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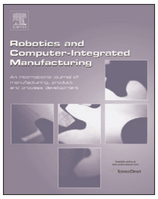

Adaptive control algorithm of flexible robotic gripper by extreme learning machine

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ABSTRACT

Adaptive grippers should be able to detect and recognize grasping objects. To be able to do it control algorithm need to be established to control gripper tasks. Since the gripper movements are highly nonlinear systems it is desirable to avoid using of conventional control strategies for robotic manipulators. Instead of the conventional control strategies more advances algorithms can be used. In this study several soft computing methods are analyzed for robotic gripper applications. The gripper structure is fully compliant with embedded sensors. The sensors could be used for grasping shape detection. As soft computing methods, extreme learning machine (ELM) and support vector regression (SVR) were established. Also other soft computing methods are analyzed like fuzzy, neuro-fuzzy and artificial neural network approach. The results show the highest accuracy with ELM approach than other soft computing methods.

1. Introduction

Robotic grasping system is the most important task for robotics. Gripper is the key of the robotic grasping system. The gripper should be designed and controlled in order to make safe grasping of fragile and objects with different stiffness and shapes. One of the solution is to use flexible gripper structure to ensure safe grasping of any objects [1,2].

The main requirements for flexible grippers are to make safe manipulation and detections of grasping objects [3–6]. The gentle grasping and manipulation of objects in dense un-structured environments, such as the agricultural, food processing, or home environments constitute a formidable challenge for robotic systems. Object grasping by robot hands is challenging due to the hand and object modeling uncertainties, unknown contact type and object stiffness properties. To overcome these challenges, the essential purpose is to achieve the mathematical model of the robot hand, model the object and the contact between the object and the hand [7]. In article [8] was presented a general method to interpret human grasp behavior in terms of opposition primitives. An 87% recognition rate was achieved over a wide range of human grasp behavior. Paper [9] presented a probabilistic approach for task-specific stable grasping of objects with shape variations. It was found that the approach can use multiple models to generalize to new objects in that it outperforms grasping based on the closest model. Paper [10] presented an approach toward planning robot grasps across similar objects by part correspondence. Paper [11] was shown that the learning from human experiences is a way to accomplish goal of robot grasp synthesis for unknown object. A three dimensional (3D) grasp synthesis algorithm to achieve distinguished grasps supporting both stability and human-like grasping was presented in [12] where the proposed algorithm overcomes the issues associated with the analytical approach, such as long computation times, unstable grasp synthesis in the presence of outliers and noise, and lack of cognitive factors. One of the solutions to make safe and stable grasp is to use vision sensors in gripper structure for grasping tasks [13–17]. However, in dark, dirty, dusty, foggy and even underwater, the vision sensors are not useful or have problematic behavior. One of the solution is to embed sensors in gripper structure and therefore to transfer

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environmental conditions directly through the gripper structure and sensors [18].

So far there are many different applications of sensors in robotic grippers. In papers [19,20] was developed a robotic gripper with mounted sensors on fingertips of two robotic fingers. Tactile sensing-based control algorithm in the robot finger was developed to control fingertips movements by defining optimum grasp pressure and perform re-push movement when slippage was detected. In paper, we present a tactile-array sensor based on flexible piezoresistive rubber was presented in [21] and it was demonstrated in active object-classification method. It was found that the mistakes that the classification method makes using the sensor were sensible. Paper [22] shows that the various sensors can be modeled ranging from tactile sensors to human-like touch. A direct process to classify contact impressions of objects gripped by a robot hand was presented in [23] where the information about the type of contact allows the selection of the most appropriate manipulating strategy to handle the grasped object. Preliminary experiments in [24] demonstrated the ability of the sensorized gripper system to detect binary tactile images of several different objects. Paper [25] presented that generating graspability maps based on scanning the object's surface rather than the volume about the object leads to a large reduction in computation time with little loss in map quality.

In this article, a gripper with embedded sensors is presented. The embedded sensors are used to ensure safe and optimal behavior of the gripper. The main goals are to detect grasping object shape and to make control algorithm for gripper input movement. The gripper is flexible and therefore safe grasping is ensured. For controlling algorithm soft computing methods are applied: extreme learning machine (ELM) [26–28], support vector regression (SVR) [29,30] and also fuzzy [31,32], adaptive neuro fuzzy system (ANFIS) [33,34] and artificial neural network approach [35]. The soft computing methods are used to learn the control algorithm from the training data. So far adaptive neuro-fuzz system (ANFIS) was applied in [36] for grasping force regulation with unknown contact mechanism.

The objective of this article investigation is to establish an SVM for estimation and prediction of the optimal input displacement of the flexible gripper. SVR schemes [37,38] with radial and polynomial kernel function are applied in the paper for the control algorithm of the gripper. In [39] we establish an ANFIS controller for the gripper. Furthermore we want to compare some other soft computing techniques with the ANFIS controller. Sensors of conductive silicone rubber are implemented in finger structure [40]. Experiments are performed with the gripper in order to extract training data of the soft computing methods.

2. Materials and methods

2.1. Flexible robotic gripper

In this study the gripper structure is passive with compliance. Also the main characteristic of the gripper is underactuation principle. Since the gripper has underactuation principle the control algorithm can be simple since underactuation allows accommodation of the gripper without control algorithm. In other words in this study the control algorithm is used only for detection of the grasping shape and according to the shape input displacement of the gripper should vary. Fig. 1 show two-fingered gripper structure with embedded sensors of conduction silicone rubber. Also input displacements for some grasping shapes can be seen in Fig. 1.

Fig. 2 presents the finger input mechanism. Fig. 2(a) shows slider crank mechanism as the basic principle for the input mechanism.

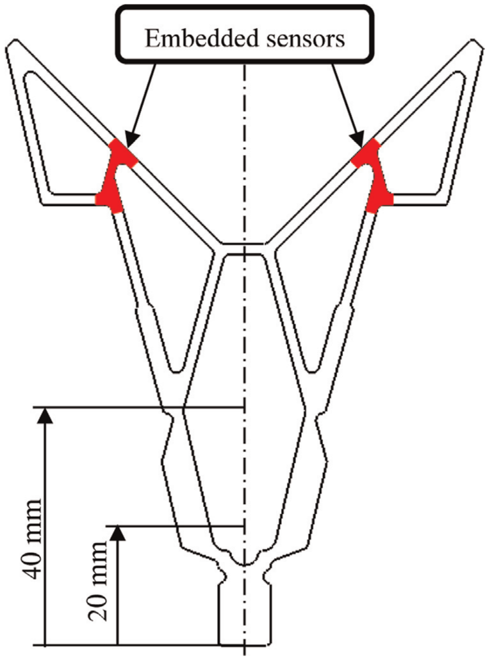

Fig. 1. Flexible gripper design with embedded sensors.

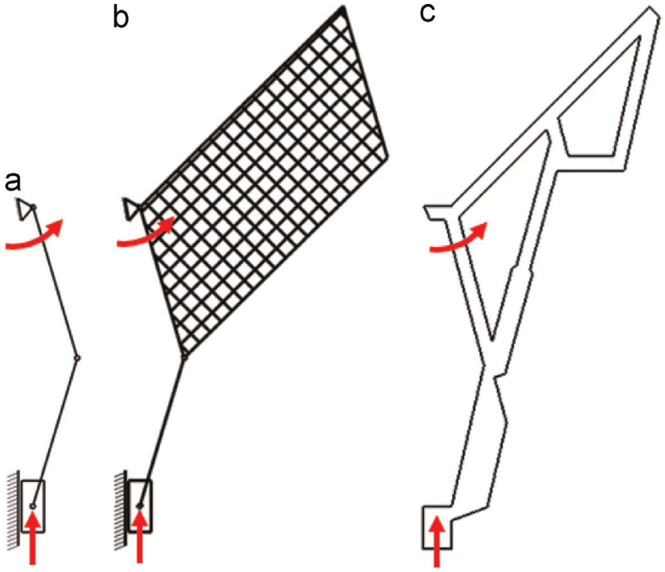

Fig. 2. (a) Slider crank mechanism, (b) finger design domain and (c) optimized finger topology.

The gripper was made of silicone rubber and the conductive silicone elastic was utilized for the embedded sensors. The used silicone rubber is electro active which makes it suitable for sensors applications. Electrical resistance of the sensors were measured for each sensor specimen to determine standard deviation of the electrical resistance. It was found that the standard deviation electrical resistance for all sensors was 144.75 before post cure process and after post cure process the standard deviation was 12.99. This confirms that the electrical resistance of the sensors was stabilized after post curing process. In other words the sensors measurement accuracy was increased after post cure process. In article [18] was presented detailed production process of the sensor elements for the gripper. In article [41] was presented detailed optimization procedure of the gripper structure.

Implemented sensors in finger structure can be used for