DEMO ABSTRACT: REAL-TIME TAG-FREE LOCALIZATION USING RADIO TOMORAPHY

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ABSTRACT

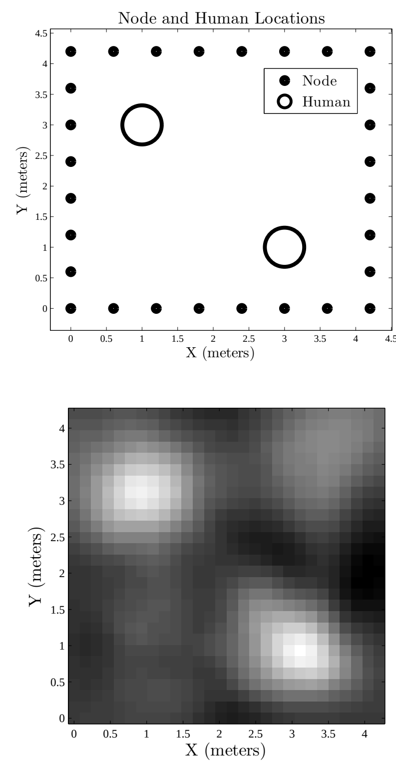
We propose to demonstrate real-time tag-free localization using radio tomography. In this demo abstract, we show the need for radio tomography, the models used, and some sample results. We discuss the needs and operation of the proposed demonstration.

1. INTRODUCTION

Radio tomography (RT) is the use of changes in radio signal strength (RSS) measurements on many links over time to estimate where people and moving objects are located [1, 2, 3]. RT is a localization technology that does not perform identification. Some advantages of RT are: its ability to see through non-metal walls, that it is non-identifying (and thus does not have the same privacy concerns as video cameras), its ability to identify multiple people in the same room, and its low cost. Real-time RT systems could be deployed across buildings to collect measurements between probe stations; forward through *bridge nodes* which connect the building network; and then process the data in real-time at a server into streams and make (application-dependent) context aware decisions. We propose to deploy and display a real-time RT system at RTAS 2009 which is small-scale, but demonstrates the concepts and capabilities of radio tomographic imaging to perform tag-free localization and tracking.

Currently, systems which attempt to locate people indoors are inaccurate, incomplete, and insecure, largely because they only locate people who participate in the system by carrying an RFID tag. Safety and security systems which react to unsafe situations or detect security threats cannot rely on all people, including wrongdoers, to participate in the system by carrying a tag. The accuracies of RFID systems must be improved in order to provide accurate relative positions within groups of occupants or to be used as input for context awareness systems.

Video camera surveillance systems are defeated by darkness, by smoke, or simply by covering their lenses. They



(a) (b)

Fig. 1. (a) Map of RT probe stations and humans, and (b) reconstructed image.

are obstructed by walls and thus for complete facility coverage would need to be deployed very densely so to record in every room and around every corner. Facility-wide video surveillance is unlikely to override privacy concerns in all but a few applications. Simple (optical) motion detectors are similarly blocked at each wall and are coarse and have high false alarm rates.

In short, current security and logistics systems have shortfalls which radio tomography systems do not. The ability to accurately track unidentified people through walls across entire facilities may provide increased capabilities for cyber-physical occupant-aware systems. Our demo will provide hands-on experience with this new technology.

Radio tomographic imaging is an ill-posed inverse problem, analogous to medical tomography systems, which image a 2D or 3D environment using many lower dimensional scans. RT is non-phase synchronous and suffers from high frequency selective fading noise, which can overwhelm the signal, which is caused when a person attenuates the highest power path of a link. In general, RT *imaging* is performed by estimating the (dB) attenuation per pixel in an image vector $\mathbf{x}$ from many pairwise link change-in-RSS measurements $\mathbf{y}$. We can (approximately) model their relationship as

$$\mathbf{y} = A\mathbf{x} + \mathbf{n}, \tag{1}$$

where A is a linear model, and $\mathbf{n}$ is the noise contribution [1, 3]. Using an appropriate regularization method, we can estimate the image $\mathbf{x}$. This linear model is the result of extensive measurements of the relationship between shadowers (*e.g.*, people) and the shadowing loss measured by links in wireless sensor networks [4]. We have shown in past research that image estimates show the person at their actual location, and can image multiple people simultaneously [3, 5]. One example is shown in Figure 1, which shows the actual locations of probe stations and people, compared to the reconstructed image of the attenuation field.

RT imaging can then be used to track untagged people. The estimated image $\mathbf{x}$ may show one or more people moving through an environment. We will show a tracking solution which tracks a person, estimating their coordinate, as the travel through the image. Such estimates are very accurate, even more accurate than currently achieved with tag-based tracking systems. Figure 2 shows one experiment for which 36 different tests show an average localization error of 16 cm.

More information, including a video of one experiment is located on the Sensing and Processing Across Networks (SPAN) website at `http://span.ece.utah.edu`.

1.1. Demo Setup and Requirements

We will demonstrate real-time radio tomographic imaging and tracking. We will deploy approximately 30 probe stations (wireless sensors measuring radio signal strength on all pairwise links) in a 5 meter by 5 meter region in the demonstration area. If space constraints are tight, the demo can be compressed as low as 3.5 m by 3.5 m. We will need a projector, one table, and one outlet to plug in the projector and laptop. The laptop will calculate images in real-time, and display them via the projector to a screen. The screen will be visible to demo participants. The participants will enter the demo area, be located in real-time by the RT system, and be able to see their location estimate in the projected image.

About one hour of setup time is required. The wireless devices use 802.15.4, at 2.4 GHz. We can adjust the channel to not interfere with WiFi signals.

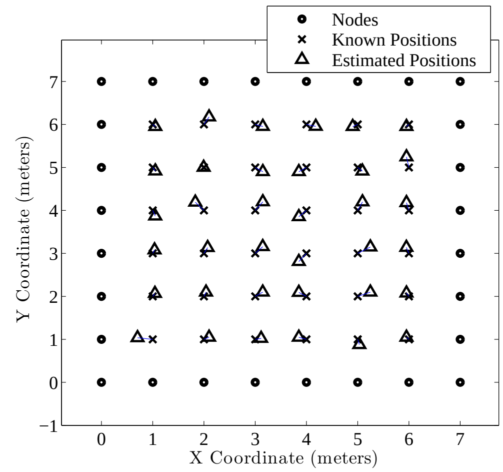


Fig. 2. Experimental RT localization estimates vs. actual person location, showing 16 cm mean location error.

2. REFERENCES

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