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VII.9 A Pattern Recognition Approach to Seismic Discrimination. Part II: Classification

As explained in Part I (Tjøstheim, 1976) the seismic discrimination problem, when identified as a pattern recognition problem, can be separated into two stages: feature extraction and classification. The construction of a primary feature vector $\underline{Y}$ containing short and long period features was described in Tjøstheim (1976). Using principal component analysis the vector $\underline{Y}$ has been further reduced to an 8-dimensional feature vector $\underline{Z}$ where

$$\underline{Z} = [Z_{EX}(1), \ldots, Z_{EX}(4); Z_{EQ}(1), \ldots, Z_{EQ}(4)] \qquad (1)$$

with

$$Z_{EX}(i) = \underline{Y} \cdot \underline{\hat{h}}^T_{i,EX} \qquad (2)$$

where $\underline{\hat{h}}_{i,EX}$, i=1,...,4 are the four major estimated principal component vectors of the explosion data set. The quantities $Z_{EQ}(i)$, i=1,...,4 are defined similarly.

It is assumed that the $\underline{Z}$ vector is governed by a multivariate Gaussian probability density function $P_1(z)$ or $P_2(z)$ corresponding to the explosion (1) population or earthquake (2) population. The density function estimation problem then reduces to estimating the respective mean vectors and covariance matrices. The following decision rule was applied: For a given observed event with a corresponding feature vector $\underline{Z}$, the quantities $P_1(\underline{Z})$ and $P_2(\underline{Z})$ were computed, and $\underline{Z}$ was assigned to the population i having the largest probability $P_i(\underline{Z})$ of having $\underline{Z}$ occurring.

In practice this means that the decision rule is to declare an explosion if $\hat{S}_1(\underline{Z}) - \hat{S}_2(\underline{Z})$ is positive and an earthquake if this difference is negative. Here

$$S_i(\underline{Z}) = -\tfrac{1}{2}\log|\hat{R}_i| - \tfrac{1}{2}(\underline{Z}-\hat{\underline{\mu}}_i)\ \hat{R}_i^{-1}(\underline{Z}-\hat{\mu}_i)^T \qquad (3)$$

where $\hat{R}_i$ and $\hat{\mu}_i$, i=1,2 are the explosion and earthquake $\underline{Z}$-vector covariance matrices and mean vectors respectively. This classification rule was applied on the data set of 52 explosions and 73 earthquakes described in Tjøstheim (1976). The results are displayed in the bottom part of Fig. VII.9.1 where the events have been plotted according to their value of $\hat{S}_1(\cdot)-\hat{S}_2(\cdot)$. It is seen that all events are correctly classified.

For matters of comparison we treated the m_b:M_s data and the X1:X2 discriminant data of Tjøstheim and Husebye (1976) in a similar way. That is, we used the discriminant (3) but with $\underline{Z}$ replaced by $\underline{U} = (m_b, M_s)$ or $\underline{V}$ = (X1, X2). (The notation L1:L2 is used on the figure.) From Fig. VII.9.1 it is seen that the m_b:M_s data produces serious overlap and that the performance is clearly inferior to the discriminant based on $\hat{S}_1(\underline{Z})-\hat{S}_2(\underline{Z})$. The X1:X2 data produces complete separation, but with one explosion very close to the explosion-earthquake decision line.

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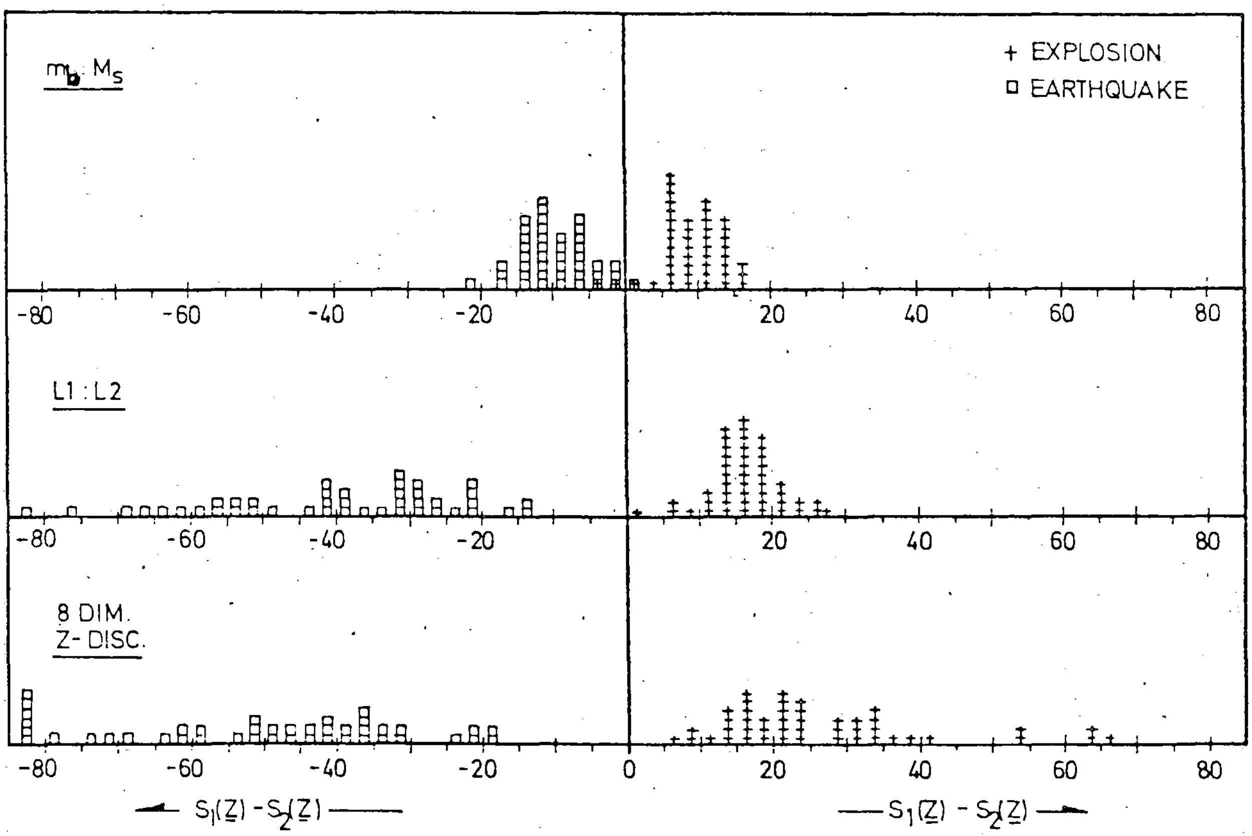

Fig. VII.9.1 Histogram of discrimination scores $S_1(\cdot)-S_2(\cdot)$ as determined by Eq. (3).