Terrain Classification, Navigation, and Gait Selection in a Leg-Wheel Transformable Robot by Using Environmental RGBD Information

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***Abstract*— This paper presents a behavior decision strategy for the leg-wheel transformable robot, TurboQuad-V. By using real-time RGBD information combined with the gait selection policy concluded from the single-leg-wheel dynamic simulation, the robot can perform autonomous gait switching and basic obstacle avoidance on multiple terrains.**

I. Introduction

TurboQuad-V, shown in Fig.1, features for its novel design of the two degree-of-freedom mechanism that can change formations between wheeled mode and legged mode. Aided with the bio-inspired Central Pattern Generator control structure, the robot is able to perform smooth transitions between different gaits to adapt to various kinds of terrains with higher efficiency and traversability [1].

Fig. 1 The leg-wheel transformable robot *TurboQuad-V*.

While adjusting dynamic motions according to the environment has been an important research topic in recent years, the main contribution of our work is the development of autonomous gait and direction switching on TurboQuad-V by using real-time color and depth image feedback. With the decision policy concluded from the simulation and the experiments, the robot is able to select a better way to move more efficiently on multiple terrains automatically.

II. Methods and Results

In this research, we use real-time vision system to obtain terrain information. Color image is used to classify different types of landscape by using Convolution Neural Network model, which can extract features of the input image and calculate the probability of each assigned output category. This model is modified and pre-trained with the database collected and labeled by ourselves. The system is proved to have high accuracy, high stability on predicting various types of landscape at day and night, even under disturbances such as motion blur effect or encountering unseen scenarios.

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Fig. 2 Experiments conducted on multiple terrains.

Point cloud data acquired from depth image can be transferred to mean elevation grids under world frame to represent the geometric distribution of the terrain. By defining cost map accordingly and implementing weighted shortest path algorithm to find the optimized route with minimum cost, the robot can adjust the forward direction to avoid high barriers. Meanwhile, the height distribution along with the route can also be used as the reference for the gait selection.

To find the best gait switching policy, this research also focuses on the development of the dynamic simulation using single-leg-wheel model. The simulation runs different gaits on various simplified terrains. Slip effect and contact geometry are considered in the model. With the analysis of indexes such as power efficiency, the ability to overcome obstacles and the height variation during motions, suitable operating points of each gait according to different terrains can also be concluded.

Through the experiments conducted on various kinds of environment , shown as Fig. 2, the real physic behaviors of the robot is proved corresponding to the simulation results. The decision policy can then be conclude accordingly. In summary, the result of color image classification provides landscape category, and the depth image processing provides height information along the optimized route. The information can be fused with the simulation result to decide proper gait and turning command.

III. Conclusion

With the integration of information from the image processing and the switching policy conclude from the simulation, TurboQuad-V is proved to have the ability to perform autonomous gait switching and basic obstacle avoidance. The updated robot equip with the vision system is able to carry out distant exploration on multiple environment with high efficiency and traversability, and can serve as a mobile platform for further usage.

References

[1] W. H. Chen, H. S. Lin, Y. M. Lin, and P. C. Lin*, "TurboQuad: A novel leg-wheel transformable robot with smooth and fast behavioral transitions," IEEE Transactions on Robotics (T-RO), Oct. 2017, vol.33 no.5, pp1025-1040.