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Title: Four Decades of Structural Pattern Recognition – An Overview of the Three Major Epochs

Abstract: Abstract. Actually, science is facing rapidly increasing amounts of data (e.g., high-throughput profiles of biological systems, to name just one ex- ample). The ability of managing, searching, classifying, or interpreting these data sets has emerged to a crucial scientific challenge. Simulta- neously, one observes that in many applications the underlying data is inherently complex, making unary, fixed size data structures rather in- appropriate for basic data representation.

This is where graphs come into effect. Graphs consist of arbitrarily sized sets of (labeled) nodes and edges, allowing us to model entities and re- lationships at the same time. Due to inherent problems that exist in the domain of graphs, both the power and flexibility are traditionally sacrificed for more rigid data representations. In recent years, however, several novel and innovative solutions for the problems of graph-based data representations have been developed and researched.

The field of graph-based pattern recognition has a long tradition and can roughly be subdivided into three main periods of time:

– First era: Graph matching

The process of evaluating the dissimilarity or similarity of two graphs is commonly referred to as graph matching. The overall aim of graph matching is to find a correspondence between the nodes and edges of two graphs that satisfies some, more or less, stringent constraints. Roughly speaking, one distinguishes between exact and inexact, some- times referred to as error-tolerant, graph matching. Major paradigms of exact graph matching are graph isomorphism, subgraph isomor- phism, maximum common subgraph, and related concepts. Examples of error-tolerant graph matching include, for instance, Graph Edit Distance, Spectral methods, Expectation Maximization algorithms, and many others.

– Second era: Graph kernel

The paradigm of kernel functions is originally developed for vecto- rial representations, but the kernel framework can be extended to graphs in a very natural. Actually, graph kernels have emerged to a widely-used technique for solving graphs classification tasks. Seminal contributions in the field of graph kernel are the works on convolution kernels, graph kernels based on the analysis of walks or pathes, diffusion kernels, or so called neighborhood aggregation approaches.

– Third era: Graph neural networks

After the first revolution of graph-based pattern recognition via graph kernels, that made powerful kernel machines applicable to graphs (like Support Vector Machines, for instance), the adapta- tion of neural networks, and in particular, deep neural networks, to the graph domain is currently the next big era in graph-based pattern recognition. Actually, graph neural networks for directed acyclic graphs have been proposed about twenty years ago. In the last decade, several variants of Graph Neural Networks such as Graph Convolutional Network (GCN), Graph Attention Network (GAT), or Graph Recurrent Network (GRN) have demonstrated superior per-formance in diverse learning tasks on graphs.

This talk is concerned with structural pattern recognition with a strong focus on graph-based data representations. In particular, we review in detail the three major eras outlined above and discuss open research problems in the area of graph-based pattern recognition.

Biography: Kaspar Riesen is a docent at the University of Bern, Switzerland and a professor at the University of Applied Sciences and Arts Northwestern Switzerland. He has a strong expertise in graph based representation in pattern recognition and related fields. He co-authored more than 65 conference papers and book chapters, 26 journal articles, and five monographs. One of my monographs has become a standard textbook on graph edit distance, that is regularly used in lectures. Research projects comprise, for instance, novel interaction models with large information bases, pioneering ways of document analysis (e.g., keyword spotting), and novel algorithms for intelligent data analysis using graphs. He presented various efficient graph matching procedures, one of which has become one of the most widely used algorithms in the field of graph-based data analysis. He co-introduced a generalized form of graph isomorphism that is particularly well suited for information retrieval from graphs (some of the proposed concepts have been implemented in commercial software products). He is also one of the co-responsible researchers behind histograph.ch and the IAM Graph Database (graph benchmark data sets for various applications).