Fast Time Scale Modification using Envelope-Matching Technique (EM-TSM)

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Introduction

- EM-TSM(Envelope-Matching Time-Scale Modification)是修改SOLA (Synchronized Overlap-and-Add)，同步疊加演算法)，減少在SOLA中對於正規化交相關的計算量。

Review of Synchronized Overlap-And-Add (SOLA)

- SOLA(Synchronized Overlap-and-Add)基於OLA(Overlap-and-Add)，增加了與相鄰的音框的相似度計算(正規化交相關)。

Review of Synchronized Overlap-And-Add (SOLA)

$$R[k] = \frac{\sum_{i=0}^{L-1} y[m \times S_s + k + i] \cdot x[m \times S_a + i]}{\left[\sum_{i=0}^{L-1} y^2[m \times S_s + k + i] \cdot \sum_{i=0}^{L-1} x^2[m \times S_a + i] \right]^{\frac{1}{2}}} \qquad (1)$$

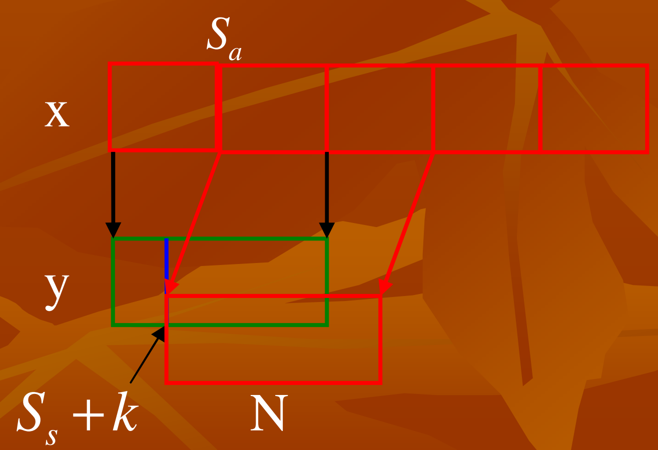
alpha>1，速度變慢，alpha<1，速度變快。

$S_s = alpha \times S_a$　　k={-sa,sa}

S_a 是分析音框長度

S_s 是合成音框長度

L是疊加區域長度



The Envelope Matching Technique

- EM-TSM（Envelope-Matching TSM）是修改於SOLA，它是使用分析音框以及合成音框之間的sign資訊來修改正規化交相關函式，雖然使用sign資訊的相似度沒有SOLA好，但是這個方法可以減少計算量，提供了很好的想法。

$$R[k]=\frac{\sum_{i=0}^{L-1} sign\{y[m\times S_s+k+i]\}\cdot sign\{x[m\times S_a+i]\}}{L} \quad (2)$$

L為重疊的區域長度

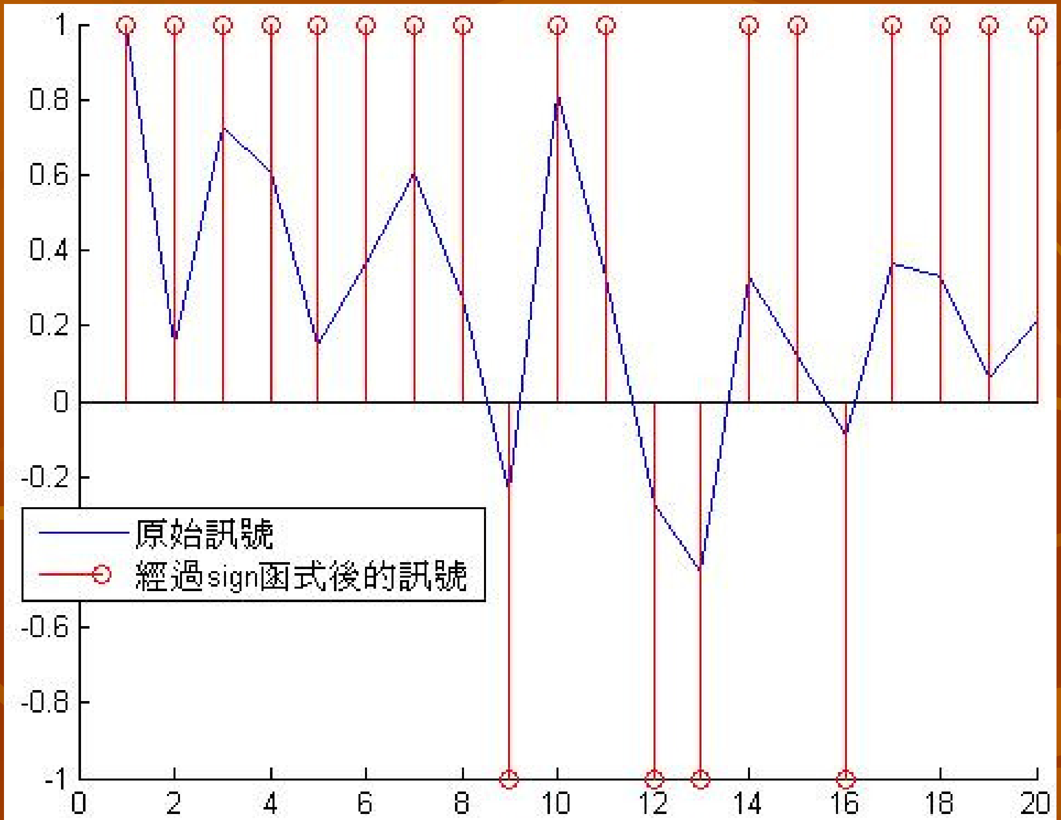
$$sign(x)=\begin{cases}1 & ,x\geq 0\\ -1 & ,x<0\end{cases}$$

The Envelope Matching Technique

- Sign資訊

$$x_2[i] = sign(x[m*S_a+i]) = \begin{cases} 1 & x[m*S_a+i] \geq 0 \\ -1 & x[m*S_a+i] < 0 \end{cases}$$

The Envelope Matching Technique



經過Sign處理後的波形

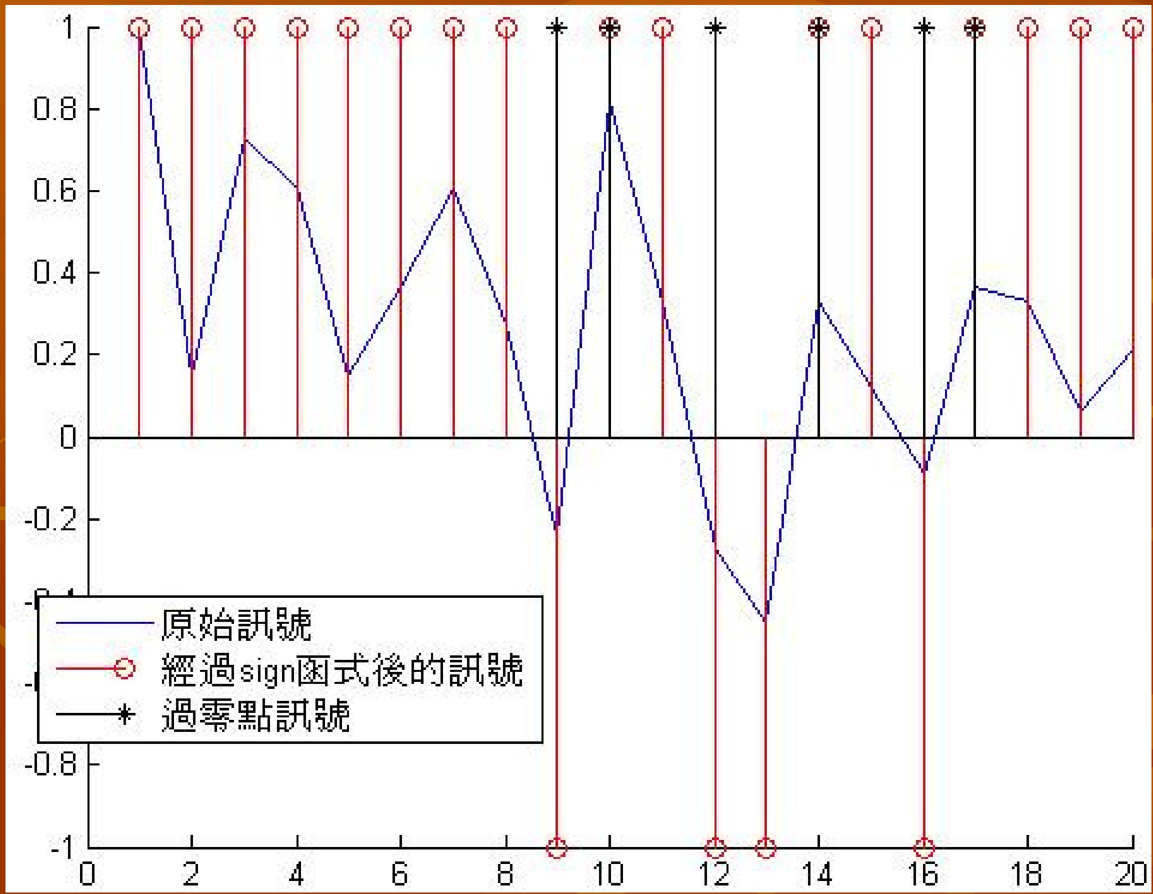
The Envelope Matching Technique

- EM-TSM是將輸入音框（分析音框x）與輸出音框（合成音框y）做sign函式簡化，再做過零點偵測，最後對已作過零點偵測的輸入音框與輸出音框做互斥或（Exclude-OR）將爲1的位置記錄下來存入C_k。

The Envelope Matching Technique

- 過零點偵測
  - $A_k=\{i:x_{2,k}[i-1]*x_{2,k}[i]=-1, 0<i<L_k-1\}$,共有p個過零點，且不超過$L_k$-1個。
  - $B_k=\{i:y_{2,k}[i-1]*y_{2,k}[i]=-1, 0<i<L_k-1\}$,共有q個過零點，且不超過$L_k$-1個。
- 然後將所有過零點的位置記錄下來。

The Envelope Matching Technique



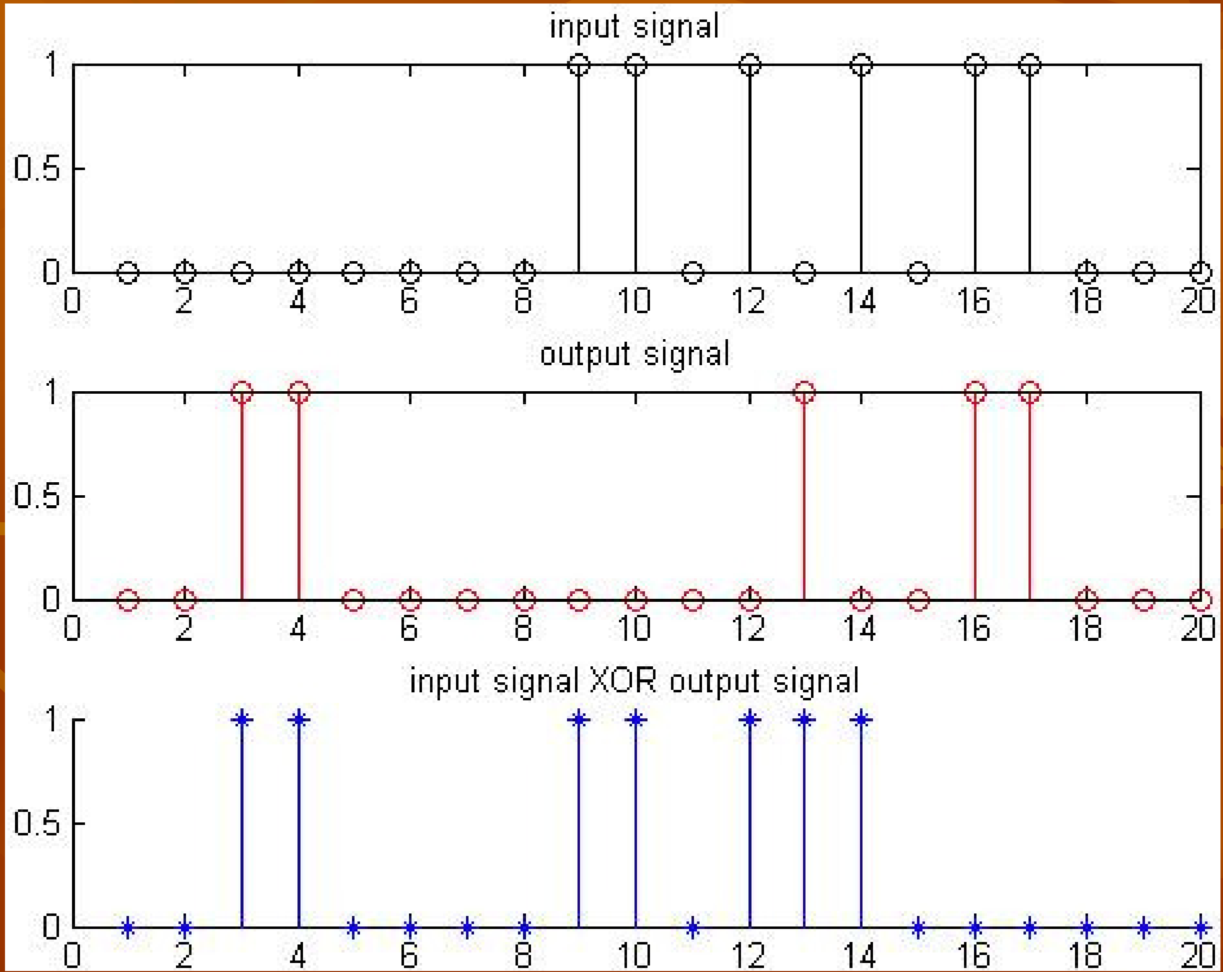
The Envelope Matching Technique

- C_k是A_k和B_k擁有不同過零點的位置，且r<=p, r<=q,所以可以得到

$$C_k = A_k \oplus B_k = \left(A_k \cap B_k^c\right) \cup \left(A_k^c \cap B_k\right). \text{Let r = cardinality of } A_k \cap B_k$$

p 是A_k的過零點數量
q 是B_k的過零點數量

The Envelope Matching Technique



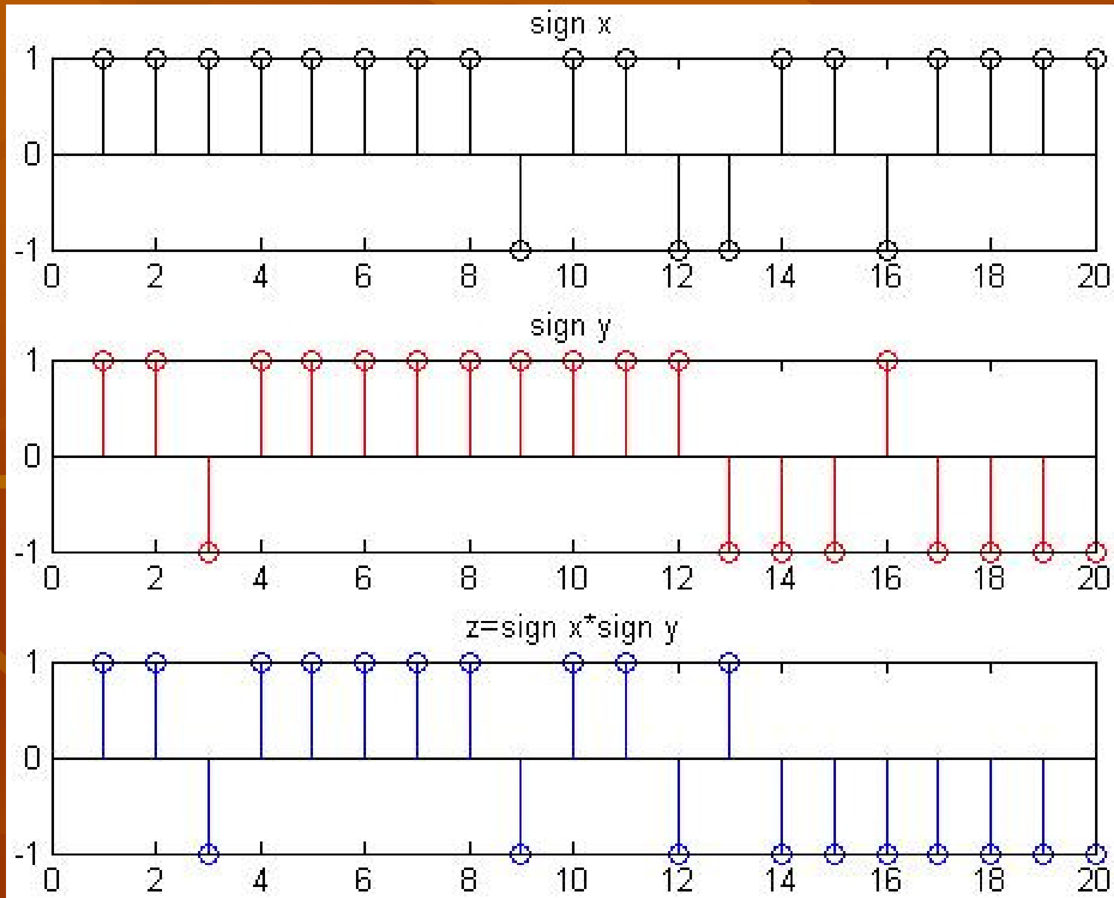
The Envelope Matching Technique

$$R[k] = \frac{\beta_k}{L}\left[2 \sum_{j=1}^{p+q-2r} (-1)^{j+1} c_{k_j} + (-1)^{p+q} L \right]$$

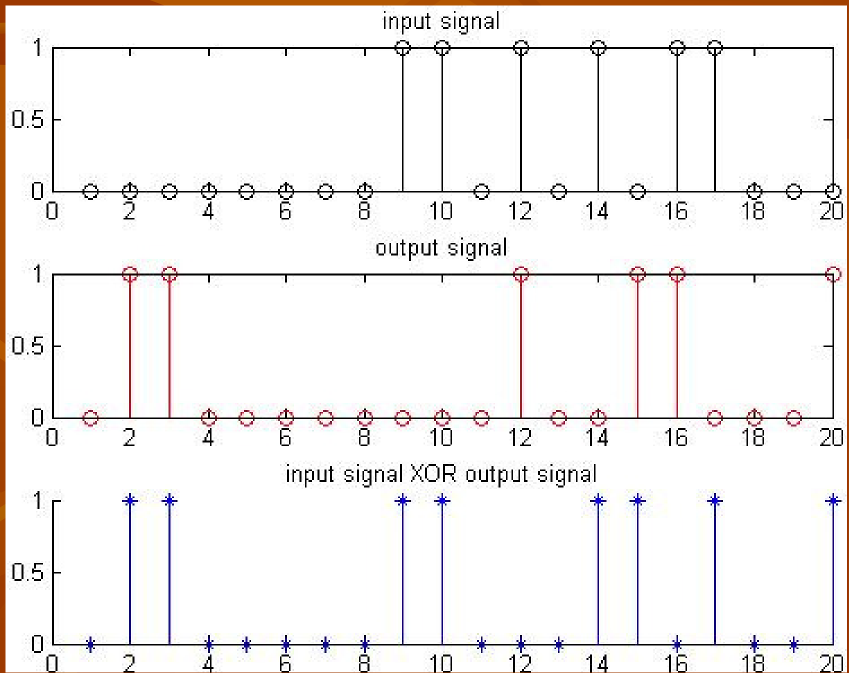
$$\beta_{z,k} = z_{2,k}[0] = z_{2,k}[1] = \ldots = z_{2,k}[C_{k,1} - 1] = -z_{2,k}[C_{k,1}] = 1$$

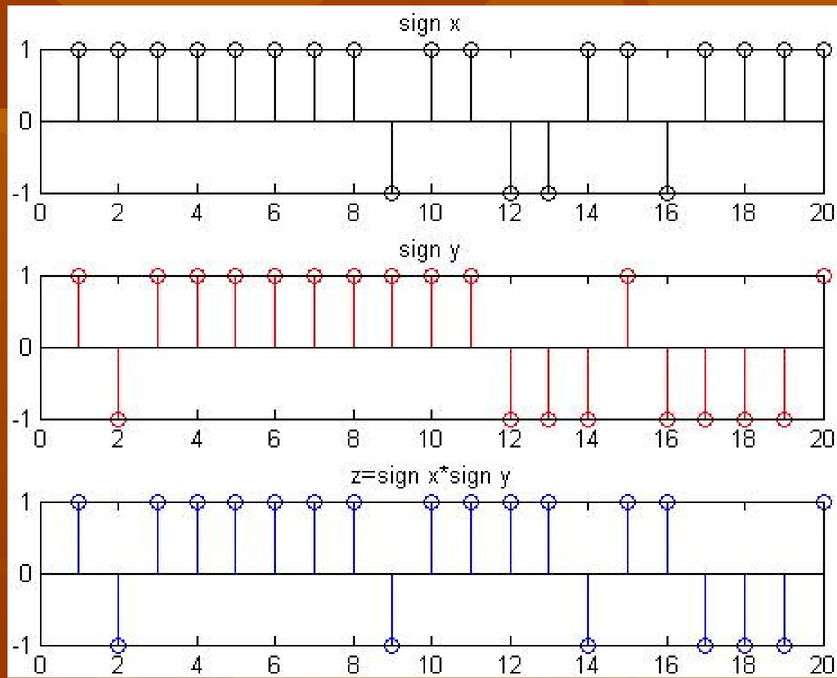
- 如果等於0的話，表示波形相同。
- 如果等於1的話，表示波形有地方不同。
- L爲重疊的區域

The Enveloape Matching Technique

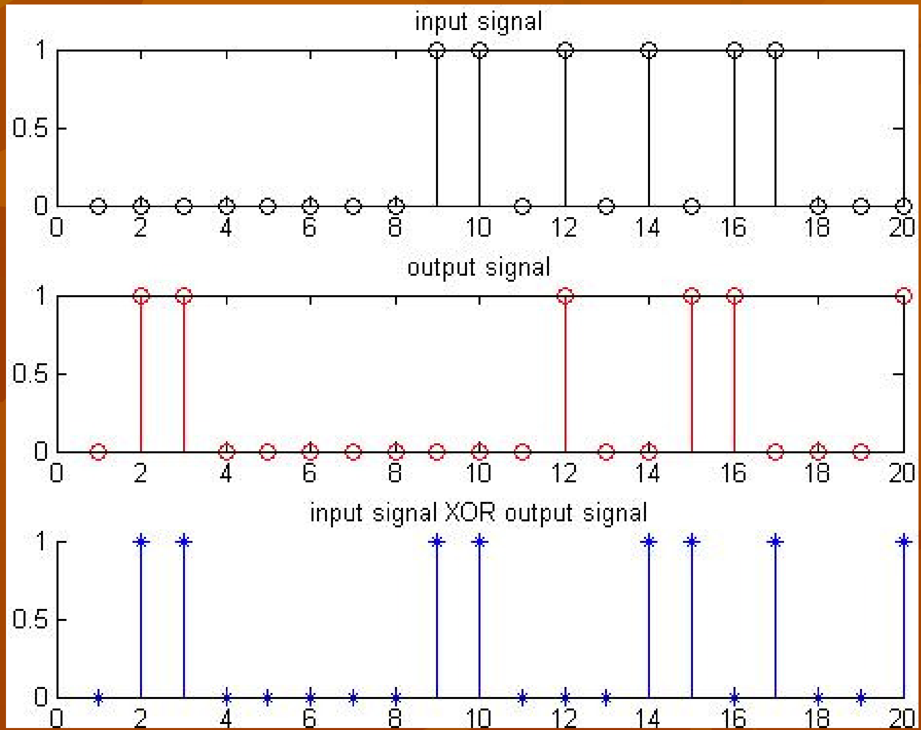


The Envelope Matching Technique





The Envelope Matching Technique



$$R[k]=\frac{\beta_{z,k}}{L}\left[2\sum_{j=1}^{p+q-2r}(-1)^{j+1}c_{k_j}+(-1)^{p+q}L\right]$$

$$C_k=\{2,3,9,10,14,15,17\}$$

$$\beta_{z,k}=z_{2,k}[0]=z_{2,k}[1]=\ldots=z_{2,k}[C_{k,1}-1]=-z_{2,k}[C_{k,1}]=1$$

$$R[k]=\frac{1}{20}[(2-0)-(3-2)+(9-3)-(10-9)+(14-10)-(15-14)+(17-15)-(20-17)]$$

$$=\frac{1}{20}[2\times(2-3+9-10+14-15+17)+20]=2.55$$

Objective Mesaurment of Synthesized Signal Quality

- Mean Square Difference

$$E = \frac{1}{M}\sum_{m=1}^{M}\frac{1}{L_m}\sum_{i=0}^{L_m-1}\left[y\left(m\times S_s + k_{opt} + i\right) - x\left(m\times S_a + i\right)\right]^2$$

method	MSD	Speed-up
SOLA	3.33E-03	1
EM-TSM	1.24E-02	33.4

Simulation and Results

- 計算量
  - SOLA
    - L_k個乘法
    - L_k-1個加法
    - 一個除法
  - EM-TSM
    - p+q-2r個加法 p,q,r<<L_k
    - 一個條件變號(β_k)
    - 一個除法

Conclusions

- 這個方法提供了我們一個好的想法，來修改TSM中的正規化交相關的公式。