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Implementation of tactile sensors on a 3-Fingers Robotiq® adaptive gripper and visualization in VR using Arduino controller

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Abstract

Tactile sensors are essential components for the implementation of complex manipulation tasks using robot grippers, allowing to directly control the grasping force according to the object properties. Virtual Reality represents an effective tool capable of visualizing complex systems in full details and with a high level of interactivity. After the implementation of cost-effective tactile arrays on a 3-finger Robotiq® gripper using an ARDUINO controller, it is presented an innovative VR interface capable of visualizing the pressure values at the fingertips in a 3D environment, providing an effective tool aimed at supporting the programming and the visualization of the gripper VR.

Keywords: Virtual reality; Robot; Calibration

1. Introduction

Flexibility has nowadays become crucial in production processes. In order to meet the changing market demand, companies need to be capable of fast modification of their products. On the other hand, traditional manufacturing lines are too rigid and do not allow fast modification of the product features. Consequently, they do not allow to meet the increasing demand for short production cycles and high-quality products.

Industrial robots, and automation technologies in general, are nowadays an essential component of the modern production plants and they will play a significant role in extending the flexibility of the production processes as well. Furthermore, the arising fourth industrial revolution (Industry 4.0), with the introduction of Cyber-Physical Systems (CPS) [1], offers new solutions to the problem of increasing flexibility in manufacturing processes [2]. Nevertheless, new technologies require in general customization in every application. That is particularly the case with industrial robots, whose programming is often still a time-consuming task. Flexible, low-cost, and easy-to-use programming methods are strongly demanded for expanding the potential of robotics in companies. On the other hand, VR is currently an effective technology allowing the user to interact with the virtual environment in real time and with a high level of immersion. The user feels “fully immersed” in the virtual environment, and is able of intuitively performing complex tasks, realistically interacting with the virtual environment by means of input/output (I/O) devices (e.g. flystick), while the feedback are provided to the user typically from head-mounted displays (HMD’s) [3], CAVE [4], 3-D sound system [5], or force/touch feedback [6]. The benefits of VR technology have been largely recognized by scientists and engineers, with applications ranging from architectural modeling, manufacturing plant layout, and training. In particular, VR has been proven to be an effective tool in simulating and optimizing both products and production processes in factory plants (Virtual Manufacturing) [7]. An area in which VR has been recognized to be particularly beneficial is in programming of robot manipulator tasks. In [8]

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the coupling of the KUKA LBR iiwa 7 R800 robot with a VR environment was addressed, resulting in a system capable of visualizing the robot motion in VR or move the robot from within the VR environment (teleoperation).

This article addresses a further development of the work described in [8]. In particular, the KUKA LBR iiwa 7 R800 robot has been equipped with a 3-finger Robotiq® adaptive gripper and with inexpensive tactile arrays in order to provide the robot with prehensile capabilities and tactile sensing. A VR interface has been implemented in instantreality [9] with the aim of intuitively visualizing the pressure values at the fingertips of the gripper in VR, in such a way to provide a better user-experience.

2. State of the art

2.1. VR and robotics

Over the years, due to the increasing expectation on robot performances in a wide range of applications, robots capabilities have been extended by means of the introduction of several technologies (e.g. multimodal sensing, neural networks). In recent years, many research efforts have been focused on possible synergy between VR and robotics in several fields [10]. An area in which VR has been recognized to be particularly beneficial is the programming of robot manipulator tasks [11], [12]. Currently, industrial robots are programmed by means of three different methods: using a teach pendants, off-line and at task level. Although a great deal of research has been focused on task-level programming, most industrial robots are still programmed using a teach pendants. This approach has the advantage of simplicity, since it does not require programming skills, but on the other hand it is very time consuming. Furthermore, teach pendants method is not suitable for tasks involving complex manipulator trajectories.

The utilization of VR in robot programming is particularly effective for industrial facilities where the environment is known a priori and well modeled. However, VR can be effective also in remote controlling of the robot by the user in an unstructured environment (teleoperation). Teleoperation is also necessary to conduct operation in adverse environment conditions, e.g. nuclear plant servicing (or decommissioning), undersea operations, space robotics, explosive environments, etc. In such cases, the robot performs the task for the human operator, and protects him/her from any harm.

2.2. Gripper

Many different kind of robotic grippers are available on the market which can be grouped into the following categories:

2.2.1. Two-finger grippers

These are the mostly used grippers in industrial applications. They are basically made up of two fingers that close against each other, remaining parallel, allowing to accomplish only a pinch grasp. For this reason, custom fingertips have to be used almost for each specific application. Adaptive two-finger grippers are more sophisticated than the standard parallel grippers, providing the production with more flexibility. In fact, the underactuated gripper fingers can adapt themselves to the shape of the grasped object (e.g. rectangular, cylinder, etc.) [13]. Since the part is always located at the same place within the gripper, the programming is also very simple.

2.2.2. Three-finger grippers

The three gripper fingers close toward a central axis while grasping the part. These gripper can usually carry a large payload, but similarly to the two-finger grippers, custom fingertips have to be used almost for each specific application. Three-finger adaptive grippers are instead capable of providing a greater flexibility and reliability. In fact, also in this case, the underactuated gripper fingers are capable of adapting themselves to the shape of the grasped geometry [13].

Robotic grippers with more than three fingers are uncommon for industrial applications. They are widely used instead, as prosthetic device for the human body. They have the advantages of flexibility, as they allow grasping a great variety of objects, but often they do not have an accurate repeatability and cannot handle a high payload.

2.3. Tactile sensors

Tactile sensors are an essential component of robot grippers for the implementation of complex manipulation tasks, e.g. contact pressure distribution is considered to be essential for effective manipulation in unstructured environments. Furthermore, assessing the contact pressure also offers the possibility to directly control the grasping force accordingly to the object properties. However, despite the research efforts already spent, and the several commercial tactile array sensors developed, there has been little experimental progress in using tactile information to control grasping and manipulation, especially in industrial environment. The main reason is certainly the cost and complexity of integrating tactile sensing into robot grippers/hands. Many sensing devices have been published in the robotic literature, but their construction often requires custom fabrication using nonstandard techniques [13], [15], [16]. On the other hand, albeit using commercial tactile arrays avoids the need of custom fabrication technologies, they are typically costly, fragile, and cover only a limited area of the hand. However, the integration of both types of sensors into the contact surface of a new robot gripper/hand still requires considerable engineering effort and the development of the multiplexing, cabling, and digitizing to get the sensor signals through the robotic arm and into the control computer is still challenging.

Recently, the use of tactile sensors based on barometric chips has been proposed in literature. Since they are implemented in consumer products, e.g. desktop weather stations and GPS systems, they are relatively inexpensive compared with the other solutions available on the market. However, the construction of the tactile array, generally by means of casting of the barometric sensor in rubber, requires special attention, as defects in casting can tremendously affect the behavior of the sensors [17].

3. Methods

In order to use VR to program and teleoperate a robot, it is firstly necessary to realize a link between the real hardware, i.e. the KUKA LBR iiwa 7 R800 robot, and the VR environment. In [8] a first step toward this direction has been done, linking the KUKA robot controller with VR environment. In this way