Syntactic Pattern Recognition

By

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Syntactic Pattern Recognition

- Statistical pattern recognition is straightforward, but may not be ideal for many realistic problems.
  - Patterns that include structural or relational information are difficult to quantify as feature vectors.
- Syntactic pattern recognition uses this structural information for classification and description.
- Grammars can be used to create a definition of the structure of each pattern class.

Classification

- Producing a classification can be done based on a measure of structural similarity in patterns.
- Each pattern class can be represented by a structural representation or description.
- It is often difficult to classify patterns that contain a large number of features.

Description

- A description of the pattern structure is useful for recognizing entities when a simple classification isn’t possible.
- Can also describe aspects that cause a pattern to not be assigned to a particular class.
- In complex cases, recognition can only be achieved through a description for each pattern rather than through classification.

When to Use It

- Picture recognition and scene analysis are problems in which there are a large number of features and the patterns are complex.
  - For example, recognizing areas such as highways, rivers, and bridges in satellite pictures.
- In this case, a complex pattern can be described in terms of a hierarchical composition of simpler subpatterns.

Hierarchical Approach

- The hierarchical approach comes from the similarity that can be seen between the structure of patterns and the syntax or grammar of languages.
- Following this analogy, patterns can be built up from sub-patterns in a number of ways, similarly to how one builds words by concatenating characters, and builds a phrase or sentence by concatenating words.

Definitions

- The simplest sub-patterns are called *pattern primitives*, and should be much easier to recognize than the overall patterns.
- The language used to describe the structure of the patterns in terms of sets of pattern primitives is called the *pattern description language*.
- The pattern description language will have a *grammar* that specifies how primitives can be composed into patterns.

Syntax Analysis

- When a primitive within the pattern is identified, syntax analysis (parsing) is performed on the sentence describing the pattern to determine if it is correct with respect to the grammar.
- Syntax analysis also gives a structural description of the sentence associated with the pattern.

Syntax Analysis

- One advantage of this approach is that a grammar (rewriting) rule can be applied many times.
- This allows for expressing basic structural characteristics for an infinite number of sentences in a number of compact ways.

Other Representations

- Relational graph - describe a pattern using the relations between sub-patterns and primitives.
- Relational matrix - any relational graph can also be expressed as a matrix.

Other Representations

- Generalizing to allow for any relation that can be determined from the pattern, we can express richer descriptions than through tree-based structures.
- Hierarchical (tree-based) approaches are convenient because it is easy to apply formal language theory.

Syntactic System

- Consists of two main parts:
  - Analysis - primitive selection and grammatical or structural inference
  - Recognition - preprocessing, segmentation or decomposition, primitive and relation recognition, and syntax analysis
- Preprocessing includes the tasks of pattern encoding and approximation, filtering, restoration, and enhancement.

Syntactic System

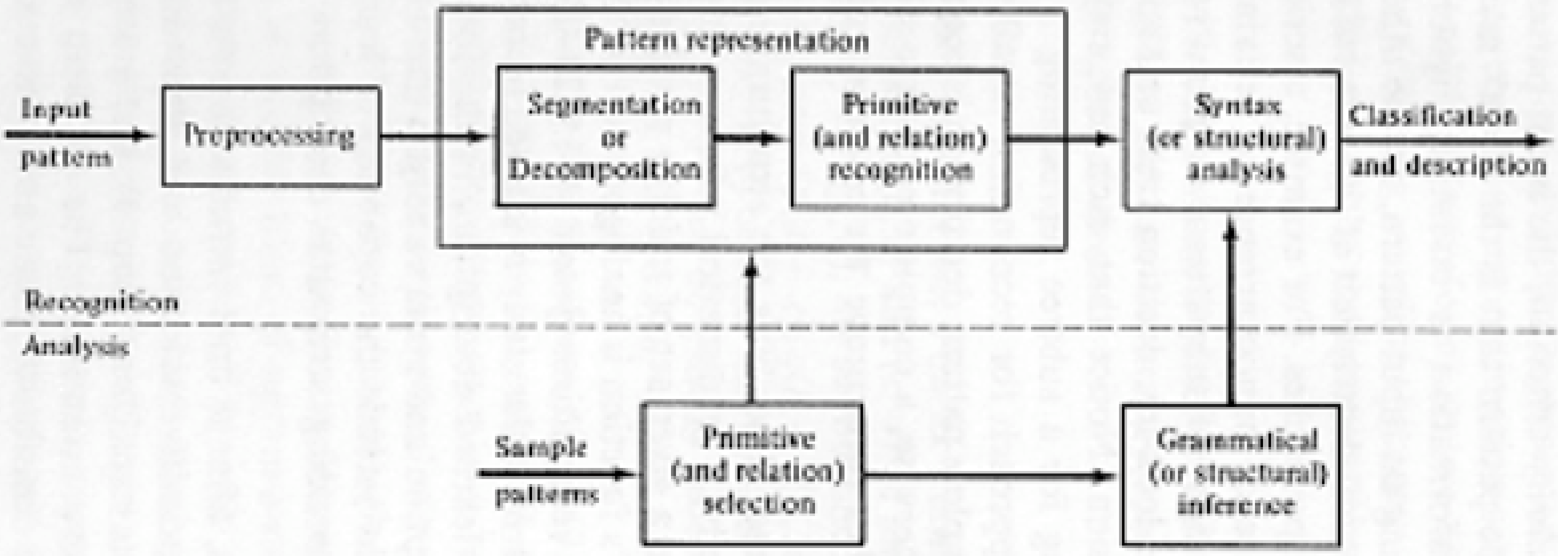


Figure 1.10. Block diagram of a syntactic pattern recognition system.

Syntactic System

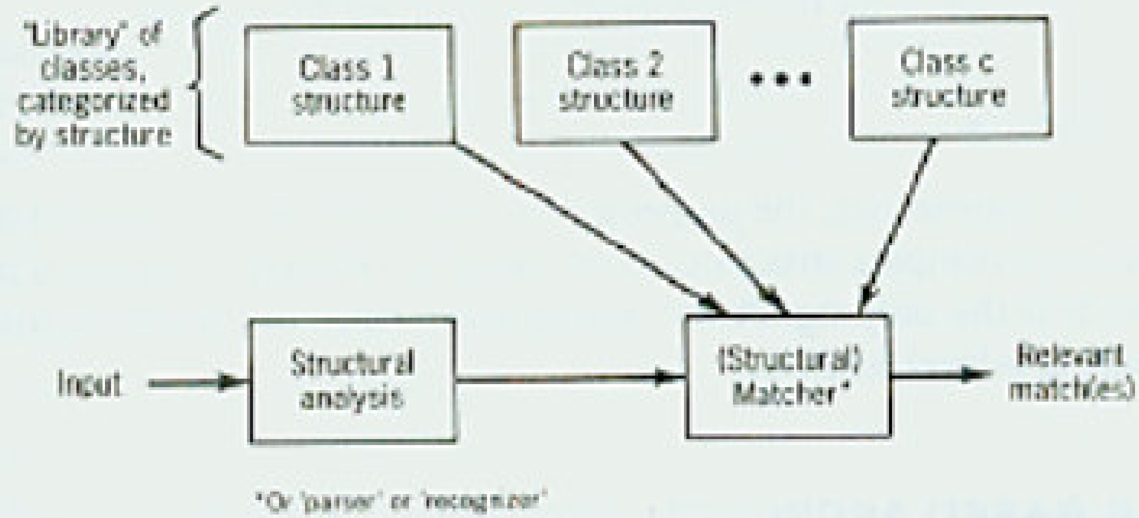


Figure 1: Using SyntPR for classification (with explicit characterization of structure).

Syntactic System

- After preprocessing, the pattern is segmented into sub-patterns and primitives using predefined operations.
- Sub-patterns are identified with a given set of primitives, so each pattern is represented by a set of primitives with the specified syntactic operations.

Syntax Parsing

- For example, using the concatenation operation, each pattern is recognized by a string of concatenated primitives.
- At this point, the parser will determine if the pattern is syntactically correct.
  - It belongs to the class of patterns described by the grammar if it is correct.

Syntax Parsing

- During parsing/syntax analysis, a description is produced in terms of a parse tree, assuming the pattern is syntactically correct.
- If it isn't correct, it will either be rejected or analyzed based on a different grammar, which could represent other possible pattern classes.

Matching

- The simplest form of recognition is template matching, in which a string of primitives representing an input pattern is compared to strings of primitives representing reference patterns.
- The input pattern is classified in the same class as the prototype that is the best match, which is determined by a similarity criterion.

Matching vs. Complete Parsing

- In this case, the structural description is ignored.
- The opposite approach is a complete parsing that uses the entire structural description.
- There are many intermediate approaches; for example, a series of tests designed to test the occurrence of certain primitives, sub-patterns, or combinations of these. The result of these tests will determine a classification.

Parsing

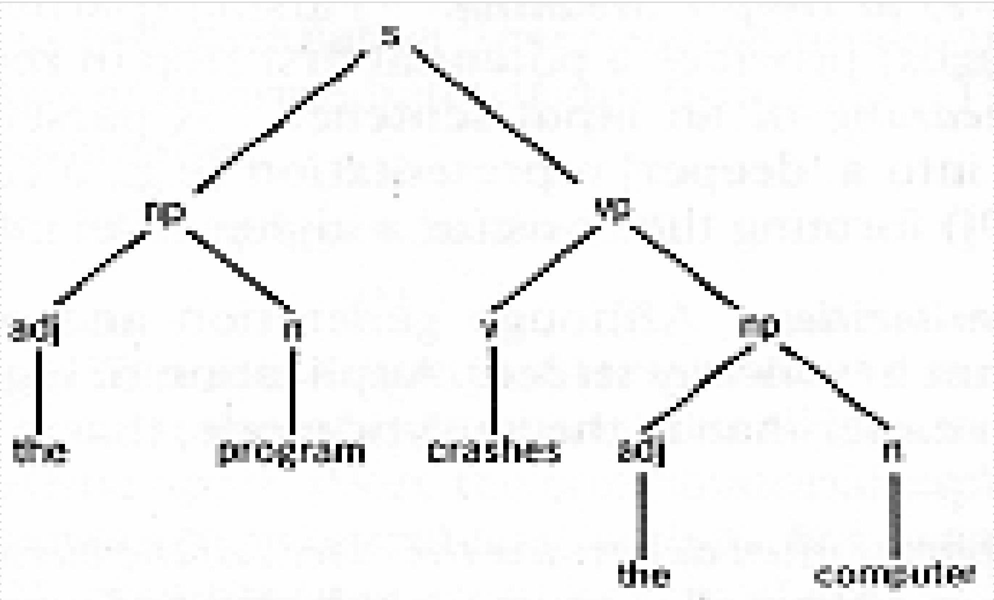
- Parsing is required if the problem necessitates using a complete pattern description for recognition.
- Efficiency of the recognition process is improved by simpler approaches that do not require a complete parsing.
- Basically, parsing can be expensive, so don't use it unnecessarily.

Inferring Grammars

- Grammatical inference machine - similar to “learning” in the discriminant approach; it infers a grammar from a set of training patterns.
- The inferred grammar can then be used for pattern description and syntax analysis.

Parsing - Fundamentals

- Parser Hierarchical Structure
  - Smaller decompositions
  - Graphically shown by derivation trees



Parsing Problems

- Approaches of Parsing
- Parsing/Generation Similarities
  - Application of grammar is easier in generative mode than analytic mode.
  - Concerns
    - Parser must determine the extent of the elements that comprise non-terminals.
    - Parser must find a use for all of x

Parsing Approaches

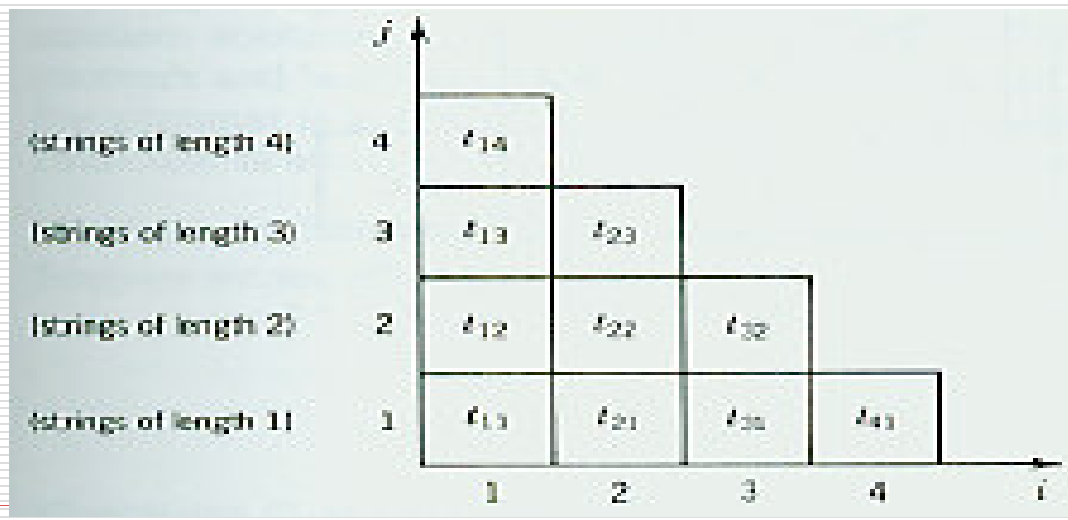
- Top-Down Parsing
  - From S to terminals. A derivation for x, where x is a sentence.
  - Method 1: Depth First Expansion of non-terminals, starting with leftmost non-terminal. Allows back-up.
  - Method 2: Recursive Descent may not work on all grammars. No back-up. Recursive functions to recognize sub-strings corresponding to the expansion of a non-terminal.
- Bottom-Up Parsing
  - Knowing x, we proceed to S by reversing the productions defined.

Comparing Top-down and Bottom-up

- Difficult to compare because the efficiency factor lies with the grammar.
- Normalization or Transformation of a grammar will affect parsing efficiency.
- Brute force method of the top-down and bottom-up approaches have computational complexity growing exponentially with $|x|$.

Alternative Approaches – CYK Parsing

- Cocke-Younger-Kasami Algorithm
  - Parse string x in number of steps proportional to $|x|^3$.
  - The CFG should be in Chomsky Normal Form
  - Building CYK table

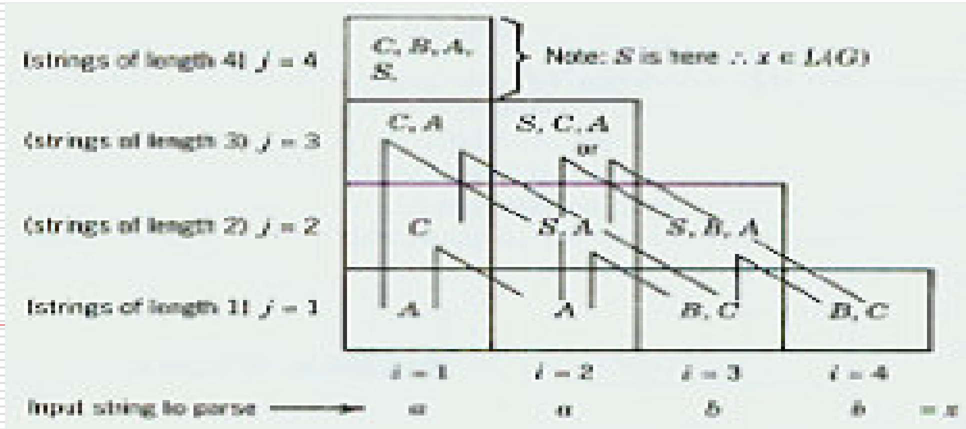


CYK Parsing contd.

- The cell (1,n) should have S. Then the parsing is said to be complete.
- Example
  - Productions

$$S \rightarrow AB|BB \qquad B \rightarrow BB|CA|b$$
$$A \rightarrow CC|AB|a \qquad C \rightarrow BA|AA|b$$

  - CYK table



Stochastic Grammars

- Assumptions of the formal grammar used in SyntPR
  - Languages are disjoint
  - No errors in the sentences produced by the grammar
- In practice the assumptions are faulty
  - Errors in the primitive extraction process
  - Noise or pattern deformation in descriptions

Stochastic Grammars contd.

- Definition
  - $G_s = \{V_N, V_T, P_s, S_s\}$
- P_s is a set of Stochastic Productions
  - Each production is of form
    - $a_i \rightarrow b_j$ with probability p_{ij}
- Derivations in Stochastic Language
  - Derivations of sentence from S_s to x
  - Labels $t_{k-1,k}$ where k=1 to n are given to each production such as β_{k-1} to β_k
  - Every production will have a probability pi
  - Unconditional Probability is given by
    - $P(t_{0,1}$ ‘n’ $t_{1,2}$ ‘n’ … ‘n’ $t_{n-1,n}) = P(t_{0,1}).P(t_{1,2}) \ldots P(t_{n-1,n})$

Stochastic Grammars contd.

- $P(t_{0,1},t_{1,2},\ldots,t_{n-1,n}) = \Pi_{q=1 \text{ to } n} P(t_{q-1,q})$
- This uses the assumption that every production is independent of the previous one applied.
- Proper Stochastic Grammar
  - Elements of Ps is of form
    - $A_i \rightarrow \beta_i$ with probability p_{ij}
  - Where $A_i \in V_N$, $\beta_i \in (V_N \cup V_T)^+$
  - $\Sigma_{k=1 \text{ to } ni}\ p_{ik} = 1$ (Sum of all the probabilities of each production in the Grammar is equal to 1)

Stochastic Grammars contd.

- Characteristic Grammar
  - Remove the probability measure from the Stochastic grammar
- Stochastic Languages
  - $L(G_s)=\{(x,p(x))|x \in V_T^+, S_S$ derives x with probability p_j, $j = 1$ to k, $p(x) = \Sigma_{j=1 \text{ to } k}\, p_j\}$
  - Where p_j is the probability to parse a string x from S_S and p(x) is the total probability of deriving various strings (Say k number of strings) using the grammar.

Stochastic Grammars contd.

- For example, x is ‘abc’ and productions of a grammar are
  - S->aA with p_1; A->bC with p_2
  - B->dC with p_3; C->eD with p_4
  - B->c with p_5; B->f with p_6
  - B->g with p_7; C->c with p_8
  - C->f with p_9; C->g with p_{10}
  - D->c with p_{11}; D->f with p_{12}
  - D->g with p_{13}
- Then to get x we have S->aA->abC->abc.
- Here the probability to get abc is $p(abc)=p_1.p_2.p_8$
- $p_1+p_2+\ldots+p_{13} = 1$ if the given grammar is Proper Stochastic Grammar

Structural Semantic Interconnections: A Knowledge-Based Approach to Word Sense Disambiguation

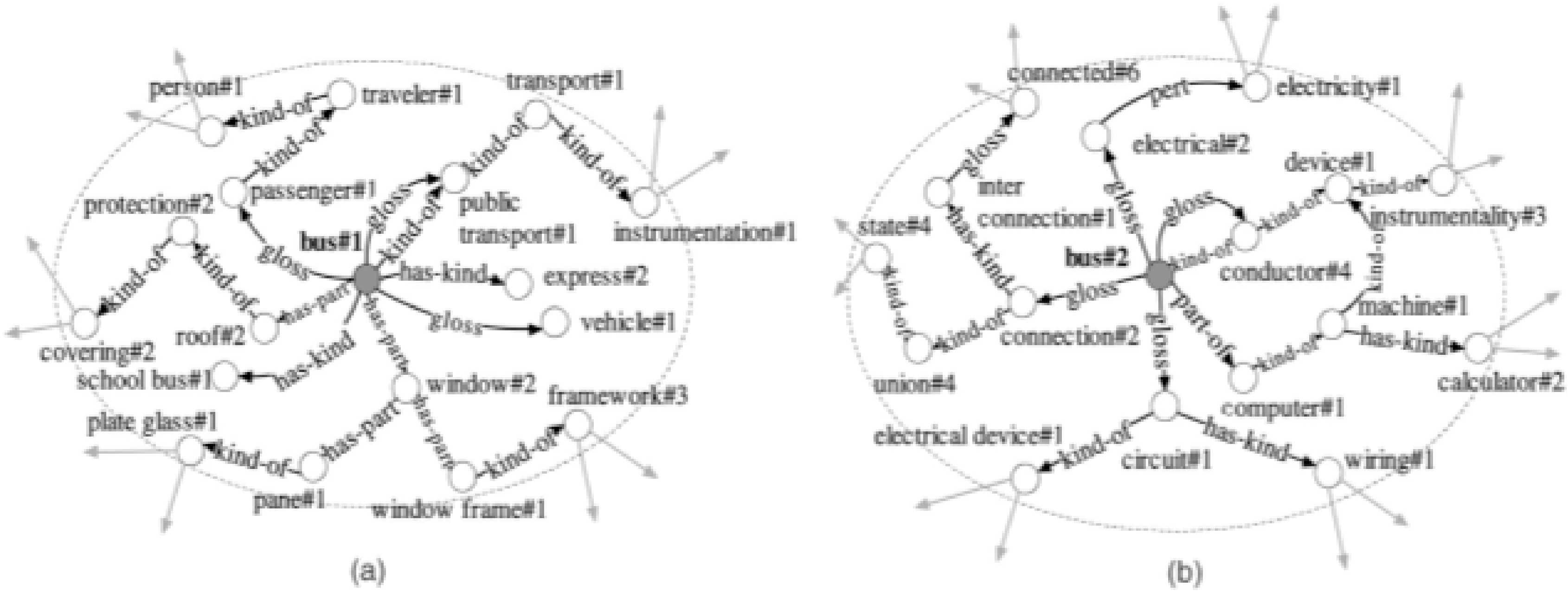
Paper by Roberto Navigli and Paola Verlardi

Word-Sense Disambiguation

- Same word, different meaning. For example, “bus” can be a vehicle or a connection on a computer.
- This leads to ambiguous situations in which it is not clear which word to use.
- This paper’s approach uses syntactic pattern recognition in attempting to improve disambiguation.

Representation

- Used a graph representation of senses:



Data

- Took data from a number of sources:
  - WordNet 2.0 - online resource featuring concepts that correspond to word senses
  - Domain labels assigned to WordNet
  - Annotated corpora - text examples of word sense usages in context
  - Dictionaries of collocations - words that belong to a semantic domain (ie: bus, stop, station)

Algorithm

- T = [t1, …, tn], I = [St1, … Stn], P = $\{t_i \mid S^{ti} = null\}$
- Algorithm iteratively disambiguates words in the pending set P of words that have no currently defined sense, where S is the chosen sense for t.

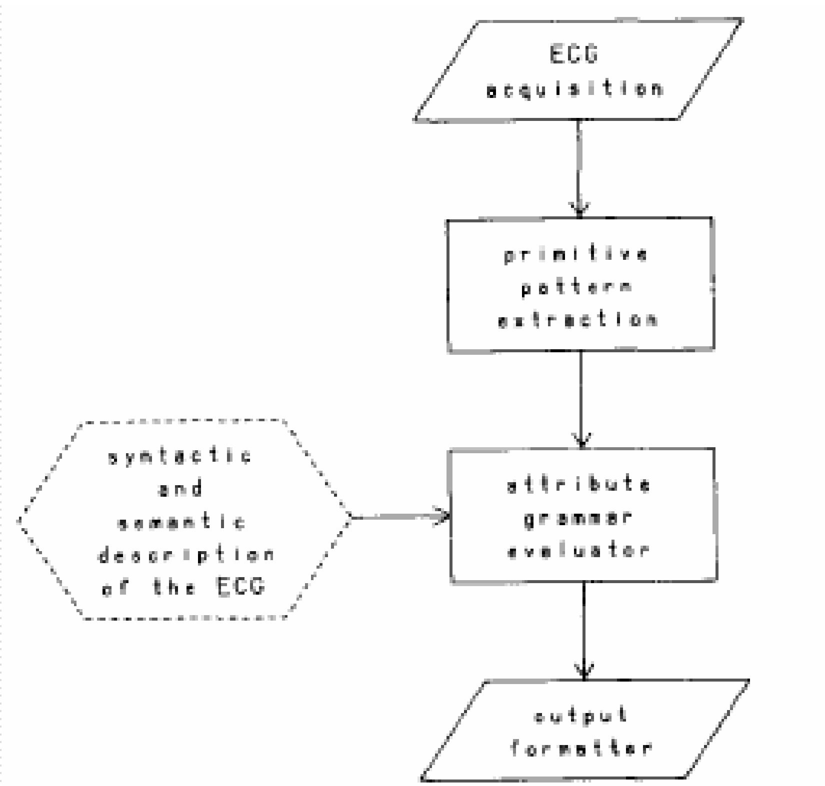
Grammar

- Describes meaningful connections in the graph representation.
- Used to do the disambiguation task in the iterative algorithm.

Results

- Performed better on large contexts.
- Achieved a 66% recall rate when the number of elements in T is 5.
- Achieved around a 90% recall rate where the number of elements in T is 40.

Synt Pattern Recognition of ECG



- Trahanias, P and Skordalakis, E speaks about how to recognize ECG information using SyntPR
- Patterns and Pattern parameters
- Primitive pattern selection
- Pattern Grammar
- Experimental results are convincing

References

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Thanks!