Electronic Letters on Computer Vision and Image Analysis 13(2):35-37, 2014

Algorithms for selecting parameters of combination of acyclic adjacency graphs in the problem of texture image processing

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Date and location of PhD thesis defense: 24 October 2013, Dorodnicyn Computing Centre of Russian Academy of Sciences, Russia

Received 10th February 2014; accepted 25th May 2014

1 Abstract

Nowadays the great interest of researchers in the problem of processing the interrelated data arrays including images is retained. In the classical theory of machine learning objects for recognition are examined independently. In the modern theory of machine learning, the problem of image processing is often viewed as a problem in the field of graph models. Image pixels constitute a unique array of interrelated elements. The interrelations between array elements are represented by an adjacency graph. The problem of image processing is often solved by minimizing Gibbs energy [2,3,6,7] associated with corresponding arbitrary adjacency graphs. The crucial disadvantage of Gibbs approach is that it requires empirical specifying of appropriate energy functions on cliques. This requirement is not always easily done. In the present work, we propose a simpler, but not less effective model, which is an expansion of the Markov chain theory indeed. In this model, the array of interrelated elements is represented in the form of a two-component Markov random field of hidden classes and their observed features. In linearly ordered arrays, the adjacency graph is a chain. This allows us to organize an efficient processing of data arrays based on popular approaches such as the dynamic programming or the Markov chain theory. The linear Markov models controlling changes of hidden classes of recognized objects are proved to be extremely efficient [4]. However, for arbitrary adjacency graphs with cycles the segmentation problem is more complicated. In particular, the adjacency graph for raster images is a lattice that contains cycles and is not an acyclic one. In this case, the using of Markov models leads to time-consuming algorithms and the processing problem belongs to the NP class [2]. In this work, our approach to image processing is based on the idea of replacing the arbitrary adjacency graphs by tree-like (acyclic in general) ones and linearly combining of acyclic Markov models in order to get the best quality of restoration of hidden classes. For acyclic adjacency graphs, the one-sided model of a Markov random field in the form of a Markov chain was previously proposed and the effective recognition algorithm [4] that is performed with three passes along the acyclic graph was developed. In this model, the problem of processing of the interrelated data arrays is solved as a problem of the supervised learning and recognition. The main idea is that results of independent learning are coordinated with each other through the graph model. The crucial advantage of this model among other things is that it allows us to restore numerically a posteriori distributions of hidden classes of a Markov random field. Properties of the one-sided model of a Markov random field can be configured using a Markov matrix of

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Recommended for acceptance by <Alicia Fornes and Volkmar Frinken>
ELCVIA ISSN:1577-5097
Published by Computer Vision Center / Universitat Autònoma de Barcelona, Barcelona, Spain

conditional transition probabilities between classes of its states. Such a matrix is often briefly called a transition matrix. The transition matrix is a parameter of the proposed model. As it was previously shown, in a particular case the transition matrix can be specified by a unique value of all its diagonal elements. It means that we can simply adjust the model by using a unique value the value of the diagonal element of the transition matrix. On the other hand, as a rule, the adjacency graphs in applied problems contain cycles. For example, in raster images the natural adjacency relation of pixels is a lattice. Obviously, an arbitrary adjacency graph can not be replaced by a tree-like graph without the loss of the fundamental property of the initial graph to represent the complete information about each element with respect to other elements. In order to reduce the losses related to the tree-like approximation of the initial graph the algorithm for combining adjacency graphs that is based on the general ideology of complexation of processing operators [8] was previously proposed. In order to find the optimal weights of graphs in their linear combination the algorithm for determining the weights of graphs based on the Gauss-Seidel method was developed. The issue is that in the algorithm for determining weights of graphs, only one transition matrix was used and the diagonal element of the transition matrix was heuristically specified without finding its optimal value. Therefore, the problem of simultaneous selection of the diagonal element and the weights of acyclic adjacency graphs in their linear combination arises. In this work, we investigate iterative algorithms for selecting parameters of combination of acyclic adjacency graphs. The essence of these algorithms is to include the adjusting of the diagonal element in the scheme of graph weights selecting based on the Gauss-Seidel method. Weights of graphs in their linear combination are normalized, so sum of the weights is equal to 1. Thus, the value of each graph weight is changed in the range from 0 to 1. Furthermore, it has proved that the diagonal element of the transition matrix must take a value in the range from 1/m to 1, where m is the number of classes. The variation of graph weights and the variation of diagonal element are treated as analogue of the coordinate-wise variation in the Gauss-Seidel method. Moreover, it is possible that either one common diagonal element is used for all acyclic adjacency graphs or each graph corresponds to its own diagonal element. In general case, the model parameters can be categorized into natural parameters or hyperparameters [1]. Sometimes the difference between natural and hyperparameters is quite unclear. The interpretation of parameters as natural ones or hyperparameters can be determined by investigators point of view. In particular, such a situation arises in the problem of selecting parameters for the combination of acyclic adjacency graphs. Markov parameters (the diagonal element of the transition matrix) and the graph weights can be viewed as either natural or hyperparameters. However, the tuning of hyperparameters based on the complete cross-validation scheme using the grid search requires an extremely high computational complexity. In this work in order to avoid the excessive computational complexity, we treat graph weights as natural parameters and Markov parameters as hyperparameters. Moreover, we propose a hybrid approach that consists in adjusting Markov parameters as natural ones in the same procedure with the adjusting of the graph weights based on the Gauss-Seidel scheme. Nevertheless, the quality of the decision rule is evaluated by a cross-validation scheme that is similar to the scheme for tuning hyperparameters. The proposed cross-validation scheme allows us to reduce the computational complexity and determine the optimal tuning of the acyclic adjacency graphs with Markov parameters treated as hyperparameters. The experiments show that the combination of acyclic adjacency graphs with the tuning of Markov parameters provides the high-level recognition quality. For example, our results are often the same and some times better than for the sequential tree-reweighed message passing algorithm [3,6,7] which today is considered as one of the most effective algorithms for image recognition. More closely, the statistical hypothesis of the same class of the quality results of these two algorithms is not rejected. Our adjusted combined one-sided Markov model allows gaining good recognition results with the high quality and accuracy for many popular real image datasets. As a result, we proposed the adjusted one-sided Markov model of a random field based on the model of a hidden Markov chains. However, such model can describe objects with significantly wider variety of properties than chains random fields. On the other hand, the ideology of machine learning allows us to formulate and solve the problem of optimal numerical estimation of a posteriori distributions of hidden characteristics of a carrying media (raster images), optimally adjust the parametric models and apply the theoretically substantiated search methods such as well-known cross-validation technique [1]. This approach allows us to theoretically develop the proposed model and study its properties

both in the direction of developing of traditional learning technologies in machine learning and in the direction of studying properties of the countable set of acyclic adjacency graphs.

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