Human Dipping and Inserting Manipulation Motion Analysis

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***Abstract*—The purpose of this project was to understand ways to model motions and interactions for use in a robotic system. The robotic system in mind was one that performs everyday tasks. Data was collected in the USF Robot Perception and Action Lab (RPAL), and the data manipulated in MATLAB to model the motion. The models showed some similar movements between a couple tasks and differences as well. The project was an effective introduction to modeling robotic motions.**

I. Introduction

THE motivation for the project was an introduction on how to model motions and interactions for use in robotics. This project related to work being developed at the USF RPAL [1], [2], [3], [4]. There, graduate students with their supervising professor, Dr. Yu Sun, are working on robotic performances of simple household tasks associated with cooking, manipulating instruments, etc [5], [6]. Thus, the tasks that were used were all types that the RPAL are already studying.

II. Data Collection

All the data was collected at the USF RPAL on equipment that is used for capturing motion data on certain simple tasks and manipulations. The equipment captured motion and interaction position, force, and torque data for the 5 simple tasks we were assigned: beat, dip, mix, loose a nut, and insert a peg.

All the tasks used a device that measures the position, force, and torque of whatever task was being performed when the data capturing program was started. The device had the ability to have different instruments attached for certain manipulative tasks. The beat task consisted of beating together flour and water in a small bowl using a wire whisk attachment. The dip task involved dipping a paint brush attachment into a small bowl of water. The mix task utilized a spoon attachment to mix together rice and beans in a small bowl. The loose a nut task used a wrench attachment to loosen a nut from a screw that was through a wooden block. Then, the insert peg task involved a peg attachment that was placed into a block with holes.

A video camera captured the motions as the tasks were performed from the start of the data collection program until when the program ended. The program was run separately for every trial, of which there was 15 for each of the 5 tasks. After the data was collected, it was cleaned up by deleting any data that occurred before or after the actual action took place. So, the remaining data only included the data associated with the frames/times showing the actual beginning and end of the task.

Course Name: Intro to Robotics. The work is supervised by Professor Yu Sun and TA David Paulius.

III. Data Processing

For the data processing phase, our group was given just 3 tasks (dip, insert peg, and insert straw) each with 10 trials to analyze. The data was then processed in MATLAB. The course TA, David Paulius, provided the basic program needed to visualize the data. We then made our own modifications to the program to properly model the motions and interactions. The modifications were necessary in order to calculate the linear velocity and angular velocity.

The tools in MATLAB were utilized to find the derivative of the rotation matrix alongside the rotation matrix itself. Both of these matrices were necessary to find the skewed matrix, that way the angular velocity could be found. For the linear velocity, every position was subtracted from the previous frame's position and divided by the time passed. A grapher script was added that allowed us to generate graphs of the position, linear velocity, and angular velocity before the program deleted the data prior to creating the airplane visualizer.

IV. Results

The resulting analysis of the models revealed some similarities between some tasks, but differences were present as well. All three motions had low reaching motion along the z-axis (as shown in Fig. 1., Fig. 2., and Fig. 3.), which makes sense because the hand has to move the instrument downward to complete all of the tasks. The dip task had more movement though along the y-axis and x-axis once it descended the z-axis, unlike inserting the peg and inserting the straw, most likely because the brush attachment moved around in the bowl.

For the angular velocities of the three tasks considering all three axes, the insert straw task seems to have a downward slope (as shown in Fig. 4.), while the other two tasks seem to have more symmetrical graphs (as shown in Fig. 5. and Fig. 6.).

The linear velocity along the z-axis of the insert peg task differs in that it stays fairly constant, see Fig. 7. On the other hand, the linear velocity along the z-axis for the dip task speeds up and then slows down halfway through the task, see Fig. 8. This sudden decrease was most likely in the moment when the motion of the brush attachment touched the bottom of the small, shallow bowl. The linear velocity along the z-axis for the insert straw task slows down at first then gradually increases until it spikes towards the end of the task, see Fig. 9. The sudden spike at the end was possibly caused by the straw attachment being fully inserted into the cup.

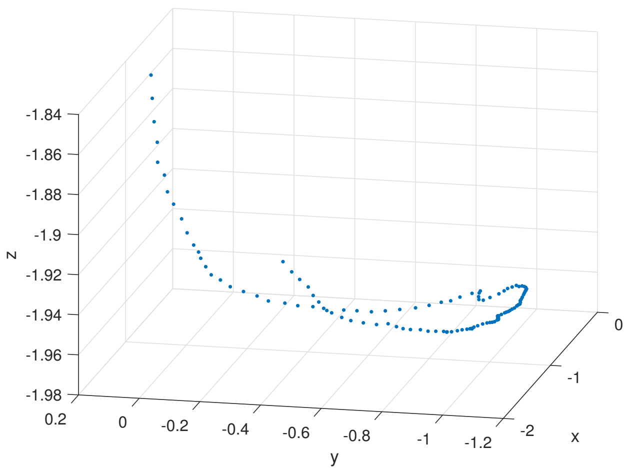

Fig. 1. 3D model of motion of dip task.

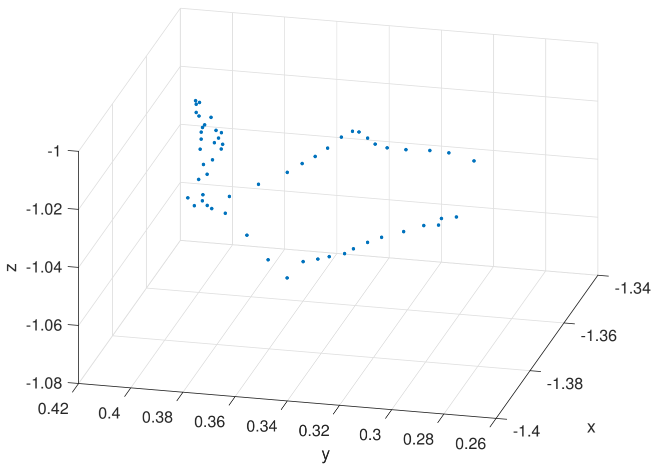

Fig. 2. 3D model of motion of insert peg task.

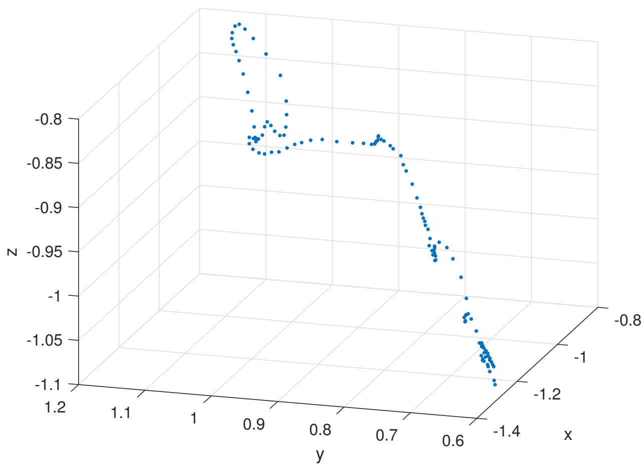

Fig. 3. 3D model of motion of insert straw task.

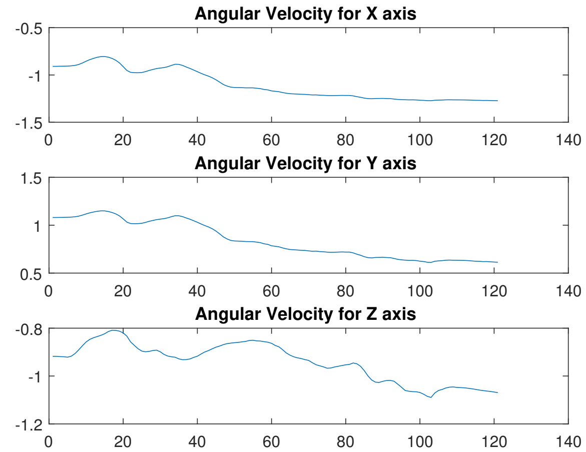

Fig. 4. 2D graphs of angular velocity of insert straw task.

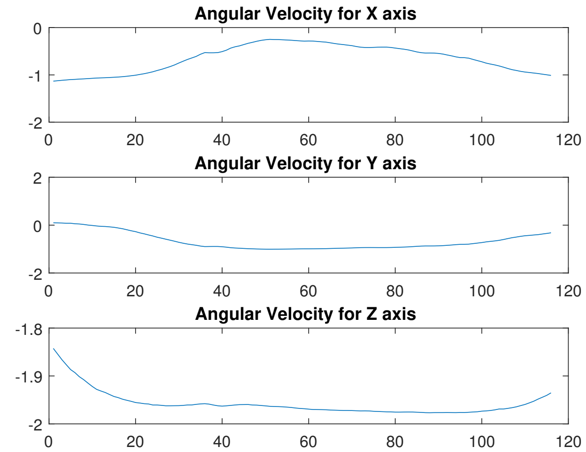

Fig. 5. 2D graphs of angular velocity of dip task.

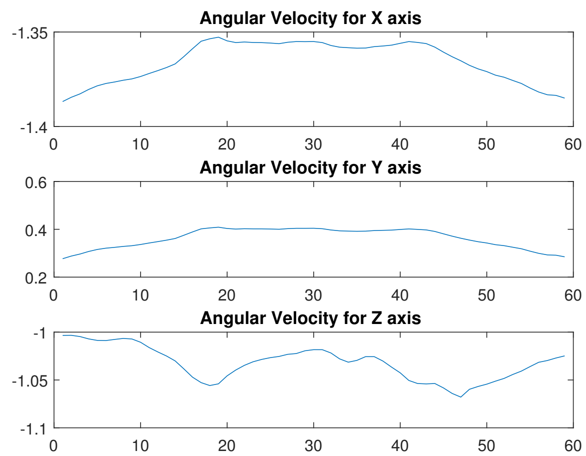

Fig. 6. 2D graphs of angular velocity of insert peg task.

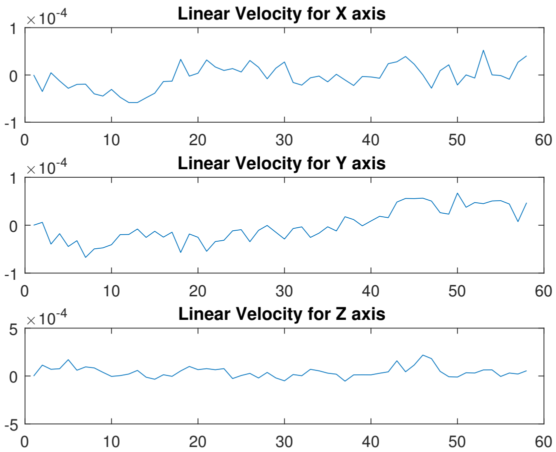

Fig. 7. 2D graphs of linear velocity of insert peg task.

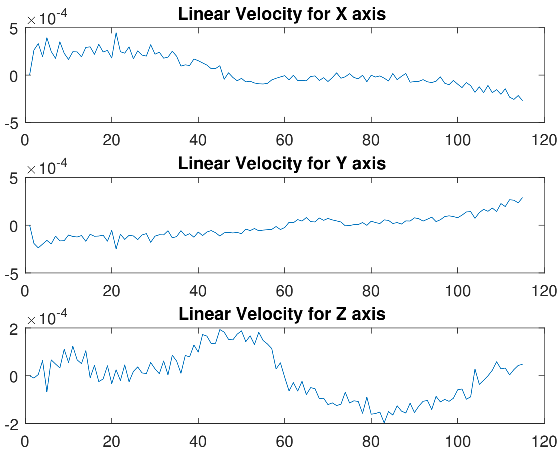

Fig. 8. 2D graphs of linear velocity of dip task.

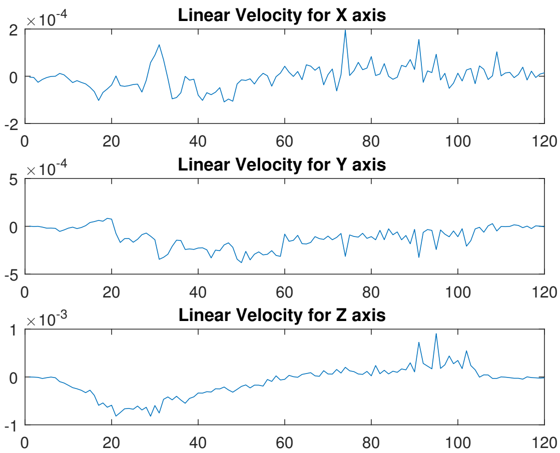

Fig. 9. 2D graphs of linear velocity of insert straw task.

V. Discussion

This project worked well at introducing how to model motions and interactions for the purpose of reproducing those motions in a robotic system. The data collection process demonstrated the importance of numerous trials for sufficient viable data. The data processing process taught us how to use programming visualization tools such as MATLAB in order to make calculations from the data and see those calculations along with 3D models of the motions. The modeling stage of robotics is quite significant as it sets the foundation for the resulting robotic movement of a device, so this project effectively revealed the methods of creating such designs.

References

[1] Y. Huang and Y. Sun, "Learning to pour," in *Intelligent Robots and Systems (IROS), 2017 IEEE/RSJ International Conference on*. IEEE, 2017, pp. 7005–7010.
[2] ——, "Datasets on object manipulation and interaction: a survey," *arXiv preprint arXiv:1607.00442*, 2016.
[3] Y. Huang, M. Bianchi, M. Liarokapis, and Y. Sun, "Recent data sets on object manipulation: A survey," *Big data*, vol. 4, no. 4, pp. 197–216, 2016.
[4] Y. Huang and Y. Sun, "Generating manipulation trajectory using motion harmonics," in *Intelligent Robots and Systems (IROS), 2015 IEEE/RSJ International Conference on*. IEEE, 2015, pp. 4949–4954.
[5] D. Paulius, Y. Huang, R. Milton, W. D. Buchanan, J. Sam, and Y. Sun, "Functional object-oriented network for manipulation learning," in *Intelligent Robots and Systems (IROS), 2016 IEEE/RSJ International Conference on*. IEEE, 2016, pp. 2655–2662.
[6] Y. Huang and Y. Sun, "A dataset of daily interactive manipulation," *arXiv preprint arXiv:1807.00858*, 2018.