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Environmental Imaging Technique for Indoor Localization using Millimeter-wave Communication Systems

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By technical progress of IoT (internet-of-things) a highly advanced automated home environment for living will be on hand in near future. Here, indoor localization and mapping will be playing an important role. Various localization/positioning techniques have been developed, but the performance of them often considerably decreases in actual multipath propagation environments. Further, device-free methods should be preferable for smart home/building applications, but most of existing techniques are not suitable because a person must carry an electronic device. The authors have proposed a novel radio tomographic imaging (RTI) method, called Multipath-RTI [1], based on millimeter-wave (mm-wave) radio systems such as 5G mobile and IEEE 802.11ad/ay WiGig systems which currently attract a great deal of attention. Originally, the RTI techniques visualize the change of path gain due to shadowing by persons on the map using a large number of wireless links within an RF sensor network, but a huge number of anchors should be needed to achieve a certain level of resolution in actual multipath environments. On the other hand, mm-wave radio systems are usually capable of high-resolution multipath component (MPC) extraction in delay and angle domains by using ultra-wideband signaling and beamforming, each MPC can be utilized as a signal path from a virtual anchor. Using such virtual anchors, we can dramatically reduce the number of sensor nodes and improve the performance even in rich multipath environments.

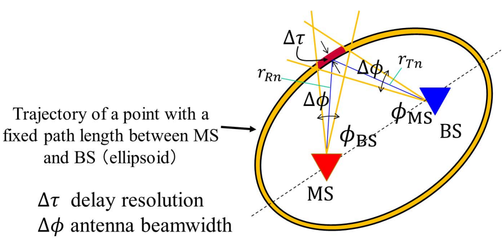
In multipath-RTI, it is supposed that the environmental model is perfectly known in advance. However, an automatic acquisition of the environmental model should be necessary to determine the virtual anchors from the aspects of practical use. This paper proposes a new environmental imaging technique for the multipath-RTI localization system extending the Kirchhoff migration (KM) that represents migration performed in time domain. It estimates the virtual anchors by imaging the surrounding large objects like a wall while a mobile station (MS) as an agent is moving around the target area. The proposed method forms an image using the object distribution function of the distance and angles. When N different measurements at different MS positions where n-th MS position has co-ordinates (x_n, y_n, z_n). The object distribution function at point (x,y,z) is

$$o(x,y,z) = \frac{1}{N}\Sigma_{n=1}^{N} R_n\left(\frac{r_{BS}+r_{MS,n}}{c}, \phi_{BS,n}, \phi_{MS,n}\right) \quad (1)$$

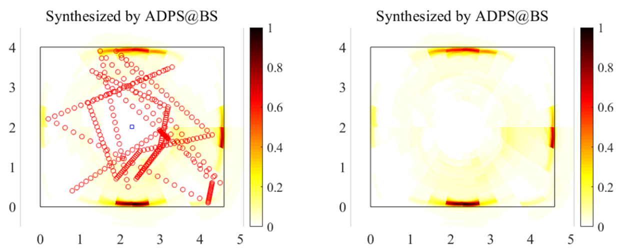
where R_n denote the angle-delay power spectrum (ADPS) at n-th MS position. τ, $\phi_{BS,n}$, and $\phi_{MS,n}$ denote the propagation delay, the angles of arrival and departure at n-th MS position, respectively. r_{BS} and $r_{MS,n}$ are the distance from the BS and n-th MS positions, respectively. c denotes the velocity of light. Fig. 1(a) and Fig. 1(b) show the principle of the proposed technique and an example result. This paper will present the performance evaluation in various aspects.

References

[1] M. Kim, T. Tasaki, S. Yamakawa, "Millimeter-Wave Radio Tomographic Imaging Technique using Multipath Components for Indoor Localization," *International Symposium on Antennas and Propagation (ISAP 2019)*, Oct. 2019.



(a) Principle



(b) Result using only τ and $\phi_{BS,n}$ (BS position: center bandwidth: 2 GHz, beamwidth: 12 deg.)

Figure 1. Proposed imaging technique.