Writing Tool for Robots

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Abstract

Writing is a valuable behavior for embodied social agents, enabling communication in such diverse forms as leaving notes for others to read and signing for packages. To enable robots like Baxter to write, we developed a tool, the B.O.O.T, which can be equipped and unequipped by a robotic arm via grasping with a parallel electric gripper. This allows Baxter, a robot that has trouble holding writing implements with its built-in parallel electric gripper, to write with human implements such as pens, pencils, and markers. The design of the tool allows Baxter to engage and disengage with the B.O.O.T completely autonomously. This paper describes our tool and its design considerations, and demonstrates the robots ability to write with the tool.

Introduction

Social robots are autonomous agents that can interact with human agents through typical social behaviors. There are many different tasks a social robot could be asked to do, such as object delivery or writing, and there is no single end effector that will allow the robot to perform these tasks effectively. Humans use tools to expand their 'hardware' capabilities; this idea motivates our research. Therefore, we have built a tool that lets Baxter grip a tool to write, and ungrip it to perform other tasks.

There has been research done to create robots that draw and write (Calinon, Epiney, and Billard 2005), (Caballero-Morales 2014), (Karina Fernandez 2002), (P. Tresset and F. Leymarie 2013) and (P. Tresset and F. Leymarie 2013), but these robots either have the writing hardware built into them or they simply tape the writing utensil onto the robot. The robot is unable to switch between writing and non-writing tasks.

On the other hand, (Hutchinson, Hoffman, and Pollack 1991) and (Idiap Research and Goldsmiths University of London 2016) have developed hardware to construct detachable tools for robots, but these works do not focus on social tasks. They are geared towards allowing industrial robots to use different tools needed to work in a factory setting. Our research looks to mix the social aspect of the first body of work with the modularity of the second.

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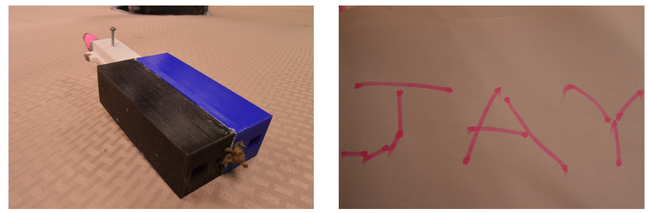

Figure 1: The Writing Tool and an example of the name JAY written

Design

The Writing Tool described below was specifically built for the Baxter research and industrial robot, manufactured by Rethink Robotics. Baxter is a humanoid robot with two seven degree-of-freedom arms. Each arm has a parallel electric gripper, RGB camera, and IR range finder on the end effector. The parallel electric gripper allows two fingers to open and close, a capability which is typically used for object delivery tasks. These grippers cannot properly grasp a writing utensil, such as a marker, because full force closure cannot be obtained with only two contact points. Baxter easily loses its grip and it is difficult to prevent the over or under application of pressure at the writing tip. We have built a tool that Baxter grips in order to write. Baxter can slip its open grippers into the slots, and then close the grippers to apply pressure to hold onto it (see Fig 2). Because the writing chamber that is holding the utensil is directly in front of Baxter's end effector, the tool acts as an extension of Baxter's arm that increases its control authority over the writing implement. The screws on the writing tool allow the writing utensil to sit securely inside the writing chamber while the connective spring mediates control from the end effector. This work looks to allow social robots to use their built in hardware to grasp a tool that lets them complete a task they could not otherwise perform. By allowing the tool to be gripped and released easily, engaging and disengaging with the writing tool can be done autonomously. The writing tool was created in Solidworks and is straightforward to 3D print. Once the parts of the writing tool are printed out, it is easily assembled. We also created a Python program that drives Baxter to perform a writing task. The Python program uses a 3D grid to represent points in space, and parameterizes letter

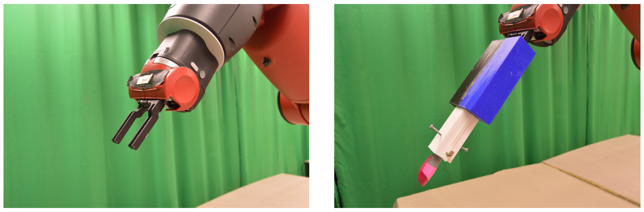

Figure 2: Baxter not holding and holding the Writing Tool

paths in this grid during drawing. The included software has preprogrammed representations of all the letters of the English alphabet, capitalized (see Fig 1). The software allows affine transformations to be applied to these representations in order to rotate, scale, and translate letters to draw. The 3D schematics, instructions for assembly, software, and further images/videos are all included in the Github repository (Eric Rosen 2016).

The speed at which the writing tool moves has an effect on the smoothness and mark impact on the writing canvas. Because Baxter's end effector is prone to small jitters, the slower the line is drawn, the more likely the line will not be straight. However, the slower the line is drawn, the more impact the mark has on the paper due to its longer time exposure. When the drawing tool is whipped quickly, it leaves more of a streak mark than a full drawn mark. Thus, the speed is a parameter in the program that can be changed in order to get the desired results. The angle at which the writing utensil interacts with the writing canvas will determine how much of the mark is let upon it. Humans typically hold their writing utensil at an angle from the canvas when they draw. While drawing, they "anchor" their hand onto the canvas, which allows more fine grain control over the precision and accuracy. This "anchoring" is not implemented in any of the demonstrations in this work, and are all performed orthogonally with respect to the canvas. However, it is still possible to start the utensil at any degree so it can swipe the writing utensil point to point. The steeper the angle, the less fine control over the mark the robot has. In order to keep the most unified stroke marks throughout the drawing, the orientation of the writing utensil's tip is held constant throughout the stroke. This means that when the program draws a line segment between two points, it calculates the angle of the vector relative to the grid, and orients the tool to match it. This allows the same side of the writing utensil to always be applied to the canvas. However, some writing utensil are used at different orientations depending on desired effect, so one can program the writing tool to rotate throughout the stroke if desired.

Possible Extensions of Work

Writing performance depends heavily upon the control system of the end effector. When writing, it is important to have constant feedback in order to match the different surface properties and tension that exists throughout the canvas. In order to accommodate this, the design of the end effector tool provides clearance for Baxter's IR sensor so that the distance from the end effector to the canvas can be tracked. This allows some degree of control over how much pressure the end effector is applying with the tool. Furthermore, since there is only one spring that sits inside the writing chamber in a very simplified domain, one can utilize basic spring physics by knowing the length of resting spring and its spring constant to see how much pressure is being applied to the canvas based on its compression. By synthesizing the IR sensor with the measurements of the spring, it is possible to create a program that measures how much pressure is currently being applied. Because the amount of pressure that is being applied to the writing canvas from the writing utensil dictates the drawing, it is important that the writing utensil's displacement from rest match the robot's intent. If the writing chamber does not properly shift with the robot's movement, the robot may start to make mistakes and could either push the writing utensil too hard into the writing canvas, or not enough to make a mark. Thus, the circumference of the writing chamber is in accordance with the circumference of the hole of the writing body that holds it such that the writing chamber does not have any room to shift horizontally, but can easily shift vertically in and out of the writing body to displace the spring accordingly. An interesting aspect of drawing is creating curves. In this work's software, we draw line segments between points in order to write and draw. However, many artists do not think about drawing from one point to another; they draw their stroke based on muscle memory. Because Baxter has a higher degree of freedom than most writing robots, the authors wonder if deep learning could be applied to this area of robotics in order to learn what servo angles are needed to be assumed in order to solve drawing curves and line segments. This could allow Baxter to have very unique and natural looking drawing marks, rather than the rigid, less natural looking ones that are currently produced. By using feedback from the IR sensor and the RGB camera, and an understanding of how the spring is working inside the writing tool, different methods of deep learning could possibly help solve for the optimal paths for Baxter to move its arm in order to draw and write.

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