学　位　論　文　内　容　の　要　旨

DISSERTATION ABSTRACT

博士の専攻分野の名称　　博士（工学）　　氏名　盖 軼之

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Soft Computing Approaches for Effective Utilization of Elastic Energy in Flexible Manipulator
(柔軟マニピュレータの弾性エネルギー活用のためのソフトコンピューティング手法)

The concept of Soft Computing was developed in the year around 1990. Soft Computing techniques are designed to model and exploit the solutions to real world problems. As the opposite concept of Soft Computing, Hard Computing requires precise model with exact input data and just produces precise answers. In engineering researches, the system with complexity, disturbances, nonlinearity, or time variation commonly requires the computing techniques that provide a certain tolerance to uncertainty, imprecision, and partial truth. Soft Computing can keep robustness, low solution cost, and flexibility to tackle such engineering problems.

Flexible manipulator own many outstanding characteristics comparing with the normal rigid manipulator such as light weight, low production cost, easy miniaturization, the characteristic of elastic energy storage, and better energy utilization efficiency. For these advantages, the manipulator with flexible structure have drawn extensive attention on many aspects and applications such as handling radiation infected waste of nuclear power plant, precision measure instrument, and manipulator equipped on space shuttle. Fast motion control of the flexible arms is more difficult than that of rigid arms for involving some problems on position trajectory and vibration suppression. And there are challenging tasks for control of flexible manipulator comparing with that of the existing rigid manipulator. Amount of researches focus on the aspect which is commonly to control the performance of the flexible manipulator, however this research mainly pays attention for utilizing the flexible manipulator's elastic energy more effectively through the Soft Computing strategy. Then it is necessary to design the proper control strategy for better elastic energy utilizing performance.

In order to research the elastic energy of the flexible manipulator, this thesis investigates a ball throwing robot design with one rigid link and one flexible link. This manipulator is made for throwing a ball with motor torques and at the same time by utilizing the elastic energy of the flexible manipulator. Then for utilizing the elastic energy of this flexible manipulator more efficiently, this dissertation consists of the four parts as follows: Firstly, the frame structure and model of the ball throwing manipulator are invented with considering the bending deformation of the flexible link. The system model is built up on the design requirements. Then the proper control torques are designed and tested through the proposed simulation models. And the profile pattern of each torque is determined through Soft Computing approaches. Thirdly, the residual vibration is generated after ball has been thrown from manipulator. The vibration of the flexible manipulator needs to be suppressed with some control strategies. Finally, the simulations and experiments were operated to validate the theoretical derivation of

the model, performance of the designed control inputs, and also the effect of the residual vibration suppression. In order to solve these problems, this thesis is organized in the following five chapters:

Chapter 1: The research background about the topic for this thesis was introduced in the first chapter. The contributions of this research were presented and the outlines of this thesis were also provided in this chapter.

Chapter 2: In order to realize the throwing motion with utilizing the elastic energy of the manipulator, we need to design the manipulator with a proper structure in the following chapter. In this chapter, a two link manipulator with one flexible link was designed and built up for utilizing the elastic energy. The structure of the manipulator was analyzed and the mathematical model of this flexible manipulator was derived through the Hamilton's principle. For the simulation of the whole motion, not only the system model while the manipulator holds the ball, but also the model after releasing the ball is necessary to be derived. Also in order to decrease the operation time of the program and code complexity for the Soft Computing approach, the linearized model is derived for the further simulation.

Chapter 3: In order to throw the ball with less vibration, the control parameters of the torque inputs should be determined properly. In this chapter, a kind of composite sinusoidal form control torque was proposed as the input for realizing the swing-throw motion and smooth releasing motion of the flexible manipulator. Then one of the swarm intelligence computations which belong to the Soft Computing approach was introduced to determine the control inputs of this ball throwing manipulator. The object functions for the swarm intelligence were designed to determine the control parameters of the input torques according to the dynamic characteristics of the flexible manipulator.

Chapter 4: After ball throwing, the residual vibration occurred on the flexible link. So in this chapter, a control strategy for residual vibration suppression was presented. For this manipulator, the control torqueses were designed before manipulator operation in the former chapter. This means during the throwing motion, the controller doesn't need to get any feedback signal from the beam structure. The input shaper was formed by a sequence of impulses with proper amplitudes and time locations and then the shaper was convolved with the desired command input. As the result, the system response of the shaped command input showed few or no vibration comparing with the unshaped one.

Chapter 5: In this chapter, some experiments were designed and implemented to check and evaluate the proposed method and simulation results based on the two link manipulator experimental device. The reliability of the model was confirmed on the experiment. And then, the performance of the Soft Computing strategy discussed in the third chapter was verified through contrast experiments. Also the effectiveness of the input shaper designed for the residual vibration suppression was evaluated through experiment in this chapter.

Chapter 6: Conclusions of the whole research are presented and the further studies are described in the final chapter.