HYBRID AGENT-BASED AND SOCIAL FORCE SIMULATION FOR MODELLING HUMAN EVACUATION EGRESS

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DOCTOR OF PHILOSOPHY

UNIVERSITI MALAYSIA PAHANG

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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 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

Simulasi adalah kaedah terkenal dalam memodelkan scenario pemindahan/ evakuasi manusia sebagai instrumen untuk memeriksa pergerakan manusia semasa normal dan kecemasan contohnya semasa evakuasi, manusia akan berada dalam keadaan panik dan tingkah laku ke luar yang akan mencari jalan keluar dari tempat berbahaya ke tempat yang selamat. Dua teknik yang biasa digunakan dalam simulasi yang dapat memodelkan tingkah laku manusia adalah 'Simulasi Berasaskan Ejen'(ABS) dan 'Simulasi Daya Sosial' (SFS). ABS menggunakan konsep sistem multi-agen yang terdiri daripada agen terdesentralisasi yang boleh bersifat autonomi, responsif dan proaktif. SFS adalah kekuatan fizikal untuk mendorong manusia secara dinamik untuk melakukan tindakan pergerakan keluar dan tingkah laku yang disusun sendiri oleh manusia dalam satu kumpulan. Isu utama dalam memodelkan ABS atau SFS (individual) adalah disebabkan ciri-ciri mereka; ABS menghadapi kesukaran untuk memodelkan elemen daya-soscial dan tingkah laku kolektif, sementara SFS tidak memberi tumpuan kepada pergerakan rawak semasa evakuasi. Tingkahlaku ini disebabkan struktur manusia (agen) di dalam ABS terdesentralisasi yang mengakibatkan perlanggaran antara agen dan pembentukan evakuasi yang diinginkan tidak tercapai. Sebaliknya, dalam model SFS, manusia tidak proaktif dalam mencari jalan keluar dan tidak mencerminkan tingkah laku sebenar manusia semasa evakuasi. ABS dan SFS adalah teknik yang berpotensi untuk digabungkan kerana ciri-ciri pembelajaran kendiri dan pergerakan bebas pada ABS dan organisasi diri pada SFS. Metodologi penyelidikan adalah berdasarkan kepada kitaran hayat pemodelan dan simulasi (M&S); terdiri daripada tiga fasa utama, iaitu kajian awal, pembangunan model dan pengesahan dan penentusahkan dan akhir sekali ialah eksperimen dan analisis keputusan dan digunakan sejajar dengan matlamat penyelidikan iaitu untuk mengkaji prestasi gabungan ABS dan SFS dalam memodelkan tingkah laku manusia semasa evakuasi. Lima faktor evakuasi telah dipilih iaitu rintangan, jumlah pintu keluar, lebar pintu keluar, waktu penggera yang dicetuskan, dan jumlah orang; faktor yang paling kerap dipilih berdasarkan tinjauan literatur. Seterusnya, tiga model simulasi (menggunakan teknik: SFS, ABS dan hibrid ABS/ SFS) telah dibangunkan, validasi dan verifikasi (disahkan dan ditentusahkan) berdasarkan data kajian kes sebenar. Pelbagai senario simulasi yang mempengaruhi pergerakan evakuasi manusia berdasarkan faktor evakuasi dimodelkan dan dianalisis. Hasil simulasi dibandingkan berdasarkan parameter pengukuran prestasi yang telah dipilih (PMP): waktu evakuasi, kecepatan, kadar aliran, kepadatan dan jumlah masa simulasi (masa pelaksanaan simulasi). Analisis daripada hasil simulasi menunjukkan bahawa SFS, ABS, dan hibrid ABS / SFS didapati sesuai untuk memodelkan evakuasi jalan keluar (EE) berdasarkan penilaian PMP. Nilai ralat piawai terkecil (SSE) melaporkan 66% untuk hibrid ABS/ SFS, 17% untuk ABS dan 17% untuk SFS di mana peratusan SSE tertinggi menunjukkan hasil simulasi yang lebih tepat. Berdasarkan keputusan eksperimen, hibrid ABS/ SFS menunjukkan prestasi yang lebih baik dengan keberkesanan dan ketepatan yang tinggi dalam simulasi tingkah laku manusia ketika memodelkan pelbagai senario yang berlaku semasa EE berbanding dengan model tunggal ABS dan SFS. Agen di dalam teknik hibrid berkomunikasi antara satu sama lain dengan membentuk kawalan terdesentralisasi untuk pergerakan EE yang lancar dan selamat. Kesimpulannya, sumbangan utama tesis ini kepada badan pengetahuan ialah teknik hibrid ABS/ SFS dalam memodelkan tingkah laku manusia semasa EE di kawasan tertutup seperti bangunan pejabat dan didapati penting untuk membantu pihak terlibat dan penyelidik untuk mengkaji perwakilan tingkah laku EE manusia dengan lebih dekat dengan mempertimbangkan teknik hibrid ABS/ SFS dan faktor-faktor yang memberi impak kepada model simulasi EE.

ABSTRACT

Simulation has become one of the popular techniques to model evacuation scenarios. Simulation is used as an instrumental for examining human movement during both normal and emergencies such as evacuation. During an evacuation, people will be in a panic situation and egress behaviour that will find the way out from a dangerous place to a safe place. Two well-known techniques in simulation that can incorporate human behaviour inside the simulation models are Agent-Based Simulation and Social Force Simulation. ABS is using the concept of a multi-agent system that consists of decentralized agents which can be autonomous, responsive and proactive. Meanwhile, SFS is a physical force to drive humans dynamically to perform egress actions and human self-organised behaviour in a group. However, the main issue in modelling both ABS or SFS alone is due to their characteristic as ABS have difficulty in modelling the force element and collective behaviours while SFS does not focus on free movements during the evacuation. This behaviour was due to the structure of humans (agents) inside ABS is decentralized which resulting collision among agents and the desired formation of evacuation was not achieved. On the other hand, in a single SFS model, the human was not proactive in finding the way out which was not reflecting the actual behaviour of humans during the evacuation. Both ABS and SFS are potential techniques to be combined due to their characteristics of self-learning and free movement in ABS and self-organization in SFS. The research methodology based on modelling and simulation (M&S) life-cycle has been utilized for this work; consists of three main phases, namely preliminary study, model development and validation and verification and finally the experimentation and the results analysis. The M&S life-cycle was utilized aligned with the research aim which is to investigate the performance of the combined ABS and SFS in modelling the egress behaviour during evacuation. To achieve the aim, five evacuation factors have been chosen namely obstacles, the number of exits, exit width, triggered alarm time, and the number of people that have been the most chosen factors in the literature review. Next, three simulation models (using techniques: SFS, ABS and hybrid ABS/SFS) have been developed, verified, and validated based on the real case study data. Various simulation scenarios that will influence the human evacuation movement based on the evacuation factors were modelled and analysed. The simulation results were compared based on the chosen performance measurement parameters (PMP): evacuation time, velocity, flow rate, density and simulation time (model execution time). The simulation results analysis revealed that SFS, ABS, and hybrid ABS/ SFS were found suitable to model evacuation egress (EE) based on the reported PMP. The smallest standard error (SSE) values reported 66% for hybrid ABS/ SFS, 17% for ABS and 17% for SFS where the highest percentage of SSE indicated the most accurate. Based on the experiment results, the hybrid ABS/ SFS revealed a better performance with high effectiveness and accuracy in the simulation model behaviour when modelling various evacuation egress scenarios compared to single ABS and SFS. Thus, hybrid ABS/ SFS was found the most appropriate technique for modelling EE as agents in the hybrid technique were communicating to each other by forming a decentralised control for smooth and safe EE movement. In addition, the impactful factors that affected the result accuracy were exits, the exit width (size), the obstacle and the number of people. Conclusively, this thesis contributed the hybrid ABS/ SFS model for modelling human behaviour during evacuation in a closed area such as an office building to the body of knowledge. Hence, this research was found significant to assist the practitioners and researchers to study the closer representation of human EE behaviour by considering the hybrid ABS/SFS model and the impactful factors of evacuation.

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