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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ADAPTIVE FUZZY PROPORTIONAL-INTEGRAL-DERIVATIVE CONTROL FOR MICRO AERIAL VEHICLE CONSIDERING EXTERNAL DISTURBANCES

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ABSTRAK

Beberapa industri telah menggunakan Micro Aerial Vehicles (MAV) untuk menyelesaikan pelbagai tugasan seperti penyemburan pertanian, penghantaran bungkusan dan pemantauan bencana. Oleh itu, sistem MAV telah menarik para penyelidik untuk menyelesaikan masalah kestabilannya yang muncul dari gangguan luaran. Gangguan yang disebabkan oleh gangguan perubahan angin dan muatan telah berlaku sebagai kecelakaan semula jadi yang menurunkan prestasi system kenderaan quad-rotor MAV pada kedudukan mendatar dan menegak dalam aspek tembakan tersasar (OS), masa kenaikan (T_r), masa penyelesaian (T_s) dan ralat kemantapan (e_{ss}). Kemudian, kesulitan tersebut menyebabkan peningkatan ralat antara kehendak dan aktual posisi system dengan masa kenaikan dan masa penyelesaian yang lebih lama untuk mencapai kondisi tunaknya. Mengadopsi system quad-rotor MAV sayap putar dengan konfigurasi 'X' sebagai landasan, kajian semasa telah menetapkan untuk meneroka pendekatan baru bagi kawalan kedudukan system yang kuat dalam gangguan angin dan perubahan muatan secara serentak. Literatur sebelumnya telah menyarankan penggunaan pendekatan linier, nonlinier and hybrid untuk menangani cabaran kestabilan quad-rotor MAV. Khususnya, kebanyakan pendekatan hibrid tidak dapat memperhitungkan perubahan semasa dalam lingkungan sistem, sementara tidak mampu menangani pelbagai gangguan secara serentak. Sebagai contohnya ialah kaedah Fuzzy-PID (FPID) yang hanya menyesuaikan keuntungan Proportional-Integral-Derivative (PID) setelah berlaku ralat kedudukan yang dijumpai kemunculan tembakan tersasar sistem. Mengakui ketidakcekapan tersebut, penyelidikan ini akan selanjutnya mengusulkan pengawal Adaptive Fuzzy-PID (AFPID) sebagai pendekatan hibrid kontemporari yang menragkumi fungsi penyesuaian untuk mengatasi ketidakliniaran sistem quad-rotor MAV sementara mengekalkan prestasi sistem yang mantap menghadapi perubahan persekitaran semasa dari gangguan angin dan perubahan muatan serentak. Dengan cadangan kabur adaptif yang diadopsi diadopsi untuk menyesuaikan keuntungan PID sesuai dengan perubahan sekitarnya, peningkatan yang dilakukan dengan ini bertujuan untuk menghilangkan pengaruh gangguan perubahan angin dan muatan di tengah menstabilkan sistem yang digunakan. Sebagai balasannya, terdapat ralat pada kedua posisi mendatar dan menegak MAV quad-rotor yang diharapkan menurun walaupun pengeboman serentak dengan banyak gangguan luaran, berikutan tembakan tersasar (OS), masa kenaikan (T_r), masa penyelesaian (T_s) dan ralat kemantapan (e_{ss}). Dalam simulasi, prestasi pengawal AFPID yang dicadangkan pada kedudukan mendatar, y seperti yang dikaji dalam keadaan halaju angin masuk yang berbeza dan kadar aliran air berkenaan dengan OS, T_r, T_s and e_{ss} diletakkan dibandingkan dengan prestasi PID dan FPID kaedah. Peningkatan diperhatikan dalam e_{ss} sistem untuk pengawal AFPID pada kedudukan mendatar, y di tengah gangguan gangguan gabungan, dengan penurunan masing-masing 0.93×10^{-3} % dan 1.35×10^{-3} % berbanding prestasi Pengawal PID dan FPID. Hasil yang diperoleh kemudian mengesahkan penurunan yang sama sebanyak 27.5% dan 21.70 % dalam OS untuk pengawal AFPID berbanding pengawal PID dan FPID. Penurunan 137.50 s dan 13.40 s di T_s dicatatkan lagi untuk pengawal AFPID berbanding dengan pengawal PID dan FPID masing-masing. Konklusinya, keputusan simulasi terbukti bahawa pengawal APFID yang dicadangkan adalah berkesan berbanding dengan pengawal PID dan FPID dalam penghasilan OS terkecil, e_{ss}terkecil, T_r dan T_s terpendek pada posisi mendatar dan menegak yang di bawah gangguan angin dan perubahan muatan secara serentak.

ABSTRACT

With multiple industries employing Micro Aerial Vehicles (MAV) to accomplish various tasks comprising agricultural spraying, package delivery and disaster monitoring, the MAV system has attracted researchers towards resolving its stability issue as emerged from external disturbances. Disruptions caused by both wind and payload change disturbances have prevailed as natural mishaps which degrade performance of the quad-rotor MAV system at the horizontal and vertical positions in the aspects of overshoot (OS), rise time (T_r), settling time $(T_s)$and steady-state error (e_{ss}). Such adversities then cause increased error between the system's desired and actual positions, with a longer rise time and settling time towards reaching its steady-state condition. Adopting the rotary wing quad-rotor MAV system with 'X' configuration as the groundwork, the current study has especially set to explore a new approach for the system's robust positional control in the concurrent presence of wind and payload change disturbances. Earlier literatures have simultaneously suggested the adoptions of linear, nonlinear and hybrid approaches towards handing stability challenge of the quad-rotor MAV. Notably, most hybrid approaches are unable to account for current changes in the system's environment, whilst incapable of concomitantly handle multiple disturbances. An instance being the Fuzzy-PID (FPID) method which merely adjusts the Proportional-Integral-Derivative (PID) gains ensuing discovered positional error from emergence of system's overshoot. Acknowledging such incompetency, this research further proposed Adaptive Fuzzy-PID (AFPID) controller as the contemporary hybrid approach that includes adaptability function for overcoming nonlinearity of the quad-rotor MAV system, while maintaining the system's robust performance facing current environmental changes from simultaneous wind and payload change disturbances. With the proposed adaptive fuzzy control being adopted to adjust the PID gains in accordance to surrounding changes, undertaken improvement is hereby targeted to eliminate the effect of wind and payload change disturbances amidst stabilizing the employed system. In return, encountered error on both the quad-rotor MAV's horizontal and vertical positions is expected to decline despite concurrent bombardment of multiple external disturbances, following a decrease to the system's overshoot (OS), rise time (T_r), settling time $(T_s)$and steady-state error (e_{ss}). In simulation, performance of the proposed AFPID controller on the horizontal, y position as studied under circumstances of different incoming wind velocities and water flow rates with respect to OS, T_r, T_s and e_{ss} is placed in comparison to the performance of the PID and FPID methods. Improvement is observed in the system's e_{ss} for the AFPID controller on the horizontal, y position amid disruption of combined disturbances, with respective reductions of 0.93×10^{-3} % and 1.35×10^{-3} % over the performances of PID and FPID controllers. Obtained results then confirm corresponding decline of 27.5 % and 21.70 % in OS for the AFPID controller over the PID and FPID controllers. A decline of 137.50 s and 13.40 s in T_s is further recorded for the AFPID controller as compared to the respective PID and FPID controllers. Accumulated findings, thus, validate AFPID as an effective controller for minimized positional error, smaller overshoot (OS) and steady-state error (e_{ss}), as well as shorter settling time (T_s) and rise time (T_r) as compared to the earlier PID and FPID controllers when faced with uncertain situations of wind and payload change disturbances.

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