NOVATEUR PUBLICATIONS
INTERNATIONAL JOURNAL OF INNOVATIONS IN ENGINEERING RESEARCH AND TECHNOLOGY [IJIERT]
ISSN: 2394-3696
VOLUME 2, ISSUE - 10, Oct.-2015

PHYSIOLOGICAL TREMOR ESTIMATION USING BANDLIMITED FOURIER LINEAR COMBINER

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ABSTRACT

In robotic assisted surgery accurate cancelation of physiological tremor plays vital role. Tremor is the core cause for human imprecision during microsurgery. Physiological tremor makes some procedures remarkably difficult to perform and this involuntary motion affects the performance of robotic based hand held instruments. The presence of phase delay due to sensing or filtering procedures degrades the performance of human-machine intervention. To conquer the phase delay, multistep prediction can be employed. The paper includes the estimation of tremor by using single step and multistep BMFLC method. The comparative study of the results proved that the multistep BMFLC method for tremor prediction is more efficient.

KEYWORDS: Physiological tremor, Bandlimited Fourier Linear Combiner (BMFLC).

INTRODUCTION

Human tremor is an undesired trembled phenomenon in one's body such as hands or arms. The tremor is an undesired, periodic-like and roughly harmonic motion. Though human tremor has no vulnerability, but its undesired character brings out inconvenience to human's daily work and some fine operations. Physiological tremor presents in all human with amplitude having in the frequency range of 8–12 Hz with amplitude varying between 50μm and 100 μm. Robotics-assisted surgical instruments and procedures are increasingly playing a vital role for biological motion compensation due to their robustness, high precision, and estimation accuracy.

This tremor leads to an intolerable ambiguity of the surgical procedure (e.g., vitroretinal surgery). Robotic technologies provide new ways to compensate quasi-periodic biological motion, enabling higher surgical accuracy without determined measures. During surgeries, accuracy of the hand held instrument also varies due to surgeons hand tremor and it reduces surgeons ability to precisely manipulate instrument. This may cause irretrievable damages to the small and delicate organs. Thus active cancellation of this tremor will improve manipulation accuracy in surgeries. Many involuntary components are present in normal human hand movement. These include physiological tremor, jerk and low frequency drift. Several types of enhanced devices have been or are being developed in order to improve manipulation accuracy of surgeons. Although adaptive tremor estimation initiates no additional phase delay, real-time tremor compensation accuracy depends on some factors such as prefiltering, numerical integration, noise, jerk, and drift. Multistep prediction is popular where time delay is inevitable or posterior information is required.The different

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methods can be used for the proposed system. The suitable method can be used for multistep prediction.

LITERATURE REVIEW

Robotic assisted surgical instruments and procedures need to concentrate on biological motion compensation due to the sturdiness, high precision, estimation accuracy [3], [5]. On the basis of this robotic technology, significant research was focused on compensation of various biological motions like respiratory motion in treatment of lung tumour , pathological tremor, heart beat in intracardiac surgery and physiological tremor [3],[6]. Different hand-held robotic instruments were developed for compensation of physiological tremor in real time [7]. In these instruments, filtering plays a fundamental role in achieving maximum accuracy. The filtered tremor signal from the sensed motion is used to generate an opposing motion to compensate the tremor motion in real time. Zero-phase filtering is required for effective tremor compensation.

To conquer the intrinsic disadvantages of linear filters, several adaptive algorithms are developed. In [2], [7] Fourier-series-based adaptive algorithms like weighted frequency Fourier linear combiner (WFLC) and band limited multiple linear Fourier combiner (BMFLC) are used.

METHODOLOGY

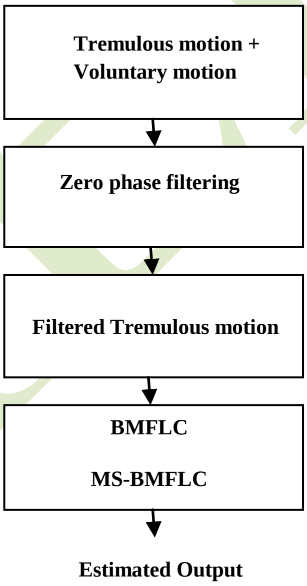

Fig: 1: Flow diagram

The input signals of hand tremor are obtained with accelerometer. The tremulous motion lies between 8-12 Hz with voluntary motion lying between 0-2 Hz.The output from accelerometer is given to the band pass filter to separate the tremulous motion from the voluntary motion. To eliminate the unwanted integration drift and noise, zero phase band pass filter is employed. The filter order and cut-off frequency need to be selected to remove unwanted low-frequency drift.

Adaptive algorithms like least mean square **(LMS)** can be employed for adaptive estimation of state. To conquer the phase delay, multistep prediction based on BMFLC method can be used. The difference between actual tremor and estimated output signal is calculated as prediction error.

BANDLIMITED MULTIPLE FOURIER LINEAR COMBINER (BMFLC)

Presence of multiple peaks in the FFT spectrum is the result of modulation of multiple frequency components in tremor. The range of frequencies and the bandwidth for subjects are analyzed in the previous section. Existing methods FLC, WFLC algorithms in general adapts to a single frequency present in the incoming signal. For the case of tremor signal modulated by multiple frequencies close in spectral domain, the performance of WFLC will be degraded. Even the presence of two or three frequencies closely spaced in spectral domain can adversely affect the performance of WFLC. One limitation of WFLC is its inability to extract a periodic signal containing more than one dominant frequency. To overcome the problems associated with WFLC, a new algorithm Bandlimited multiple Fourier linear combiner (BMFLC) which comprises of several Fourier Linear Combiner's was developed. Bandlimited Multiple-Fourier Linear Combiner (BMFLC) is suitable for estimation of band limited signals consisting of multiple frequency components. For the estimation of the unknown tremor signal, a series comprising of sine and cosine components to form Bandlimited multiple Fourier linear combiner at time instant 'k' is given by equation (8).

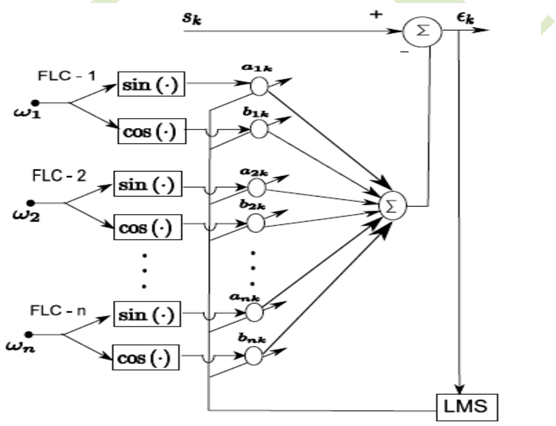

Fig: 2: BMFLC

$$y_k = \sum_{r=1}^{n} a_{rk} \sin(w_r k) + b_{rk} \cos(w_r k) \qquad (1)$$

where *are* the frequencies within a given band of interest and $'n'$ represents the number of frequencies used. The frequencies can be an integer as well as a rational number. Here LMS algorithm is used to update the weight vector. The weights of BMFLC can be updated via equations as:

$$\varepsilon_k = s_k - y_k \qquad (2)$$

$$\vec{w}_{k+1} = \vec{w}_k + 2\mu \vec{x}_k \varepsilon_k \qquad (3)$$

ISSN: 2394-3696
VOLUME 2, ISSUE - 10, Oct.-2015

An estimate of the desired signal can be given by:

$$y_k = \overrightarrow{w_k}^T . \overrightarrow{x_k} \qquad (4)$$

MULTISTEP BANDLIMITED MULTIPLE FOURIER LINEAR COMBINERS (MS-BMFLC)

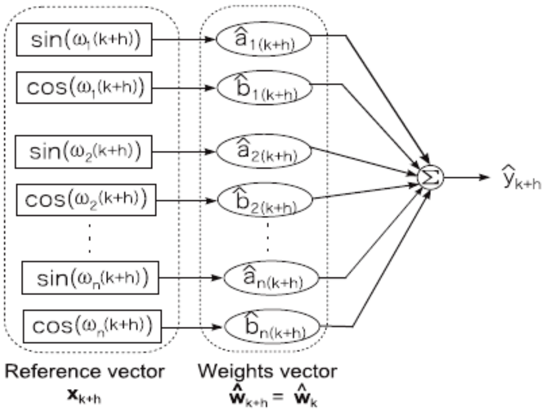

Fig: 3: MS-BMFLC

Multistep prediction requires prediction of the signal y_{k+h} samples ahead, based on its previous inputs. As in BMFLC, the vector x_k i.e. the input reference can be accurately known for prediction. Assuming adaptive weights to be constant over prediction length, multistep prediction can be obtained. With the reference vector x_{k+h} accurately known at the '$k + h$' instant, the weight vector at the current sample can be employed to obtain multistep prediction for output y_{k+h} as:

$$y_{k+h} = \overrightarrow{w_k}^T . \overrightarrow{x_{k+h}} \qquad (5)$$

COMPARATIVE STUDY OF SINGLE AND MULTISTEP BMFLC

The performance analysis is made by using single step and multistep BMFLC. Five specimen tremor signals are analysed for delays in msec and corresponding accuracy is obtained for prediction of tremor as follows.

$$\%\ \text{Accuracy} = \frac{\text{RMS}(S) - \text{RMS}(e)}{\text{RMS}(S)} \times 100$$

Table 1: Results for single step BMFLC prediction.

Samples	4 ms	8 ms	12ms	16ms	20ms
Signal 1	77.05	75.85	75.25	74.95	74.55
Signal 2	75.97	74.77	74.17	73.87	73.47
Signal 3	76.54	75.34	74.74	74.44	74.04
Signal 4	76.35	75.15	74.55	74.25	73.85
Signal 5	75.23	74.03	73.42	73.13	72.73

Table 2: Results for multistep step BMFLC prediction.

Samples	4 ms	8 ms	12ms	16ms	20ms
Signal 1	86.88	86.88	86.88	86.89	86.88
Signal 2	86.87	86.82	86.89	86.88	86.88
Signal 3	86.88	86.88	86.88	86.88	86.88
Signal 4	86.88	86.88	86.89	86.88	86.89
Signal 5	86.88	86.88	86.88	86.88	86.88

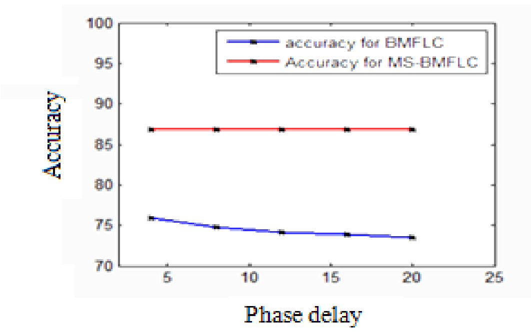

Fig4. : Graph of Accuracy Vs. phase delay.

CONCLUSION

The accuracy results for sampling frequencies and delays are obtained with single step BMFLC and multistep BMFLC prediction methods. The results are consistant. The multistep BMFLC method is more efficient than single step BMFLC.

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