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Recent Advances on the Use of Kernel-based Learning-by-Examples Techniques for Electromagnetic Subsurface Sensing

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To return areas contaminated (or potentially contaminated) with unexploded ordnance (UXO) and anti-tank/anti-personnel landmines to a civilian use, the ordnances should be obviously removed and a wide-area surveillance is needed in order to circumscribe those regions where the dangerous targets reside. Such a process is inevitably time-expensive and involves complex acquisition procedures. These are some of the main motivations of the growing research interest in developing unsupervised techniques able to effectively repair landmine/UXO contaminated areas. Several solutions have been proposed based on various methodological approaches, which consider different sensor modalities such as ground-sensors (e.g., magnetometers, electromagnetic radars, sensors based on electromagnetic induction, etc.) or synthetic aperture radars. In general, these techniques are aimed at achieving the following goals: (*a*) correctly localizing a large number of dangerous targets, thus ensuring the future security of cleaned areas; (*b*) reducing the false-alarm rate, which strongly contributes to the costs of the clearing procedure; (*c*) reducing the time devoted to the detection process, thus realizing a quick area surveillance.

In such a framework, electromagnetic approaches based on learning-from-samples (LFS) techniques [1] have been proposed for the on-line [after the learning process (or training phase) performed once and off-line] detection of subsurface objects. The detection process is recast as a regression problem where the unknowns (i.e., the position as well as the geometric and dielectric characteristics of the target) are directly evaluated from the data (i.e., the values of the scattered field) by approximating the data-unknowns relation through an off-line data fitting process (training phase). LFS regression-based approaches demonstrated their effectiveness in dealing with detection processes where a limited number of unknowns (related to a single object) is considered. However, because of the complexity of the underlying architecture, some difficulties occur when a larger number of unknowns (related to multiple objects) is taken into account. Unfortunately, from a structural point-of-view, the regression technique does not permit one to simultaneously identify multiple positions. As a consequence, LFS regression-based approaches turn out to be very effective for the detection of a single (or few organized in a single cluster of objects) buried object, whereas they are not-so-suitable in dealing with the detection of multiple targets. On the other hand, it should be pointed out that the identification of free-areas and an estimate of the concentration of subsurface objects (instead of the localization of each buried scatterer) might be enough in several situations. Then, the goal of a subsurface sensing technique could be moved from the "*object detection*" to the "*definition of a risk map*" [2]. Consequently, a classification approach, instead of a regression one, should be employed. In this contribution, the classification approach based on a LFS technique preliminary presented in [3] for an on-line sub-surface sensing is analysed and compared to state-of-the-art classification approaches. Starting from the knowledge of the scattered field values collected above the surface, the method is aimed at defining a risk map of the domain under test. By considering a SVM-based classifier, the proposed method estimates the a-posteriori probability of the presence of subsurface dangerous objects. The advantages of the use of such an instance-based classification method compared to more traditional optimization techniques as well as other classification approaches can be summarized as follows: (*a*) no *a-priori* knowledge about the system that generated the data is required, but only a set of input/output measurements; (*b*) the algorithm for the solution of the arising quadratic optimization problem with constraints is simple and reliable (no local minima/maxima occur); (*c*) SVMs are based on the "*Statistical Learning Theory*" by *Vapnik and Chervonenkis*, which permits one to design optimal classifiers with a solid theoretical framework; (*d*) the estimation function is composed by a weighted sum of kernel functions, that can be easily implemented in hardware for real-time applications.

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