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Editorial

Special issue “Advances in graph-based pattern recognition”

A graph is an important class of representations in pattern recognition. Graph-based representation and learning/inference algorithms have been widely applied to structural pattern recognition and image analysis, such as image segmentation, shape recognition, scene parsing, document analysis, social network mining, and so on. On the other hand, the application needs in network era have posed new challenges to graph-based pattern recognition, such as matching for large graphs, automatic learning of graph models, inference in graphical models incorporating multi-source knowledge and contexts, applications to real-life large and noisy data, and so on.

Facing the multitude of scientific problems and the wide applications of graph-based representations, the IAPR TC-15 (Graph-based Representations in Pattern Recognition) has sponsored a series of workshops called IAPR-TC15 Workshop on Graph-based Representations in Pattern Recognition (GbR). The workshop has benefitted the community in triggering scientific research and exchanging progresses. The latest edition, the 10th IAPR-TC15 on GbR, was held in Beijing, China, on May 13-15, 2015.

This special issue is aimed to report the state of the art in theory, methods and applications in graph-based pattern representation and recognition. The scope ranges from various computing issues of graph-based representation, learning and inference, to applications in pattern recognition, computer vision and data mining.

We received 41 full submissions for consideration. All submitted papers underwent a strict peer review process, with each one assigned to at least two reviewers. After at least two rounds of reviews for each submission, we selected 27 papers to be published in this special issue.

The 27 accepted papers include one survey paper and 26 papers grouped into four categories: graph-based representation, graph matching, graph-based classification and learning, and applications.

The survey paper “Revealing Structure in Large Graphs: Szemerédi’s Regularity Lemma and Its Use in Pattern Recognition”, by Marcello Pellilo, et al., provides an overview of Szemerédi’s regularity lemma and its algorithmic aspects, and discusses its relevance in the context of pattern recognition research. Szemerédi’s regularity lemma has emerged over time as a fundamental tool in different branches of graph theory, combinatorics and theoretical computer science. It provides us a way to obtain a good description of a large graph using a small amount of data, and can be regarded as a manifestation of the all-pervading dichotomy between structure and randomness.

In the category of graph-based representation, the paper “The Mutual Information between Graphs”, by Francisco Escolano et al., shows how manifold alignment can be combined with copula-based entropy estimators to efficiently estimate the mutual information between graphs. They compare the empirical copula with an Archimedean copula (the independent one) in terms of retrieval/recall after graph comparison. In “Image Representation and Matching with Geometric-Edge Random Structure Graph”, Bo Jiang et al. develop a new robust structure graph model for image representation and matching. They propose a novel random structure graph, called Geometric-Edge random graph (G-E graph), which explores the probabilities of edges between node pairs to indicate the uncertainty or variations of edges in the graph generated under some noise or perturbation of image units. In “Robust Graph Representation for Classification of Images with Underlying Structural Networks”, Denis Bujoreanu et al. consider scenes constituted by underlying structural networks. The extraction of information from such networks requires characterization methods specifically designed to preserve the topological structure of the network hidden in the image. They propose an entire image processing pipeline for this task with a robust joint segmentation and graph-based representation approach. The method relates to the Maximally Stable Extremal Region here extended to extremally stable graph.

The category of graph matching includes eight papers. In “Graph Edit Distance as a Quadratic Assignment Problem”, Sébastien Bougleu et al. propose to extend the linear assignment model for graph edit distance (GED) to a quadratic one through the definition of a family of edit paths induced by assignments between nodes. They formally show that the GED, restricted to the paths in this family, is equivalent to a quadratic assignment problem. They then propose to compute an approximate solution by adapting two algorithms. In “Optimising Volgenant-Jonker for Approximating Graph Edit Distance”, William Jones et al. revisit the Volgenant-Jonker (VJ) algorithm and propose a series of refinements that improve both the speed and memory footprint without sacrificing accuracy in the graph edit distance approximation. They quantify the effectiveness of these optimisations by measuring distortion between control-flow graphs, and document an unexpected behavioural property of VJ in which the time required to find shortest paths to unassigned vertices decreases as graph size increases. In “Improved Quadratic Time Approximation of Graph Edit Distance by Combining Hausdorff Matching and Greedy Assignment”, Andreas Fischer et al. compare two quadratic-time approximate graph matching algorithms based on Hausdorff matching (Hausdorff Edit Distance) and greedy assignment (Greedy Edit Distance), and derive a novel upper bound (BP2) which

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combines advantages of both. In “Anytime Graph Matching[1]”, Zeina Abu-Aisheh et al. address the so-called anytime graph matching algorithm which quickly provides the first solution to the problem, finds a list of improved solutions and eventually converges to the optimal solution. They describe how to convert a recent depth-first GM method into an anytime one, to create an anytime heuristic search algorithm that allows a flexible trade-off between the search time and the solution quality. In “Multilayer Matching of Metric Structures Using Hierarchically Well-separated Trees”, Yusuf Osmanlioglu and Ali Shokoufandeh consider the matching problem between two metric distributions where establishing a one-to-one matching of features may not always be possible. They propose a novel technique, multilayer matching, which utilizes both the individual node features and the clustering information of nodes, and further provide a primal-dual approximation algorithm which runs several orders of magnitudes faster. In “A Generalization of the Most Common Subgraph Distance and Its Application to Graph Editing”, Michael Hecht relates the graph edit distance to a generalized weighted version of the most common subgraph distance. After introducing the new concepts of isotonic shifts and vector weighted graphs, they give a weak but sufficient condition on cost models to result in an edit metric, and give a within cubic time computable upper bound on the edit distance for arbitrary instances. In “Obtaining the Consensus of Multiple Correspondences between Graphs through Online Learning”, Carlos Francisco Moreno-García and Francesc Serratosa present a method for combining multiple correspondences of graphs to conform a single one called a consensus correspondence. They also propose an online learning algorithm to deduce some weights that influence on the generation of the consensus correspondence. In “Game Theoretic Hypergraph Matching for Refining Multi-source Feature Correspondences”, He Zhang and Peng Ren develop a game theoretic hypergraph matching framework to refine feature correspondences of multi-source images. For efficient computation, they exploit the Baum-Eagon scheme for computing the maximum average game payoff for Nash equilibrium within the association hypergraph.

In the category of graph-based classification and learning, “Quantum Jensen-Shannon Graph Kernels Using Discrete-Time Quantum Walks”, by Lu Bai et al., presents a new family of graph kernels where the graph structure is probed by means of a discrete-time quantum walk. The kernel between the graphs is defined as the negative exponential of the quantum Jensen-Shannon divergence between their density matrices. For coping with large graph structures, they propose to construct sparse graphs using a simplification method by computing the minimum spanning tree over the commute time matrix of a graph. In “Graph based Skill Acquisition and Transfer Learning for Continuous Reinforcement Learning Domains”, Farzaneh Shoeleh and Masoud Asadpour propose a novel graph based skill acquisition method (named GSL) and a skill based transfer learning framework (named STL) for continuous reinforcement learning problems. GSL discovers skills as high-level knowledge using community detection from the connectivity graph, while STL incorporates skills previously learned from the source task to speed up learning on a new target task. In “Optimum-Path Forest based on k-connectivity: Theory and Applications”, João Paulo Papa et al. consider a deeper theoretical explanation concerning the supervised Optimum-Path Forest (OPF) classifier with k-neighbourhood (OPFk), and propose two different training and classification algorithms that allow OPFk to work faster. In “Optimizing the Class Information Divergence for Transductive Classification of Texts Using Propagation in Bipartite Graphs”, Thiago de Paulo Faleiros et al. propose a new graph-based transductive algorithm that use the bipartite graph structure to associate the available class information of labelled documents. By associating the class information to edges linking documents to terms, they guarantee that a single term can propagate different class information to its distinct neighbours. Two more papers consider feature selection and extraction using graph-based representation. In “High-order Covariate Interacted Lasso for Feature Selection”, Zhihong Zhang et al. devise a new regularization term in the Lasso regression model to impose high order interactions between covariates and responses. They use a feature hypergraph as a regularizer on the covariate coefficients, and present an efficient alternating direction method of multipliers (ADMM) to solve the resulting sparse optimization problem. In “Two-Dimensional Discriminant Locality Preserving Projection Based on L1-Norm Maximization”, Si-Bao Chen et al. propose a new linear dimensionality reduction method for image matrices. The method, named 2DDLPP-L1, makes full use of the robustness of l1-norm to noise and outliers. Two graphs, separation graph and cohesiveness graph, are constructed with feature vectors as vertices to represent the inter-class separation and intra-class cohesiveness. An iterative algorithm with proof of convergence is proposed to solve the optimal projection matrix.

The category of applications includes nine papers applying graph-based methods to image processing, computer vision, document retrieval and bioinformatics. In “Sequential Image Segmentation Based on Minimum Spanning Tree Representation”, Ali Saglam and Nurdan Akhan Baykan improve a graph-based data-clustering algorithm which uses Prim’s sequential representation of MST for the purpose of image segmentation. They show that the proposed method can compete with the most popular image segmentation algorithms in terms of low execution time. In “Category Independent Object Discovery via Background Modeling”, Gang Chen and H.Y. Zhang propose to model background to localize possible object regions based on the assumption that the background has limited categories. They localize objects based on voting from fore/background occlusion boundary, where graph-based image segmentation is used to yield high quality segments. In “Learning Arbitrary-Shape Object Detector from Bounding-Box Annotation by Searching Region-Graph”, Liantao Wang et al. propose location positiveness which encodes the information of bounding-box annotation to realize the arbitrary-shape detection from bounding-box human annotation. They propose two graph-based methods to embed the location positiveness for more accurate model training from simpler annotation. In “Exploring Generalized Shape Analysis by Topological Representations”, Zhen Zhou et al. propose to use tools in algebraic topology for computing topological invariants (such as the number of connected components and the number of holes) at different resolutions. They test the proposed method in 2D shape classification, 2.5D gait identification and 3D facial expression recognition. In “Graph Based Approach for Kite Recognition”, Kamel Madi et al. propose a graph-based approach for kite recognition from satellite images. The approach combines graph invariants with a geometric graph edit distance computation leading to an efficient kite identification process. In “Graph-Based Approach for 3D Human Skeletal Action Recognition”, Meng Li and Howard Leung propose to characterize the human actions with a novel graph-based model which preserves complex spatial structure among skeletal joints according to their activity levels as well as the spatio-temporal joint features. They use a graph kernel for measuring the similarity between two graphs by matching the walks from each of the two graphs to be matched. In “Large-scale Graph Indexing using Binary Embeddings of Node Contexts for Information Spotting in Document Image Databases”, Pau Riba, et al. propose a graph indexation formalism and apply it to word and symbol spotting in document images. Given a database of labelled graphs, graph nodes are complemented with vectors of

[1] This article has been published with the Pattern Recognition Letter’s issue 84C (2016), p. 215–224.

attributes, and graph retrieval is formulated in terms of finding target graphs in the database with small Hamming distance from the query nodes. In “Protein Functional Annotation Refinement Based on Graph Regularized l1-norm PCA”. Dengdi Sun et al. formulate the protein functional annotation refinement problem as a decomposition of the available functional tag matrix. They cast the problem into a convex optimization model named graph regularized l1-norm PCA, and propose an iterative procedure with efficient convergence for the method based on augmented Lagrangian multiplier. In “Chemoinformatics and Stereoisomerism: A Stereo Graph Kernel together with Three New Extensions”, Pierre-Anthony Grenier et al. consider the prediction of properties of molecules (called stereoisomers) in chemoinformatics. They present three extensions to a previous method which encodes the stereoisomerism property of each atom by a local subgraph, called minimal stereo subgraph.

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