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A Survey on Applications of Grammar formalism In Image Processing

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Abstract

The tacticwhich is used to transfigure an image into digital form and accomplish some tasks is image processing, we can also get an enhanced image or to extractsome expedient information from it. It is a type of signalauthorizationin which input is image, like video frame or photograph and output may be image or featuresrelated with that image.In linguistics, a logical system or intentions that possess a certain set of grammatical cuffs (i.e., finite sequences) is fabricated from symbols of a certain finite set called an alphabet or basic (terminal)vocabulary. Applications of grammar formalism in image processing are the field of research that investigates the connection between two different domains.Grammar formalism provides a useful mechanism for describing operational manipulationtechniques like image formation in Scanning Electron Microscope(SEM), image formation in Transmission Electron Microscope (TEM), image storage and manipulation, image enhancement of multi-dimensional images. In this paper, we briefly review the application of grammar formalism for various image processing operations in real images. In this regard, we make an attempt to explore the working nature, applications, runtime and accuracy of various Image processing techniques like image segmentation, image steganography, image parsing, image classification and pattern recognition.

Keywords: Image segmentation, Image steganography, Image parsing, Image classification and Pattern recognition.

Introduction

Image processing is the field which relates mathematics, computer science and medical image processing. The various operations in image processing are *Image Formation, Image Distortion, Image Digitization, Image Quantization and Image Sampling*.A grammar G can be formally defined as G = (N, T, S, P), where N is a finite non-empty set of non-terminals/variables, T is a finite non-empty set of terminals, S is a start symbol ($S \in N$) and P is a finite non-empty set of productions of the form $\alpha \to \beta$. Grammars are usually classified based on a hierarchy established by Noam Chomsky (1965), according to the form of their productions ($\alpha \to \beta$). Each of the levels in the hierarchy has a corresponding automaton class: Type 0 or unrestricted grammar: Languages generated by type 0 grammar is called recursively enumerable language and are recognizedbyTuring machine. Type 1 or context-sensitive: β never shorter than α, $|\alpha| \leq |\beta|$. Languages generated by type 1 grammar are called context sensitive language and are recognized by linearly-bounded automata (LBA). Type 2 or context-free: α is a single variable / non terminal $\alpha \in N$. Languages generated by type 2 grammar are called context free language. Type 3 or regular grammar: if α is a single non-terminal / variable and β is any of the forms *a* or *aB* where $a \in T$ and $B \in N$. Regular grammars are recognized by finite sate automata (FSA).

For programming languages, grammar is synonymous with Context-free grammar(CFG). CFG is not only used to define the syntax of a programming language, but also used as input to compiler writing tools such as YACC [26]. A commonly used mathematical system for modelling component structurein Natural Language is Context-Free Grammar (CFG) which was first defined for Natural Language by Chomsky [22].

Grammar formalism concepts are used in the development of various image modelslike *pinhole camera model, point spread function, digitization, ideal sampling, aliasing, ringing*.Here, we start with the various grammar formalism approaches towards image processing. First, we start explaining with grammar based image segmentation part, it is an important step in the processing by which an image is partitioned into regions with similar featuressuch as content- based image retrieval, machine vision, medical imaging, object detection, and video surveillance. However, it is a difficult task and a very active research field and many approaches have been proposed [1, 2, 3]. Image steganography, initiated in[5], embodies a better approach, how would be the digital data has been hided into uncompressed image files by using a randomized algorithm and Context Free Grammar.Image parsing [6, 7, 8] is one of the Image processing techniques which use the Stochastic Scene Grammar for computing 3D scene layout, detecting 3D objects, 2D faces and segmenting the background [24]. The grammar proposed in [6, 7, 8] represents the compositional entities from scene categories i.e., 3D foreground/background, 2D faces, to 1D lines. Image classification [10], presents a new approach to represent an image as a string so that standard grammar initiation can be used in computer trickeryproblems. Some resultsin this domain will lead to a milestone for pattern recognition. Patternrecognition [11, 13, 15], presents an idea of using tree grammar and tree automata representing a set of multidimensional images by using some optimal algorithm to solve S-equivalence problem [12]. The goal of this work is to outline a device for signifying a set of images as a collection of trees and todesign a parallel algorithm to test the S-equivalence problem of two 2^d- ary trees. The main usage is to recognize the multidimensional images.This technique [1,20] is achieved by considering the human actions as a sequence of atomic body poses, and these poses are extracted from a set of multiview, multiperson video sequence with the help of ProbabilisticContext Free Grammar (PCFG).

This paper is organized as follows: Section-2deals with Image segmentation, Section-3deals with Image Steganography, Section-4deals withImage Parsing, Section-5deals with Image Classification, Section-6pacts with Pattern Recognition and finally conclusion.

Image Segmentation

In this section, we discuss aboutthe shape grammar which is used for image segmentation. The image segmentation is the process of partitioning a digital image into multiple segments. The main aim of segmentation is to streamline and/or variationis the illustration of an image into something that is more meaningful and informal to investigate. Image segmentation is typically used to locate objects and boundaries in images.The domain of image processing has many challengeslike modelling, segmenting, representing and recognizing complex objects. [1, 2, 3] shows that how the cardio graphic image segmentation can be done with the help of grammar. In [1],the proposed algorithmis to segment an image and create an automated estimation of cardio graphic image constructed bygrammar.

In [2], the proposed effort is compositional and-or graph grammar model for human pose estimation. This model hasthree distinguishing features: (i) large appearance variancesbetween people are handled compositionally by allowingparts or collections of parts to be substituted with alternativevariants, (ii) each variant is a sub-model that canexpress its own articulatedgeometry and context-sensitivecompatibility with neighbouring part variants. (iii) Backgroundregion segmentation is incorporated into the partappearance models to find a better estimate inthe contrastpart region from its surroundings, and improve livelinessto background chaos. Salah Hamdi et al., has expressed the technique which considers the image as a set of letters based on image vocabulary, grammar formalism and Hilbert transform for region depiction.Elias Mahfoud et al., has given the idea that uses 3D shape grammars to segment and estimate rectilinear shapes in non- rectified images. In [4], the work done is to project the 3D shapes which is used to define non-rectangular regions and to estimate the unknown shape parameters by using shape grammar.A shape grammar comprises of shape rules and a generation engine that selects and processes rules. A shape rule defines how an existing shape can be altered. A shape rule consists of two parts separated by an arrow pointing from left to right. The shape grammar consists of four tuples,SG= (V_T, V_M, R,I)

Where,

- V_T is a finite set of shapes
- $V_M$is a finite set of shapes such that $V_T^* \cap V_M = \varphi$
- R is a set of ordered pairs (u,v) such that u is the shape consisting of an element of V_T^* combined with an element of $V_M$and v is the shape consisting of elements of
    a) the element of V_T^*contained in u or
    b) the element of V_T^*contained in u combined with V_M*or*
    c) the element of V_T^* contained in u combined with an additional element of V_T^* and an element of V_M
- I is the shape consisting of elements of $V_T^*$and V_M.

The language generated by Shape Grammar L(SG) is that set ofshapes generated by the grammar that does not contain any element of V_M.The Shape grammars [27, 28] are tougher to gadget than context-free grammars, generally because we need to deliberate conditions as to whether or not a production can be applied, and we need to do some geometric computations to perform the split. However, a basic shape grammar is straightforward to implement[22]. The use of shape grammar in image segmentation is to project the 3D shapes to define non-rectangular segmentation regions and to estimate the shape parametersof the imaged objects[26].

Image Steganography

In this section, we discuss about Steganography, is the technique of hiding the information in other information. Many different carrier file formats can be used, but digital images are the most popular because of their usage on the Internet [5, 7]. For hiding secret information in images, there exist a large variety of steganography techniqueslike information hiding, water marking, security system, linguistic steganography, among these techniques few of them are complex [29]. Each and every application requires different steganography techniques. This paper, deals with the uses and techniques involved over the image steganography by using grammars.It also triesto discoverthe necessities of a good steganography algorithm and rapidlyimitates on which steganography techniques are more relevantfor applicationslike substitution method, spread spectrum technique, statistical method, distortion technique, cover generation method.

Elements of Steganography

In general, the procedures involved in steganography are, for covering and one for uncovering the secret data. The main purpose of covering process is hiding over data into a cover medium, also known as carrier file. In divergence, the uncovering process is just the reverse of covering process; it is nothing but an extracting the hidden data from the carrier file and recurring them back to their original state. Primarily, existing digital steganography is governed by five key barebones. They are as follows [7]:

1. **Covert Data:**It represents how the secret data can be structured or placed. These kinds of data can adapt the binary format, and can convert simple messages to executable files. So it is otherwise called as consignment.
2. **Carrier Medium:**It is a medium which deals about how the data has been hidden. These medium are readable by the computer like image, audio, video or text file.
3. **Carrier File:**These files are called as package, which deals with how the covert data can be embedded on a file.
4. **Carrier Channel:**These channels describe about the carrier, for example, BMP, JPG, MP3, PDF, etc.
5. **Capacity:**The vastness of data, the unbalancing of the carrier file can be identified with the help of the capacity barebones.

The proposed scheme is addressed on a randomized algorithm to erratically select the carrier pixels into which the secret data can be obscured. Acontext-free grammar of the English language that will generate correct English sentences and that will encode the position of the random carrier pixels in the carrier image which is present in the English languages[5].

Definition

Next, we discuss about the context free grammar with an example for a hypothetical language called L that is a subset of the English language.

NP →Det Nominal

NP → ProperNoun

Nominal → Noun | Nominal Noun

Det → an

Det → the

Noun → apple

The symbols which are used in a CFG are separated into two modules: one is the terminals which are related to indestructible words in the language such as “apple”, “the”, and “an”. The other one is non-terminal which are variables that can be substitutedby terminals and other non-terminal variables.In [7], the steganography using context-free grammar using two mediums, which is used to deliver the secret data. The first medium deals with a carrier image to hold the secret data and the second mediums discuss about the well- structured and syntactically correct English text which is made up of English sentences.Here, the English text is coupled with a lexicon of English words.

Next, we present a simple example how steganography is performed using Context-free grammar to hide the string 0100110.

Start → adjective noun tense verb

adjective → the size | a size

size → tiny | small | large | big

noun → saw | ladder | truth | boy

tense → is | was

verb → waiting | standing

In the above example, first nonterminal is adjective. The production for this nonterminal has twochoices, so one bit can be hidden by picking the right choice. The first bit to be hiddenis 0, so the first choice the size is selected. The terminal “the” is appended to thetext and the nonterminal sizeis replaced next. There are four choices, so two bits canbe hidden. The next two bits are 10, so the third choice, “large,” is selected. The nextnonterminal is noun. Again, there are four choices and the next bit pair to be hiddenis 01, so“ladder” is selected. The choice for tenseis “was” (directed by the next bit,1), and the choice for verbis “waiting,” since the last bit is 0. The resulting sentenceis “the large ladder was waiting.”

Image Parsing

In this section, we discuss about image parsing.The scene indulgent is an important task in neural information processing systems. By analogyto natural language parsing, Yibiao Zhao et al.,cover-upthe scene understanding problem as parsing an image into ahierarchical structure of visual entities by using the Stochastic Scene Grammar (SSG) or Stochastic Context free grammar. Theliterature of scene parsing can be categorized into two categories: discriminative approaches andgenerative approaches

[9]. Discriminative approaches will take care of categorizing super pixel to a semantic label. Generative approaches mark efforts to model the reconfigurable graph structures in generative probabilistic models and the stochastic grammar were used to parse natural languages.

Stochastic Context Free Grammar

In this subsection, we discuss aboutstochastic context-free grammar (SCFG) is a Context Free Grammarwitha probability distribution on productions:G = (V,α, S, R, P_p)

- V is a nonterminal alphabet
  α is a terminal alphabet
- S$\in$V is a special start symbol
- R is a set of rewriting rules called productions
- Productions in R are rules of the form : X $\rightarrow \lambda$
- $P_p$is a set of probabilities on production rules.

Consider an example, Let G= ($V_{G,}\alpha$, S, R_G, P_G),for V_G={S, L, N}, α={a,c,g,t}, and

$S \rightarrow$ a S t | t S a|c S g | g S c| L(P=0.2)

$L \rightarrow N\ N\ N\ N$ (P=1.0)

$N \rightarrow$ a | c | g | t (P=0.25)

Where $\forall_\lambda P_G(S\rightarrow\lambda)$=0.2, $P_G(L\rightarrow NNNN)$=1, and $\forall_\lambda P_G(N\rightarrow\lambda)$=0.25.

Then the probability of the sequence acgtacgtacgt is given by:

P(acgtacgtacgt) =P($S\Rightarrow$ aSt

$\Rightarrow$ ac$S$gt

$\Rightarrow$ acg$S$cgt

$\Rightarrow$ acgt$S$acgt

$\Rightarrow$acgt$L$acgt

$\Rightarrow$ acgt$NNNN$acgt

$\Rightarrow$ acgtaNNNacgt

$\Rightarrow$acgtacNNacgt

$\Rightarrow$ acgtacg$N$acgt

$\Rightarrow$ acgtacgtacgt)

$= 0.2 \times 0.2 \times 0.2 \times 0.2 \times 0.2 \times 1 \times 0.25 \times 0.25 \times 0.25 \times 0.25 = 1.25\times10^{-6}$

Overview of The Approach

The major contributions of [9, 11] is based on scene parsing problems, i.e., parse an image into a hierarchical structure, namelya parse tree. The parse tree refuges a wide spectrum of visual entities, includingscene categories, 3D foreground/background, 2D faces, and 1D line segments.The proposed algorithm is ahierarchical cluster sampling algorithm which will perform inference efficiently in SSGmodel. The algorithm accelerates a Markov chain search by exploring contextual relations. It hastwo stages:

1. **Clustering:** Based on the detected line segments.
2. **Sampling:** The sampling process makes a big reversible jumps by switching among competing sub-structures.

Image Classification

In this section, we discuss about image classification.An image is classified according to its visual content. An important application is image retrieval i.e., searching through an image dataset to obtain (or retrieve) those with particular visual content. In [14, 15], a new strategy was proposed to represent animage as a string so that standard grammar induction techniquescan be used in computer vision problems. Two sets of experimentsusing an artificial and a real dataset have been conducted. Inorder to explore the new strategy parameters, have a firstglimpse on its comparative performance against some standardmachine learning techniques. The results are encouraging and theproposal opens a new path of exploration for syntactical patternrecognition.The main aim of exploring formal language techniques and grammar inference in computer vision is how torepresentthe images [14].

Speed-Up Robust Features – SURF

In this subsection, we explain about SURF algorithm [14]which is usedto detect and designate the interest points.It is a point of an image and it has to satisfy the following characterizes like it has a clear, preferably, mathematically well- defined images. It has a well-defined position in image space with the high degree of reproducibility. from an image.Interest points are detected using a very basic butfast estimation of the Hessian matrix (Gaussian SecondOrder Partial Derivatives). SURF descriptors are based onsimilarpropertiesis robust, and describes the interest points as the Scale-Invariant Feature Transform(SIFT) technique.

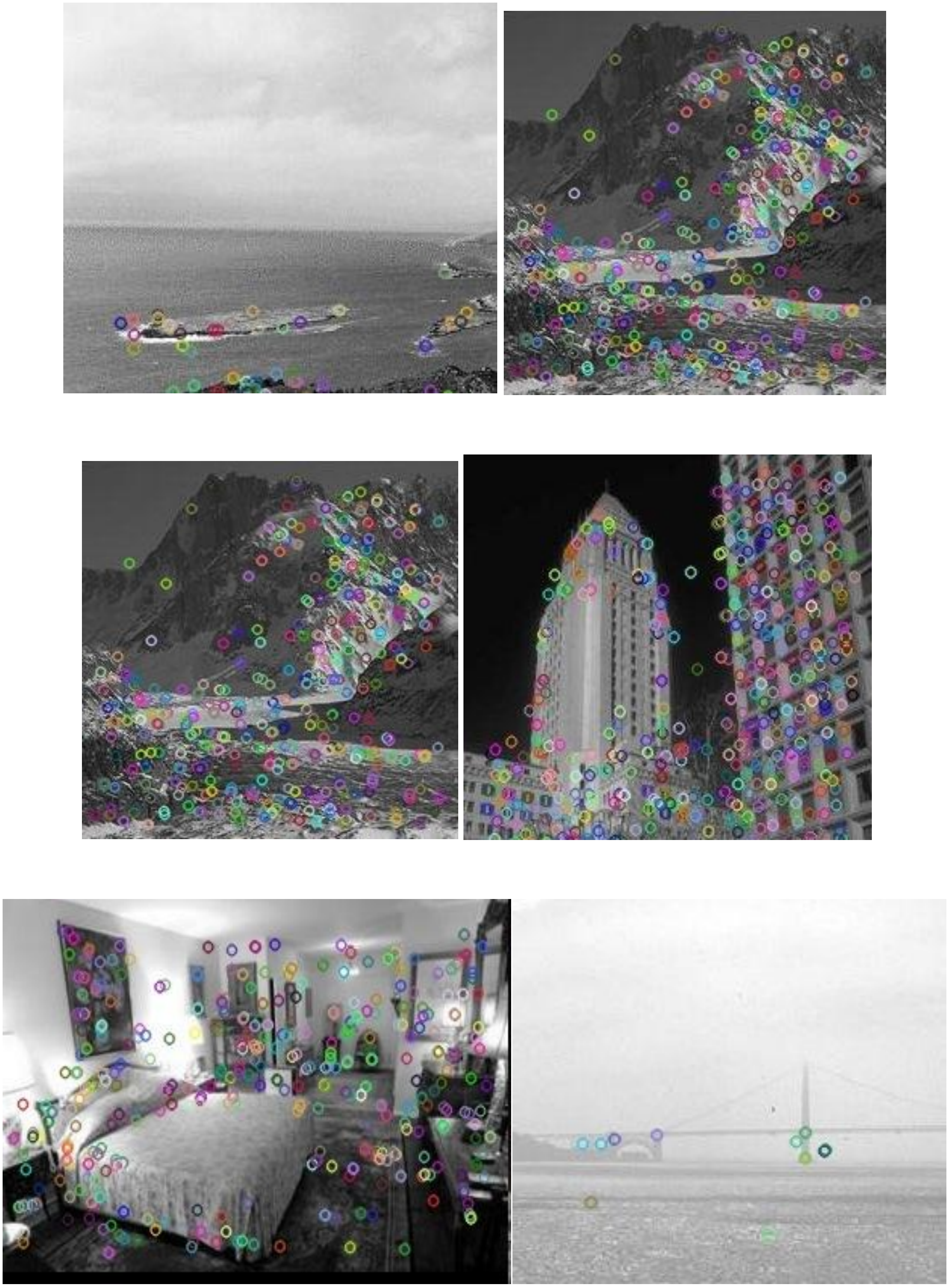

Figure 1: SURF interest points extracted 6 images of the 15 scenes dataset described in [14]

First, the overall direction of a small circular region around the interest point is calculated. A rectangular region aligned using this orientation is constructed around the interest point. This rectangular region is split regularly into 4 × 4 square sub-regions and sampled Haar wavelet retorts on vertical and horizontal direction, weighted with a Gaussian centred at the key point. At last, 16 sub- regions, 4 values are calculated, by producing 64dis a feature vector which is generated by SURF, and feature vectoris an n-dimensional vector of numerical features that represent some objects.In the above figure, we have shown how the SURF interest points are extracted from the 15 scene dataset.

Bag of Words – BOW

Both SIFT and SURF algorithms describe an image usinga variable size set of benefit points, with their correspondingkey point descriptors. In order to use a standard machine learning that needsa fixed size vector as input, the Bag of Words (BOW) strategycan be used. In BOW, the benefit points extracted from aset of training images are clustered, using k-means and the symbol is ignored and the automaton proceeds reading the nextsymbols without varying the current state. An error retrievalstrategy is used so that the automaton will always read all thesymbols of the input string.

Pattern Recognition

In this section, we discuss about object detectionwhich is amethod of defining the cases of real-world objects such as faces, bicycles, and buildings in images or videos. Here the object detection algorithm is playing a main role of extracted structures and learning algorithms to identify occurrences of an object category [21, 23, 30]. It is commonly used in applications such as image retrieval, security, surveillance, and automated vehicle parking systems [16, 17].

Grammar Models

Object detection grammars [16] denote objects recursively in terms of other objects. Let N be aset of non-terminal symbols and T be a set of terminal symbols. Here the terminals are thebasic building blocks that can be found in an image. The non-terminal describes about theabstract objects whoseappearance is defined in terms of extensions into terminals.Let Ω be a set of possible locations for a symbol within an image. A placed symbol, Y (ω), specifiesa placement of $Y \in N \cup T$ at a location $\omega \in \Omega$. The structure of a grammar model is defined by aset, R, of weighted productions of the form,

$$X(\omega_0) \to_s \{Y1(\omega_1),\ldots,Y_n(\omega_n)\}$$

Where $X \in N$, $Yi \in N \cup T$, $\omega_i \in \Omega$ and $s \in R$ is a score.

Creating a Probabilistic Context-Free Grammar (PCFG)

In [18],Abhijit S. Ogale et al., discussedabout how the PCFG is playing a major role in identifying the human actions.Human actions areshort classificationof atomic body poses. The facts of body poseis stored only implicitlyas a set of outlines seen frommultiple lookouts; no explicit 3D poses or body modelsare used, and individual body parts are not identified [25]. Actionsand their constituent atomic poses are extracted froma set of multiview, multiperson video sequences by an automatickey frame selection process, and are used to automaticallyconstruct a probabilistic context-free grammar(PCFG).

The probabilistic context-free grammar(PCFGs) are defined as follows,

A PCFG consists of,

1. A CFG G= (N, Σ,S, R)Where,
   - N is a finite set of Non-terminal symbols
   - Σis finite set of terminal symbols
   - R is a finite set of rules of the form $X \rightarrow Y_1,Y_{2,}\ldots,Y_{n,}$ where X ∈ N, n>0 and Y_i∈ (N ∪ Σ) for i =1,...,n
   - S ∈ N is a start symbol.
2. A parameter q (α→ β), for each rule α→ β ∈ R.
   - The parameter q (α→ β), can be interpreted by choosing rule α→ β in left-most derivation.
   - For the given parse tree t ∈ $T_G$consisting of rules like $\alpha_1 \rightarrow \beta_1$, $\alpha_2 \rightarrow \beta_2,\ldots,\alpha_n \rightarrow \beta_n$.
   - $p(t) = q(\alpha_i \rightarrow \beta_{i)}$ limits with i= 1 to n.

For example the parse tree for the statement *the dog sleeps* is given as:

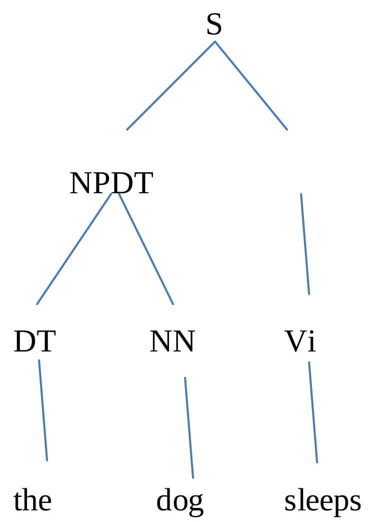

Figure 2: A derivation can be represented as a parse tree

To calculate the probability of any parse tree, we have to multiply together with the q values of context free rules.

The objective of [19, 20] is to give *an* overview about the use of syntactic pattern recognition methodsin image representations. To achieve this goal, RicardoWandre Dias Pedro et al.,suggested a systematic reviewprocess which consists of (i) planning on protocol (ii) conduction according to the inclusion and exclusion of the protocol and (iii) data extraction.

Conclusion

In this paper, we hadpresented the importance of grammar formalisms with various image processing techniques such as segmentation,steganography, parsing, classification and pattern recognition.Image segmentation gives the idea how the image, entity and the language entity is used to segment the image. To validate this method, a study is done with a set ofsynthetic and real objects. Grammar- based Image steganographyis one of the major steganography methods which use only one medium to transmit the secret information. It is hard-to-notice, as it preserves the quality of the carrier image. It can generate the text medium in different languages depending on the CFG and lexicon used.In image parsing, we have discussed about the traditional probabilistic context-free grammars (PCFGs) is used to parse the images and some of the aspects are spatialcontext, production rules for multiple occurrences of objects, richer image appearance and geometricproperties.In image classification section, we have discussed about how the images can be converted into a string by using the algorithms like SURF and SIFT. Finally, we have discussed aboutGrammar- based pattern recognitionlearning or extracting the grammar structure from the class of images.

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