$\vec{w} = \sum \alpha_i \vec{x}_i$

$w \quad S_B$

$\sum \sum \alpha_i \vec{x}_i^T (m_2 - m_1)(m_2 - m_1)^T \vec{x}_j \alpha_j .$

$$J(w) = \frac{\vec{w}^T S_B \vec{w}}{\vec{w}^T S_W \vec{w}}$$

$(19 \times 1040) \times (19 \times 1040)$

$\Rightarrow . \quad \underline{S_B \vec{w} = \lambda S_W \vec{w}}$

let $\underline{\vec{w} = \sum_{i=1}^{20} \alpha_i \vec{x}_i}$ $\qquad \vec{x}_i : \underline{\mathbb{R}^{19 \times 1040}}$, $i \in \{1, 2, \cdots, 20\}$

then, $$J(\vec{w}) = \frac{\sum_{i=1}^{20} \alpha_i \vec{x}_i^T S_B \sum_{j=1}^{20} \alpha_j \vec{x}_j}{\sum_{i=1}^{20} \alpha_i \vec{x}_i^T S_W \sum_{j=1}^{20} \alpha_j \vec{x}_j}$$

$$= \frac{\vec{\alpha}^T P_B \vec{\alpha}}{\vec{\alpha}^T P_W \vec{\alpha}}$$

where $P_B = X^T S_B X$
$P_W = X^T S_W X$

$X \in \mathbb{R}^{19760 \times 20}$

So, $P_B, P_W \in \mathbb{R}^{20 \times 20}$

$\Rightarrow . \quad P_B \vec{\alpha} = \lambda P_W \vec{\alpha}$

$S_B = (m_2 - m_1)(m_2 - m_1)^T$

$P_B = \left(\underline{X^T (m_2 - m_1)}\right)(m_2 - m_1)^T X$

$X \in \mathbb{R}^{19760 \times 20}$

$m_2 - m_1 \in \mathbb{R}^{19760 \times 1}$

let $F = X^T \cdot (m_2 - m_1) \in \mathbb{R}^{20 \times 1}$

then, $P_B = F \cdot F^T \in \mathbb{R}^{20 \times 20}$