PATH PLANNING FOR AUTONOMOUS NAVIGATION IN ROUNDABOUTS USING AN IMPROVED TRIANGULAR BASED POLYNOMIAL ESTIMATION TECHNIQUE FOR BEZIER CURVE GENERATION WITH AA AND AA* ALGORITHMS

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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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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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Thesis submitted in fulfillment of the requirements
for the award of the degree of
Master of Science

Faculty of Manufacturing & Mechatronics Engineering Technology

UNIVERSITI MALAYSIA PAHANG

MARCH 2023

ACKNOWLEDGEMENTS

It is undeniable that the completion of this thesis is impossible without the support from people around me. I am obligated to express my deepest gratitude to those who stood by my side, cheering and motivating me throughout the journey. My first thanks will be to the Almighty God, for the strength and guiding me throughout the journey.

Next, I would like to acknowledge the support of my supervisor, Dr Muhammad Aizzat bin Zakaria for his never-ending guidance and patience throughout the journey. I am lucky to be granted the most understanding and friendliest support. Dr Aizzat has offered me to research under his supervision and kept monitoring and motivating me until I manage to complete my master's degree.

Naturally, family members are the greatest source of strength for me throughout the journey. My parents Sajith and Deepa, have been providing me with the care and support, motivating me to complete my Master's Degree. Not forgotten to my sibling Arun Vinayak who stood by my side boosting my morale. I would also like to thank my friends who were there to provide me with support and encouragement.

Thank you to all the members of the iMAMS Laboratory, be it members of the past and especially present members, for their continuous assistance along the journey of this research. The members have provided much-needed assistance as well as moral support during the journey, and I cannot imagine completing this study without their assistance. I would also like to thank Vaishak Sunil, Gayathry Ganesh, Baarath Kunjunni, Jothi Letchumy for there continuous support through out my studies

I dedicate this thesis to everyone who was there throughout the journey. Thank you all.

Akhil Vinayak

17 MARCH 2023

ABSTRAK

Pembangunan kereta swa-pandu (AV) merupakan bidang penyelidikan yang sedang membangun. Kereta swa-pandu perlu mengimbas persekitaran sekeliling untuk mengenal pasti halangan justeru membentuk laluan yang sesuai dengan persekitaran (*path planning*). Perancangan laluan merupakan salah satu aspek penting dalam pembangunan AV di mana laluan yang di bentuk mengambil kira faktor persekitaran. Laluan tersebut di bentuk untuk diikut oleh kereta swa-pandu melalui pelbagai persimpangan. Salah satu persimpangan yang mencabar dalam pembentukan laluan ialah bulatan disebabkan oleh bentuk yang kompleks dan peraturan trafik yang berbeza. Untuk mengatasi cabaran ini, satu kaedah penyesuaian lengkung yang berbeza perlu digunakan. Salah satu kaedah penyesuaian lengkung yang biasa di gunakan ialah kaedah Bezier yang bergantung kepada posisi titik kawalan. Para penyelidik telah membangunkan pelbagai kaedah untuk mencari lokasi titik kawalan (*control points*). Namun perubahan bentuk bulatan menyebabkan laluan yang dibentuk melalui algoritma perancangan laluan tidak tepat kerana lokasi titik kawalan yang tidak berubah. Oleh itu, objektif penyelidikan ini ialah untuk memperkenalkan satu kaedah yang menambahbaik kaedah sebelum ini; iaitu mengira titik kawalan untuk pengiraan lengkungan Bezier mengikut bentuk bulatan. Satu kaedah penganggaran polynomial berasaskan segi tiga dibincangkan di dalam tesis ini untuk membantu mengira titik kawalan lengkungan Bezier berdasarkan titik yang dipilih dalam laluan. Satu persamaan telah diperkenalkan yang akan mengira titik kawalan berdasarkan titik yang di pilih dan nilai faktor segmentasi (t). Pemilihan titik dalam bulatan di buat dengan mencipta bahagian segi tiga di mana titik di pilih dalam segi tiga berdasarkan nisbah ataupun lokasi titik kordinat terakhir (Algoritma AA) atau berdasarkan pengiraan nilai nisbah kordinat bucu bulatan (Algoritma AA Star). Nilai faktor segmentasi (t) dikira berdasarkan jarak antara titik bagi mengoptimumkan output lengkungan Bezier terhadap bulatan. Selain itu, laluan bulat di dalam bulatan di bentuk menggunakan kaedah yang dicadangkan supaya laluan tersebut boleh di ubah mengikut bentuk bulatan tersebut. Kaedah yang dicadangkan telah diuji di beberapa bulatan yang berbeza untuk mengenal pasti kecekapan kaedah tersebut. Kemudian, laluan yang di bentuk telah diuji keberkesanannya menggunakan model sistem kawalan Model Predictive Control (MPC). Selain itu, kaedah yang dicadangkan juga telah dibandingkan dengan kaedah perancangan laluan berdasarkan lengkungan Bezier lain untuk menunjukkan keberkesanan algoritma dicadangkan. Berdasarkan keputusan yang diperoleh, kaedah yang dicadangkan mempunyai kadar ralat RMS yang rendah iaitu 0.208m pada permulaan bulatan dan 0.139m pada bulatan keluar berbanding kaedah tanpa pengoptimuman titik kawalan lengkung. Kaedah anggaran polynomial berdasarkan segi tiga yang dicadangkan dapat membantu membentuk laluan mengikut bentuk bulatan justeru, mengatasi kekurangan kaedah-kaedah lain.

ABSTRACT

Autonomous vehicle (AVs) development is a rapidly growing research field. The AVs need to inspect the environment and detect the obstacle to create a path according to the environment. Path planning is a critical stage in the operation of vehicles, wherein the path is generated based on the surrounding environment to ensure safe and efficient navigation. The path is created for the vehicle to travel through different intersections. Among that roundabout is a type of intersection where path planning is challenging due to their complex shape and different traffic rules. To overcome this, different curve fitting methods were used to create path. However, the commonly used method is Bezier curve based curve fitting method which depends on the position of the control points. Many researchers have established different methods to position the control points but the change in the shape of roundabout cause the path to be inaccurate as the position of the control points are fixed. Therefore, the objective of the research is to introduce an enhanced method for calculating the control points for Bezier curve generation according to the shape of the roundabout. A triangular-based polynomial estimation technique is introduced, which helps calculate the Bezier curve's control points based on the points selected in the path. An equation is introduced which helps in calculating the control points based on the points selected and the respective segmentation factor (t) value. The point selection in the roundabout is carried out by creating a triangular section where points are selected inside the triangle based on ratios (AA algorithm) or depending on the edge coordinates (AA star algorithm). The segmentation factor value for the points are calculated based on the distance between the points to avoid curve overfitting or underfitting. The circular path inside the roundabout is also created using the proposed method so that path can be adjusted according to the shape of the roundabout. The proposed method was tested in different roundabouts with different shapes to check the efficiency of the proposed method. The created path is tested using the Model predictive controller (MPC) vehicle model. Additionally, the proposed method is compared with other Bezier curve based path planning methods. The proposed method has RMS error of 0.208m for entry and 0.1319m for exit curve with the reference path which is the lowest compared to other path planning methods. The triangular-based polynomial estimation technique helps create the path according to the roundabout shape, thus overcoming the drawbacks of the previous methods.

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