ECE 445: Senior Design Laboratory

Project Proposal

# Design and Control of a Fetching Quadruped


Team #3

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## 1. Introduction

### Objectives and Background

Create an integrated robotic system with the combination of a robot dog with a custom-built manipulator arm

Enable object fetching through visual recognition algorithms and precise grasping capability

Develop a lightweight, accurate, and robust robotic arm that is compatible with existing commercial robot dog platforms

Achieve coordinated control between the robot dog and the mounted arm

Bridge the gap in commercial robotic dog platforms that lack manipulation abilities

### High Level Requirements

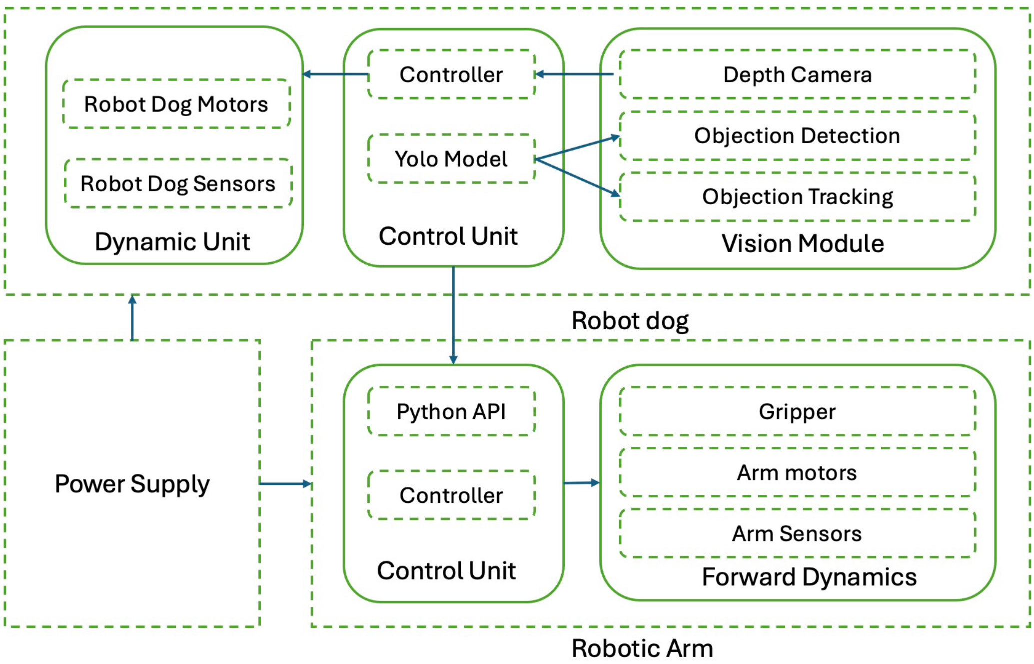
Robot arm must be lightweight enough to be mounted on the robot dog while maintaining 6-DoF functionality, while keeping the total cost under 1500 RMB

System must successfully identify and track target objects using visual feedback

Integrated system must coordinate movement between dog and arm to achieve accurate object grasping

# 2. Design

## 2.1 Block Diagram




## 2.2 Robot Dog

### 2.2.1 Dynamic Unit

The dynamic unit of the robot dog is come with the commercial robot dog by Unitree.

Robot Dog Motors

Drive the robot dog’s leg to achieve walking, turning, and other locomotion tasks. Powered by brushless motors and dedicated drivers.

Requirement: Must provide enough torque and fast response to ensure stable movement on flat ground.

Robot Dog Sensors

Comprises IMU (Inertial Measurement Unit), force sensors, and encoders. These obtain information on the robot’s pose, joint angles, contact forces, etc.

Requirement: Sensors must have high sampling rates and low noise to offer real-time motion control and state estimation.

### 2.2.2 Control Unit

Controller

The primary control and processing unit for the robot dog. It processes data from the Vision Module and built-in sensors, and then executes motion control algorithms.

Requirement: Requires real-time computing power to perform data processing and high-frequency control.

Yolo Model

The embedded visual AI model for object detection. It must run locally transfer data with the Vision Module.

Requirement: Must strike a balance detection accuracy and speed.

### 2.2.3 Vision Module

Depth Camera

Takes RGBD images of the environment which provides 3D information.

Requirement: Must provide valid images under different lighting conditions, and must provide accurate depth information within 3 meters.

Object Detection

Uses YOLO or similar existing models to detect objects in the camera feed.

Requirement: Must achieve high frame rates to achieve real-time operation, and also maintain high detection accuracy.

Object Tracking

Keeps tracking objects detected by computing trajectory, velocity, and position for motion planning.

Requirement: Must be robust against target loss and achieve real-time tracking while in motion.

## 2.3 Robotic arm

### 2.3.1 Control Unit

The task undertaken by the controller is to receive advanced instructions, the advanced instructions mentioned here such as target position instructions, grasp instructions, etc., and will convert these advanced instructions received into joint level instructions of the arm, the requirements of the controller is that it must support the inverse kinematics algorithm and path planning algorithm, so as to ensure that the mechanical arm can carry out safe and effective movement.

### 2.3.2 Python API

The Python API is a high-level interface that developers use to program in Python and test robotic arms. The requirements for the Python API are that it needs to be compatible with mainstream Python versions and provide stable communication, for example, Communication can be achieved with ROS, RPC, or similar protocols.

### 2.3.3 Forward dynamics

The role of forward dynamics is to deal with the dynamic calculation of the arm, such as calculating the required joint torque and load distribution, etc., relying on such processing to help the robot arm achieve accurate trajectory tracking, the requirements of forward dynamics are that it must find a suitable balance point between real-time performance and calculation accuracy. More need to do this.

### 2.3.4 Clamp

the end effector of the mechanical arm, its main function is responsible for grasping and manipulating the object, the requirements for the clamp are that it should have adjustable clamping force, and can adapt to a variety of different sizes and different shapes of the object,

### 2.3.5 Arm motor

The arm motor is a motor and driver used to drive the joint of the robot arm. The requirement for an arm motor is that it should provide sufficient torque and a suitable speed range, maintain synchronization and have low latency during coordinated movement of multiple joints.

### 2.3.6 Arm sensors

Arm sensors include joint encoders, force/torque sensors and other types of sensors, which are used to provide real-time feedback information for closed-loop control. For arm sensors, there are such requirements that it can provide accurate joint position and load information, and rely on providing such accurate information. To ensure that the robotic arm can achieve accurate and safe operation.

## 2.4 Power Supply

The main role of the power supply part is to provide stable and reliable power support for the robot dog, robot arm, vision module and other types of electronic equipment. The general power supply generally covers the battery (can also be an external power supply), charging circuit and voltage regulation, etc. The requirements for power supply are: To meet the peak power requirements of the two subsystems in the operation process, it is also necessary to have the function of overcurrent protection and overvoltage protection, so as to ensure the safety of the entire system.

# 3. Ethics and Safety

## 3.1 Ethics

According to the IEEE code of ethics [1], we must:

Clearly specify intended application and operational constraints (IEEE Code 2)

Accurately describe workspace and payload capabilities (IEEE Code 5)

Recognize and promptly fix technical deficiencies (IEEE Code 6)

Adequately credit team members' contributions (IEEE Code 6)

Ensure vision system doesn't collect unnecessary personal information (IEEE Code 1)

Consider environmental footprint throughout product lifecycle, especially with 3D printing (IEEE code 1)

Establish open communication channels for reporting concerns and issues (IEEE Code 7)

## 3.2 Safety

High voltage protection when working with motor drivers and power systems

Regular checks of safety of power cables and connections

Clear instruction for operation of the robot dog and arm for end users

Emergency stop mechanism implemented

Torque limiters on joints to prevent overload

Mechanical limits to prevent over-extension

Regular maintenance checks of mechanical components

Limitation on maximum grip force

Designated testing areas in the lab

Adequate ventilation during 3D printing

Documentation of standard operating procedure

# References:

[1] IEEE, IEEE Code of Ethics, Online, Available: https://www.ieee.org/about/corporate/ governance/p7-8.html, 2020.