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To: Scientific and Engineering Computation Group

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Date: January 26, 1955

SUBJECT: A PROPOSED TRANSLATION PROGRAM FOR THE NUMERICALLY CONTROLLED MILLING MACHINE

Abstract: A tentative proposal for a Whirlwind I (WWI) program to produce tapes for the Numerically Controlled Milling Machine (NCMM) is described.

To produce a control tape for the NCMM, even for a relatively simple piece, may require many hours of tedious hand computation. The procedure requires the determination of the tool cutter-center locus (the path of the center of the cutting tool, as opposed to the path actually being cut) and the location of the points on this locus which correspond to the significant points on the work itself. After the tool path has been calculated as a sequence of straight-line segments, it is often necessary to subdivide these segments further in order to be consistent with the feedrates and timing permitted by the NCMM. After the actual NCMM instructions have been decided upon, they must be converted to the octal number system and the binary digits of logically distinct numbers combined with one another in the rather unusual octal code used in punching tapes for the machine.

An examination of the procedure just outlined indicates that, at least for the case of plane curves consisting solely of line segments and circular arcs, it is feasible to carry out many of the steps of the tape preparation using a high-speed digital computer. A program for WWI, which would translate a verbal description of the problem (stated in a useful but rigidly prescribed vocabulary) into a NCMM tape, appears theoretically possible. A proposed vocabulary for such a program is set forth below. All words, equations, and instructions would be typed on a Flexowriter tape-perforating machine in the form shown; interpretation and translation would be done by the digital computer.

By convention, the positive direction on a straight line is in the direction of increasing x ; on a vertical line, the positive direction is that of increasing y . The positive direction on a circle is clockwise. Starting from the point of minimum x and proceeding along a curve in its positive direction, the first intersection with a

second curve is the near intersection; the other is the far intersection. Two circles, or a line and a circle, are said to be tangent when they have one and only one intersection and their positive directions coincide at the point of intersection; they are antitangent if their positive directions do not coincide at their only point of intersection.

Points, lines, and circles must be specified using a definition of one of the following types. A symbol may not appear in a definition unless it has already been defined.

Points

- | | |
|---|--|
| 1) p16 = -2.734, 6.2545 | coordinates |
| 2) p35 = s12 s17 | intersection of two lines |
| 3) p12 = N s1 c12 }
p12 = F s1 c15 } | intersection of a line
with a circle |
| 4) p15 = N c3 c5 }
p15 = F c3 c16 } | intersection of two
circles |
| 5) p17 = C c12 | center of circle |
| 6) p19 = c17 82° | on circle, angle with
positive x axis |

Lines

- | | |
|---|-------------------------------------|
| 1) s3 = p1 - p2 | two points |
| 2) s2 = p1 Tc2 }
s2 = p1 Ac3 } | through point, tangent
to circle |
| 3) s1 = Ac1 Ac3 }
s2 = Tc1 Ac3 }
s3 = Ac1 Tc3 }
s4 = Tc1 Tc3 } | tangent to two circles |

Circles

- | | |
|-----------------------------------|--------------------------------------|
| 1) c7 = p1, 2.7405 | center, radius |
| 2) c2 = p1 Tc1 }
c2 = p1 Ac3 } | center, tangent to
another circle |
| 3) c5 = p5 s2 | center, tangent to line |

After all points, lines, and circles have been defined, the actual cuts required would be specified in terms of them. Special words of the following form must precede these instructions and may be inter-mixed with them if changes are required during the course of the cutting.

RIGHT	Tool to right of cut
LEFT	Tool to left of cut
TOOL RADIUS = 0.5	
TOLERANCE = 0.0005	

Cutting instructions assume the tool is initially at $x = 0$, $y = 0$. Subsequent cutting instructions assume the tool to be where the preceding instruction left it.

7.5, p3	move at 7.5 in/min feedrate in a straight line to p3
15, c1+, p2	move at 15 in/min along circle c1 in its positive direction, to p2
7.5, c3-, p5	move at 7.5 in/min along circle c3 in its negative direction to p5
PLUNGE 7.2307	lower tool 7.2307 in.
RAISE 2.6034	raise tool 2.6034 in.
STOP	stop the NCMM (punch feedout)
END	signifies end of Flexowriter instruction tape

The vocabulary described is one which it is believed to be possible to implement on WWI or on a similar high-speed digital computer. It is considered that such a program would be useful to the MIT Instrumentation Laboratory and would represent a forward step in the application of digital computers to automatic-control processes. It should be pointed out that the proposed vocabulary and, indeed, the proposal that any WWI program of this sort be undertaken at all, is tentative and subject to further discussion by Instrumentation Laboratory and Digital Computer Laboratory personnel.

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