# A SOLUTION TO FINITE ESCAPE TIME IN $H_\infty$ FILTER SLAM

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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

Pengetahuan mengenai kedudukan dan orientasi robot mudah alih berautonomi sangat berguna dalam pelbagai tugas dan keadaan. Pada tahun 1986, salah satu teknik yang dicipta berdasarkan konsep saling kebergantungan antara pemetaan dan lokalisasi diperkenalkan dan dinamakan sebagai *Simultaneous Localization and Mapping (SLAM)*. SLAM mendapat perhatian penyelidik sejak berdekad lalu. Walau bagaimanapun, ia masih menghadapi pelbagai masalah ketidakpastian semasa proses pemerhatian robot bergerak yang perlu dipertimbangkan. *Extended Kalman Filter (EKF)* menjadi teknik yang paling popular yang digunakan oleh SLAM, namun terdapat batasan dalam hingar persekitaran *(non-Gaussian)* yang perlu dipertimbangkan. Atas sebab itu, teknik lain yang melebihi prestasi EKF yang dikenali sebagai *H ∞ Filter (HF)* mungkin menawarkan penyelesaian yang lebih baik. HF mampu bekerja dalam hingar persekitaran *(non-Gaussian).* Akan tetapi, ia dibatasi oleh satu isu lain yang tidak dapat diabaikan dan dikenali sebagai *Finite Escape Time (FET)*. FET perlu dipertimbangkan untuk memastikan HF berada di prestasi yang baik. Untuk mendapatkan prestasi terbaik SLAM, penyelidikan ini mencadangkan penyelesaian untuk mengurangkan masalah FET dengan menggunakan teknik *H∞ Filter with Fuzzy Logic (FHF).* Objektif utama adalah untuk mencadangkan penyelesaian baru untuk masalah SLAM menggunakan FHF dengan menggunapakai dua *Fuzzy Logic membership* iaitu trapezoid dan segitiga. Teknik yang dicadangkan menggunakan maklumat yang diekstrak dari inovasi pengukuran HF, pengawal *Fuzzy Logic* digunakan sebelum nilai *gain K* bagi mengawal saiz kovarian dengan cara mengawal masukan dari setiap *Landmarks* agar mendapatkan keluaran terbaik semasa pemerhatian orientasi robot mudah alih. Analisa dilakukan dalam dua bahagian dimana is menggunakan *Fuzzy Logic membership* iaitu trapezoid dan segitiga. Berdasarkan analisis, telah dibuktikan kewujudan FET dalam kedua-dua kaedah iaitu HF dan FHF. Manakala hasil simulasi menunjukkan bahawa FHF dapat digunakan untuk mengurangkan FET daripada berlaku dalam orientasi robot mudah alih bergerak untuk mencapai keputusan yang lebih baik dengan pemilihan skala *Fuzzy Logic* yang betul. Implikasi kajian ini secara langsung dapat memberikan ruang kepada aplikasi robot automasi dalam penggunaan persekitaran sebenar dimana kesan hingar yang wujud dapat diadaptasi dengan naik oleh system FHF yang dicadangkan.

# ABSTRACT

Knowledge about the position and orientation of autonomous mobile robots is very useful in different tasks. In 1986, an available technique for designing based on the interdependence between mapping and positioning was introduced, called Synchronous Positioning and Mapping (SLAM). SLAM has been receiving attention from researchers for decades. However, there are still many uncertainties that need to be considered in the observation process of mobile robots. The extended Kalman filter (EKF) has become the most popular technique in SLAM, but the limitations of non-Gaussian noise environments need to be considered. Therefore, another filter that exceeds the performance of EKF, called H∞ filter (HF), may provide a better solution. HF can work in a non-Gaussian noise environment, but is limited by another problem called Finite Escape Time (FET), which needs to be considered to ensure HF performance. In order to pursue the best performance of SLAM, this research proposes a solution to avoid the problem of Finite Escape Time (FET) by using H∞ filter fuzzy logic technology (FHF). The main goal is to propose a new solution to the SLAM problem using FHF with trapezoid and triangular membership. The proposed technique applies the information extracted from the HF measurement innovation, the fuzzy logic controller is applied before gain K in order to control the size of the covariance by controlling the measurement input of each landmark to ensure the best output for the positioning of the mobile robot during the observation period. The investigation is done in two cases which use fuzzy logic with trapezoid membership and triangular membership. Triangular membership is chosen as it simple and easy to handle while trapezoid is good in computation cost compare to Gaussian members type. Based on the analysis, the result proved the present of FET in both original HF and proposed FHF. With suitable range of each membership produces the simulation result that proves FHF can be used to refrain the FET from occurring in the mobile robot localization in order to achieve better estimation. This study may emphasize the application of autonomous mobile robot in a real life application may be considered since the environment noise are imprecise.

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