Abstract
(論 文 の 内 容 の 要 旨)

論文題目　High Speed Robotic Manipulation for Rotation Control using Visual Encoder
(ビジュアルエンコーダを用いた回転制御のための高速ロボットマニピュレーション)

氏　名　金　賢梧 / Hyuno Kim

A rotor takes a key responsibility in various mechanical systems, for power generation, power transmission as well as transportation, via the rotation in the system. In particular, a rotary system which includes a flexible object, such as thread, shows beneficial features in that the flexibility enhances the tolerance related to the connection between the rotor and the other parts owing to the morphologic characteristics. Accordingly, the precise control for the rotation of the rotor has been considered as a significant function for robotic systems. However, since the model for a flexible thread is complicated to construct and the nonlinear dynamics of the flexible thread is intricate to handle, the high-speed rotation control via thread by a robotic manipulator has been regarded as a difficult task. In order to simplify this problem, a high-speed vision-robot system with a simple PD controller can be suggested as a promising method, because this system can handle an event for a very short time interval and can be less influenced by the nonlinearity as well as by the modeling error. Also, since the conventional measurement methods were not suitable in terms of accuracy and robustness for the rotation control via thread, a new robust measurement method that can replace the existing methods is required, to exploit the high-speed vision-robot system for the rotation control.

This dissertation firstly introduces a new method to measure the rotation angle of a rotor, which is named as a visual encoder method, and then presents its applications into the field of robotic manipulation for the rotation control. The visual encoder method is developed in order to provide with a robust and precise measurement result for a rotor that rotates at high speed, even under the condition that the rotation axis is movable and experiences a fluctuation in the space. To achieve such features, the principles of vision-based method and the optical encoder are exploited with high-speed vision system. With the ability of the visual encoder in its operation at high-speed up to 6,000 rpm, a new kind of robotic manipulation regarding 'high-speed rotation' via thread is now accomplishable. The method to sense and control the high-speed rotation of the rotor by a robotic manipulator system, which involves dynamic motion, is described with the consideration of the academic and the industrial contribution.

The rotation control for the objects with flexible part is conducted in two applications, and the robotic 'button spinner' and the robotic 'yo-yo' are selected in order to prove the visual encoder method for the rotation control via twisting and bending of the thread, respectively. In the applications, the transformation of thread is modeled with the complicated dynamics, and the nonlinearity and the modeling error are evaluated to define the limitation of the conventional approach for the tasks. As a result, in case of the robotic button spinner, the position and the rotation of the rotor are controlled within 1 mm and in sub-turn order, respectively, using high-speed visual feedback with the visual encoder method. Also, a stable performance of the robotic yo-yo is achieved in two example tasks, 'throwing and catching' and 'continuous playing', using the rotation-based feedback control. Consequently, the performance of the high-speed vision-robot system with visual encoder method was successfully verified in both applications. Additionally, in order to compensate the occlusion problem of the visual encoder, a high-speed distributed camera network is suggested and confirmed in the capability of synchronization among the camera nodes, based on MPI and RTC.