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学位論文題目	Wheelchair Robot System Based on Drivable Road Detection Using Genetic Algorithm and Deep Learning （遺伝的アルゴリズムと深層学習を用いた道路検出に基づく車いすロボットシステム）
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学位論文内容の要旨

学位論文題目　Wheelchair Robot System Based on Drivable Road Detection Using Genetic Algorithm and Deep Learning
(遺伝的アルゴリズムと深層学習を用いた道路検出に基づく車いすロボットシステム)

専攻名　　数理・ヒューマンシステム科学専攻

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Many societies are facing with a growing aging population. This growing number of aging individuals is also accompanied by age-related diseases and impairments. With increases in the number of aging and disable population, there is growing demand for intelligent robotic systems and care equipment to support their daily life. A vast majority of elderly individuals suffer from mobility decline. It is well known that individual mobility is an important part of the mental and social well-being of the disabled people. In this scenario, Intelligent wheelchair robot can play indispensable roles for individual mobility. Usually, robot navigation in outdoor environments are rely on multiple sensors and GPS receiver for environment perception and localization. While GPS and laser sensor based navigation methods have achieved great advances in past few decades, outdoor environments perception and localization is still a challenging issue. The main limitation of using laser sensor is that it is unable to properly detect roadside fences and fence- like objects because the signal of the sensor passes through the fence. Hence, it is not sufficiently good to navigate the robot in an outdoor environment by using a laser sensor. Furthermore, the low-cost GPS receiver does not function properly in GPS-denied environments. Most of the developed navigation systems use expensive devices and

sophisticated technologies to solve these issues that block the intelligent navigation system to move into the commercialization phase. Therefore, efficient navigation systems are required with at lower degree of complexity to aid disabled individuals for safe navigation in outdoor environments.

In this study, one of the main challenges is to develop drivable road detection. Single camera vision is definitely good as it cheap in cost but rich in information. However, it is very sensitive to illumination. Besides, robot navigation relying on a single camera is also a critical task for integrating road detection, localization, and navigation together. In order to minimize the limitations, a deep learning based approach is proposed. The robot detects road area using Deep Belief Neural Network (DBNN) and measures distances using estimated camera parameters. During navigation, the camera takes a snapshot of the road, and the captured image is then converted into an illuminant invariant image. Subsequently, a deep belief neural network considers this image as an input. It extracts additional discriminative abstract features by using general purpose learning procedure for detection. During obstacle avoidance, the robot measures the distance from the obstacle position by using estimated parameters of the calibrated camera, and it performs navigation by avoiding obstacles. This study develops a cost-effective navigation method by using a single camera. It performs better in terms of navigation when compared to LRF-based methods in LRF-denied environments, such as road with fence and fence-like objects.

However, a single camera vision based navigation performance can be affected by different weather conditions such as, sunny, cloudy, and rainy environments. For road detection in different weather conditions, a dataset becomes to be a large scale, because the dataset has to include many images of different weather, which leads to heavy computation and decrease autonomous system performance. Therefore, two computation reduction approaches are proposed and analyzed on detection accuracy and processing time. The first approach is Kernel Principal Component Analysis-Deep Belief Neural Network (KPCA-DBNN), and the second one is Dimensionality Reduction Deep Belief Neural Network (DRDBNN). Finally, the DRDBNN is applied for drivable road detection due to its good performance. The proposed DRDBNN is trained on a large database, which is created from road images of different weather conditions, such as sunny, cloudy, and rainy. Due to the dimensionality reduction ability of the DRDBNN, it

detects the drivable road area in a short time for controlling the robot in real time. A feed-forward neural network and Genetic Algorithm (GA) are used to control the robot for the boundary following navigation. The robot detects road junction area and takes turning decision from Google Map data, thus reach to the final destination. The navigation performance in different weather conditions and a comparison with laser range finder (LRF)-based methods were demonstrated through experiments.

Finally, the developed method is implemented on a wheelchair robot, and it is verified by navigating the wheelchair robot on different types of urban curve roads and road junction in different weather conditions. Navigation in real environments indicates that the wheelchair robot can move safely from one place to another. The wheelchair robot correctly detects the drivable road areas and navigates by following road junction and taking desired turning decision in road junction using Google Map data and GPS receiver.

【審査結果要旨】

当学位論文審査委員会は，標記の博士学位申請論文を詳細に査読し，また論文発表会を平成 31 年 1 月 28 日（月）に公開で催し，詳細な質疑とともに論文の審査を行った。

近年，超高齢社会となり自律して走行する車いすロボットが求められている。これらのロボットには，道路に沿って安全に走行し， 目的地まで到達する必要がある。そこで，申請論文では，車椅子ロボットに取り付けられた単眼カメラの入力画像から Deep Belief Neural Network（DBNN）を用いて走行可能な道路領域を検出し，その道路領域に沿って走行する手法を提案している。申請論文は 4 つの内容に分けられる。第 1 は DBNN の構成および DBNN を用いた道路領域と障害物の検出手法の提案，第 2 は曇りや雨の天候に対応するための大規模データセットによる道路領域の検出手法の提案，第 3 は遺伝的アルゴリズムを用いて最適化した NN によるロボットの制御手法の提案，第 4 は提案手法を備えると伴に google Map との連携により目的地まで走行するロボットシステムを構築していることである。そして， DBNN の次元数を削減することにより処理時間の短縮が図れることや，晴れ，曇り，および雨などの異なる天候においても単眼カメラの入力画像から道路を検出し， 目的地まで走行できることなどの研究成果が纏められている。なお申請論文の研究成果は 2 編の英文原著論文として国際学術専門誌に掲載されている。

当審査委員会は，研究内容及び研究成果を慎重に吟味した結果，審査論文は，ロボティクス，情報工学，人工知能の諸分野において学術的価値のある知見を与えていると判断し，博士（工学）の学位を授与するに十分値するものと認め，合格と判断した。