Supporting personnel in warehouses with an inertial measurement unit

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Abstract

Reducing the number of misplaced items in warehouses has a huge impact on the efficiency of companies. These human errors can cause a significant loss of money and time. Therefore, supporting warehouse staff is crucial. Currently proposed solutions use ultrasonic technology. In this paper we experiment with inertial measurement units (IMU) to test if they are capable of fulfilling the same needs. Particularly, we develop a wristband protoype using commodity smartphone IMU. This device is validated in an experiment where items are between containers.

Contents

List of Acronyms and Abbreviations

IMU Inertial Measurement Unit

RFID Radio-Frequency Identification

1 Introduction

In the past, several companies introduced certain devices to track motions of their employees and goods in warehouses in order to support employees there. Due to high labor cost, it is crucial that picking items is efficient [1]. These are either dedicated devices, using different ways to operate (e.g. wristbands using ultrasonic or voice-assisted technology [2]. Amazon wants to measure arm movements and eventually give haptic feedback to the worker. This creates technological challenges to be precise enough with a low error rate. However, it raises ethical questions. For instance, will employers abuse their tracking capabilities to put pressure on employees, or track during breaks or other private activities?

1.1 Problem Statement

Wristband solutions mentioned in the previous section are either not dedicated to supporting activities in warehouses, e.g. fitness wristbands, or have not been made commercially available [2]. Common warehouse management technologies, for instance, pick-by-voice, radio-frequency identification (RFID), or barcodes, support workers during their job [3]. However, workers still do mistakes which require post-correction or compensations implying a higher cost. Goods can lose traceability when wrongly placed. This decreases productivity and slows down the speed of delivery. Finally, it results in higher cost. Looking at the above mentioned initiative from Amazon, it can be examined whether wristbands can be used to identify errors by humans when placing items.

1.2 Theoretical framework/literature study

"An inertial measurement unit (IMU) is a small and portable device that combines information obtained from multiple electromechanical sensors (e.g. accelerometers, gyroscopes, and magnetometers)"[4]. The usage of IMU to detect human body motion has been proofed by several studies in the past [4] [5] [6].

All IMU sensors are sourceless, meaning that they work independently. However, especially in small wearable devices, they are very noisy. [7]. A common method to reduce this noise is the Kalman filter [8]. It allows to reduce the impact of the noise by mathematical calculations. Kalman also provides a prediction feature to correct the gyroscope drift [9] [10].

1.3 Research questions, hypotheses

Regarding at recent literature, we can see that several solutions exist for displacement tracking using ultrasonic sensors [11]. However, we would like to experiment with an IMU and find out if it is capable of executing similar measurements. Our hypothesis is that IMU would be precise enough to detect placing an item had been inside the correct container or not. In this scenario we assume that the containers are around the size of 50-100 cm wide and long.

1.4 Ethics and sustainability

Regarding ethics and sustainability aspects of introducing wristbands with tracking capabilities for employees, several questions and side effects arise. From an ethical perspective, there are three main concerns:

- to what extend is the privacy of an employee guaranteed?
- Is the employer able to abuse these tracking capabilities and will he use them?
- Do employees have the possibility to pause or stop the tracking mode? Are they even allowed to take off the bracelet?

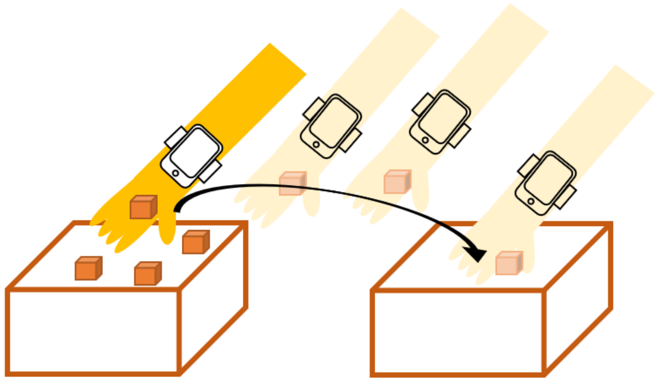

Figure 1: Setup of the experiment (own representation)

The sustainability aspects of wristbands affect the bracelet itself rather than the employees. Subject of investigation is the production with regards to the environmental-friendliness. This covers the production line as well as the usage of recyclable materials for the wristband (e.g. leather or bio-degradable polymers). Finally, it can be questioned what happens when a device is worn off or its battery needs replacement. In this case, the device's modularity plays an important role.

2 Method(s)

The method of this project is empirical prototyping and an experiment. A regular smartphone will be used for the app. Simple software will run on the device that will analyze the sensor output data. Creating our own microprocessor (Arduino) device would require more time than is available during the course. We believe a smartphone is the best way to approach this problem as we already have such a device and it already contains the IMU and easy to write applications for this Android smartphone.

2.1 Experiment

In order to test the prototype, we will conduct experiments, rather than rely on simulations, e.g. an Android studio development environment. We rather ask users to move items between two containers. The following setup is made: placing two square boxes of tens of centimeters close to each other. Using the hand with the "wristband" (smartphone attached to wrist), the balls in one container are grabbed and moved to the other container one by one. Negative tests are done, too. In this case, the items will be deliberately moved to a wrong place outside of the container. The app will detect if the placement is correct or not. We will consider a video recording of the experiment. We want to collect the data on the mobile device after every try. Furthermore, publications will be analyzed in order to have a clear understanding of the current technologies used.

We aim to conduct the experiment with a small number of persons, including us. All participants will be adults and in good health condition. Ethical concerns regarding data privacy are not expected because we do not collect data which can be rooted back to the participant. Although the exact setup needs to be determined, we consider a small number of repetitions for each person.

2.2 Development of a Prototype

We implement our own software for Android operating system[12]. The integrated development environment for our application and to deploy it to the mobile device is Android Studio [13] . We decided to use Java programming language [14] for this project. Our test device is a Xiaomi Redmi Note 4 mobile phone [15] and its inbuilt measurement units. A second device is a Motorola G5 Plus [16].

For the implementation, we take advatage of already existing libraries on GitHub to avoid implementing complex algorithms, especially Kalman filter [17]. In our application, we use two GitHub [18] projects. After collecting the sensor data, we use FSensor [19] to filter the data. This helps us filter out the noise and keep the useful data. This step is an important step as the raw data is very noisy, as mentioned in section 1.2 . In the next step, the acceleration data is integrated twice to get the position. At this point, GraphView [20], another GitHub repository, is used. It provides a simple way to plot data on the phone screen. This method displays the X and Y position data and the results can be viewed. After starting the app, the tracking starts and automatically stops after a few seconds, concluding the results. This time is long enough to perform the movement of placing the item from one container to another but short enough not to accumulate too much error increasing the accuracy of the final position.

3 Results and Analysis

Up until now, we have run our newly developed app a few times and tested it by moving the phone without any complex setup. Fig. 2 shows an example picture of the result we can see on the phone screen after the measurement ends. Right now, the app needs more development but we can see on the upper graph that the phone was moved along the x-axis. The figure shows that the displacement was around one meter. The lower graph shows that there was a slight change of position along the y-axis which could also be just error. Under the graphs, we can see four numbers, which are currently not well-divided but the first two show the acceleration data of the x and y axis, respectively. The last two show the change of position in these axises. Finally, at the bottom, we can see the real-time acceleration of the phone.

In conclusion, our current achievements are a position tracker algorithm and the visualization of the results. We can measure the approximate distance of movements, although we have not yet scientifically validated the accuracy. More tests are needed to be able to conduct a thorough analysis on the gathered data.

4 Discussion

For a proper discussion, it is necessary to fully test the prototype and to conduct the experiment.

References

[1] E. Frazelle, *World-class Warehousing and Material Handling*. New York N.Y.: McGraw Hill, 2002. ISBN 9780883184080

[2] Samuel M. Berger and Timothy D. Ludwig, “Reducing warehouse employee errors using voice-assisted technology that provided immediate feedback,” *Journal of Organizational Behavior Management*, vol. 27, Jun. 2007. [Online]. Available: https://doi.org/10.1300/J075v27n01_01

[3] A. Daria Battini, Martina Calzavara and Fabio Sgarbossa, “A comparative analysis of different paperless picking systems,” *Industrial Management and Data Systems*, vol. 115, pp. 483–503, 2015. [Online]. Available: https://doi.org/10.1108/IMDS-10-2014-0314

[4] Z. M. Wenjin Tao and Zhaozheng Yin, “Accuracy and repeatability of an inertial measurement unit system for field-based occupational studies,” *Ergonomics*, vol. 59, p. 591–602, Apr. 2016. [Online]. Available: DOI:10.1080/00140139.2015.1079335

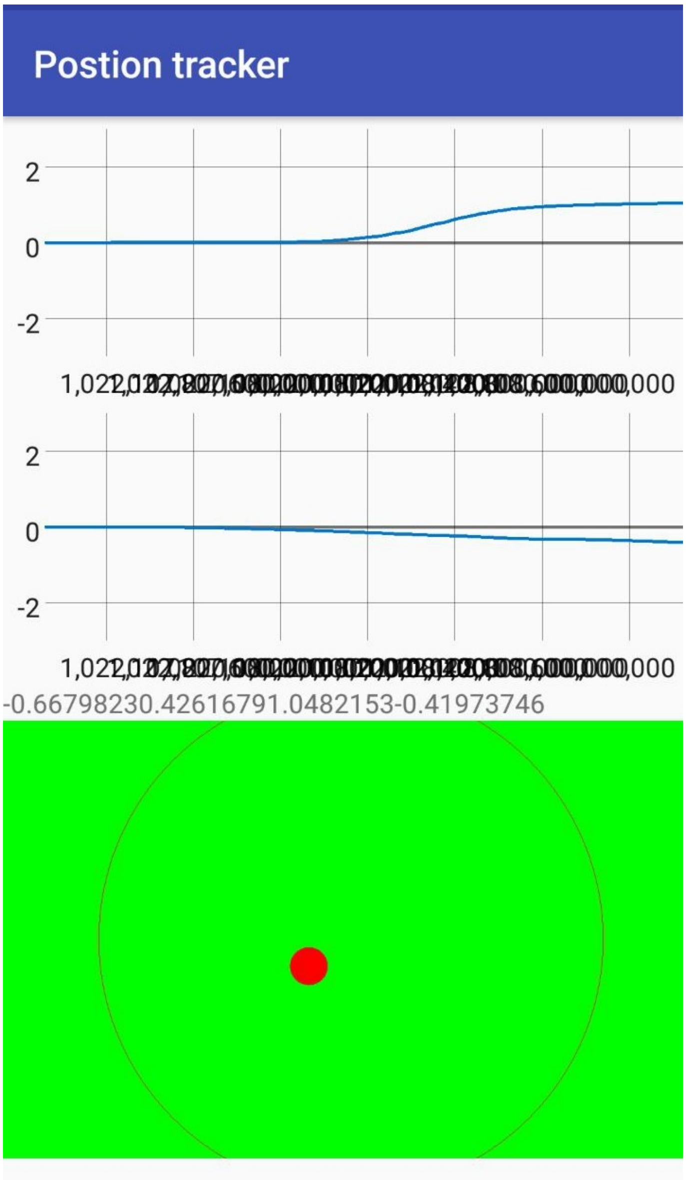

Figure 2: Screenshot of the position tracker app after conducting the test (own representation)

[5] M. Wenjin Tao, Ze-Hao Lai and Zhaozheng Yin, "Worker activity recognition in smart manufacturing using imu and semg signals with convolutional neural networks," *Procedia Manufacturing*, vol. 26, pp. 1159–1166, Apr. 2017. [Online]. Available: DOI:10.1016/j.promfg.2018.07.152

[6] C. Marcus Georgi and Tanja Schultz, "Recognizing hand and finger gestures with imu based motion and emg based muscle activity sensing," *Proceedings of the International Joint Conference on Biomedical Engineering Systems and Technologies*, vol. 4, p. 99–108, Apr. 2015. [Online]. Available: DOI:10.5220/0005276900990108

[7] A. Gallagher, Y. Matsuoka, and W.-T. Ang, "An efficient real-time human posture tracking algorithm using low-cost inertial and magnetic sensors," in *Intelligent Robots and Systems, 2004.(IROS 2004). Proceedings. 2004 IEEE/RSJ International Conference on*, vol. 3. IEEE, 2004, pp. 2967–2972.

[8] R. E. Kalman, "A new approach to linear filtering and prediction problems," *Journal of basic Engineering*, vol. 82, no. 1, pp. 35–45, 1960.

[9] G. Welch and G. Bishop, "An introduction to the kalman filter," 1995.

[10] H.-J. Lee and S. Jung, "Gyro sensor drift compensation by kalman filter to control a mobile inverted pendulum robot system," in *Proceedings of the 2009 IEEE International Conference on Industrial Technology*, ser. ICIT '09. Washington, DC, USA: IEEE Computer Society, 2009. doi: 10.1109/ICIT.2009.4939502. ISBN 978-1-4244-3506-7 pp. 1–6. [Online]. Available: https://doi.org/10.1109/ICIT.2009.4939502

[11] Y. Qi, C. B. Soh, E. Gunawan, and K.-S. Low, "A wearable wireless ultrasonic sensor network for human arm motion tracking," *Conference proceedings : Annual International Conference of the IEEE Engineering in Medicine and Biology Society. IEEE Engineering in Medicine and Biology Society. Annual Conference*, vol. 2014, 2014.

[12] https://www.android.com/, last accessed on 10-10-2018.

[13] https://developer.android.com/studio/, last accessed on 10-10-2018.

[14] https://docs.oracle.com/javase/8/docs/technotes/guides/language/index.html, last accessed on 10-10-2018.

[15] https://www.mi.com/in/note4/, last accessed on 10-10-2018.

[16] https://www.motorola.com/us/products/moto-g-plus, last accessed on 11-10-2018.

[17] P. Zarchan and H. Musoff, *Fundamentals of Kalman Filtering: A Practical Approach*, ser. Fundamentals of Kalman filtering: a practical approach. American Institute of Aeronautics and Astronautics, Incorporated, 2000. ISBN 978-1-56347-455-2. [Online]. Available: https://books.google.se/books?id=AQxRAAAAMAAJ

[18] https://www.github.com, last accessed on 11-10-2018.

[19] https://github.com/KalebKE/FSensor, last accessed on 10-10-2018.

[20] http://www.android-graphview.org/, last accessed on 10-10-2018.