Dynamics of Mechanical Systems - Homework 3

Group 3:
96429 Manuel Luis da Fonseca Ferreira
96485 Samuel Coelho Teixeira
98555 Afonso Costa Henrique

March 16, 2024

1 Objectives

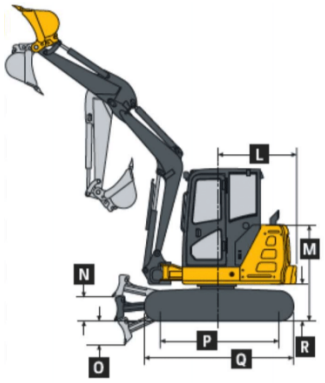
Use the program MUBOKAP, presented in class and made available in your dropbox to perform the kinematic analysis of the mechanism presented in the figure (Excavator) to develop one of the tasks assigned. The task consists in digging one of the areas listed in the figure with one of the excavators. The coordinates of the points limiting the areas are in meter. A different bucket size is specified for each excavator, and in a single path it cannot dig more than that area. See Section 2.5.3 of DSMBook-Chapter02-CartesianCoordinates for the details on a similar Excavator model and its model input file (note that the dimensions of your excavator are different from those in the course notes.

- Build a path (or a sequence of paths) for the bucket to perform the excavation prescribed in your application (selected according to your group number). Note that for each pass of the bucket there is a limit of material that can be removed. If more than 2 passes are necessary, consider only the first 2 passes and identify the approximate shape of what is left to dig.
- Guide the bucket position and orientation with the position drivers directly applied to the bucket body and, obtain the history of the positions of the points to which the hydraulic actuators are connected.
- Plot the trajectories of the bucket, obtained with the kinematic simulation, and the length of each one of the hydraulic actuators as functions of time.
- Instead of driving the bucket of the excavator, drive the hydraulic actuators with point2point drivers so that the end kinematics of the bucket is that one prescribed in phase 1. Plot the bucket trajectory and orientation obtained with the new drivers together with the trajectory obtained in phase 1 (driving the bucket directly)
- Compare the angular velocities and accelerations of the arm and boom using the two types of drivers (the driven bucket in phase 1 and the point2point drivers in phase 2)

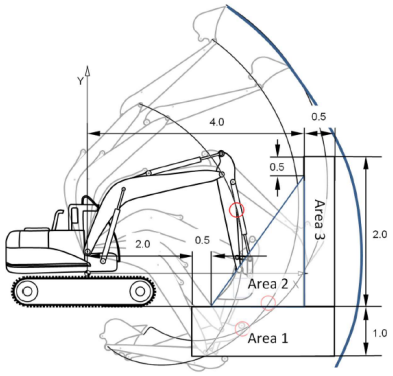
All dimension are obtained by measuring the drawings of the mechanisms in the figures and scaling them appropriately (so that the dimensions specified are fulfilled).

2 Excavator & Area to dig

For our group (number 3), the excavator to be used was number 1, which is a John Deer 60G model with a 0.35 m^2 bucket, and the area to be dug was also number 1, both pictured below:



(a) John Deer 60G excavator



(b) Area to be dug is identified as *Area 1* in the figure

Figure 1: Excavator model and digging area

2.1 Local Reference Frames

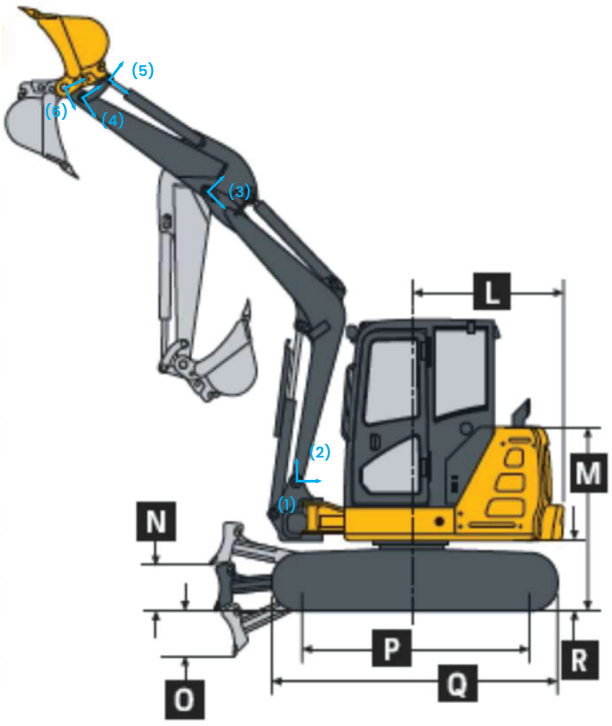


Figure 2: Local reference frame for each body.

3 Defining a digging path

Given the bucket capacity of $0.35m^2$, and $2.5m$ the length of the hole, the maximum cutting depth of each pass will be $\frac{0.35}{2.5} = 0.18\ m$.

To ensure the hole is nearly square at the corner, we'll want the bucket to enter the dirt in a vertical orientation, and exit, at the other end, in an horizontal position.

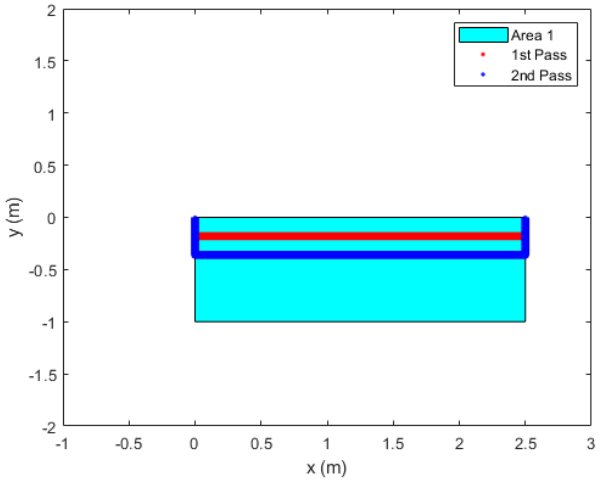


Figure 3: Idealized path for 2 passes of the excavator bucket.

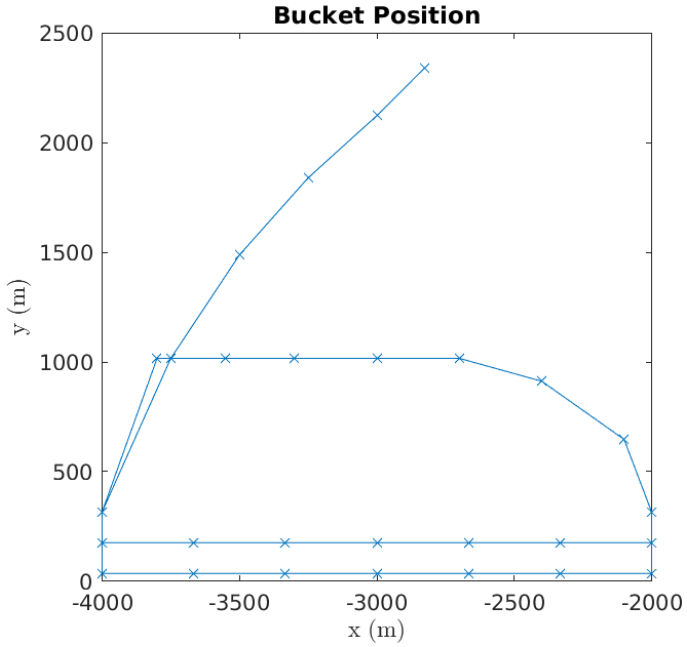


Figure 4: Bucket Positions

4 Guiding the bucket position and orientation with drivers directly applied to it

4.1 Input file for MUBOKAP

```
6 6 0 0 0 0 0 3 3 8
0 0 0
0 0 0
-1195.69 2339.01 0
-2653.95 2339.01 0
-2653.95 2619.35 6.0683
-2826.95 2339.01 0.1557
1 2 0 0 0 0
2 3 -1195.69 2339.01 0 0
3 4 -1458.26 0 0 0
3 6 -1631.26 0 0 0
4 5 0 280.34 0 0
5 6 -230 0 0 333.4
1 1 0
1 2 0
1 3 0
3 6 1 0 0.000 0.000 0.000 0.000 4 1
3 6 2 0 0.000 0.000 0.000 0.000 4 2
3 6 3 0 0.000 0.000 0.000 0.000 4 3
1 -100 0
2 -253.06 1672.45
3 -260.7 0
3 -640.43 0
3 0 0
4 0 0
5 0 0
6 -816.38 0
12 0.000001
0 0.1 32
```

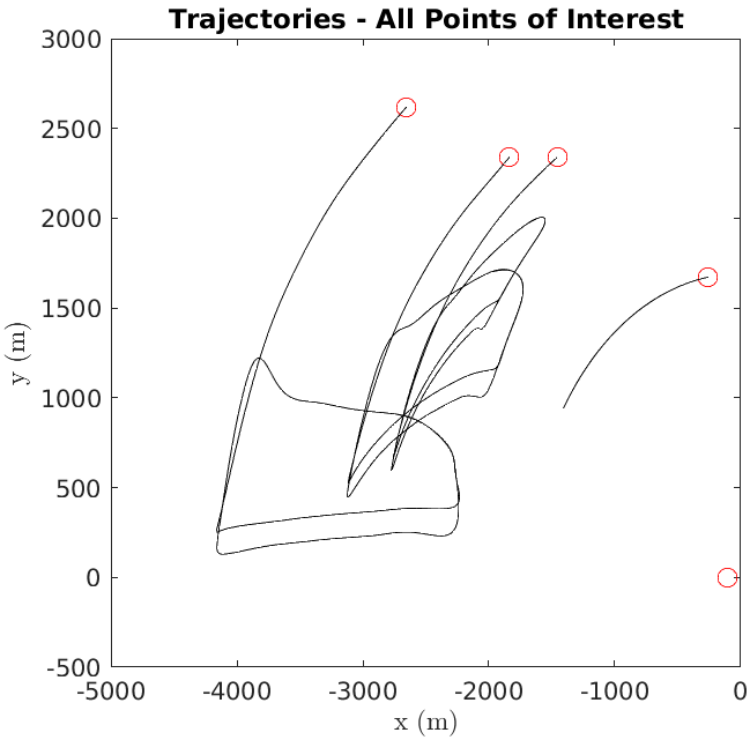
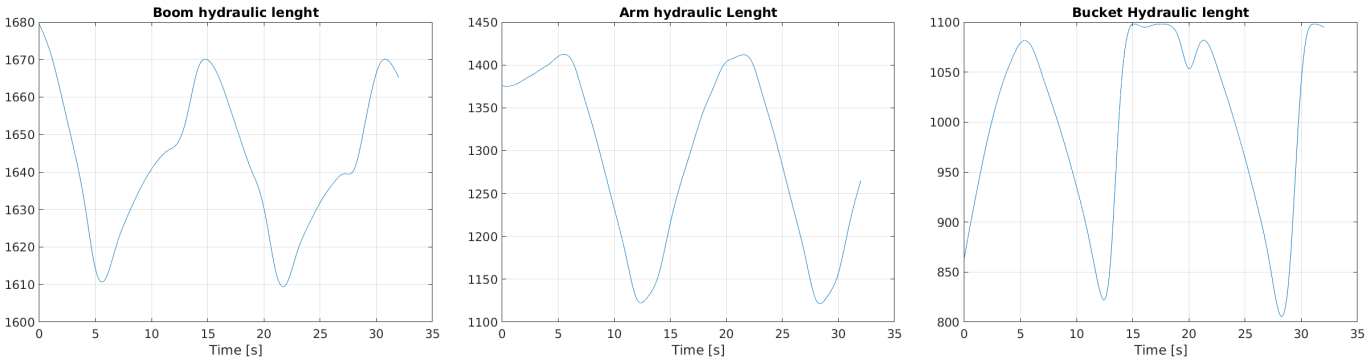


Figure 5: Trajectories when guiding the bucket with drivers directly applied to it.

4.2 Recording the position of the linear actuators in the excavator's arm while the bucket performs the desired path



(a) Boom actuator length. (b) Arm actuator length. (c) Arm actuator length.

Figure 6: Hydraulic actuator lengths when guiding the bucket with drivers directly applied to it.

5 Driving the bucket using point2point drivers with the information found in 4.2

5.1 New Driver Constraint Data

```
5 1 0 2 -100.000 0.000 -253.06 1672.45 4 4
5 2 0 3 -253.06 1672.45 -260.7 0.000 4 5
5 3 0 5 -640.43 0.000 0.000 0.000 4 6
```

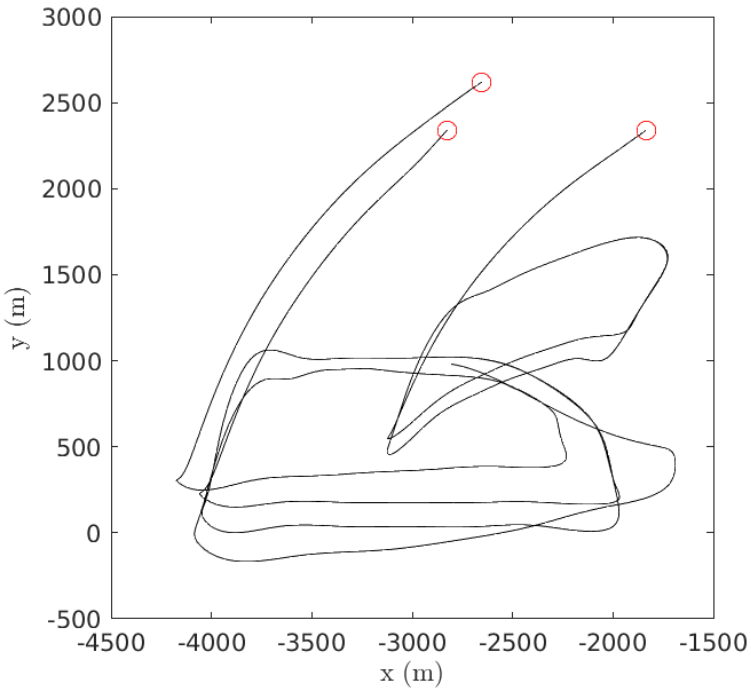
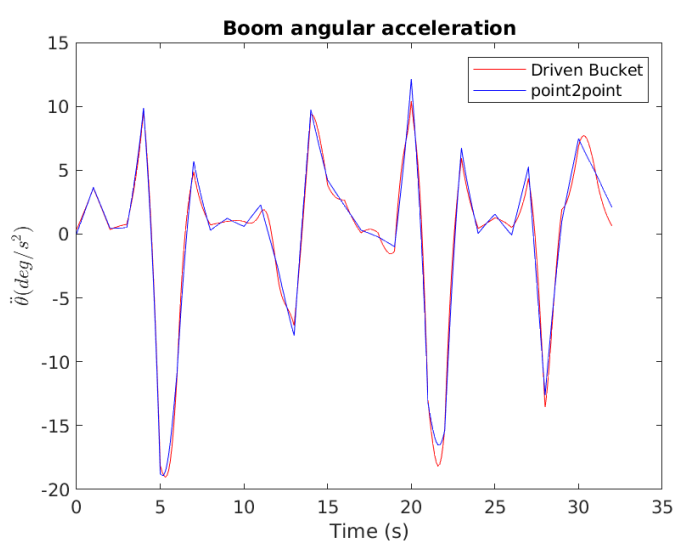
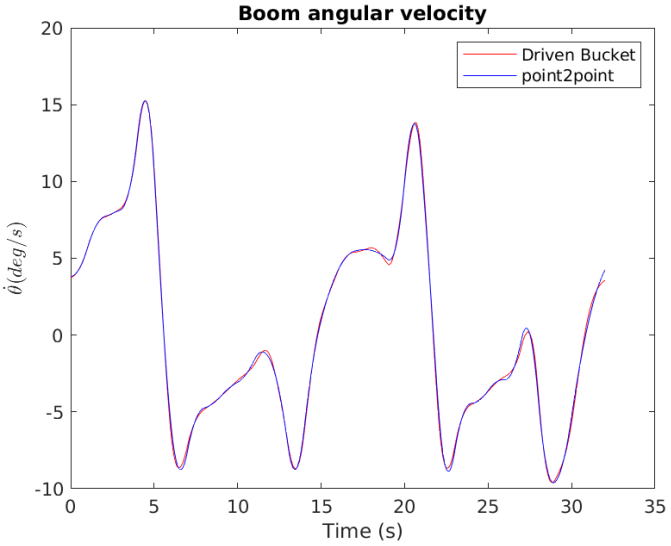


Figure 7: Trajectories when driving the hydraulic actuators with *point2point* drivers.

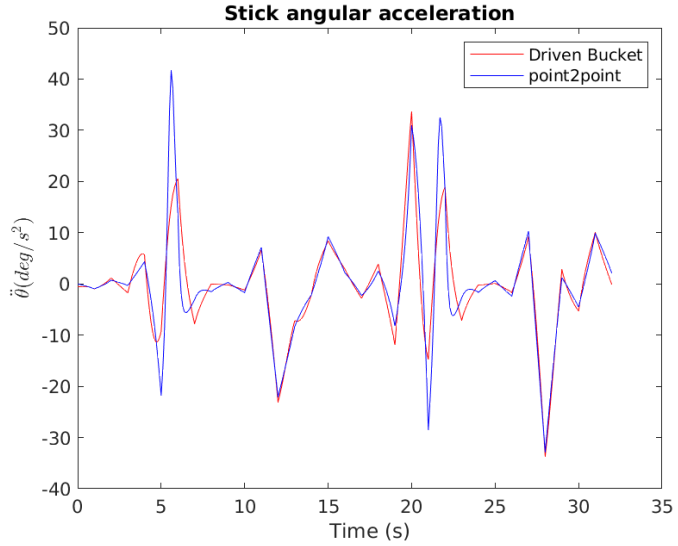
6 Comparing angular velocities and accelerations of the arm and boom using both types of drivers



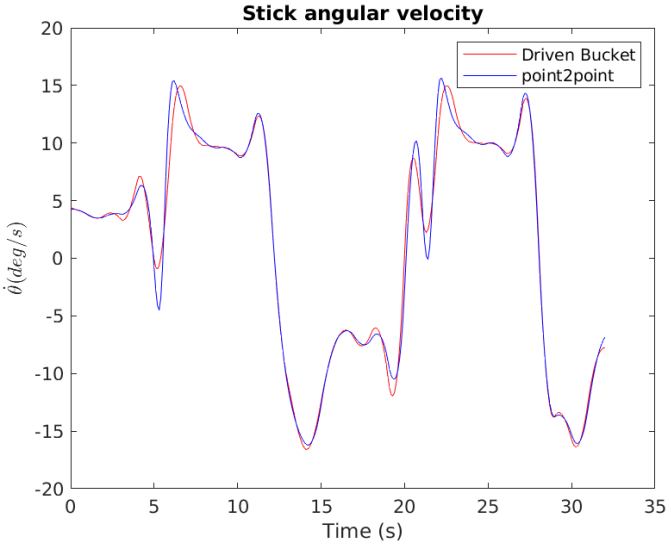
(a) Boom angular acceleration over time.



(b) Boom angular velocity over time.



(c) Stick angular acceleration over time.



(d) Stick angular velocity over time.

Figure 8: Comparing velocities and accelerations when using different methods to drive the bucket.