A UWB based Tracking and Management System for Streamlining Steel Ladle Operations

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***Abstract*—Ladle monitoring systems are crucial for optimizing steel melting operations, enhancing material and equipment flow, reducing wait times, boosting production, facilitating rapid problem-solving, and ensuring steel quality. While GPS and RFID are common tracking methods, GPS's accuracy is indoor limited, and RFID's precision is constrained by range and proximity. However, a proposed Ultra-Wideband (UWB) system, offering precise tracking by utilizing radio waves. UWB translates pulses into data, operating at a high frequency. UWB anchors transmit signals to UWB tags, calculating roundtrip time for location determination (Time of Flight). These values are converted into location coordinates using a plane position algorithm and stored in a database. A web app in the centralized control system retrieves and displays tracked data, including the ladle's current position, ensuring efficient material flow and real-time monitoring of steel quality.**

Keywords—UWB, Plane position algorithm, ESP 32, Time of Flight, Turtle Graphics, Indoor Positioning System, Real Time monitoring, RFID and GPS

I. INTRODUCTION

Ladles are used to transfer the molten metal from one location to another. The ladles are logged and monitored to improve the distribution system's effectiveness. Ladle monitoring systems ensure precise control of molten steel, optimizing quality, efficiency, and safety through real-time monitoring and data analysis. RFIDs are now utilized with passive tags and antennae for tracking reasons. However, continuous monitoring and live placement were not possible. This causes unnecessary effort and time expenditure. To address these issues, this study suggests installing a steel ladle tracking and management system in the steel melting shops (SMSs) of steel plants. Accurate positioning is provided by the grey bus positioning system for a variety of uses, including position detection and unloading [1, 2] and laser ranging with a phototransistors array, a charge-coupled device (CCD), and laser triangulation [3, 4]. Repair costs for even minor damage to the grey bus are costly, and laser ranging is susceptible to vibrational inaccuracy. Technologies such as ultrasonic or infrared transmitters are used to track the location of objects in indoor environments [5- 8]. These transmitters can be put on stationary places like walls, ceilings, or pillars. The precision with which GPS can follow moving targets is increasing. Phones, pets, kids, merchandise, cars, and other vehicles are just some of the things that can be tracked with this technology [9-11].

When used indoors, GPS might need help with issues such as signal reflection or non-line-of-sight communication [12], making it less ideal than when used outdoors. The receiver's position can be estimated based on the strength of the signal it receives, thanks to the corresponding system. However, since these ultrasound and infrared sensors need a clear path of sight in order to function, they are rarely used in congested areas. Therefore, radio frequency identification (RFID) systems are preferable because of their ability to withstand vibration, their precision, and their low cost. Using radio frequency identification (RFID) tags attached to the item being monitored and readers reading the tags, real-time position tracking can be achieved. The passive RFID variety is the most common. When multiple tags are being read at once or when the tags are placed on or near conductive materials like water or metal, the signals can interfere with one another, leading to data loss [13-18]. Due to the mobile nature of cranes, wireless local area networks (WLAN) can be integrated for data transmission and terminals communication in place of wires or cables [19]. In conclusion GPS provides high accuracy outdoors but struggles indoors or in obstructed areas like steel plants due to signal blockage or multipath effects, whereas RFID offers precise indoor tracking within a limited range, suitable for localized tracking where GPS signals may be obstructed.

Ultra-Wide Band (UWB) is a special kind of Real-Time Location System (RTLS) that uses billions of RF pulses for transmission and reception [20]. UWB receivers work by picking up signals sent from transmitters and determining where those signals originated. As detailed in this paper, high accuracy and precision, greater performance in harsh conditions, low power consumption, and no interference from RF systems are just some of the advantages that UWB-based positioning offers over other RTLS technologies [21].

2024 10th International Conference on Advanced Computing and Communication Systems (ICACCS) | 979-8-3503-8436-9/24/$31.00 ©2024 IEEE | DOI: 10.1109/ICACCS60874.2024.10717148

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Time of Flight (ToF) calculations is used to determine distance in ultra-wideband (UWB) tracking. ToF is determined using triangulation, the sum of ranging and the time difference of arrival [22]. In order to map and display crucial steps in a process, UWB sensors are used in a technique known as digital value stream mapping [23]. Using UWB sensors for motion analysis has led to improved player performance, analysis, and tracking [24]. The orientation method [25] determines coordinates in an indoor Positioning System based on the measured distance.

Data integrity and security are essential aspects of database management [26], together with the syntax and execution of SQL commands for constructing and modifying tables, inserting and updating data, and obtaining data via queries. In this article, we look at the available resources and the basics of database modules that have been tested with Python [27].

The system aims to use UWB technology, a powerful and accurate indoor tracking technology, to keep tabs on the ladles, optimize the plan for their arrivals and departures from one region to another, and improve the ladles' mobility. there are many advantages to using UWB sensors for steel ladle real-time monitoring, such as improved safety, optimized material flow, decreased downtime, and improved steel quality, all of which eventually help the steel manufacturing sector become more efficient and competitive.Top of Form

II. General Structrue Of The System

The ESP 32 UWB DW1000 is a sensor that incorporates Wi-Fi module into its architecture. The transmitters and receivers of UWB technology are commonly referred to as anchors and tags. Tags are attached to the ladle, and Anchors are attached to the walls of the facility at predetermined intervals. The Table I shows the designation of Tag and Anchor of UWB module.

TABLE I. Designation Of UWB Module

S. No.	UWB Module ID	Designated as
1.	UWB module 1782	Anchor 1
2.	UWB module 1783	Anchor 2
3.	UWB module 1784	Anchor 3
4.	UWB module 1785	Anchor 4
5.	UWB module 1786	Tag 1

Anchors and tags communicate with one another via a technique called Pulse-Position Modulation (PPM). The distance between the tag and the anchors is determined by the Time of Flight (ToF) principle, which calculates the duration of the tag's signal transmission.

The Plane Orientation Algorithm is used to convert the distance to coordinates, and Python Turtle graphics are used to visually show the existence of a tag in a two-dimensional space. The coordinate values are retrieved from the database and subsequently presented on the website. Fig. 1 shows the general setup of this UWB-based Ladle tracking system.

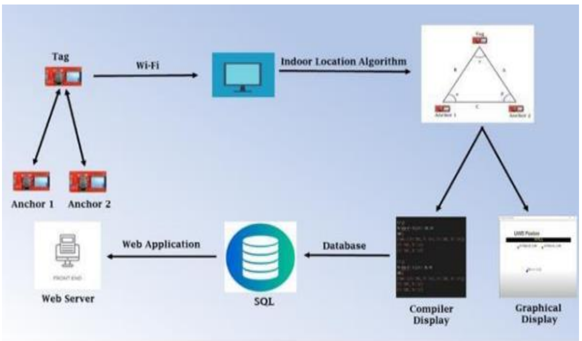

Fig. 1. Structure of The UWB Tracking System.

III. Hardware Scheme Of The System

A. Collection of Data from UWB

A UWB transmitter works by broadcasting billions of pulses across a wide spectrum of frequencies. Pulses are transmitted for every two nanoseconds, which helps UWB to achieve its real-time accuracy. UWB uses PPM technology for its transmissions. The digital data is represented as a sequence of pulses in the PPM protocol, and the relevance of the information being conveyed may be inferred from the timing of those pulses. The UWB anchors scan the room like radar, seeking for anything with a UWB tag that can generate radio waves at low frequencies. Once the tag and anchor connection has been made, the object will begin to learn its location and provide information.

UWB tags possess the capability to receive signals from all available anchors simultaneously, as they are not constrained to establish connections with particular anchors. As a result, this situation necessitates fixing the module's requirements of being reset every time to track the ladles. In order to overcome these challenges, with the UWB module the ESP 32 devkit V1 was connected and, the user remotely turn these pins on and off using the ESP 32 web server. The Python code used to get sensor data is the only thing that can limit the area that can be seen. The Fig. 2 shows the UWB and ESP 32 Dev Kit V1.

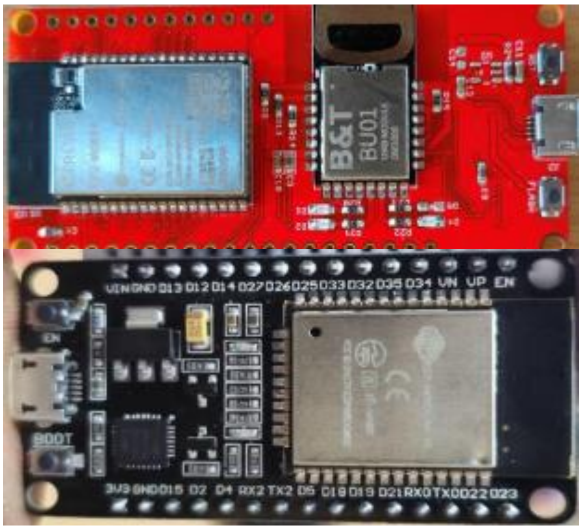

Fig. 2. UWB and ESP 32 Dev Kit V1.