Demo Abstract: A Radio Tomographic System for Real-Time Multiple People Tracking

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ABSTRACT

A radio tomographic (RT) system uses the received signal strength (RSS) measurements collected on the links of a wireless mesh network composed of low-power transceivers in order to form real-time images of the attenuation field of the monitored area. These images indicate the position of people, without requiring them to participate in the localization effort by wearing or carrying any electronic device. Accurate localization and tracking of multiple people in real-time is required in several real-world applications, such as ambient-assisted living, tactical operations, and pedestrian traffic analysis in stores. In these scenarios, RT systems must perform reliably also *a*) when the number of targets is not known a priori and varies over time, and *b*) when people interact, i.e., have intersecting trajectories, in the monitored area. We demonstrate a RT system which tackles all of these challenges and provides accurate tracking of a varying and unknown number of people (both stationary and mobile) in real-time.

Categories and Subject Descriptors

C.3 [**Special-Purpose and Application-Based Systems**]: Real-time and embedded systems; I.5.4 [**Pattern Recognition**]: Applications—*Computer Vision*

Keywords

Radio tomography; Device-free localization; Received signal strength; Multiple target tracking;

1. INTRODUCTION

Radio tomographic (RT) systems are RF sensor networks [7] capable of localizing and tracking people in indoor environments without requiring them to carry or wear any electronic device. These systems use the received signal strength (RSS) measurements collected on the links of a wireless mesh network composed of low-power transceivers in order to form images of the change in the propagation field of the monitored area due to the presence of people - a process known as radio tomographic imaging (RTI) [9]. These images can be processed as *frames* of a video showing the position and movements of multiple people, as shown in Figure 1. The RT system we present in this demonstration applies machine vision methods adapted to the characteristics of RTI to track the *blobs* corresponding to real people *a*) when their number is not known a priori and varies over time, and *b*) when these have intersecting trajectories [2].

RT systems can be used in several applications, including smart buildings and perimeter surveillance, ambient-assisted living and elder care, and tactical and rescue operations. Compared to other sensing technologies applied for indoor localization, such as infrared, ultrasonic range finders, ultra-wideband (UWB) radios and video cameras, RT systems provide several advantages: they work in the dark and can penetrate smoke and walls; they are less invasive in domestic environments than video camera networks; they are significantly less expensive than UWB transceivers; their installation and maintenance time is minimal.

Previous works in this area [3, 5, 10] have mostly focused on localizing a single person, while the few existing methods for multiple people tracking are either non-real time, assume that the number of targets is fixed and known a priori, or do not attempt to track people having intersecting trajectories [8, 6]. However, the real-world scenarios in which RT systems can be used require them *a*) to correctly estimate the number of people to be tracked as they enter and exit the monitored area, *b*) to be able to track people even when they have intersecting trajectories, and *c*) to do this in real-time. The RT system we demonstrate tackles all of these challenges.

A RT system is composed of several radio transceivers, placed at known positions, which form a wireless mesh network. These RF *sensors* collect RSS measurements which are then processed in order to estimate a discretized image of the change in the propagation field of the monitored area caused by the presence of people. People moving in a space where wireless transceivers are communicating affect the propagation of the radio signals by shadowing, reflecting, diffracting or scattering a subset of their multipath components. In uncluttered environments, where line-of-sight (LoS) communication among the transceivers is predominant, a person obstructing a link line generally decreases the measured RSS. However, in cluttered environments, where multipath propagation is predominant, the change in RSS due to the presence of a person on the link line is more un-

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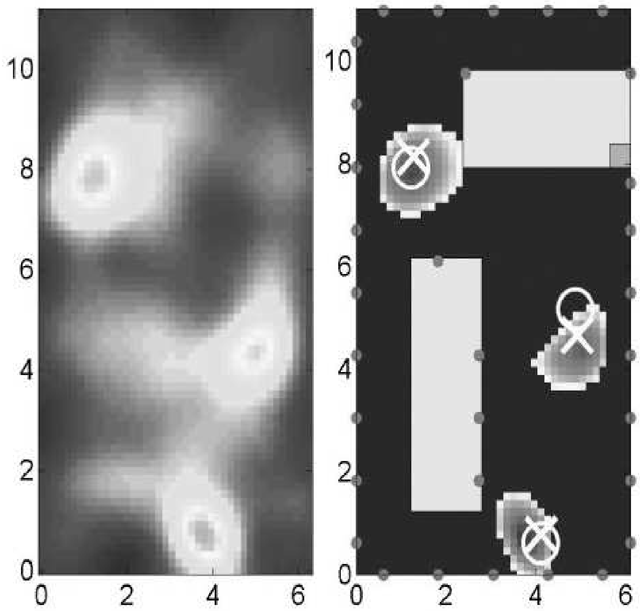

Figure 1: On the left, the original RT image formed by the system when three people are located in the monitored area. On the right, the RT image after being processed by the machine vision methods used to track multiple people. The dots represent the radio transceivers, the white circles the true position of people, the white crosses their estimated position, and the grey rectangles furniture present in the area.

predictable, as the RSS can also remain constant or increase. In addition, due to the multipath propagation, people can affect the RSS also when located far away from the link line. To mitigate the undesired effects of multipath propagation, our system exploits frequency diversity in order to reduce the noise of the formed RT images and facilitate multiple people tracking [4].

The radio transceivers composing our RT system continuously collect RSS measurements on all the links of the network on different frequency channels through a multi-channel TDMA token-passing protocol. The measurements are then weighted differently based on the fade level [8, 1] of the frequency channel on which they were collected. The system forms a new RT image at the completion of each round of communication. Machine vision methods adapted to the characteristics of RTI process the RT images in real-time to detect and track the blobs (see Figure 1) corresponding to people located in the monitored area. Due to measurement noise and the simultaneous presence of multiple people, objects and obstructions, spurious blobs (not corresponding to real people) can appear in the image. For the same reasons, blobs corresponding to real people can also temporarily disappear from the image. These factors increase the difficulty of multiple people tracking, especially when these have intersecting trajectories. In our system, we apply computationally light-weight, yet effective methods providing real-time execution and accurate tracking also in the case of intersecting trajectories.

2. DEMONSTRATION

In our demonstration, battery-powered radio transceivers are deployed on all four sides of an area in which people are free to move individually or interact with other people. The sensors are placed on podiums at a height of one meter. A laptop is used to collect the RSS measurements of all the links of the wireless network and execute in real-time the image estimation and tracking algorithms. The display of this laptop shows in real-time the RT images formed by the system and the position estimates of the people located in the deployment space. The system indicates also at all times the number of people that are located in the monitored area, detecting in real-time their entry and exit.

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