ECE 445

SENIOR DESIGN LABORATORY

EARLY PROPOSAL

Early Proposal for ECE 445

Team #

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1 Introduction

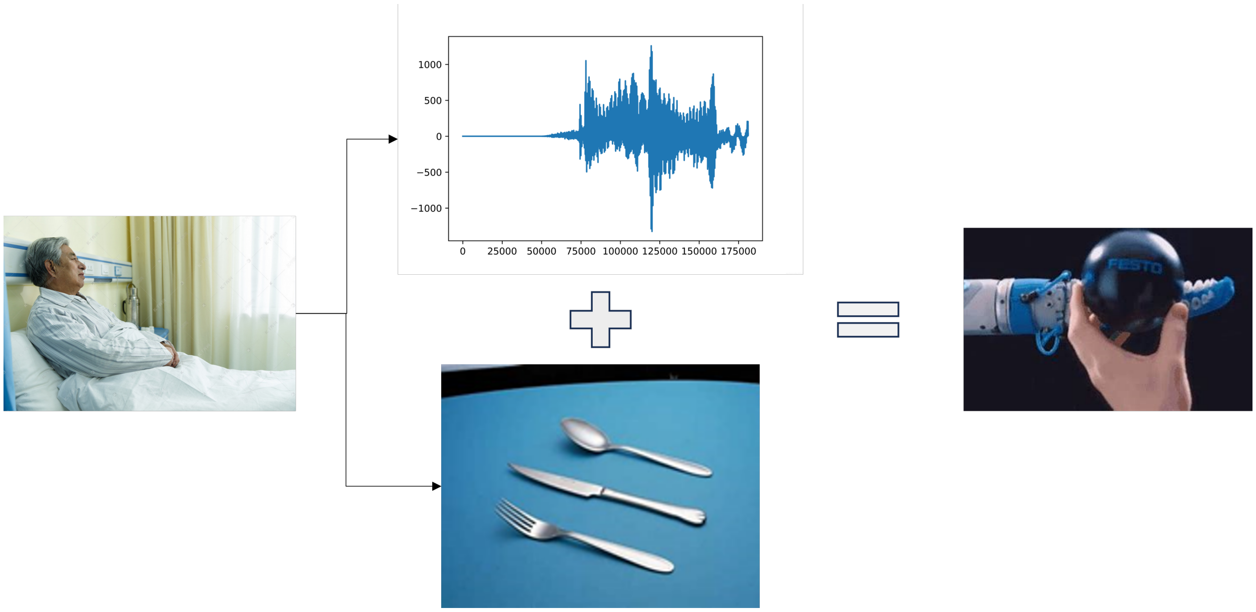
1.1 Problem

With the intensification of China's aging population, the forms of geriatric diseases in China are becoming more and more severe, and the number of patients is increasing rapidly. Among them, Parkinson's disease (PD) is a common neurological degenerative disease, the elderly are more common, the average age of onset is about 60 years old. The prevalence of PD in people over 65 years old in China is about 1.7%. With the increase of age, the prevalence rate further increased, over 80 years old more than 4%; By 2030, the number of Parkinson's disease patients in China will reach 5 million, accounting for almost half of the global number of patients.
Patients with Parkinson's disease may tremor, rigidity, bradykinesia, or postural gait disturbance, which seriously affects daily life. In life, we often see Parkinson's patients can not freely control the body to complete the removal of objects and other actions. At the same time, considering that Parkinson's disease patients are mostly elderly, a simple operation, intelligent function of the health assistance and daily cooperation system is very important.

1.2 Solution

Our graduation project aims to conceptualize an intelligent robotic arm capable of proficiently performing various tasks through speech and visual recognition. The most important concept is that the user verbally identifies objects on the table, such as common daily necessities, to the robot. After receiving the voice command, the robot arm determines the target pointed by the voice, and uses its own camera and visual recognition system to detect and locate the target object, and then carries out corresponding operations on it, such as picking up the target object and placing it in the corresponding position.
The specific system can be divided into three subsystems: language model, visual recognition, and robotic arm. These systems interact with each other and cooperate with each other in the process of completing the ordered tasks. First, the language model recognizes the operator's language instructions and converts them into computer signal instructions for transmission to the visual recognition system. The visual recognition system automatically recognizes the target object according to the instruction and the visual information from the camera as input, and generates the position information of the target object as output. Finally, after the robot arm obtains the position information from the visual recognition system, the corresponding motor moves initially, reaches the predetermined position and completes the command task.

1.3 Visual Aid



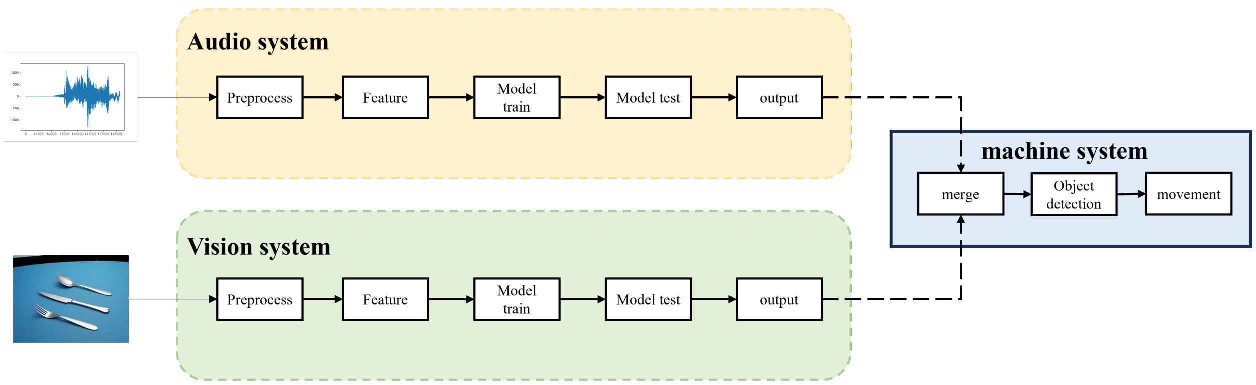
1.4 High-level Requirements List

Reliability: The system maintains a high level of reliability and recognition accuracy, and our goal is to maintain the accuracy of speech recognition and visual recognition above 90%.
Range: The designed manipulator system should cover a bamboo area range of 500mm · 500mm.
Intelligence: The robot arm should be designed to recognize and execute enough commands to complete them.

2 Design

2.1 Block Diagram

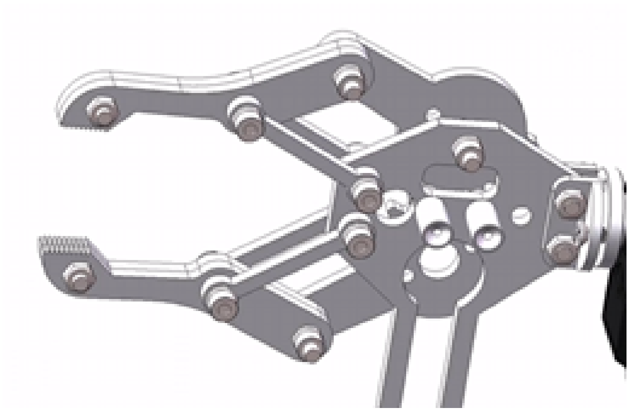
The overall design process involves inputting both voice and image data into the system. The system then recognizes and processes these inputs, before sending feedback to the robotic arm, instructing it to perform corresponding actions. This process encompasses the complete journey from perception to execution, achieving the goal of intelligently controlling the robotic arm's operations through voice and image inputs.



2.2 Subsystem 1: Robot Arm

2.2.1 Overview and Requirements

Robotics arm system This subsystem contains an arm and grab mechanism. We plan to use 4 axis arm, which means there are 4 motors or joints to control the arm. This subsystem will receive the target point coordinates of the object from the vision system and use the Inverse Kinematics Algorithm to calculate the rotation of each joint. This algorithm will be run on a PC inside of a signal chip microcomputer. For the grab mechanism, we will use a clamp to take objects. Since all the objects we will grab have some hardness, we do not need to consider adding a sensor to the clamp to control the force that will be applied to the object.

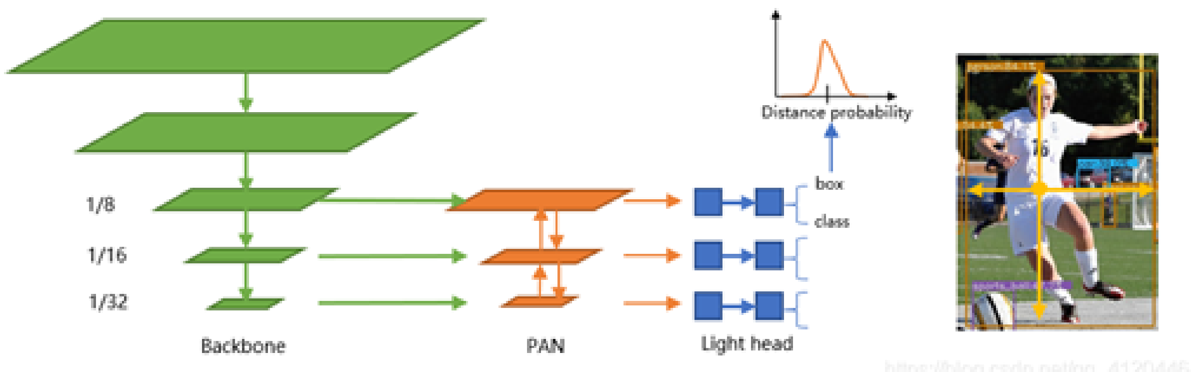
For the material, we will use PLA and use 3D printing technology to print all parts For the arm joints, we plan to use Xiaomi's Cyber Gear motors and KP035 bearing to achieve the movement of the robotics arm.

2.3 Subsystem 2: Visual Model

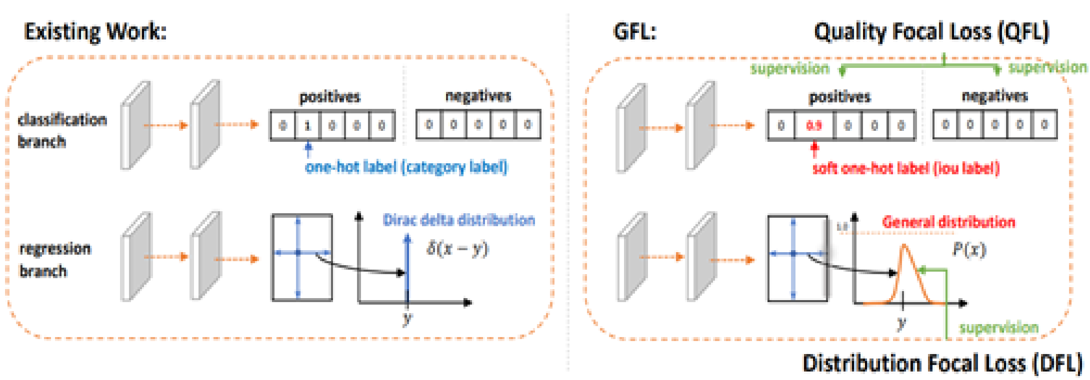
2.3.1 Overview and Requirements

Our task is to perform real-time single-object detection using the camera mounted on the robotic arm. Therefore, we need to employ a lightweight and fast single-object detection algorithm and network. This choice ensures that we can effectively identify and locate target objects while meeting real-time requirements. During the selection process, we will prioritize algorithms and networks with lightweight characteristics to ensure optimal performance within limited resources. The input of this subsystem is the output label (object) of the language model, and the image obtained from the camera. We consider our task as a traditional single object detection task; the output of this task should be the relative location of the input object in the input image. Then According to the relative location, we estimate the location of the object in the camera coordinate system, which is the final output in this stage.
We use COCO dataset as our train and test dataset. The COCO dataset is a comprehensive collection used for object detection, segmentation, and captioning tasks. It is designed for scene understanding and is extracted from diverse and complex everyday scenes. Objects in images are precisely delineated through segmentation, enabling accurate positioning within the scene. The dataset comprises 91 object categories and includes 328,000 images with 2,500,000 labeled instances. As of now, it stands as the largest dataset for semantic segmentation, featuring 80 classes and over 330,000 images, with annotations available for 200,000 of them. The dataset encompasses more than 1.5 million object instances across various categories, providing rich and extensive data for object detection

challenges. With an average of 7.2 objects per image, COCO poses a significant challenge for object detection tasks and remains one of the most widely used databases in the field. We use NanoDet as our desired network. NanoDet is a lightweight object detection model designed for efficient inference on resource-constrained devices, such as embedded systems or edge devices. It is tailored to provide a balance between model size, speed, and accuracy, making it suitable for real-time applications where computational resources are limited. NanoDet typically utilizes streamlined architectures and optimization techniques to achieve its goals, often sacrificing some accuracy compared to larger and more complex models in exchange for faster inference times and lower resource requirements.



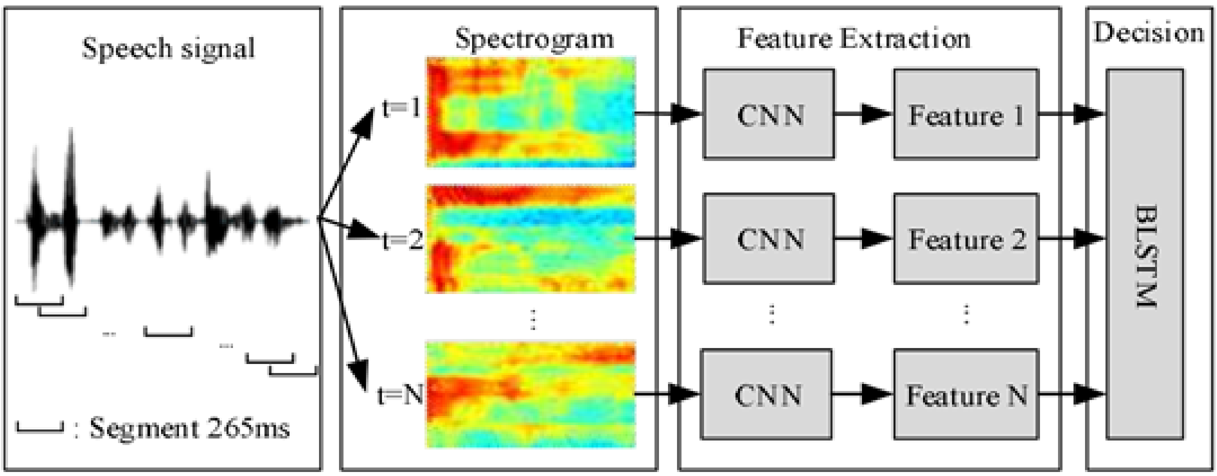
NanoDet indeed utilizes the Generalized Focal Loss as its loss function. By removing the centerness branch of FCOS, NanoDet reduces the computational overhead of the detection head, making it more suitable for lightweight deployment on mobile devices. This optimization helps in reducing the model's complexity while maintaining its effectiveness in object detection tasks, particularly in scenarios where computational resources are limited, such as mobile devices or embedded systems.



2.4 Subsystem 3: Audio recognition

2.4.1 Overview and Requirements

In the speech module, we first segment the speech signal through practical segmentation, dividing it into appropriate segments. Then, we use Convolutional Neural Networks (CNNs) to extract features from each segment, aiding in capturing crucial information within the speech signal. Subsequently, we input these features into a Bidirectional Long Short-Term Memory network (BiLSTM) for further processing. BiLSTM effectively models long-term dependencies in sequential data, thus better understanding contextual information within the speech signal. Ultimately, we use the output of BiLSTM as the target vector for subsequent speech recognition or other related tasks. This end-to-end process fully leverages the advantages of CNNs and BiLSTM, enabling efficient processing and accurate recognition of speech signals.



2.5 Tolerance Analysis

The first problem would be the imprecise movement of the robotics arm caused by the leak capability of the motor. A leaky motor can result in inconsistent movement patterns, causing the robotic arm to deviate from its intended path. This inaccuracy can lead to errors in positioning, impacting the arm's ability to perform tasks with precision. In tasks requiring delicate maneuvers or fine adjustments, such as in manufacturing or surgery, this imprecision could be critical. We would use control a PID controller to fix this problem.

3 Ethics and Safety

Considering that our target group is mainly the elderly and disabled, ethics and safety are very important requirements in our design. In this section, we will divide into two parts to complete our proposal.

3.1 Ethics

In order to fulfill our obligations as ZJUI students and avoid ethical violations in the conduct and results of the project, our project team will strictly abide by the IEEE Code of Ethics [1] and ACM Code of Ethics [2]. We will undertake to fulfill but not limited to the following obligations and requirements:
1. Put the safety, health and welfare of the public first, strive to adhere to ethical design and sustainable practices, and have an obligation to report any signs of systemic risk that could lead to harm.
2. The project aims to contribute to society and human well-being by improving individual and team understanding of the capabilities and societal impact of traditional and emerging technologies.
3. Be honest and trustworthy, refrain from illegal acts in professional activities, and reject all forms of bribery.

3.2 Safety

In order to ensure the safety of the team and others, and to avoid any safety problems or hidden dangers during the project, our project team will strictly follow the ECE 445 SAFETY GUIDELINES [3]. We will undertake to fulfill but not limited to the following requirements:
1. No one on the team is allowed to work alone in the lab at any time.
2. In order to be allowed to work in the lab, everyone on the team must complete safety training.
3. Any group charging or using certain battery chemicals must read, understand, and follow safe battery usage guidelines.

References

[1] IEEE. “”IEEE Code of Ethics”.” (2016), [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html (visited on 03/07/2024).

[2] ACM. “”ACM Code of Ethics”.” (2018), [Online]. Available: https://www.acm.org/code-of-ethics (visited on 03/07/2024).

[3] ZJUI. “”ECE 445 SAFETY GUIDELINES”.” (2024), [Online]. Available: https://courses.grainger.illinois.edu/ece445zjui/guidelines/safety.asp (visited on 03/07/2024).