Identification, Compensation and Estimation of Joint Friction of Robotic Manipulators

岩谷, 正義

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氏　　名　：岩谷　正義

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（ロボットマニピュレータの関節摩擦の同定，補償および推定）

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論 文 内 容 の 要 旨

This dissertation focuses on the treatment of joint friction of robotic manipulators, specifically, the identification, compensation and estimation of joint friction. The contributions of this dissertation are the following new techniques: (1) a procedure for identification of rate-dependent friction laws of robotic manipulators with limited motion ranges, (2) a friction compensator improving the backdrivability of robotic joints and (3) a friction force estimator for external force estimation and a further application to admittance control. The new techniques are tested through experiments using setups such as a belt-driven actuator system and a six-axis industrial manipulator.

Chapter 1 provides the background on modeling, identification, compensation and estimation of joint friction. The problems and solutions of friction reported in previous studies are reviewed and the contributions of this dissertation are overviewed. The interconnection among chapters of the dissertation is also provided.

Chapter 2 proposes a new identification procedure for rate-dependent friction in robotic manipulators of which the motion is limited due to the configuration or the environment. The procedure is characterized by the following three features: (i) the rate dependency is represented by a set of line sections connecting sampled velocity-force pairs, (ii) the robot is position-controlled to track desired trajectories that are composed of some cycles of sinusoidal motion with different frequencies, and (iii) each velocity-force pair is sampled from one cycle of the motion with subtracting the effects of the gravity and the inertia. The procedure is validated through experiments that show that the identification is achieved with a sufficient accuracy within limited motion ranges.

Chapter 3 proposes a new friction compensator based on an elastoplastic friction model. Hayward and Armstrong’s elastoplastic friction model is one of the simplest friction models. A limitation of a friction compensator using the elastoplastic friction model is that, in the static friction state, the compensator continues commanding non-zero output force, which hampers the system’s reaction to external forces. The proposed compensator in this dissertation is an improved version of the elastoplastic friction compensator with an additional term, which makes the output force decay exponentially in the static friction state. Through experiments, it is shown that the proposed compensator enhances backdrivability of robotic joints. This chapter provides a further improved algorithm of the friction compensator for a situation where robotic joints are moved by human hand.

Chapter 4 proposes a new friction force estimator for external force estimation. External force estimation is a technique to estimate the external force acting on the robotic systems based on the equation of motion including friction term. This chapter improves the external force estimation by using a friction force estimator, of which the mathematical expression is the same as the friction compensator in Chapter 3, and which decays the output estimated force in the static friction state. The proposed estimator is tested through some experiments, which show its advantages over conventional model-based estimator. In addition, a further improvement is also proposed for the application in the admittance control.

Chapter 5 provides the concluding remarks and future works.

〔作成要領〕

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