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Prediction of contact forces of underactuated finger by adaptive neuro fuzzy approach

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ABSTRACT

To obtain adaptive finger passive underactuation can be used. Underactuation principle can be used to adapt shapes of the fingers for grasping objects. The fingers with underactuation do not require control algorithm. In this study a kinetostatic model of the underactuated finger mechanism was analyzed. The underactuation is achieved by adding the compliance in every finger joint. Since the contact forces of the finger depend on contact position of the finger and object, it is suitable to make a prediction model for the contact forces in function of contact positions of the finger and grasping objects. In this study prediction of the contact forces was established by a soft computing approach. Adaptive neuro-fuzzy inference system (ANFIS) was applied as the soft computing method to perform the prediction of the finger contact forces.

1. Introduction

If one mechanism has fewer active inputs than degrees of freedom, one can say that this mechanism has an underactuated principle. Passive elastic elements could be used to achieve the underactuated mechanism principle. These elements should reduce the not actuated degrees of freedom of the mechanism. Also the underactuated mechanism has to have an adaptive transmission mechanism, i.e. when one finger phalange is blocked, the other phalanges should continue to grasp the object. If all the phalanges are stopped, the contact forces of the all phalanges should be uniformly distributed through all the phalanges [1–5].

To improve the grasping and contact capabilities of the underactuated fingers one needs to analyze a finger grasp. Screw theory [6–8] can be used for contact analysis of the underactuated robotic finger. The screw theory can describe the contact conditions of the underactuated finger's phalange. The proposed finger structure in this study has torsional springs implemented in every finger joint and two phalanges. The main goal of the study is to establish a soft computing-based prediction model for the finger contact forces estimation in relation to contact positions of the finger with grasping objects.

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Soft computing tools are modeling tools that can learn the mathematical mapping between input and output parameters of nonlinear systems. One of the most powerful types of soft computing system is adaptive neuro-fuzzy inference system (ANFIS) [9]. ANFIS can automatically learn from data and adapt to new conditions [10–16]. Thus far there have been many studies of the ANFIS application for prediction in many different systems [17,18]. In [19] ANFIS was uses to predict non-uniformity of the wafer surface. For training and testing data finite-element model was used. A neuro-fuzzy model was applied to predict the hardness and porosity of shape memory alloy in [20]. Paper [21] presented ANFIS application for time-series prediction. An ANFIS model was applied to predict the flow stress in hot deformation process of Ti6000 alloy in [22]. In [23] optimum cure time of the rubber compounds was predicted using the ANFIS model. Various principles of the neural network approach for predicting certain properties of polymer composite materials were discussed in [24].

The main part of the ANFIS is fuzzy inference system (FIS). FIS is based on linguistic 'IF–THEN' rules. The ANFIS network merged the FIS with the learning algorithm of a neural network. In this study the ANFIS model will be used to predict the finger contact forces in relation to contact positions. ANFIS training and testing data are obtained from the kinetostatic analysis of the finger by the screw theory.

2. Methodology

2.1. Finger structure optimization

Finger structure was optimized before kinetostatic analyzing. Fig. 1 shows grasping objects for the optimization procedure. The target functions represent two grasping shapes, convex (a) and concave (b). The optimization procedure was performed based on compliant mechanism behavior. In this case the optimization of compliant mechanisms can be performed based on continuum, as well as truss and frame, and discretization. In this study the continuum discretization was used.

Fig. 2 shows the optimization domain and all parameters for the optimization process. The optimization process is based on the following studies [25,26,27]. The input is assumed as a linear strain-based actuator and it can be modeled by a spring with stiffness k_1 and force f_1. The input port has input displacement u_1. The goal of the optimization problem is to maximize output displacement u_2 performed on a work piece modeled by a spring with stiffness k_2. By specifying different values of k_2 the output displacement amplification can be controlled. Here, a unit force (f_1) is applied to the input spring on the right. Therefore, the objective is to maximize the displacement at the output spring (u_2). The optimal finger structure is shown in Fig. 3.

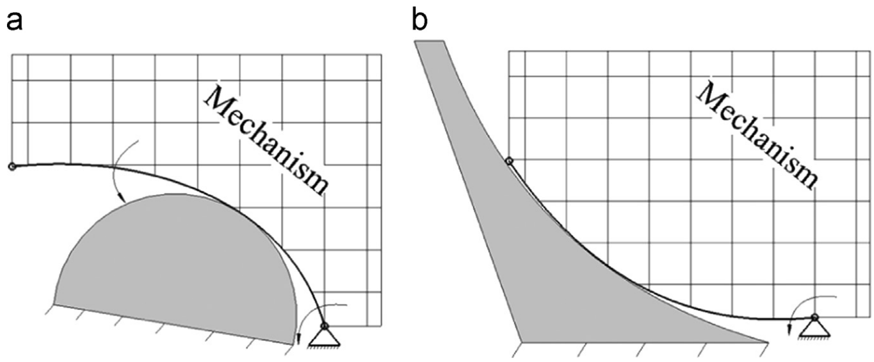

Fig. 1. Target grasping objects for optimization procedure: (a) convex and (b) concave grasping shape.

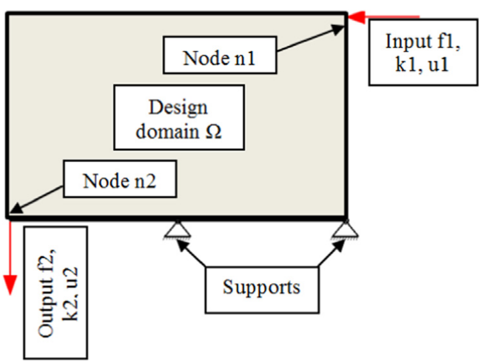

Fig. 2. Design parameters of the optimization process of the finger.

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