Graduate School of Advanced Science and Engineering
Waseda University

博士論文審査報告書
Screening Results Report

論　文　題　目
Thesis Theme

Visual planning of humanoid robot locomotion considering world geometry and friction

環境の形状と摩擦を考慮したヒューマノイドロボットの視覚に基づく歩行計画に関する研究

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February, 2017

This thesis deals with the problem of humanoid robot locomotion, from the point of view of both perception and motion planning. The problem is of high interest to the robotics community and has applications in service, industry and disaster response.

The thesis proposes several novel ideas and solutions to the problem.

a) It provides a new algorithm for hierarchical locomotion planning which is robust and consistent between levels. It is inspired by human gait analysis, using learned models to map step parameters to energy and required-friction predictions, thanks to which it improves robot energy consumption, reduces slippage and increases stability. The fact that these factors are considered at all planning levels make the planner more consistent and comprehensive than previous state-of-the-art planners. The planner is also robust to perception uncertainty at the footstep planning level, which is another novel and crucial idea for real-world applications.
b) It investigates the problem of visual estimation of friction, with relevant insights both for autonomous perception and teleoperation. It introduces, as far as we know, the first algorithm to estimate friction and its probability distribution at all pixels of input images. The algorithm and insights are widely applicable to other areas of robotics such as manipulation and assistance to the disabled.
c) It investigates the problem of visual estimation of geometry with stereo sensors and their uncertainty models. In this front it provides an in-depth analysis of these models and proposes novel ways to improve and estimate them. In practice, the thesis shows that these improvements also lead to better 3D reconstruction performance for robotics.

The thesis has wide-ranging applications and will certainly have an impact in the academic fields of robot motion planning, locomotion, and computer vision. As for societal impacts, the developed technologies can be used to improve robot locomotion and manipulation skills in the industry, locomotion skills for domestic service and disaster response robots, as well as wellbeing devices to assist the blind with navigation.

Throughout its review stage, the members of the jury made several comments and suggestions that were later included in the final version

of the thesis. Overall, the structure of the thesis was improved by adding objectives to each section and corresponding discussion subsections for each objective. Numbering and bulleting were also made more uniform, and the discussion and summary sections separated. In Chapter 1, a general introduction to robot applications was added, as well as a thesis flowchart and tabular comparison with the state-of-the-art. In Chapter 2, more details on the robotic platform were added; the cost-of-transport figures were changed to a 3D representation for readability; and figures with image sequences slightly improved for readability. In Chapter 3, the limitations of the system were further discussed. In Chapter 5, a block diagram for the whole architecture was added, as were new experiments in real-world scenarios acquired with a 3D camera. In Chapter 6, the discussion of the limitations of the thesis was enlarged, such as the system's serial design and the absence of motion cues on the friction datasets. A discussion of the applicability of the developed technologies to other fields was also included.

This thesis contributes to the advancement of the state-of-the-art in several fields, from humanoid locomotion planning to robot perception and teleoperation. It also led to an outstanding publication record in major journals and conferences. The manuscript is well structured and written, and discussions are thorough. The jury's comments were addressed. For all these reasons, this thesis is eligible for the application for Doctor of Engineering.

2017 年 2 月

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This thesis, entitled “Visual planning of humanoid robot locomotion considering world geometry and friction”, by Martim CRISTINA DE SERPA BRANDAO, is eligible for the application for Doctor of Engineering.

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