Real-Time Social Distancing for Tackling COVID-19 in Workplaces Using Wearable Inertial Sensor

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Abstract: With the unprecedented outbreak of unknown pneumonia in Wuhan, China, in December 2019, a new coronavirus, Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), aroused the attention of the entire world. The World Health Organization (WHO) identified the pneumonia as Coronavirus Disease 2019 (COVID-19) and declared it as a Public Health Emergency of International Concern (PHEIC). Worldwide, several countries have adopted social distancing as the main strategy of limiting the spread of the virus. In this paper, we explored the effectiveness of the indoor positioning system based on Ultra-WideBand (UWB) technology specifically for keeping a social distance for the prevention of the COVID-19 infection in the workplace. In static and dynamic experiments, our verified system demonstrated a real-time 3D millimeter accuracy and simultaneous tracking of multiple wearable tags that successfully visualized in the 3D space, which provide an enough accuracy 3D positioning of around 100-150 mm for the monitoring of the infection process. The results indicated that 3D tracking of multiple tags effectively work in the real-time manner with a high accuracy 3D positioning, which is applicable to further detail analyses of how an infection happen and why a social distancing is important for the prevention.

Key words: Indoor positioning, IMU, inertial sensors, COVID-19, ultra-wideband.

1. Introduction

An outbreak of mystery pneumonia in Wuhan since December 2019 has been drawing enormous attention around the world. The causative agent of the mystery pneumonia has been identified as novel coronavirus (2019-nCoV) by the World Health Organization (WHO) on January 7, 2020 [1]. The virus was subsequently renamed Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), and the out- break of infections with SARS-CoV-2 was termed Coronavirus Disease 2019 (COVID-19). Then the WHO declared COVID-19 outbreak in China as a Public Health Emergency of International Concern (PHEIC) [2]. Coronaviruses are distributed broadly among mammals including humans and birds. Six species are known to cause human disease-229E, OC43, NL63, and HKU1 which cause common cold; severe acute respiratory syndrome coronavirus (SARS-CoV); and the Middle East Respiratory Syndrome coronavirus (MERS-CoV) [3].

Worldwide, several countries including Japan have adopted social distancing as the main strategy of limiting the spread of the virus. But this effective strategy enforces the closing of shops, factories and universities. Indeed, the life should continue and the workplaces should be able to keep their business and work as usual, but for the purpose of preventing new outbreaks measures must be taken. This is where an accurate indoor positioning system for tracking workers can assist to enforce social distancing for tackling COVID-19 in workplace.

Social distancing is effective to track the people for example within a workplace and save their positions for further reference. Accordingly, the one who tracked and showed symptoms of the virus, it can easily list the areas in which this worker was active in the past two weeks. Based on this information, only the target areas have to be disinfected and can be reopened quickly. Using the contact tracing history, a list of workers can be identified which were within close proximity in the past two weeks and would be at risk of infection. These people could be subjected to a test to see if they are safe. For tackling COVID-19 in workplace, distance of at least 1 m (3 feet) should be maintained between individuals and those having coughing, sneezing, and fever. Therefore, an accurate position system is required. In addition, sensing location information in indoor environments requires a high precision because various objects reflect and disperse signals. This is where an UWB technology is recommended to use in the field of indoor positioning that has shown better performance compared to other technologies.

2. Methodology

2.1. Wearable Inertial Sensor

Wearable inertial sensors have been developed extensively over the past several years. Inertial sensors typically come in the form of an Inertial Measurement Unit (IMU) which consists of accelerometers, gyroscopes and sometimes also magnetometers. It can be embedded in the body, such as the trunk, leg, arm, etc [4].

Nine-axis IMU with a three-axis acceleration sensor, three-axis gyroscope and three-axis gyroscope magnetometer can measure the linear acceleration, rotational rate and a heading reference respectively. In recent years, wearable sensors based on miniaturized IMU are increasingly being used in various applications includes the tracking of human activities [5]. Hence, the position and motion of object can be detected and tracked accurately.

Despite the advantage of an inertial sensing which is not require an external reference for calculation the rotation and position of the object, it suffer from accumulated errors and therefore is subject to drift. Because these systems measure relative positions instead of absolute positions. Accordingly, a periodic re-calibration of the system can provide more accuracy or positional tracking systems like GPS or other technology would be used to continually correct drift errors. In this study research, real-time desired social distancing is to be achieved with precise positioning that's accurate up to centimeter. This naturally leads us to choose the UWB technology.

2.2. Ultra-WideBand Technology

In fact, UWB is a radio technology based on the IEEE 802.15.4a and 802.15.4z standards that can enable the high accurate measure of the Time of Arrival (TOA) of the radio signal, leading to centimeter accuracy distance/location measurement. The main three areas where UWB can be highly used are (1) communication and sensors; (2) positioning and tracking; and (3) radar [6]. According to our research, positioning and tracking is to be investigated based on inertial sensors. UWB is an emerging technology in the field of indoor positioning that has shown better performance compared to the existing wireless technologies, such as Wi-Fi, Bluetooth and GPS [7].

In literature, a number of positioning algorithms have been proposed for the positioning problem based on some estimating measurements: (1) time of arrival (TOA); (2) angle of arrival (AOA); (3) received signal strength (RSS); (4) time difference of arrival (TDOA); and (5) hybrid algorithm [7]. TOA algorithm is selected to investigate the position and tracking system. It has higher accuracy relative to other algorithms because of the high time resolution of the UWB signals. 3D positioning with centimeter accuracy would be achieved to enforce social distancing with the use of UWB technology. A lot of benefits behind using UWB including high accuracy positioning, provides wireless message communication that enables automation and communication, the signals can penetrate walls and make it suitable for indoor environments and an efficient Time-of-Flight calculation. In addition, UWB will not interfere with existing RF systems if properly designed.

High bandwidth and signal modulation of UWB technology leading to not affected by the existence of other communication devices or external noise [8]. Furthermore, unlike other positioning technologies, it does not require a line-of-sight which is suitable to deploy in indoor positioning system (IPSs). Various IPSs were implemented commercially using UWB such as Ubisense system [9] and POZXY system [10].

In this paper a method to enforce social distancing with the use of UWB based on POZXY system is proposed. POZXY system is used to implement the measurement system of position and motion in XYZ with high accuracy. The system consists of anchors and developer tags as presented in Fig. 1 [10]. Anchors are the cornerstone of successful positioning and used as a reference points for the tags and their positioning algorithm. They capture signals, process data, and make it available to the central engine for further analysis. Developer tag is a shield that provides accurate positioning and motion information using 9-axis IMU and an UWB transceiver. With its small size and incredible battery life, the developer tag can be wearable. Anchors at known locations exchange signals with a wearable developer tag to the purpose of estimating its position from range measurements. Using the wireless two-way ranging (TWR) with the anchors based UWB technology, positioning is achieved. To perform 3D positioning, 4 anchors are required while with 3 anchors it is possible to describe a 2D coordinate system.

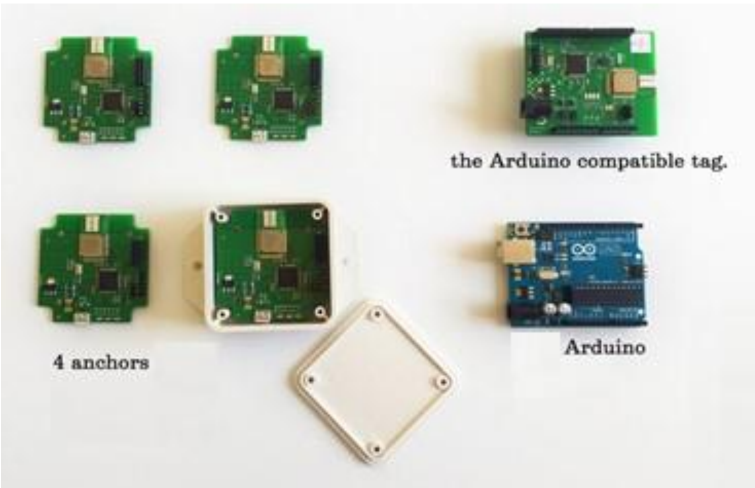

Fig. 1. The full POZYX system devices.

3. Experiments

3.1. Experiment Setup

The experimental setup of POZYX system has been established successfully in real environment. In particular, we consider a network of anchors deployed inside a university laboratory or workplace and emitting UWB signals. Their locations are known while the unknown coordinates of a wearable developer tag must be determined from TWR measurements.

Fig. 2 shows the coordinates of four anchors which are sufficient to accurately estimate the 3D position of a user as it moves inside a laboratory. It can be seen the X, Y, Z coordinate and the distance between each anchor. To increase the system's performance, the UWB parameters are carefully selected. It is defined in a way that all devices (anchors and tags) in the system must be on the same UWB settings to compatibly work together.

As recognized in the IEEE standard 802.15.4a, a number of UWB channels of at least 500MHz wide are defined. The lower the channel center frequency, the better the range. Therefore, in this experimental research, channel 2 was selected which has 3993.6 MHz Center frequency and 499.2 MHz Bandwidth. The data bitrate is 110kbit/sec, Pulse Repetition Frequency (PRF) is 64MHz and Preamble length is 1024. After that the positioning settings is also defined before proceed to the experiments. The operation of the positioning algorithm based on TOF was configured. Moving average filter for 3D position is selected. Ultimately, the configuration system is ready to be used and the experiments have been accomplished successfully as introduced in the next subsection.

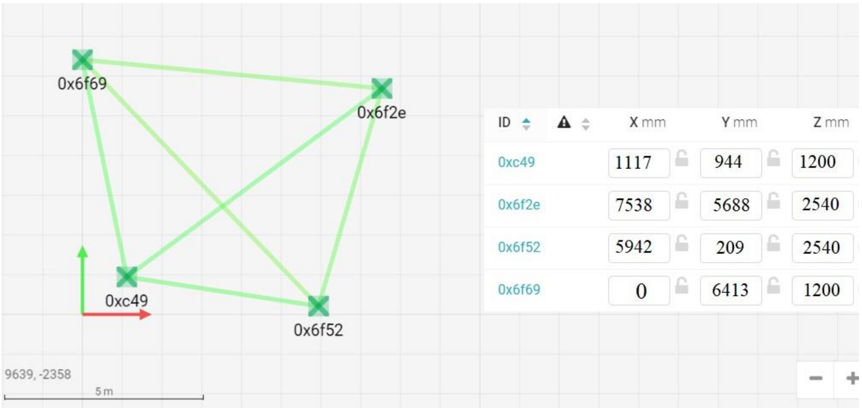

Fig. 2. The experimental setup for POZYX coordinate system.

3.2. Static and Dynamic of Single and Multi-tag Positioning

After the experimental setup was successfully set, the experiment test was performed within work space of 7m x 8m. For this test, four anchors were used, placed at known locations as previously mentioned. Both static and dynamic experiments were undertaken using three tags to test the single and multi-tag UWB positioning system. First of all, a master static single tag connected with Arduino Uno compatible tag in which it was used to implement the algorithm of tracking position and to communicate with anchor. This tag (Tag 2) was fixed on a constant object (end effector of robot arm) as shown in Fig. 3. Its position was calculated (4736, 2558, -755) (x, y, z) [mm]. A static tag can help in mitigating error caused by UWB receivers and accumulated error of IMU since this error is consistent across all tags being positioned [11].

After that a dynamic experiment was performed using multiple tags where two wearable tags move inside the workplace while the other tag serves as a reference in a static location as presented in Fig. 3. Real-time 3D tracking of wearable multiple tags was successfully determined as illustrated in Fig. 4. The raw position data received at the computer through Arduino serial communication where each row is representing the 3D positions of tag 1, tag 2 and tag 3 as presented in Fig. 4. The distance between tags can be easily calculated in 3D space so that it easy to enforce social distancing and create a safe workplace for everyone. The accuracy of real-time measurement was calibrated for single and multiple tags. The results shown 3D tracking of multiple tags in real-time with high accuracy 3D positioning of around 100-150 mm which is acceptable for social distancing purpose.

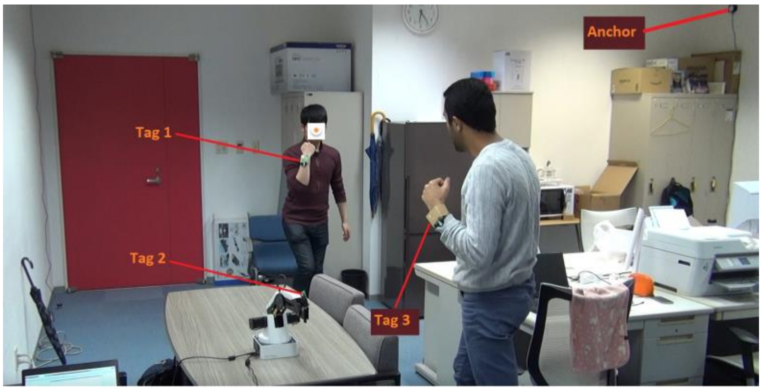

Fig. 3. Single and multi-tag positioning experiment taken in a workplace as a study case.

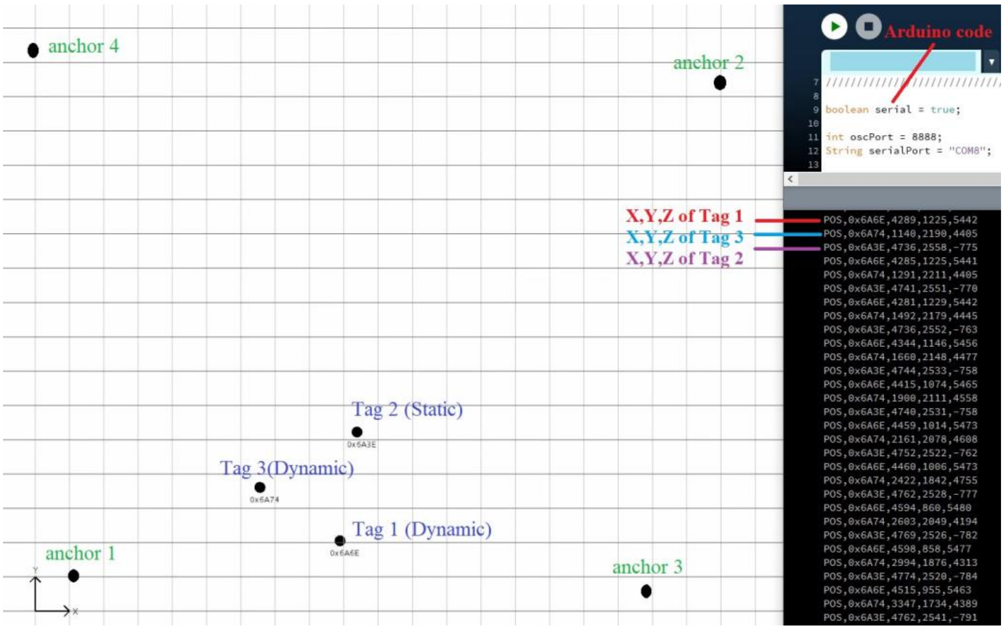

Fig. 4. The static and dynamic experimental result of Multi-tag positioning.

4. Discussion

A possibility of the IMU based position system with the UWB communication for applying to measurements for social distancing on COVID-19 was discussed [12]; however, those properties in spatial and temporal domains were unclear in the actual workspace environment. Distancing with at least 1 m (3 feet) is highly recommended to prevent an infection between individuals who have symptoms such as coughing, sneezing, and fever and the actual infection mechanism still remain hidden from view. Therefore, real-time accurate position system is beneficial for the clarification of the infection process. Our experimental framework is not only available for detecting individual distances at a workspace but also can be extended to a context-dependent distancing in a complex environment with transparent barriers against infection in specific areas. For example, a static tag can help in mitigating error caused by UWB receivers and accumulated errors of IMU. Visualizing of physical distances associated with other environmental properties and face-to-face physical positioning of counterparts has a high expectation for analyses of the infection mechanism, developments of the effective distancing methods and technological improvements for the purpose.

5. Conclusion

Measures at workplace based position system should include social distancing for tackling Covid-19. Technology can be used to enforce the social distancing by tracking worker's movements via wearable tags, potentially sending alerts when the distance rules are breached. A possibility of the IMU based position system with the UWB communication for applying to measurements for social distancing was introduced. Our experimental results clearly demonstrated the 3D tracking of single and multiple tags in real-time with the accuracy 3D positioning of around 100-150 mm, which can be updated in 10 ms order (100Hz). Future work includes dynamic experiments tracking more tags (e.g. 10-20) in real-time inside the workplace which may be blocked by thick walls or metallic obstacles and risk-benefit analyses with individuals as risks and barriers as benefits.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

The contributions of authors are as follows: Conceptualization, Ahmed M. M. Almassri; methodology, Ahmed M. M. Almassri; data collection, Ahmed M. M. Almassri and Natsuki Shirasawa; Funding acquisition, Hiroaki Wagatsuma; Investigation, Ahmed M. M. Almassri and Hiroaki Wagatsuma; Validation, Ahmed M. M. Almassri and Natsuki Shirasawa; Writing—original draft, Ahmed M. M. Almassri; Writing—review and editing, Hiroaki Wagatsuma; All authors have read and agreed to the published version of the manuscript.

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