International Journal for Innovative Engineering and Management Research
PEER REVIEWED OPEN ACCESS INTERNATIONAL JOURNAL
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FLOOR BASED SENSORS WALK IDENTIFICATION SYSTEM USING DYNAMIC TIME WARPING WITH CLOUDLET SUPPORT

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ABSTRACT

Advances in sensor design, computing power, and artificial intelligence have paved the way for smart assistive living systems that can significantly enhance the lives of individuals, especially older adults. With the increasing desire for aging in place, it is essential to develop systems that monitor the health status of older adults, detect emergencies, and notify healthcare providers promptly. This paper presents an improved version of a floor-based monitoring system, referred to as the "smart carpet," originally designed to detect falls. The continuous 24/7 monitoring capability of the system not only aids in fall detection but also enables the collection of valuable information on gait, the number of people traversing the carpet, and the analysis of sensor waveforms for additional insights. Recently, research has focused on analyzing the characteristics of waveforms obtained from the sensors using computational intelligence techniques, such as feature extraction and classification, to distinguish between individuals. In this paper, Dynamic Time Warping (DTW) is applied to improve the identification of walking patterns, and the results are compared to those obtained using Mel-frequency cepstral coefficients (MFCC) for feature extraction. The findings reveal that the DTW algorithm, coupled with the K-Nearest Neighbor (KNN) classifier, achieves a precision of 86%, recall of 76%, and accuracy of 81% for walking identification. Furthermore, the paper introduces a cooperative cloudlet mobile computing model designed for eldercare and medical applications, where timely decision-making is crucial. In this model, sensor data is sent to the nearest cloudlet for real-time analysis, enabling quick decision-making with minimal delay. Users can access the results and make decisions on their mobile devices in real time, ensuring that the system operates efficiently and with low latency. This approach is especially beneficial for applications in eldercare, where prompt responses are critical

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for the well-being of individuals. The integration of Internet of Things (IoT) technologies, cloudlet computing, and real-time data analysis demonstrates a promising direction for enhancing the safety and quality of life for older adults living independently. By utilizing advanced computational techniques and cloudlet-based models, this system provides a scalable and responsive solution for monitoring and managing the health of elderly individuals, with potential applications extending to broader healthcare and assistive living contexts.

I.INTRODUCTION

The global population of individuals aged 65 and older is steadily increasing, and by 2030, one in five Americans is expected to be 65 or older. This demographic shift has prompted the development of various assistive living technologies aimed at supporting elderly individuals in their homes or nursing facilities. However, designing a system that is unobtrusive, user-friendly, hands-free, cost-effective, and capable of providing privacy while supporting assisted living remains a significant challenge. Numerous systems have been proposed to address these needs, including InfraRed, audio, video, and multiple acceleration sensors, as well as floor-based systems for detecting falls, estimating gait, monitoring elderly activities, recognizing and counting people, and tracking movements. Each of these technologies has its limitations, including concerns about privacy, cost, interference, and occlusion. Our research focuses on a non-computer vision-based, context-aware human recognition and fall detection system that employs a floor-based array sensor system, specifically the "smart carpet." This system, which offers complete privacy, is capable of being installed in environments where traditional sensors, such as Kinect depth sensors or video cameras, may struggle due to occlusion or environmental factors. The smart carpet system records and stores sensor data by capturing a person's movement, activating a set of sensors that output voltage signals. These signals are then amplified, decoded, and translated into a frame for further processing. By employing computational intelligence algorithms, our system can recognize individuals, estimate their gait, detect falls, and monitor their movements. This approach has been enhanced by studying the characteristics and behavior of sensor waveforms, which exhibit different patterns based on the individual, the material covering the sensors, and the environmental conditions. Our lab has used data from previous studies to apply the Dynamic Time Warping (DTW) algorithm with the K-Nearest Neighbor (KNN) classifier to improve the accuracy of walk identification. Prior to implementing DTW, we experimented with various signal analysis techniques, including Fourier transformation, wavelets, and statistical software like JMP. While these methods provided some insights, they were ultimately not suitable for our needs, particularly due to the non-linear nature of the sensor signals. The DTW algorithm was selected for its ability to align signals with varying time phases, an approach commonly used in speech recognition and other fields such as dance pattern recognition, handwriting analysis, fingerprint analysis, and pedestrian movement. DTW is particularly effective in handling signals with different lengths, making it an ideal choice for analyzing the sensor data collected by our system. By using DTW as a feature for classification, we avoid the complications of signal length variation and improve the reliability of the classification process. In parallel with these developments, we have explored Mobile Cloud Computing (MCC) as a promising technology for real-time data processing in healthcare applications. MCC integrates cloud computing with mobile devices, enabling the offloading of computationally intensive tasks to the cloud for faster analysis. This capability is especially beneficial in healthcare scenarios where real-time decision-making is crucial, and results need to be delivered with minimal delay. A key innovation in MCC is the use of cloudlets, which are localized servers that offer fast network connections and low latency. By processing data through nearby cloudlets instead of distant cloud servers, users can benefit from reduced energy consumption and quicker response times. Our research proposes using a cooperative cloudlet-based MCC model to enhance eldercare systems, such as the smart carpet. In this model, sensor data collected from the smart carpet is sent to the nearest cloudlet for analysis, and the results are transmitted to users in real time. This approach ensures that the system can make timely decisions for elderly individuals, such as detecting falls or monitoring gait, with minimal delay. The use of cloudlets in the MCC model offers a more efficient and responsive solution compared to traditional cloud-based models. While security concerns related to data transmission in mobile cloud systems are an ongoing issue, this paper does not delve into this aspect in detail, as it is beyond the scope of the current study. The findings presented here highlight the potential of combining Dynamic Time Warping with KNN classifiers for improved gait and walk identification, as well as the advantages of using cloudlet-based MCC for real-time healthcare applications. The following sections of the paper will outline the system architecture, methodology, experimental results, and conclusion. Through this work, we aim to contribute to the development of more efficient and reliable assistive technologies for the elderly, enhancing their ability to live independently and safely.

II.METHODOLOGY

A) System Architecture

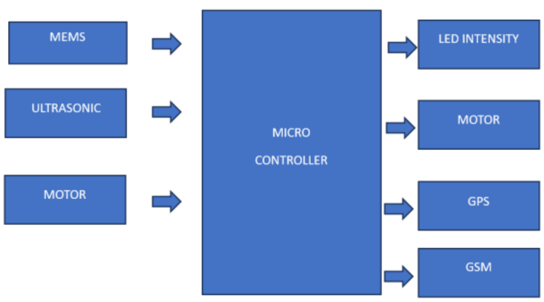

Fig1 .Block Diagram

The system architecture for a floor-based sensors walk identification system using Dynamic Time Warping (DTW) with cloudlet support consists of several key components. Floor-based sensors, such as pressure sensors or accelerometers, are installed on the floor to capture the movement and gait patterns of individuals as they walk. These sensors send real-time data to a local processing unit (such as a microcontroller or edge device), where Dynamic Time Warping (DTW) algorithms are applied to analyze and compare walking patterns. The processed data is then transmitted to a cloudlet for further analysis, which serves as a decentralized computing unit offering low-latency processing closer to the user. The cloudlet processes the data in real-time, identifies walking patterns, and stores them for future comparisons. The system enables the identification of individuals based on their unique walking gait, providing applications in security, health monitoring, or personalized services. The cloudlet support ensures scalability, low latency, and efficient data processing, while cloud integration allows for long-term data storage and analysis.

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 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. 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

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conditioner that can be controlled remotely via the internet. Given the widespread adoption of embedded systems across various industries.

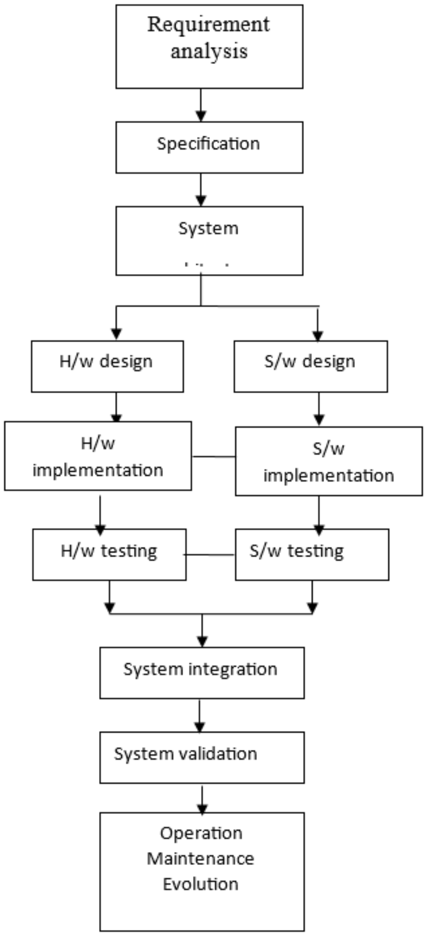

Fig 2. Embedded Development Life Cycle

III.CONCLUSION

In this study, we focused on analyzing the characteristics and behavior of sensor waveforms generated by subjects walking on a smart carpet system designed to monitor gait and detect falls. Seven subjects participated in multiple walking trials, and their sensor data were recorded and analyzed to explore the different patterns in the voltage waveforms. The results revealed distinct waveform behaviors, which allowed us to distinguish between different individuals using advanced computational techniques. We applied the Dynamic Time Warping (DTW) algorithm, which is particularly effective in handling time-series data with varying lengths, and coupled it with a K-Nearest Neighbor (KNN) classifier (with K=1) for accurate classification. This combination yielded impressive results, with an average precision of 86% and sensitivity of 76%, demonstrating the effectiveness of our approach in recognizing and distinguishing individual walking patterns. The high precision indicates that the system is highly accurate in identifying the correct person, while the sensitivity reflects the system's ability to correctly detect and classify individuals based on their unique gait characteristics. These results underline the potential of using machine learning techniques, such as DTW and KNN, in real-time monitoring systems designed for healthcare applications. However, the computation and data processing required for such algorithms are resource-intensive, especially when dealing with large volumes of sensor data from multiple subjects. To address these challenges, we proposed the integration of cooperative cloudlets into the system architecture. Cloudlets are small, localized cloud computing resources that are positioned closer to the user or sensor network, reducing latency and improving the efficiency of data processing. By utilizing cloudlets, we can offload the computationally expensive tasks from local devices to nearby servers, ensuring faster and more efficient processing of sensor data. This approach leverages the scalability and flexibility of cloud computing while minimizing the energy consumption and delays typically associated with traditional cloud systems, where data has to travel long distances. Cloudlets not only provide increased computational power but also ensure more accessible and timely access to the results through mobile devices, making the system more responsive and user-friendly. In addition, the use of cooperative cloudlets enables seamless data fusion from multiple sources, improving the accuracy of the system and enabling real-time decision-making for healthcare providers or caregivers. This model enhances the performance of the overall monitoring system, allowing for rapid identification of health issues, such as falls or changes in gait, which is crucial for elderly care and other medical applications. The cooperative nature of cloudlets ensures that the system remains scalable and adaptable to future needs, while also providing the necessary infrastructure for secure and efficient data transmission. Furthermore, the proposed cloudlet-based solution allows for better integration of real-time sensor data with healthcare platforms, facilitating quicker responses and improving patient outcomes. In conclusion, this research demonstrates the potential of combining advanced algorithms like DTW and KNN with cloudlet-based mobile cloud computing for real-time health monitoring systems. The results validate the feasibility of the proposed approach in achieving accurate individual identification through gait analysis, while also addressing the computational challenges associated with large-scale sensor networks. By incorporating cooperative cloudlets, we enhance the efficiency, scalability, and accessibility of the system, making it a promising solution for the healthcare sector, particularly in the context of elderly care and assistive technologies. Future work can explore further optimization of the algorithms and the integration of additional sensor modalities to improve the system's robustness and functionality.

IV.FUTURE SCOPE

The future scope of the floor-based sensors walk identification system using Dynamic Time Warping (DTW) with cloudlet support includes further enhancing accuracy and scalability by integrating AI and machine learning algorithms for more precise gait recognition and adaptive learning over time. With the growth of 5G technology, the system could enable real-time, high-speed data transmission, reducing latency even further. Additionally, cloudlet architecture could be expanded to support more advanced applications, such as multi-user identification and integration with smart home systems for personalized interactions. The system could also be extended to monitor health metrics, such as gait abnormalities, for medical applications, offering valuable insights into an individual's health over time.

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