

APPENDIX E

SOURCE CODE LISTING FOR COMPUTER PROGRAM PEAK

Some routines used by program PEAK are copyright (C) 1987,1988,1992 Numerical Recipes Software and are reproduced by permission, from the book Numerical Recipes: The Art of Scientific Computing, published by Cambridge University Press.

E.1 Input

Input to program PEAK is interactive. The program is invoked with a command line argument which is the name of the file created by program AMB. The rest of the input, such as the frequency band-width for peak searching, the number of peaks searched for, and the name of the output file, is entered interactively by the user.

E.2 Output

The output of the file is in the form of a table. Examples of these tables are given in Appendices B and C.

E.3 Example of Terminal Session

```
reeltime 8% peak G52cen
  Number of Peaks: 4
  Minimum frequency for peak-picking: 0.1
  Maximum frequency for peak-picking: 2
  Closest peak spacing (Hz): 0.25
  Results file name: r52cen
reeltime 9%
reeltime 9% more r52cen
                                Peaks In G52cen

Hz-data    Hz-fit    Amp^2-data    Amp^2-fit    Phase Damping %
0.2441     0.2426     8.4451e-05    8.5265e-05    1    2.8
0.9888     0.9891     4.7639e-06    4.7664e-06    2    1.3
1.5259     1.5243     1.4874e-07    1.4911e-07    158  1.8
1.8066     1.8102     1.3160e-05    1.3314e-05    3    2.2

                                RMS-acc    RMS-vel    RMS-dsp
                                3.057e-02    9.156e-03    6.181e-03

reeltime 10%
```

```

/*****
/* Program peak.c - Spectral Peak Picking For Ambient Data */
/* Use data from the output of program amb.c for ambient parameter est. */
/* Finds amplitudes and phases using peak picking methods. */
/* Estimates frequencies and damping using a quadratic curve-fit and */
/* a band-width method combining raw data with the estimated frequency. */
/* RMS-displacement computation de-emphasizes low frequencies: line 71 */
/* */
/* to compile: cc -O -o peak peak.c gaussj.c nrutil.c */
/* to run: peak 'amplitude / phase filename' */
/* (c) H.P. Gavin, Dept. of Civil Eng., Princeton University, 2-91 */
*****/

```

```

#include <stdio.h>
#include <math.h>

```

```

main(argc,argv)
int    argc;
char   *argv[];
{
    char    filename[85], /* output file name */
           c;

    FILE    *fp;          /* file pointer */

    float   frq, amp, pha, /* frequency, amplitude, and phase */
           frq_old,       /* previous frequency */
           amp_old,       /* previous amplitude */
           pha_old,       /* previous phase */
           f_tol,         /* closest spacing of 2 peaks */
           f_min,         /* minimum frequency for peak picking */
           f_max,         /* maximum frequency for peak picking */
           df,            /* frequency interval */
           rms_a = 0.0,   /* rms acceleration */
           rms_v = 0.0,   /* rms velocity */
           rms_d = 0.0,   /* rms displacement */
           **pk_data,     /* data in a high peak region */
           **C,           /* power polynomial coefficients */
           **matrix();    /* allocates matrix storage */

    int     n_pk,         /* number of peaks to pick */
           slope,         /* sign of [ dG(f) / df ] (+/- 1) */
           slope_old,     /* previous slope */
           slp_cond,      /* 1: change in slope, 0: same slope */
           amp_cond,      /* 1: next largest amplitude, 0: not */
           frq_cond,      /* 1: far from a peak, 0: close to pk */
           i,j,k,n;       /* current peak number */

    struct  peak {float f,a,p,d,F,A;} pk[20];

    void    poly_fit(),   /* general least squares polynomial fit */
           dter_fit(),    /* deterministic curve fitting */

```

```

        free_matrix(); /* deallocates matrix storage */

if ( ( fp = fopen(argv[1],"r") ) == NULL ) {
    printf ( " error: cannot open %s\n", argv[1]);
    printf ( " usage: peak 'amplitude/phase filename'\n");
    exit (0);
}

/*          Find The RMS Values          */
/* Change These Lines If The Data Is Velocity */

while ( (c = fscanf(fp,"%f %f %f", &frq,&amp;,&pha)) != EOF ) {
    if(frq < 0.15) frq=0.16; /* filter low frequency noise */
    frq *= 2.0*acos(-1.0); /* w = 2.pi.f */
    frq *= frq; /* w^2 = w.w */
    rms_a += amp; /* a^2 = a^2 or a^2 = v^2*w^2 */
    rms_v += amp/frq; /* v^2 = a^2/w^2 or v^2 = v^2 */
    rms_d += amp/(frq*frq); /* d^2 = a^2/w^4 or d^2 = v^2/w^2 */
}
rms_a = sqrt(rms_a);
rms_v = sqrt(rms_v);
rms_d = sqrt(rms_d);
rewind(fp);

printf ( " Number of Peaks: ");
scanf ("%d", &n_pk);
printf ( " Minimum frequency for peak-picking: ");
scanf ("%f", &f_min);
printf ( " Maximum frequency for peak-picking: ");
scanf ("%f", &f_max);
printf ( " Closest peak spacing (Hz): ");
scanf ("%f", &f_tol);

pk_data = matrix(1,20,1,2);
C = matrix(1,3,1,1);

/*          Find The Peaks By Amplitude */

i=1;
pk[1].a = 0.0;
while ( (c = fscanf(fp,"%f %f %f", &frq,&amp;,&pha)) != EOF ) {
    if (frq > f_max) break;
    if (frq > f_min)
        if (pk[1].a < amp) {
            pk[1].f = frq;
            pk[1].a = amp;
            pk[1].p = pha;
        }
    if (i) {
        df = frq;
        i=0;
    }
}

```

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    }
)
rewind(fp);

for (i=2; i <= n_pk; i++) {
    frq_old = amp_old = pk[i].a = slope = slope_old = 0;
    while ((c = fscanf(fp, "%f %f %f", &frq, &amp, &pha)) != EOF )
        if (frq > f_max) break;
        if (frq > f_min) {

            slp_cond = 0;
            if (amp > amp_old) slope = 1;
            if (amp < amp_old) slope = -1;
            if (slope_old == 1 && slope == -1) slp_cond

            amp_cond = 0;
            if (pk[i].a < amp_old && amp_old < pk[i-1].
                amp_cond = 1;

            frq_cond = 1;
            for(k=1; k<i; k++)
                if (fabs(frq_old - pk[k].f) < f_tol
                    frq_cond = 0;

            if (slp_cond && amp_cond && frq_cond) {
                pk[i].f = frq_old;
                pk[i].a = amp_old;
                pk[i].p = pha_old;
            }
            frq_old = frq;
            amp_old = amp;
            pha_old = pha;
            slope_old = slope;

        }
    }
rewind(fp);
}

/*      Sort The Peaks By Frequency */

for (i=2; i<=n_pk; i++) {
    frq = pk[i].f;
    amp = pk[i].a;
    pha = pk[i].p;
    k=i-1;
    while (k > 0 && pk[k].f > frq) {
        pk[k+1].f = pk[k].f;
        pk[k+1].a = pk[k].a;
        pk[k+1].p = pk[k].p;
        k--;
    }
    pk[k+1].f = frq;

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        pk[k+1].a = amp;
        pk[k+1].p = pha;
    )

    /*      Curve-fit The Peaks With A Quadratic      */

    amp_cond=0; n=i=1;
    while ((c = fscanf(fp,"%f %f %f", &frq,&amp;,&pha)) != EOF ) {
        if (i > n_pk || frq > f_max) break;
        if (frq > pk[i].f - 1.1*df) n = amp_cond = 1;

        while (amp_cond) {
            pk_data[n][1] = frq;
            pk_data[n][2] = amp;
            if (frq > pk[i].f + 0.9*df) amp_cond = 0;
            fscanf(fp,"%f %f %f", &frq,&amp;,&pha);
            n++;
        }
        n--;
        if (frq > pk[i].f && n > 2) {

            if (n == 3)      dter_fit (pk_data,n,C);
            else              poly_fit (pk_data,n,2,C);

            pk[i].A = C[1][1] - C[2][1]*C[2][1] / (4.0*C[3][1]);
            pk[i].F = -0.5*C[2][1]/C[3][1];
            i++;

        } else if (frq > pk[i].f) {
            pk[i].F = pk[i].f;
            pk[i].A = pk[i].a;
            i++;
        }
    }

    /*      Estimate The Damping With Raw Data      */

    rewind(fp);
    i=1;
    while ((c = fscanf(fp,"%f %f %f", &frq,&amp;,&pha)) != EOF ) {
        if (i > n_pk || frq > f_max) break;
        if (frq == pk[1].f) {
            while (amp > 0.7*pk[i].a) {
                fscanf(fp, "%f %f %f", &frq, &amp;, &pha);
                pk[i].d = 100.0 * fabs(frq - pk[i].F) /
                    (pk[i].F * sqrt(pow((frq/pk[i].F),4
                        pk[i].A/amp - 1.0)));
            }
            i++;
        }
    }
    fclose (fp);

```

```

        /*      Print The Results      */

printf (" Results file name: ");
scanf ("%s", filename);
if (( fp=fopen(filename,"w")) == NULL ) {
    printf (" error: cannot open %s\n", filename);
    exit (0);
}

fprintf (fp, "\t\t\t\tPeaks In %s\n\n", argv[1]);
fprintf (fp, "Hz-data\t\tHz-fit\t\tAmp^2-data\tAmp^2-fit\t");
fprintf (fp, "Phase\tDamping %%\n");

for (i=1; i <= n_pk; i++)
    fprintf (fp, "%7.4f\t\t%7.4f\t\t%.4e\t%.4e\t%4.0f\t%5.1f\n"
        pk[i].f,pk[i].F,pk[i].a,pk[i].A,pk[i].p,pk[i].d);
fprintf (fp, "\n");
fprintf (fp, "\t\tRMS-acc\t\tRMS-vel\t\tRMS-dsp\n");
fprintf (fp, "\t\t%.3e\t%.3e\t%.3e\n", rms_a, rms_v, rms_d);
fprintf (fp, "\n\n");

free_matrix(pk_data,1,20,1,2);
free_matrix(C,1,3,1,1);

fclose (fp);
}

/*      Function dter_fit()      */
/* Fit a power polynomial to data deterministically      */

void dter_fit (data,n,C)
float    **data,          /* the data to be fit      */
**C;          /* the power polynomial coeffs & [X]t {y} */
int      n;          /* the number of data points */
{
    float    **X,          /* the power poly basis function matrix */
**matrix();

    int      i,j;

    void      gaussj(),          /* gauss-jordan elimination */
free_matrix();

    X = matrix(1,n,1,n);

    for (i=1; i<=n; i++) {
        X[i][1] = 1.0;
        for (j=2; j<=n; j++)
            X[i][j] = X[i][j-1]*data[i][1];
        C[i][1] = data[i][2];
    }
}

```

```

    }

    gaussj (X,n,C,1);

    free_matrix(X,1,n,1,n);
    return;
}

/*          Function poly_fit()          */
/* Fit a power polynomial to a set of data using          */
/* linear least squares & gauss-jordan inversion          */

void poly_fit (data,n,order,C)
float  **data,      /* the data to be fit          */
      **C;          /* the power polynomial coeffs & [X]t {y}          */
int    order,       /* the order of the fit          */
      n;            /* the number of data points > order          */
{
    float  **X,      /* the power poly basis function matrix */
      **A,          /* [X]t [X]          */
      **matrix();

    int    i,j,k;

    void    gaussj(), /* gauss-jordan elimination          */
      free_matrix();

    A = matrix(1,order+1,1,order+1);
    X = matrix(1,n,1,order+1);

    printf ("%d\n",n);
    for (i=1; i<=n; i++) printf ("%e\t%e\n", data[i][1], data[i][2]);

    for (i=1; i<=n; i++) {
        X[i][1] = 1.0;
        for (j=2; j<=order+1; j++)
            X[i][j] = X[i][j-1]*data[i][1];
    }
    for (k=1; k<=order+1; k++)
        for (j=k; j<=order+1; j++) {
            A[k][j] = 0.0;
            for (i=1; i<=n; i++)
                A[k][j] += X[i][k]*X[i][j];
            A[j][k] = A[k][j];
        }
    for (k=1; k<=order+1; k++) {
        C[k][1] = 0.0;
        for (i=1; i<=n; i++)
            C[k][1] += X[i][k]*data[i][2];
    }
}

```

```
gaussj (A,order+1,C,1);

free_matrix(X,1,n,1,order+1);
free_matrix(A,1,order+1,1,order+1);
return;
}
```



```

/*          FILE gaussj.c          */
/*      Gauss-Jordan Elimination from Numerical Recipes in C      */

#include <math.h>

#define SWAP(a,b) {float temp=(a);(a)=(b);(b)=temp;}

void gaussj(a,n,b,m)
float **a,**b;
int n,m;
{
    int *indxc,*indxr,*ipiv,*ivector();
    int i,icol,irow,j,k,l,ll;
    float big,dum,pivinv;
    void nrerror(),free_ivector();

    indxc=ivector(1,n);
    indxr=ivector(1,n);
    ipiv=ivector(1,n);
    for (j=1;j<=n;j++) ipiv[j]=0;
    for (i=1;i<=n;i++) {
        big=0.0;
        for (j=1;j<=n;j++)
            if (ipiv[j] != 1)
                for (k=1;k<=n;k++) {
                    if (ipiv[k] == 0) {
                        if (fabs(a[j][k]) >= big) {
                            big=fabs(a[j][k]);
                            irow=j;
                            icol=k;
                        }
                    } else if (ipiv[k] > 1)
                        nrerror("GAUSSJ: Singular Matrix-1")
                }
        ++(ipiv[icol]);
        if (irow != icol) {
            for (l=1;l<=n;l++) SWAP(a[irow][l],a[icol][l])
            for (l=1;l<=m;l++) SWAP(b[irow][l],b[icol][l])
        }
        indxr[i]=irow;
        indxc[i]=icol;
        if (a[icol][icol] == 0.0) nrerror("GAUSSJ: Singular Matrix-");
        pivinv=1.0/a[icol][icol];
        a[icol][icol]=1.0;
        for (l=1;l<=n;l++) a[icol][l] *= pivinv;
        for (l=1;l<=m;l++) b[icol][l] *= pivinv;
        for (ll=1;ll<=n;ll++)
            if (ll != icol) {
                dum=a[ll][icol];
                a[ll][icol]=0.0;
                for (l=1;l<=n;l++) a[ll][l] -= a[icol][l]*dum
                for (l=1;l<=m;l++) b[ll][l] -= b[icol][l]*dum
            }
    }
}

```

```

        )
    }
    for (l=n;l>=1;l--) {
        if (indx[l] != indxc[l])
            for (k=1;k<=n;k++)
                SWAP(a[k][indx[l]],a[k][indxc[l]]);
    }
    free_ivector(ipiv,1,n);
    free_ivector(indx,1,n);
    free_ivector(indxc,1,n);
}

```

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- NCEER-87-0025 "Proceedings from the Symposium on Seismic Hazards, Ground Motions, Soil-Liquefaction and Engineering Practice in Eastern North America," October 20-22, 1987, edited by K.H. Jacob, 12/87, (PB88-188115/AS).
- NCEER-87-0026 "Report on the Whittier-Narrows, California, Earthquake of October 1, 1987," by J. Pantelic and A. Reinhorn, 11/87, (PB88-187752/AS). This report is available only through NTIS (see address given above).
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