Demo Abstract: TotTernary - A Wearable Platform for Social Interaction Tracking

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ABSTRACT

We present TotTernary, the first infrastructure-free, long-term research platform which enables domain scientists to measure human interactions with previously unprecedented accuracy and flexibility. The platform can be tailored to varying scenarios by adjusting the ranging fidelity and the update rate and demonstrates dynamic adaptation to its environment. As a mobile, accurate, and reliable system for ranging measurements, it allows users to gather both distance and position information with decimeter accuracy. Measuring only 61×35 mm and weighing 7.7 g, it integrates two radios to achieve both low-power neighbour discovery and direct user interactions using Bluetooth Low Energy as well as precise ultra-wideband ranging measurements. The system introduces a novel energy-efficient ranging protocol with linear message complexity to achieve life times of up to 39 days. Furthermore, leveraging both antenna and frequency diversity, we demonstrate that the median ranging error can be reduced by up to 86% through an efficient aggregation of measurements over multiple channels. Our system is capable of highly reliable and consistent measurements with as little as 14.8 cm of ranging error in the 99th percentile and a 90% confidence interval of 11.3 cm.

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1 INTRODUCTION

Research in epidemiology, sociology, and robotics has shown that fine-grained interaction information about social networks can offer new insights into fields such as the spreading of diseases, inter-racial and cultural relations, and verbal communication [1]. Social scientists are however still struggling to obtain high-fidelity data of cohorts in their natural environment and seek possible ways to reduce blind spots in their observation and analysis of social interactions [8]. Wearable sensors offer an opportunity to cover a large space of environments, cultures and social classes.

Previous systems tried to address this problem using infrastructure [2] or signal-strength based solutions [6]. However, none of them could fulfil the requirements of social scientists to cover either the various environments of the cohort or achieve sufficient temporal and spatial resolution in the order of Hz and decimeters. Time-of-flight based distance measurements enable a much finer-grained observation of the interactions, as the unpredictability and instability of the signal strength can be circumvented. However, traditional solutions still suffer from imprecision due to multipath interference, common in indoor situations [5], and are ill-suited for mobile deployments due to their low energy efficiency.

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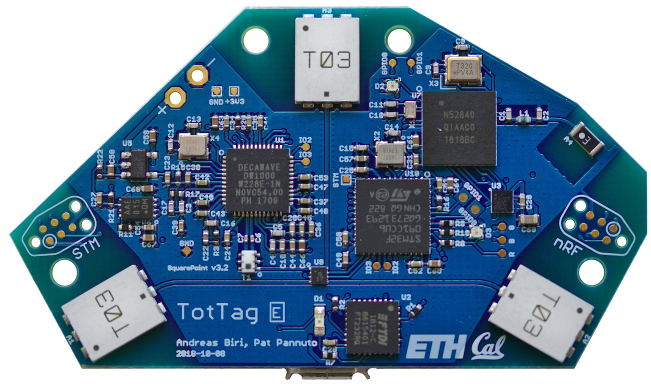

Figure 1: The board can be worn easily on lanyards or wrist bracelets in an unobtrusive manner to achieve minimal interference with the experiment.

2 PLATFORM

TotTernary provides an infrastructure-free, scalable tracking platform to detect interactions reliably and with high accuracy. Inspired by SurePoint [5], we use the concept of frequency and antenna diversity to obtain high-fidelity ranging data and complement it with a neighbour discovery protocol based on BLEnd [4] to permit mobile deployment scenarios through a reduction of the energy consumption of idle listening by more than 95%. We distinguish ourselves in the following points from previous systems:

- Leveraging a dual-radio architecture, we enable infrastructure-free deployments using energy-efficient wake-ups over BLE and combine it with UWB diversity ranging to gather ranges with high fidelity.
- Using constructively-interfering Glossy floods [3], we disseminate control information for scheduling and global time stamping with high reliability despite high node mobility and obstructed line-of-sight. Through the exclusive usage of broadcasts, we reduce the message complexity of the protocol from quadratic to linear.

- The large bandwidth of ultra-wideband radios mitigates the influence of multipath interference and enables distance estimations with high accuracy. By aggregating over multiple antenna positions and frequency channels, we improve measurement precision and reduce the 90th percentile error by 72% compared to the state-of-the-art UWB ranging system [5], achieving a 99th percentile accuracy of up to 14.8 cm.

Hardware. We separate the functionality of our platform logically into two distinct segments: The carrier board consists of a Nordic Semiconductor nRF52840 BLE radio as well as an SD card for long-term storage and an accelerometer for motion detection and sensor fusion. Connected only over an I^2C bus and three antenna traces, the module includes the DecaWave DW1000 UWB radio as well a STMicroelectronics STM32F091CCU6 and an RF switch. Hence, the module contains all necessary components for the ranging protocol, including the entire ranging protocol logic, and supports simple integration into new designs as a modular design block to facilitate adoption.

Measurements are logged locally on an SD card and are retained permanently for extensive offline analysis. Additionally, they can be accessed remotely over a BLE characteristic, enabling real-time data streams to smartphones and laptops which could be used for live observation of the cohort, as shown in this demo.

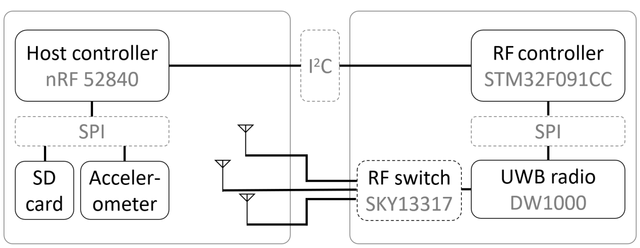

Figure 2: Separation into carrier (left) and module (right).

Protocol. Various improvements over the state-of-the-art diversity ranging protocol [5] reduce the message complexity from quadratic to linear and boost life time by up to 77%. Protocol details [1] are outside of the scope of this abstract.

Energy model. Based on detailed current measurements of the platform [1], we give social scientists the capability to accurately predict the influence of design parameters such as ranging update rate, network size and discovery latency on the life time of the network. This analysis enables system designers to adapt the platform for various application scenarios.

Results. First experiments verified the importance of diversity for reliable distance estimation. The node is capable of gathering more than 45 hours of continuous ranges with 1 Hz update rates. However, we estimate based on simulations that the platform could be optimized to achieve life times up to 39 days with up to 6 ranges per minute.

The platform is currently undergoing preliminary tests with social scientists to verify the practicability in real-life scenarios. We further envision the application of the accelerometer for activity detection and an enrichment of the data with movement information.

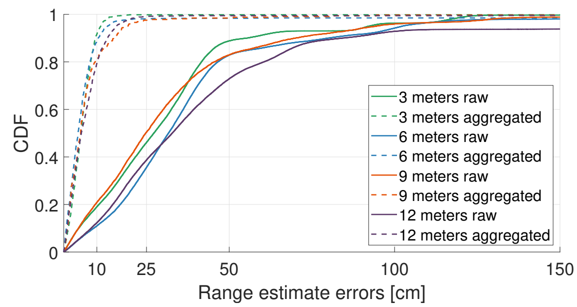

Figure 3: By aggregating measurements over different frequency channels with varying antenna positions, we achieve sub-decimeter accuracy in all tested scenarios.

Both the hardware design as well as a complete software stack is open-sourced and available at github.com/lab11/totternary.

3 DEMONSTRATION

For this demo, we showcase the entire platform [1] in action. We deploy both stationary nodes as well as multiple mobile nodes which attendees can wear themselves. All nodes will perform bidirectional ranging and stream their measurements in real-time over Bluetooth Low Energy. This data can then be accessed both on personal devices using a smartphone application as well as on a provided laptop. Through visualisations, we will display both raw and filtered time series for each pair of nodes as well as the full live connectivity graph in a 2D space.

Furthermore, we leverage the accuracy of our sensors to enable attendees to dynamically explore the difference of personal spatial zones [7] by directly interacting with a stationary sensor. A monitor will provide visual feedback on the current distance and corresponding zone to demonstrate the capabilities of our presented platform and how it can benefit social scientists in their research.

REFERENCES

[1] Andreas Biri. 2018. *TotTernary: A wearable platform for social interaction tracking.* Master's thesis. ETH Zurich.
[2] Ciro Cattuto, Wouter Van den Broeck, Alain Barrat, Vittoria Colizza, Jean-François Pinton, and Alessandro Vespignani. 2010. Dynamics of person-to-person interactions from distributed RFID sensor networks. *PloS one* 5, 7 (2010).
[3] Federico Ferrari, Marco Zimmerling, Lothar Thiele, and Olga Saukh. 2011. Efficient network flooding and time synchronization with Glossy. In *IPSN '11*. IEEE, 73–84.
[4] Christine Julien, Chenguang Liu, Amy L Murphy, and Gian Pietro Picco. 2017. BLEnd: Practical continuous neighbor discovery for Bluetooth Low Energy. In *IPSN '17*. ACM, 105–116.
[5] Benjamin Kempke, Pat Pannuto, Bradford Campbell, and Prabal Dutta. 2016. SurePoint: Exploiting ultra wideband flooding and diversity to provide robust, scalable, high-fidelity indoor localization. In *SenSys '16*. ACM, 137–149.
[6] Kyeong T Min, Andrzej Forys, Anh Luong, Enoch Lee, Jon Davies, and Thomas Schmid. 2014. WRENSys: Large-scale, rapid deployable mobile sensing system. In *LCN '14*. IEEE, 557–565.
[7] Michael L Walters, Kerstin Dautenhahn, René Te Boekhorst, Kheng Lee Koay, Christina Kaouri, Sarah Woods, Chrystopher Nehaniv, David Lee, and Iain Werry. 2005. The influence of subjects' personality traits on personal spatial zones in a human-robot interaction experiment. In *RO-MAN '05*. IEEE, 347–352.
[8] Charles H Zeanah. 2018. *Handbook of Infant Mental Health, Fourth Edition.* Guilford Publications.