ON THE DETERMINATION OF DISPLACEMENT FROM STRONG-MOTION ACCELEROGRAMS

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SUMMARY

A new method is proposed for the deconvolution of true ground motion with regard to permanent displacement from the accelerograph records. It is shown that this method is stable when the dynamic range (signal-noise ratio) exceeds 50 (35 db). A method of filtering (integrating) of accelerograms is proposed, which permits to determine ground displacements and velocities in limited frequency range from the accelerograms of low quality.

METHOD

There are many papers about the restoration of ground displacement from accelerograms. But all proposed methods (1,2) permit the determination of only the oscillative motion, neglecting the permanent displacement. The method of deconvolution of displacement, including the permanent, was first elaborated by V.I.Bogdanov and V.M. Graizer (3). The general peculiarity of modern methods of deconvolution is the application of apriori information about the input signal, which makes the solution stable.

The connection between the ground displacement $X(t)$ and accelerogram $Y(t)$ is described by the equation

$$Y'' + 2w_s D_s Y' + w_s^2 Y = -V_0 X'' \qquad (1)$$

where w_s, D_s, V_0 - are the coefficients. Eq.(1) is true when the influence of turning and inclination may be neglected. Displacement $X(t)$ may be determined by the integration of Eq.(1) with zero initial conditions

$$X(t)=-(1/V_0)\cdot(Y+2w_s D_s\int_0^t Y\,dt+w_s^2\int_0^t\int_0^t Y\,dt^2) \qquad (2)$$

Because the digitized accelerogram is distorted by the systematic and random errors, the integration with Eq.(2) results in the accumulation of the errors. The distortions arising in this way are connected mainly with the incorrect drawing of zero line.

The correction of the baseline is accomplished by the polynomial of the third degree which is found from the minimum of the functional

$$W_1=\int_0^{T_1}(X'(t))^2dt + \int_{T_2}^{T}(X'(t))^2dt \qquad (3)$$

The latter is based on the assumption of the least squares of velocities in the segments $0,T_1$ and T_2,T, corresponding to the small oscillations as compared with the

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main amplitudes (T is the duration of digitized accelerogram). This algorithm permits to determine the oscillative and the residual displacement.

In the case, when it is apriori known that the permanent displacement is abseht (is considerably smaller than the oscillative), it is recomended instead of functional W_1 to minimize

$$W_2=\int_0^{T_1}(X(t))^2dt + \int_{T_2}^{T}(X(t))^2dt \qquad (4)$$

For the determination of the ground velocity and acceleration numerical differentiation after smoothing the computed displacement is made.

A series of numerical and shaking-table experiments were accomplished to evaluate the accuracy and limitation of the application of this algorithm. It was shown (4), that for determination of residual displacement with the error less than 25% the signal-noise ratio should exceed 50 (35 db).

When the dynamic range of the accelerogram is small and the restoration of true ground motion is impossible, a method of filtering is proposed, which permits to determine displacements and velocities in limited frequency range. For integrating in certain frequency range a digital filter, equivalent to the mechanical seismograph (velocigraph), may be used. In this case the output motion $Z(t)$ of accelerograph-filter system is described

$$Y''+2w_sD_sY'+w_s^2Y=-V_0X'', \qquad (5)$$
$$Z''+2w_fD_fZ'+w_f^2Z=-V_fY.$$

where Y is accelerogram, X - displacement. At the output of this system the displacement in frequency range from w_f to w_s ($D_f<1$) or velocity ($D_s\gg1$) may be obtained. Before filtering the accelerograms, the baseline was corrected by the polynomial of the third degree.

RESULTS

In fig.1 a determination of true ground displacement, velocity and acceleration from the strong-motion record of the Parkfield, California earthquake of June 28 1966 is shown. This accelerogram was recorded at the station N 2, at a distance from a fault approximately 80 m (5). The estimated amplitude of displacement reaches 55 cm and the residual displacement - 28 cm. This result agrees satisfactorily with the theoretical calculations, computed on the basis of the dislocation theory(6).

The Gazli earthquake of May 17 1976 was recorded in the epicentral zone. However, the record is incomplete, as a result of which general restoration of the true ground motion is impossible. The results of filtering (integration in limited frequency range) are shown in fig.2 (velocities in frequency range 0,1-15 Hz, displacements - 0,02-15 Hz).

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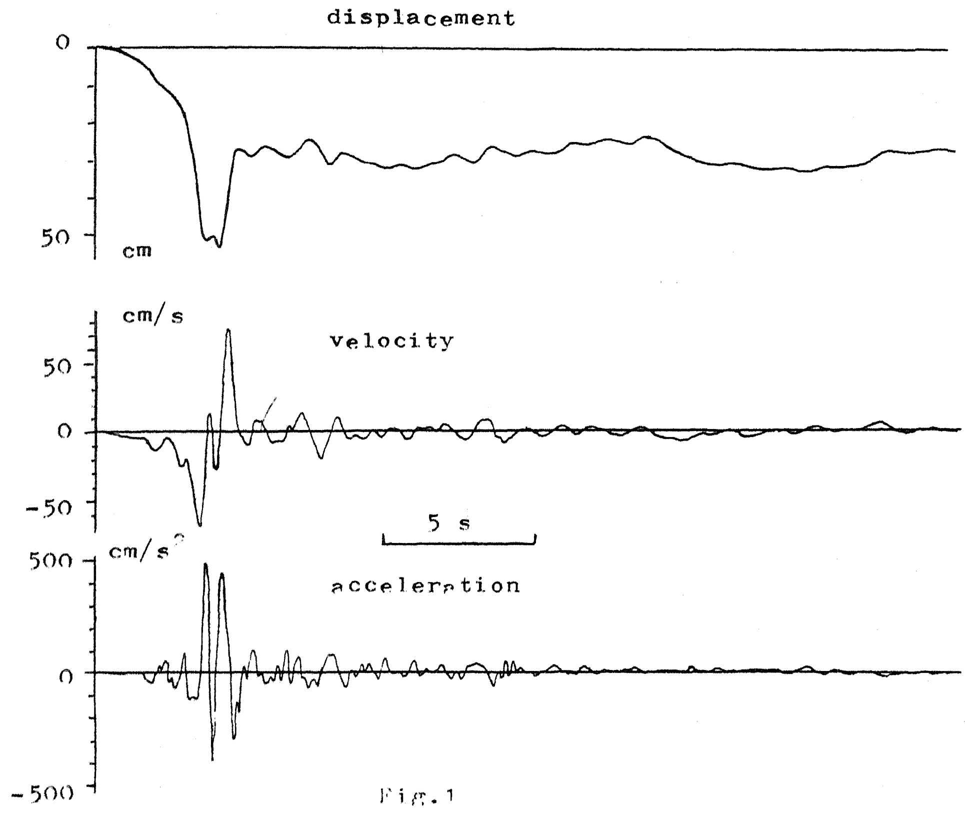

Fig.1

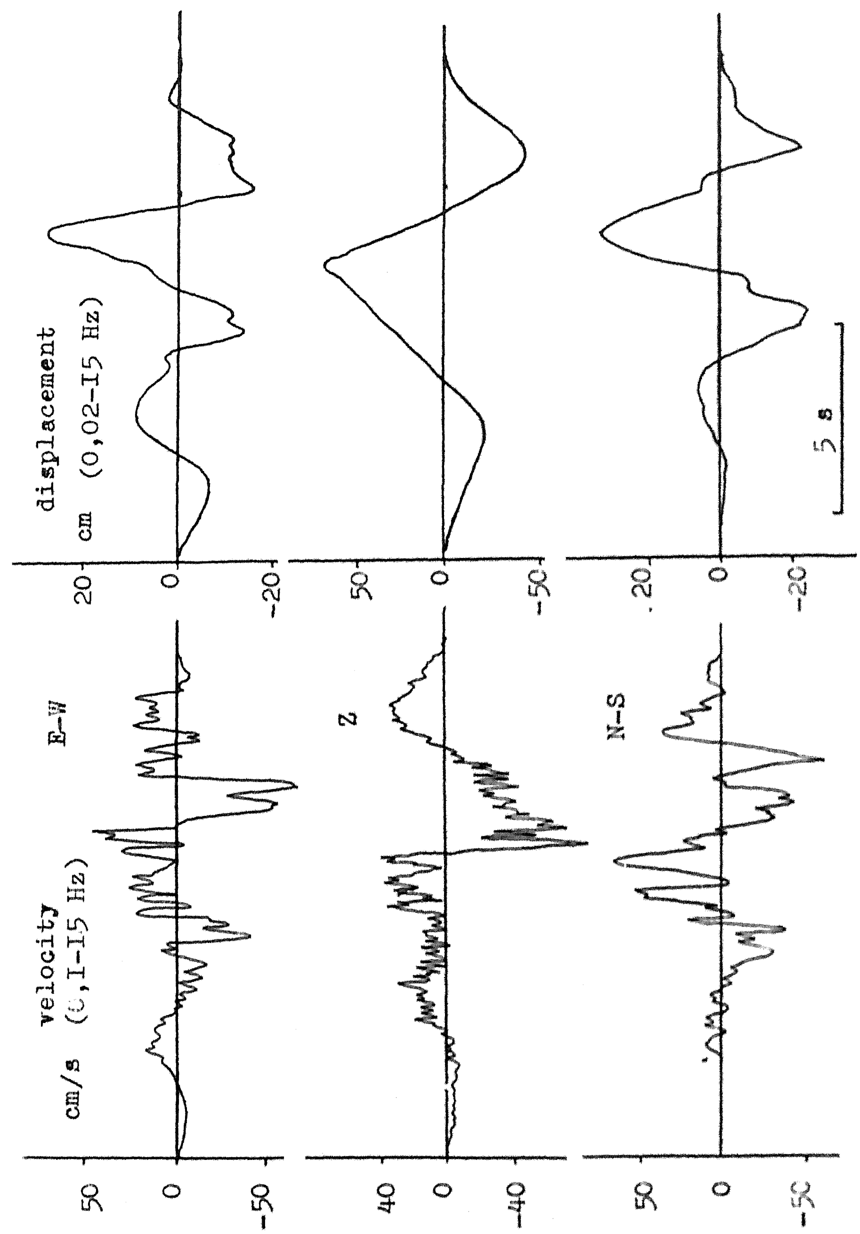
velocity
cm/s (0,I-I5 Hz)
displacement
cm (0,02-I5 Hz)
E-W
Z
N-S
5 s
50
0
-50
40
0
-40
20
0
-20
50
0
-50
20
0
-20

Fig.2