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FEM-based Detection of Moving Targets via Particle Filtering and Artificial Neural Network

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Detection of a moving target in a complex environment is a daunting task that is treated in several ways exploiting the band of electromagnetic waves from few MHz to optical frequencies. Radio-localization of targets in the microwave band has several advantages, among which low cost of the devices and the fact that the device is usually much less evident and have a wider angle of observation than a surveillance camera.
Radio-localization can be passive, in the case in which what is detected and tracked is actually some mobile transmitting device held by the target (e.g. a mobile phone). This can be done by deploying several nodes in an area and guessing target position even on the basis of amplitude-only measurements (S. Maddio, G. Pelosi, M. Righini, S. Selleri, V. Sorrentino, "A dual band circularly polarized square patch for indoor positioning systems," IEEE APS 2017 pp. 2523-2524). Radio localization can also be on non-cooperating targets, meaning that they do not emit themselves a signal, and this is much more relevant in security applications, where targets must be assumed to be non-cooperating. In this case active (radar) detection can be inappropriate since an active radar is itself easily detected by the non-cooperating target which can immediately take appropriate countermeasures. A fully passive system, relying only on the field existing in the environment, for example that due to radio or TV broadcasting, will not alert the target (A. Farina, P. Gallina, L. Lucci, R. Mancinelli, G. Pelosi, S. Selleri, "Back lobe minimization for a VHF LPDA-based interferometer," ISMOT-2007, pp. 195-198).
In this contribution, samples of the scattered field in a complex environment illuminated by a far-away radio source will be used to detect the presence of a target and track it by combining the finite element method (FEM) with particle filtering and artificial neural networks (ANNs). The FEM is used to simulate the values of the scattered field in a given number of sampling points (corresponding to the positions of the field sensor) for different positions of the target within the domain (including the case in which the target is not present). These data are used to train an ANN with the objective of learning the mapping from the target position to the samples of the scattered field. Then, a filter is designed to solve in real time the inversion problem of detecting the target and determining its kinematic state (i.e., position and velocity) from the measurements of the scattered field in the sampling points. For this purpose, a particle filter is employed in which a set of particles is used to approximate the probability distribution of the target existence and kinematic state conditioned to the collected measurements. The FEM-trained ANN allows one to compute in real-time the likelihood of each particle (representing a hypothesis for the target existence and kinematic state) given the measured scattered field.