IMPROVED PID CONTROLLER BASED ON PIECEWISE AFFINE FUNCTION IN DATA DRIVEN CONTROL FRAMEWORK

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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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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

Pada masa kini, sejajar dengan perkembangan sains dan teknologi, pelbagai bidang dan sektor telah menjadi lebih rumit dan kompleks. Antara sektor yang terkesan ialah sektor perkilangan, pembuatan serta pemprosesan. Ini termasuklah juga industri petrokimia, industri elektrik dan elektronik serta industri minyak dan gas. Dalam erti kata lain, sistem kawalan bagi setiap industri telah menjadi lebih sukar dan kompleks. Secara asasnya, sistem kawalan PID telah meluas digunakan dalam pelbagai aplikasi. Namun begitu, masalah yang dihadapi ialah nilai parameter sistem kawalan iaitu nilai perkadaran (K_p), pengamiran (K_i) dan terbitan (K_d) adalah tetap dan tidak berubah dalam jangkamasa yang diberikan. Keadaan ini telah menyukarkan bagi mengawal sistem kawalan yang kompleks serta tidak lelurus. Kesannya adalah, sistem kawalan bagi sesuatu aplikasi akan menjadi tidak tepat. Oleh yang demikian, kajian baharu terhadap meningkatkan sistem kawalan PID berdasarkan fungsi kawalan Piecewise Affine dalam lingkaran data kawalan serta dioptimumkan oleh algoritma Percubaan Dinamik Selamat (SED) telah dibangunkan bagi menangani masalah ini di mana set formula linear disahkan pada setiap PID parameter pada setiap perubahan ralat. Algoritma SED telah diadaptasi bagi mencari optimum parameter untuk sistem kawalan PID termaju PA-PID, oleh itu ralat tidak terpadu persegi dan nilai masukan sistem kawalan dapat dikurangkan. Antara paramater penting yang ada pada sistem kawalan PID termaju PA-PID ialah parameter perkadaran, pengamiran dan terbitan dimana ianya adalah adaptif kepada ralat variasi pada fungsi Piecewise Affine (PA). Tambahan pula fungsi sistem kawalan PA-PID yang dibangunkan ini dijangka mampu untuk menghasilkan hasil sistem kawalan PID yang lebih tepat berbanding sistem kawalan PID optimum. Ianya telah diaplikasi kepada sistem kawalan seperti aplikasi kawalan penjejakan sudut halaju untuk menggerakkan motor DC bagi buck converter, aplikasi kawalan penjejakan kedudukan troli, cangkuk dan sudut penindasan bebanan berhayun bagi double pendulum type overhead crane (DPTOC) dan aplikasi kawalan voltan bagi penjana segerak pada tahap tertentu bagi automatic voltage regulator (AVR). Prestasi sistem kawalan PID termaju yang dibangunkan ini dapat dinilai melalui nilai ralat tidak terpadu persegi, nilai masukkan sistem kawalan, analisis masa tindak balas serta peratusan peningkatan fungsi objektif. Ujian simulasi telah menunjukkan bahawa, sistem kawalan PID termaju yang baharu iaitu PA-PID telah menghasilkan ketepatan yang lebih tinggi berbanding sistem kawalan PID optimum iaitu peningkatan fungsi objektif kawalan sebanyak 99.8% bagi aplikasi sistem kawalan penjejakan sudut halaju untuk menggerakkan motor DC bagi buck converter, peningkatan fungsi objektif kawalan sebanyak 3.8% bagi aplikasi sistem kawalan double pendulum type overhead crane serta peningkatan fungsi objektif kawalan sebanyak 98.1% bagi aplikasi sistem kawalan voltan bagi penjana segerak pada tahap tertentu bagi automatic voltage regulator. Daripada fakta ini, dapat disimpulkan bahawa sistem kawalan termaju PA-PID mempunyai ketepatan yang lebih tinggi berbanding sistem kawalan PID optimum dan ianya boleh diaplikasi pada sistem kawalan yang lebih kompleks dan berskala besar di masa hadapan.

ABSTRACT

In recent years, with the rapid developments of science and technology, practical applications in various fields such as chemical, machinery, electronics and electricity industries have caused the process to become more complex. This subsequently causes the modelling of the plant using first principles or system identification to become more difficult. In general, the PID controller has been successfully applied in various applications. However, the PID gains which are proportional (K_p), integral (K_i) and Derivative (K_d) are normally fixed within the given time response. Therefore, it is difficult to control a complex system with highly nonlinear and time-varying parameters. As a result, the control performance accuracy will be degraded for such cases. Therefore, this study focuses on improved PID controller based on piecewise affine function in data-driven control framework which will be tuned by Safe Experimentation Dynamics (SED) Algorithm where combined sets of linear equation are verified on each PID parameter according to the change of error. In particular, the proposed control scheme has been applied for angular velocity tracking of a buck converter generated DC motor, cart position tracking, hook and load sway angle suppression of a double pendulum-type overhead crane (DPTOC) and automatic voltage regulator (AVR) to hold terminal voltage magnitude of a synchronous generator at a specified level. The SED algorithm is utilized as a data-driven optimization tool to find the optimal PA-PID controller parameter such that the control accuracy in terms of integral square error and integral square control input are reduced. The essential feature of the PA-PID controller is that the parameters of proportional, integral and derivative gains are adaptive to the error variations according to the Piecewise Affine (PA) function. Moreover, the proposed PA-PID function is expected to produce better control accuracy compared to the optimized PID controller. The performance of the proposed controller was observed based on the integral square of error, integral square control input, time response and percentage of objective function improvement. Specifically, the performance of the proposed controller was evaluated by the response of the angular velocity and duty ratio input for buck converter generated DC motor, the response of the cart position, the hook and load sway angle of the control input for the nonlinear model of DPTOC controller and terminal voltage magnitude of the synchronous generator at a specified level for the automatic voltage regulator. The simulations results verified that the proposed Piecewise Affine Proportional-Integral-Derivative (PA-PID) controller yields higher accuracy than the optimized PID controller of buck converter generated DC motor by 99.8% of control objective function improvement, double pendulum-type overhead crane by 3.8% of control objective function improvement and 98.1% of control objective function improvement for the automatic voltage regulator. These findings justify the effectiveness of the data-driven PA-PID controller in providing better control performance than the optimized PID thus can be applied to a larger class of system.

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