HYBRIDIZATION OF NONLINEAR SINE COSINE AND SAFE EXPERIMENTATION DYNAMICS ALGORITHMS FOR SOLVING CONTROL ENGINEERING OPTIMIZATION PROBLEMS

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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 Doctor of Philosophy.

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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

Dalam landskap kejuruteraan kawalan yang berkembang pesat dalam kejuruteraan elektrik dan elektronik, kajian ini menangani cabaran kritikal yang ditimbulkan oleh kerumitan reka bentuk sistem yang semakin meningkat. Apabila teknologi terus berkembang, permintaan untuk metodologi yang berkesan untuk mereka bentuk, menganalisis dan mensintesis model sistem yang kompleks menjadi penting. Sebagai jawapan kepada keharusan ini, para penyelidik semakin beralih kepada pendekatan berasaskan pengoptimuman, dengan Algoritma Kosinus Sinus (SCA) muncul sebagai penyelesaian yang menonjol. Walau bagaimanapun, batasan sedia ada dari segi ketepatan penumpuan dan genangan optima tempatan telah mendorong pengenalan penambahbaikan inovatif dalam kajian ini. Algoritma Kosinus Sinus Tak Linear (NSCA) diperkenalkan sebagai sambungan utama, menggabungkan keuntungan menurun tak linear serba boleh ke dalam mekanisme parameter peralihan. Peningkatan ini menawarkan keseimbangan yang disesuaikan antara penerokaan dan eksploitasi, sejajar dengan keperluan khusus masalah kejuruteraan elektrik dan elektronik yang kompleks. Selain itu, Dinamik Percubaan Selamat Algoritma Sinus Tak Linear (NSCA-SED) memperkenalkan penghibridan algoritma berbilang ejen dan ejen tunggal, mempersembahkan pendekatan dinamik dengan gangguan rawak untuk menavigasi trajektori carian dengan berkesan, dan mengeluarkan parameter reka bentuk yang mungkin terperangkap dalam genangan optima tempatan. Penilaian empirikal kaedah yang dicadangkan ini merangkumi set pelbagai 23 fungsi penanda aras, menunjukkan keberkesanannya setanding dengan algoritma metaheuristik yang mantap seperti Pengoptimum Serigala Kelabu (GWO), Pengoptimuman Multi-Verse (MVO), Algoritma Kosinus Sinus (SCA), Ant Lion Optimizer (ALO), Algoritma Pengoptimuman Moth-Flame (MFO) dan Algoritma Pengoptimuman Belalang (GOA). Aplikasi ini melangkaui masalah pengoptimuman yang telah ditetapkan, menangani eksperimen kontemporari dalam kejuruteraan kawalan, termasuk Pengurangan Pesanan Model, Pengenalan Sistem Tak Linear dan Kawalan Didorong Data. Keputusan simulasi menggariskan kekukuhan dan keunggulan algoritma NSCA dan NSCA-SED dalam konteks ini, mempamerkan penambahbaikan antara 13.97% hingga 97.17% untuk Pengurangan Pesanan Model, 17.76% hingga 99.37% untuk Pengenalan Sistem Tak Linear dan 84.51% hingga 89.47% Kawalan dipacu data jika dibandingkan dengan SCA standard. Ringkasnya, kajian ini bukan sahaja menyumbang kemajuan kepada algoritma pengoptimuman tetapi juga menangani secara langsung dan meningkatkan metodologi dalam kejuruteraan elektrik dan elektronik. Dengan mengatasi batasan pendekatan sedia ada, algoritma NSCA dan NSCA-SED berdiri sebagai alat berharga dalam pengumpulan jurutera kawalan, memudahkan reka bentuk dan pengoptimuman sistem kompleks dalam aplikasi elektrik dan elektronik kontemporari.

ABSTRACT

In the rapidly developing landscape of control engineering within electrical and electronics engineering, the study addresses critical challenges posed by the escalating complexity of system designs. As technology continues to advance, the demand for effective methodologies to design, analyse, and synthesize complex system models becomes vital. In response to this imperative, researchers have increasingly turned to optimization-based approaches, with the Sine Cosine Algorithm (SCA) emerging as a prominent solution. However, existing limitations in terms of convergence accuracy and local optima stagnation have prompted the introduction of innovative improvements in this study. The Nonlinear Sine Cosine Algorithm (NSCA) is introduced as a key extension, incorporating a versatile nonlinear decreasing gain into the transition parameter mechanism. This enhancement offers a tailored balance between exploration and exploitation, aligning with the specific requirements of complex electrical and electronics engineering problems. Moreover, the Nonlinear Sine Cosine Algorithm-Safe Experimentation Dynamic (NSCA-SED) introduces a hybridization of multi-agent and single-agent algorithms, presenting a dynamic approach with random perturbation to navigate search trajectories effectively, and release design parameters that might be trapped in local optima. The empirical assessment of these proposed methods encompasses a diverse set of 23 benchmark functions, demonstrating their efficacy comparable to well-established metaheuristic algorithms such as as the Grey Wolf Optimizer (GWO), Multi-Verse Optimization (MVO), Sine Cosine Algorithm (SCA), Ant Lion Optimizer (ALO), Moth-Flame Optimization Algorithm (MFO), and Grasshopper Optimization Algorithm (GOA). The applications extend beyond established optimization problems, addressing contemporary experiments in control engineering, including Model Order Reduction, Nonlinear System Identification, and Data-driven Control. Simulation results underscore the robustness and superiority of the NSCA and NSCA-SED algorithms in these contexts, showcasing improvements ranging from 13.97% to 97.17% for Model Order Reduction, 17.76% to 99.37% for Nonlinear System Identification, and 84.51% to 89.47% for Data-driven Control when compared to the standard SCA. In summary, this study not only contributes advancements to optimization algorithms but also directly addresses and enhances methodologies in electrical and electronics engineering. By overcoming the limitations of existing approaches, the NSCA and NSCA-SED algorithms stand as valuable tools in the collection of control engineers, facilitating the design and optimization of complex systems in contemporary electrical and electronics applications.

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