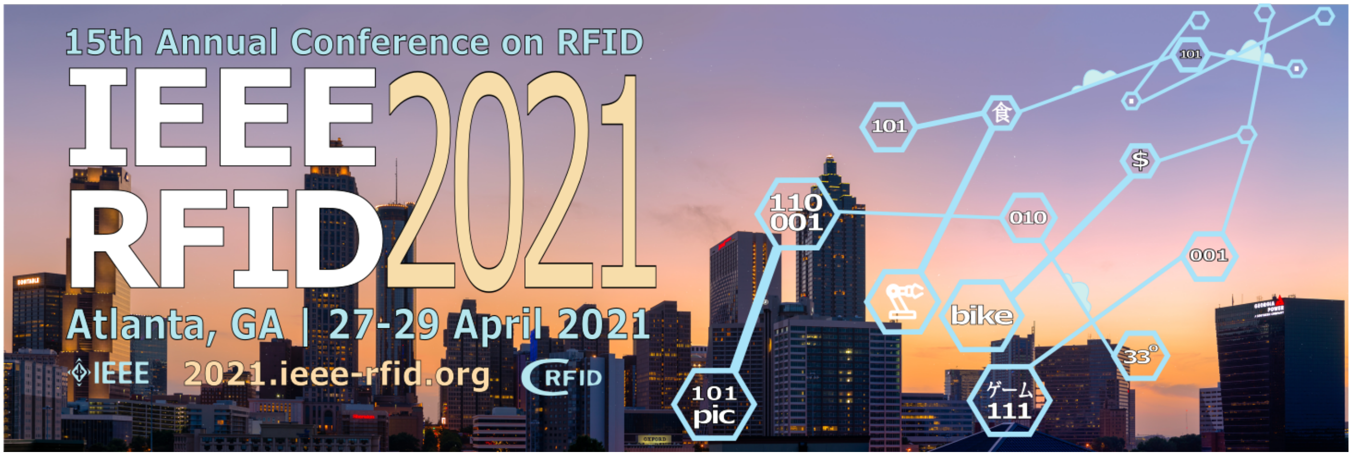

IEEE RFID 2021 Workshop on Wireless MoCap

IEEE CRFID Technical Committee on Motion Capture & Localization

28-29 April 2021

Organizers: Edwin Kan, Yongtao Ma, Qian Yang, Jim Stratigos, Gregory D. Durgin

Final Program

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Letter from the Organizers

Welcome, MoCappers, to the **second** IEEE Workshop on Wireless Motion Capture and Fine-Scale Localization! This is also the first annual workshop since formalizing the IEEE CRFID Technical Committee on Motion Capture and Localization. For more information on TC-MoCap's activities, check out the web page http://mocap.ieee-rfid.org.

In forming the workshop, we cast a broader net to consider cutting-edge works in the following fields of interest:

- Wireless localization techniques with cm-scale accuracy or techniques that approached or exceeded the 100:1 range-to-accuracy limit.
- RF-based techniques for identifying motion, gestures, and vehicles
- Mobile RFID and RF sensing platforms
- Wireless imaging and tomography techniques

Our sincerest appreciation to the Technical Program Committee for *IEEE RFID 2021* for accommodating the unique demands of this workshop. In addition to next year's IEEE RFID 2022, look for MoCap workshops at the following venues and publications.

- IEEE RFID-TA 2021, Online 6-8 October 2021, https://2021.ieee-rfid-ta.org
- IEEE WiSEE 2021, Cleveland OH, 12-14 October 2021, https://attend.ieee.org/wisee-2021/
- Special MoCap Issue for IEEE Journal on RFID, http://mocap.ieee-rfid.org/jrfid/

Hoping to see everyone in person some time soon!

Sincerely,

The Organizers

Edwin Kan[1], Qian Yang[2], Yongtao Ma[3], Jim Stratigos[4], Gregory D. Durgin[2]

[1]Cornell University; [2]Georgia Tech; [3]Tianjin University; [4]Cognosos

    

Presentations

MoCap: Welcome from Chair of IEEE TC-MoCap
Alice Buffi (University of Pisa, Italy)

A welcome address to open the 2nd annual Workshop on Wireless Motion Capture and Fine-scale Localization as well as an overview for the newly-formed IEEE CRFID Technical Committee on Motion Capture and Localization. A summary of TC-MoCap's mission and future plans are included. These include additional workshops at two more CRFID-sponsored conferences later this year (IEEE RFID-TA and IEEE WiSEE) as well as a special issue call for papers for IEEE Journal on RFID in the area of Motion Capture and Localization.

Keynote: 3D Cellphone Localization in E911
Jian Zhu (Polaris Wireless LLC, USA)

This talk provides an overview of cellphone location technologies in E911 services today. We'll review location accuracy requirements set by FCC and present technologies currently available to enhance location accuracy further, especially in the vertical dimension, also known as the z-axis.

MoCap: Device-Free Indoor Localization via RFID Tomography
Yang-Hsi Su and Alanson Sample (University of Michigan, USA)

Device-free localization methods allow users to benefit from location-aware services and smart environments without the need to wear a transponder or carry a mobile device continuously. However, conventional radio tomographic imaging approaches that place active wireless sensor nodes around the perimeter of a living space for localization require wired power or continual battery maintenance, limiting usability and deployability. We present a real-time multi-user UHF RFID tomographic localization system that employs a novel signal processing pipeline that uses communication channel parameters such as RSSI, RF Phase, and Read Rate to create tomograms which are processed by our custom-designed convolutional neural network to predict user's locations. Results show that our system is highly accurate, with an average mean error of 17.0 cm for a stationary user and 20.2 cm when walking and moving. We also demonstrate multi-user tracking with an average mean error of 39.4 cm. Overall, the method empowers a minimally intrusive, scalable, and deployable system for locating un-instrumented users in indoor environments.

Underdetermined Beam-space Compressed Sensing DOA Estimation

Amgad Salama (Alexandria University, Egypt)

In this paper, new compressive sensing (CS)-based direction of arrival (DOA) estimation technique using the beamspace (BS) processing is proposed. Two techniques have been proposed, namely, full beam-space (FBS) as well as multiple beam-space (MBS), and investigated versus the ordinary element-space (ES) technique in a CS-based framework. More, the rank one update covariance matrix has been combined along with all the investigated techniques. Both of the proposed schemes can identify more source signals than the number of sensors used, without requiring an a priori knowledge of the number of source signals to be estimated. The performance of the proposed schemes is compared to that of the ES-based technique.

Self-Locating RFID Robot for Tag Localization in Retails

Andrea Motroni, Fabio Bernardini, Alice Buffi, Paolo Nepa and Bernardo Tellini (University of Pisa, Italy)

This paper presents a RFID-based mobile robot able of self-locating within an indoor scenario and to estimate the position of target UHF-RFID tags. To locate itself, the robot exploits a sensor-fusion method which combines data from an infrastructure of passive reference RFID tags arranged in known locations and data from rotary wheel encoders. Besides, during its motion it is able of measuring the target tag locations through a synthetic-array approach. The knowledge of the reader antenna trajectory is here achieved from the RFID-based sensor-fusion method which exhibits a localization error lower than 0.27 m for 20-m long paths in a real office environment. Then, the estimated trajectory is exploited for target tag localization with high accuracy by using the synthetic-array approach.

Robust RFID Localization in Multipath with Phase-Based Particle Filtering and a Mobile Robot

Evangelos Giannelos, Emmanouil Andrianakis and Konstantinos Skyvalakis (Technical University of Crete, Greece); Antonis G Dimitriou (Aristotle University of Thessaloniki, Greece); Aggelos Bletsas (Technical University of Crete, Greece)

This work revisits particle filtering RFID localization methods, solely based on phase measurements. The reader is installed on a low-cost robotic platform, which performs autonomously (and independently from the RFID reader) open source simultaneous localization and mapping (SLAM). In contrast to prior art, the proposed methods introduce a weight metric for each particle-measurement pair, based on geometry arguments, robust to phase measurement noise (e.g., due to multipath). In addition, the methods include the unknown constant phase offset as a parameter to be estimated. No reference tags are employed, no assumption on the tags' topology is assumed and special attention is paid for reduced execution time. It is found that the proposed phase-based localization methods offer robust performance in the presence of multipath, even when the tag phase measurements are variable in number and sporadic. The methods can easily accommodate a variable number of reader antennas. Mean absolute localization error, relevant to the maximum search area dimension, in the order of 2% - 5% for 2D localization and 9.6% for 3D localization was experimentally demonstrated with commodity hardware. Mean absolute 3D localization error in the order of 24 cm for RFID tags in a library was shown, even though the system did not exploit excessive bandwidth or any reference tags. As a collateral dividend, the proposed methods also offer a concrete way to classify the environment as multipath-rich or not.

Preliminary Analysis of RFID Localization System for Moving Precast Concrete Units using Multiple-Tags and Weighted Euclid Distance k-NN algorithm

Barrett Durtschi, Mahesh Mahat, Mustafa Mashal and Andrew Chrysler (Idaho State University, USA)

This paper presents two RFID localization methods based on a k-NN algorithm for multiple moving tracking tags attached to a concrete masonry unit (cinder block). This work uses passive RFID tags for localization and seeks to provide rapid wireless analysis for future smart infrastructure projects where precast concrete modular structures are moved during transport and assembly. The RFID localization system uses four reader antennas, four tracking tags, and 28 reference tags in a realistic indoor assembly environment. Results show average error in the direction of movement as low as 10.5 cm. Increasing the number of nearest neighbors in the k-NN algorithm is shown to reduce error in all coordinate directions. Increasing k from 4 to 6 is shown to reduce error by 4 cm or 10%. The localization environment is analyzed, and reference tags 22, 9, 5, and 8 around the moving cinder block are seen most commonly as nearest neighbors. A modified k-NN algorithm, described here as a weighted Euclidian distance k-NN algorithm is presented that reduces total error from 41.1 cm to 32.5 cm.

A Real-time RFID Positioning System Using Tunneling Tags

Cheng Qi (Georgia Institute of Technology, USA); Francesco Amato (ITIS Galileo Galilei Roma, Italy); Gregory Durgin (Georgia Tech, USA)

This paper proposes a new type of real-time decimeter-level radio-frequency identification (RFID) positioning system at 5.8 GHz. The system uses received signal phase (RSP)-based positioning techniques and tunneling tags (TTs). TTs amplify the signal strength of their backscattered signals while preserving the phases allowing for ultra-precise position estimates at long distances. A proof-of-concept RSP-based real-time frequency hopping reader is implemented on Software-Defined Radio (SDR) and Universal Software Radio Peripheral (USRP) platform. Experimental results show an average one dimensional and two-dimensional positioning accuracy of 11 cm and 17 cm, respectively, in outdoor environments.

On Fast and Accurate 3D RFID Mobile Localization

Hankai Liu, Yongtao Ma, Yue Jiang, Yunlei Zhang and Xiuyan Liang (Tianjin University, China)

This paper proposes an ultrahigh-frequency (UHF) radio frequency identification (RFID) based 3D mobile localization system (3DRML) for passive tags and tagged objects. Influenced by factors such as calculation model, grid scale and phase center shift (PCS), prior RFID based 2D and 3D mobile localization methods are subject to certain restrictions in computational time and accuracy. To overcome these limitations, 3DRML has the following features. First, 3DRML achieves grid based mobile localization with low time cost by leveraging the idea of reflection coefficient reconstruction (RCR) which regards each point representing an area as a reflection point and calculates the reflection coefficients from simple matrix operations. Second, a PCS calibration process is performed to compensate the phase shift caused by the antenna phase center change. Third, 3DRML uses the nonlinear optimization algorithm to solve the least square localization model for a quick localization, and then constructs a much smaller grid area to facilitate the grid based real-time accurate localization. The performance of 3DRML is evaluated by simulations with various interferences, and the results show that 3DRML enables fast 3D localization while achieving higher accuracy.

A Backscatter Channel Sounder Using Tunneling RFID Tags

Cheng Qi (Georgia Institute of Technology, USA); Francesco Amato (ITIS Galileo Galilei Roma, Italy); Yiliang Guo and Ying Zhang (Georgia Institute of Technology, USA); Gregory Durgin (Georgia Tech, USA)

This paper introduces a backscatter channel sounder technique used for a radio-frequency identification (RFID) positioning system at 5.8 GHz. This system applies received signal phase (RSP)-based positioning and channel sounding techniques to a tunneling tag, providing sufficient information to calculate the delay spectrum for accurate positioning in a complicated multipath environment. Ultra-precise (0.45%) position estimates at long distances (100 m) are achieved using the proposed channel sounding techniques.

Intra-Spacecraft RFID Localization

Joel Simonoff, Jesse Berger, Aidan Abdullali and Osher Lerner (NASA, USA); Lazaro Rodriguez (NASA JSC, USA); Patrick Fink (NASA, USA)

In this paper we explore two machine learning approaches to improve RFID tag localization in the highly reflective environment imposed by the International Space Station. We propose P-RFIDNet (Passive RFID Net), a neural network with a ResNet50 (He, et al., 2015) [1] backbone for localizing passive RFID tags in high multipath environments with fixed antennas. Furthermore, we show how transfer learning can be used to generalize P-RFIDNet to new RFID environments with limited training data. In addition to P-RFIDNet, we present REALMRFC, a random forest (Breiman, 2001) [2] model with feature engineering performed by an RFID localization expert. We benchmark P-RFIDNet and REALMRFC using data from the RFID Enabled Autonomous Logistics Management (REALM) RFID system on International Space Station (ISS).

Estimating physical work-load on ED clinicians and staff using real-time location systems

Anoushka Kapoor (University of Minnesota, USA); Moein Enayati (Mayo Clinic, USA); Alisha Chaudhry (University of Minnesota, USA); Nasibeh Zanjirani Farahani, Shivaram Arunachalam, David Nestler and Kalyan Pasupathy (Mayo Clinic, USA)

Clinicians' work pressure and burnout turned out as an important factor in modern hospitals which urges us to search for rapid and accurate methods to proxy the workload. By using RFID technology, we hope to monitor the physical pressure on the clinical staff of the emergency department (ED) at the Mayo Clinic Saint Mary's Hospital. The data collected will be used to determine the workload and pressure put on various staff members. A real-time location system (RTLS) has been used to monitor and track the movements of the hospital team and compute active vs. sedentary time for staff. Risk thresholds for the sedentary time from a previously published paper were utilized to visualize trends in staff sedentary time. Members of the ED team are under great stress at all times; we use RFID technology to get a better understanding of how much their work environment contributes to the pressure of their jobs.