Automatic Arrival Time Picking Using many parameters for the onset discrimination

Shigeki Horiuchi (NIED), and Yoshihisa Iio (DPEI., Kyoto Univ.)

1. Introduction Many authors developed the methods of automatic P and S wave arrival time picking in 1980's. Most of them are based on mathematical methods using AIC. However, reliable picking data are not obtained. Owing to the poor accuracy of automatic pickings, manually picked data are still used for the hypocenter location or studies of the seismic tomography. Because the performance of the recent computer rose drastically compared with that in 1980's, we can develop high quality automatic arrival time picking system, which can measure arrival times as accurate as nearly the same level with human being. We developed a picking code, which **firstly picks several candidates of arrival times and select a correct arrival time by using various algorithms and parameters** for the judgment.

2. Method of P wave picking

1) Detect event occurrence.
2) Determine 10 candidates(Fig1) by changing threshold levels with intervals of 20%.
3) Gather candidates having nearly same onset times.
4) Calculate time differences, average amplitudes, predominant frequencies, later part of amplitude, and displacement amplitude for time sections corresponding to each candidate.
5) Select one waveform pattern among seven patterns having similar characteristic by using observed parameters calculated in 4),
6) Select correct arrival times among candidates by using observed parameters in 4) and several ten parameters for the judgment, which are defined previously according to the waveform pattern. These parameters for the judgment are determined with considering how a human being reads onset times.
7) Check the inclusion of a short period or long period noise. If there are some special noises, search for correct onset time.
8) Check if it reads P wave arrival but not S wave. There are records triggered by S wave and no P wave onset.

Picking of P wave arrival time candidates.

F(j); Filtered wave (200 Hz high cut filter, 50 Hz notched filter if AC noises are included)
F_0 :Average amplitude of noise
N: Number of data

$$Z_k(j) = Z_k(j-1) + (|F(j)| - F_0 * R_k)$$
$$Z_k(j) = 0 \quad ; \text{if } Z_k(j) < 0$$
$$R_k = 1 + C\,K$$
$$C = 0.2$$
K:1～10
Arrival point Jk is determined so that it satisfies
$$Z_k(j) > 0, \quad j = J_k, N$$

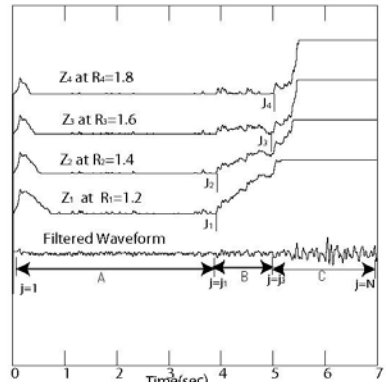

Fig. 1 Method of the picking of arrival time candidates (J1, J2, J3…).

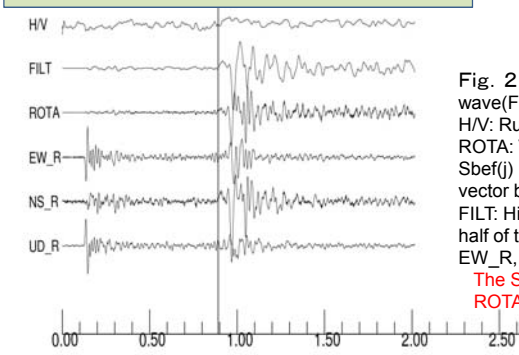

Fig. 2 Plot of seismograms used for the picking of S wave(FILT).
H/V: Running average of ratios between horizontal and vertical.
ROTA: Values of the rotation of two S wave vectors; S(j) and Sbef(j) . S(j) ; S wave vector at point j. Sbef(j) ; Average S wave vector before 0.01 sec from point j.
FILT: Hi-cut filter of ROTA. Cut off frequency is set by a value half of the predominant frequency of P wave.
EW_R, NS_R,UD_R; three components raw data.
The S/N ratio of S wave is increased by the introduction of ROTA and FILT.

3. Method of S wave picking

1) Calculate rotation vector defined by the following equation.

$$R(t) = (S(t) \times U(t-\Delta t)/|U(t-\Delta t)|) \cdot E_Z \qquad (1)$$

Where, S(t), U(t,Δt) and E_Z are S wave vector at time t, unit S wave vector of running average at t-Δt , and unit vector of Z component. R(t) becomes same with SH wave just after S wave arrival. Sign of (1) does not change so long as S wave particle motion continues an elliptic motion, which makes the predominant frequency of R(t) long.
2) S wave picking is made with the same method of P.
3) Calculate Hypocenter.
4) Re-select S wave arrival times from candidates in 2) using S wave travel time residuals. However, we do not change arrival times with large residuals if their selection in 2) are considered to be reliable.

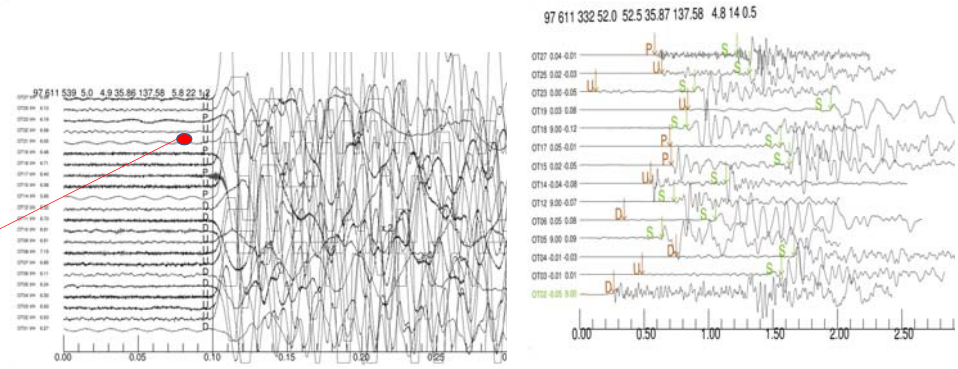

Fig.3. An Example of the result of automatic picking applied to waveform data recorded by a temporal observation near a swarm area with 10kHz sampling.

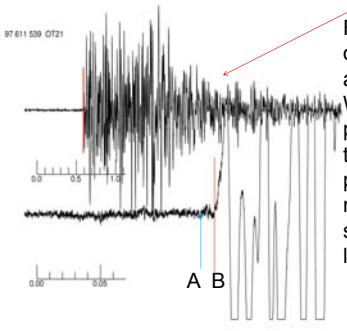

Fig.4 An example of the result of automatic picking. We chose parameters so that our system picks point B but not A in the similar waveform like this example.

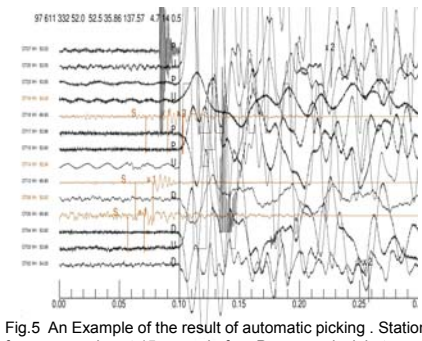

Fig.5 An Example of the result of automatic picking . Station OT27 has high frequency noise at 15 m sec before P wave arrival, but correct arrival time is measured owing to the function of removing high frequency signal. Red color shows waveforms without the recorded of P wave onset. Their time axis is 10 times longer than the others with P wave onset. Our system could not pick onset for events without noise data longer than about 0.01 sec.

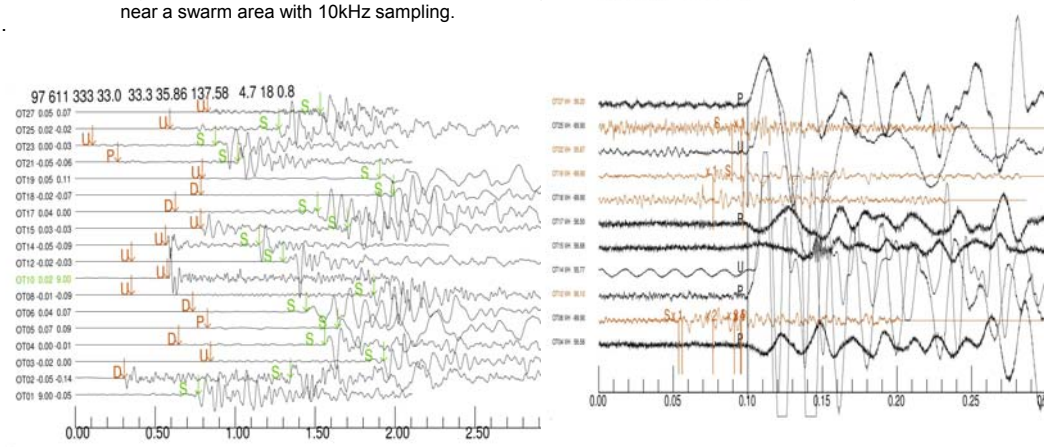

Fig.6 An Example of the result of automatic picking of S wave.

4.Result We developed a code for the automatic picking of P and S wave arrival times using many parameters for the judgment of the correct onset time. We made Offline array seismic observation since 1995 at western Nagano Prefecture with sampling frequency of 10KHz. The application of the code to this data shows that our new code can pick P wave arrival times with accuracy of 1-2 m sec for nearly 99 % of events which occur beneath the array. We found that the rotation in Fig.2 is effective for the increase of S/N ratio of S wave. However, there are events difficult to discriminate correct S wave arrival among candidates even for the present authors, that makes difficult to teach computer how to discriminate correct onsets.