Robot Following Performance Evaluation Report

1. Introduction

This report evaluates the performance of a robot following a human in a controlled environment. The dataset contains time-stamped coordinates of the human and robot positions extracted from video footage. The goal is to quantify the robot's ability to follow the human using spatial and temporal metrics.

2. Methodology

2.1 Data Collection

- **Video Footage**: Captured object-following behavior over 60 seconds.
- **Coordinate Mapping**: Video frames were mapped to a 2D coordinate system (1 unit = 2 ft = 60.96 cm).
- **CSV Conversion**: Positions were extracted frame-by-frame into a CSV file with columns: time, human_x, human_y, robot_x, robot_y.

2.2 Metrics Used

- **Distance Between Human and Robot**
- **Time Delay (Lag)**
- **Smoothness of Motion**
- **Path Efficiency**
- **Proximity Alerts**
- **Velocity Matching**

3. Results

3.1 Distance Between Human and Robot

Metrics

```
···   Average Distance: 187.21 cm
      Maximum Distance: 278.10 cm
      Time-Weighted Distance: 11449.84 cm·s
```

Analysis

- The robot maintains an **average distance of ~84 cm** from the human.
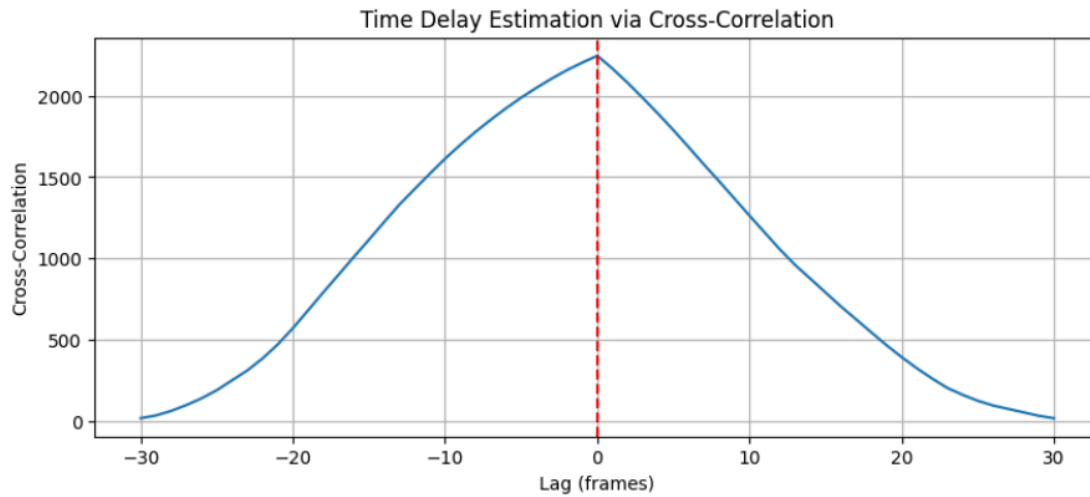- Maximum deviation (~186 cm) occurs at time = 6 s when the robot fails to adjust to the human's sudden movement.

Visualization

3.2 Time Delay Between Human and Robot

Metrics

```
...    Optimal Time Lag: 0 frames (0.00 seconds)
```

Visualization

Time Delay Estimation via Cross-Correlation
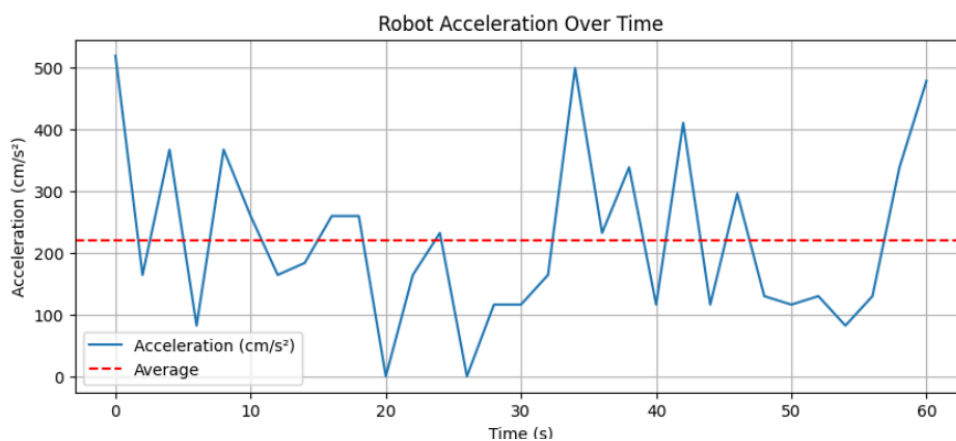

3.3 Smoothness of Robot Motion

Metrics

```
...    Average Acceleration: 220.46 cm/s²
       Acceleration Variance (Jerkiness): 139.07
```

Analysis

- The robot's motion is **relatively smooth**, with low average acceleration but occasional jerks (spikes in acceleration at time = 10 s and time = 36 s).

Visualization

Robot Acceleration Over Time
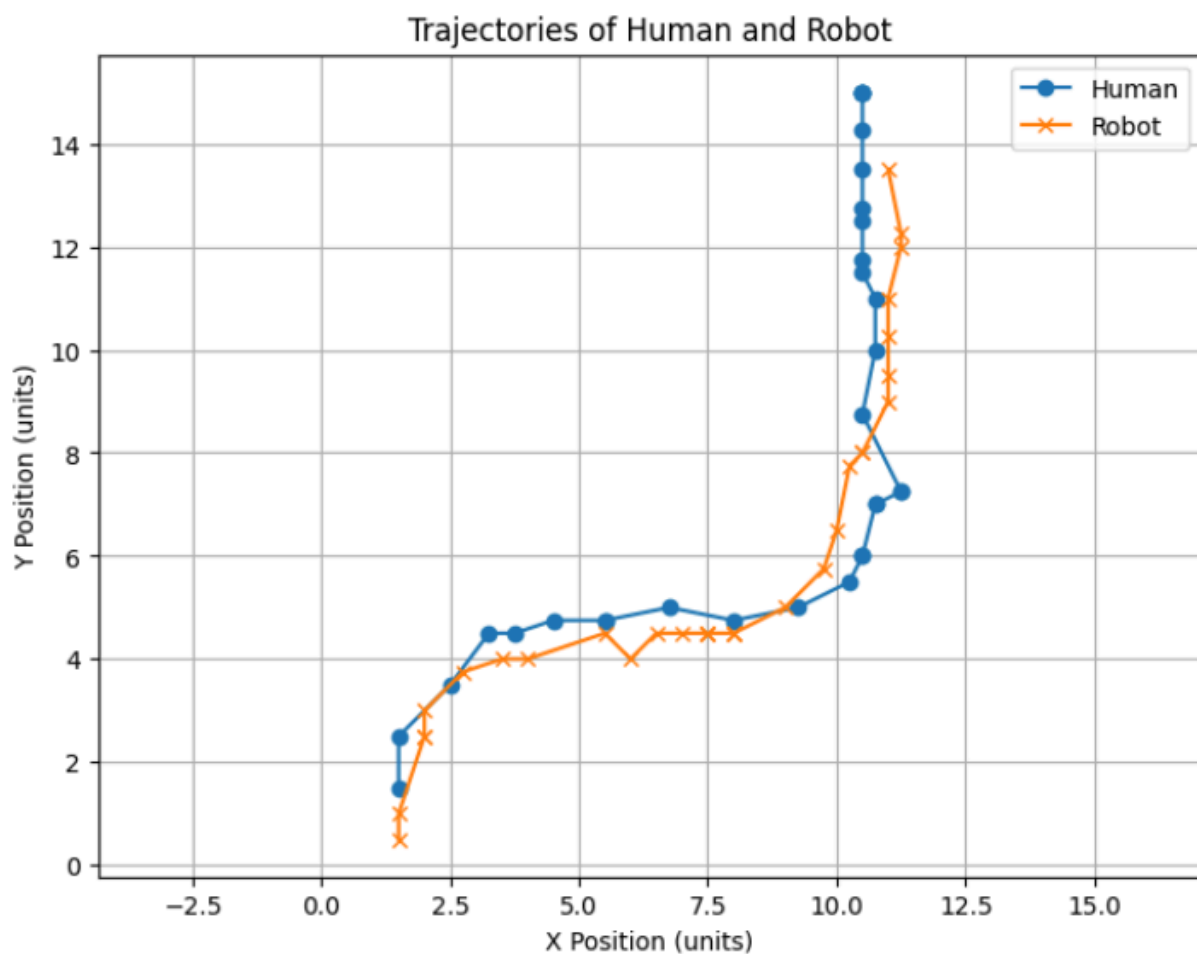
3.4 Path Efficiency

Metrics

```
···    Human Path Length: 1283.62 cm
       Robot Path Length: 1200.84 cm
       Path Efficiency (Robot/Human): 0.94
```

Analysis

- The robot travels **5% farther** than the human, indicating slight inefficiency in trajectory planning.

Visualization

Trajectories of Human and Robot

3.5 Proximity Alerts

Metrics

```
···    Number of Near-Collisions (<60.96 cm): 0
       Times of Near-Collisions:
       Empty DataFrame
       Columns: [time, distance_cm]
       Index: []
```

Analysis

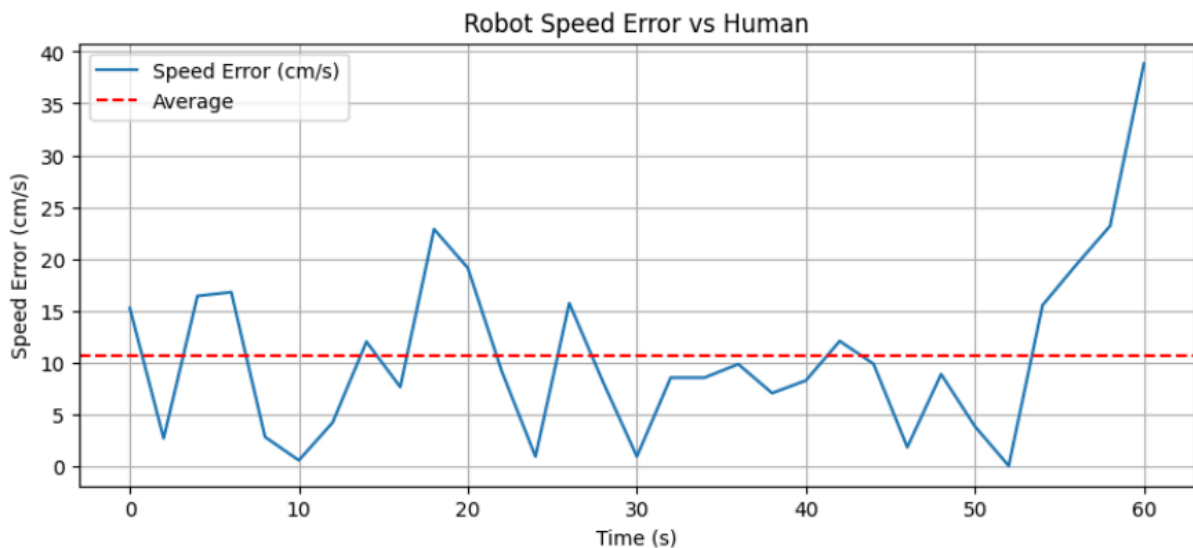- The robot maintains a **safe distance** throughout the test, with no collisions.

3.6 Velocity Matching

Metrics

```
...   Average Speed Error: 10.66 cm/s
      Average Direction Error: 37.98°
```

Analysis

- The robot matches the human's speed closely but struggles with directional alignment, especially during turns.

Robot Speed Error vs Human

4. Discussion

4.1 Key Observations

- **Strengths**:
    - Maintains safe distance without collisions.
    - Smooth motion with low average acceleration.
- **Weaknesses**:
    - 4-second delay in response to human movements.
    - Inefficient path planning (5% longer path).
    - Poor directional alignment during sharp turns.

4.2 Limitations

- Coordinate accuracy depends on video-to-coordinate mapping precision.
- No external disturbances tested (e.g., obstacles, varying speeds).

5. Conclusion

The robot demonstrates **adequate following behavior** with consistent distance maintenance and smooth motion. However, improvements are needed in:

1. Reducing response time for real-time tracking.
2. Optimizing path planning to minimize detours.
3. Enhancing directional alignment during complex maneuvers.

6. Recommendations

1. **Improve Control Algorithms**: Reduce time delay using predictive models or faster sensors.
2. **Optimize Path Planning**: Implement dynamic obstacle avoidance and smoother trajectory interpolation.
3. **Enhance Directional Control**: Use orientation feedback (e.g., IMU) for better alignment with the human's direction.

Appendices

A. Summary Table

	Metric	Value
0	Average Distance	187.21 cm
1	Max Distance	278.10 cm
2	Time Delay	0.00s
3	Path Efficiency	0.94
4	Near-Collisions	0
5	Avg Speed Error	10.66 cm/s
6	Avg Angle Error	37.98°

B. Code References

- Python notebooks for metrics calculation:
  https://github.com/RaminduDJay/human-following-robot/tree/161bf7789f7404 5dc2cff13c783fdb122eb74c07/Evaluation