Empirical Match Algorithm

The task of determining the primary user activity sequence using the estimated HMM parameters like prior probability \( \pi \), state transition probabilities \( p_{10}, p_{01} \) & channel transition probabilities \( h_{10}, h_{01} \) and the secondary user observation sequence is conventionally done using the Viterbi algorithm. “Empirical Match” an alternative approach to the Viterbi algorithm in estimating the primary user activity is proposed. The Empirical Match algorithm is based on minimizing the Sum Squared Error (SSE) between the parameters obtained by iterative updation of the estimated sequence and the estimated HMM parameters, which is an outcome of Particle Swarm Optimization (PSO).

It is assumed that the primary user activity sequence is known for 3.33% of the total length of sequence \((100 \times 3000)\) slots. The performance of the classical Viterbi algorithm is compared with the novel Empirical Match algorithm as number of the matches between the estimated and actual sequences. The estimation of primary user activity is done for the rest 96.67% of the sequence.

A comparison of the Viterbi algorithm and the Empirical match algorithm which is based on the number of matches between the actual and the estimated PU activity sequence is given in the table. An average improvement of 10.0592% is achieved using the proposed algorithm which accounts for a improved match of around 3 lakh slots. This article is accepted as a reviewed book chapter in the edited volume of “Computational Intelligence for Pattern Recognition” in Springer publications.

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Decomposition of signal space and noise space

The summation of two discrete sinusoidal sequences (with two different frequencies) with arbitrary phase and amplitude can be viewed as the outcome of the random process \( (x_n) \). The elements of the random vector \( x \) are obtained by collecting the data points across the process at time instant \( n \) and \( n-1 \) \( \forall n \). The vector space spanned by the collected random vectors form the signal space. If the basis vectors of the identified space are chosen \( [x_n x_{n-1}]^T \) and \( [x_{n-1} x_{n-2}]^T \), we can think of generating the sinusoidal sequence as the linear combinations of these vectors in the recursive manner. The co-efficients are obtained using MMSE technique. Summation of the two sinusoidal signals (refer Fig.1) obtained using the recursive technique (red color) and is compared with the actual sinusoidal signal (blue color).

![Fig. 1](image1)

![Fig. 2](image2)

Sinusoidal sequence \( (x_n) \) is added with white noise random process \( (w_n) \) to obtain the random process \( y_n = x_n + w_n \). Consider the vector space \( (Y) \) spanned by collecting the vectors (with elements sampled at time instant \( n \), \( n-1 \) and \( n-2 \) \( \forall n \) of \( y_n \)). We compute the eigen basis of this considered vector space (dimension 3) corresponding to the three eigenvalues. The eigenvector corresponding to the lowest eigenvalue corresponds to the noise space \( (W) \) and the other two eigenvectors belongs to the signal space \( (X) \). In Fig. 2, the subplot (1,1) illustrates the decomposition of an arbitrary vector \( y \) into signal vector \( X \) and noise vector \( W \). The subplot (1,2), (2,1) and (2,2) illustrates the sample vectors \( (3 \times 1) \) belonging to the vector space \( Y \), \( X \) and \( W \) respectively.

Link to the m-file: Signal and noise space

Quotes

"Don't read success stories, you will only get a message. Read failure stories, you will get some ideas to get success." — Dr. A.P.J. Abdul Kalam

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