EXTENDED BAT ALGORITHM FOR PID CONTROLLER TUNING OF WHEELED MOBILE ROBOT AND SWARM ROBOTICS TARGET SEARCHING STRATEGY

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We hereby declare that We have checked this thesis, and, in our 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

Robotik kawanan adalah sistem multi-robot yang mengandungi lebih daripada dua robot bekerja bersama-sama untuk mencapai satu tugas yang tertentu. Robotik kawanan mempunyai potensi besar yang boleh digunakan dalam pelbagai sektor seperti dalam bidang pertanian dan tentera kerana bilangan ketersediaan tenaga kerja dalam sistem dan keupayaan robot untuk melaksanakan dan menyelesaikan tugas lebih cepat daripada kerja kasar. Sistem robotic kawanan terdiri daripada sekurang-kurangnya dua robot dan boleh sehingga beratus-ratus dan beribu-ribu bilangan robot dalam kawanan. Oleh itu, terdapat keperluan segera untuk memantau dan menguruskan pergerakan semua robot untuk mengelakkan apa-apa perlanggaran dan kemalangan antara robot dan pada masa yang sama mengoptimumkan prestasi sistem robotik kawanan. Dalam usaha untuk membina sebuah sistem robotik kawanan yang dapat melaksanakan tugas sasaran mencari, keperluan sistem adalah untuk mempunyai strategi yang mantap. Walau bagaimanapun, penyelesaian semasa strategi pencarian sasaran untuk robotik kawanan adalah tidak memuaskan kerana penyelesaian tidak dapat bergerak dengan cekap dan tidak tiba di kedudukan sasaran dengan tepat. Terdapat banyak faktor yang mungkin menyumbang kepada pengawal bahawa keadaan contohnya, algoritma dan komunikasi. Setiap robot dalam keperluan swarm yang dilengkapi dengan pengawal yang baik, contohnya keteguhan pengawal PID. Walaupun PID adalah pengawal tradisional dengan seni bina mudah, tetapi, penalaan PID pengawal untuk keuntungan yang terbaik dalam usaha untuk membangunkan sistem prestasi yang baik adalah sukar. Oleh itu, untuk mengenal pasti dan menyediakan penyelesaian, kajian penyelidikan ini memutuskan untuk memulakan pendekatan dengan mengoptimumkan pengawal PID di robot beroda bergerak (WMR). Ini kerana, WMR mesti dapat bergerak dengan berkesan dari satu titik ke titik yang lain untuk melaksanakan tugas pencarian sasaran dan menunjukkan prestasi yang baik dalam sistem robotik kawanan. Objektif kajian ini bertujuan untuk penalaan dan mengoptimumkan daripada berkadar-Integral-derivatif (PID) pengawal untuk beroda robot mudah alih (WMR), membangunkan sasaran mencari strategi untuk sistem robotik kawanan dan membandingkan prestasi kaedah dicadangkan dengan kaedah, strategi sasaran pencarian berdasarkan Particle Swarm Optimization (PSO) dan Bat Algoritma (BA). EBA adalah kaedah swarm pengoptimuman hibrid BA dengan SDA. Kelemahan BA untuk meneroka penyelesaian sewajarnya telah diatasi dengan teknik SDA. Kaedah kajian ini dimulakan dengan pengawal berasaskan penalaan PID untuk WMR. Seterusnya, EBA penyesuaian digunakan untuk membangunkan sasaran pencarian robotik swarm untuk dua kes iaitu kedudukan awal yang berbeza dan berbeza jarak robot dalam kawanan dan berbeza penduduk robot dalam kawanan. Akhir sekali, prestasi algoritma dicadangkan berbanding dengan PSO dan BA. Keputusan yang diperolehi daripada kajian penyelidikan ini menunjukkan bahawa pengawal PD ditala oleh EBA mengatasi prestasi PID dan pengawal PI oleh daripada 11.00s dan 12.11s masa kenaikan untuk kedudukan X dan Y masing-masing, 20.08s dan 22.08s menetap masa dan tiada masa terlajak. Dengan menggunakan robot maju dengan pengawal PD, EBA membuktikan potensi untuk membangunkan sasaran terbaik strategi pencarian kepada sistem robotik swarm dengan nombor 5 lelaran dalam tempoh 49 saat yang merupakan nombor yang paling rendah lelaran dalam masa yang singkat dan 99% daripada ketepatan untuk tiba di lokasi yang dikehendaki berbanding dengan strategi pencarian sasaran berdasarkan PSO dan BA. Oleh itu, EBA yang merupakan kaedah yang dicadangkan mampu untuk membangunkan sasaran pencarian algoritma untuk swarm sistem robotik dan keuntungan pengawal penalaan PD untuk robot beroda mudah alih.

ABSTRACT

Swarm robotics is a multi-robot system which consists of more than two robots working together to accomplish a specific task. Swarm robotics has a huge potentiality to be applied in many sectors such as in agriculture and military due to the availability number of manpower in the system and the capability of robots to execute and accomplish task faster than manual labor. Swarm robotics system consists of at least two robots and can up to hundreds and thousands number of robots in the swarm. Thus, there is an urgent need to monitor and manage the movement of all robots in order to avoid any collision and accident among robots and at the same time to optimize the performance of swarm robotics system. In order to build a swarm robotics system that able to perform target searching task, the system needs to have a robust strategy. However, current solutions of target searching strategy for swarm robotics are unsatisfactory as the solutions are unable to make the robots move efficiently and not arrive at the target position precisely. There are many factors that might contribute to that condition e.g. controller, algorithm and communication. Each robot in the swarm needs to be equipped with good controller, e.g. robust PID controller. Although PID controller is a traditional controller with simple architecture, tuning PID controller to the best gains in order to develop good performance system is difficult. Thus, in order to identify and provide the solution, this research study decided to start the approach with the optimization of PID controller of Wheeled Mobile Robot (WMR). This is because, WMR must able to move effectively from one point to another point in order to execute the target searching task and to perform well in swarm robotics system. The objectives of this research study is 1)to tune and optimize gains of Proportional-Integral-Derivative (PID) controller for wheeled mobile robot (WMR), 2)develop target searching strategy for swarm robotics system and 3)compared the performance of proposed method with the well-established methods, target searching strategy based on Particle Swarm Optimization (PSO) and Bat Algorithm (BA). Extended Bat Algorithm (EBA) has been chosen as swarm intelligent based method for this research study. EBA is the hybrid swarm optimization method of BA with SDA. The weakness of BA to explore the solution appropriately has been overcome with SDA technique. The method of the research study is initiate with tune PID based controller for WMR. Next, adaptive EBA is applied to develop target searching of swarm robotics for two cases i.e. 1) different initial position and varies distance of robots in the swarm and 2) different population of robots in the swarm. Last but not least, the performance of proposed algorithm is compared with PSO and BA. Results obtained from this research study indicates that PD controller tuned by EBA outperformed the performance of PID and PI controller by of 11.00s and 12.11s of rise time for X and Y position respectively, 20.08s and 22.08s settling time X and Y position respectively and no overshoot for both position. By applying the developed robot with PD controller, EBA prove its potentiality to develop the best target searching strategy to the swarm robotics system with 5 number of iterations within 49 seconds. The result is the lowest number of iterations in the shortest of time. The accuracy is 99% to arrive at the desired location compared with target searching strategy based on PSO and BA. Hence, EBA which is the proposed method is able to develop target searching algorithm for swarm robotic system and tuning PD controller gains for wheeled mobile robot.

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LIST OF SYMBOLS

x	Position robot in x axis
y	Position robot in y axis
θ	Orientation angle of robot
r	Radius of mBot's wheel
ω_r	Right wheel angular velocity
ω_L	Left wheel angular velocity
L	Distance between mBot's wheels
v	Velocity of the agents / robots
ω	Angular velocity of the agents / robots
K_P	Proportional gain
K_I	Integral gain
K_D	Differential gain
v_x	Velocity for x component
v_y	Velocity for y component
$x_{desired}$	Desired / goal position in x axis
$y_{desired}$	Desired / goal position in y axis
x_{actual}	Actual / current position in x axis
y_{actual}	Actual / current position in y axis
f	frequency
$x(agent)$	Agents in algorithm
A	Loudness
p	Pulse rate
$R(\theta)$	Rotation matrix
$r(k)$	Step rate
t	time
i	Number of agents/robot
f_{min}	Minimum frequency
f_{max}	Maximum frequency
β	Random vector
x^*	Current global best
I_n	Identity matrix

k	Number of iteration
ε	Random vector for local movement
x_{new}	New position of agents
x_{old}	Old position of agents
A^{+}	Mean loudness of all bats
α	Random vector for loudness
γ	Random vector for pulse rate
D	Distance
C_1	Social coefficient
C_2	Cognitive coefficient
P_{best}	Individual best position
g_{best}	Local best position
w	Inertia coefficient
T_r	Rise time
T_s	Settling time
O_s	Overshoot
P	The highest peak
T_p	Time for the highest peak
f_T	Total fitness
f_1	First fitness value
f_2	Second fitness value
W_1	First weightage
W_2	Second weightage
SSE	Steady state error

LIST OF ABBREVIATIONS

PID	Proportional-Integral-Derivative
PI	Proportional-Integral
PD	Proportional -Derivative
WMR	Wheeled mobile robot
SRS	Swarm Robotics System
EBA	Extended Bat Algorithm
PSO	Particle Swarm Optimization
BA	Bat Algorithm
IAE	Integral Absolute Error
ISE	Integral Sum Error
ITAE	Integral Time Absolute Error
ITSE	Integral Time Sum Error
MIMO	Multi input multi output
SAR	Search and Rescue

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