Human Beating, Brushing, Screwing, Inserting, and Pouring Motion Analysis

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***Abstract*—The purpose of this project is to gain an understanding of how to model motions that will be carried out by a robotic system. This includes the gathering of data, transforming the data to a different coordinate system, the identification of principal axes and ranges, as well as the calculation of linear and rotational velocity.**

I. Introduction

IN this project we were tasked with collecting our own data for 5 motions through 15 trials during step 1. This data was collected in the lab with the help of the TA. Then we were tasked with viewing the data in MATLAB and trimming it for submission to the TA in step 2. To do this we used video we recorded of the motion and cut out the data that happened before or after the action. Then we used MATLAB again to plot the data, to translate the data with respect to the origin, and find the linear and angular velocity between all points for step 3. To translate and get the velocities we edited code provided by the TA. Finally in step 4 we wrote a report on our findings. This work was done as a continuation of the previous work done about observing manipulations seen in daily household tasks and routines (See:[1], [2]) and work done analyzing motions and trajectories. (See:[3], [4], [5], [6])

II. Data Collection

The data collection portion of the project consisted of collecting coordinate and orientation data of various motions. The set of motions performed were the following: beating (or whisking) an egg, brushing powder on a smooth surface, inserting a straw into the slotted lid of a cup, loosening a screw, and pouring water from a measuring cup into a glass. Two instruments were used to capture the data as the subject performed the motion, one which tracked the 3-dimensional coordinates of the subjects hand, and another which recorded the rotation of the subjects hand. As the motion was being performed the coordinate and rotation data at each frame was fed into a program that stored the data as a csv file for later processing.

Each action was repeated for 15 trials. Once gathered, the data for each trial was trimmed of any unneeded data collected by the devices before the beginning of the action or after the completion of the action. After trimming was completed, the data was submitted and combined with data from other groups. We then received a portion of the pooled data to be used for processing.

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

III. Data Processing

The gathered data was processed using MATLAB. The first step of data processing was aimed at zeroing out the initial position and orientation of the object. This was done by coordinate system transformation to bring the initial pose to the origin of the new coordinate system. The resulting data was then plotted and visualized using MATLAB. The plots were then analyzed to determine the principal moving axes, rotating axis, and moving and rotating ranges. These transformations and rotations will be analyzed later on.

Using the transformed data, the linear velocity and angular velocity were calculated between data points. The linear velocity was calculated by taking the distance between each point over the amount of time between the collection of each point. As for the angular velocity, it was determined by taking the derivative of the rotation matrix and multiplying it by the original matrix transposed to obtain a skew matrix.

The dip motion is characterized by an arching movement forwards and backwards. The motion starts at a high point on the Z axis then moves on a diagonal in the X and Y axis to reach a low point this low point is the "Dip". The motion then arcs back to its start height on the Z axis to complete the motion. This translation can be visualized in Fig. 1.

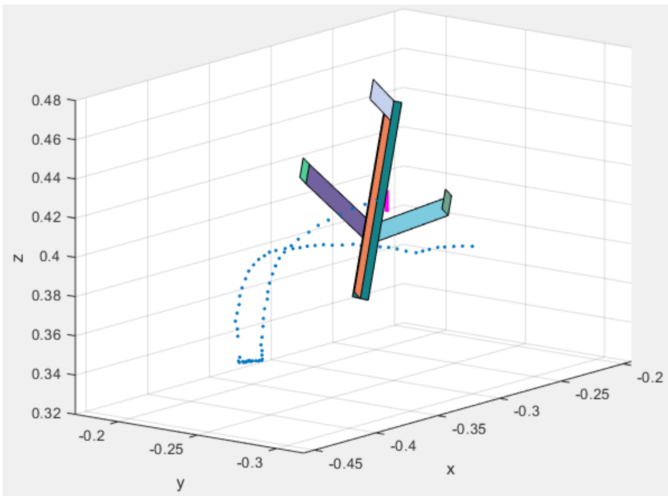

Fig. 1. The side view of the dip motion showing the translation happening during the motion.

The principle movement plane of the dip motion is strait along a Diagonal to the X and Y axis. If the movement was not on the diagonal but along the X or Y axis it would only need that axis and the Z axis to demonstrate the motion. Because of this the movements translation can be sufficiently described in 2 dimensions. The coordinate plane created by this motions translation can be seen in Fig. 2.

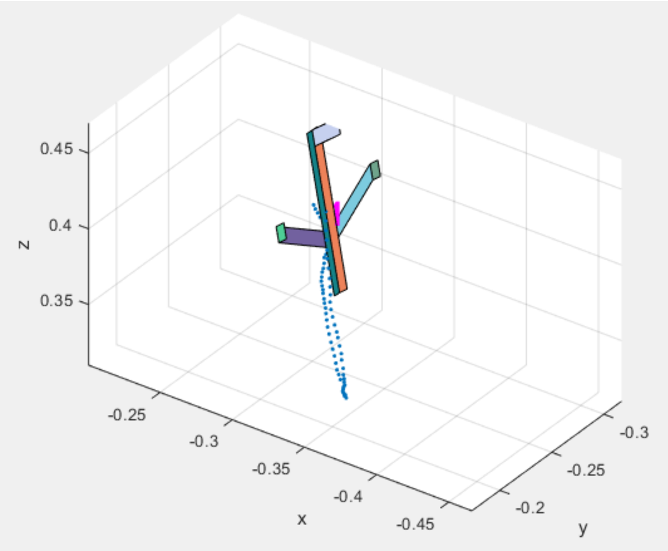

Fig. 2. The front view of the dip motion displaying the principal movement plane.

The pour motion consists primarily of a rotation, without much change in the location. There is a counter-clockwise rotation of just over 90 degrees followed by another rotation clockwise back to the starting orientation. This movement can be seen between Fig. 3 and Fig. 4 with a return to its original orientation in Fig. 5. Throughout this motion the sensor moves very little from its starting coordinates.

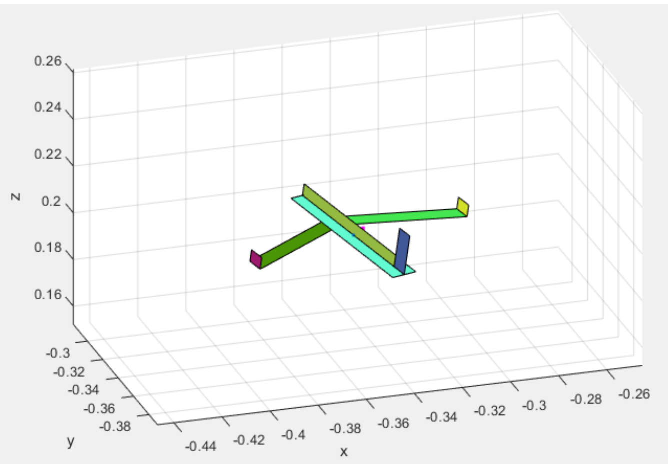

Fig. 3. The start of the pour motion displaying its original orientation

The furthest degree of rotation for the pour motion can be seen in Fig. 4.

The end of the pour motion is shown in Fig. 5. This demonstrates the return to the original position displayed in Fig. 3 and how little translation takes place during the motion. The blue dotted line seen in Fig. 5 show that translation, most

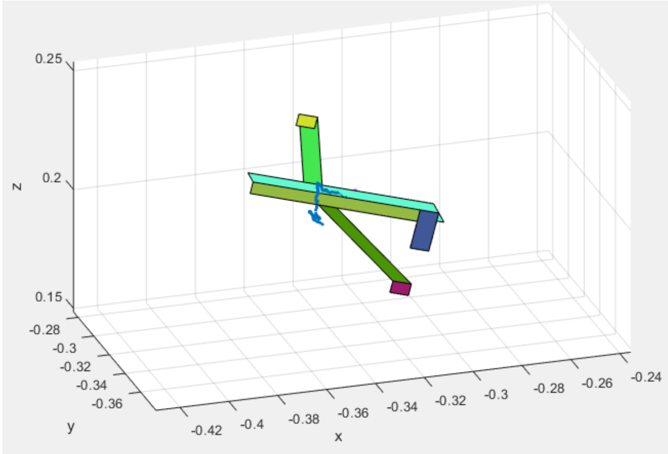

Fig. 4. The middle of the pour motion displaying the change in rotation.

of that movement can be attributed to subtle movements of the hand doing the motion or a slight upward movement to get a proper pour. This movement is negligible as the pour motion can be displayed on a single point with only rotation.

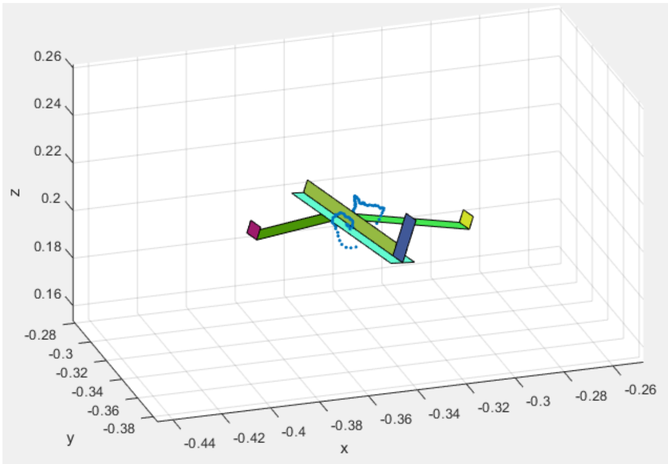

Fig. 5. The end of the pour motion showing the return to its original orientation

The scoop motion starts with a large translation upward to where the actual scoop takes place. This motion starts at a low point on the Z axis and then hits a high point on the Z axis before coming down slightly for the final scoop. This large translation can be seen in Fig. 6.

Similar to the Dip motion the principle movement plane of the scoop motion is strait along a Diagonal to the X and Y axis. Also like the Dip motion This movement can be represented in one plane or in 2 dimensions. The diagonal motion is circumstantial the motion could just as easily be along the X axis an eliminate the or the Y axis to eliminate the X. The coordinate plane created by this motions translation can be seen in Fig. 7.

The scoop motion has both translation and rotation. At the end of the large translation shown in Fig. 6 and Fig. 7 their is a small rotation that completes the scoop motion. The beginning

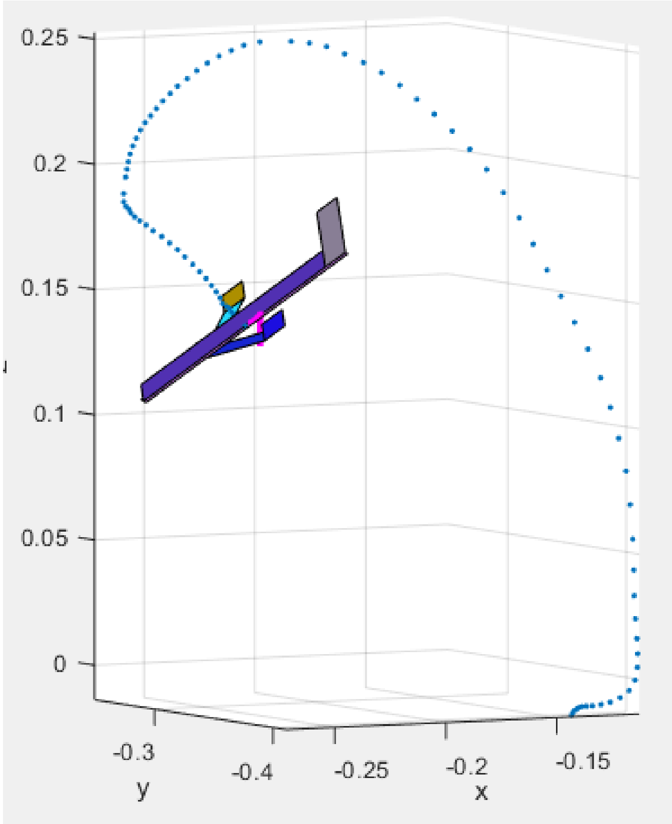

Fig. 6. The side view of the scoop motion showing the translation happening during the motion.

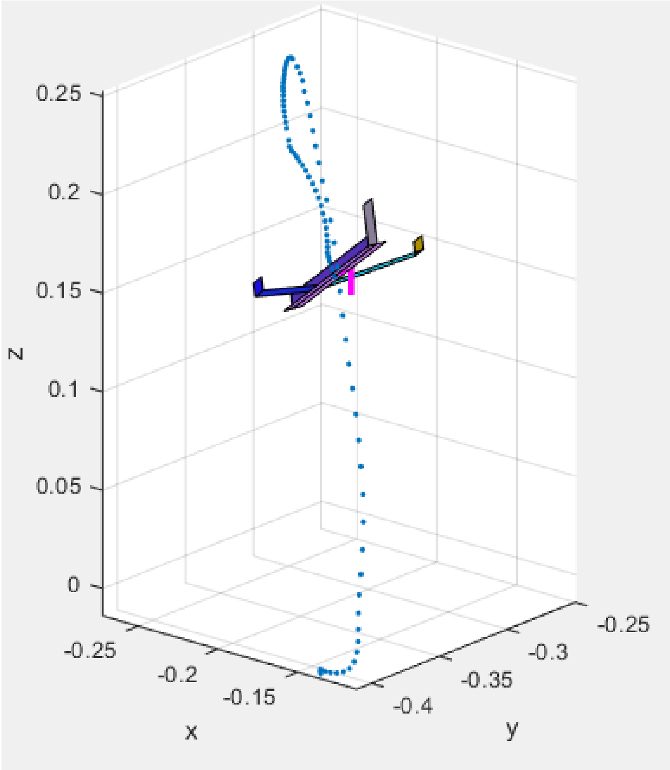

Fig. 7. The front view of the scoop motion showing the principal movement plane.

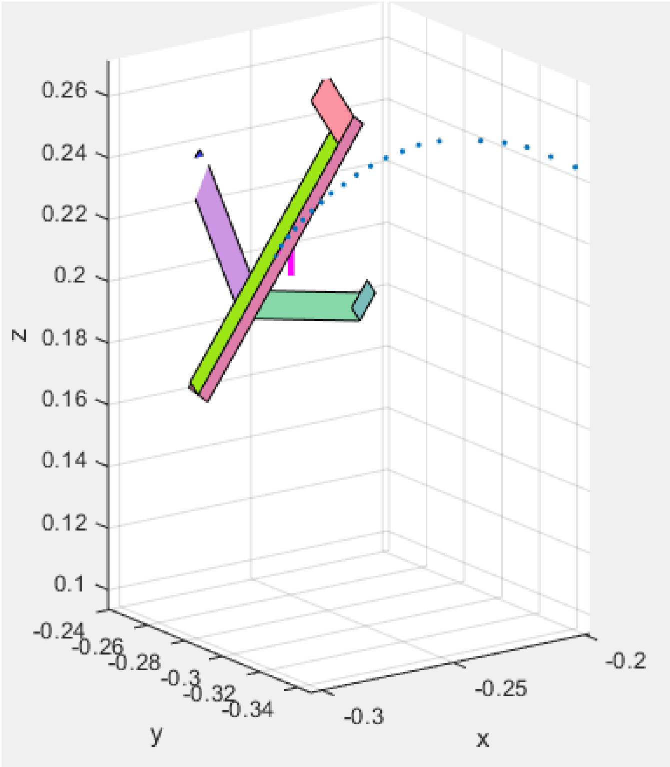

Fig. 8. The beginning of the rotation at the end of the scoop translation.

orientation of this motion can be seen in Fig. 8. The airplane is almost vertical strait down at this point.

In Fig.9 the end of the scoop rotation can be seen. The airplane at this point is more horizontal compared to the vertical orientation displayed in Fig.8. Since Fig. 8 the orientation has changed by nearly 90 degrees. This motion is the point where the scoop motion being performed.

These motions have many similarities and differences. The scoop and dip motions have the same principle movement plane along the X, Y diagonal and in the Z plane. All of these motions are also characterized by a rotation. The pour rotation is almost the entire motion, but in the dip and scoop case the rotation is only done after a translation.

IV. Results

After collecting and analyzing the data, we edited the given program to output the linear and angular velocities for each trial between each point. For the linear velocity we took the distance and time at each point, subtracted them by the distance and time at the point before, then divided the distance by the time. For the angular velocity we took the rotation matrix given at each point, found the derivative of that matrix, then multiplied it by the transpose of the original rotation matrix. All of this data was processed by the edited program then written to a CSV.

We also calculated the average linear and angular velocity for each axis of each motion. The averages for the dip motion are shown in Table 1. The dip motion had the lowest average roll velocity of all three of the motions, and the highest average

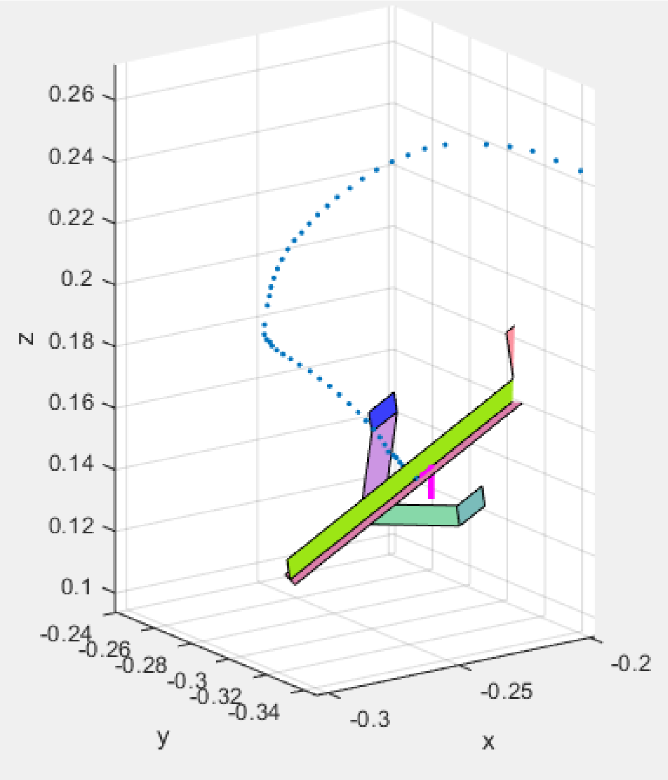

Fig. 9. The end of the scoop rotation.

pitch and yaw velocities. The X, Y, and Z averages were all average when compared to the other motions.

TABLE I
AVERAGE LINEAR AND ANGULAR VELOCITY: DIP

Axis	Linear Velocity	Angular Velocity
X / Roll	0.00000129943	-0.046232016
Y / Pitch	-0.0000000315891	0.936690649
Z / Yaw	-0.0000304605	1.983160552

The Pour motions averages in Table 2 when compared to the other motions were surprising. The angular velocity in the pitch and yaw were the lowest of all three motions and the roll was average. The Pour motion was almost completely rotation so the averages their were expected to be higher, but the change in motion may not have happened as fast due to the risk of spillage when pouring.

TABLE II
AVERAGE LINEAR AND ANGULAR VELOCITY: POUR

Axis	Linear Velocity	Angular Velocity
X / Roll	0.00000155323	1.103954041
Y / Pitch	-0.00000138684	-0.256005163
Z / Yaw	0.00000550221	1.117989409

The Scoop data in Table 3 was close to what is expected. The average velocity in the X direction is the highest of all the motions by far and the movement in the Z direction was also the fastest of all the motions, this is most likely due to the violent upward motion in the beginning of the recorded scoop data.

TABLE III
AVERAGE LINEAR AND ANGULAR VELOCITY: SCOOP

Axis	Linear Velocity	Angular Velocity
X / Roll	0.000056726	1.025074129
Y / Pitch	-0.000057617	0.768523058
Z / Yaw	-0.0000549128	1.215086019

A some of the averages for the linear and angular velocity did not display what was expected from looking at the motion itself. However these discrepancies may be explained by inconsistent movement during the data collection or by differences in the velocity when compared to what the primary movement axis may suggest.

Using the Data in tables 1 through 3 and looking at the motions themselves we picked relevant data to plot and display in figures 10 through 12.

The linear velocity for the Z axis of the dip motion shown in figure 10 displays the high start velocity as the motion arcs into place then a decline as the dip occurs and a steady increase after the dip to return to the original position.

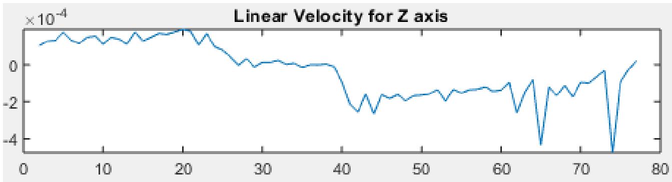

Fig. 10. The plot of the Dip Z axis motion translation.

The linear velocity for the Z axis of the Scoop motion shown in figure 11 displays something similar to the dip motion. This plot displays the fast movement to the initial position in the middle of the plot with a the velocity tapering off toward the end when the actual scoop takes place.

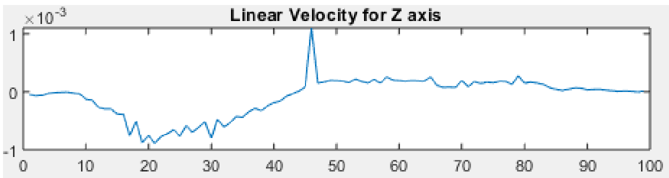

Fig. 11. The plot of the Scoop Z axis motion translation.

The Plot in figure 12 shows the angular velocity of the roll and pitch for the pour motion. These 2 plots are the most telling. The higher velocity in the start when the pour takes place is expected. Then as the liquid leaves the container the velocity slows, until the container is empty. The container is empty about 2/3rd's of the way through the motion and when it does the velocity picks up again to bring the container back to its original position.

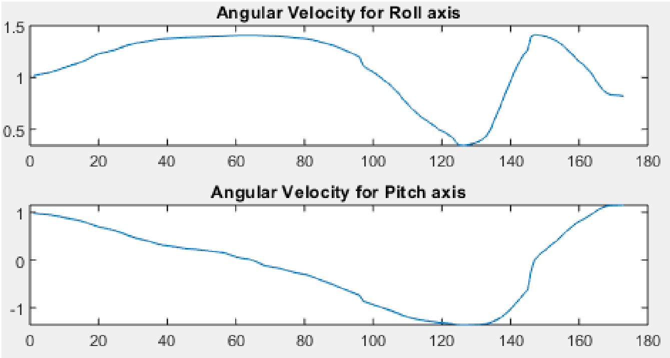

Fig. 12. The plot of the pour motions roll and pitch.

V. Discussion

The purpose of this project was to understand the motions that will be carried out by a robotic system. We were tasked with collecting our own data for 5 motions through 15 trials then viewing the data in MATLAB and trimming it for submission to the TA. Then we used MATLAB again to plot the data, to translate the data with respect to the origin, and find the linear and angular velocity. We analyzed the motions using the visualizer and compared them based on their primary movement plane and rotations. We also analyzed the linear and angular velocities, came up with averages, and plotted the most relevant motions for study.

For future work we will be applying the velocities we collected to a robotic system and have it perform the Dip, Pour, and Scoop motions itself.

Acknowledgments

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References

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