### Extending the Kinematic Description

left\_front\_wheel and right\_front\_wheel:

For the 2 wheels, I branched from the front\_axle\_frame and shifted the frame left and right by 28 mm on the Z axis of the front\_axle\_frame as measured from the center to the outer-most part of the wheel.

left\_hook and right\_hook:

For the 2 hooks, I branched from the lift\_attach\_frame. Both hooks were 15 mm left and right from the center and protruded forward by 7 mm from the lift\_attach\_frame. In addition, the Z axis for the hooks had to point up with X pointing forward. As a result, the point had to shift by d=15 or -15 on the Z axis of the lift\_attach\_frame depending on whether the hook was on the right or left. Theta = 0 because the X axis of the lift\_attach\_frame was already pointing forward. Then, it had to shift by r=7 on the X axis of the new frame, which was the same as the X axis of the lift\_attach\_frame. Finally, the Z axis had to rotate by alpha=-pi/2 around the X axis so that the Z axis was now pointing up.

### **Kinematics Calculations**

Results:

|  |  |
| --- | --- |
| Angle (degrees) | Calculated distance from front axle (mm) |
| -10 | 101.83 |
| 0 | 104.73 |
| 10 | 104.91 |
| 20 | 101.58 |
| 30 | 95.02 |
| 40 | 84.19 |

### **Inverse Kinematics: Pointing the Camera**

To find the angle at which the robot should be turning its body to face the object, I transposed the location of the object to the frame of the center of rotation. Then the angle was found by applying arctan to the x and y position of the object relative to the center of rotation. To find the angle at which the robot should turn its head to face the top of the object, I first found the new coordinates of the object relative to the base\_frame after Cozmo has turned to face the object. Then, the new coordinates of the object was transformed to the camera frame. The z and y coordinates of the object relative to the camera was then used to find the angle at which the head should turn to look at the top of the object. When 3 cubes were stacked to the height of 135mm placed at 150 mm front and 100 mm to the left at coordinate (150, 100) relative to the base\_frame of Cozmo, the Cozmo was able to look towards the object. The accuracy was not great but close enough in the general direction, as Cozmo was looking slightly above and to the left of the top of the cubes.

