Enhancing Ultra-Wideband(UWB) Localization Accuracy using Spatial Filtering

Fahad Alsifiany
King Fahad Security college
Email: sufyanyf@kfsc.edu.sa
ID: 20004

A short resume of the presenter

- Fahad Alsifiany received the B.Sc. degree in electrical and electronic engineering from King Abdulaziz University, Jeddah, Saudi Arabia, in 2000.
- Fahad received the M.Sc. degree in telecommunications and networking from the University of Pittsburgh, Pittsburgh, USA, in 2011.
- Fahad received the Ph.D. degree with the Intelligent Sensing and Communications Group, Newcastle University, Newcastle upon Tyne, U.K, in 2020.
- From 2001 to current, Fahad was a Lecturer with the Faculty of King Fahad Security College, Riyadh, Saudi Arabia.
- Fahad also currently holds the position of Assistant Director of the Institute for Postgraduate Studies
- Fahad current research interests include, noncoherent systems, physical layer security, UWB, AI, and massive MIMO.

Introduction(1)

A. Localization systems

- Localization refers to the process of determining the exact or tentative location of an object, machine, or person in an indoor or outdoor environment.
- Most of the existing localization systems utilize technologies such as Wi-Fi, Radio Frequency Identification (RFID), Infra-Red(IR), Global Positioning Systems(GPS), and Ultra-Wideband (UWB).

Introduction(2)

- Some of the aforementioned technologies have been utilized outdoors such as GPS, while others such as UWB has proven to be efficient in both indoor and outdoor environments.
- Despite being in existence for a long time, Ultra-WideBand (UWB) technology has not been fully exploited.

Introduction(3)

B. Accuracy in UWB systems

- UWB technology uses a broad spectrum of frequencies to transmit data over short distances with high data rates, with more accuracy in positioning as compared to other technologies.
- Improving the accuracy of UWB localization systems would offer a futuristic solution to our growing localization needs, which can be done using advanced signal processing algorithms such as spatial filtering and Machine Learning(ML) algorithms.
- Also optimized antenna rays have been proposed to play an important role in achieving high spatial resolution and accuracy for these systems.

Statement of the Problem

- There is need to improve UWB accuracy to make it a reliable choice for demanding applications.

- While UWB technology offers many advantages, its accuracy limitations can hinder its adoption in applications that require precise location tracking.

- This research aims to address this challenge by exploring the use of beam-forming, a spatial filtering technique, to suppress unwanted signals caused by multipath and interference. By improving UWB accuracy, we can unlock its full potential for various real-world applications.

Aims and Objectives

This research has three specific goals:

- Develop a spatial filtering technique: To achieve this, we will explore the use of beam-forming as a method to filter out unwanted signals and improve the accuracy of UWB localization.

- Implement a conventional beam-forming algorithm: We will implement a standard beam-forming algorithm to enhance UWB signal directionality, reducing interference from unwanted signals arriving from other directions.

- Evaluate performance gains: Through real-world experiments and simulations, we will evaluate the effectiveness of the implemented beam-forming approach in improving UWB localization accuracy.

Related Work

- Related work in UWB localization includes studies on adaptive Kalman filters for accuracy improvement, UWB positioning in varied environments, drift correction algorithms, digital twin concepts, and strategies to mitigate human occlusion effects, enhancing UWB system performance.

Theoretical Framework(1)

A. UWB technology

UWB technology utilizes a much wider frequency spectrum compared to traditional wireless communication methods, typically ranging from 3.1 GHz to 10.6 GHZ. This broad bandwidth offers the following advantages:

- Resistant to multipath loss
- Ability to transmit signals through opaque media
- UWB technology can operate at very low power.
- UWB signals are difficult to detect due to their wide bandwidth.
- It provides robust communication due to its large processing power.
- High data rates

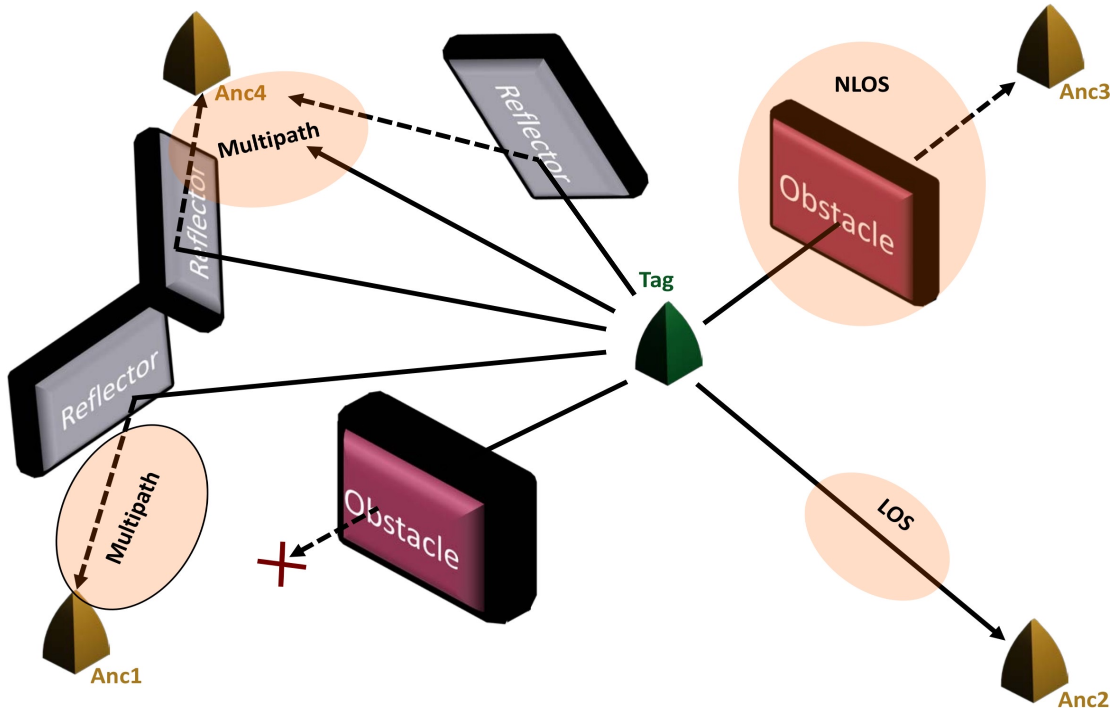
Theoretical Framework(2)

B. (LOS) and (NLOS) propagation of UWB signals

- Line of Sight (LOS) propagation of UWB signals occurs when the signals travels in a straight line between a transmitter and receiver without any significant obstructions.
- However in real world environments, there are obstacles such as buildings, trees, and walls which leads to Non-Line of Sight(NLOS) propagation which can significantly affect the performance and reliability of UWB systems.
- Techniques such as adaptive antenna rays, Time-of-Arrival estimation, and angle-of –arrival estimation can be used to improve signal quality and reduce errors in UWB communication systems.

Theoretical Framework(3)

- The figure below shows Line of Sight (LOS) and Non-Line of Sight (NLOS) propagation of UWB signals.



Theoretical Framework(4)

C. UWB Localization systems

UWB localization systems utilize different algorithms for measurement approximations. These algorithms include:

- Time of Arrival (TOA)
- Angle of Arrival (AOA)
- Received Signal Strength (RSS)
- Time Difference of Arrival (TDOA)
- Hybrid Algorithms

Methodology(1)

- The Qorvo DWM1000 IC Modules were used as UWB transceiver modules in different setups.
- In one setup, a Qorvo DWM1000 module was designated as the anchor transceiver, and another transceiver was placed 30 meters away as the tag transceiver.
- The location of the tag transceiver was determined from the anchor transceiver, and the measured distances were recorded and compared to the actual distances.

Methodology(2)

- In another setup, the tag transceiver was moved to 90 and 160 meters in two environments.
- One environment was an indoor cluttered space to test UWB performance with multipath effects.
- The other environment was an outdoor space with a clear line of sight.
- Five UWB transceivers were placed at similar distances in both environments.
- Localization was done, and the measured distances were recorded.

Methodology(3)

- The accuracy for the developed system was then evaluated as a percentage using the ranged and the actual distances, and the corresponding Signal-to-Noise (SNR) Ratio recorded.
- The behavior of this system was then modeled on MATLAB software. A conventional beam-forming algorithm was then developed.

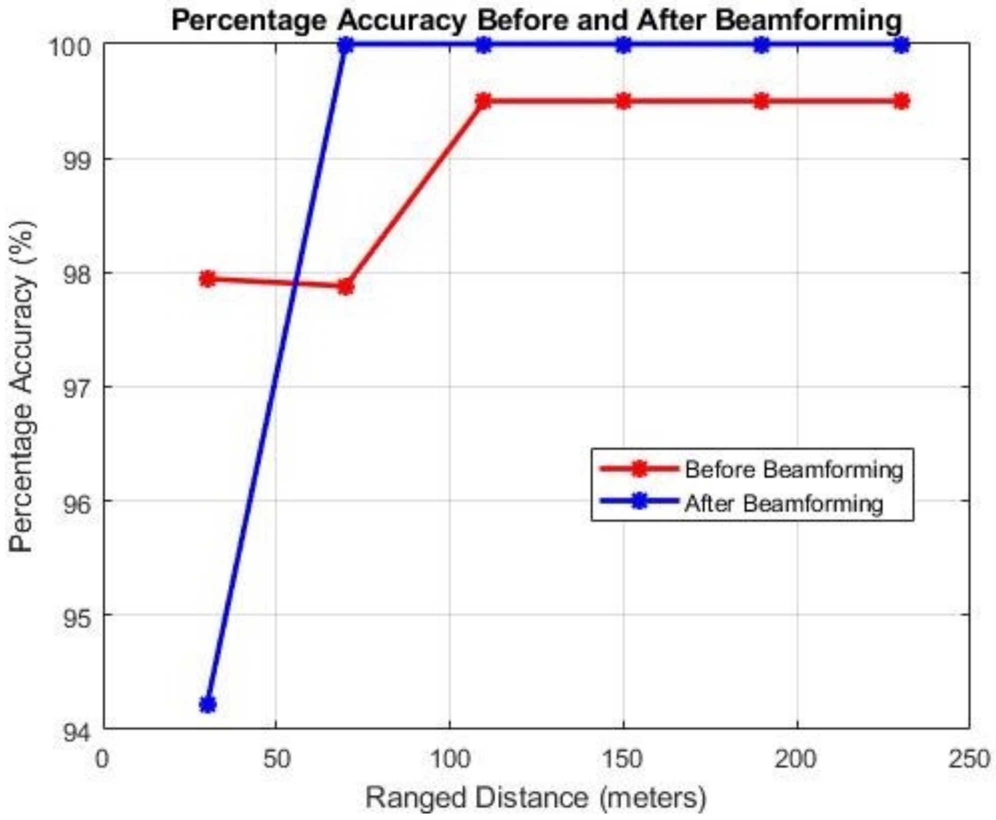
Methodology(4)

- To improve UWB localization, a beam-forming algorithm focuses received signals toward the target.
- Channel gains, time delays, and noise, affect the received signals ($y_i(t)$).
- Beam-forming weights (w_i), are calculated based on carrier frequency (f_c) and time delays (τ_i).
- Combining signals with weights creates the beam-formed signal ($s(t)$).
- Time delay (τ) is estimated from $s(t)$ and used to calculate distance (d) using the speed of light (c).

Results(1)

- The figure in the next slide is a plot of the accuracy before beam-forming and after beam-forming. The maximum realized ground-truth accuracy for the developed system was around 99.5% while the maximum accuracy realized after beam-forming was 100%.

Results(2)


Percentage Accuracy Before and After Beamforming
Percentage Accuracy (%)
100
99
98
97
96
95
94
0
50
100
150
200
250
Ranged Distance (meters)
Before Beamforming
After Beamforming

Results(3)

- There was a significant reduction in the amplitude of the beam-formed signals compared to the original signals.
- This property is associated with beam-forming, where energy is directed in a particular direction, resulting in lower amplitudes in other directions.
- However, this does not necessarily depict the efficiency of the developed conventional beam-forming algorithm.

Results (SNR)

- In an attempt to establish the accuracy of the system, the Signal-to-Noise Ratio (SNR) metric was used.
- By analyzing the change in SNR before and after beam-forming, there was a significant measure of improvement in signal quality, which in turn played an important role in maximizing local accuracy.

Conclusion

- Beam-forming improves UWB localization accuracy through focused power, even with lower signal amplitude.
- Multiple antennas enhance accuracy by mitigating multipath fading in NLOS environments.
- The system requires multiple antennas, increasing implementation cost.
- Future work aims to combine beam-forming with machine learning for further improvement and real-world application.

References

- Chen Yi, An Ze Da, Chen Hui, Chen Shan, Zhou Xuan (2021). A UWB Location Algorithm Based on Adaptive Kalman Filter. Journal of Physics: Conference Series, 3(2).
- Zirui Wang, Shaoxian Li, Zhengyuan Zhang, Fan Lv, Yanzhao Hou (2018). Research on UWB Positioning Accuracy in Ware- house Environment. Elsevier.
- Ping Lou, Qi Zhao, Xiaomei Zhang, Da Li and Jiwei Hu (2022). Indoor Positioning System with UWB Based on a Digital Twin. MDPI, sensors. Shang-Hsien Lin, Hung-Hsien Chang Chien, Wei-Wen Wang, Kuang-Hao Lin and Guan-Jin Li (2022). An Efficient IAKF Ap- proach for Indoor Positioning Drift Correction. MDPI, Sensors.
- Hao Zhang, Qing Wang, Chao Yan, Jiujing Xu and Bo Zhang (2022). Research on UWB Indoor Positioning Algorithm under the Influence of Human Occlusion and Spatial NLOS. MDPI, remote sensing, 4(2).
- Yiyang Liu (2023). Research on indoor positioning algorithms based on Ultra-WideBand technology. SPIE Digital Library.
- Umma Hany and Lutfa Akter (2023). Accuracy of UWB Path Loss-Based Localization of Wireless Capsule Endoscopy. Hin- dawi Publishers, 14(2).
- Fuhu Che, Qasim Zeeshan Ahmed, Pavlos I. Lazaridis, Pradorn Sureephong and Temitope Alade (2023). Indoor Positioning Sys- tem (IPS) Using Ultra-Wide Bandwidth (UWB)—For Industrial Internet of Things (IIoT). MDPI Sensors, 7(2).
- Sujata Mohanty, Aruna Tripathy and Bikramaditya Das (2020). UWB Based Indoor Localization Techniques. Proceedings of the National Conference on VSPICE 2020.
- Shang-Hsien Lin, Hung-Hsien Chang Chien, Wei-Wen Wang, Kuang-Hao Lin and Guan-Jin Li (2022). An Efficient IAKF Ap- proach for Indoor Positioning Drift Correction. MDPI, Sensors.
- Cung Lian Sang, Bastian Steinhagen, Jonas Dominik Homburg, Michael Adams, Marc Hesse and Ulrich Ru¨ckert (2020). Identifi- cation of NLOS and Multi-Path Conditions in UWB Localization Using Machine Learning Methods. MDPI Applied Sciences, 3(2).
- M. Schussel (2016). Angle of Arrival Estimation using Wi-Fi and Smartphones. Computer Science, 3(1).

Thank you