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# TIDAL PREDICTION WITH A SMALL PERSONAL COMPUTER

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## ABSTRACT

This paper shows how a personal computer with 16Kb only can be used to work out the prediction of tides with a large number of constituents. In addition, such constituents can be chosen at one's convenience and their harmonic and other constants can be recorded in any standard mini-cassette tape.

## 1. BACKGROUND

Some years ago I prepared a program for a programmable mini-calculator to predict tides with ten constituents. As in the "Tables des marées des grands ports du monde" (BONNOT & SIMON, 1984), there was no choice as regards the limited number of constituents which could be used. Thus, the small machine worked in a similar manner to the old Kelvin analogue tide-predictor.

Since the personal micro-computer came into common use, I have bought one of the Sinclair systems and have written out programs to work out several kinds of calculations which were done earlier in large computers. In fact, I am now in a position to carry out Fourier analysis in this machine, with FFT algorithm, for $2^{11}$ samples; adjust polynomials up to 10 degrees; wave refraction by using more than 1 000 depths; predict tides with about sixty constituents; and many other computations.

The Brazilian method of tidal analysis indicates constituents which must be statistically rejected. Such constituents appear flagged in the printed list. Thus our standard predicting program, for large computers, is sufficiently flexible to use any non-flagged constituents.

Based on that standard program I prepared one for the personal computer and I succeeded in using a large number of constituents of my choice.

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## 2. ASTRONOMICAL ELEMENTS

The first step of the procedure is to find the perinodal factor $f$ and the phases $V + u$ for 0h of the desired date, for the 37 purely astronomical constituents. A 38th fictitious constituent with $f = 1$ and $V + u = 0$ was used in order to simplify the calculations.

In order to compute the uniformly variable part $V$ of astronomical arguments, it was necessary to store in the machine : 38 frequencies (°/h) and a matrix $V(37,5)$, containing, in each row I, the five coefficients $j_0, j_1, j_2, j_3$ and $j_4$, so that the argument for the Ith purely astronomical constituent is given by

$$U(I) = j_0\tau + j_1 s + j_2 h + j_3 p + j_4 90° \qquad (1a)$$

where, as usual

$\tau \equiv$ hour angle of the mean moon
$s \equiv$ mean longitude of the moon
$h \equiv$ mean longitude of the sun
$p \equiv$ mean longitude of the perigee.

Since the mean longitude $p'$ of the perihelion had to be added to (1a) to obtain $U(I)$ for ($\pi_1$, $t_2$) and subtracted from (1a) to find $U(I)$ for ($\psi_1$, $R_2$), the correction to $U(I)$ was taken into account in the program.

To compute the perinodal correction $f$ and $u$ two matrices of (37,13) had also to be stored (FRANCO, 1981), with a total of 962 values. The vector, depending on $p$, $N'$ (360° − longitude of the ascending node) and $p'$ to be pre-multiplied by the (37,13) matrices, is generated by the product of a matrix of 13 × 3 elements, stored in the machine, by the vector $\{ p\, N p' \}^T$. The values of $U(I)$ are then corrected by summing $u$.

In short, the machine had to swallow 1 214 constants once and for all. Let us explain how it is possible.

My small computer, a TK 85 made in Brazil, permits recording in the mini-cassette the program with all the numbers entered with the input instruction. Thus I programmed all the necessary inputs. Afterwards, I removed these instructions, but kept the respective DIM ( ). Then the program was recorded in the mini-cassette. Hence, when the program is read, all the constants will be there. Consequently, to run the program it is not possible to press the key RUN because in this case all the stored values would be cleared out. However, by using instead the GOTO instruction and the convenient program's label XXX, following the last constant input, the stored constants will be preserved and the program will run normally and the $f$ and the $V + u$ values will be computed for the 37 purely astronomical constituents.

The harmonic and other constants for the constituents used in the prediction are recorded on a mini-cassette.

## 3. PREPARING THE TAPE WITH THE CONSTITUENTS

The order for the 37 purely astronomical constituents is fixed. Thus all their elements are related to rigid subscripts. In addition, the constituents used in the prediction can be related to these subscripts. If we ignore some very small shallow-water constituents, those handled in the prediction can be purely astronomical or the combination of three astronomical constituents at most.

Let us suppose that we wish to form the shallow water constituents $2MNK_2$. The subscripts of $M_2$, $N_2$ and $S_2$ are 28, 26 and 32 respectively; thus we have :

$$G(I) = U(26) + 2U(28) - U(34) \qquad (3a)$$

where $U$ is the matrix containing the values of $V + u$ for the purely astronomical constituents.

If $W$ is the matrix of the astronomical constituent frequencies, then the compound frequency is :

$$R(I) = W(26) + 2W(28) - W(34) \qquad (3b)$$

The value $f$ for the same constituent is :

$$H(I) = F(26) * [F(28)]^2 * F(34) \qquad (3c)$$

Expressions (3a) and (3b) are both of the form :

$$S_i = \sum_{n=1}^{3} a_{in} b_{in} \qquad (3d)$$

where $a_{in}$ and $b_{in}$ are, respectively, the three coefficients 1, 2, 1 of order I and the subscripts of the purely astronomical $U(I)$ and $W(I)$. Expression (3c) can be expressed as :

$$T_i = \sum_{n=1}^{3} b_{in}^{\ |a_{in}|} \qquad (3e)$$

The program uses expressions (3d) and (3e), in a recurrent form, where $a_{in}$ and $b_{in}$ are extracted from an alphanumeric matrix X$ and converted into numbers with the VAL function, in order to fill matrices $G(I)$, $H(I)$ and $R(I)$. The harmonic constants $g$ and $H$, extracted from X$ are, respectively, added to $G(I)$ and multiplied by $H(I)$, transforming the elements of these matrices into phases and amplitudes respectively.

If the constituent is purely astronomical, as for instance $M_2$, then the corresponding coefficients and subscripts taken from X$ will be 1 0 0 and 28 38 38.

For a combination of two constituents only, say 2 $SM_2$, we must find 28 32 38 and −2 1 0. A large table has been organized, from which is extracted the table to be recorded on the mini-cassette. Table 1 is an extract of that table for the constituents used in the prediction. The symbol ƀ corresponds to the key SPACE in the used micro; $g$ and $H$ are harmonic constants and the last figure in $H$ is the datum.

Numbers can neither be recorded on nor read out from the mini-cassette tape. Only alphanumeric symbols can be recorded or read. Thus a tailored FORMAT was prepared, so that each row of the four matrices had to be formed with six

TABLE 1

| | Coefficients | Subscripts | $g$ | $H$ |
|---|---|---|---|---|
| $Q_1$ | ƀ1ƀ0ƀ0 | ƀ83838 | ƀƀ6Ø.8 | ƀƀƀ3.6 |
| $O_1$ | ƀ1ƀ0ƀ0 | 1Ø3838 | ƀƀ78.1 | ƀƀ11.8 |
| $P_1$ | ƀ1ƀ0ƀ0 | 153838 | ƀ147.7 | ƀƀƀ1.8 |
| $K_1$ | ƀ1ƀ0ƀ0 | 173838 | ƀ147.7 | ƀƀƀ5.5 |
| $\mu_2$ | ƀ1ƀ0ƀ0 | 253838 | ƀ112.4 | ƀƀƀ1.5 |
| $N_2$ | ƀ1ƀ0ƀ0 | 263838 | ƀ124.4 | ƀƀƀ4.2 |
| $\nu_2$ | ƀ1ƀ0ƀ0 | 273838 | ƀ124.4 | ƀƀƀƀ.8 |
| $M_2$ | ƀ1ƀ0ƀ0 | 283838 | ƀƀ72.7 | ƀƀ33.4 |
| $L_2$ | ƀ1ƀ0ƀ0 | 3Ø3838 | ƀ1Ø7.1 | ƀƀƀ3.7 |
| $S_2$ | ƀ1ƀ0ƀ0 | 323838 | ƀƀ76.Ø | ƀƀ2Ø.Ø |
| $K_2$ | ƀ1ƀ0ƀ0 | 343838 | ƀƀ76.Ø | ƀƀƀ5.6 |
| $M_3$ | ƀ1ƀ0ƀ0 | 373838 | ƀ219.3 | ƀƀƀ1.4 |
| $MN_4$ | ƀ1ƀ1ƀ0 | 282638 | ƀ222.3 | ƀƀƀ3.6 |
| $M_4$ | ƀ2ƀ0ƀ0 | 283838 | ƀ 17.6 | ƀƀƀ8.4 |
| $MS_4$ | ƀ1ƀ0ƀ0 | 283238 | ƀ1Ø3.4 | ƀ2ƀ4.4 |
| $S_0$ | | | Datum → | ƀ2Ø7.3 |

symbols, as shown in Table 1. The input of each matrix is worked out as a whole by writing all the rows of six symbols successively. After printing the last row of each matrix, the NEWLINE key is pressed. After the input of matrix $H$, the datum is introduced.

The number of constituents must be known beforehand, because the size of a matrix like X$ has to be equal to the exact number of symbols. From Table 1 one can deduce that this number is given by $4 \times 6 \times 15 + 6 = 366$. This result can be expressed in a general form by :

$$24 \times NC + 6$$

where $NC$ is the number of constituents.

## 4. WORKING OUT THE PROGRAM

The program starts with a GOTO XXX.

Input by hand is limited to six data only :

1) The time interval, in decimal hours, at which the heights are desired;
2) The number of the month's day;
3) The number of the year's month;
4) The year
5) The number of days for which the prediction is worked out;
6) The number of constituents.

The TV screen shows the call for each of the above data. After input of the last datum the micro computes all the $f$ and $V+u$ for the date, for all the 37 astronomical constituents. Then the TV screen calls for the mini-cassette tape. Thus the counter of the tape deck is adjusted to the number corresponding to the constituents to be used, the key CONT of the micro is pressed and the key PLAY of the tape deck is pressed. Then one stops the deck and waits for the result, which is given in two columns : one with the time and the other with the heights.

Since the TV screen permits the printing of 22 rows only, one needs to press key CONT to obtain the remaining heights.

After the printing of the last height of the day a message appears on the TV screen : IF THE PREDICTION FOR THE NEXT DAY IS DESIRED THEN PRESS GOTO XXX.

## 5. COMMENTS AND CONCLUSIONS

Now a little bit of an old-timer hydrographer's recollections.

Young people cannot have any idea of the enthusiasm a hydrographer of the forties feels towards modern computing facilities. I remember how difficult it was to analyse tides with a desk machine and how tedious it was to predict them with special tables for ten constituents only.

DOODSON used to say that there was no tidal analysis without mistakes ! In fact the manipulation of a one-year tidal record to digitize 8 520 hourly heights and analyse them was a tremendous task : it was a task to be done by two experienced people taking about two and a half to three months.

Prediction with many constituents was unthinkable without a tide analogue predictor with a fixed number of constituents. These machines were very refined and the largest one, at the German Hydrographic Institute, was able to handle 60 constituents. Nowadays, this kind of predictor is a beautiful piece for a museum. In fact our previous description shows that a very small computer can replace such machines with great advantage, since the 60 constituents can be chosen at one's convenience.

In order to give an idea of the efficiency of the prediction proposed, I observed the time spent in each step of the program, when 15 constituents are used, and a 1-hour interval is desired for the heights :

| | |
|---|---|
| Astronomical calculation | 54 s |
| Reading constants | 10 s |
| Amplitudes, phases and frequencies | 20 s |
| Hourly heights | 54 s |

The time taken to compute the heights can be reduced if an additional memory is available. In fact, if a cosine table is stored in the computer, the computations can be worked out in even less time. I wonder if the classical tide tables are still necessary.

The main conclusion is that the limit for thinking is now reduced to about nothing. Almost everything we imagine can be checked out at once.

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