverable

Number Missing - Incomplete machine command input
- Unrecoverable

Undefined "G" Code - Improper machine pre-function command-valid cycle types include drill, bore, mill
- Unrecoverable

Undefined "M" Code - Improper machine miscellaneous function command - Valid ones include depth/cam and tool changes
- Unrecoverable

Number too Large - Number out of bounds
- Unrecoverable

When unrecoverable errors are encountered, the user may strike "Q" to exit to the monitor. If the user wishes to restart the simulation program at any time from the point at which the work area has already been specified, he can do so by striking "R".

The command codes in addition to the absolute X and Y cutting positions and operator messages are provided as the cutting path is simulated on the display screen. The I and J values used in circle interpolation are also provided to aid in input tape debugging and error isolation. This information appears at the top of the IMLAC CRT.

IV. PUNCH SIMULATION PROGRAM

This cutting path program simulates the operation of the Strippit sheet metal punch. By means of paper tape or disk input, "PUNCH" interprets the N/C machine commands for the Superior Electric Slo-Syn model ENC control and represents each tool pass as a "." on the display screen. "PUNCH", like "MILL", does not utilize tab sequential (relative) positioning. Absolute coordinate values are provided by the N/C input tape along with the alpha-numeric command sequences.

A. OPERATING PROCEDURE

The operating procedure for "PUNCH" is as follows:

(1) Start the program by typing "PUNCH" and striking carriage return (CR) for paper tape input, or by typing "PUNCH/⟨File Name⟩" and striking carriage return (CR) where ⟨File Name⟩ is the name of an IMLAC disk dataset for disk file input.

(2) Specify work area as previously described. The format for the travel ranges is +nnnnn with an implied decimal point after the second digit (+nn.nnn).

(3) Specify EIA or ASCII coded input as requested (for paper tape input only).

(4) Mount N/C tape in paper tape reader as requested (for paper tape input only).

(5) Strike "TAB" or "FORM" to begin simulation.

B. PROGRAM EXECUTION

The program starts with a "+" displayed at the origin. The "TAB" and "FORM" keys place the simulation in step by step and continuous modes

respectively, as previously described. The program stops reading the
N/C input tape when:

(1) Tool change (M06) is specified by input
   - Strike "Q" to exit to monitor
   - Strike "R" to restart simulation
   - Strike "TAB" or "FORM" to continue

(2) End of program (M02) is specified by input
   - Strike "Q" to exit to monitor
   - Strike "R" to restart simulation
   - Strike "TAB" or "FORM" to continue

(3) Errors are detected
   Parity - Input tape probably is not aligned in paper tape reader,
   or wrong code (EIA or ASCII) was specified by user
   - Strike "Q" exit to monitor
   - Strike "R" restart simulation
   - Strike "TAB" or "FORM" to continue
   Undefined Letter - A letter has appeared in the input string for
   which there is no corresponding machine command code
   - Unrecoverable
   Number Missing - Incomplete machine command input
   - Unrecoverable
   Number too Large - Number out of bounds
   - Unrecoverable

When unrecoverable errors are encountered, the user may strike "Q" to
exit to the monitor. If the user wishes to restart the simulation program at
any time from the point at which the work area has already been specified,
he can do so by striking "R".

The command codes in addition to the absolute X and Y cutting
positions and operator messages are provided as the punch is simulated on
the display screen to aid in input tape debugging and error isolation. This
information appears at the top of the IMLAC CRT.

V. WWM SIMULATION PROGRAM

This program simulates the operation of the Standard Logic models 300 and 600 wire wrap machines. By means of paper tape or disk input, "WWM" interprets the N/C machine commands and represents each tool pass as a wire wrap motion on the display screen. "WWM", like both "MILL" and "PUNCH", does not utilize tab sequential (relative) positioning. Absolute coordinate values are provided by the N/C input tape along with the alphanumeric command sequences.

A. OPERATING PROCEDURE

The operating procedure for "WWM" is as follows:

(1) Start the program by typing "WWM" and striking carriage return (CR) for paper tape input, or by typing "WWM/⟨File Name⟩" and striking carriage return (CR) where ⟨File Name⟩ is the name of an IMLAC disk dataset for disk input.

(2) Specify work area as previously described. The format for the travel ranges is +nnnnn with an implied decimal point after the second digit (+nn.nnn).

(3) Specify EIA or ASCII coded input as requested (for paper tape input only).

(4) Mount N/C tape in paper tape reader as requested (for paper tape input only).

(5) Strike "TAB" or "FORM" to begin simulation.

B. PROGRAM EXECUTION

The program begins by displaying a "X" at the origin. The "TAB" and "FORM" keys place the simulation in step by step and continuous modes respectively, as previously described. The program stops reading the N/C input tape when:

(1) M69 code is specified by input - This "X Y ZERO" condition is raised every 25 position cycles to reset the wrapping tool to the origin and to provide the user with the option of clearing the simulated image.

- Strike "D" to clear display screen

- Strike "Q" to exit to monitor

- Strike "R" to restart simulation
- Strike "TAB" or "FORM" to continue and overlay previous screen contents

(2) End of program (R) is specified by input
- Strike "Q" to exit to monitor
- Strike "R" to restart simulation
- Strike "TAB" or "FORM" to continue

(3) Errors are detected
Parity - Input tape probably is not aligned in paper tape reader, or wrong code (EIA or ASCII) was specified by user
- Strike "Q" to exit to monitor
- Strike "R" to restart simulation
- Strike "TAB" or "FORM" to continue
Undefined Letter - A letter has appeared in the input string for which there is no corresponding machine command code
- Unrecoverable
Number Missing - Incomplete machine command input
- Unrecoverable
Number too Large - Number out of bounds
- Unrecoverable

When unrecoverable errors are encountered, the user may strike "Q" to exit to the monitor. If the user wishes to restart the simulation program at any time from the point at which the work area has already been specified, he can do so by striking "R".

The command codes in addition to the absolute X and Y wrapping positions and operator messages are provided as the machine function is simulated on the display screen. "WWM" also identifies which of the two terminals is currently being wrapped as well as signalling "X Y ZERO" (M69 position resets) and "SONALERT" (M59 audible machine warning) conditions. This information appears at the top of the IMLAC CRT.

REFERENCES

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4. "WWM Manual," Standard Logic Incorporated, Santa Ana, California, no date.

5. "Slo-Syn Continuous Path Contouring Controls," Superior Electric Company, Bristol, Conn., no date.

6. "Slo-Syn Numerical Control Equipment, Series C," Superior Electric Company, Bristol, Conn., no date.

7. Weiner, John M., <u>Editing of EIA Coded, Numerically Controlled, Machine Tool Tapes</u>, Technical Memorandum 33-739. Jet Propulsion Laboratory, Pasadena, California, October 1, 1975.

MILL SIMULATION

ENTER MILLING RANGES

XMIN=+050000 XMAX=+200000 YMIN=+020000 YMAX=+110000

Fig. 1. Work area specification

N147 G79 X+113125 Y+59375 I   J   F300 W2 M
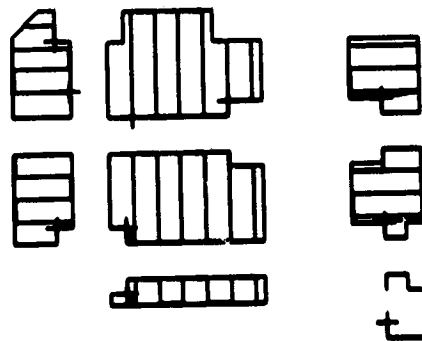
STRIKE KEY TO CONTINUE

Fig. 2. Initial Simulation

0377 G78 X+113125 Y+84995 I J F300 W3 M

CAM CHANGE
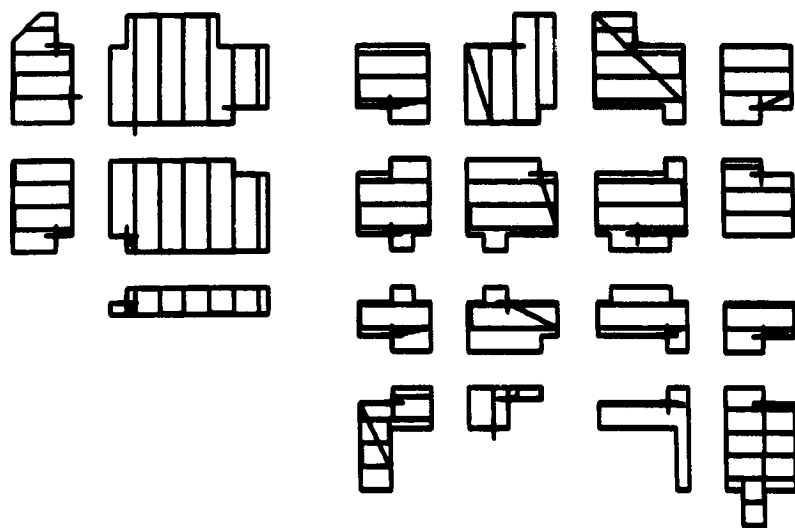

Fig. 3. Simulation halts at cam change

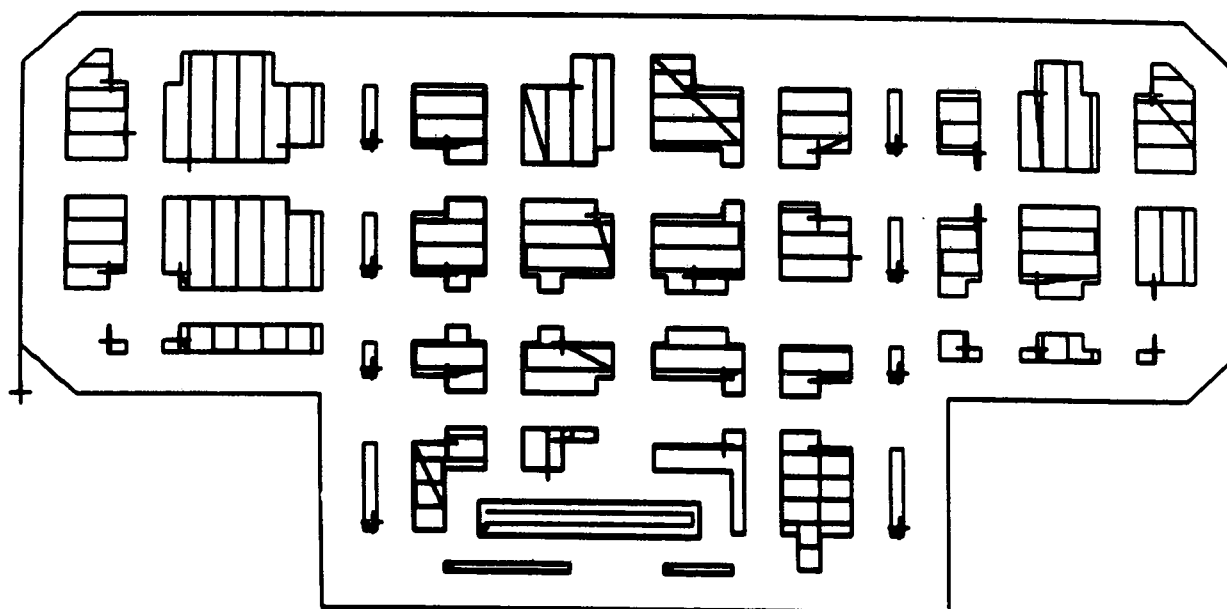N993 G80 X+61250 Y+58964 I   J   F300 W9 M02

END OF PROGRAM, EXIT?

Fig. 4.   End of job

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