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Auto-Grasping Algorithm of Robot Gripper Based on Pressure Sensor Measurement

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ABSTRACT

This paper presents an auto grasping algorithm of a proposed robotic gripper. The purpose is to enhance the grasping mechanism of the gripper. Earlier studies have introduced various methods to enhance the grasping mechanism, but most of the works have not looked at the weight measurement method. Thus, with this algorithm, the weight of the object is calculated based on modified Wheatstone Bridge Circuit (WBC) which is controlled by programmable interface controller (PIC) method. Having this approach introduces and improves the grasping mechanism through an auto grasping algorithm. Experimental results show that an auto grasping algorithm based on pressure sensor measurements leads to a more precise grasping measurement and consequently enhance the sensitivity measurement as well as accurate movement calibration. Furthermore, several different grasping objects based on the proposed method are examined to demonstrate the performance and robustness of our approach.

Keywords: Auto grasping algorithm; pressure sensor; grasping mechanism; Wheatstone bridge circuit

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INTRODUCTION

Human beings have long recognised the importance of robots, especially the robotic manipulators such as robotic hand or robotic gripper. Robotic grippers have become important to grasp objects, perform tasks or even emulating the human hand (Almassri et al., 2015). Robotic hands and grippers have been used for various purposes such as dexterous manipulation (Rodriguez et al., 2014), artificial limbs (Lee et al., 2008), grasping objects (Lippiello et al., 2013), rehabilitation application (Iqbal et al., 2010) and pick and place application (Almassri et al., 2013). Some of these applications require manual labour for assembly line and material handling. Therefore, there is a need to have a dedicated machine, which is suitable for such applications taking into consideration safety issues.

However, the current issue of robotics system is to have a secure grasp during the robotic grasping operation (Pokorny et al., 2013). In addition, auto grasping algorithm remains an open and difficult problem. In order to synthesise sequences of actions to perfectly solve a complicated task, automatic calibration is important for a secure grasp and control to execute the calibration movement (Righetti et al., 2014). Examples of good grasps can be found in (Bicchi & Kumar, 2000) and (Bohg et al., 2014). In (Righetti et al., 2014), a good grasp using humans were demonstrated. The weight measurement method based on WBC was introduced by Almassri et al. (2015) that explains the optimisation of grasping object based on pressure sensor measurement for a robotic hand gripper. From that point of view, it seems natural to create an algorithm that shows the nature of grasping and manipulating objects.

A new auto grasping algorithm based on pressure sensor is hence proposed to introduce a grasping mechanism. This paper introduces a PIC control algorithm to improve a movement calibration through the grasping operation. In order to apply an auto grasping algorithm, we design and propose a robotic gripper prototype with a new configuration of pressure sensor distribution based on modified Wheatstone Bridge Circuit (WBC) as it has a high sensitivity as well as capability for grasping mechanism and weight measurement.

ROBOTIC GRIPPER SYSTEM BASED ON AUTO-GRASPING ALGORITHM

In order to fulfil an auto grasping algorithm using a robotic gripper based on pressure sensor the researcher design and propose a gripper prototype while a software PIC algorithm control based on Flexiforce pressure sensors was used for grasping and measurement purposes. These three stages are shown in the block diagram in Figure 1. The input is the object which is detected automatically using Infrared Sensor (IR). Subsequently, a modified Wheatstone Bridge Circuit (WBC) is applied to investigate the pressure distribution and measure the output. The analog readout circuit has been designed and utilised to adjust the sensor signals to be compatible with the requirements of the subsequent system and to provide a voltage supply to the whole system as shown in the figure below. The controller part (the red colour of the block diagram) is useful for grasping mechanism after detecting the object. This mechanism is based on proposed grasping algorithm that is applied based on a PIC controller for signal conditioning of multiple sensors output points simultaneously. The output part, which is grasping the object effectively and measuring its weight then, displays the measured output on LCD. A servo motor with driver circuit is selected for this purpose to be incorporated into the system. In addition, a feedback closed loop system is used during the grasping mechanism to insure the secure grasp and to control the calibration.

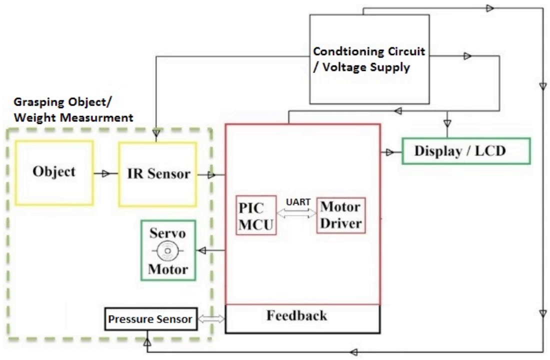

Figure 1. Block diagram of the robotic gripper based on proposed auto-grasping algorithm

Robotic gripper prototype

The function of the proposed robotic gripper prototype is to grasp the solid object effectively. Figure 2 illustrates the robotic gripper prototype from different sides. It consists of: Pressure Sensor[1], Claw[2], Frame[3], Base[4], Carrier[5] and DC Servo Motor[6] as arranged in (a) respectively. The robotic gripper prototype is equipped with two types of sensors, including IR sensor for automatic grasp purpose as well as pressure sensor for the purpose of measuring the pressure forces. A front view as shown in (b) indicates how the robotic gripper grasp a rectangular solid object automatically. The four pressure sensors are assembled and arranged on the left and right claw of the prototype robotic gripper based on modified WBC as shown in (c). The gripper's surface is covered with a thin, double-sided tape in which the distributed pressure sensors are placed under it. All these conditions are significantly important for the operation of the current robotic gripper prototype.

In this study, a new method of modified WBC is used to enhance the pressure measurement and increase sensitivity output of the pressure sensor. Based on the traditional method as presented in (Ahmed M ALmassri et al., 2014), the sensitivity output of the pressure sensor still needs to be increased. Therefore, our proposed modified WBC has investigated the sensitivity output of the pressure sensors as shown in Figure 3. It comprises four resistors and two of them are changing resistance and represented by pressure sensors (Ps1, Ps2) while the

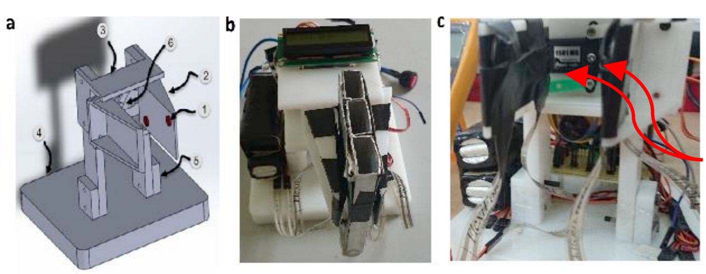

Figure 2. (a) The parts of the proposed robotic gripper; (b) front view of grasping a rectangular object; (c) pressure sensors distribution left view

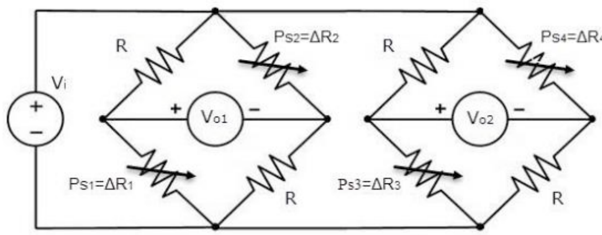

Figure 3. Schematic diagram of the proposed modified WBC

other two are constant (R). The main advantage of this proposed circuit compared with using a single and simple construction is that some of the error sources cancel each other out due to the symmetry of the circuit. Furthermore, any changes in any one of the pressure sensors will cause a change in the output voltage (Vo) as seen in equation 1. These voltages can be conditioned and transmitted for data calibration purpose. Those advantages enhance the output force measurement and increase the sensitivity output by eliminating the error. In addition, the active pressure sensors (Ps1, Ps2) are assembled in front of each other in the circuit as well as in the claw of the prototype robotic gripper to insure and observe any changing of the pressure forces in both sides either in the robotic claw or detected object. Thus, sensitivity will be increased and measured output data will be enhanced.

$$Vo = Vo1 + Vo2 \quad (1)$$

Where Vo is the total output voltage of the modified Wheatstone bridge circuit, Vo1 and Vo2 is the output voltage of the modified WBC individually.

Control system

The control system of a robot gripper has been developed and investigated for different applications. The robot gripper executes a particular task of grasping the object. Nevertheless, the weight measurement method which grasps objects based on auto-grasping algorithm has not been created yet for the current robotic gripper applications. Thus, in order to fulfil the auto-grasping mechanism effectively, the control system must be executed. The feedback control is also important in this process to ensure accuracy and stability of the measurement and grasping respectively. The pressure sensor is essential to measure the interface pressure between the claw of robotic gripper and the object whereby it is useful to measure the exact weight of the object as well as the feedback of the entire system. Figure 4 shows the block diagram of the feedback system for grasping mechanism. The position of servo motor also plays a significant role in this mechanism. This position is considered as reference to execute the grasping as well as its completion.

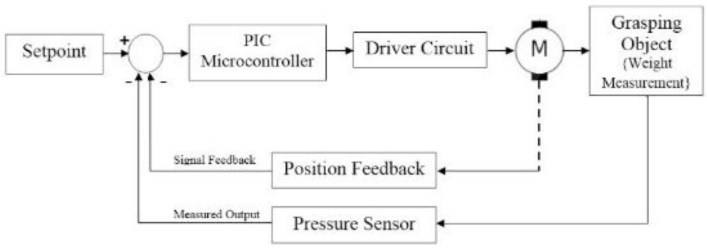

Figure 4. Block diagram of feedback system for grasping mechanism

In order to operate the auto grasping mechanism, the control of movement calibration has to be considered. For this purpose, the speed and position of the servo motor should be controlled. Basically, the claw of the robotic gripper prototype will be moved in x-axis to grasp the object after being detected automatically. To calibrate this movement, one servo motor is used. In addition, a completed system comprises the microcontroller, the motor driver and some peripheral devices that are used for sending and receiving the commands based on PIC software algorithm. The control circuit of the servo motor receives an input signal from its driver to control the speed of the motor to drive it to the desired position between 0 & 180 degrees. As a result, a series of pulses at a regular rate will move the servo motor from one position to another based on the proposed software algorithm and this will enhance the grasping mechanism.

The proposed auto grasping algorithm

Grasping an object is achieved by controlling interaction forces between the object and the claw of the robotic gripper, ensuring the stability and accuracy of the grasping mechanism. In order to execute these procedures successfully, the auto grasping algorithm is implemented based on software PIC system flowchart as shown in Figure 5. There are three stages as seen in the flowchart. The first step of the first stage after the system initialisation is to operate the claw of the robotic gripper since no object has been detected yet. The second step is to automatically check whether there is any object between the claw of the robot or not by using the digital IR sensor. The first step in the second stage is to move the claw of the robotic gripper towards the object after being detected automatically. This process is carried out with the movement calibration, as mentioned before, by controlling the speed of the servo motor. The second step is to check if the object touches all the pressure sensors which are assembled on the left and right claw of the robotic gripper. Simultaneously, the Analog to digital converter (ADC) channels of microcontroller unit (MCU) continues reading data from the analog readout circuit. Whenever the microcontroller receives data from all four pressure sensors, it converts them into digital signals to be analysed. The received data is essential for calibration process as well as the control of the servo motor movement. The third stage is to analyse and evaluate the data in order to calculate the pressure, weight, duty cycle and position of the object. Database information is required to be stored at this stage. The measured output is monitored via the LCD and using a serial communication after analysing and calculating it. Eventually, the object will be adjusted according to the measured output and the influence of the external forces.

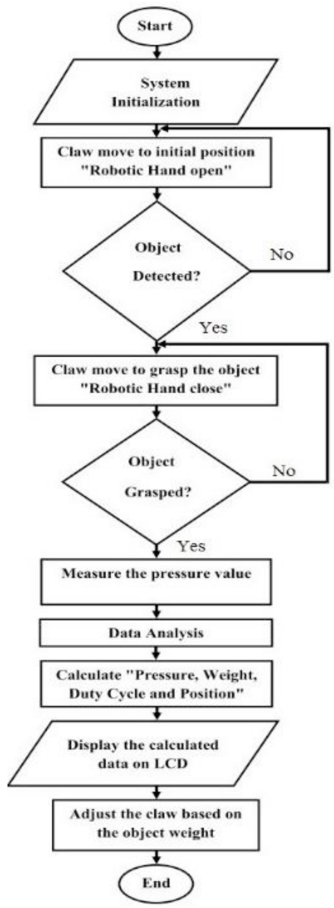

Figure 5. Flowchart of the proposed auto grasping algorithm

EXPERIMENTAL RESULTS

An experiment using with different weights of grasped object based on the proposed auto grasping algorithm are conducted in order to validate the new approach. The auto grasping algorithm is applied to a solid sample object with diverse weights. The initial object`s weight is 40 grams and it is consistent with the allowed force range of the pressure sensor. Furthermore, the weight of this object can be increased by adding a weight scale . Based on the first stage of the proposed algorithm, the relationship between pressure and pulses of DC motor is depicted in Figure 6. It can be seen that the claw of the robotic gripper moves from zero to attach the object at 0.66 ms in which the object is grasped successfully with 0.09 (lbs) pressure forces. The same object with increasing different weights is grasped automatically by increasing the pressure forces as well as the pulse of motor to achieve the stability grasping based on the proposed algorithm. The weighted object with 500g requires 1.10 (lbs) with 1.09 ms . A secure grasp was achieved by controlling the movement calibration of robot gripper based on the proposed auto grasping algorithm.

Based on the second stage of auto grasping algorithm, the sensitivity measurement of pressure sensor after detecting an object was introduced and the object was grasped effectively. The frequency and voltage output signals are very important to recognise and evaluate the signal in order to improve the performance of the grasping mechanism system. In addition, it is important to discover the relationship between two signals under different features. Figure 7 illustrates the output signal for all sensors which are set on the robotic claw based on modified WBC with 85 g weighted object. The curve of CH1 is the output signal of the front set of sensors (first Wheatstone bridge), whereas CH2 is the output signal of the set of sensors positioned in the back (second Wheatstone bridge) as illustrated in section 2.1. The CH3 represents the output voltage of the proposed WBC, which is the summation of CH1 and CH2. The Vavg (average) for both channels is different; 1.11V for CH1 and 0.191V for CH2, which implies that the total pressure is distributed between the two sensor sets and the output voltage in CH3 is 1.301 which is the total voltage of both sensors sets. Furthermore, there is a little change in the duty cycle for each set of sensor output.

After investigating the pressure distribution and sensitivity, the weight curve of the object is shown in Figure 8. It indicates a linear proportionality between the voltage and the object's weight. Comparing with the three methods of pressure distribution in (Ahmed M ALmassri et al., 2015), this proposed method has achieved a high sensitivity and offers a better grasping

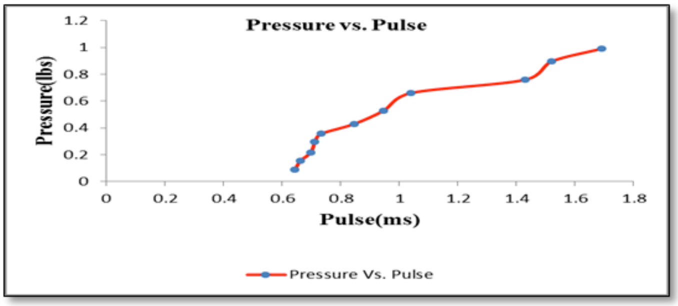

Figure 6. Output pressure value versus pulse of servo motor

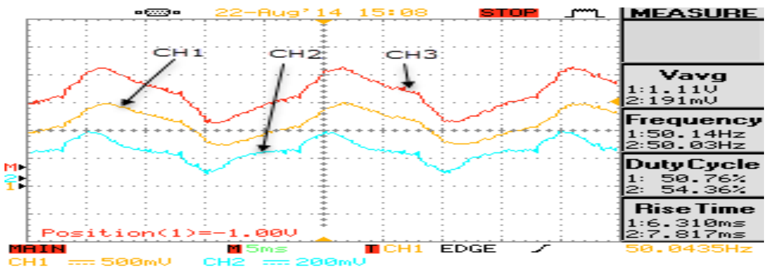

Figure 7. Output signal for 85g grasped object

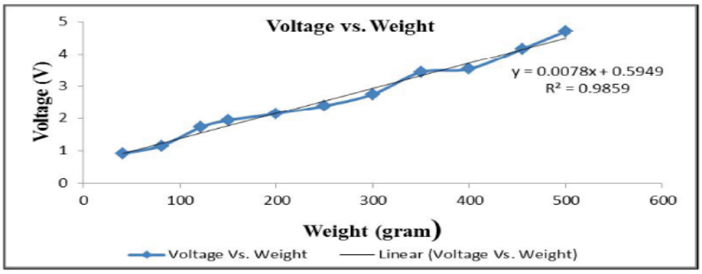

Figure 8. Output voltage versus weight based on pressure sensor measurement

mechanism and accurate data. This is due to the connection between the pressure sensors compared with previous methods that used conventional circuit and the integration with current algorithm (Ahmed M ALmassri et al., 2014). The sensitivity here refers to the small changes from pressure to the weight based on the constant (1 gram (g) equal 0.0022 lbs). The object's weight can be calculated using equation 2.

$$Voltage_{(v)} = 0.0078 \times Weight_{(g)} + 0.5949 \quad (2)$$

CONCLUSION

In this paper, we had proposed an auto grasping algorithm for robotic gripper based on pressure sensor measurement. Due to that, the enhancement of grasping mechanism is increased by controlling the interaction forces between the object to be grasped and the robotic gripper. Our system has demonstrated robust grasping in various weights of object and high sensitivity of measurement pressure using the proposed auto grasping algorithm based on the modified Wheatstone Bridge Circuit (WBC). Future research should look at the grasp quality evaluation based on accurate real time calibration algorithm for better autonomous manipulation.

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