

# CHAPTER I

## INTRODUCTION

### 1.1. Background

Child safety during bicycle riding is a major concern in the context of child development. Accidents experienced by children are fundamentally caused by a lack of supervision from caregivers or parents during outdoor activities. Based on WHO (2023) data in the Global Status Report on Road Safety, bicyclists are categorized into the vulnerable road users group alongside pedestrians and motorcyclists. The existing report highlights bicycle-related accidents caused by the lack of bicycle-friendly infrastructure, such as the absence of dedicated lane separation, and the low awareness of road users, which increases the risk for bicyclists [1]. In recent years, preventive approaches have been developed to minimize the risk of accidents involving small vehicles. The implementation of sensor technology and computer vision represents an effort within preventive systems to detect potential hazards in the user's vicinity [2].

YOLO (You Only Look Once) is a deep learning-based object detection system capable of detecting various types of objects in real-time [3]. The edge computing approach allows AI inference processing to be conducted directly on small single-board computers (SBCs), such as Raspberry Pi or Jetson Nano, without relying on cloud computing. Edge computing devices are highly beneficial for implementing systems that require direct and portable processing [4].

The use of devices like Raspberry Pi and Jetson Nano is prevalent in system development however, Set-Top Boxes are rarely utilized for edge computing control, being more commonly developed into NAS and home servers [5]. This Set-Top Box device is utilized due to its relatively affordable cost, ease of modification, and adequate computational power, particularly in the HG680P series. By modifying the operating system to be Linux-based, this Set-Top Box can function as a single-board computer device [5]. Linux is an open-source operating system developed in 1991 and is currently widely used across various modern computing systems, supporting multiple hardware platforms, ranging from personal computers and servers to small devices. The open nature of the Linux system allows for

customized development according to specific needs, making it highly popular among Internet of Things (IoT) developers. The designed system integrates a camera and an ultrasonic sensor, which are then connected to the Set-Top Box, enabling it to analyze data and activate the servo for braking if a potential collision is detected.

The integration of an ultrasonic sensor for distance detection and YOLO for visual classification creates a highly complementary combination. The ultrasonic sensor provides real-time distance-based data, while YOLO presents object recognition capabilities for detecting entities such as vehicles, pedestrians, or walls. Research indicates that multi-sensor fusion systems have proven to be more accurate than utilizing a single sensor in tests conducted on micro-vehicles [6].

This research utilizes the HG680P Set-Top Box as the primary computing device for YOLO visual processing and employs the ESP32 microcontroller as a synchronizing interface between the sensor and actuator components. The ESP32 is renowned for its stable serial communication capabilities and integrated Wi-Fi connectivity, facilitating seamless communication across all sensors and enabling remote control [7]. Through this device, distance data provided by the ultrasonic sensor is transmitted to the Set-Top Box to be processed alongside the object detection results from the camera. The Set-Top Box subsequently sends a signal back to the ESP32 to activate the braking system. With this approach, the system is able to establish an efficient collaborative edge computing architecture, where the processing load remains on the Set-Top Box while hardware control is managed by the ESP32.

Therefore, this research is conducted with two primary objectives. First, to explore the potential of utilizing the HG680P Set-Top Box as an edge computing device to process YOLO requirements. Second, to understand the design process of an automatic accident prevention system on bicycles using the HG680P Set-Top Box, integrating an ultrasonic sensor and a camera for object detection. It is hoped that this research will lead to the development of an automatic prevention system for small vehicles and demonstrate the viability of Set-Top Boxes as the primary computing unit for running YOLO systems, which can subsequently be applied by other researchers and the general public.

## **1.2. Research Questions**

Based on the aforementioned background, the author formulates the following research questions:

1. How does the HG680P Set-Top Box perform as an edge computing device in processing YOLO, in terms of speed, accuracy, and resource efficiency?
2. What is the design process for an automatic accident prevention system on bicycles utilizing the HG680P Set-Top Box, integrating the ESP32 as an interface alongside an ultrasonic sensor and a camera to control the servo's behavior as an automatic brake?

## **1.3. Research Objectives**

Based on the formulated research questions, the objectives of this research are:

1. To analyze the performance of the HG680P Set-Top Box as an edge computing device in executing the YOLO model, evaluated from the aspects of processing speed, object detection accuracy, and resource utilization efficiency.
2. To design and implement an automatic accident prevention system on a bicycle by integrating the ESP32 with an ultrasonic sensor and a camera, processed through the HG680P Set-Top Box, and to test the response of the servo actuator as an automatic braking system based on the detection of distance and objects in front of the bicycle.

## **1.4. Research Significance**

This research is expected to provide benefits to society and the development of science, which include:

1. Academic Benefits:
  - a. Expanding scientific knowledge and literature: This research serves to broaden scientific knowledge and literature in the fields of Microcontrollers and the Internet of Things (IoT), particularly regarding the application of the You Only Look Once (YOLO) model for object identification.
  - b. Contributing to edge computing research: This research serves as a contribution to edge computing studies regarding the use of single-board

computers (SBCs), with a focus on Set-Top Box device development, specifically the HG680P. It can be utilized as a reference for related studies exploring the alternative use of Set-Top Boxes for developing edge computing devices.

## 2. Practical Benefits:

- a. **Enhancing bicyclist safety:** The developed system is capable of detecting objects in front of the bicycle and automatically activating the brakes to minimize the risk of accidents. This implementation has the potential to reduce incidents caused by delayed bicyclist reaction times.
- b. **Efficient implementation of edge computing concepts for safety systems:** This research demonstrates that low-cost devices like the HG680P Set-Top Box can be utilized as a single-board computer (SBC) alternative to run YOLO-based object detection in real-time. This approach aligns with the trend of processing efficiency in edge devices.
- c. **Contributing to educational technology innovation and applied research:** This research can be used as a learning project in the fields of embedded systems, IoT, and computer vision, particularly in the context of integrating sensors, actuators, and AI algorithms on resource-constrained devices.

### **1.5. Scope and Limitations**

To ensure this research is conducted effectively and remains focused on the investigated problem, it is necessary to establish boundaries. Therefore, the scope and limitations of this research are:

1. The system only detects objects in front of the bicycle, excluding the sides and rear.
2. The system solely detects objects classified by YOLO, which excludes walls or flat surfaces.
3. The YOLO algorithm employed is a lightweight version to ensure device efficiency.
4. The primary processing unit is the HG680P Set-Top Box, running a Linux-based Operating System.

5. The research is conducted in limited field test scenarios, excluding various extreme weather conditions.