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Wireless Sensor for Precision Grasping of Objects and Tools by Robotic Hands

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Abstract

A preliminary study for a novel approach of detecting the orientation of a robotic hand with respect to non-metallic objects is illustrated. This goal is pursued by using a radiofrequency (RF) probe on the robotic hand and a printed resonator on the tagged item. In order to detect the hand orientation with respect to the target, the real part of the probe input impedance is examined for different angular orientations of the resonator placed on the object. The relation relating the oriented angle between the reader and the sensor to the impedance is addressed to define a proper calibration curve. A half wavelength dipole antenna as a probe on the hand and a metal strip (*dipole resonator*) placed on the object is employed. The sensing is performed within a near range distance from the object. As the result, it is observed that he proposed probe-resonator configuration allows the identification of the relative angular position of the hand with respect to the object with an encouraging level of accuracy.

1. Introduction

Nowadays robot hands are adopted in several industrial processes that exploit the benefit of automated operations. Using them to help disabled persons to do their daily chores, working in conditions and environments which could be dangerous for humans and increasing productivity and accuracy in the production lines are some of these activities which replace robot hands with humans. Also, the use of sensors for robots to detect and grasping various objects is of particular importance. Focusing more on the robot hand tactile and proximity sensors can be efficient components to contributes real value. Therefore, over the years different types of sensors and designs have been investigated and developed for this application by researchers. However, in the current robotics research landscape, a lot of effort is still dedicated to overcoming the challenges posed by unstructured environments. In industry 4.0 application, and exploration endeavors in space, as well as underwater, are waiting to profit from the robotic technologies that are currently in development. Furthermore, in terms of unstructured environments or situations, one of the main challenges is to develop robotics technologies that enable safe and reliable interaction with the human [1, 2]. Optical sensors, capacitive sensors, radars, acoustic, inductive, whiskers, and Radio Frequency Identification (RFID) tags are the most important approaches in literature which are used in robot manipulation applications [3 – 8].

One of the most common solutions for robot grasping and manipulation relies on optical sensors. The combination of both tactile and proximity sensing to improve the perceptive capabilities of multi-fingered hands has been proposed in [9]. Hard optical, soft optical, and optical proximity sensors were used in their design to detect the force from the contact, stability, and measuring the distance from the object. As a result, it was possible to determine the sensor position concerning an object during approach, contact, and grasp. In [10] a fingertip-sized proximity sensor that detects the distance from an object and the tilt angle of the related surface was presented for a high-speed robot.

Capacitive sensors are another type of approach that is developed for robot grasping [7, 11]. Smith et al. used electric field servoing for pre-shaping the geometry and pose of objects to be grasped [5]. By servoing each finger according to the values of EF (Electric Field) sensors built into each finger and arm it is able to align itself in two dimensions with a target object by exploiting electric field measurements [12]. In [11] a novel type of capacitive sensor, which can measure internal properties of materials that are inaccessible to vision or tactile sensing, has been introduced to categorize empty and non-empty bottles.

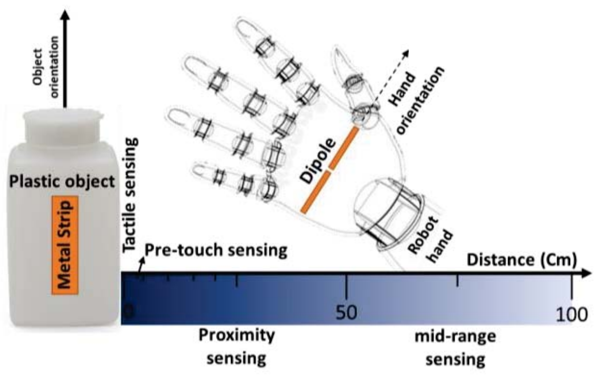


Figure 1. Definition of the sensing range and robot grasping situation.

By examining the works done so far, all these approaches are successful in some applications but still, some important points need to be investigated more. Production cost, simplicity, adaption with small sizes, ability to work in all environments and conditions are some of these items. For example, optical sensors are not able to work in dark or foggy conditions. They have limitations in the detection of transparent objects. Their cost more in applications and their fabrication is not so simple. On the other hand, in literature there is no relative work for the orientation of capacitive sensors with the object, also, they have some limitations regarding detection of not grounded parts. In addition, their sensing range to detect nonmetallic objects is limited.

In this article, aa preliminary investigation is carried out to achieve the best parameters for designing a wireless sensor for robot grasping applications of plastic objects. The final goal is to realize a system that is able to work in various environments in a tactile sensing range with the aim of orienting the robot hand toward the object using the probe-resonator interaction (Figure 1). The coupling of a an electromagnetic field with a resonator for angular monitoring has been exploited in a far-field reading scenario in [13] and it is further developed in this near-field framework. A fixed operation frequency has been chosen in order to provide a solution requiring a simple electronic for the reader. The orientation angle of the hand and the object is retrieved by observing the change in the impedance of the antenna probe which will be modulated by rotating the hand around the axis perpendicular to the object and tag. With this setup the system is able to determine when the desired alignment between the probe and the resonator is achieved. The possibility of estimating also the relative distance of the hand to the object is also addressed in order to ease the correct grasp of the tagged item.

2. Modeling Description

In order to find the desired alignment between the hand and the object, a dipole antenna is used as a reader on the robot hand and a *dipole resonator* consisting in a metal strip printed on the object as a tag. The system shown in Figure 2 comprises a half wave dipole antenna placed on the palm of the hand and a plastic box with the metal strip. All the simulations were carried out by using CST Microwave Studio. The values of real part of the antenna impedance were observed for orientation angles from -90 degrees to 90 degrees between object and hand by steps of 5 degrees. Each case has been considered for various distances from 30 mm to 5 mm between hand and object with step distance of 2.5 mm.

The dipole antenna has a length of 70 mm and a width of 1 mm and it is etched on the 80 mm × 110 mm rectangular PTFE substrate, which represents the hand, with a relative dielectric constant $\varepsilon_r = 2.1$ and thickness of 45 mm. The back side of the hand is grounded (i.e.., perfect electric conductor, PEC). The object is a PTFE rectangular box with dimensions of 80 mm×80 mm×110 mm and wall thickness of 2 mm. The dimensions of the metal strip resonator are 5 mm ×90 mm which is oriented along the box. axis. The operation frequency of the half-dipole in free space is equal to f = 2.143 GHz which reduces to 1.68 GHz once placed on the hand. In this case the maximum impedance was observed near the frequency of 3.0 GHz and for this reason all the simulations were carried on in frequency domain and the simulation frequency range selected from 2.5 GHz to 3.5 GHz in all simulations. Figure 3 shows the mesh view for the hand and dipole antenna.

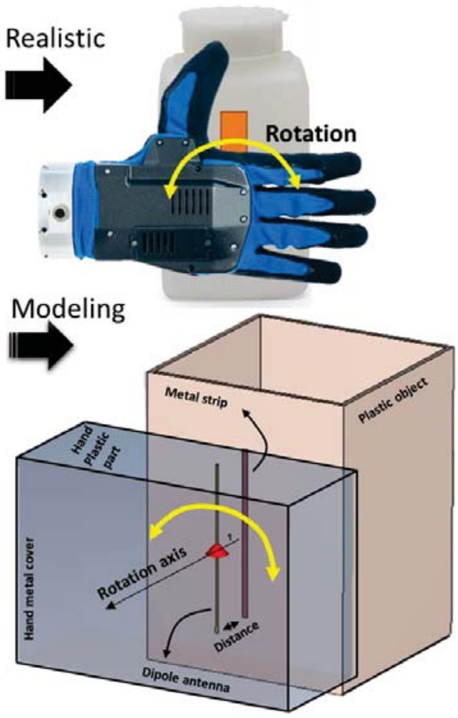
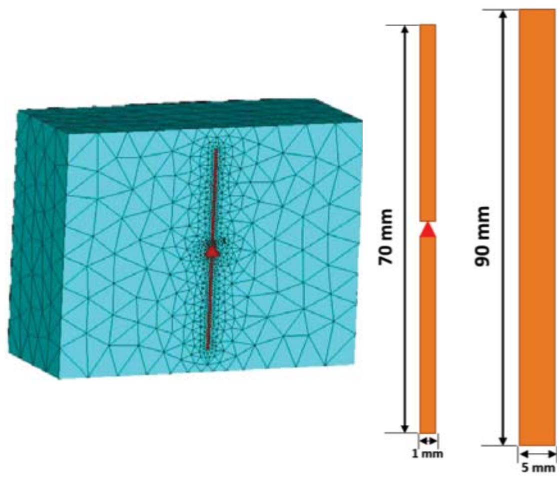


Figure 2. Realistic and simulation setup for robot grasping operation.



(a) *(b)* *(c)*

Figure 3. Meshing and dimension details of a) the hand and antenna in CST microwave studio, b) probe dipole antenna, c) dipole resonator.

3. Preliminary results and discussion

Grasping of objects using a robot hand is a function which should follows some steps and provides some conditions to grasp and lift the object in safe and correct way. First, depending on the shape of the object the hand should be in right orientation, correct direction, and right position relative to the object. In the next step the distance between object and hand must be appropriate. In our setting for grasping to achieve this goal the strip should be attached on the object at the intended place and orientation. Figure 4 reports the real impedance of the dipole antenna at various distances for perfect alignment between the object and the hand (*i.e.,* zero degree) which is considered the desired orientation for the grasping the object. As it is apparent in the Figure, the maximum impedance increases as the hand moves toward the object. Another interesting point is that there is a considerable jump in maximum impedance when the object is at a distance of 5mm from the hand where could be the adequate one to close the hand for grasping it. To select the operating frequency GHz, it is necessary to consider that the frequency at which the maximum impedance is generated increases as the distance between hand and object becomes lower. This frequency is almost 3.0 GHz at the distance of 30mm however it is about 3.2 GHz as the distance becomes to 5mm. For this reason, during the searching operation for grasping, a frequency range (3.0 to 3.2 GHz) should be selected. To avoid long launch time and faster response of the sensor the frequency can be fixed at 3.2 GHz which is the frequency of desired position for grasping.

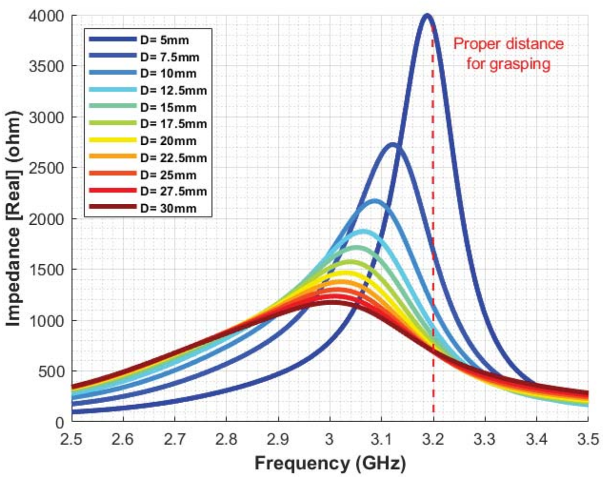
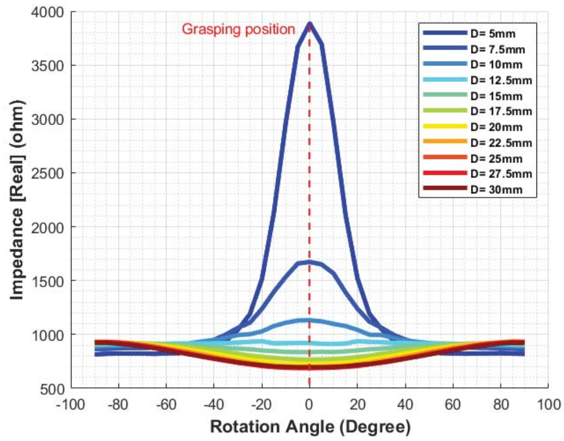
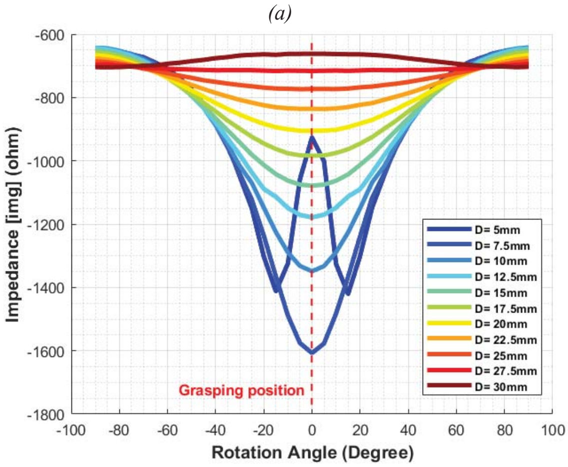


Figure 44. Real input impedance versus frequency of the sensor in 0 degree (*i.e.*., grasping position) for different distances between the resonator and the reader.

The input impedance of the sensing system at 3.2 GHz and for different orientation angles of the hand relative to the object is illustrated in Figure 5. There is not a sensible change in the values of the real part of impedance for different orientation angles when the distance is between 30 mm and 12.5 mm. However, when the distance reaches 10 mm the impedance starts to increase as the angle approaches the zero-degree condition. The shape of the curves become narrower as the distance decrease more. Furthermore, there is a dramatic leap in the input impedance when the orientation angle is near 0 degree (*i.e.,* -5, 0, +5 degrees) and for a distance of 5mm, where the hand is in the proper distance/angle situation for grasping the object. The imaginary part of the impedance shows similar trend to the real part but there are some differences. The changes are considerable when the distance is less than 22.5 mm and the spacing between the curves are smoother. Another difference is that the impedance in 0 degree has a sharp decrease in imaginary part unlike the real part of the impedance.



(a)



(b)

Figure 5. Input impedance of the reader at the 3.2 GHz as a function of tag/reader orientation angle and at different hand/object distances: *a)* real part and *b)* imaginary part.

By taking both imaginary part and real part of the impedance into consideration it can be said that analyzing the real part of the impedance helps the system to find the correct orientation for grasping with high accuracy. Besides it is possible to relatively estimate the distance and the angle of the hand with the object. It important to be noted that the main goal of this sensor system is the alignment of the hand and object which occurs when the axis of the antenna and resonator are both on the same plane which is called the zero-degree position. In addition, examining the imaginary part helps the system to confirm the estimated results and increasing the sensitivity of function of the system. Moreover, imaginary part could be used for longer distance for relative orientation and guide the hand toward the object to start sensitive sensing in close distance with assistance of the real part of the impedance.

4. Conclusion

In this study, a sensor for the alignment of aa robot hand to a tagged object has been proposed and preliminary investigated. Simulations suggests that the input impedance of the probe can be exploited to allow the desired relative angular orientation between the hand and the object. The observed variation of these quantities as a function of the distance suggests that distance too could be assessed. Ongoing work is devoted toward the definition of a strategy for precise grasping and the assessment of the proposed strategy for various kind of objects.

5. Acknowledgements

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