

SYNAPSE SCIENCE CENTER

S N D A
SEISMIC NETWORK DATA ANALYSIS

Part 2
DESCRIPTION OF THE PROCESSING ALGORITHMS
FOR ANALYSIS OF SEISMIC DATA
FROM SMALL APERTURE ARRAYS AND LOCAL NETWORKS

(Edited by Prof. A.Kushnir)

© SYNAPSE Science Center,
117526, Vernadskogo Ave., 101, Bld. 1,
Suite 303, Moscow, Russia
Voice: (495) 434-3638;
Fax: (495) 434-3638

Moscow, January 2000

© SYNAPSE Science 303, Moscow, Russia

Telephones; (095) 434-3638; FAX: (095) 343-3249;

CONTENTS

1. PROGRAM PACKAGE FOR 1-COMPONENT SEISMIC ARRAY DATA ANALYSIS	5
1.1. Program MARMAMO : multidimensional ARMA modeling of seismic array data	5
1.2. Program ARMAGRF : synthesis of vector frequency responses for adaptive spatial rejecting and BEAM group filters	9
1.3. Program FPSFSA : group filtering in frequency domain	12
1.4. Program FKAN : multimode F-K analysis	14
1.5. Program PHASEDET : detecting weak seismic phases in wavetrain by adaptive statistical detector	19
2 PROGRAM PACKAGE FOR 3-COMPONENT ARRAY DATA ANALYSIS	22
2.1. Program MODELS : Modeling of 3-component array seismograms	22
2.2. Program POL : Polarization filtering of data from single 3-component station by Flinn method	29
2.3. Program POLCFLTS : Vector polarization filtering of multichannel data	34
2.4. Program ARMAFS : Estimating of inverse matrix power spectral density of multichannel data by ARMA modeling.....	37
2.5. Program GRFILTF5 : Optimal Wiener group filtering of 3-component array data for different types of wave polarization	41
2.6. Program GRFLTFCS : Extraction of waveforms of differently polarized seismic phases using 3 component array data with the help of optimal Wiener group filtering	49
2.7. Program GRFLTFK : Adaptive broad band 3-component F-K analysis	56
2.8. Program SP3C : Adaptive multimode F-K analysis of 3-component array data	63
3 PROGRAM PACKAGE FOR STATISTICAL IDENTIFICATION OF SEISMIC SOURCE TYPE	68
3.1. Program LD : Input of data for learning and classification in the SNDA stack	68
3.2. Program LDSTST : Evaluation of standard learning data statistics	70
3.3. Program FSEL : Automatic selection of informative features providing minimum of probability of classification errors using linear discriminator.....	73
3.4. Program FSELQ : Automatic selection of informative features providing minimum of probability of classification errors using the quadratic discriminator.....	75
3.5. Program RECLLD : Reclassification of learning vectors by the linear discriminator	78
3.6. Program EXAMLD : Estimation of error probability by cross-validation method using linear discriminator	80
3.7. Program EXAMQD : Estimation of error probability by cross-validation method using quadratic discriminator	81
3.8 TEXT OF SNDA JCL SCRIPT "BPFMES.SCR"FOR MEASURMENT OF EVENT SOURCE CLASSIFICATION FEATURES FROM EVENT SEISMOGRAM.....	84

4. PROGRAM PACKAGE FOR EVENT SOURCE LOCATION	93
4.1 Program ESTIMTT : estimating travel times for regional and teleseismic events	93
4.2 Program ARLOC : event locating based on single array data	95
4.3 Program SOURCELOC : location of event epicenters by the emission tomography method	99
5. Program NVCLASS: Classification of event features by neural network algorithm with cross-validation estimation of probability of classification errors.....	103
6. Short description of program package for event source moment tensor estimation and event discrimination based on these estimates.....	111

1. PROGRAM PACKAGE FOR 1-COMPONENT SEISMIC ARRAY DATA ANALYSIS

1.1. Program MARMAMO: multidimensional ARMA modelling of seismic array data

DESCRIPTION OF ALGORITHM

The program calculates parameters of autoregressive-moving average (ARMA) model for a multidimensional (vector) random time series. The ARMA model of vector time series $\mathbf{x}(t)=(x_1(t),\dots,x_M(t))^T$, $t=1,\dots,N$, is a new random vector time series $\mathbf{y}(t)=(y_1(t),\dots,y_M(t))^T$ which satisfies the following finite difference equation:

$$\mathbf{y}(t) = \sum_{j=1,p}\{\mathbf{A}(j)\mathbf{y}(t-j)\} + \sum_{j=0,q}\{\mathbf{B}(j)\mathbf{e}(t-j)\}, \quad t=1,\dots,N, \quad (1)$$

where $\mathbf{e}(t)=(e_1(t),\dots,e_m(t))^T$, $t=1,2,\dots,N$, is a zero-mean Gaussian random vector time series with zero correlation between $e_k(t)$ $e_j(s)$ for different s,t and variances equal 1 for all s,t ; $\mathbf{A}(j)$, $j=1,\dots,p$ and $\mathbf{B}(j)$, are $(M \times M)$ matrices: AR and MA matrix parameters of time series $\mathbf{x}(t)$. These parameters are estimated to provide a fit of the statistical characteristics of model $\mathbf{y}(t)$ to the same characteristics of time series $\mathbf{x}(t)$. The matrices $\mathbf{A}(j)$, $j=1,\dots,p$ and $\mathbf{B}(j)$, $j=1,\dots,q$ are the output data of the program and are saved to disc files with specified names.

The particular cases of ARMA modelling are autoregressive (AR) modelling and moving average (MA) modelling. In the first case, one has $\mathbf{B}(j)=0$ for $j=1,\dots,q$, and $\mathbf{B}(0) \neq 0$. In the second case, $\mathbf{A}(j)=0$ for $j=1,\dots,p$. The program has several calculation modes providing different particular cases of ARMA modelling and different methods for calculation of AR and MA matrix parameters.

The program incorporates a subroutine for LOW-PASS filtering of input components (channels) $x_j(t)$, $j=1,M$ by the Chebyshev filter (the same filter is applied to all channels). The frequency response of the filter is calculated inside the program for given parameters: cut off frequency, frequency response lobe and resampling factor. Preliminary LOW-PASS filtering and resampling improves the fit of a time series by a multidimensional ARMA model in the case where the high frequency part of data spectrum (starting from some cut off frequency) contains much less power than the low frequency part. This case is a common one for applications in seismology. The resampling factor after filtering has to be chosen to provide a new Nyquist frequency of data to be as close as possible (but greater) than the filter cut of frequency.

The input vector time series $\mathbf{x}(t)$ are read into the program from the SNDA stack. An arbitrary sequence of channels can be chosen for subsequent processing.