Synthesis Essay - Predicate Logic Based Image Grammars for Complex Pattern Recognition

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The approach “Predicate Logic Based Image Grammars” used for complex pattern recognition, is proposed by Shet et al from 2007. In general, it exploits the prior world knowledge in characterizing patterns compositional and hierarchical, then manipulates this symbolic information to explicitly logic reason and finally infers the presence of interest pattern. With this intention, the proposed approach uses first order predicate logics, extended with a bilattice for encoding pattern grammars, and rule weight optimization method for automated procedures of learning rules within bilattice framework. In this synthesis essay, the combination of Predicate Logic Based Pattern Grammar and Bilattice Framework, and rule weight optimization method Knowledge Based Artificial Neural Networks (KBANN) are respectively described.

The proposed pattern grammar is encoded as logical rules based on the prior knowledge and parses a set of low level image features as logical facts. A level of uncertainty is assigned to these rules by bilattice framework. In detail, the rule of the form “if fact – then facts” is into three categories being composition, embodiment and context, which determine a hierarchical representation of object pattern, geometric layout and surrounding context respectively. Facts, capturing coordinates and scale of patterns, are used by a first order logic programming system for satisfying the rules and infer the presence of a specific pattern at a particular location. The bilattice framework measures the level of uncertainty of rule and fact in a coordinate system with information and belief degree axis. In this case, the bilattice square for continuous valued logic is defined by the two diagonals, line of indifference and consistency. Therefore, fact and rule are represented by an element of the form <belief for, belief against> on this square. The line of consistency joins element “true”, indicating no evidence for but full evidence against, and element “false” otherwise, while the line of indifference joins “unknown” indicating no information and “contradiction”. As a result, combining facts for firing a rule becomes operations between elements, which means conjunction - disjunction in degree of belief, evidence combination - consensus in degree of information, and negation operation. These operations are based properties of triangular norm and conorm. Justification of an interest pattern detection hypothesis is an element <belief for, belief against> which comes from the combination of the bilattice operations, namely closure operation. As shown above, the image features are described in facts, the knowledge of target pattern is represented by rules, and its presence is inferred by using uncertainty of bilattice framework.

The rule uncertainties are learned automatically by using rule weight optimization method, KBANN, which means that “belief for” of a rule is the link weight in neural network and back-propagation algorithm optimizes this weight. In this neural network, the facts from if-clause and then-clause of a rule are input and output nodes respectively. In addition, there are nodes of conjunction and disjunction for combining single rules. This back-propagation algorithm has two phases of propagation and updating weight. Propagation gives the ground truth of output nodes and then the link weights are updated for minimizing the mean square error between this ground truth and predicted value of output nodes. The sigmoid function, in this case, is closure operation of bilattice framework. By using the online weight update technique, the weight gradient is computed for each data point. After all, the rule weight is automatically computed with a given training dataset.

The system of predicate logic based approach extended the bilattice formalism is capable of predicting the presence of a specific pattern and its location in the image. Moreover, it provides the proof in linguistic form by using the facts inferred and the level of uncertainty of this hypothesis. In comparison with model free approach, logic based approach of this system requires less volume of training data and captures complex images such as hierarchical and compositional image. However, for its knowledge representation, encoding automatically the rules of image grammar is very expensive. Bilattice framework solves the problem of information incompleteness by computing the degree of information and using negation operations. In addition, this framework provides a reliability 's continuous value of rule and fact, includes new information without much re-engineering, hands contradictory data and evidences from multiple sources. For the problem of the complexity of inference, degree of reliability and information of a fact and rule is calculated once and reused significantly, which reduces this complexity. KBANN modifies the standard back-propagation for computing the error of rules which infer the output variables and its gradient descent algorithm could converge upon a set of weights providing an optimal performance in case of incomplete or inconsistent knowledge base. This method permits joint weight optimization and prevent the maximal contradictory state of bilattice.

In conclusion, the framework, predicate logic based approach extended using the bilattice formalism, is a promising choice in time-sensitive, resource-bound and computer vision application. It is evaluated via application to the problems of detecting the presence of humans under partial occlusions and detecting large complex man made structures as viewed in satellite imagery, which gives favorable results.