博士論文審査結果の要旨

博士論文審査委員会

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論文題目	Dynamic Modeling and Motion Control on Holonomic and Non-holonomic Vehicle Robots

〔論文審査の要旨〕

1）結論：審査員全員が合格と判定した。

2）論文の内容：
本論文は移動ロボットのモデリング・同定・位置推定・マルチレート制御に関する総合的な設計手法を提案する論文である。具体的には、車輪型倒立振子ロボット及び全方向移動ロボットを題材にしてモーションコントロール技術を追求している。その特長は、厳密な運動方程式の導出と、独自のシステム同定法により動的モデルを導き出して摩擦補償を行った他、ロボット及び障害物の位置推定を Kinect センサにより行い、独自のマルチレートサンプリング制御法による実験検証結果を報告するものである。

3）研究業績：第一著者としての査読つき論文数の原則 2 編に対し 1 編。但し、第一著者としての国際会議論文 2 編の発表が行われ、さらに 1 編が採択された。

4）審査経過
・予備審査は平成 26 年 5 月 23 日　及び　平成 26 年 5 月 26 日に、最終審査は、平成 26 年 8 月 21 日及び 8 月 23 日に行った。
・当初、内容が多岐に渡り、相互の関係が不明確である点、研究の位置づけやオリジナリティに関する記述が十分でない点が指摘されたが、最終審査においては改善が見られ、完成度が高まったことが確認された。
・研究題名と内容とにずれが生じているとの指摘から題名(Development of Vehicle Robots Based on System Modeling and System Identification)が(Dynamic Modeling and Motion Control on Holonomic and Non-holonomic Vehicle Robots)に変更された。

論　文　要　旨

Thesis Abstract

2014 年　07 月　02 日

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主論文題名　（Title）

Dynamic Modeling and Motion Control on
Holonomic and Non-holonomic Vehicle Robots

内容の要旨　（Abstract）

This thesis investigates on development of advanced motion control system for mobile robots considering dynamic uncertainty, holonomic and non-holonomic problem, and multi-rate sampling problem, which remain in the current studies of literature. The mobile robots utilized in this research are a two wheeled inverted pendulum robot and a four wheeled omni-directional robot. Then, the development of the mobile robots in this thesis is all-around improvement relative to these problems. The problems, the contributions, the experiment and the results are described as follows;

Dynamic model is a mathematical model of a physical system in order to express locomotion of physical system. It is the most important part in motion control design.Then, this thesis considers the dynamic uncertainty effect to the control performance. To analysis the uncertainty, system modeling and system identification have been presented for improving and estimating the dynamic model. Considering the motion of wheeled inverted pendulum robot, the dynamic models in literature reviews are derive considering only rotation of wheel. The presented dynamic model is derived with considering not only wheel-rotation but also body-rotation. Moreover, the system identification is introduced based on autoregressive with exogenous inputs model (ARX), which does not concern about measurement uncertainty. To improve the control systems using odometry, Kinect is mounted in operating space in order to observe the locomotion of the robots so that the space can locate the locomotion of the robots. It is called intelligent space. The space can locate the robot locomotion precisely than the odometry based locomotion because some uncertainties may appear in the odometry such as slip motion and global positioning error. The multi-rate control systems for holonomic and non-holonomic robots are dissimilar structure because the motion of non-holonomic robot is limited. Then, only position feedback is not enough to perform the robot on the trajectory. The trajectory tracking algorithm is included in the motion control to navigate non-holonomic robot on the trajectory. It is designed corresponding to non-holonomic constraint. Therefore, the multi-rate control systems for omni-directional robot and the inverted pendulum robot are contrast at the trajectory tracking algorithm. Therefore, this thesis has introduced the new dynamic model of the inverted pendulum robot, the system identification considering low accuracy

measurement, and the multi-rate control systems for holonomic and non-holonomic robots. The new dynamic model is improved by considering the rotation of body with wheel and autoregressive moving average with exogenous and sensor disturbance model (ARMAXD) was established in order to identify the linear model with low accuracy measurement. The uncertainty is assumed that it is the high frequency of the error between the output and the estimate output, which is derived by the estimate of the state matrix and the input matrix. Then, it is recognized as the members in the regressive vector so that the effective of the sensor noise is decreased in the identification result, which means that the identification accuracy is better.

By the way, the multi-rate control systems were evaluated with the position estimators, which estimate the robot position by involving the robot positions from the intelligent space and the odometry. To track the trajectory, way point denotes desired position. It is slided on the trajectory, and then, the control system tracks the way point. It is called continuous tracking control (CT). For approaching the way point, omni-directional robot can perform on every degrees of freedom by sliding mode and the input torques of four wheels can be derived by the attractive force on world coordinate and Jacobian matrix. On the other hands, the inverted pendulum can not directly perform on sideway so that it approaches to the desired position by straight or curve motions in order to archive the way point at the flank of the robot. The trajectory tracking algorithm is evaluated to treat the curve motion. It transforms the distance error on world coordinate to the distance error on the vehicle fixed coordinate, and then the distance error is bounded by trigonometric functions. It seems the weight function that the priority of yawing is higher than the straight motion.

As the result, the presented dynamic model of the inverted pendulum robot is derived with considering new motion constraint and the new structure model is established as autoregressive moving average with exogenous and sensor disturbance (ARMAXD) model. The simulation of system identification and the experiment on friction compensation have corroborated that ARMAXD model can identify the robot system precisely than ARX model. Moreover, the experiment of the multi-rate control consists of the experiments of the multi-rate control for the omni-directional robot and the inverted pendulum robot. The simulation of trajectory tracking deals the tracking performance of vision feedback control and multi-rate control. It shows that the robot with the multi-rate control can approach to the end of the trajectory faster than vision feedback control. The experiment on the omni-directional robot and the inverted pendulum robot can track the trajectory successfully.