ROBOT PATH PLANNING USING FAMILY OF SOR ITERATIVE METHODS WITH LAPLACIAN BEHAVIOUR-BASED CONTROL

AZALI BIN SAUDI

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Sabah.

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(PROF. MADYA DR. JUMAT SULAIMAN)
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27th August 2015

Azali Bin Saudi
PS20099014

CERTIFICATION

NAME : **AZALI BIN SAUDI**

MATRIC NO : **PS20099014**

TITLE : **ROBOT PATH PLANNING USING FAMILY OF SOR ITERATIVE METHODS WITH LAPLACIAN BEHAVIOUR-BASED CONTROL**

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VIVA DATE : **27th July 2015**

DECLARED BY

Signature

1. **MAIN SUPERVISOR**
   Associate Professor Dr. Jumat Sulaiman

2. **CO-SUPERVISOR**
   Dr. Mohd. Hanafi Ahmad Hijazi

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ABSTRACT

A truly autonomous robot must have the capability to find path from its start point to a specified goal point. This study proposed a robot path planning technique that relies on the use of Laplace's equation to constrain the generation of potential values. It is based on the theory of heat transfer, when there exist a temperature gradient within a surface, heat energy will flow from the region of high temperature at heat source to the region of low temperature at heat sink. In this model, high Laplacian potentials are assigned to outer boundary, inner walls and obstacles. Whilst, the goal point is assigned the lowest and no Laplacian potentials are assigned to all other free spaces. The Laplacian potentials for nodes on free spaces are then computed iteratively using numerical techniques. In the literature, computing these Laplacian potentials using numerical techniques produced encouraging results. The numerical implementations of these previous works, however, were only based on family of point iterative methods i.e. Jacobi, Gauss-Seidel and Successive Overrelaxation (SOR). These standard methods are too slow when handling large environment. Therefore, this study introduces the concepts of half-sweep and quarter-sweep iterations, and initiates the first application of using family of Point SOR and family of Four Point-Block SOR iterative methods for computing the Laplacian potentials to solve the path planning problem. The implementations employ two finite difference discretization schemes that are based on 5-Point and 9-Point Laplacian. Within the family of Point SOR iterative methods, the simulation results shows that the application of half-sweep and quarter-sweep concepts reduced the computational complexities of the algorithms by approximately 50% and 75%, respectively. Significantly, simulations with family of Four Point-Block SOR iterative methods provide even faster computation. In terms of iterations count, the iterative methods based on the 9-Point Laplacian give the less number of iterations than the 5-Point Laplacian. Whilst, in terms of execution time, the speed difference between iterative methods based on 5-Point and 9-Point Laplacian is very minimal. Once the Laplacian potentials are obtained, the standard Gradient Descent Search (GDS) technique is performed for path tracing to the goal point. The existing GDS, however, suffers from the occurrence of flat region in a more difficult environment which causing the path generation to fail. Thus, this study proposes a new control known as Laplacian Behaviour-Based Control (LBBC) to overcome such problem. Due to its robustness, the LBBC successfully generated smooth path even in a more complex configuration space. Therefore in conclusion, the significant contribution of this study is in introducing for the first time the fast half-sweep and quarter-sweep iterative methods using families of Point SOR and Four Point-Block SOR methods via 5-Point and 9-Point Laplacian. These faster iterative methods overcome the slow performances of the existing standard methods, particularly when handling large environment. In addition, the newly proposed LBBC overcomes the drawback of the existing GDS that face difficulty when handling complex environment. Finally, the path planning problem is solved by combining the fast iterative method with the robust path searching LBBC technique, so that the path planning algorithm is capable of handling large and complex environment.

ABSTRAK

PERANCANGAN LALUAN ROBOT MENGGUNAKAN FAMILI KAEDAH LELARAN SOR DENGAN KAWALAN BERASASKAN-KELAKUAN LAPLACIAN

Robot automatik yang sebenar perlulah berkeupayaan untuk mencari laluan dari titik permulaan hingga ke titik destinasi. Kajian ini mencadangkan teknik perancangan laluan robot yang menggunakan persamaan Laplace untuk menjana nilai-nilai potensi. Ianya berdasarkan teori pemindahan haba, apabila terdapat kecerunan suhu pada permukaan, haba akan mengalir dari kawasan sumber suhu yang bersuhu tinggi ke kawasan bersuhu rendah yang bertindak sebagai penarik suhu. Dengan model ini, nilai potensi Laplacian yang tinggi diberikan kepada dinding luar, dinding dalaman dan objek halangan. Manakala titik destinasi diberikan nilai paling rendah, dan tiada nilai potensi Laplacian diberikan kepada titik-titik bebas yang lain. Nilai potensi Laplacian untuk titik-titik bebas kemudiannya akan dihitung secara lelaran menggunakan teknik berangka. Dalam kajian lepas, pengiraan nilai-nilai potensi Laplacian dengan menggunakan teknik berangka menghasilkan keputusan yang menggalakkan. Bagaimanapun, implementasi teknik berangka dalam kajian-kajian yang lepas ini hanya berasaskan kaedah lelaran titik iaitu Jacobi, Gauss-Seidel dan Successive Overrelaxation (SOR). Kaedah-kaedah lelaran lazim ini terlalu perlahan apabila digunakan untuk persekitaran yang luas. Oleh yang demikian, kajian ini memperkenalkan konsep lelaran sapuan-separuh dan sapuan-suku dengan buat pertama kali mengaplikasikan penggunaannya melalui kaedah lelaran family of Point SOR dan family of Four Point-Block SOR untuk menghitung potensi-potensi Laplacian bagi menyelesaikan masalah perancangan laluan. Dalam implementasinya, dua skima pendiskretan pembezaan terhingga digunakan yang berasaskan 5-Point dan 9-Point Laplacian. Dengan kaedah lelaran family of Point SOR, keputusan simulasi menunjukkan aplikasi sapuan-separuh dan sapuan-suku telah mengurangkan kekompleksan pengiraan algoritma masing-masing sekitar 50% dan 75%. Manakala, kaedah lelaran family of Four Point-Block SOR pula telah menyediakan pengiraan yang lebih pantas. Dari segi bilangan lelaran, kaedah berasaskan 9-Point Laplacian memberikan bilangan lelaran lebih rendah berbanding kaedah 5-Point Laplacian. Manakala, dari segi masa pelaksanaan, perbezaan kepantasan antara kaedah 5-Point dan 9-Point Laplacian adalah sangat minimum. Setelah nilai-nilai potensi Laplacian diperolehi, teknik Gradient Descent Search (GDS) digunakan untuk menjejak laluan ke titik destinasi. Namun, teknik GDS mengalami masalah apabila terdapat kawasan rata dalam persekitaran yang lebih sukar dan menyebabkan penjanaan laluan gagal. Oleh itu, kajian ini mencadangkan teknik kawalan baru yang dikenali sebagai Laplacian Behaviour-Based Control (LBBC) bagi mengatasi masalah tersebut. Teknik LBBC telah berjaya menjana laluan yang lancar walaupun pada ruang konfigurasi yang kompleks. Sebagai kesimpulan, sumbangan terpenting kajian ini ialah memperkenalkan buat pertama kali lelaran sapuan-separuh dan sapuan-suku dalam kaedah lelaran family of Point SOR dan family of Four Point-Block SOR dengan berasaskan 5-Point dan 9-Point Laplacian. Kaedah-kaedah lelaran yang laju ini mengatasi kaedah sedia ada yang terlalu perlahan, terutamanya untuk persekitaran yang luas. Selain itu, teknik baru LBBC dapat mengatasi kelemahan teknik sedia ada GDS yang mengalami kesukaran apabila mengendalikan persekitaran yang kompleks. Seterusnya, masalah perancangan laluan diselesaikan dengan menggabungkan kaedah lelaran yang laju dengan teknik carian laluan LBBC yang cekap, lantas algoritma mampu mengendalikan persekitaran yang luas dan kompleks.

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