IDENTIFICATION OF CONTINUOUS-TIME MODEL OF HAMMERSTEIN SYSTEM USING MODIFIED MULTI-VERSE OPTIMIZER

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Science.

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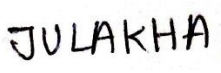
STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.



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ABSTRAK

Tesis ini mengimplementasikan algoritma pengoptimuman metaheuristik yang diilhamkan oleh alam semula jadi, iaitu algoritma Multi-Verse Optimizer (mMVO) yang diubah suai untuk mengenal pasti sistem Hammerstein yang berterusan. Multi-Verse Optimizer (MVO) adalah salah satu algoritma metaheuristik berinspirasi alam semula jadi yang paling kuat yang telah berjaya dilaksanakan dan digunakan untuk menyelesaikan beberapa masalah pengoptimuman dalam pelbagai bidang. Namun, metaheuristik tersebut juga mempunyai beberapa masalah, seperti masalah lokal optima, kemampuan mencari yang rendah dan ketidakseimbangan antara penerokaan dan eksploitasi. Dengan mempertimbangkan masalah-masalah ini, dua pengubahsuaian dibuat berdasarkan MVO konvensional dan mengusulkan algoritma baru yang disebut modifikasi Multi-Verse Optimizer (mMVO). Dalam algoritma mMVO yang dicadangkan, kami membuat dua pengubahsuaian dengan mempertimbangkan masalah ini pada MVO konvensional. Mekanisme pengemaskinian parameter reka bentuk rata-rata untuk menyelesaikan masalah lokal optima dalam MVO tradisional adalah pengubahsuaian pertama kami. Ciri asas proses pengemaskinian untuk parameter reka bentuk rata-rata adalah bahawa ia membolehkan setiap parameter reka bentuk yang terperangkap keluar dari zon lokal optima dan memulakan trek pencarian baru. Pengubahsuaian kedua adalah meng hibridisasi MVO dengan Sine Cosine Algorithm (SCA) untuk meningkatkan mencari rendah algoritma MVO tradisional. Hibridisasi bertujuan untuk menggabungkan kelebihan algoritma MVO dan SCA dan meminimumkan keburukan, seperti keupayaan mencari rendah kerana ketidakseimbangan antara penerokaan dan eksploitasi. Khususnya, kapasiti pencarian algoritma MVO telah diperbaiki dengan menggunakan fungsi sine dan cosine dari SCA yang menyeimbangkan proses penerokaan dan eksploitasi. Untuk mengenal pasti subsistem linear dan nonlinear model Hammerstein menggunakan data input dan output yang diberikan, kaedah berdasarkan mMVO kemudian digunakan. Untuk pengenalpastian ini, diandaikan bahawa struktur subsistem linear dan nonlinear diketahui. Selain itu, kajian ini menganggap subsistem masa berterusan linear, sedangkan beberapa kaedah menggunakan model seperti itu. Dua contoh berangka dan satu aplikasi dunia nyata, seperti Twin Rotor System (TRS), menggambarkan kecekapan kaedah berdasarkan mMVO. Pelbagai subsistem bukan linear seperti fungsi kuadratik dan hiperbolik (sine dan tangent) digunakan dalam eksperimen tersebut. Nilai analisis statistik (mean) diambil dari indeks sisihan parameter untuk melihat sejauh mana algoritma yang dicadangkan kami telah bertambah baik. Untuk Contoh-1, peningkatan masing-masing adalah 29%, 33.15% dan 36.68%, untuk variasi gangguan masing-masing 0.01, 0.25 dan 1.0. Untuk Contoh-2, peningkatan masing-masing adalah 39.36%, 39.61% dan 66.18%, untuk perbezaan paras gangguan masing-masing 0.01, 0.25 dan 1.0. Akhirnya, untuk aplikasi TRS sebenar, peningkatannya adalah 7%. Hasil numerik dan eksperimen dianalisis mengenai keluk konvergensi fungsi kecergasan, indeks variasi parameter, tindak balas domain frekuensi dan masa dan ujian peringkat Wilcoxon. Untuk pengenalpastian berangka, tiga tahap variasi gangguan putih telah diambil. Hasil numerik dan eksperimen juga menunjukkan bahawa kedua-dua subsistem model Hammerstein didefinisikan dengan berkesan menggunakan kaedah berdasarkan mMVO mengenai ralat anggaran output kuadratik dan indeks parameter pembezaan. Hasil kajian selanjutnya mengesahkan bahawa kaedah berasaskan mMVO yang dicadangkan memberikan penyelesaian yang lebih baik daripada teknik pengoptimuman lain, seperti PSO, GWO, ALO, MVO dan SCA.

ABSTRACT

This thesis implements a novel nature-inspired metaheuristic optimization algorithm, namely the modified Multi-Verse Optimizer (mMVO) algorithm, to identify the continuous-time model of Hammerstein system. Multi-Verse Optimizer (MVO) is one of the most recent robust nature-inspired metaheuristic algorithm. It has been successfully implemented and used in various areas such as machine learning applications, engineering applications, network applications, parameter control, and other similar applications to solve optimization problems. However, such metaheuristics had some limitations, such as local optima problem, low searching capability and imbalance between exploration and exploitation. By considering these limitations, two modifications were made upon the conventional MVO in our proposed mMVO algorithm. Our first modification was an average design parameter updating mechanism to solve the local optima issue of the traditional MVO. The essential feature of the average design parameter updating mechanism is that it helps any trapped design parameter jump out from the local optima region and continue a new search track. The second modification is the hybridization of MVO with the Sine Cosine Algorithm (SCA) to improve the low searching capability of the conventional MVO. Hybridization aims to combine MVO and SCA algorithms advantages and minimize the disadvantages, such as low searching capability and imbalance between exploration and exploitation. In particular, the search capacity of the MVO algorithm has been improved using the sine and cosine functions of the Sine Cosine Algorithm (SCA) that will be able to balance the processes of exploration and exploitation. The mMVO based method is then used for identifying the parameters of linear and nonlinear subsystems in the Hammerstein model using the given input and output data. Note that the structure of the linear and nonlinear subsystems is assumed to be known. Moreover, a continuous-time linear subsystem is considered in this study, while there are a few methods that utilize such models. Two numerical examples and one real-world application, such as the Twin Rotor System (TRS) are used to illustrate the efficiency of the mMVO-based method. Various nonlinear subsystems such as quadratic and hyperbolic functions (sine and tangent) are used in those experiments. Numerical and experimental results are analyzed to focus on the convergence curve of the fitness function, the parameter variation index, frequency and time domain response and the Wilcoxon rank test. For the numerical identifications, three different levels of white noise variances were taken. The statistical analysis value (mean) was taken from the parameter deviation index to see how much our proposed algorithm has improved. For Example 1, the improvements are 29%, 33.15% and 36.68%, and for the noise variances, 0.01, 0.25, and 1.0 improvements can be found. For Example 2, the improvements are 39.36%, 39.61% and 66.18%, and for noise variances, the improvements are by 0.01, 0.25 and 1.0, respectively. Finally, for the real TRS application, the improvement is 7%. The numerical and experimental results also showed that both Hammerstein model subsystems are defined effectively using the mMVO-based method, particularly in quadratic output estimation error and a differentiation parameter index. The results further confirmed that the proposed mMVO-based method provided better solutions than other optimization techniques, such as PSO, GWO, ALO, MVO and SCA.

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