A computation program for numerical filtering

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Ricevuto il 9 Aprile 1968

Riassunto. — Viene descritto un programma, scritto in linguaggio FORTRAN IV, per il filtraggio numerico di serie temporali. Tale programma è stato provato con un calcolatore del tipo IBM 7094/7040 DCS.

L'operazione di filtraggio numerico permette di estrarre o sopprimere, in una serie temporale, onde di frequenza prefissate indipendentemente da variazioni di fase ed ampiezza con cui esse si possono presentare.

Summary. — A computation program, written in FORTRAN IV language, for numerical filtering of time series is described. It was tested with an IBM 7094/7040 DCS computer.

The numerical filtering operation allows to extract or suppress in a time series prefixed frequency waves indipendently by the change of phases and wideness with which they can appear.

Method.

It has been described, in a previous paper (1), a filtering operation of time series on equispaced data, corresponding to a prefixed response.

In the following paper is described a computation program based on the method developed in (1).

A numerical filtering operation on an equispaced data series $n_i (i = 1,2, \ldots\ldots)$ is obtained by computing a new series:

$$n'_k = \sum_{j=-r}^{+s} a_j \, n_{k+j} \,, \qquad k \geqslant r + 1 \,, \qquad [1]$$

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where the $(r + s + 1)$ quantities a_j are called coefficients or weights of the numerical filter, as described in [1]. The series n'_k contains the allowed frequencies computed by means of the used filter.

For obtaining a new series n''_k which does not contain the same frequency bands, one must reverse the coefficients sign of the filter, except the central one which is replaced with the difference between number 1 and the central coefficient, and the so obtained filter must be used on the original data series.

The two operations, numerical filtering and the difference from the original series, are equivalent to the resulting series $n''_k = n_k - n'_k$.

The choice of the coefficients of the filter is stricly connected to the knowledge of the physical problem and it depends on the restrictions imposed on the frequency band to search and also on the independence of the results.

Description of the Program.

The program has been carried out at "Centro di Calcolo del CNEN" in Bologna using the FORTRAN IV language, version 13, under the IBSYS 7094/7040 DCOS monitor control.

The data set that can be elaborated is practically unlimited; the maximum allowed set of coefficients of the filter is 99. This data set is extremely sufficient for many problems but it can also be increased by modifyng the appropriate statements.

Sometimes it may be necessary to compute series of filtering operations on the same data, and, in this case, it will be sufficient to follows the suggestions described after for obtaining series of computations at a lowest time.

It has also foreseen the elaboration of several data series with the same coefficients or with different coefficients for gaining the set-up time, in the computer, of the running program.

Besides, it has been considered the necessity of groupping the initial of filtered series data before a numerical filtering: it allows to reduce that random noise that should give no information about the testing series.

The problem to treat will suggest, time after time, the right choice for groupping.

The problem consists in keeping the time position of the original data, naturally providing that the number of the coefficients $(r + s + 1)$

will be odd. The computed coefficient n'_k is set in the middle of the interval only if the condition $r = s$ is satisfied. The conditions $r = s$ must be satisfied in order to use this program correctly.

A further expedient, to avoid over-excess of figures for subsequent elaborations and with no damage to the clearness of the problem and to the amount of the gainable information, consists in selecting the significant figures, in the results of every operations, for the considered problem.

Besides, this expedient allows to rescale the results as desired so as to be seen in an appropriate scale.

Further expedients have been described below.

ORDER OF DATA CARDS DECK SET-UP.

All cards must be included in the order shown below.

[A] = time series data parameter card.

[B] = variable format card for time series input data.

[C] = time series data.

[D] = END punched in col. 1-3.

[E] = comment card.

[F] = parameter card for a filter operation.

[G] = variable format card for output data to be put on logical tape NTPO.

[H] = variable format card for output data to be printed.

[I] = filter coefficients.

Repeat [E] through [I] as desired.

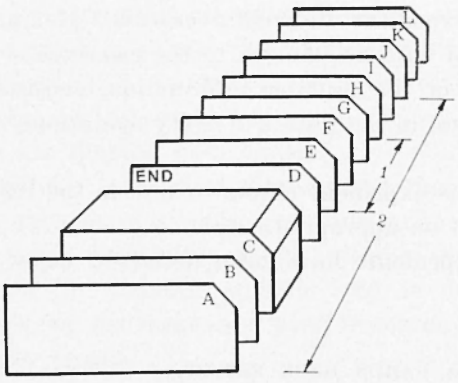
[J] = blank card.

[K] = blank card.

Repeat [A] through [K] as desired.

[L] = blank card (to notify the program that the entire jobs is completed and control must be returned to the Monitor).

EXAMPLE OF DATA DECK SET-UP.



1. Repeated as desired (see page 3)
2. Repeated as desired (see page 3)

CARD PREPARATION.

Card columns	Corresponding variable	DESCRIPTION
[*A*] *card*		FORMAT (4I2)
1-2	NDS	— number of time series data contained in each input card.
3-4	NTPI	— logical tape number of input (5 if input is from punched cards).
5-6	KE	— number of decimal figures if conversion is used (*)
7-8	IT	— = 0 if input conversion is required (*) ≠ » » » » not required (*).

(*) One must use conversion when time series input data are punched as integer constants having the sign (hole zone) over the less significant figure of the number. In this case each field of width w, containing the number, is considered like it were formed of two sequential fields: the 1st of integer-type of whidth $w - 1$, the 2nd of alphameric-type of width 1, i.e.: if number 12.125 is punched according to the format specification F 7.3 no conversion is required, being a Fortran number (in this case $IT = 0$). The character string 1212*N*, (where *N* means holes 5 and 11, minus sign overpunched) columns of the card punched in a field of width $w = 5$ for having the same value as the above one, must be read according to the format specification (I4, A1) and *must* be $KE = 3$ (decimal figures of the number) and $IT \neq 0$.

Card columns	Corresponding variable	DESCRIPTION
[*B*] *card*		FORMAT (13A6,A2)
1-80	FR1	— format of time series input data must be like (A3, specifications for input data). Columns 1-3 cannot be used. This restriction is used to allow an indefinite number of time series input data cards, the end of which is reached when the program reads the [D] card.
[*C*] *card*		FR1 format (see [B] card)
4-n ($n \leqslant 80$)	EL (KA, KB)	— time series input data (those data will be the 1st file of a tape where logical number is 3. This file is addressed by means the value 1 assigned to the NFEL variable). The initial time series data and successive filtered ones are recorded on logical tape 3 to form a sequence of files. Each file contains a sequence of recorded data. As desired, to filter data recorded into one of those files, one must assign to the NFEL parameter the value of the file address (its physical position on the reel) assumed puring the file recording.
[*D*] *card*		FORMAT (A3)
1-3	KEND	— the word END *must* be punched in the corresponding columns. This card notify the program that all the cards containing time series input data have been read.
[*E*] *card*		FORMAT (13A6,A2)
1-80	FCOM	— this is a comment card (i.e. it may contains a comment about the numerical filter operation).
[*F*] *card*		FORMAT (9I2,E14.6)
1-2	NFEL	— specifies the address of the file of logical tape 3 containing the input data for the filter operation (NFEL = 1 addresses initial input data) (see [C] card).
3-4	N	— number of filter coefficients.
5-6	NDP	— number of data per record to be put on logicel tape NTPO. (Must always be NDP > 0).

Card columns	Corresponding variable	DESCRIPTION
[*F*] *card* (cont.)		
7-8	NR	— number of input data to be groupped before executing filter operation.
9-10	NTPO	— logical tape number on which (if MPER $\neq$ 0) output data are put (i.e. for punching off-line).
11-12	MSTA	— 1 to print output 0 not to print output
13-14	MPER	— 1 to put output on logical tape NTPO 0 not to put output on logical tape NTPO
15-16	IC	— 1 if output conversion for recording on logical tape NTPO is required 0 if output conversion is not required.
17-18	KA2	— number of figures for output data.
19-32	A1	— rescale factor. The rescale factor (A1) allows the program the rescaling of the obtained results. KA2 allows the user to fix the number of output figures of the rescaled results. i.e.: if the filter operation has given the number 23456 and user desires to output only the number 34 (2nd and 3rd figures of that result) he must fix KA2 = 2 and A1 = 0.01.
[*G*] *card*		FORMAT (13A6,A2)
1-80	FR2	— format of output data to be put on logical tape NTPO (see [H] card) if these output are not desired (MPER = 0 in [F] card) this card can also be a blank card. If MPER $\neq$ 0 the format specified *must* be like (I3, specifications for output data). Columns 1-3 of output records to be put on logical tape NTPO contain a card sequence number. « specification for output data » must be like ....., Iw, A1, ... where w = KA2-1 if IC = 1, or like..... Iw..... where w = KA2 if IC = 0 for each output data.
[*H*] *card*		FORMAT (13A6,A2)
		— format of output data to be printed. If this output is not desired (MSTA = 0 in [H] card) this card can also be a blank card.

Card colums	Corresponding variable	DESCRIPTION
[*H*] *card* (cont.)		If MSTA $\neq$ 0 the format specified *must* be like (I5, specifications for output data). The 1st 5 characters of each printing line are the line sequence number. " specifications for output data " must be like..... Iw, ... where w = KA2 for each output data.
[*I*] *card*		FORMAT (8X,12F6.5)
9-80	COEF	— filter coefficients. (These must be punched in the following order: central coefficient and those at its right).

[J], [K] and [L] must be blank cards.

Repeat [E] through [I] cards to do other numerical filter operation or using initial data (NFEL = 1) or using output data obtained from the initial ones (see [C] card).

COMMENT.

In the following pages it has been reproduced the list of the described program. As an example of usage of the results it has been also reproduces a plotter (see Fig. 1) obtained handling the 7094/7040 DCS outputs by an additional program running on an IBM 1620 computer.

The authors have mainly contributed each in their activity field.

ACKNOWLEDGMENTS.

Prof. M. Galli gave the opportunity of very interesting discussion. Prof. E. Clementel, Dr. A. Chiarini, Dr. C. Lolli made easy the IBM 7094/7040 DCS computers utilisation at the " Centro di Calcolo del CNEN " of Bologna (SHARE Installation BI).

REQUIRED ROUTINES: RF 5K01 SDA n. 3061
and RF 5K03 SDA n. 3057

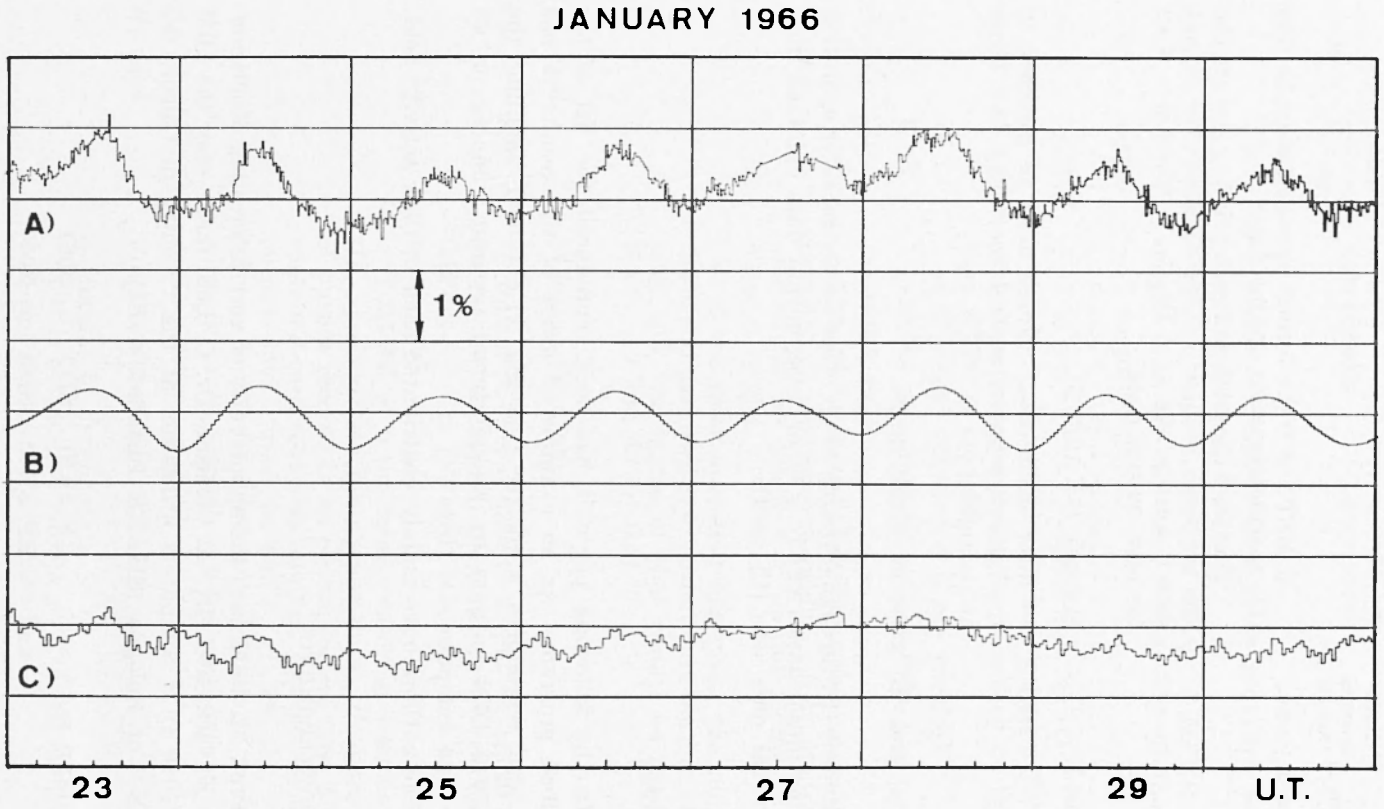


Figure 1 – Caption: A) Original Data; B) Filtered Data; C) Filtered Data by reversed *b*) filter coefficients.

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      DIMENSION FCOM(14),FR1(14),FR2(14),FR3(14),EL(5000),FIL(5000) ,
     1KFIL( 5000),NREC(100),COEF(100)
      DIMENSION KA(40),KB(40)
      EQUIVALENCE(FIL,KFIL)
      DATA KEND/3HEND/,KIFT/1073741824/
  530 READ(5,203)NDS,NTPI,KE,IT
      IF(NTPI.EQ.0.OR.NDS.EQ.0) GO TO 1530
  203 FORMAT(9I2,E14.6)
      KE=10**KE
      REWIND 3
      READ(5,202)(FR1(K),K=1,14)
  202 FORMAT(13A6,A2)
C
C
      END FILE 3
      NFILE=1
      NTOT=0
      IF(IT.LE.0)GO TO 500
  503 READ(NTPI,FR1)KFIN,(KA(J),KB(J),J=1,NDS)
      IF(KFIN.EQ.KEND)GO TO 501
      DO 502 J=1,NDS
      KB(1)=MOD(KB(J)/KIFT ,16)
  502 EL(J)=ISIGN(KA(J)*10+IABS(MOD(KB(1),10)),KB(1))/KE
      NTOT=NTOT+1
      WRITE(3)NTOT,(EL(J),J=1,NDS)
      GO TO 503
C
  500 READ(NTPI,FR1)KFIN,(EL(J),J=1,NDS)
      IF(KFIN.EQ.KEND)GO TO 501
      NTOT=NTOT+1
      WRITE(3)NTOT,(EL(J),J-1,NDS)
      GO TO 500
C
  501 END FILE 3
      NREC(NFILE)=NTOT*NDS
  536 READ(5,200)(FCOM(K),K=1,14)
  200 FORMAT(13A6,A2)
      WRITE(6,201)(FCOM(K),K=1,14)
  201 FORMAT(1H1,6(/),28X,13A6,A2//28X,80(1H-))
C
C
  506 READ(5,203) NFEL,N,NDP,NR,NTPO,MSTA,MPER,IC,KA2,A1
      IF(NFEL.EQ.0.OR.NFEL.GT.NFILE.OR.N.EQ.0.OR.NREC(NFEL).EQ.0)GOTO530
      READ(5,202)(FR2(K),K=1,14),(FR3(K),K=1,14)
      REWIND 4
      MFIL=NFILE-NFEL+2
      CALL BAKFIL(3,MFIL)
C
C
      M1=N/2
      M2=M1+1
      READ(5,337)(COEF(I),I=M2,N)
  337 FORMAT(8X,12F6.5)
      DO 50 I=1,M1
      M3=N-I+1
      EL(I)=0.
   50 COEF(I)=COEF(M3)
      KA2=10**KA2
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```
      NN=NTOT-NVR+1
      DO 8 J=1,NVR
      EL(J)=EL(NN)
    8 NN=NN+1
      I2=NVR
C
C
      NSP=K3/NDP
      GO TO 513
   17 NSP=1
      IF(K3.EQ.NDP) GO TO 513
      K4=K3+1
      DO 514 MM=K4,NDP
  514 FIL(MM)=0.
  513 DO 15 J1=1,K3,NDP
      J2=J1+NDP-1
      WRITE(4)     (FIL(J),J=J1,J2)
  505 IF((MSTA+MPER).LE.0) GO TO 301
      DO 16 MJ=J1,J2
      IF(FIL(MJ).NE.0.) GO TO 416
      KFIL(MJ)=0
      GO TO 16
  416 KFIL(MJ)=MOD(IFIX(FIL(MJ)*A1+SIGN(.5,FIL(MJ))),KA2)
   16 CONTINUE
      IF(MSTA.GT.0)WRITE(6,FR3)JNP,(KFIL(J),J=J1,J2)
      IF(MPER.LT.1) GO TO 301
      IF(IC.EQ.1) GO TO 613
      WRITE(8,FR2)JNP,(KFIL(J),J=J1,J2)
      GO TO 301
  613 DO 300 J=J1,J2
      JJ=J-J1+1
      KA(JJ)=IABS(KFIL(J)/10)
  300 KB(JJ)=MOD(KFIL(J),10)*KIFT
      WRITE(NTPO,FR2) JNP,(KA(J),KB(J),J= 1,JJ)
  301 JNP=JNP+1
   15 CONTINUE
      GO TO(511,110),KKK
  511 NRE=NRE-NTOT+IG-1
      IG=NVR+1
      IF(NRE.LE.0 )GO TO 104
      GO TO 11
  104 IF(NVR.LT.NR*N)GO TO 110
      KKK=2
      GO TO 105
  110 MFIL=MFIL-1
      CALL SKPFIL(3,MFIL)
      NFILE=NFILE+1
      REWIND 4
C
C
      JNP=JNP-1
      INP=0
      IF(JNP.LT.NDS)GO TO 507
      K1=JNP/NDS
      DO 508 MM=1,K1
      J1=1
      J2=NDP
      DO 509 MJ=1,NDS
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```
      JNP=1
      NVR=0
      N1=1
      KKK=1
      IF(NR.GT.1)GO TO 13
      NR=1
      GO TO 111
   13 N1=2
      M1=M1*NR
       DO 600 I=M2,M1
  600 EL(I)=0.
      M2=M1+1
  111 IG=M2
C
C
      K1=4800
      NRE=NREC(NFEL)
   11 IF(K1.GT.NRE)K1=NRE
      K1=K1+IG-1
      DO 1 I1=IG,K1,NDS
      I2=I1+NDS-1
    1 READ(3)NUM,(EL(J),J=I1,I2)
  105 NTOT=I2
      WRITE(6,767)(EL(J),J=1,NTOT)
  767 FORMAT(24F5.0)
      NRAG=NTOT/NR
      K3=NRAG-N+1
      IF(KKK.EQ.2)GO TO 18
      KRES=MOD(K3,NDP)
      K3=K3-KRES
   18 GO TO (701,702),N1
C
C
  702 NR1=1
      NR2=NR
      NRAG=K3+N-1
      FRAG=NR
      DO 20 KRA=1,NRAG
      EL(KRA)=EL(NR1)
      NR1=NR1+1
      DO 21 IRA=NR1,NR2
   21 EL(KRA)=EL(KRA)+EL(IRA)
      EL(KRA)=EL(KRA)/FRAG
      NR1=NR2+1
   20 NR2=NR2+NR
C
C
  701 DO 12 KK=1,K3
      FIL(KK)=EL(KK)*COEF(1)
      KZ=KK
      DO 14 MK=2,N
      KZ=KZ+1
   14 FIL(KK)=FIL(KK)+EL(KZ)*COEF(MK)
   12 CONTINUE
C
C
      IF(KKK.EQ.2) GO TO 17
      NVR=NTOT-K3*NR
```

```
      READ(4)(FIL(J),J=J1,J2)
      J1=J2+1
  509 J2=J2+NDP
      J1=1
      J2=NDS
      DO 510 MJ=1,NDP
      INP=INP+1
      WRITE(3)INP,(FIL(J),J=J1,J2)
      J1=J2+1
  510 J2=J2+NDS
  508 CONTINUE
  507 KM=MOD(JNP,NDS)
      IF(KM.EQ.0)GO TO 561
      J1=1
      J2=NDP
      DO 512 MJ=1,KM
      READ(4)(FIL(J),J=J1,J2)
      J1=J2+1
  512 J2=J2+NDP
      IF(KKK.NE.2)K3=NDP
      NTRA=KM*NDP-NDP+K3
      KM=NDS-MOD(NTRA,NDS)
      IF(KM.EQ.0)GO TO 515
      DO 516 MJ=1,KM
      MM=NTRA+MJ
  516 FIL(MM)=0.
  515 KM=NTRA/NDS+1
      IF(MOD(NTRA,NDS).EQ.0) KM=KM-1
      J1=1
      J2=NDS
      DO 517 MJ=1,KM
      INP=INP+1
      WRITE(3)INP,(FIL(J),J=J1,J2)
      J1=J2+1
  517 J2=J2+NDS
  561 NTOT=INP
      GO TO 501
C
C
 1530 STOP
      END
```

TIMING:

1) to test 960 input data of a time series with 2 numerical filtering each of 69 coefficients groupping initial data 2 by 2, it takes 1'12'' (including the monitor time and the program compilation, therefore the time of computation is only 20'').

2) to test 3456 input data of a time series with 3 numerical filtering of 9, 69, 35 coefficients respectively groupping 2 by 2 on crossing from 1° to 2° it takes 1'43'' (ihcluding the monitor time and the program compilation: therefore the time of computation is only 32'').

REFERENCES

(1) GALLI M., RANDI P., *On the Design of the Optimum Numerical Filter with a Prefixed Response.* "Annali di Geofisica", **XX**, 4, (1967).