Electronics Club

IIT KANPUR

Flexe Glove

Summer Project 2025

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Contents

1 Timeline

- Ubuntu installation and setup, git setup.
- **Task 1:** Made an ASCII art in Linux terminal.
- **Fusion 360:** Learnt about joints by following a tutorial.
- **Task 2:** Made a model of a car (imported tyres from GrabCAD).
- Learnt Turtlesim.
- **Task 3:** Made a spiral using Turtlesim (ROS2).
- In Fusion, learnt to convert Fusion files to URDF and STL files using ACDC4ROBOT add-in in Fusion 360.
- Made launch '.py' files.
- Imported a model of a hand from the internet and converted it similarly.
- Loaded the hand model into RViz.
- Made changes in URDF so that yaw, pitch, and roll rotation could be changed using Joint State Publisher.
- Integrated IMU sensor data to control rotations.

2 Objective

- To make a 3D fully controlled hand model that can translate voltage signals to hand movements.
- Use Flexe Glove to detect gestures and translate sign language to English.
- Use audio mixing software to add effects to a song in real time using signals from Flexe Glove.

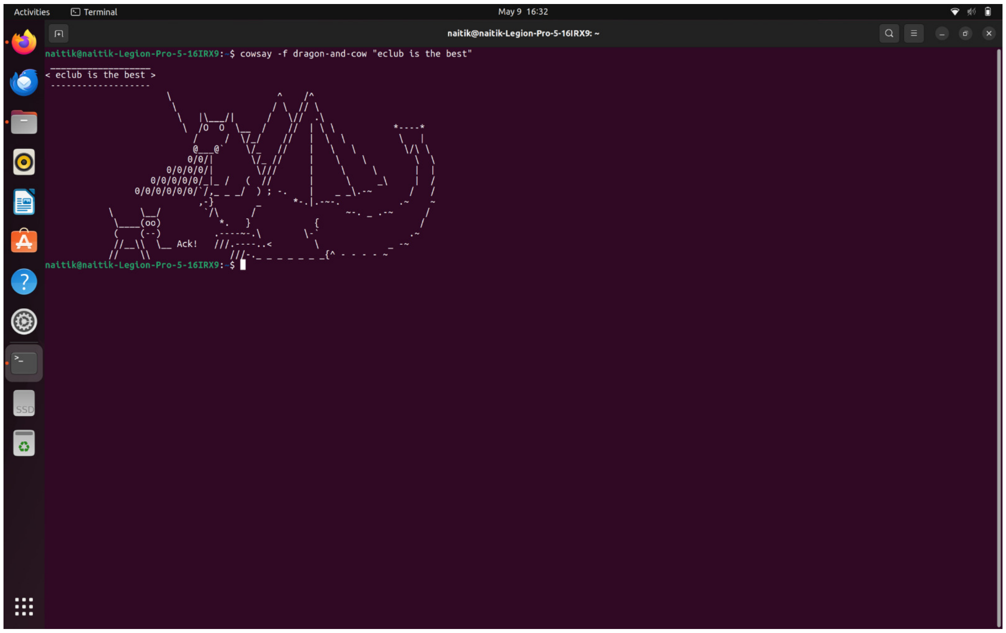
3 Introduction to Linux and Ubuntu Setup

3.1 Assignment 0

We installed packages like `cowsay`, `cmatrix`, `nyancat`, etc., to get started with Linux commands.

3.1.1 Installing `cowsay`

```
$ sudo apt install cowsay
$ cowsay "hello world"
$ cowsay -l
$ cowsay -f dragon "hello world"
```



```
naitik@naitik-Legion-Pro-5-16IRX9:~$ cowsay -f dragon-and-cow "eclub is the best"
 ___________________
< eclub is the best >
 -------------------
                       \                    ^    /^
                        \                  / \  // \
                         \   |\___/|      /   \//  .\
                          \  /O  O  \__  /    //  | \ \           *----*
                            /     /  \/_/    //   |  \  \          \   |
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                           0/0/|       \/_ //     |    \    \         \  \
                       0/0/0/0/|        \///      |     \     \       |  |
                    0/0/0/0/0/_|_ /   (  //       |      \     _\     |  /
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              //__\\  \__ Ack!   ///.----..<        \             _ -~
             //    \\               ///-._ _ _ _ _ _ _{^ - - - - ~
naitik@naitik-Legion-Pro-5-16IRX9:~$
```
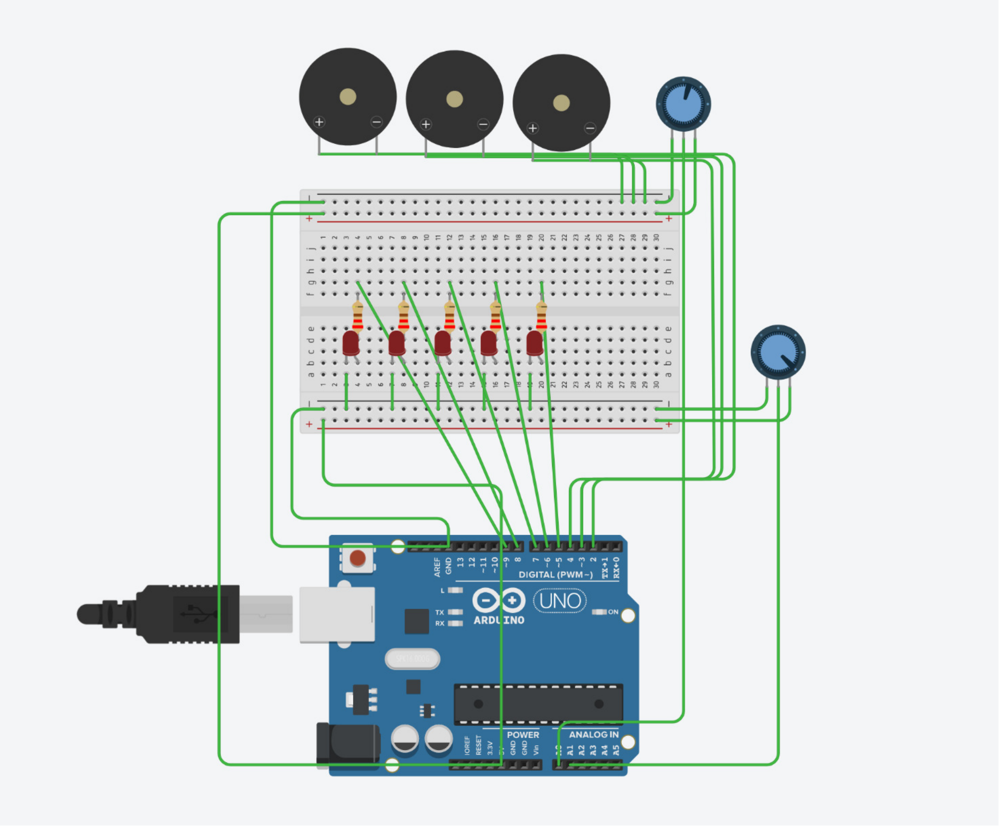

3.2 Second Assignment 0: TinkerCAD Simulation

- Pot1 controls 3 buzzers:
  - 0–341: Buzzer 1
  - 342–682: Buzzer 2
  - 683–1023: Buzzer 3
- Pot2 controls LED delay

Connections:

- Pot1 → A0, Pot2 → A1
- Buzzers: D2, D3, D4
- LEDs: D5 to D9 (through 220Ω resistors)



3.2.1 Arduino Code

```
int leds[] = {5, 6, 7, 8, 9};
int numLeds = 5;
float t;

void setup() {
  pinMode(4, OUTPUT);
  pinMode(2, OUTPUT);
  pinMode(3, OUTPUT);
  Serial.begin(9600);
  for (int i = 0; i < numLeds; i++) {
    pinMode(leds[i], OUTPUT);
  }
}

void loop() {
  int POT1 = analogRead(A0);
  float POT2 = analogRead(A1);
  t = (POT2 + 113.666667)/1.1366667;
  Serial.println(t);

  if (POT1 <= 341) {
    digitalWrite(4, HIGH); digitalWrite(2, LOW); digitalWrite(3, LOW);
  }
  else if (POT1 <= 682) {
    digitalWrite(4, LOW); digitalWrite(2, HIGH); digitalWrite(3, LOW);
  }
  else {
    digitalWrite(4, LOW); digitalWrite(2, LOW); digitalWrite(3, HIGH);
  }

  for (int i = 0; i < numLeds; i++) {
    digitalWrite(leds[i], HIGH);
    delay(t);
    digitalWrite(leds[i], LOW);
  }
}
```

4 Introduction to Fusion 360

4.1 Types of Joints

1. Rigid: 0 DOF
2. Revolute: 1 rotational DOF
3. Slider: 1 translational DOF
4. Cylindrical: 1T + 1R DOF
5. Pin-slot: 1T + 1R DOF (different axes)
6. Planar: 2T + 1R DOF
7. Ball: 3 rotational DOF

4.2 Assignment 1: Car Model

Created a car model in Fusion 360. Used GrabCAD tyres. Applied revolute joints for wheel movement.

4.3 ACDC4ROBOT Add-in

ACDC4ROBOT converts Fusion 360 models to URDF, SDFormat, MJCF for use in robotics simulation like ROS.

5 Robot Operating System (ROS2)

5.1 Overview

ROS2 offers a distributed system using nodes for various robotic functions. It makes robotics software modular and scalable.

5.2 ROS2 Workspace File Structure

```
my_ros2_ws/
 src/
    my_package/
        setup.py
        package.xml
        resource/
        launch/
        setup.cfg
        my_package/
        test/
 install/
 build/
 log/
```

5.3 Creating a Package and Node

```
$ mkdir my_ros2_ws && cd my_ros2_ws
$ mkdir src
$ cd src
$ ros2 pkg create --build-type ament_python my_package --dependencies
   rclpy
$ cd my_package/my_package
$ touch node_name.py
$ chmod +x node_name.py
```

In setup.py:

```
entry_points={
    'console_scripts': [
        'node_name = my_package.node_name:main',
    ],
}
```

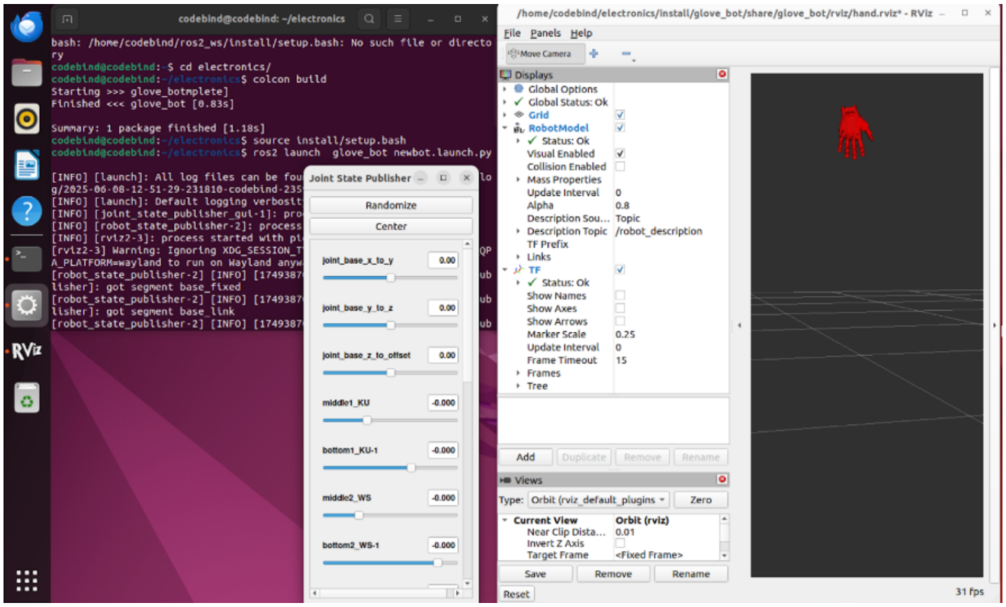
5.4 Assignment 2: Spiral Motion Using Turtlesim

```
import rclpy
from rclpy.node import Node
from geometry_msgs.msg import Twist

class CircleTurtle(Node):
    def __init__(self):
        super().__init__('circle_turtle')
        self.publisher_ = self.create_publisher(Twist, 'turtle1/cmd_vel',
           10)
        timer_period = 0.1
        self.timer = self.create_timer(timer_period, self.move_in_circle)
    def move_in_circle(self):
        msg = Twist()
        msg.linear.x = 2.0
        msg.angular.z = 1.0
        self.publisher_.publish(msg)
        self.get_logger().info('Publishing: Linear x = %.2f, Angular z =
            %.2f' % (msg.linear.x, msg.angular.z))

def main(args=None):
    rclpy.init(args=args)
    node = CircleTurtle()
    rclpy.spin(node)
    node.destroy_node()
    rclpy.shutdown()

if __name__ == '__main__':
    main()
```

6 Importing the Hand Model

Imported a hand model using ACDC4ROBOT, generated ‘.stl‘ and ‘.urdf‘ files, and launched in RViz.

```
$ colcon build
$ source install/setup.bash
$ ros2 launch my_package newbot.launch.py
```



```
bash: /home/codebind/ros2_ws/install/setup.bash: No such file or directo
ry
codebind@codebind:~$ cd electronics/
codebind@codebind:~/electronics$ colcon build
Starting >>> glove_botmplete]
Finished <<< glove_bot [0.83s]

Summary: 1 package finished [1.18s]
codebind@codebind:~/electronics$ source install/setup.bash
codebind@codebind:~/electronics$ ros2 launch  glove_bot newbot.launch.py

[INFO] [launch]: All log files can be fou                            lo
g/2025-06-08-12-51-29-231810-codebind-235
[INFO] [launch]: Default logging verbosit
[INFO] [joint_state_publisher_gui-1]: pro
[INFO] [robot_state_publisher-2]: process
[INFO] [rviz2-3]: process started with pi
[rviz2-3] Warning: Ignoring XDG_SESSION_T                            QP
A_PLATFORM=wayland to run on Wayland anyw
[robot_state_publisher-2] [INFO] [1749387                            ub
lisher]: got segment base_fixed
[robot_state_publisher-2] [INFO] [1749387                            ub
lisher]: got segment base_link
[robot_state_publisher-2] [INFO] [1749387                            ub
```

joint_base_x_to_y 0.00
joint_base_y_to_z 0.00
joint_base_z_to_offset 0.00
middle1_KU -0.000
bottom1_KU-1 -0.000
middle2_WS -0.000
bottom2_WS-1 -0.000

- Global Options
- ✓ Global Status: Ok
- Grid ☑
- RobotModel ☑
  - ✓ Status: Ok
  - Visual Enabled ☑
  - Collision Enabled □
  - Mass Properties
  - Update Interval 0
  - Alpha 0.8
  - Description Sou... Topic
  - Description Topic /robot_description
  - TF Prefix
  - Links
- TF ☑
  - ✓ Status: Ok
  - Show Names □
  - Show Axes □
  - Show Arrows □
  - Marker Scale 0.25
  - Update Interval 0
  - Frame Timeout 15
  - Frames
  - Tree

Type: Orbit (rviz_default_plugins

- Current View Orbit (rviz)
  - Near Clip Dista... 0.01
  - Invert Z Axis □
  - Target Frame <Fixed Frame>

7 Making new joints in URDF

Created additional links and joints for 3-axis control using URDF.

Listing 1: Added joints in URDF for 3-axis rotation

```
<joint name="base_joint_fixed" type="fixed">
    <parent link="base_fixed"/>
    <child link="base_x"/>
    <origin xyz="0 0 0" rpy="0 0 0"/>
</joint>

<joint name="base_joint_x" type="revolute">
    <parent link="base_x"/>
    <child link="base_y"/>
    <origin xyz="0 0 0" rpy="0 0 0"/>
    <axis xyz="1 0 0"/>
    <limit lower="-3.14" upper="3.14" effort="100000000" velocity="
       10000000"/>
</joint>

<joint name="base_joint_y" type="revolute">
    <parent link="base_y"/>
    <child link="base_z"/>
    <origin xyz="0 0 0" rpy="0 0 0"/>
    <axis xyz="0 1 0"/>
    <limit lower="-3.14" upper="3.14" effort="10000000" velocity="10000000
       "/>
</joint>

<joint name="base_joint_z" type="revolute">
    <parent link="base_z"/>
    <child link="base_link_offset"/>
    <origin xyz="0 0 0" rpy="0 0 0"/>
    <axis xyz="0 0 1"/>
    <limit lower="-3.14" upper="3.14" effort="10000000" velocity="10000000
       "/>
</joint>

<joint name="base_link_offset_joint" type="fixed">
    <parent link="base_link_offset"/>
    <child link="base_link"/>
    <origin xyz="0.25921036 0.01309030 0.99916261" rpy="0 0 0"/>
</joint>
```

8 Moving the model using Arduino

8.1 Using a potentiometer

We attempt to control one joint using a potentiometer. The node for the following is given:

```
import rclpy
from rclpy.node import Node
from sensor_msgs.msg import JointState
import serial
import time

class JointPublisherFromSerial(Node):
    def __init__(self):
        super().__init__('joint_state_from_serial')

        # customize this based on your URDF joint name + limits
        self.joint_name = 'middle2_WS'
        self.min_angle = -0.25      # min joint angle in radians
        self.max_angle =  0.7   # max joint angle in radians

        # connect to Arduino (make sure Serial Monitor is CLOSED)
        try:
            self.ser = serial.Serial('/dev/ttyUSB0', 9600, timeout=1)
            time.sleep(2)  # wait for Arduino to reset
        except serial.SerialException:
            self.get_logger().error("Could not open /dev/ttyUSB0. Is it in use?")
            exit(1)

        self.joint_pub = self.create_publisher(JointState, '/joint_states', 10)
        self.timer = self.create_timer(0.05, self.timer_callback)

        self.get_logger().info("JointPublisherFromSerial Node Started")

    def timer_callback(self):
        if self.ser.in_waiting > 0:
            try:
                line = self.ser.readline().decode('utf-8').strip()
                pot_val = int(line)

                mapped_angle = self.map_range(pot_val, 0, 1023, self.min_angle, self.max_angle)

                # full joint list
                self.joint_names = [
                    'middle1_KU', 'bottom1_KU-1',
                    'middle2_WS', 'bottom2_WS-1',
                    'middle3_SR', 'bottom3_SR-1',
                    'middle4_SE', 'bottom4_SE-1',
                    'middle5_MA', 'bottom5_MA-1',
                    'base_link_MA-2', 'base_link_SE-2',
                    'base_link_SR-2', 'base_link_WS-2',
                    'base_link_KU-2'
                ]
                positions = [0.0] * len(self.joint_names)

                # just change one joint's value
                idx = self.joint_names.index('middle3_SR')
                positions[idx] = mapped_angle

                msg = JointState()
                msg.header.stamp = self.get_clock().now().to_msg()
                msg.name = self.joint_names
                msg.position = positions

                self.joint_pub.publish(msg)
                self.get_logger().info(f"Updated middle3_SR: {mapped_angle
                    :.2f} rad")

            except Exception as e:
                self.get_logger().warn(f"Serial read error: {e}")


    def map_range(self, x, in_min, in_max, out_min, out_max):
        return (x - in_min) * (out_max - out_min) / (in_max - in_min) +
           out_min

def main(args=None):
    rclpy.init(args=args)
    node = JointPublisherFromSerial()
    rclpy.spin(node)
    node.destroy_node()
    rclpy.shutdown()

if __name__ == '__main__':
    main()
```

8.2 Using an IMU sensor

Next, using similar logic we do this for changing the orientation of hand using an IMU sensor. For that the ros2 node is given:

```
import math
import rclpy
import numpy as np
from rclpy.node import Node
from sensor_msgs.msg import Imu
from geometry_msgs.msg import TransformStamped
import tf2_ros
from tf_transformations import quaternion_multiply, quaternion_about_axis
from rclpy.parameter import Parameter

class GyroHandPosePublisher(Node):
    def __init__(self):
        super().__init__('gyro_hand_pose_publisher')
        self.get_logger().info("Gyro Hand Pose Publisher Node:
           Initializing...")

        self.tf_broadcaster = tf2_ros.TransformBroadcaster(self)

        self.use_sim_time = self.get_parameter('use_sim_time').value
        self.get_logger().info(f"Gyro Hand Pose Publisher Node:
           use_sim_time: {self.use_sim_time}")
        self.declare_parameter('hand_frame_id', 'base_link')
        self.hand_frame_id = self.get_parameter('hand_frame_id').value
        self.get_logger().info(f"Gyro Hand Pose Publisher Node: Hand frame ID: {self.hand_frame_id}")

        self.current_orientation = np.array([0.0, 0.0, 0.0, 1.0])
        self.last_imu_timestamp = None

        self.imu_subscriber = self.create_subscription(
            Imu,
            '/imu/data_raw',
            self.imu_callback,
            10
        )
        self.get_logger().info(f'Gyro Hand Pose Publisher Node: Subscribing to {self.imu_subscriber.topic_name} topic.')

    def imu_callback(self, msg: Imu):
        current_timestamp = msg.header.stamp

        delta_t = 0.0
        if self.last_imu_timestamp is not None:
            last_sec = self.last_imu_timestamp.sec + self.last_imu_timestamp.nanosec / 1e9
            current_sec = current_timestamp.sec + current_timestamp.nanosec / 1e9
            delta_t = current_sec - last_sec

            if delta_t < 0:
                self.get_logger().warn(
                    f"Negative delta_t ({delta_t:.4f}s) detected. "
                    "Resetting orientation and last timestamp to prevent instability."
                )
                self.current_orientation = np.array([0.0, 0.0, 0.0, 1.0])
                self.last_imu_timestamp = current_timestamp
                return

        self.last_imu_timestamp = current_timestamp

        wx = msg.angular_velocity.x
        wy = msg.angular_velocity.y
        wz = msg.angular_velocity.z

        if delta_t > 0:
            omega_magnitude = math.sqrt(wx**2 + wy**2 + wz**2)

            if omega_magnitude > 1e-6:
                angle_increment = omega_magnitude * delta_t

                axis_x = wx / omega_magnitude
                axis_y = wy / omega_magnitude
                axis_z = wz / omega_magnitude
                delta_q = quaternion_about_axis(angle_increment, [axis_x,
                   axis_y, axis_z])
                self.current_orientation = quaternion_multiply(self.
                   current_orientation, delta_q)
                self.current_orientation = self.current_orientation / np.
                   linalg.norm(self.current_orientation)

        transform_stamped = TransformStamped()
        transform_stamped.header.stamp = (
            msg.header.stamp if self.use_sim_time else self.get_clock().
               now().to_msg()
        )
        transform_stamped.header.frame_id = 'world'
        transform_stamped.child_frame_id = self.hand_frame_id

        transform_stamped.transform.rotation.x = self.current_orientation
           [0]
        transform_stamped.transform.rotation.y = self.current_orientation
           [1]
        transform_stamped.transform.rotation.z = self.current_orientation
           [2]
        transform_stamped.transform.rotation.w = self.current_orientation
           [3]

        transform_stamped.transform.translation.x = 0.0
        transform_stamped.transform.translation.y = 0.0
        transform_stamped.transform.translation.z = 0.0

        self.tf_broadcaster.sendTransform(transform_stamped)

def main(args=None):
    rclpy.init(args=args)
    gyro_hand_pose_publisher = GyroHandPosePublisher()
    gyro_hand_pose_publisher.get_logger().info("Gyro Hand Pose Publisher
       Node: Entering rclpy.spin()...")
    try:
        rclpy.spin(gyro_hand_pose_publisher)
    except KeyboardInterrupt:
        gyro_hand_pose_publisher.get_logger().info(
            "Gyro Hand Pose Publisher Node: Shutting down cleanly via
               KeyboardInterrupt."
        )
    finally:
        gyro_hand_pose_publisher.destroy_node()
        rclpy.shutdown()

if __name__ == '__main__':
    main()
```