Replication Study

on

A Machine Learning Approach for Improving the Movement of Humanoid NAO's Gaits

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Introduction

Background: Introduce the NAO humanoid robot and the significance of improving its walking gait for applications like RoboCup tournaments.

Objective: Explain the aim of replicating the experiment from the paper to predict and implement improved joint angles in a NAO simulator.

Dataset Description

Data Source: Describe the dataset comprising 4 ZIP archives of CSV files, each containing the requested and measured joint angles of leg joints from B-Human robots during multiple RoboCup tournaments in 2019 and 2022.

Data Structure: Detail the filename structure, including game date, field, teams, and robot identifier. Explain the segmentation of data with 12ms intervals and the significance of the hipYawPitch angle.

Experiment Design

Replication Approach: Outline the steps taken to replicate the experiment, including the extraction and processing of data from the B-Human system and loading it as tf.Dataset. In this experiment, we actually dealt with these degrees of freedom. Joint names are mentioned below.

```
joint_state.name = ['LHipRoll', 'LHipPitch', 'LKneePitch', 'LAnklePitch',
'LAnkleRoll', 'RHipRoll', 'RHipPitch', 'RKneePitch', 'RAnklePitch',
'RAnkleRoll’,'LHipYawPitch', 'RHipYawPitch']
```

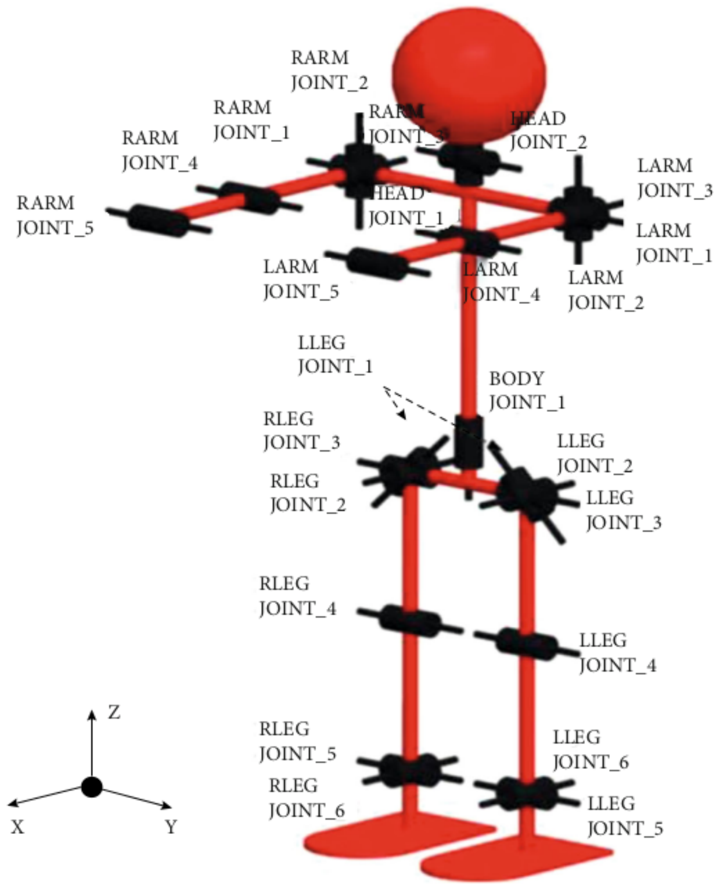


FIGURE 1: NAO 24 joints: 12 parameters for legs and feet and 12 for hands and arms.

Simulation Setup: Discuss the implementation of inferred joint angles in a NAO simulator, referencing the provided Python code for publishing joint states.

```python

def publish_joint_states(csv_file_path):
    # Initialize the ROS node
    rospy.init_node('nao_joint_state_publisher', anonymous=False)
    # Create a publisher for the 'joint_states' topic
    pub = rospy.Publisher('/joint_states', JointState, queue_size=10)
    # Read the CSV file
    df = pd.read_csv(csv_file_path)
    # Define the rate (in Hz) at which to publish the messages
    rate = rospy.Rate(1/0.02) # 12 ms
    # Infinite loop to continuously animate the robot
    while not rospy.is_shutdown():
        # Iterate over each row in the DataFrame
        for index, row in df.iterrows():
            # Check if ROS is shutting down
            if rospy.is_shutdown():
                break
            # Create a JointState message
            joint_state = JointState()
            joint_state.header.stamp = rospy.Time.now()
            # Assuming the joint names are known and correspond to the columns
            joint_names = ['lHipRoll', 'lHipPitch', 'lKneePitch', 'lAnklePitch', 'lAnkleRoll',
                           'rHipRoll', 'rHipPitch', 'rKneePitch', 'rAnklePitch', 'rAnkleRoll']
            # Fill in the joint names and positions
            joint_state.name = ['LHipRoll', 'LHipPitch', 'LKneePitch', 'LAnklePitch', 'LAnkleRoll',
                                'RHipRoll', 'RHipPitch', 'RKneePitch', 'RAnklePitch', 'RAnkleRoll',
                                'LHipYawPitch', 'RHipYawPitch']
            joint_state.position = [row[f'Request.angles.{name}'] for name in joint_names]
            joint_state.position.append(row[f'Request.angles.hipYawPitch'])
            joint_state.position.append(row[f'Request.angles.hipYawPitch'])
            rospy.loginfo(joint_state.position)
            # Publish the joint state
            pub.publish(joint_state)
            # Sleep to maintain the loop rate
            rate.sleep()
```

Results

Predicted Joint Angles: Summarize the outcome of the prediction of joint angles for the NAO gait.

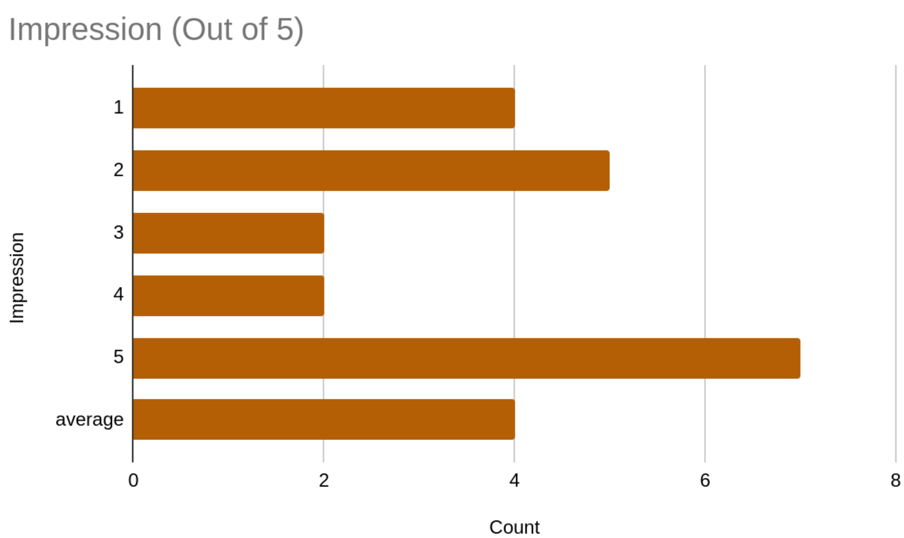
Simulation Observations: Describe how the NAO simulator responded to the implemented joint angles, possibly including any notable patterns or improvements in movement efficiency.

Survey Method and Results

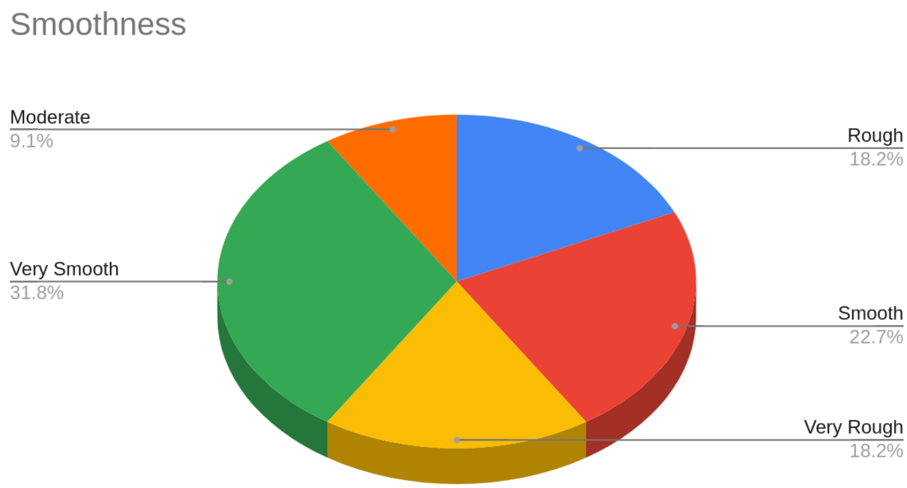
Conducting the Survey: After implementing the new walking gaits, we showcased the NAO robot's movements to 20 individuals. Their feedback was gathered via a Google Forms survey, focusing on various aspects of the robot's motion.

Key Findings:

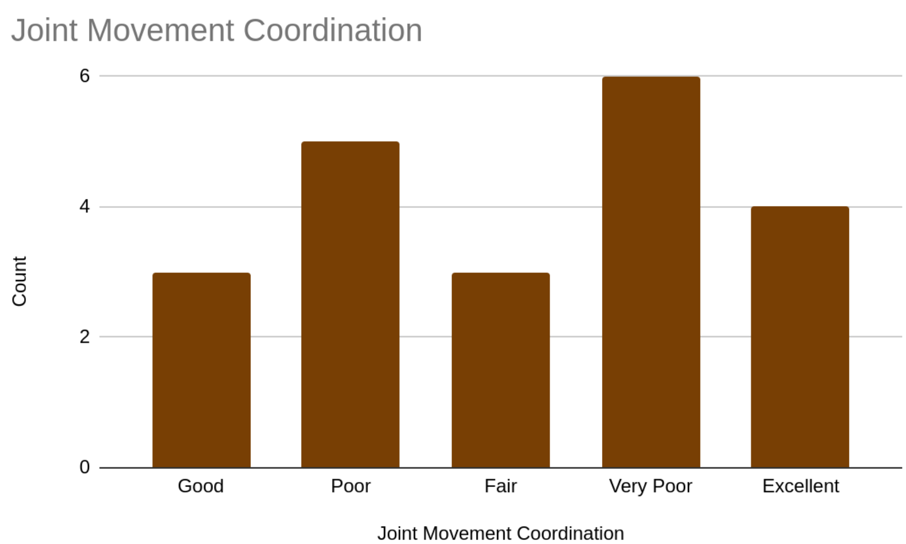
- **Overall Impressions**: Ratings varied, with some describing the robot's motion as smooth and others finding it rough. But, the average impression was 4 out of 5 which can be considered as very good.



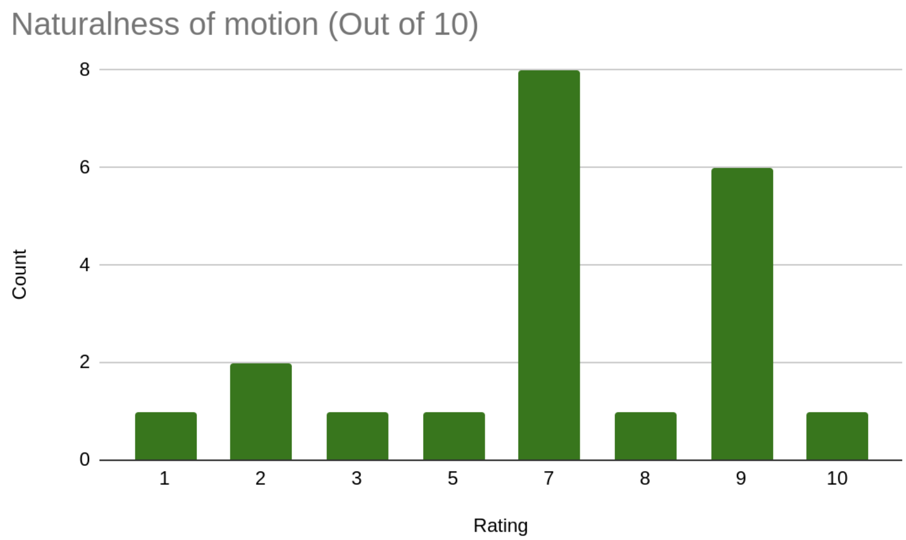
- **Gait Analysis**: Opinions on the similarity of the robot's gait to human walking were mixed.
- **Movement Aspects**: Responses on joint coordination, balance, and stability were diverse, indicating areas of both strength and weakness. Also in terms of smoothness, it achieves around 32% good feedback.



The Joints movement coordination of the experiment was not up to mark. The result has been shown below.



- **Responsiveness and Predictability:** The robot's response to terrain changes and the predictability of its movements received varied feedback.
- **Naturalness and Complexity:** Views on the naturalness and complexity of the movements ranged from 'very human-like' to 'not human-like at all'.



- **Improvement Areas:** Suggestions included enhanced coordination, more natural posture, better balance, increased responsiveness, and greater fluidity.

This survey provides a nuanced view of the robot's gait, highlighting areas for future improvements.

Replicating to What Extent

In the context of our research paper, our primary objective revolves around inferring the set of joint angles necessary to facilitate the optimal gait of the NAO robot. Our primary emphasis is on achieving smooth and graceful movements while simultaneously optimizing the robot's walking speed. It's worth noting that our approach is somewhat constrained due to the unavailability of an extensive dataset.

Our research is driven by the aspiration to replicate and emulate the fluidity and precision of NAO robot gaits as closely as possible. This entails the development of a machine learning model that deduces the joint angles essential for ensuring the smoothness of the robot's movements. While our primary focus is on the aspect of smoothness, we acknowledge the challenge posed by the limited dataset, which necessitates a refined and innovative approach to achieve our replication goals.

Conclusion

Findings Summary: Conclude with a summary of key findings, particularly how the experiment contributed to understanding and improving NAO robot gaits.

Future Work: Suggest potential areas for further research or improvement, such as refining prediction algorithms or exploring different simulation parameters.