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1. Introduction

The search for flexible and quick movement has always been a problem in the field of robotics. This project explores the design and development of a quadruped robot, appropriately dubbed "Doggy," with an emphasis on using inverse kinematics to achieve smooth and versatile movement. Inverse kinematics is an important area of robotics that is crucial in figuring out the joint angles required to achieve the desired position and orientation of the end-effector. Our four legged friend, Doggy, illustrates how advanced hardware design and complex control algorithms work together to enable dynamic navigation and interaction with its surroundings.

- Motivation

The motivation behind Doggy's conception is rooted in the quest for robotic locomotion that mirrors the agility and adaptability observed in nature. Quadruped robots, inspired by the biomechanics of animals, possess inherent advantages in traversing complex terrains and confined spaces. By employing inverse kinematics, we aim to unlock a higher level of control, enabling Doggy to execute precise and coordinated movements, ultimately enhancing its utility in various real-world applications.

- Key Objective

The primary objectives of this project are twofold: to design a robust quadruped robot capable of agile locomotion, and to implement an inverse kinematics control system that empowers Doggy with the ability to navigate its surroundings with finesse. Through meticulous hardware design, sophisticated kinematic modeling, and innovative control algorithms, we aspire to push the boundaries of quadruped robotics, demonstrating the potential for versatile and adaptive robotic motion.

2. Hardware Design:

- Overview

Doggy's hardware design is inspired by the renowned SpotMicro quadruped robot, renowned for its robust and agile structure. By adopting a similar framework, Doggy inherits the proven design principles that contribute to stability, versatility, and ease of customization. The hardware components are meticulously selected to ensure a harmonious integration that aligns with the locomotion requirements and the overall objectives of the project.

- Structural Components

1. **Frame**:
   Doggy's frame mirrors the quadrupedal anatomy, comprising a durable yet lightweight material such as aluminum or carbon fiber. The frame is designed to withstand mechanical stresses during dynamic movements while maintaining the necessary structural integrity.

2. **Legs**:
   The quadruped structure features four articulated legs, each equipped with high-torque actuators. These legs are strategically positioned to mimic the agility and adaptability observed in quadrupedal locomotion, allowing Doggy to navigate various terrains seamlessly.

3. **Joints**:
   Precision-engineered joints enable a wide range of motion for each leg. These joints facilitate coordinated movement and contribute to Doggy's ability to execute complex maneuvers. Potentiometers or encoders are integrated into the joints to provide feedback for accurate position control.

4. **Sensors**:
   Doggy is equipped with a suite of sensors to perceive its environment. These may include but are not limited to:

- Inertial Measurement Unit (IMU): Provides information about orientation and acceleration.
- Camera(s): Facilitate visual perception for interaction.

• Actuation System

1. **Actuators**:
   High-torque servo motors act as the primary actuators for Doggy's leg joints. These servos offer precise control over joint angles, allowing for accurate and dynamic motion.

2. **Power System:**
   A reliable power supply, typically in the form of rechargeable batteries, ensures sustained operation during experiments and demonstrations. The power system is designed to meet the energy requirements of both the actuators and onboard electronics.

• Communication and Control

1. **Microcontroller**:
   A powerful microcontroller Raspberry Pi serves as the brain of Doggy. It processes sensor data, executes control algorithms, and communicates with other components.

2. **Communication via SSH**:
   Doggy's communication is established through SSH, providing secure and efficient remote access. This allows operators to control the robot, monitor sensor data, and execute commands from a distance.

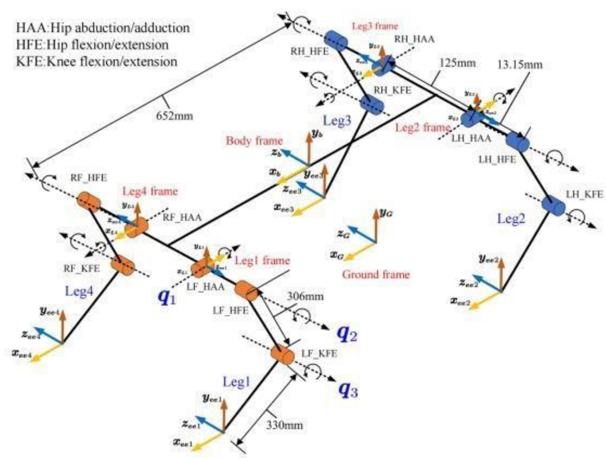
3. <u>Kinematics Model</u>

• Overview

Doggy's kinematics model relies on geometric inverse kinematics, a method that directly computes joint angles based on the desired end-effector position and orientation. This approach is chosen for its simplicity and efficiency in solving the kinematic equations, allowing Doggy to achieve precise and coordinated movements. In this section, we delve into the specifics of the geometrical inverse kinematics model employed for Doggy's quadruped locomotion.

• Leg Kinematics

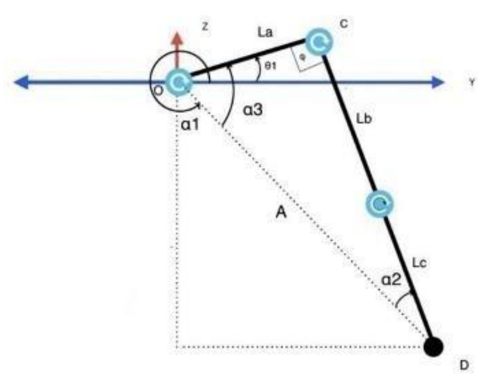
1. **Leg Configuration**:
   Doggy's quadrupedal structure features four identical legs, each comprising multiple articulated joints. The joints include hip, knee, and ankle, forming a kinematic chain that mimics the biomechanics of quadruped animals.



2. **Geometric Representation**:
   The kinematics model employs geometric representations of the robot's limbs, expressing joint angles and link lengths geometrically. This approach simplifies the mathematical calculations required for determining the leg's end-effector position and orientation.

• Geometric Inverse Kinematics

1. **Objective**:
   Geometric inverse kinematics is applied to calculate the joint angles necessary to position Doggy's end-effectors precisely. The objective is to determine the optimal joint configurations that achieve a specified position and orientation in Cartesian space.



2. **Trigonometric Solutions**:
   The geometric inverse kinematics algorithm relies on trigonometric solutions to compute joint angles. By leveraging trigonometric relationships within the kinematic chain, the algorithm efficiently determines the joint values needed for accurate positioning.

3. **Constraint Handling**:
   Physical constraints, such as joint limits and the robot's mechanical range of motion, are integrated into the geometric inverse kinematics calculations. This ensures that the computed joint angles adhere to the robot's physical capabilities.

4. Software Setup

• Operating System:

Doggy uses a Linux-based operating system, typically Raspbian for Raspberry Pi. Ensure that the operating system is up-to-date and configured for robotics applications.

• Raspberry Pi Configuration:

Configure the Raspberry Pi with necessary settings, such as enabling SSH, setting up a static IP address, and ensuring internet connectivity.

• Camera Interface:

To enhance user interaction, a dedicated application has been developed for Doggy. The application provides a live streaming feature, allowing users to observe Doggy's surroundings in real-time. Additionally, users can capture photos from the application at any moment.

• IMU Integration:

Integrate the IMU with the Raspberry Pi. Install the necessary drivers and libraries for reading IMU data

5. Troubleshooting

If you encounter issues during the setup or programming phases, refer to the troubleshooting section for common problems and solutions.

6. Conclusion

In the journey of designing and developing Doggy, a quadruped robot with a focus on geometrical inverse kinematics, we have embarked on a quest to push the boundaries of robotic locomotion. Doggy, inspired by the proven structure of SpotMicro, marries sophisticated hardware design, a robust kinematics model, and a meticulously crafted software setup to achieve versatile and adaptive movement.

- Achievements

1. **Hardware Design**:
   The quadrupedal structure, comprised of carefully selected materials and components, provides Doggy with a stable and agile foundation. The adoption of SpotMicro's proven design principles ensures reliability and ease of customization.

2. **Kinematics Model**:
   Leveraging geometrical inverse kinematics, Doggy's kinematics model empowers precise control over joint angles. This model is pivotal in achieving coordinated movements, allowing Doggy to navigate its environment with finesse and adaptability.

3. **Software Setup**:
   The software environment for Doggy seamlessly integrates advanced control algorithms, SSH communication, and sensor data processing. This synergy enables real-time control, secure remote access, and robust interaction with the robot.