Challenges in graph-based representations 2011

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This protocol documents the discussion about challenges in graph-based representations held at the 8th IAPR - TC-15 workshop on graph-based representations in pattern recognition. The workshop took place in Münster (Germany) from the 18th to the 20th of May 2011. The discussion was initiated by four presenters (Milan Sonka, Luc Brun, Edwin Hancock, Pasquale Foggia) and moderated by Horst Bunke. In the following text the discussion between the participants of the workshop is documented in a chronological order.

Medical image processing/analyses is an active field of research and an important application of graph-based representations. With today's hardware and multi-scale approaches it is possible to process an image with the size of 1000 x 1000 pixels in a minute, which facilitates faster and more efficient treatment of patients. Nevertheless, automatic methods fail in 10 – 20 % of the cases to supply the desired output/result. Thus, the "just enough interaction" paradigm is currently used to reach better results with minimal user interaction. Experiments showed that the accuracy of automatic methods can be distinctly improved by a quick interaction of the user, but more detailed interaction brings only little additional improvement.

Since the beginning of TC15, Jean-Michel Jolion categorized graphs people in the community work with according to their size. Although machines become faster and graphs increasingly larger and larger, the algorithms used to analyze and process data do not develop in the same manner. Therefore, it is necessary to identify the cases where algorithms do not deliver results in reasonable time, and to find novel concepts and algorithms. We need to find the limits of traditional algorithms/thinking. Algorithms should be clear and transparent to allow the user to observe the process and to understand how the parameters affect the outcome. This enables the user to decide if the algorithm is behaving as expected and delivering the desired output. It is a good idea to look at how humans solve a problem, especially for NP-hard problems. Humans are able to solve the traveling sales person problem in linear time. Even though the solution might not be the optimal one, it is fast and often sufficient. We do not always need the optimal solution, in particular for applications which are critical in terms of time (e.g. navigation).

Dealing with large datasets is a challenging topic in the graph community. In the extreme case, graphs can consist of hundred thousand or even over one million nodes (e.g. protein-protein interaction networks, social networks, telecommunication networks, etc.), which makes tasks like graph matching and computing distances between graphs even more difficult. (Edwin Hancock refers to Ernesto Estrada's invited talk at S+SSPR 2010 „Structural Patterns in Complex Networks through Spectral Analysis".) Denoting a graph as large or complex should not solely depend on its size (number of nodes), but also the type of labels (information stored in nodes) and its edge density.

Researchers are getting more and more interested in trying to understand what the function of a graph is rather than what it is representing. For example in a graph representing a social network it is more interesting to know what is going on than who knows whom. In physics, people are using several properties to characterize graphs: topological (e.g. average degree, degree distribution, edge-density, diameter, cycle frequencies etc.), spectral or algebraic (use

Eigen values of adjacency matrix or Laplacian, or equivalently the coefficients of characteristic polynomials), complexity (use information theoretic measures of structure, e.g. Shannon entropy). The idea would be to use these measures/properties to understand the function of a graph, which would definitely make a substantial impact in the fields of biology and complex networks.

Besides the problem of understanding the function of a graph, there is the problem of automatically building graph representations (design of new networks), which fulfill certain properties (e.g. inferred from experiments). After the graph is built, the next problem is how to deal with errors (e.g. wrong edges/links, noise, etc.).

Graph embedding is able to bridge the gap between structural and statistical pattern recognition, which allows combining the advantages of both fields (high representational power of graphs and effective and efficient algorithms from statistics).

Pasquale Foggia organized a contest on graph embedding for pattern recognition at the ICPR 2010. The contest was based on three large image databases (ALOI, COIL, ODBK), where the graphs were of medium size (up to 700 nodes). At the moment graph embedding is not ready for graphs larger than medium size. The aim of this contest was to evaluate the performance of graph embedding algorithms (including implicit ones) in the context of pattern recognition problems. In the ideal case the graph embedding approach is invariant w.r.t. node permutations, maps similar graphs to vectors which are close according to a vector distance function and maps dissimilar graphs to distant vectors. Such an embedding would make all the algorithms on vector spaces applicable to patterns represented as graphs.

This contest clearly showed open issues in the field. There are mathematical foundations to compare graphs, but there is a lack in comparing techniques and benchmarking strategies. Furthermore, there is no performance measure to compare, for example, the results gained by graph embedding to graph kernels (implicit graph embedding). The contest demonstrated that it would be good to have a larger repertoire of databases to stimulate further contests and attract new people to the community. Future contests should not be limited to embedding, but also cover topics like classification etc.