Detection and determination of user position using reflective methods in radio tomography

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ABSTRACT

The main aim of the research is the adaptation of reflection/radar technology in a detection and navigation system using radio-tomographic imaging techniques. A key aspect of the work is the optimisation of radar parameters for indoor use in buildings with user safety and energy optimisation. The work also discusses the methodology for extracting information from signal echoes and how they are transported and aggregated. Logistic regression and neural networks were used for image reconstruction.

CCS CONCEPTS

• Radio frequency and wireless circuits → Digital signal processing → Surveillance mechanisms → Machine learning algorithms

KEYWORDS

reflective tomography, radar technology, radiolocation, indoor navigation system, signal echo analysis

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1. Introduction

With the development of radar targeting techniques [3,4,7] and the increased availability of microwave technology, it has become an excellent alternative to the already well-known targeting techniques using the transmission properties of radio devices. Amplitude, frequency or phase analysis of the reflected wave often allows an object to be detected and its position in space many times more accurately and quickly. This is one reason why radar may become a significant support for in-building detection and navigation systems in the future. Unfortunately, these systems are still relatively sophisticated and present a high difficulty level in device synchronisation, signal processing and analysis of acquired data. The novelty of presented solution is the new design of the measuring device and signal processing algorithms, but the advantage is possible to detect the position of people based on the wave reflected from the person.

2. Hardware solutions

The basic element of the detection system is the reflective radio probe presented in Figure 1. It consists of a 5.8 GHz carrier frequency synthesis system, a detection system and a preliminary analysis of the received signal. The signal can be transmitted by a quad-patch microwave antenna, capable of transmitting and receiving EM waves simultaneously. The system has also been adapted to take advantage of the Doppler phenomenon. Data acquired from the RF circuits can be fed into the system via the CAN or RS-485 bus.

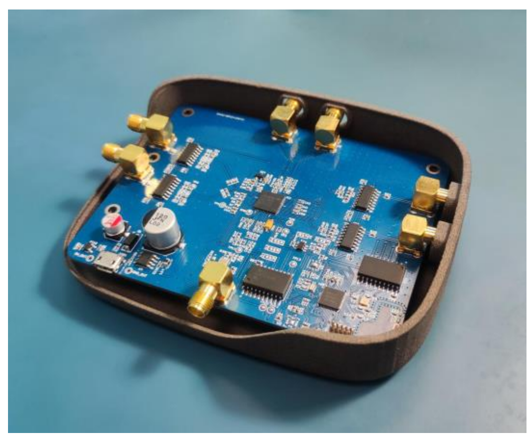

Fig. 1: Radio reflection probe prototype

The system is complemented by 2.4 GHz wireless communication on one of the selected PAN communication protocols (IEEE 802.15.1 or IEEE 802.15.4). Additional data such as sensor calibration parameters can be sent via these channels. This procedure is intended to relieve the main (wired) communication bus as much as possible. For faster reconfiguration of the device, any signals fed to the main RF circuit (base frequency, QAM signals, etc.) can be generated by the device or fed via SMA connectors from outside.

3. Problem formulation

The main objective of the work is to develop an algorithm that can predict the position of people in the room. The image reconstruction consists of a solution to the forward and inverse problems based on measurement data (signals obtained from sensors). The room was modelled as a mesh containing 6951 nodes. From these nodes, 13468 finite elements were created. There were 16 sensors installed in the room. Due to the specificity of the room, not all sensors communicate with each other. Two types of models were used to recognize the position of people in the field of view: logistic regression [6,7,9] and neural network[1,2, 5,7]. In applying logistic regression, we create the logistic regression model for each finite element. As a result, we obtain the classifier of belonging of the finite element to the inclusion. The final layer for the neural network was the softmax function, which also creates the classifier.

4. Conclusions and results

The Structural Similarity Index (SSIM) [1,9] has been calculated to assess the quality of reconstruction images. Let $\{x_t\}_{1 \le t \le n}$ and $\{y_t\}_{1 \le t \le n}$ denote the pattern and reconstruction images presented as a sequence (n denotes the number of finite elements). The formula calculates the SSIM value:

$$SSIM = \frac{(2\bar{x}\bar{y}+c_1)(2\sigma_{xy}+c_2)}{(\bar{x}^2+\bar{y}^2+c_1)(\sigma_x^2+\sigma_y^2+c_2)}, \quad (1)$$

where $\bar{x}$, $\bar{y}$, σ_x^2, σ_y^2 denote mean values, variances of pattern and reconstruction images, respectively, σ_{xy} - covariance between pattern and reconstruction, $c_1 = (0.01L)^2$, $c_2 = (0.03L)^2$, where $L = 2^k - 1$, k- number bit per pixel (in this case, we have $k = 1$). The examples below present the two patterns and the reconstruction obtained for these patterns based on logistic regression and neural networks.

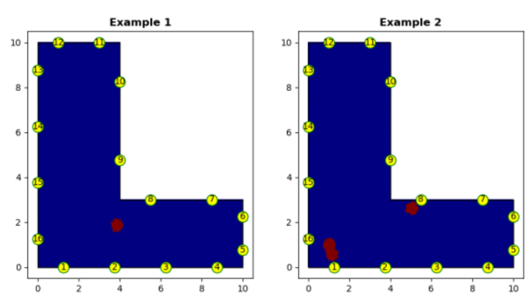

Fig. 2. Positioning patterns of people in the room.

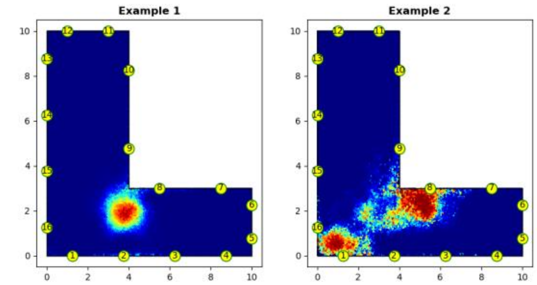

Fig. 3. Reconstructions based on Logistic Regression.

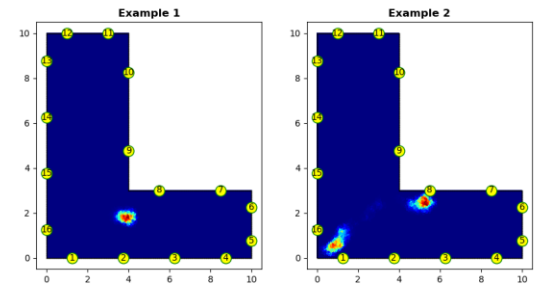

Fig. 4. Reconstructions based on Neural Network.

Table 1. The values of structural similarity index for reconstructions.

	Logistic Regression	Neural Network
Example 1	0.71717	0.9404
Example 2	0.7718	0.816

Based on a comparison of the similarity indices summarised in Table 1, it can be concluded that the use of a neural network yielded better results.

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