Improved Machine Vision by Image processing for Design of ANFIS Based Adaptive Gripper

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***Abstract*—New flexible adaptive grippers need to have an ability to adapt, detect and recognize objects in their environments. Passively compliant under actuated mechanisms are one way of obtaining a finger which could accommodate any irregular and unpredictable grasping object. The under actuation can morph the shapes of a robotic finger to accommodate different objects. This paper proposes a novel design using ANFIS strategy for controlling the input displacement of a new adaptive-compliant gripper. This design of the gripper has embedded sensors as part of its structure. The use of embedded sensors in a robot gripper gives the control system the ability to recognize particular shapes of the grasping objects and to control input displacement of the gripper. The simulation results presented in this paper show the effectiveness of the developed method.**

***Index Terms*—Sensors, compliant gripper, adaptive gripper, ANFIS controller**

I. INTRODUCTION:

Grabbing is one of the most frequently examined subjects in robotics owing to the requirement of moving or manipulating different objects. The grasping techniques developed to realize grasping processes, their current limitations make them expensive and with low flexibility. The key point in the grasping system is the gripper. The gripper performance is very important when fragile objects of different stiffness and shapes are manipulated and hence a reliable force control is crucial. This problem can be overcome with the use of deformable or flexible fingers which improve the limited capabilities of rigid robotic fingers [1]. The new flexible fingers need to have the ability to make safe grasps, to detect and recognize objects [2]. Their modalities of applications differ highly from conventional grippers since conventional grippers are equipped in a domestic environment and are usually not intended for repetitive tasks that require high precision. For such purposes, when conventional grippers must be equipped with sensors, vision sensors are a popular choice. However, they may have limitations in such environmental conditions as in darkness, in very dirty or dusty situations, in foggy conditions, or even underwater. Being equipped with embedded sensors is a good choice because the information about object properties is directly provided with the influence of the environmental condition. Embedded sensors also offer a great potential for improving the grasp synthesis in object recognition and manipulation due to their good sensitivity and capability of detection and recognition of the grasping object shape.

The embedded sensing capability allows changes in the gripper manipulation strategy in real time to achieve an adaptive grasp. To improve the control of a robotic gripper, fuzzy logic (FL) or artificial neural network (ANN) control has attracted much attention in recent years. The merged technique of the learning power of the ANNs with the knowledge representation of FL is a hybrid technique, called the Adaptive Neuro-Fuzzy inference system (ANFIS) [3]. ANFIS, as a hybrid intelligent system that enhances the ability to automatically learn and adapt, was used by researchers for modeling [4,5], predictions [6,7] and control [8] in various engineering systems. In this paper, the application of ANFIS is proposed to control the input displacement for the gripper. The fingers of the robot gripper are equipped with embedded sensors of conductive silicone rubber [9]. Developed new adaptive gripper is the competence to find and identify objects in their new locations. An accurate design of an adaptive neuro-fuzzy inference strategy (ANFIS) for monitoring input displacement of a new adaptive compliant gripper is presented in [10]. The ANFIS is one of the methods to establish the fuzzy inference model with given input/output data pairs [11]. An experimental setup of the sensors exposed to different time-dependent strain histories is verified. In order to examine the electrical characteristics, the resistance of silicone was measured during the mechanical tests [12]. To design and maintain the greatest output power of wind turbine, a unique intelligent controller based on the adaptive neuro-fuzzy inference system (ANFIS) is presented [13]. A control algorithm based on changing the embedded sensors voltage was derived to perform tasks of detection and recognition of a grasping object. Simultaneously, the controller provided the input displacement signal according to the shape of the grasping object. To evaluate the shape recognition algorithm, many experiments of object-grasp detaching exploration were performed with the robotic gripper.

II. ADAPTIVE FLEXIBLE GRIPPER WITH EMBEDDED SENSORS:

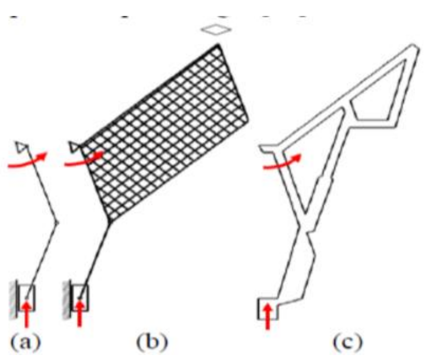


Fig. 1. (a) Slider crank mechanism, (b) finger design domain and (c) optimized finger topology

The fig.1 shows the input mechanism principle for one of the fingers. As it is shown in Fig. 1(a) the basic input mechanism for the finger can be presented as a slider crank mechanism. Fig. 1(b) shows the slider crank mechanism with the addition of the finger design domain. Finally, Fig. 1(c) shows the optimized structure of the compliant adaptive finger [10].

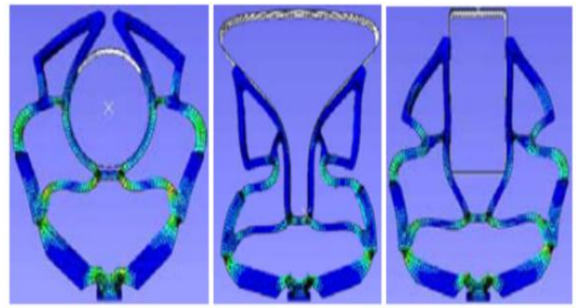


Fig. 2. Verification of the two-fingered gripper functions for different shapes and sizes of grasping objects

This article presents a new design of the adaptive under actuated compliant gripper with distributed compliance and embedded sensors in the gripper structure (Fig. 3). Embedded sensors have features to detect and recognize the grasping objects shape according to sensors deformations [11]. Fig.3 shows some examples of grasping objects and correspondent grasping patterns. Here, segment t3 was used as a grasping shape indicator. Embedded sensors have opposite deformations for the two main grasping shapes. When there is no grasping object, embedded sensors have no deformation. It is important to mention that the grasping objects were fixed during the measurement procedure.

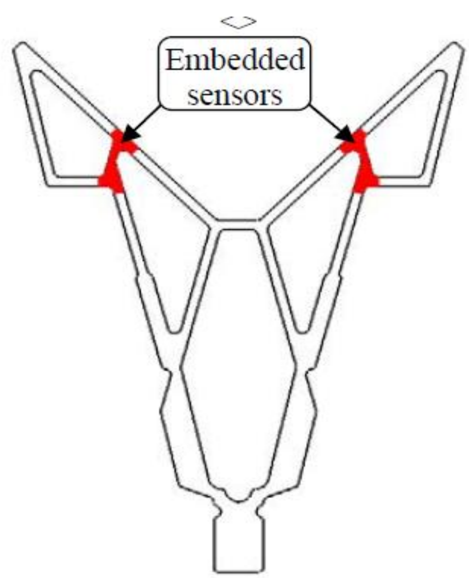


Fig. 3. Gripper design with embedded sensors

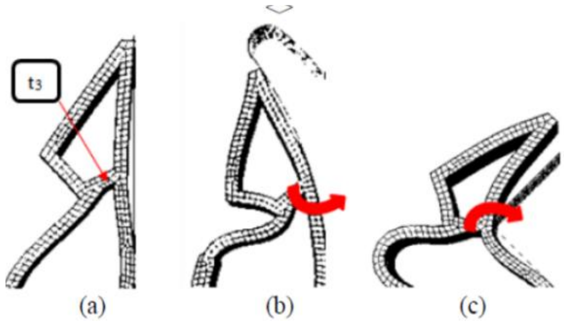


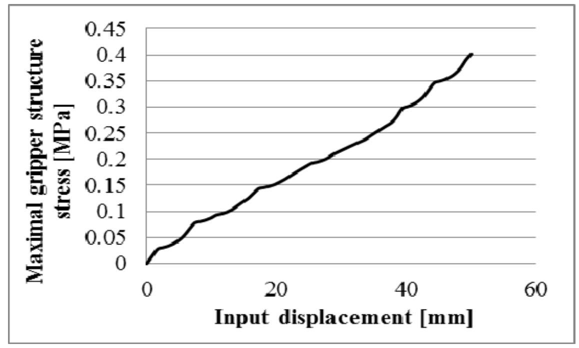
Fig. 4. Different grasping objects grouped in three main grasping patterns: (a) no object (b) concave shape (c) convex shape

III. TESTING:

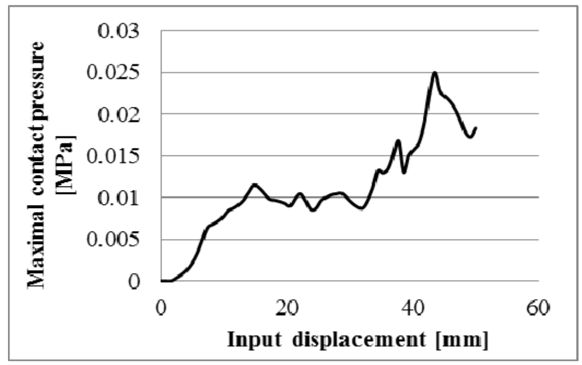
The gripper was made of a silicone rubber as a monolithic structure and the conductive silicone rubber was used for embedded sensors. Conductive silicone rubber is an electro active material whose electrical resistance changes with deformation. These properties make this material suitable to develop force or deformation sensors [12, 13]. The figure 5(a) shows the changes in the gripper maximal stress during the grasping of a cylindrical object with radius r = 50 mm. As it can be seen, the relationship is almost linear in relation to input displacement. The maximal stress in the gripper structure is 0.4 Mpa at the end of the grasping process. The maximal contact pressure in relation to input displacement is shown in Fig. 5(b). This graph shows that the maximal contact stress increases up to 17 mm of input displacement.

Afterwards, the graph is almost constant until approximately 30 mm of input displacement. The reason for that may lie in the detachment of gripper contact surfaces from the grasping object. A drastic increase in the maximal contact pressure occurred after approximately 35 mm of input displacement. The maximal contact pressure is 0.025 Mpa, which is especially suitable for sensitive and fragile grasping objects. Taken together, these results provide support for the model concerning sensitive grasping objects, since the goal was to eliminate the part of the drastic increase in the contact pressure.

Fig.6 shows maximal contact pressures changing in relation to input displacement for the right finger of the ripper. It can be noticed that the maximal contact pressures on the contact surface do not increase linearly. Maximal contact pressure was 0.04 MPa on the right contact surfaces.



(a)



(b)

Fig. 5. Relationships between (a) input displacement and maximal stress of the gripper structure and (b) input displacement and maximal contact pressure

Fig. 6. Maximal contact pressure changing on the right finger in relation to input displacement

The relationship between the input displacement and the total area in contact for both fingers is shown in Fig. 7. It is interesting to note that the area in contact decreased after approximately 25mm of input displacement. The result indicates that there was a detachment between the gripper surfaces and the grasping object at approximately half of the input displacement since there was a drastic decrease in the total area in contact.

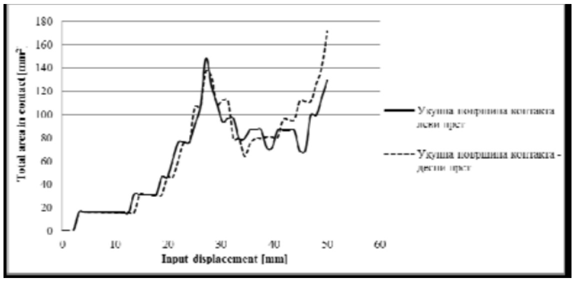


Fig. 7. Changes in the total area in contact for the both fingers separately

IV. INPUT DISPLACEMENT CONTROL:

Based on experimental tests, three main grasping patterns could be created as shown in Fig. 8. These are "concave", "convex" and "no object" patterns. Each of these grasping patterns requires different input displacements for the gripper. Fig. 9 shows the acquired experimental results depicted as separate clusters for each grasping pattern and desired input displacements as well. "No object" needs zero input displacement; grasping pattern "convex" needs 40 mm input displacement and grasping pattern "concave" needs 20 mm input displacement for the gripper.

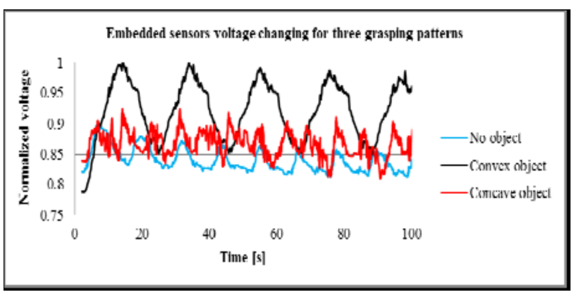


Fig. 8. Embedded sensors voltage changing for three grasping patterns

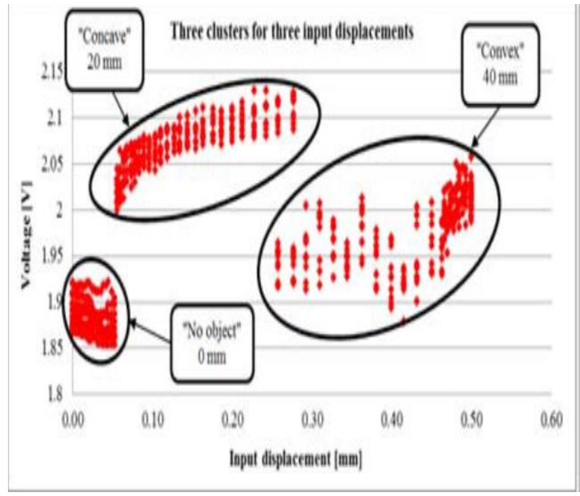


Fig. 9. Experimental results as three separate clusters for three grasping patterns and desired input displacements for each of the clusters (patterns)

In this article, the application of ANFIS is proposed to control the input displacement for the gripper. A control algorithm based on changes in the embedded sensors voltage was derived to perform tasks of detection and recognition of a grasping object. The block diagram of the ANFIS control scheme is shown in Fig.10. The main problem with the fuzzy logic controller generation is related to the choice of the regulator parameters [14]. For this reason, we apply the ANFIS methodology to adapt the parameters of the fuzzy controller according to the real data about the problem.

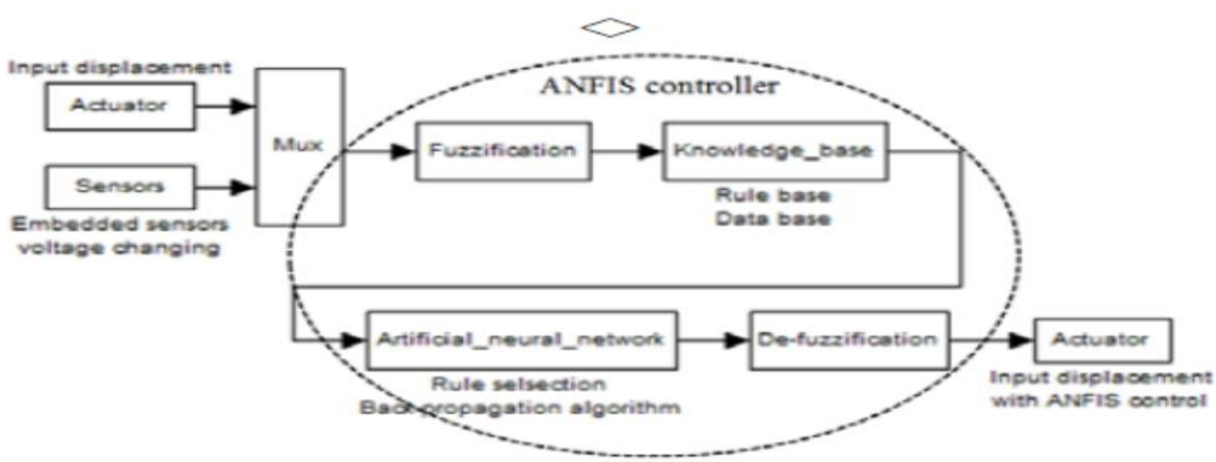


Fig.10. Block diagram of the ANFIS control scheme for the input displacement control of the gripper

Two ANFIS inputs were the change in the embedded sensors voltage and input displacement of gripper. An ANFIS output represents a desired input displacement according to current inputs.

V. EXPERIMENTAL CONTROL SETUP:

Fig.11 shows the experimental control equipment for the grasping object shape recognition and control of the gripper input displacement.

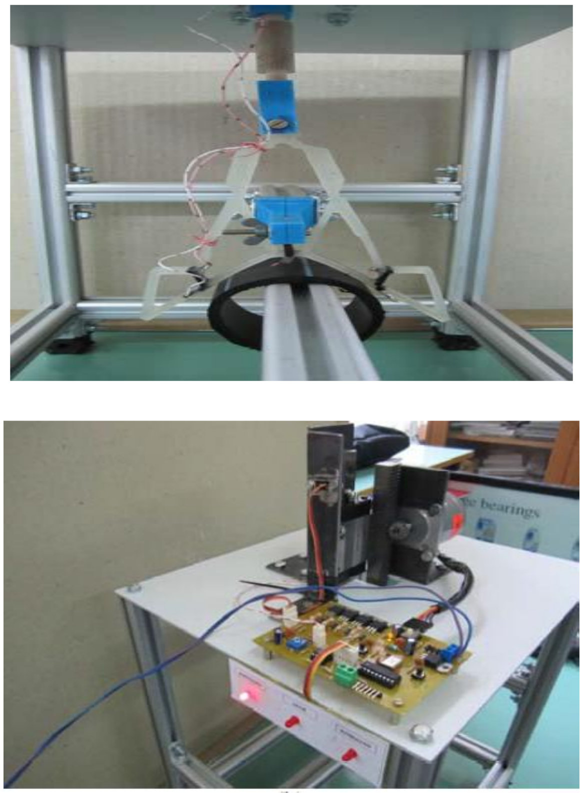


Fig. 11. (a) Experimental gripper prototype, (b) gripper controller for object classification

The gripper prototype with embedded sensors is shown in Fig. 11(a). Fig 11(b) shows the controller design. Three LED identifications can be noticed, one for each recognized grasping object shape (Fig.4).Fig.12 (a) shows the convex object recognition (left LED diode) and, according to the embedded sensor electrical resistance, the controller provided the signal for input displacement of 40 mm. Fig. 12(b) shows the concave object recognition (right LED diode) and, according to the embedded sensor electrical resistance, the controller provided the signal for input displacement of 20 mm.

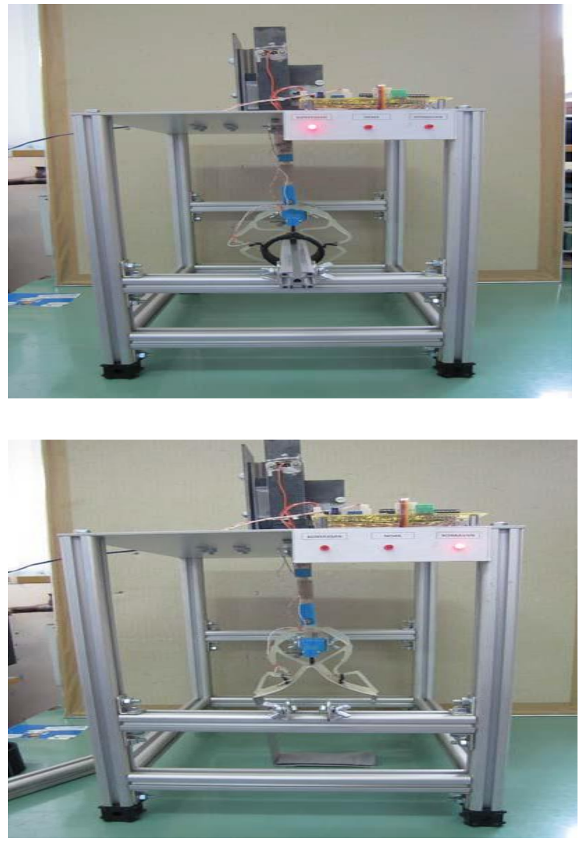


Fig. 12. (a) Convex grasping shape, (b) concave grasping Shape

VI. CONCLUSION:

The handling of irregular, unpredictably shaped and sensitive objects introduce demands on gripper flexibility and dexterity. Reaching the dexterity and adaptation capabilities require the control of a lot of actuators and sensors. The dexterity can also be obtained by under actuation, which consists in equipping the finger with fewer actuators than the number of degrees of freedom. In manipulating objects by robot grippers, information about the object gives some clues to the controller for selecting the manipulation strategy to be applied. In general, when handling an object, the configuration of the grasp depends on the type and nature of the object, i.e. the shape of the object. In this paper, based on experimental results, a controller was developed, which can recognize three different grasping shapes of objects and control input displacement of the gripper. The main advantage of designing the ANFIS coordination scheme is to control the input displacement of the gripper according to the grasping shape of the object. In line with numerous experimental tests, three grasping patterns were created. These were "no object", "concave" and "convex" grasping patterns. Each of the patterns requires a different input displacement for the gripper. The developed control strategy is not only simple, but also reliable and may be easy to implement in real time applications using certain interfacing cards. ANFIS can also be used with systems handling more complex parameters. Another advantage of ANFIS is its speed of operation, which is much faster than in other control strategies; the tedious task of training membership functions is done in ANFIS.

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