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ORIGINAL ARTICLE

An inverse problem approach to pattern recognition in industry

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Abstract Many works have shown strong connections between learning and regularization techniques for ill-posed inverse problems. A careful analysis shows that a rigorous connection between learning and regularization for inverse problem is not straightforward. In this study, pattern recognition will be viewed as an ill-posed inverse problem and applications of methods from the theory of inverse problems to pattern recognition are studied. A new learning algorithm derived from a well-known regularization model is generated and applied to the task of reconstruction of an inhomogeneous object as pattern recognition. Particularly, it is demonstrated that pattern recognition can be reformulated in terms of inverse problems defined by a Riesz-type kernel. This reformulation can be employed to design a learning algorithm based on a numerical solution of a system of linear equations. Finally, numerical experiments have been carried out with synthetic experimental data considering a reasonable level of noise. Good recoveries have been achieved with this methodology, and the results of these simulations are compatible with the existing methods. The comparison results show that the Regularization-based learning algorithm (RBA) obtains a promising performance on the majority of the test problems. In prospects, this method can be used for the creation of automated systems for diagnostics, testing, and

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control in various fields of scientific and applied research, as well as in industry.

1. Introduction

No patterns can be derived solely from empirical data (Yee and Haykin, 1993). Some hypotheses about patterns have to be chosen and, from among patterns satisfying these hypotheses, a pattern with a good fit to the data must be sought.

Neurocomputing brought a new terminology to data analysis: searching for parameters of their input/output functions is called learning, and samples of data training sets and a capability to satisfactorily process new data that have not been used for learning is called generalization.

The capability of generalization depends upon the choice of a hypothesis set of input/output functions, in which one searches for a pattern (a functional relationship) that matches the empirical data. So a restriction of the hypothesis set to only physically meaningful functions can improve generalization.

Inverse problems frequently arise in experimental situations when one is interested in the description of the internal structure of a system and is given indirect, noisy data. Estimating the response of a system given a complete specification of the internal structure, on the other hand, is the forward problem.

The modeling problem arises when one is given noisy data, observed over irregular intervals of space and time, and is asked to develop a reasonable model to fit those observed data (Vapnik, 1998).

With the advent of high-speed computers and artificial intelligence techniques, this modeling problem underwent a metamorphosis and emerged as a machine learning problem (Bauer et al., 2007; Gdawiec and Domanska, 2011). Tikhonov and Lanweber regularized that learning algorithms have recently received an increasing interest due to both theoretical and computational motivations (Abrukov et al., 2006; Kurkova, 2012; Tiknonov and Arsenin, 1977). Fractal, optimization, and a two-dimensional functional relational model have been used as a feature in several pattern recognition methods (Chang et al., 2010; Lo Gerfo et al., 2008; Noureddine, in press). Considerable attention is currently being devoted to new possibilities of using artificial neural networks (ANN) in view of their increasing importance for solving the problem of automated reconstruction of the inner structure of an object. Accompanying algorithms that effectively quantify uncertainties, deal with ill-posedness, and fully take the nonlinear model into account are needed Therefore, it is necessary to both look for possible ways to improve the classical learning algorithms already existent in the literature, and to identify new methods which can compete with the traditional ones in speed, robustness, and quality of results.