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An Interactive Computer Program to Compute the Convolution of Discrete Seismic time Series

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Abstract **– Convolution is a mathematical way of combining two signals (discrete time series for our present study) to achieve a third modified signal. It is the most general representation of the process of linear or invariant filtering. We present a simple interactive FORTRAN program to compute the convolution of any two seismic time series to yield the convolution output. The program was equally used to affirm the commutative property of the convolution operation.**

Keywords **– Convolution, Linear Filtering, Discrete Time Series, FORTRAN Program, Commutative Property.**

I. Introduction

Convolution is a mathematical operation that defines the change in form of a waveform when passed through a filter. This change in form is termed convolution. In the process of convolution, the filter discriminates some forms of the waveform with regards to either amplitude or phase. Convolution can be applied to any two functions of time or space (or other variables) to yield a third function, the output of the convolution. Although the mathematical definition is symmetric with respect to the two input functions, it is a common practice in signal processing to say that one of the functions is a filter acting on the other function [1]. The response of many physical systems can be represented mathematically by a convolution. For instance, a convolution operation could be used to model the filtering of seismic energy by the various rock layers in the earth subsurface [2].

Mathematically, convolution can be expressed by the relation

$$y(t) = g(t) * f(t)$$

$= \int g(u)\, f(t-u)\, du$ where the integral exist.

Presented below is a basic example to illustrate convolution of two discrete functions (series);

If $f(t)$ = (4, 3, 2, 1) and $g(t)$ = (2, 0, 1), the convolution of $f(t)$ and $g(t)$ produces a new function $y(t)$ such that the convolution result becomes

⇒ (4, 3, 2, 1)
(1, 0, 2) →

8
6
8
5
2
1

The convolution result $y(t)$ **= (8, 6, 8, 5, 2, 1) ⇒ (n + m) – 1**

In computer code $yk = \sum_{i=1}^{m} gi\, fk-1$ **(k = 1, 2,…. m+n -1)**

FORTRAN which means formulation translation is a basic and fundamental high level programming language in wide use for scientific and engineering applications. The programming language has evolved and has been revised over the years since it's formulation as far back as 1957 – 1966 [3]. FORTRAN continues to be a vital language for programming applications even amongst recent other competitive high level or multi-purpose languages. The program codes for the present study were written in FORTRAN 2008.

Our primary motivation for this paper is to present a simple interactive FORTRAN flow chart and computer program to compute the convolution of any two discrete seismic time series. This presented interactive computer program could as well be adapted to compute cross – correlation and auto – correlation of seismic time series.

II. Basic Layout of a Modern FORTRAN Program

The FORTRAN programming language has a basic structure just like every other programming language. A modern FORTRAN program structure is presented below:

PROGRAM *program-name*
IMPLICIT NONE
[*Specification Part*]
[*Execution Part*]
[*Subprogram Part*]
END PROGRAM program-name

As shown from the layout, a modern FORTRAN program starts with the keyword PROGRAM, and then followed by the program name, the IMPLICIT NONE statement which mandates the programmer to declare all variables, then followed by the specification statements, execution parts and possibly a set of internal subprograms as is the case with the program presented in this paper for the computation of the convolution of any two discrete seismic time series and finally the END PROGRAM part followed closely by the program name. It is usually a common and good practice to include comment lines in programs to make such programs to be more readable and ensure they are easily understood. Such comments lines could actually appear in any part or section of the program and they are usually un-executable unlike the main program parts which can be executed. It is also desirable to provide appropriate

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program flow charts to demonstrate how the program works or how it is to be implemented. The proposed program is explained with the flow chart presented in Figure 1.0.

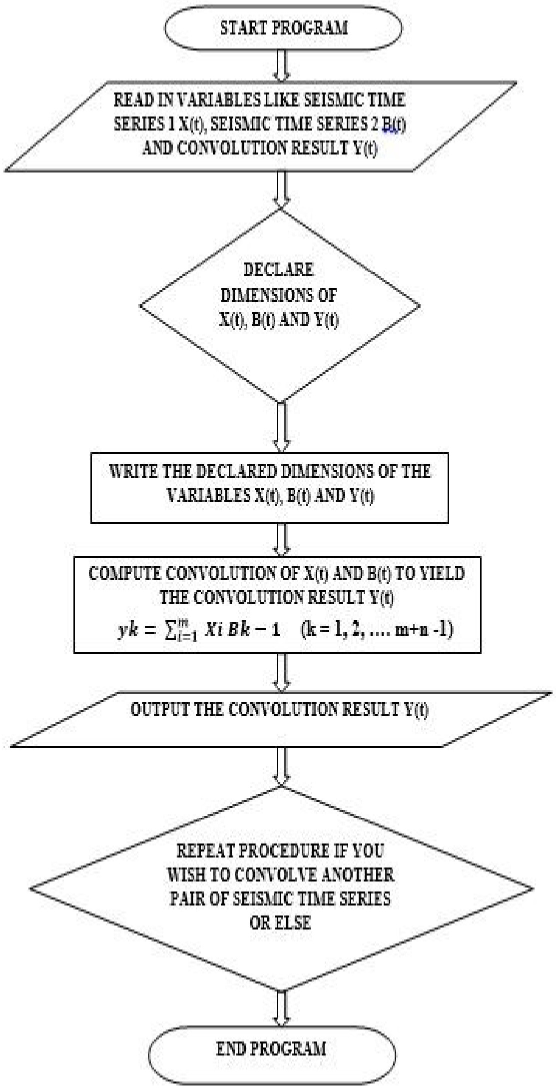

Fig. 1.0. A Explanatory program flow chart demonstrating the procedure for computing the convolution of any two seismic times series X(t) and B(t) to yield the convolution result Y(t)

III. Program Presentation

```
PROGRAM Convolution of Discrete Seismic Time Series
C   A DRIVER FORTRAN PROGRAM THAT CALLS
    SUBROUTINE CONVY TO CARRY OUT CONVOLUTION
    BETWEEN ANY TWO DISCRETE SEISMIC TIME SERIES.
C   THE SUBROUTINE (CONVY) WAS ADAPTED FROM A
    REFERENCE TEXT BY CLEARBOUT/BRACEWELL.
C   ONE IS REQUIRED TO DECLARE THE DIMENSIONS OF
    THE TWO TIME SERIES AND THAT OF THE
    ANTICIPATED OUTPUT.

IMPLICIT NONE
    DIMENSION X(3), B(4), Y(6)
     OPEN(7, FILE = 'CVY.TXT')
     WRITE(*,*) ' WHAT IS THE LENGHT OF X? '
     READ(*,*) LX
      WRITE(*,*) ' WHAT IS THE LENGHT OF B ?'
        READ(*,*)LB
        LY = (LX + LB) - 1
      DO 2 I = 1, LX
      WRITE(*,*) 'ENTER THE WAVE FUNCTION'
      READ(*,*)X(I)
    2 CONTINUE
      DO 3 I = 1, LB
      WRITE(*,*) 'ENTER THE FILTER
  FUNCTION'
      READ(*,*)B(I)
    3 CONTINUE
C        LX = 4
C        LB = 4
C        LY = 7
C
      CALL CONVY(X,B,Y,LX,LB,LY)
      WRITE(7,100)Y
  100 FORMAT(1X,'Y = ',F8.2)
      STOP
      END
*********************************************
C     STARTING SUBROUTINE
*********************************************
      SUBROUTINE CONVY(X,B,Y,LX,LB,LY)
      DIMENSION X(LX),B(LB),Y(LY)
      LY=LX + LB - 1
      DO 10 I = 1, LY
C       LX = 4
      Y(I) = 0
   10 CONTINUE
      DO 20 I = 1, LX
      DO 20 J = 1, LB
      Y(I + J - 1) = Y(I + J - 1) + X(I)*B(J)

   20 CONTINUE

      RETURN
END ROGRAM Convolution of Discrete Seismic Time
Series
```

IV. Application of Program to Discrete Seismic Time Series and Results Presentation

Convolution Application:

Convolution Example 1:

The presented FORTRAN Program would now be deployed to compute the convolution of the following two discrete seismic time series; $f(t)$ = **(1, -2, 4)** and $g(t)$ = **(5, 2, 1, 4).**

The convolution of ***f (t)* * *g (t)*** was computed as well as ***g (t)* * *f (t)*** with the program and the results obtained were the same which affirms that the convolution operation is commutative.

```
C   THIS SHOWS THE OUTPUT OBTAINED FROM THE
    CONVOLUTION BETWEEN TIME SERIES f(t) WITH g(t).

OUTPUT:
 Y = 5.00
 Y = -8.00
```

Y = 17.00
Y = 10.00
Y = -4.00
Y = 16.00

C THIS IS THE OUTPUT FOR THE CONVOLUTION OF TIME SERIES *G(t)* WITH *f(t)*.
C THE RESULT OBTAINED IS EXACTLY THE SAME AS THE ONE OBTAINED IN *f(t)* CONVOLVING WITH *g(t)*
C THIS PROVES THE COMMUTATIVE PROPERTY OF THE CONVOLUTION OPERATION

OUTPUT:
Y = 5.00
Y = -8.00
Y = 17.00
Y = 10.00
Y = -4.00
Y = 16.00

Convolution Example 2:

The presented FORTRAN Program would also be now deployed to compute the convolution of the following two discrete seismic time series; $\boldsymbol{f(t)}$ **= (4, 3, 2, 1)** and $\boldsymbol{g(t)}$ **= (2, 0, 1).**

The convolution of ***f (t) * g (t)*** was computed as well as ***g (t) * f (t)*** with the program and the results obtained were the same which affirms that the convolution operation is commutative

C THIS SHOWS THE OUTPUT OBTAINED FROM THE CONVOLUTION BETWEEN TIME SERIES *f(t)* WITH *g(t)*.

OUTPUT:
Y = 8.00
Y = 6.00
Y = 8.00
Y = 5.00
Y = 2.00
Y = 1.00

C THIS IS THE OUTPUT FOR THE CONVOLUTION OF TIME SERIES *G(t)* WITH *f(t)*.

OUTPUT:
Y = 8.00
Y = 6.00
Y = 8.00
Y = 5.00
Y = 2.00
Y = 1.00

C THE RESULT OBTAINED IS EXACTLY THE SAME AS THE ONE OBTAINED IN *f(t)* CONVOLVING WITH *g(t)*
C THIS PROVES THE COMMUTATIVE PROPERTY OF THE CONVOLUTION OPERATION

V. Conclusions

We have presented an interactive FORTRAN flow chart and program to compute the convolution output of any two discrete seismic time series. We have equally used the written program to affirm that the convolution operation commutes. The program presented here could as well be adapted to compute cross – correlation and auto – correlation of any two seismic time series. If the latter is the aim, the second time series would need to be manually reversed when being inputted into the program. Recall that in convolution, the second time series is normally reversed where as in cross and auto correlations, the second time series are not reversed. This is the reason a manual reversal needs to be done on the second time series to counter the reversal done by the main program if computation of auto and cross correlation of the seismic time series is the objective.

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