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PARAMETERS ESTIMATION OF DOUBLE EXPONENTIAL SMOOTHING FOR HAND JITTER REDUCTION USING GENETIC ALGORITHM

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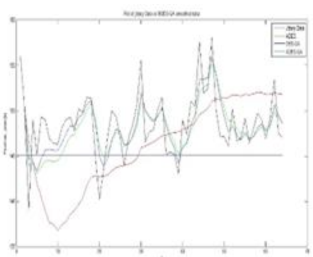
Graphical abstract



Abstract

Hand jitter is a natural tremor that has become a concern in many areas such as microsurgery, collaborative environment and tele-tutoring as it can cause imprecision, inaccuracy and misleading pointer information. Over the recent years, many researches have been done to reduce hand jitter but they are either too complex or too time consuming. Hence, to overcome the limitations, Double Exponential Smoothing (DES) has been used as an alternative, which is a simple and fast prediction algorithm. However, estimating the parameter values of DES is a difficult process that requires juggling between several criteria. In this paper, an optimal parameter estimation technique of DES using Genetic Algorithm was developed to find the optimal parameter values. Thorough comparisons have been made with previous methods to prove the magnitude of improvement. Our study found that the proposed method is able to reduce the hand jitter by 52% compared to the benchmarked methods. Hence, DES is suitable to be implemented in many applications that require precise and accurate hand-based pointing system.

Keywords: Parameter estimation; hand jitter reduction; double exponential smoothing; genetic algorithm

Abstrak

Ketar tangan adalah gegaran semula jadi yang menjadi perhatian dalam banyak bidang seperti mikropembedahan, persekitaran kolaboratif dan tele-pembelajaran kerana ia boleh menyebabkan ketakpersisan, ketakjituan dan maklumat penunjuk yang mengelirukan. Sejak beberapa tahun kebelakangan ini, banyak kajian telah dilakukan untuk mengurangkan ketar tangan namun mereka adalah terlalu kompleks atau terlalu memakan masa. Oleh itu, untuk mengatasi halangan-halangan ini, Pelicinan eksponen berganda (DES) telah digunakan sebagai alternatif, yang mana ia merupakan satu algoritma ramalan yang mudah dan pantas. Walau bagaimanapun, menganggar nilai parameter DES adalah satu proses yang sukar yang memerlukan kesimbangan antara beberapa kriteria. Dalam kertas cadangan ini, satu teknik penganggaran parameter yang optimum bagi DES menggunakan Algoritma Genetik telah dibangunkan untuk mencari nilai-nilai parameter yang optimum. Perbandingan yang teliti telah dibuat dengan kaedah terdahulu untuk membuktikan magnitud pembaikan. Kajian kami mendapati bahawa kaedah yang dicadangkan mampu mengurangkan ketar tangan sebanyak 52% berbanding dengan kaedah tanda aras. Oleh itu, DES sesuai untuk dilaksanakan dalam banyak aplikasi yang memerlukan kepersisan dan ketepatan dalam sistem penunjuk berasas tangan.

Kata kunci: Penganggaran parameter; pengurangan ketar tangan; pelicinan ekponen berganda; algoritma genetik

1.0 INTRODUCTION

Jitter or tremor is a small amplitude oscillation of the body part which appears as if twitching. This natural tremor, which is also known as physiological tremor may happen because of stress, nervousness, lack of sleep or involuntary muscle construction and relaxation. It may affect legs, vocal cords, arms but the most commonly affected body part is the hand, which is commonly known as hand jitter. Hand jitter may occur to a healthy person if he held up a laser pointer in an outstretch hand for a period of time [1], or a surgeon positioning a small incision during microsurgery [2]. It is hard to ignore the negative effect of hand jitter as it usually leads to erratic and jerky laser spot in a teleconference, unsteady laser interaction with home devices for smart home system for the elderly, or the more crucial effect, an inexcusable inaccuracy of incision in the surgical procedure.

Recently, many researchers have shown more interest in the research of lessening the jitter effect in various fields. Smart surgical instruments which implement the assistance of a robotic handheld device was introduced to reduce the surgeons' tremor during microsurgery [3]. Apart from that, other researchers avoided the jitter problem altogether with a special design for system-specific approach [4]. Various filtering techniques such as Fourier Linear Combiner (FLC) [2] and Kalman filters [5] have also been used to reduce jitter. The disadvantages of these methods are that they are complex, which leads to high computational requirement.

Double exponential smoothing (DES) is a popular predictive tool used in stock market forecasting, which has been introduced as an alternative to Kalman filter [6] where it has been proven to be faster and more accurate. LaViolas have employed Brown's one parameter linear method, in which a static parameter was used to predict the users' positions and orientations in virtual environment. Chung and Kim [7] then have improved the method by adding an adaptive element in estimating the parameters by employing Holt's two parameters method for laser interaction system. Zuhaimy and Yeng [8] have explored the potential of Genetic Algorithm (GA) in estimating the static parameters of DES method to overcome weaknesses in parameter selection.

The basica idea of the proposed method is similar to [7], which is to reduce hand jitter based on Double Exponential Smoothing method with adaptive parameters with an additional optimal parameter estimation module by using Genetic Algorithm. The proposed method differs from the method in [8] because of the usage of adaptive parameters estimation rather than fixed parameters estimation.

This paper is organized in the following way. Section 2 begins by laying out the model of the proposed system using GA optimization technique. Then, to the next section discusses the obtained results and finally conclusion is given in section 4.

2.0 METHODOLOGY

In order to record the hand jitter, the laser spot movement projected to a screen was captured by using video camera and translated into a time series data. The experiment was set up using a basic laser pointer interaction system as shown in Figure 1.

Five participants aged between 25 to 35 years old were asked to point to the cross section of a crosshair target, shown in Figure 2 using a laser pointer. They were required to hold the laser pointer steadily for 20 seconds at a 10 feet distance from the projection screen. The test videos were captured at a rate of 15 fps with 360 x 640 pixels of resolution.

58 test videos were taken with more than 500 time series data were extracted from each test. Firstly, the time series data in the form of laser spot's coordinates were detected from the test video by using maximum intensity method, which is the most common method to detect a laser spot [9]. Then, the time series data, which hereafter will be called jittery data were smoothed using the proposed method to reduce the jitter.

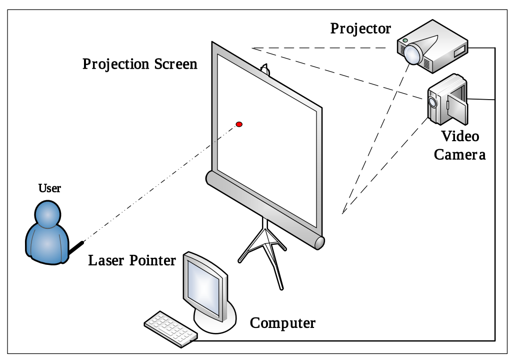


Figure 1 Basic laser pointer interaction system

Figure 2 Crosshair target used in the proposed system

2.1 System Modelling

Time series is a sequence of observations which contain some form of random variation. Exponential smoothing is a popular method to reduce the effect of random variation in time series. An extension to basic exponential smoothing is Double Exponential Smoothing, which uses past data to generate future prediction. Exponentially decreasing weights were then assigned to the older data. DES operates based on the assumption that the system model has a constant and linear trend. The DES method at a time instant t_k is given by the equations below:

$$S_k = \alpha Z_k + (1-\alpha)(S_{k-1} + b_{k-1}) \quad (1)$$
$$b_k = \gamma(S_k - S_{k-1}) + (1-\gamma)b_{k-1} \quad (2)$$

where
S_k : Smoothed output
Z_k: Original data
b_k: Trend rate
α : Smoothing constant with α∈[0,1]
γ: Trend constant with γ∈[0,1]

Equation 1 eliminates the lag and adjusts the current smoothing output directly to the previous trend rate, which was added to the previous smoothed output. Equation 2 finds the displacement between current and previous smoothing output in order to updates the trend weightage.

Determining appropriate values for α and γ are crucial in DES as it affects the performance efficiency. Undoubtedly, an optimal selection of smoothing constant parameter, α and trend constant parameter, γ are needed to minimize the statistical error. GA is well-known powerful search and optimization technique. Thus, by integrating GA as parameter estimator [8], the optimal parameters with minimum statistical errors can be identified.

The adaptive variant of Double Exponential Smoothing (ADES) proposed by Chung and Kim have adaptively estimated α and γ parameters. Minor modification has been made to equation 1 and 2 to adjust for the dynamic change. The equations for ADES were expressed as follows:

$$\boldsymbol{S}_k = \alpha_k \boldsymbol{Z}_k + (1-\alpha_k)(\boldsymbol{S}_{k-1} + \boldsymbol{b}_{k-1}) \quad (3)$$
$$\boldsymbol{b}_k = \gamma_k(\boldsymbol{S}_k - \boldsymbol{S}_{k-1}) + (1-\gamma_k)\boldsymbol{b}_{k-1} \quad (4)$$
$$\alpha_k = f(u_k), \quad \gamma_k = g(u_k) \quad (5)$$

where $\boldsymbol{S}_k, \boldsymbol{Z}_k$ and $\boldsymbol{b}_k$ are 2D vectors that represent the position of laser spot. α_k and γ_k are the adaptive variant of smoothing and trend constants respectively that dynamically updated for the time instant, t_k. α_k and γ_k values also change accordingly to the linear function shown in Figure 3, where $u_k = \|\boldsymbol{Z}_k - \boldsymbol{S}_{k-1}\|$ is the difference between current observation and previous smoothed output. The $u_{\min\_\alpha}$ and $u_{\max\_\alpha}$ in ADES were set to 1 and 100 respectively. The same values were set for $g(u_k)$.

The hybridization of adaptive element and GA in parameter estimation is assumed to give a better accuracy and performance in reducing the hand jitter. In order to combine both methods, ($u_{\min\_\alpha}$, $u_{\max\_\alpha}, u_{\min\_\gamma}$ and $u_{\max\_\gamma}$), were chosen as the input variables to GA. The variables are subjected to the following nonlinear inequality constraints and bounds

$$u_{\min\_\alpha} \le u_{\max\_\alpha}$$
$$u_{\min\_\gamma} \le u_{\max\_\gamma}$$
$$1 \le u_{\min\_\alpha} \le 1000$$
$$1 \le u_{\max\_\alpha} \le 1000$$
$$1 \le u_{\min\_\gamma} \le 1000$$
$$1 \le u_{\max\_\gamma} \le 1000$$

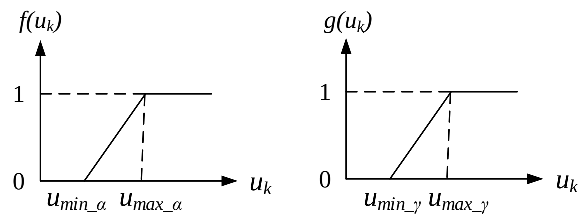


Figure 3 Linear functions for adaptive variant

2.2 Genetic Algorithm

Genetic Algorithm (GA) is a search method that is based on the process of evolution and natural selection to solve various numerical optimization problems. GA allows an initial population composed of potential solutions called chromosomes to evolve over a number of generations and finally minimize or maximize the fitness function. Fitness value is used to provide a measure of how individuals have performed in the problem domain.

In each generation, the fitness value of the individuals is evaluated where fit parents are selected through selection process. The selection process will choose the parents for next generation based on their evaluated fitness values. Then, the children are created by using the genetic operators called crossover and mutation from the fit parents. The old population is then replaced by the new population and the process is repeated until stopping criteria are met.

In this study, each chromosome is represented as a vector that consists of 4 variables that need to be optimized ($u_{\min\_\alpha}$, $u_{\max\_\alpha}, u_{\min\_\gamma}$ and $u_{\max\_\gamma}$), represented in binary numbers. The main objective is to find the best combination of these four variables that will minimize the fitness function. By using these values in Adaptive DES model, the fitness of each chromosome is evaluated to obtain the mean squares error (MSE) between the output and target. The fitness function that will be minimized for this system is the Mean Squared Error (MSE). Stochastic uniform selection method was used in this study.

The GA properties used to find the optimal α and γ are shown in Table 1:

Table 1 GA properties

GA Properties	Properties used
Selection	Stochastic uniform
Crossover	Arithmetic
mutation	Adaptive Feasible
Initial Population	20
Population size	200
Maximum Generation	100

3.0 RESULTS AND DISCUSSION

58 dataset have been evaluated to study the performance of the proposed method. The proposed method, Adaptive variant Double Exponential Smoothing with Genetic Algorithm (ADES-GA) was simulated repetitively to produce different solutions as recorded in Table 2. This is to find the optimum combination of input variables that produce the minimum MSE. The combination of 5, 425, 39 and 720 as input variables were obtained for a few times by running the GA. Therefore, these values were chosen as the optimal solution since they also produce the minimum MSE. The value of these variables were then used to evaluate the ADES-GA system.

Performance of the proposed ADES-GA method were compared with Adaptive Double Exponential Smoothing (ADES) [7] and Double Exponential Smoothing with GA estimator (DES-GA) [8] using the Minimum Squared Error (MSE) analysis. An example of one dataset output for all three methods were compared as shown in Figure 4. From the graph, the ADES-GA data can be seen smoother than ADES and DES-GA.

Table 2 Different solution obtained from ADES-GA system

Solutions	1	2	3	4	5	6	7	8	9	10
u_{min_α}	1	5	41	1	50	26	68	1	5	11
u_{max_α}	434	425	347	446	335	414	278	434	425	412
u_{min_γ}	84	39	71	85	69	99	68	84	39	56
u_{max_γ}	467	720	545	439	539	320	743	467	720	628
MSE	65.98	65.45	66.20	66.15	66.41	68.20	67.57	65.98	65.45	65.60
MAD	4.47	4.46	4.39	4.51	4.40	4.55	4.21	4.47	4.46	4.45

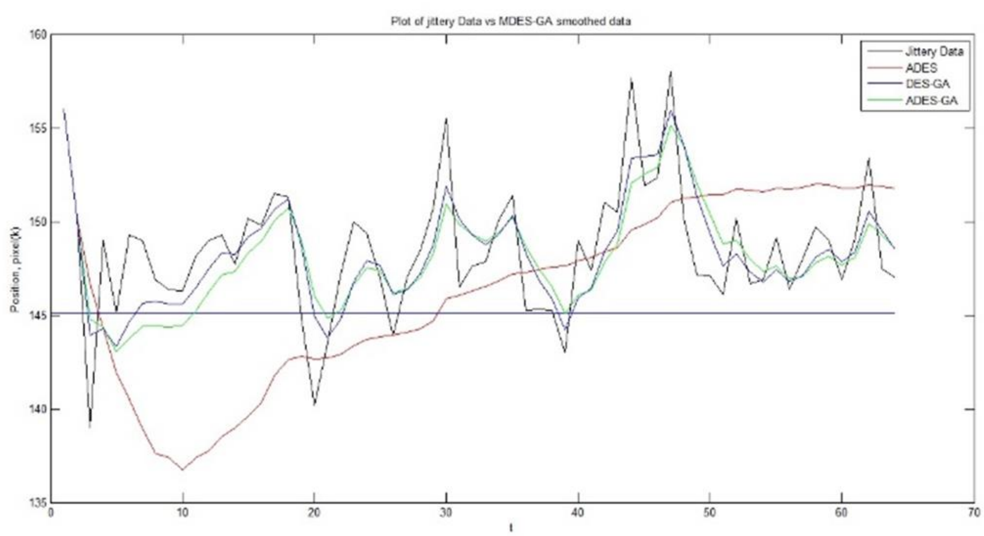


Figure 4 Comparison of output of one dataset

Figure 5 shows samples of comparison of Minimum squared error (MSE). 97% of the datasets from ADES-GA return better MSE compared to the jittery data.

The average MSE for all dataset was computed and compared with ADES and DES-GA as shown in Table 3. The proposed method performed 26% better than MDES, yet only performed 1% better than DES-GA. The accuracy of the system was measured by using the mean of absolute deviation as shown in Table 4. Our proposed method has improved the accuracy of the system with 0.97 compared to ADES but only a small improvement in accuracy with just 0.03 compared to DES-GA.

Table 3 Average MSE comparison

Method	MSE
Jittery data	135.67
ADES	100.83
DES-GA	65.91
ADES-GA	65.45

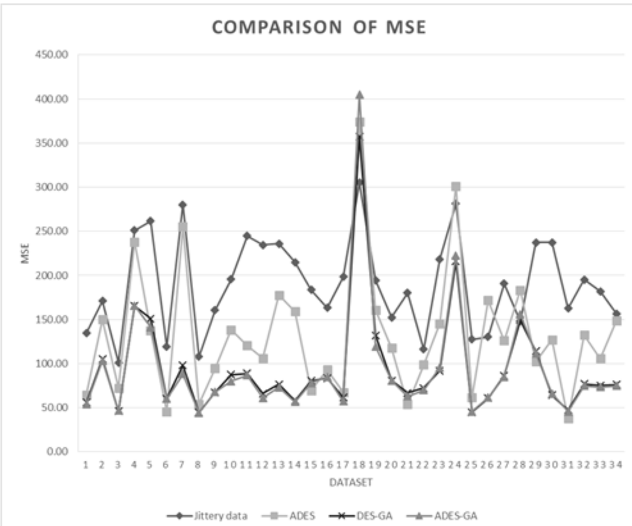


Figure 5 Comparison of MSE for all dataset

Table 4 Average MAD comparison

Method	MAD
ADES	5.43
DES-GA	4.49
ADES-GA	4.46

4.0 CONCLUSION

In conclusion, ADES-GA technique has been developed to reduce hand jitter problem where the results proved that it managed to increase the performance with a reduction of 52%. Several thorough comparisons have also been made with ADES and DES-GA. In a nutshell, the crucial part in DES implementation is to choose the optimal values for α and γ. ADES-GA estimated the optimal parameter values that give the minimum MSE. In the future, we would like to apply a more complex predictive method such as Multiple-hypothesis method [10].

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