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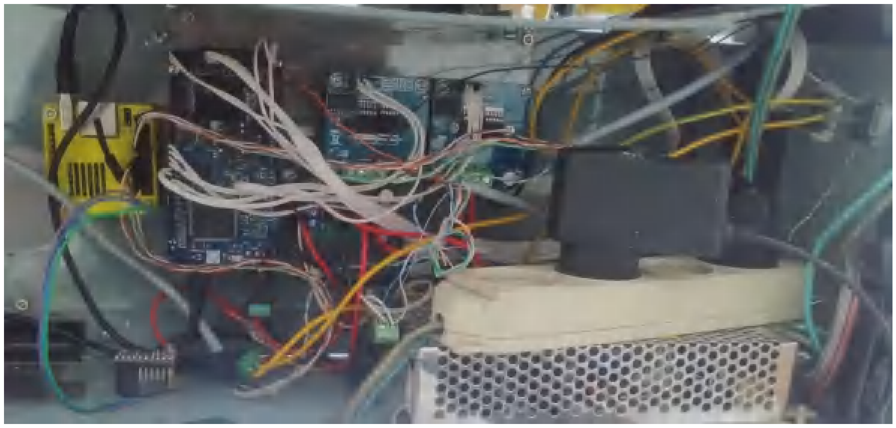
LAMPIRAN

Lampiran 1 Tampak depan robot kursi beroda

Lampiran 2 Tampak belakang robot kursi beroda

Lampiran 3 Rangkaian elektronik



Lampiran 4 Program Orange Pi (master)

```
import OPi.GPIO as GPIO
import time
import serial

# Inisialisasi GPIO
GPIO.setmode(GPIO.BOARD)

# Inisialisasi serial untuk komunikasi dengan Arduino
ser = serial.Serial('/dev/ttyUSB0', 115200, timeout=1)
time.sleep(2)  # Tunggu beberapa saat untuk memastikan koneksi serial siap

# Definisikan pin untuk setiap sensor
sensors = {
    "Sensor 1": {"trigger": "PA12", "echo": "PA11"},
    "Sensor 2": {"trigger": "PL0", "echo": "PL1"},
    "Sensor 3": {"trigger": "PA19", "echo": "PA18"},
    "Sensor 4": {"trigger": "PA15", "echo": "PA16"},
    "Sensor 5": {"trigger": "PA14", "echo": "PA13"}
}

# Definisikan pin untuk setiap tombol
buttons = {
    "Button 1": "PA3",
    "Button 2": "PA18",
    "Button 3": "PA19",
    "Button 4": "PA2"
}

# Konfigurasi pin GPIO untuk sensor dan tombol
for sensor, pins in sensors.items():
    GPIO.setup(pins["trigger"], GPIO.OUT)
    GPIO.setup(pins["echo"], GPIO.IN)
```

```
for button, pin in buttons.items():
    GPIO.setup(pin, GPIO.IN, pull_up_down=GPIO.PUD_UP)

def distance(sensor):
    # Kirim sinyal trigger
    GPIO.output(sensors[sensor]["trigger"], GPIO.HIGH)
    time.sleep(0.00001)
    GPIO.output(sensors[sensor]["trigger"], GPIO.LOW)

    # Waktu awal dan akhir
    pulse_start = time.time()
    pulse_end = time.time()

    # Tanggapi sinyal echo
    while GPIO.input(sensors[sensor]["echo"]) == GPIO.LOW:
        pulse_start = time.time()

    while GPIO.input(sensors[sensor]["echo"]) == GPIO.HIGH:
        pulse_end = time.time()

    # Hitung waktu perjalanan suara
    pulse_duration = pulse_end - pulse_start

    # Hitung jarak
    distance = pulse_duration * 17150
    distance = round(distance, 2)

    return distance

def read_serial():
    if ser.in_waiting > 0:
        return ser.readline().decode('utf-8').strip()
    return None

try:
    robot_state = "diam"

    while True:
        # Membaca jarak dari semua sensor
        distances = {sensor: distance(sensor) for sensor in sensors}

        for sensor, dist in distances.items():
            print(f"{sensor}: {dist} cm")

        # Cek status tombol
        button_pressed = None
        for button, pin in buttons.items():
            if GPIO.input(pin) == GPIO.LOW:
                button_pressed = button
```

```
                break

        if button_pressed:
            if button_pressed == "Button 1":
                if distances["Sensor 1"] >= 60 and distances["Sensor 2"] >= 60:
                    print("Maju")
                    ser.write(b'1')  # Kirim kode 1 ke Arduino
                else:
                    print("Kondisi tidak sesuai")
            elif button_pressed == "Button 2":
                if distances["Sensor 5"] >= 60:
                    print("Mundur")
                    ser.write(b'2')  # Kirim kode 2 ke Arduino
                else:
                    print("Kondisi tidak sesuai")
            else:
                print("Kondisi tidak sesuai")

        # Baca data dari Arduino
        arduino_code = read_serial()
        if arduino_code == '1':
            robot_state = "maju"
        elif arduino_code is None:
            robot_state = "diam"

        # Tindakan berdasarkan kondisi robot
        if robot_state == "maju":
            print("Robot maju")
            if distances["Sensor 1"] < 60 or distances["Sensor 2"] < 60:
                ser.write(b'3')  # Kirim kode 3 ke Arduino

        time.sleep(1)

except KeyboardInterrupt:
    GPIO.cleanup()
    ser.close()
```

Lampiran 5 Program Arduino mode rintangan

```
#include <Arduino.h>
#include <Adafruit_BNO08x.h>
#include <Wire.h>

#define TURN_LIMIT 150
#define PWM_FORWARD 30
#define PWM_TURN 30
#define TURN_TIME 1500
#define STRAIGHT_TIME 1000
#define FORWARD2_TIME 2000
#define TURN_LEFT2_TIME 1300
#define STRAIGHT2_TIME 1000
#define TURN_RIGHT2_TIME 1800
#define STOP_TIME 1000

#define BNO08X_CS 10
#define BNO08X_INT 9
#define BNO08X_RESET -1

#define M1_RPWM 2
#define M1_LPWM 3
#define M1_L_EN 4
#define M1_R_EN 5

#define M2_RPWM 6
#define M2_LPWM 7
#define M2_L_EN 8
#define M2_R_EN 9

enum class State { FORWARD, TURN_RIGHT, STRAIGHT, TURN_LEFT, FORWARD2,
TURN_LEFT2, STRAIGHT2, TURN_RIGHT2, END };
State state = State::FORWARD;
unsigned long stateMillis;
unsigned long previousPingMillis[5] = {0, 0, 0, 0, 0}; // untuk setiap sensor
const long pingInterval = 50;  // interval di mana Anda ingin melakukan ping (50 milidetik
dalam kasus ini)

struct euler_t {
  float yaw;
  float pitch;
  float roll;
} ypr, offset;

Adafruit_BNO08x  bno08x(BNO08X_RESET);
sh2_SensorValue_t sensorValue;
sh2_SensorId_t reportType = SH2_ARVR_STABILIZED_RV;
long reportIntervalUs = 5000;
bool calibrated = false;
```

```
float pwm_kiri = 35.0, pwm_kanan = 35.0;
float target_yaw = 0.0;
float KP = 10.0, KI = 3.0, KD = 4.0;
float integral_error = 0.0, previous_error = 0.0;
float dt = 0.1; // Waktu antara sampel dalam detik. Ganti dengan waktu aktual antara
loop() jika diperlukan

void setReports(sh2_SensorId_t reportType, long report_interval) {
  if (! bno08x.enableReport(reportType, report_interval)) {
    Serial.println("Could not enable report");
  }
}
void setupMotor();
float PID_Controller(float target, float actual);
void motor(float pwmki, float pwmka);
void quaternionToEuler(float qr, float qi, float qj, float qk, euler_t* ypr, bool degrees =
false) {
    float sqr = sq(qr);
    float sqi = sq(qi);
    float sqj = sq(qj);
    float sqk = sq(qk);

    ypr->yaw = atan2(2.0 * (qi * qj + qk * qr), (sqi - sqj - sqk + sqr));
    ypr->pitch = asin(-2.0 * (qi * qk - qj * qr) / (sqi + sqj + sqk + sqr));
    ypr->roll = atan2(2.0 * (qj * qk + qi * qr), (-sqi - sqj + sqk + sqr));

    if (degrees) {
      ypr->yaw *= RAD_TO_DEG;
      ypr->pitch *= RAD_TO_DEG;
      ypr->roll *= RAD_TO_DEG;
    }
    if (ypr->yaw < 0) ypr->yaw += 360;
    if (ypr->pitch < 0) ypr->pitch += 360;
    if (ypr->roll < 0) ypr->roll += 360;
}
void quaternionToEulerRV(sh2_RotationVectorWAcc_t* rotational_vector, euler_t* ypr,
bool degrees = false) {
    quaternionToEuler(rotational_vector->real, rotational_vector->i, rotational_vector->j,
rotational_vector->k, ypr, degrees);
}
void setupMotor() {
  // Setup Motor Control Pins
  int motorPins[] = {2, 3, 4, 5, 6, 7, 8, 9};
  for (int i = 0; i < 8; i++) {
    pinMode(motorPins[i], OUTPUT);
  }
  // Enable motor
  digitalWrite(M1_L_EN, HIGH);
  digitalWrite(M1_R_EN, HIGH);
  digitalWrite(M2_L_EN, HIGH);
```

```
  digitalWrite(M2_R_EN, HIGH);
}

void motor(float pwmki, float pwmka) {
  pwmki = constrain(pwmki, -255, 255);
  pwmka = constrain(pwmka, -255, 255);
  if (pwmki <= -1 && pwmki > -255) {
    analogWrite(M2_RPWM, (int)(-pwmki));
    analogWrite(M2_LPWM, 0);
  }
  if (pwmki >= 1 && pwmki < 255) {
    analogWrite(M2_RPWM, 0);
    analogWrite(M2_LPWM, (int)pwmki);
  }
  if (pwmka >= 1 && pwmka < 255) {
    analogWrite(M1_RPWM, (int)pwmka);
    analogWrite(M1_LPWM, 0);
  }
  if (pwmka <= -1 && pwmka > -255) {
    analogWrite(M1_RPWM, 0);
    analogWrite(M1_LPWM, (int)(-pwmka));
  }
  if (pwmka > -1 && pwmka < 1) {
    analogWrite(M1_RPWM, 0);
    analogWrite(M1_LPWM, 0);
  }
  if (pwmki > -1 && pwmki < 1) {
    analogWrite(M2_RPWM, 0);
    analogWrite(M2_LPWM, 0);
  }
}
float PID_Controller(float target, float actual) {
  float error = target - actual;
  integral_error += error * dt;
  float derivative_error = (error - previous_error) / dt;
  previous_error = error;

  return KP * error + KI * integral_error + KD * derivative_error;
}

void setup() {
  Serial.begin(115200);
  if (!bno08x.begin_I2C()) {
    Serial.println("Failed to find BNO08x chip");
    while (1) { delay(10); }
  }
  setReports(reportType, reportIntervalUs);

  setupMotor();
}
```

```
void loop() {
  if (Serial.available() > 0) {
    char instruksi = Serial.read();
    if (instruksi == '1') {
      Serial.write('3'); // Kirim kode 3 ke Orange Pi
        while (true) {
          if (bno08x.wasReset()) {
            setReports(reportType, reportIntervalUs);
          }

          if (bno08x.getSensorEvent(&sensorValue)) {
            if (sensorValue.sensorId == reportType) {
              quaternionToEulerRV(&sensorValue.un.arvrStabilizedRV, &ypr, true);
              if (!calibrated) {
                offset = ypr;  // save the first reading as the offset
                calibrated = true;
              }
              ypr.yaw -= offset.yaw;
              ypr.pitch -= offset.pitch;
              ypr.roll -= offset.roll;

              // Normalize to 0-360
              if (ypr.yaw < 0) ypr.yaw += 360;
              if (ypr.pitch < 0) ypr.pitch += 360;
              if (ypr.roll < 0) ypr.roll += 360;

              Serial.println();
              Serial.print("Yaw: "); Serial.print(ypr.yaw); Serial.print("\t");

              switch (state) {
                case State::FORWARD:
                if (Serial.available() > 0 && Serial.read() == '3') {
                    state = State::TURN_RIGHT;
                    stateMillis = millis();
                    Serial.println("Obstacle detected. Turning right.");
                    motor(30, -30);
                  } else {
                    Serial.print("Moving forward.");
                    if (calibrated) {
                      float error = target_yaw - ypr.yaw;
                      float adjust = PID_Controller(target_yaw, ypr.yaw);

                      if (ypr.yaw >= 0.5 && ypr.yaw <= 180) {
                        pwm_kiri = constrain(pwm_kiri - adjust, 30.0, 55.0);
                        pwm_kanan = constrain(pwm_kanan + adjust, 30.0, 55.0);
                      } else if (ypr.yaw > 180 && ypr.yaw <= 359.9) {
                        pwm_kiri = constrain(pwm_kiri + adjust, 30.0, 55.0);
                        pwm_kanan = constrain(pwm_kanan - adjust, 30.0, 55.0);
                      }
                      motor(pwm_kiri, pwm_kanan);
```

```
    Serial.print("\tPWM Kiri: "); Serial.print(pwm_kiri);
    Serial.print("\tPWM Kanan: "); Serial.println(pwm_kanan);
   }
  }
  break;

 case State::TURN_RIGHT:
  if (millis() - stateMillis >= TURN_TIME) {
   state = State::STRAIGHT;
   stateMillis = millis();
   Serial.println("Turn right completed. Moving straight.");
   motor(30, 40);
  } else {
   Serial.print("Turning right.");
   motor(30, -30);
  }
  break;

 case State::STRAIGHT:
  if (millis() - stateMillis >= STRAIGHT_TIME) {
   state = State::TURN_LEFT;
   stateMillis = millis();
   Serial.println("Straight completed. Turning left.");
   motor(0, 0);
  } else {
   Serial.print("Moving straight.");
   motor(30, 35);
  }
  break;

 case State::TURN_LEFT:
  if (millis() - stateMillis >= TURN_TIME) {
   state = State::FORWARD2;
   stateMillis = millis();
   Serial.println("Turn left completed. Moving forward2.");
   motor(30, 35);
  } else {
   Serial.print("Turning left.");
   motor(-30, 30);
  }
  break;

 case State::FORWARD2:
  if (millis() - stateMillis >= FORWARD2_TIME) {
   state = State::TURN_LEFT2;
   stateMillis = millis();
   Serial.println("Forward2 completed. Turning left2.");
   motor(0, 0);
  } else {
   Serial.print("Moving forward2.");
```

```
      motor(30, 35);
    }
    break;

  case State::TURN_LEFT2:
    if (millis() - stateMillis >= TURN_LEFT2_TIME) {
      state = State::STRAIGHT2;
      stateMillis = millis();
      Serial.println("Turn left2 completed. Moving straight2.");
      motor(30, 35);
    } else {
      Serial.print("Turning left2.");
      motor(-30, 30);
    }
    break;

  case State::STRAIGHT2:
    if (millis() - stateMillis >= STRAIGHT2_TIME) {
      state = State::TURN_RIGHT2;
      stateMillis = millis();
      Serial.println("Straight2 completed. Turning right2.");
      motor(30, -30);
    } else {
      Serial.print("Moving straight2.");
      motor(30, 35);
    }
    break;

  case State::TURN_RIGHT2:
    if (millis() - stateMillis >= TURN_RIGHT2_TIME) {
      state = State::END;
      stateMillis = millis();
      Serial.println("Turn right2 completed. Ending.");
      motor(0, 0);
    } else {
      Serial.print("Turning right2.");
      motor(30, -30);
    }
    break;

  case State::END:
    if (millis() - stateMillis >= STOP_TIME) {
      state = State::FORWARD;
      stateMillis = millis();
      Serial.println("1 second elapsed. Returning to forward state.");
    }
    break;
  }
 }
}
```

```
      }
    }
  }
 else {
   Serial.println("Tunggu Tombol Ditekan");
   delay(1000);
 }
}
```

Lampiran 6 Program Arduino mode tanpa rintangan

```
#include <Arduino.h>
#include <Adafruit_BNO08x.h>

#define M1_RPWM 2
#define M1_LPWM 3
#define M1_L_EN 4
#define M1_R_EN 5
#define M2_RPWM 6
#define M2_LPWM 7
#define M2_L_EN 8
#define M2_R_EN 9

#define BNO08X_CS 10
#define BNO08X_INT 9
#define BNO08X_RESET -1

struct euler_t {
  float yaw;
  float pitch;
  float roll;
} ypr, offset;

Adafruit_BNO08x  bno08x(BNO08X_RESET);
sh2_SensorValue_t sensorValue;
sh2_SensorId_t reportType = SH2_ARVR_STABILIZED_RV;
long reportIntervalUs = 5000;

bool calibrated = false;

float pwm_kiri = 35.0, pwm_kanan = 35.0;
float target_yaw = 0.0;
float KP = 10.0, KI = 3.0, KD = 4.0;
float integral_error = 0.0, previous_error = 0.0;
float dt = 0.1;
void setReports(sh2_SensorId_t reportType, long report_interval) {
  if (! bno08x.enableReport(reportType, report_interval)) {
    Serial.println("Could not enable report");
  }
```

```
} void setupMotor();
//void adjustPWM();
float PID_Controller(float target, float actual);
void motor(float pwmki, float pwmka);

void setup() {
  Serial.begin(115200);
  if (!bno08x.begin_I2C()) {
    Serial.println("Failed to find BNO08x chip");
    while (1) { delay(10); }
  }
  setReports(reportType, reportIntervalUs);

  setupMotor();
}

void quaternionToEuler(float qr, float qi, float qj, float qk, euler_t* ypr, bool degrees =
false) {
    float sqr = sq(qr);
    float sqi = sq(qi);
    float sqj = sq(qj);
    float sqk = sq(qk);

    ypr->yaw = atan2(2.0 * (qi * qj + qk * qr), (sqi - sqj - sqk + sqr));
    ypr->pitch = asin(-2.0 * (qi * qk - qj * qr) / (sqi + sqj + sqk + sqr));
    ypr->roll = atan2(2.0 * (qj * qk + qi * qr), (-sqi - sqj + sqk + sqr));

    if (degrees) {
      ypr->yaw *= RAD_TO_DEG;
      ypr->pitch *= RAD_TO_DEG;
      ypr->roll *= RAD_TO_DEG;
    }

    if (ypr->yaw < 0) ypr->yaw += 360;
    if (ypr->pitch < 0) ypr->pitch += 360;
    if (ypr->roll < 0) ypr->roll += 360;
}

void quaternionToEulerRV(sh2_RotationVectorWAcc_t* rotational_vector, euler_t* ypr,
bool degrees = false) {
    quaternionToEuler(rotational_vector->real, rotational_vector->i, rotational_vector->j,
rotational_vector->k, ypr, degrees);
}

void loop() {
  if (Serial.available() > 0) {
    char instruksi = Serial.read();
    if (instruksi == '1') {
    while (true) {
      if (bno08x.wasReset()) {
```

```
      setReports(reportType, reportIntervalUs);
    }

    if (bno08x.getSensorEvent(&sensorValue)) {
      if (sensorValue.sensorId == reportType) {
        quaternionToEulerRV(&sensorValue.un.arvrStabilizedRV, &ypr, true);
        if(!calibrated) {
          offset = ypr;  // save the first reading as the offset
          calibrated = true;
        }
        ypr.yaw -= offset.yaw;
        ypr.pitch -= offset.pitch;
        ypr.roll -= offset.roll;

        // Normalize to 0-360
        if (ypr.yaw < 0) ypr.yaw += 360;
        if (ypr.pitch < 0) ypr.pitch += 360;
        if (ypr.roll < 0) ypr.roll += 360;
    if (calibrated) {
      float error = target_yaw - ypr.yaw;
      float adjust = PID_Controller(target_yaw, ypr.yaw);

      if (ypr.yaw >= 0.5 && ypr.yaw <= 180) {
        pwm_kiri = constrain(pwm_kiri - adjust, 35.0, 50.0);
        pwm_kanan = constrain(pwm_kanan + adjust, 35.0, 50.0);
      } else if (ypr.yaw > 180 && ypr.yaw <= 359.9) {
        pwm_kiri = constrain(pwm_kiri + adjust, 35.0, 50.0);
        pwm_kanan = constrain(pwm_kanan - adjust, 35.0, 50.0);
      }

      motor(pwm_kiri, pwm_kanan);

      Serial.print("Yaw: "); Serial.print(ypr.yaw);
      Serial.print("\tPWM Kiri: "); Serial.print(pwm_kiri);
      Serial.print("\tPWM Kanan: "); Serial.println(pwm_kanan);
    }
  }
    }
  }
}
else if (instruksi == '2') {

  while (true) {
    if (bno08x.wasReset()) {
      setReports(reportType, reportIntervalUs);
    }

    if (bno08x.getSensorEvent(&sensorValue)) {
      if (sensorValue.sensorId == reportType) {
        quaternionToEulerRV(&sensorValue.un.arvrStabilizedRV, &ypr, true);
```

```
        if(!calibrated) {
          offset = ypr;  // save the first reading as the offset
          calibrated = true;
        }
        ypr.yaw -= offset.yaw;
        ypr.pitch -= offset.pitch;
        ypr.roll -= offset.roll;

        // Normalize to 0-360
        if (ypr.yaw < 0) ypr.yaw += 360;
        if (ypr.pitch < 0) ypr.pitch += 360;
        if (ypr.roll < 0) ypr.roll += 360;
      if (calibrated) {
        float error = target_yaw - ypr.yaw;
        float adjust = PID_Controller(target_yaw, ypr.yaw);

        if (ypr.yaw > 1 && ypr.yaw < 180) {
          pwm_kiri = constrain(pwm_kiri + adjust, 35.0, 50.0);
          pwm_kanan = constrain(pwm_kanan - adjust, 35.0, 50.0);
        } else if (ypr.yaw > 180 && ypr.yaw < 359.9) {
          pwm_kiri = constrain(pwm_kiri - adjust, 35.0, 50.0);
          pwm_kanan = constrain(pwm_kanan + adjust, 35.0, 50.0);
        }

        motor(-pwm_kiri, -pwm_kanan);

        Serial.print("Yaw: "); Serial.print(ypr.yaw);
        Serial.print("\tPWM Kiri: "); Serial.print(pwm_kiri);
        Serial.print("\tPWM Kanan: "); Serial.println(pwm_kanan);
      }
    }
      }
    }
  }
  }
  else {
    Serial.println("Tunggu Tombol Ditekan");
    delay(1000);
  }
}

void setupMotor() {
  // Setup Motor Control Pins
  int motorPins[] = {2, 3, 4, 5, 6, 7, 8, 9};
  for (int i = 0; i < 8; i++) {
    pinMode(motorPins[i], OUTPUT);
  }

  // Enable motor
  digitalWrite(M1_L_EN, HIGH);
```

```
  digitalWrite(M1_R_EN, HIGH);
  digitalWrite(M2_L_EN, HIGH);
  digitalWrite(M2_R_EN, HIGH);
}

float PID_Controller(float target, float actual) {
  float error = target - actual;
  integral_error += error * dt;
  float derivative_error = (error - previous_error) / dt;
  previous_error = error;

  return KP * error + KI * integral_error + KD * derivative_error;
}

void motor(float pwmki, float pwmka) {
  pwmki = constrain(pwmki, -255, 255);
  pwmka = constrain(pwmka, -255, 255);

  if (pwmki <= -15 && pwmki > -255) {
    analogWrite(M2_RPWM, (int)(-pwmki));
    analogWrite(M2_LPWM, 0);
  }
  if (pwmki >= 15 && pwmki < 255) {
    analogWrite(M2_RPWM, 0);
    analogWrite(M2_LPWM, (int)pwmki);
  }
  if (pwmka >= 15 && pwmka < 255) {
    analogWrite(M1_RPWM, (int)pwmka);
    analogWrite(M1_LPWM, 0);
  }
  if (pwmka <= -15 && pwmka > -255) {
    analogWrite(M1_RPWM, 0);
    analogWrite(M1_LPWM, (int)(-pwmka));
  }
  if (pwmka > -15 && pwmka < 15) {
    analogWrite(M1_RPWM, 10);
    analogWrite(M1_LPWM, 10);
  }
  if (pwmki > -15 && pwmki < 15) {
    analogWrite(M2_RPWM, 10);
    analogWrite(M2_LPWM, 10);
  }
}
```