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Collaborative Robots and Set of Sensors for Learning by Demonstration

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Summary: Nowadays, industrial and collaborative robots are more and more used in the industry. However, deploying a robot to perform a task or reprogramming it is complex and time-consuming. Thus, our solution is a new way to simplify programming of robots. The operator performs the operation holding the tool of the robot. This tool is attached to an HTC VIVE Tracker sensor which allows recording the movement of the operator. This permis to generate a trajectory using the recorded points. The operator can view the recorded points using Microsoft HoloLens 2 glasses. If necessary, the recorded trajectory can be filtered in order to smooth it and/or remove some outliers. Once the trajectory is validated, it can be replayed by the robot. The points of the trajectory are provided to MoveIt, a trajectory generator for robots running on ROS (Robot Operating System). It automatically generates a trajectory for each robot joint. The calculated trajectory is then transmitted to the robot controller which executes it.

Keywords: Collaborative robot, Industrial robot, Human-robot collaboration, Human-robot interaction, ROS, MoveIt, learning from demonstration, HTC VIVE tracker, Microsoft HoloLens.

1. Introduction

The capabilities of robots and humans are more and more complementary allowing them to work together. However solutions need to be developed in order to simplify robot programming. Learning by demonstration is one of them.

According to a recent review [1] in the area of demonstration-based robot learning, our work remains an important area of research. The plethora of existing approaches to learning by demonstration as well as the multiple evaluation criteria make comparisons between methods extremely difficult. The initial approach for this project was to increase the accuracy of motion data using a system composed of multiple sensors [2] and to extract a trajectory from the motion and fingers' position using machine learning. Different sensors including gloves and cameras were tested. However, due to accuracy and occlusion issues, we settled with an innovative solution by using an HTC Vive Tracker sensor. A study [3] has shown that this sensor is accurate enough for robotic applications. The HTC VIVE Tracker sensor is attached to the tool used by the operator. It can then track the movement of the tool, in three dimension, by locating its position relative to a VIVE Base Station. Since the tool position and rotation is directly tracked, it is not necessary to understand the intent and gesture of the user using complex machine learning models. Moreover, our solution is coupled with the Microsoft HoloLens 2 glasses. This allows the user to have an immediate feedback. It also provides tools to correct, in an intuitive way, possible recording errors. The Microsoft HoloLens glasses were developed and introduced in 2016. They are now widely used in medical robotics applications but still relatively limited in industrial robotics applications [4].

2. Methodology

We decided to merge the data from the following sensors: a RealSense D435 (depth camera) to detect objects with precision and the Trackers. The depth camera is placed above the workspace. An algorithm detects the plane of the table and then a threshold is applied to the depth of each pixel. This allows to detect items dimensions with accuracy (±3 mm delta error) on different kind of boxes.

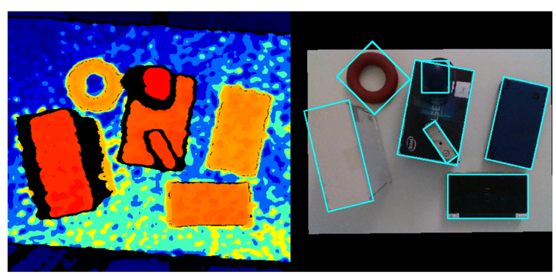

Fig. 1. Left: depth camera data, right: detected objects and color camera.

Two Trackers are used, one to track the tool and one to define the origin. A QR code is used to synchronize the origins of the Tracker and the HoloLens 2. The operator can view the limits of the workspace through the HoloLens and use controls to start and stop recording, as can be seen in Fig. 2.

Once the task is recorded, it can be uploaded to a web server for future usage. The communication between the web server, the HoloLens and the Trackers is done in a modular way.

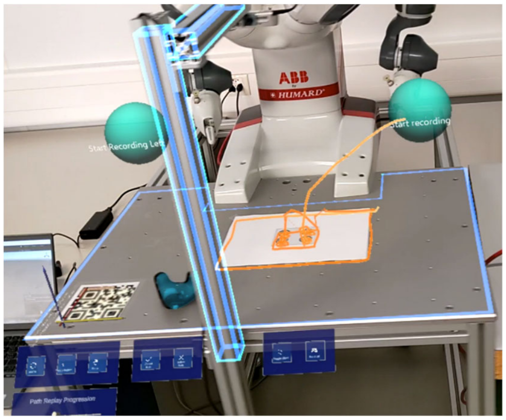

Fig. 2. Workspace viewed through the HoloLens.

3. System Architecture and Protocols

The system is separated into multiple modules, as can be seen in Fig. 3. The modules in red are physical sensors. The module in the middle contains two ”sensor aggregator” applications which retrieve and merge data from sensors. A communication bus exchanges data between the HoloLens 2 module, the web server and the sensor aggregators. The server module stores the recorded trajectories. It is then accessed by the ROS (Robot Operating System) module, which converts the operator trajectories into robot trajectories, before sending them to the robot.

4. HTC VIVE Tracker and HoloLens 2

Multiple hand tracking sensors were tested before settling for the HTC VIVE Tracker, such as the Hi5 Gloves, Senso Gloves and more. However, they can be cumbersome to wear and some of them had low tracking accuracy. Additionally, their main purpose is to track fingers and hand position of the operator, which in many cases cannot be easily converted to a tool movement. To solve this in a pragmatic way, we decided to attach the tool to the Tracker. Since we could not use the gripper of the robot directly, we 3D printed a “pen” representing a gluing tool. However, in future work, it will be possible to print custom tips, either to attach existing tools, or to print “smart” tools. For example a gripper with a small electronic circuit, could automatically track the opening of the clamp during the recording, as the HTC VIVE Trackers has programmable pins.

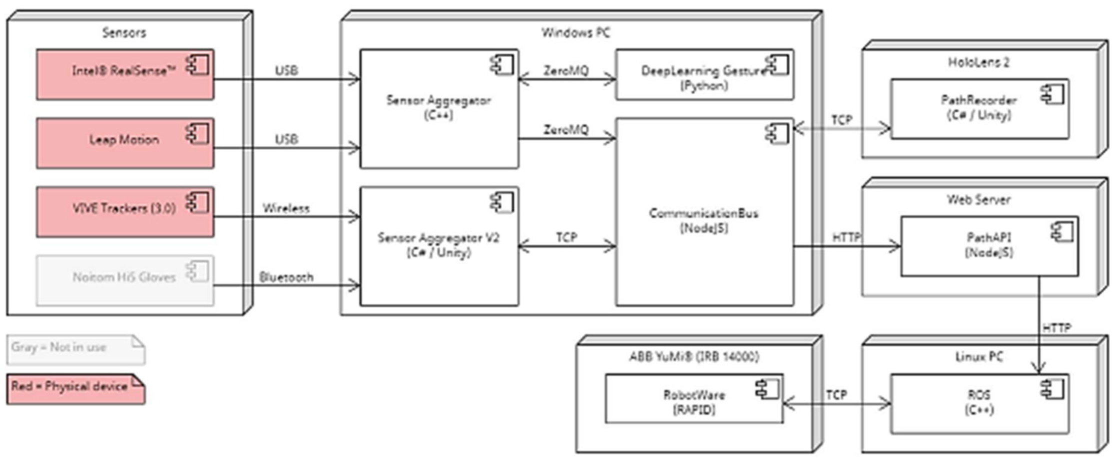

Fig. 3. System Architecture.

The accuracy of the Tracker with the pen has been measured by touching with the tip of the pen, points at a known distance drawn on a sheet of paper. The results of the positions are summarized below in Fig. 4.

The use case for our demonstration is a “gluing task”, the operator picks an item and moves it, before applying glue on it and then gluing the other half. Fig. 5 shows the operator during the recording of the trajectory, which is displayed in orange. While this example shows applying glue on a flat paper, the path recorded is three dimensional.

For this use case, an ABB YuMi robot has been used. This robot has two arms. The operator can decide which arm is used in teaching mode, by touching the arm of the robot with the pen. Technically, two Trackers could be used to record trajectories for both arms at the same time.

x	y	z	x	y	z	x	y	z
Expected			Measured			Absolute error		
0	0	0	1	1	1	1	1	1
0	0	53	0	0	54	0	0	1
0	0	143	3	8	145	3	8	2
(More lines truncated...)								
HTC Tracker				Average :		1.875 [mm]		
				Max :		8 [mm]		

Fig. 4. HTC VIVE Tracker measured accuracy.

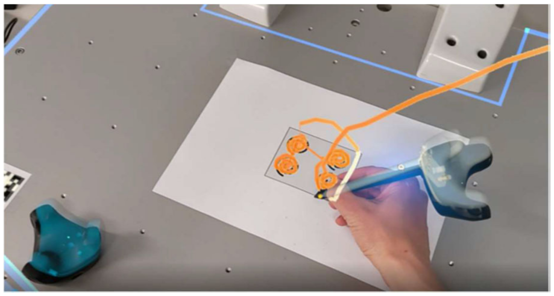

Fig. 5. Recorded path to apply glue on a paper.

5. ROS

The goal is to be able to reproduce the trajectory of the tool that has been recorded with a robot. In our case, we use the ABB YuMi robot . However, the idea is to be able to reproduce the trajectory on any robot. For this reason the framework ROS and in particular its trajectory generator tool MoveIt have been used. This solution is thus robot brand agnostic.

As input, the points recorded, the robot configuration (number of joints, geometry, kinematic limits, …) and the 3D environment have to be given to the tool. As output, we get a trajectory that can be executed by the robot following the path recorded and avoiding collisions with the environment.

Fig. 6 shows MoveIt generating a trajectory from the points recorded in the previous step.

5. Conclusion

New solutions in the robotics field are emerging with new sensors like the HTC Vive Trackers as we could see in the description of our experience. In order to have an industrially exploitable solution we propose to work on the tracking accuracy by exploring methods [5] to improve it.

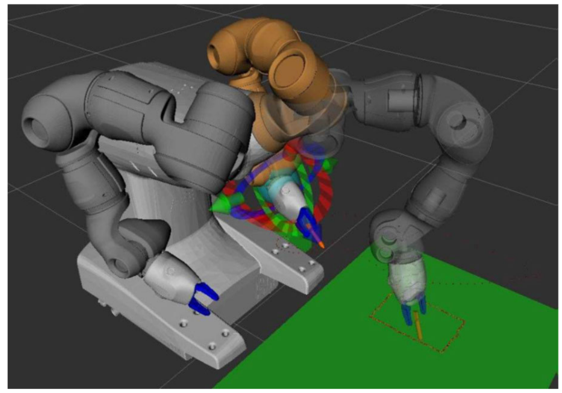

Fig. 6. MoveIt generating a trajectory.

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