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DESIGN AND IMPLEMENTATION OF PORTABLE SMART WIRELESS PEDESTRIAN CROSSING CONTROL SYSTEM

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ABSTRACT

Walking is a daily activity that requires an appropriate crosswalk as a key part of the provision of safe transportation infrastructure. In this paper, we design and develop a portable smart wireless control system for pedestrian crossing areas to manage the traffic automatically and allow the pedestrian, like school children, to cross the road safely and effortlessly. The system incorporates the concept of smart sensing to detect the presence of pedestrians and in turn, automatically controls the crosswalk traffic lights. The system composes of two Arduino microcontrollers, two infrared PIR motion sensors, and a bidirectional wireless communication link based on Bluetooth for mitigating wiring installation and transmitting the signal among traffic light units on both roadsides. The system is fabricated and implemented as a portable LED-based traffic light testbed. The developed system is tested and validated in a real environment with a 6 m road width on the university campus. According to the obtained results, the system worked effectively and fulfilled the design criteria where the communication between both sides lights is successfully functioning and the PIR sensors can accurately detect the existence of pedestrians. The developed system is cost-effective, energy efficient, easy to install, and maintenance-free.

I.INTRODUCTION

Walking is considered as the most basic and simple mode of transportation. Precisely, any person not riding a vehicle is known as a pedestrian. As compared to other road users, pedestrians, who are also defined as vulnerable road users, are not related to any vehicle mode [1]. They are unprotected (more exposed) during interaction with road traffic system, especially when involved in road accidents unlike other road users inside

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vehicles with protection "shell", as well as motorcyclists and cyclists with compulsory/recommended crash helmets. Crosswalk allows pedestrians to crossroads at a specific location with a reasonable safety level. At the road crossing area, pedestrians are typically assisted in road crossing by using a manually pedestrian crossing control system, which may comprise lighted signs ("WALK", "DON'T WALK"), integrated to the existing traffic lights [2]. Every year roughly 1.35 million people die and up to 50 million more people suffer non-fatal injuries as a result of a road traffic crash according to the World Health Organization [3]. The school children (Fig. 1) and elderly people are considered to be at a higher risk regarding pedestrian crashes. Studies show that the majority (40.3%) of pedestrian casualties (including fatal) were children. From this, at least 40% were either killed or severely injured during collisions, with the highest proportion being children aged 6-10. There is evidence that children are only completely capable to select required information to perform the task of crossing the road from the age of 11. Furthermore, it has been reported that the skills which are essential for crossing roads safely such as observation, perception of unsafe locations and information processing, are still inadequately developed for young children [4], [5]. A study of pedestrian fatalities on age group also indicates that elderly pedestrians between 66 and 70 years old contributed the highest number of fatalities than any other age group. These effects are probably due to functional limitations, such as slower reaction time and motor skill dysfunction, experienced by elderly pedestrians [6], [7]. In fact, fatalities of the pedestrian are more frequent than other road fatalities. In today's world with everybody is moving so fast and having little time for others, people's safety becomes the main concern. Busy urban area streets and roadways can frequently be unsafe spots for drivers and pedestrians alike. It might be hard to consolidate pedestrian activity with the stream of automobiles. Cities authorities must make a point to implement road arrangements to move traffic in a smooth flow and secure pedestrians [8]. It is particularly imperative to ensure that pedestrians are given safe areas to cross busy streets as crosswalks, walkways that traverse over occupied roads, and different strategies. As the world keeps growing with advanced

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technology and more people are required for it, the main roads in the city or any pedestrian's walk spaces become hustle and bustle nowadays. Therefore, any street crossing area may be less safe and effective for pedestrians when using them. One of the major factors is the button functions as a human detector, alerting the system to the presence of a pedestrian and requesting a "WALKING" signal as soon as possible. In some cases, the pedestrian may have to push the button to cross, otherwise, the system does not know there is a pedestrian waiting and will proceed through its cycles without ever displaying a "WALKING" signal and pushing the button simply reduces wait time. According to [9], only 60% of pedestrians would initiate the step to locate and push the activation feature before crossing the road. Therefore, 40% of pedestrians were left at greater risk, in not having the system in operation for their intended crossing.

II.METHODOLOGY

A) System Architecture

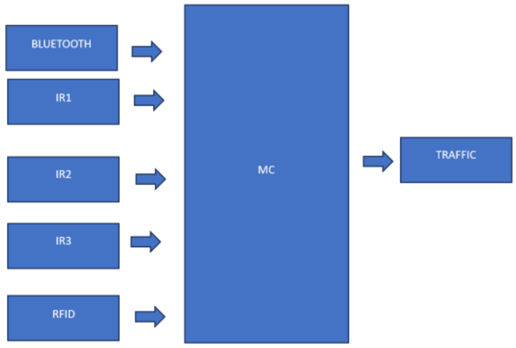

Fig1 .Block Diagram

The system architecture for the design and implementation of a portable smart wireless pedestrian crossing control system involves several interconnected components aimed at ensuring safe and efficient pedestrian crossings. At the core of the system is a microcontroller (MCU) that serves as the central unit for controlling operations and processing data from various sensors. The system is equipped with wireless communication modules, such as Wi-Fi or Bluetooth, to enable real-time communication between the crossing system and nearby infrastructure, like traffic lights or mobile apps for remote monitoring and control. Pedestrian detection is facilitated through infrared (IR) sensors or ultrasonic sensors, which trigger the activation of the crossing signals when a pedestrian is detected. The system also includes LED indicators for both pedestrian and vehicle signals, ensuring clear visibility for road users. A portable power supply, such as a battery or solar panel, ensures that the system can function in diverse environments, making it adaptable to various locations without requiring permanent installation. The system is also integrated with a wireless camera for monitoring pedestrian flow and potentially collecting data for traffic analytics.

B) Proposed Raspberry pi

The Raspberry Pi Pico is an affordable microcontroller board created by the Raspberry Pi Foundation. Unlike full-fledged computers, microcontrollers are small and have limited storage and peripheral options, such as the absence of devices like monitors or keyboards. However, the Raspberry Pi Pico is equipped with General Purpose Input/Output (GPIO) pins, similar to the ones found on Raspberry Pi computers, allowing it to connect with and control a variety of electronic devices. Introduced in January 2021, the Raspberry Pi Pico is based on the RP2040 System on Chip (SoC), which is both cost-effective and highly efficient. The RP2040 SoC includes a dual-core ARM Cortex-M0+ processor that is well-known for its low power consumption. The Raspberry Pi Pico is compact, versatile, and performs efficiently, with the RP2040 chip as its core. It can be programmed using either Micro Python or C, providing a flexible platform for users of various experience levels. The board contains several important components, including the RP2040 microcontroller, debugging pins, flash memory, a boot selection button, a programmable LED, a USB port, and a power pin. The RP2040 microcontroller, custom-built by the Raspberry Pi Foundation, is a powerful and affordable processor. It features a dual-core ARM Cortex-M0+ processor running at 133 MHz, 264 KB of internal RAM, and supports up to 16 MB of flash memory. The microcontroller provides a wide range of input/output options, such as I2C, SPI, and GPIO. The Raspberry Pi Pico has 40 pins, including ground (GND) and power (Vcc) pins. These pins are grouped into categories such as Power, Ground, UART, GPIO, PWM, ADC, SPI, I2C, System Control, and Debugging. Unlike the Raspberry Pi computers, the GPIO pins on the Pico can serve multiple functions. For instance, the GP4 and GP5 pins can be set up for digital input/output, or as I2C1 (SDA and SCK) or UART1 (Rx and Tx), though only one function can be used at a time.

C) Design Process

The design of embedded systems follows a methodical, data-driven process that requires precise planning and execution. One of the core elements of this approach is the clear separation between functionality and architecture, which is crucial for moving from the initial concept to the final implementation. In recent years, hardware-software (HW/SW) co-design has gained significant attention, becoming a prominent focus in both academia and industry. This methodology aims to align the development of software and hardware components, addressing the integration challenges that have historically affected the electronics field. For large-scale embedded systems, it is essential to account for concurrency at all levels of abstraction, impacting both hardware and software components. To facilitate this, formal models and transformations are employed throughout the design cycle, ensuring efficient verification and synthesis. Simulation tools are vital for exploring design alternatives and confirming the functional and timing behavior of the system. Hardware can be simulated at different stages, including the electrical circuit, logic gate, or RTL level, often using languages like VHDL. In certain setups, software development tools are integrated with hardware simulators, while in other cases, software runs on the simulated hardware. This method is generally more suited for smaller parts of an embedded system. A practical example of this methodology is the design process using Intel's 80C188EB chip. To reduce complexity and manage the design more effectively, the process is typically divided into four main phases: specification, system synthesis, implementation synthesis, and performance evaluation of the prototype.

APPLICATIONS

Embedded systems are being increasingly incorporated into a wide range of consumer products, such as robotic toys, electronic pets, smart vehicles, and connected home appliances. Leading toy manufacturers have introduced interactive toys designed to create lasting relationships with users, like "Furby" and "AIBO." Furbies mimic a human-like life cycle, starting as babies and growing into adults. "AIBO," which stands for Artificial Intelligence Robot, is an advanced robotic

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dog with a variety of sophisticated features. In the automotive sector, embedded systems, commonly referred to as telematics systems, are integrated into vehicles to offer services like navigation, security, communication, and entertainment, typically powered by GPS and satellite technology.

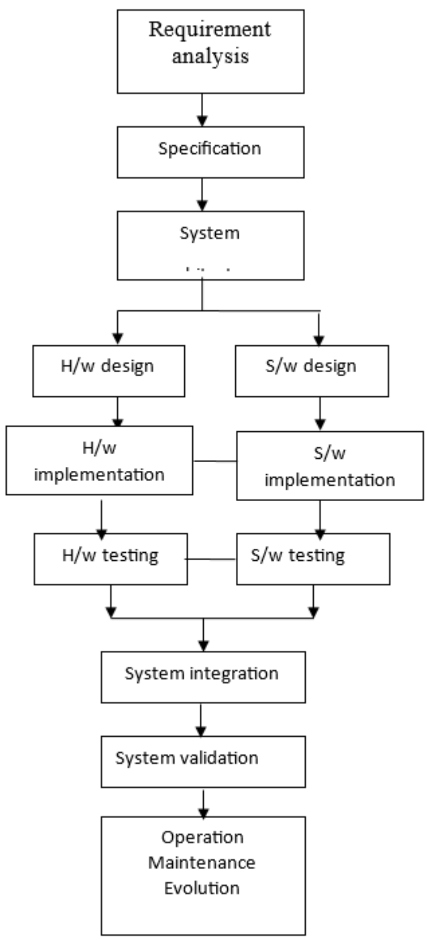

Fig 2. Embedded Development Life Cycle

The use of embedded systems is also expanding in home appliances. For example, LG's DIOS refrigerator allows users to browse the internet, check emails, make video calls, and watch TV. IBM is also developing an air conditioner that can be controlled remotely via the internet. Given the widespread adoption of embedded systems across various industries.

III.CONCLUSION

We have developed a portable, smart, and wireless-enabled traffic light system for the crosswalk. It is an efficiently functioning testbed to improve pedestrian safety and convenience by automating traffic light control based on the detection of pedestrians. This system helps pedestrians to cross the road safely without extra efforts to activate the walk signal. Besides, the cost of system installation and construction, needs for maintenance and energy efficiency of the system were among our main considerations. The system's Bluetooth enables the bidirectional communication between the traffic lights of both sides of the crossing road area. The portability nature of the system makes it easy to move and deployed in temporary locations like in universities and schools to help students at in/out times. The system testbed is able to save energy and deduct electricity bills by exploiting LEDs with rechargeable batteries. There are several limitations to this research that have found. One of them is the PIR sensor which has a very wide detection range which is 120 degree and distance of a minimum 3 m. Because of that, the PIR sensor will give a false signal because it can detect the presence of pedestrians at far from the traffic light. To solve this problem, the PIR sensor put inside a hole to narrowing the angle to 45 degree instead and reduce the distance of sensor detection. We suppose that the technical contributions of this paper will be valuable assets for the related applied researches on improving transportation infrastructure that involving pedestrians, particularly in the Smart City environment. A potential extension of the current study is to implement a solar cell to enhance system dependency on the rechargeable battery. The solar panel can provide energy to the system directly during day time and charging the battery to be used in the night time. The utilization of IoT and 5G communication networks in the future.to monitor such crosswalk systems will be helpful.

IV.FUTURE SCOPE

The future scope of a portable smart wireless pedestrian crossing control system lies in its potential for integration with smart city infrastructure, enabling seamless communication between traffic lights, pedestrian signals, and other urban systems. With advancements in 5G and IoT, these systems could evolve to offer real-time data sharing and adaptive traffic control based on pedestrian flow, weather conditions, or emergency situations. Artificial Intelligence (AI) could be incorporated for predictive analytics, optimizing crossing times and reducing congestion. Additionally, future systems may include solar-powered solutions for greater sustainability, machine learning algorithms for improved pedestrian detection, and integration with mobile apps for user-friendly interaction. Enhanced security features, such as cybersecurity measures, will be critical to protect the system from potential threats. Ultimately, these advancements will lead to smarter, more efficient, and safer pedestrian crossing systems in urban environments.

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