A Computor Program for Computing Sun-Tide Indices For the Outer Planets From Cartesian Coordinates

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This program was written to calculate Sun-Tide Indices for the outer planets from cartesian coordinates supplied by the United States Naval Observatory in Washington, D.C. The data produced by this program is to be used by Professor Clyde J. Bollinger of the University of Oklahoma in his investigations of the effect of Sun-Tides upon the weather of the earth.

The computor used is the high speed IBM 650 computor located in the Nuclear Engineering Building on the campus of the University of Oklahoma, Norman, Oklahoma. This computor is a magnetic-drum storage unit and is equipped with the following auxiliary units: IBM 533 card input-output; IBM 407 line printer; IBM 727 magnetic tape units (2); IBM 653 storage unit (including immediate access storage, indexing registers, and automatic floating-decimal arithmetic unit); IBM 355 magnetic disk storage unit (model 1).

The input to this machine is IBM cards. They contain eighty columns that may contain any one, or combination of, twelve possible digits in each column. These digits are 0-9 and two others designated as 11 and 12 punches, which are sometimes used with the 0-9 digits to indicate sign or an alphabetic letter. The output can be any one or all of the following: punched cards; line writing from the 407; storage on the magnetic tape units; or storage on the magnetic disk.

The input cards received from the U.S. Naval Observatory are in the following format:

for Jupiter:

Column	Data	Decimal point location
1-8	Julian day	7/8
9-18	X	9/10
19-26	$\Delta''X$	
27-31	M^{iv}	
32-41	Y	32/33
42-49	$\Delta''Y$	
50-54	M^{iv}	
55-64	Z	55/56
65-72	$\Delta''Z$	
73-77	M^{iv}	
78-79	Blank	
80	Planet No.	

for other planets:

1-4	year	
5-6	month	
7-8	day of month	
9-13	Julian day = 2xxxxx0.5	
14-24	X	15/16
25-31	$\Delta''X$	
32-35	$\Delta^{iv}X$	

36-46	Y	37/38
47-53	Δ"Y	
54-57	Δ^{iv}Y	
58-68	Z	59/60
69-75	Δ"Z	
76-79	Δ^{iv}Z	
80	Planet No.	

The planet numbers are: 5 = Jupiter, 6 = Saturn, etc. The columns 9, 19, 27, 32, 42, 50, 55, 65 and 73 are over-punched 11 for negative bits of information on the Jupiter cards. The columns 14, 25, 32, 36, 47, 54, 58, 69 and 76 are over-punched 11 for negative bits of information on the other cards. There are 3721 cards per planet or 14,884 cards total. These cards represent planet position in forty-day intervals from 1653 A.D. to 2060 A.D. They are grouped by planet.

The IBM 533 control boards, then existing in the O.U. computor lab, could not handle cards of these formats. Therefore, it was necessary to modify an existing board or to wire a new one. It was decided that wiring a new board would be more satisfactory. The wiring of this board would accomplish the following: first, it would shift the X to the third ten-digit word, it would shift the Y to the fourth ten-digit word, and shift the Z to the sixth ten-digit word; secondly, it would shift the overpunches in columns 9, 32 and 55 to columns 30, 40 and 60 for negative X, Y and Z on the Jupiter cards and the overpunches in columns 14, 36 and 58 to columns 30, 40 and 60 for negative X, Y and Z on the other planet cards; and lastly, it would put zeros in every column except where an X, Y, Z, the date, or the Julian day occurred. This rearranging of data is necessary in order to use these data cards from the Naval Observatory.

In this particular program the output used was punched cards, line writing (407), and tape storage. The output of this program on punched cards and on the line printer was to follow the following format. The 80 digits or columns of the cards and of a line on the 407 was to be divided into eight, ten digit words as follows:

first word—date

date month year
D D B B M M B Y E A R
blank blank

Julian day
second word—Julian day B B X X X X X X X.X
blank

third word—heliocentric longitude and the radius for Jupiter
HHH.H / R.RRRRR

fourth word—heliocentric longitude and the radius for Saturn
HHH.H / RR.RRRR

fifth word—heliocentric longitude and radius for Uranus
HHH.H / RR.RRRR

sixth word—heliocentric longitude and radius for Neptune
HHH.H / RR.RRRR

seventh word—Suntide Index for that day
SSSS.SSSSSS

eighth word—0000000000

From consultation with Professor Bollinger the equation for the Sun-Tide Index was established:

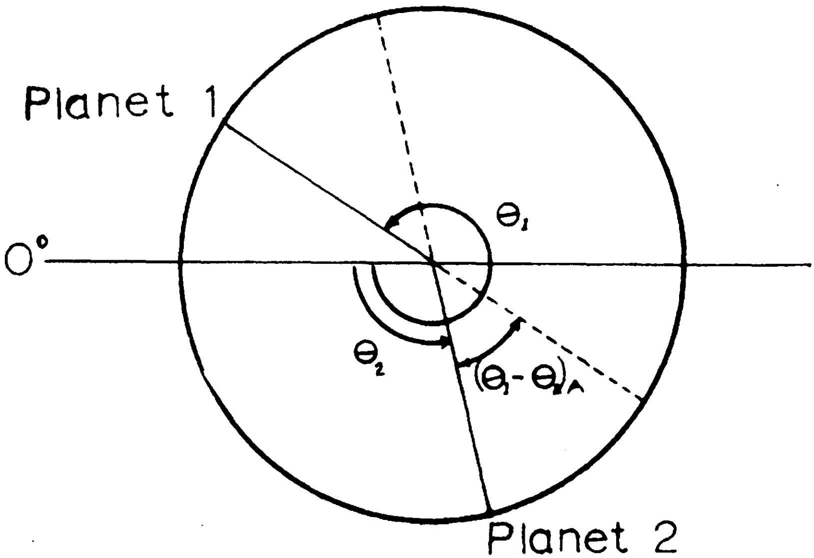
$$STI = \frac{M_5}{r_5^3} + \frac{M_6}{r_6^3}\cos(\theta_6 - \theta_5) + \frac{M_7}{r_7^3}\cos(\theta_7 - \theta_5) + \frac{M_8}{r_8^3}\cos(\theta_8 - \theta_5)$$

where: M_5 = Mass of Jupiter = 314.5
M_6 = " " Saturn = 94.07
M_7 = " " Uranus = 14.4
M_8 = " " Neptune = 17.05

This expression $(\theta_i - \theta_5)$ (Fig. 1) does not mean the algebraic difference between the heliocentric longitudes of Saturn and Jupiter. It represents the acute angle between the intersecting diameters through each of the planets as in the diagram. Geometrically the relationship between the algebraic difference ($\Delta\theta$) and the angle sought depends upon whether the algebraic difference is

$0<\Delta\theta<\frac{\pi}{2}$ or $\frac{\pi}{2}<\Delta\theta<\pi$ or $\pi<\Delta\theta<\frac{3\pi}{2}$ or $\frac{3\pi}{2}<\Delta\theta<2\pi$. If $0<\Delta\theta<\frac{\pi}{2}$ then $(\theta_i - \theta_5) = |\Delta\theta|$.
If $\frac{\pi}{2}<\Delta\theta<\pi$ then $(\theta_i - \theta_5) = 180 - |\Delta\theta|$. If $\pi<\Delta\theta<\frac{3\pi}{2}$ then $(\theta_i - \theta_5) = |\Delta\theta| - 180$.
If $\frac{3\pi}{2}<\Delta\theta<2\pi$ then $(\theta_i - \theta_5) = 360 - |\Delta\theta|$.

Therefore, the program should test $\Delta\theta$ for its classification and proceed accordingly.



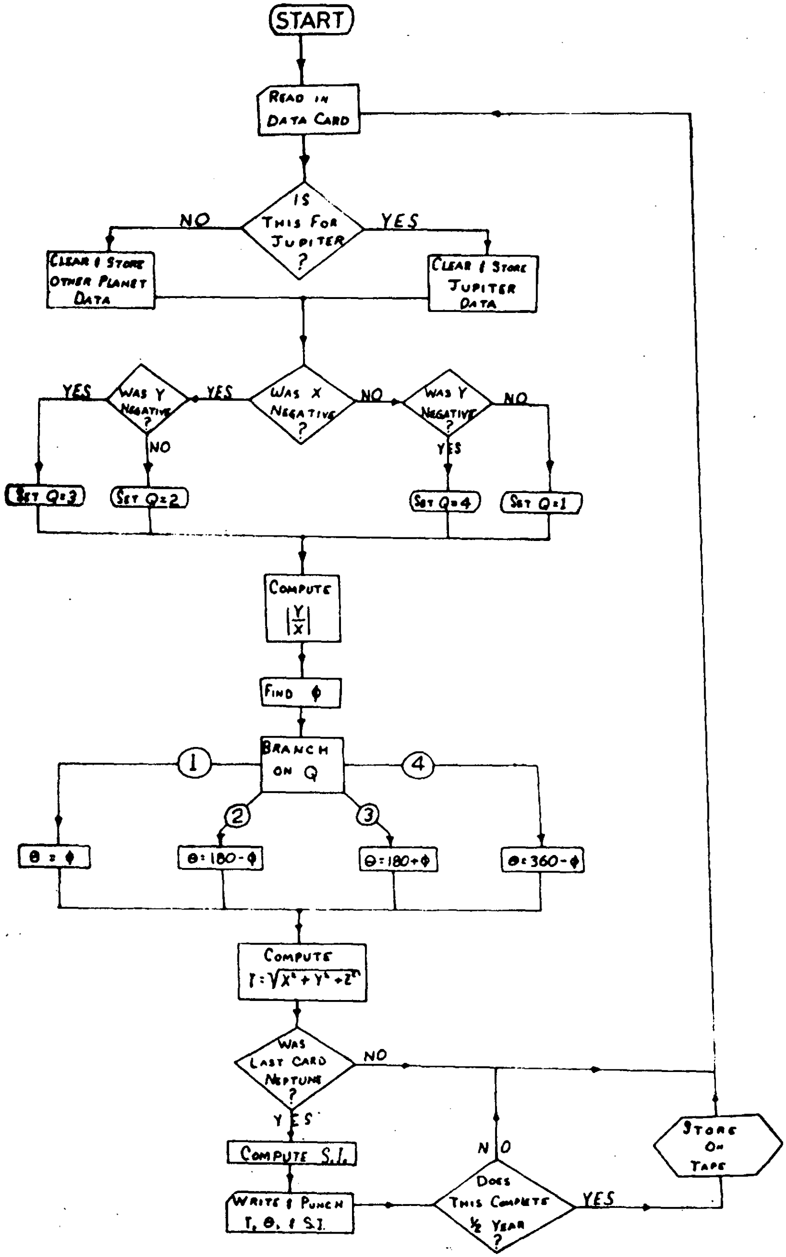
$$(\Theta_1 - \Theta_2)_A = \Theta_1 - \Theta_2 - 180^\circ$$

Figure 1

The radius is obtained from the equation $r = \sqrt{X^2+Y^2+Z^2}$

The first thing accomplished in programming an IBM 650 computor is the drawing of a flow chart (Fig. 2.). The accompanying diagram is the flow chart of this particular program. First is the block, "START", to indicate the beginning of the program. The next block is "READ A CARD". This block uses one IBM 727 tape machine to read the first data card equivalent. The next block tests to see if this card just read is a Jupiter card. This is done by testing the eightieth column for a five. If it is a Jupiter card it uses the part of the program set up to rearrange the date and Julian day for Jupiter and sets them up for output. If it is not a Jupiter card the machine assumes that the card follows the format of the other planets and rearranges the digits accordingly, to set them up for output. The next set of blocks tests the sign on X and Y to establish in what quadrant the planet lies. After doing that, the machine sets Q = t/o 1, 2, 3 or 4 depending upon what quadrant the planet is in. Next, the program computes $|Y/X|$. This represents the tangent of the principal angle of the radius. The program then, using a subroutine for calculating arctangent, finds this principle angle. Next, depending upon what quadrant the radius lies, it computes the heliocentric longitude in radians and readies it for output. The step that follows is the computation of the radius itself and readying it for output. The program now tests to see if the data card it just processed was a Neptune card. If it wasn't, it then returns to the read instruction and begins to process the next card equivalent. If it was a Neptune card it now has enough information to compute the Sun-Tide Index. It now does compute the STI and readies it for output. The block following this is a write and punch instruction. This instruction causes the machine to write out the information on the IBM 407 and punch the information on a card through the IBM 533. The next operation is to test the dates and see if a half year of Sun-Tide Indices has been computed. This is the amount that is stored on the magnetic tapes at one time. If it does complete a half-year the information is stored on the output magnetic tape unit. If it doesn't, the machine is sent back to the read instruction and the process begins again. This process continues until the machine returns to the read instruction and there is a tape mark on the input tape indicating the end of information. You then write a tape mark on the output tape which indicates to the machine that the end of information has been reached, and remove all the data from the machine.

The program takes approximately six seconds to compute one STI. There are four cards involved in each STI. Therefore, there will be (60/6 x 4 = 40) cards read per minute. That would be (60 x 40 = 2400) cards read per hour. At that rate, assuming no machine errors and no delays, it would take (15,000/2400 = 6.2) hours to complete the calculations of STI from 1653 A.D. to 2060 A.D. in forty-day intervals. To this small amount of time must be added the time for sorting the cards (manually or by machine sorters). This time might be as much as 10 hours by machine or 24 hours by hand. This would increase the time to from 16 to 30 hours. However, if the data cards were sorted and stored on tape at the same time using the 650 lab machines, the time would be much shorter. At the rate of input of the 533 (200 cards per minute), 15,000 cards could be sorted and stored on tape in 75 minutes or 1.25 hours. In addition to this time savings, the STI program would run ⅓ second faster per card. Therefore, decreasing computation by (⅓ x 15,000 = 5000) seconds or (5000/3600 = 1.4) hours. Making the total time (6.2-1.4+1.25 = 6.05) hours plus delay time as compared to 16 hours plus delay time or 30 hours plus delay time. Delay time includes program writing, debugging, and machine errors. In this case delay time was approximately 60 hours. This is not an excessive number. Of this 60 hours, debugging took the major part (45 hours).



$$S.I. = \frac{m_5}{r_5^3} + \frac{m_6}{r_6^3}\cos(\theta_6-\theta_5) + \frac{m_7}{r_7^3}\cos(\theta_7-\theta_5) + \frac{m_8}{r_8^3}\cos(\theta_8-\theta_5)$$

Figure 2