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FUZZY–ATTRIBUTED GRAPHS AND THEIR APPLICATION IN CHARACTER RECOGNITION SYSTEMS

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Abstract: The description of handwritten and printed characters by methods of graph theory can be improved by introducing fuzzy attributes into the formal description. This opens several new ways to use the graph theory in order to process data extracted from characters and other patterns.

Key words: Fuzzy logic, character recognition, pattern recognition, fuzzy attributed graph.

1. Introduction

The presented paper proposes an extension of the classical combinatory perception of a graph by the introduction of fuzzy–attributed graphs offering various applications in character and document recognition systems. The progress of graph theory [4], [5], [6], [8] opened various applications mainly in the field of combinatory optimization. The main criteria are here properties of connections and coherents. Thus a graph $G = (V, E)$ is characterized by a limited set $V \neq 0$ of vertices and a set E (edge) of subsets of V, the edges. For application in different problem fields this definition can be extended by adding the definitions of directions for the edges, of metrical lengths, costs etc. So e. g. the edges can be interpreted as points in an orthogonal system of coordinates resulting in the perception of a geometrical graph and thus bridging the different views of graph theory and euclidian geometry. Many algorithms to optimize the solution of combinatory problems (an example is the "travelling salesman") have been developed and encourage to try applications in other fields, e.g. of the character and pattern recognition. Classical methods use here statistical operators and extracts of the attributes. Usually

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already by definition no attention can be paid to the inner coherence and the connectional properties of the pattern to be recognized, although the application of graph theory - mainly of geometrical graphs - suggests itself. Certainly the exact numerical algorithms of a graph theory in application to the seemingly "chaotical" data material of bitmaps are discouraging mainly regarding the preprocessing steps of thinning, vectorising, edge detecting etc. All that seems to be a big disadvantage compared to the classical exact numerical processing of pattern recognition.

2. Fuzzy-Attributed Graphs

The new perception of fuzzy-attributed graphs [3] adds a new concept of pattern recognition:

Definition: A fuzzy-attributed graph is a tupel $G = (V, E)$ of a limited set $V \neq 0$ of edges and a set E, containing an attribute and a 2-element subset of V.

The named attributes of the edges are qualitative variable names of the edge type, represented in terms of the fuzzy logic by linguistic variables. These fuzzy variables allow a remarkable great flexibility and fault tolerance in describing the type of edges, better than purely geometrically defined vector graphs can offer. Anyhow these linguistic variables should be defined in such a way that they can be processed by algorithms. This means to transfer their qualitative contents into an analytical variable using the fuzzy logic perception of membership functions. A certain edge can hereby belong to several edge types whereby the membership function values add generally to 1. The definition of membership functions for such fuzzy designs shall be exemplified for the problem field of character recognition.

3. Example for an Application of Fuzzy Distributed Graphs

Regarding structures and forms of different alphabets (hebrew, cyrill, latin, chinese etc.) and fonts exemplifies that a restricted number of geometrical forms in different combinations can always be redetected [2], [3]. To perform a character recognition by fuzzy attributed graphs a character must be described by a fuzzy attributed graph, Figure 1. collects different forms of such fuzzy attributed graphs defining an edge between a starting and an end point of the edge.

- Single-Point:Point formed edge of low length

- Line: smallest connection between two points
- Right or left bend edge: defined bend
- Right-left or left-right bend edges: first convex,then concave bends
- Single loops or loops with a stetched content starting and endpoint are identical in the sense of a graph theoretical circle

Figure 1 illustrates the similarity between different edge attributes and empirically defined membership functions μ_{fix}. These fixed membership functions μ_{fix} determine the upper frame of the similarity between two edges of corresponding qualitative similar form. Nevertheless also regions of floating transfer between the different attributes should be admitted because allocations of the type usually cannot be realized by crispy definitions.

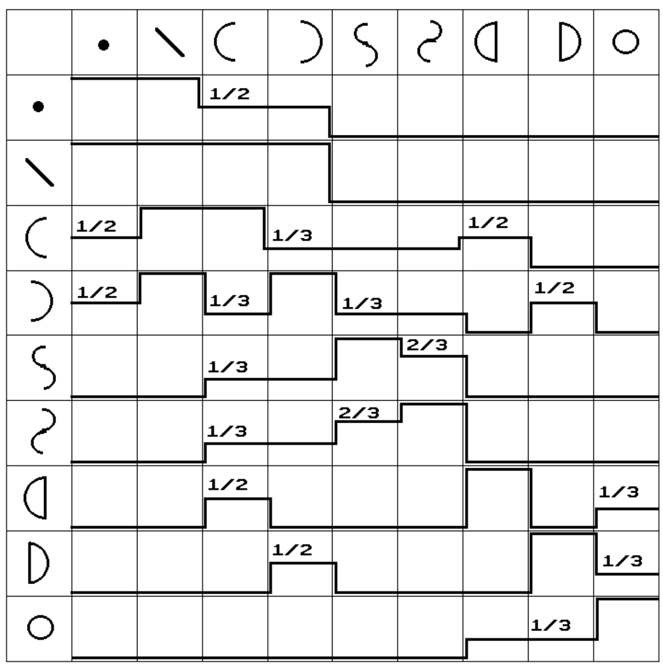

Fig. 1 Connection types and their membership functions.

Definitions in order to admit also in these cases steps of “grey” means to introduce as a measure of “convexity” the quotient of real length of an edge and euclidian distance d between starting and endpoint. Thus the fuzzy set for the characterized edge contains with n possible attributes n membership functions to each edge attribute. The membership functions are defined as

$$\mu = \frac{1}{d} \cdot \mu_{fix}$$

This means fixed or maximal membership values are weighted by the "convexity". This weighting is mainly important for stretched (quasi linear) edges. It is not so important for loops.

3. Results

The introduction of fuzzy-attributed graphs can improve the successful instrument of graph theory to open further applications in pattern recognition and further fields mainly by new defined formulations of existing optimization problems and in the classical context of graph theory.

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