A GENERATIVE GRAMMAR FOR PRE-COLUMBIAN ARTISTIC PRODUCTION: THE CASE OF EL TAJÍN STYLE

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Abstract

This paper presents a shape grammar for the production and recognition of images conformed to the artistic style of El Tajín, an archaeological city in México. After an introductory review of previous archaeological and computational works, the paper describes the syntax and the process by which the Generative Grammar of El Tajín Style (GGTS) composes depictions of images. Subsequently, the paper presents a brief description of the Prolog implementation of GGTS and brings forward some reasons for considering GGTS an anthropological cognitive model of creativity. The paper finishes discussing the virtues and shortcomings of the Generative Grammar of the El Tajín Style (GGTS).

Keywords: Computational creativity, shape grammar, cognitive anthropology.

1 Introduction

Most computational applications for archaeology focus on statistical analysis, geographical information systems, automated cartography, virtual reality, 3D scanning, and internet applications (Wise and Miller, 1997; Prinke, 2005; Dawson and Richard, 2005; Bellanger et al., 2006; Ebert, 2006). However, automatic tools for the description, classification, interpretation and generation of iconographic material are necessary too. An overview of the methods currently used in iconographic studies is done by Camiz (2004). He describes some notational methods, and discusses their conveniences and limitations. All those methods are algebraic languages where symbols representing spatial relations articulate symbols standing for icons (e.g., {*iconName1 . iconName2*}, where "." may mean "is besides"). Unfortunately, none of these languages can be considered an objective definition, because none of them generates novel instances of a given style.

In contrast, shape grammars have been more successful in this respect. The first examples were designed in the early 70s, but it was in the 80s when grammars were used to define specific artistic styles (Kirsch and Kirsch, 1988), and in the 90s when they were combined with pattern recognisers (Scidmore and Bajcsy, 1979; Bajcsy et al., 1984; Matsello et al., 2002) [1].

In this paper we present a Generative Grammar similar to those created by Kirsch and Kirsch. The grammar, referred to as the **G**enerative **G**rammar of the El **T**ajn **S**tyle (GGTS), does not work with pixel maps. Instead, it generates and recognises surrogate representations.

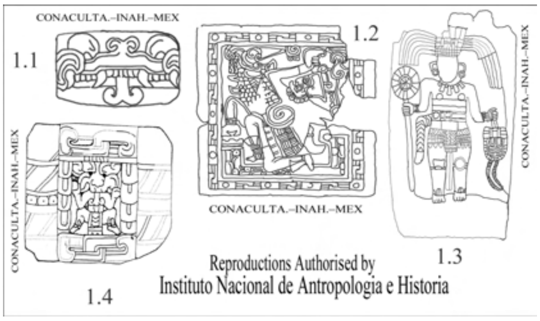

Figure 1: Examples of the El Tajín Style

2 Former Archaeological Studies

El Tajín City is an archaeological site located at the East Coast of México (300a.d-900a.d). The reliefs of the city have been studied in multiple occasions, although the bulk of these works concentrates in the symbolic or religious content of the sculptures. Amidst the few works studying the compositional structure of the images, the most cited are those authored by Proskouriakoff (1953), Kampen (1972), Castillo-Peña (1995), Pascual Soto (1990) and Pascual Soto (2005).

Among the numerous and decisive contributions made by all these researchers, we review the one of Pascual Soto (1990), for only this author employs a formal language as part of his proposal. His syntax, very similar to those discussed by Camiz (2004), describes a compositional structure in which a "base" (principal) symbol is surrounded by outer symbols. This syntax has two shortcomings. It does not allow any kind of inference and it does not offer

[1] For a brief history of shape grammars consult http://www.shapegrammar.org/

any objective method for the translation of a formula into the image it depicts. The formulas indicate that an icon (complex or simple) is over, below, at the left, or at the right of a central icon. They do not give any hint about the exact position and appearance of the symbols[2].

To sort out this problematic, it was sought a formal representation that could model the cognitive skill behind the design and contemplation of the sculptures. This representation was constructed with an inductive method. First, a sample of the known sculptures was analysed in a hierarchical manner in order to detect the compositional regularities characterising the El Tajín Style. Later, these regularities were extrapolated and represented with formulas expressing the common layout of similar scenes and objects. At the end, since these formulas depicted similitudes of different levels of abstraction, it was necessary to define rules describing which compositional arrangements could be jointed with what others. These rules, once organised, gave rise to a generative grammar.

3 Compositional Principles of EL Tajín Style

Every relieve in El Tajín City is engraved over a stele or a pile of stones. The engraved images show single objects or scenes (characters inside a context). Scenes are always framed, while single objects may appear without a frame. Single objects are pumpkins, serpent heads (Fig. 1.1), and solitary anthropomorphic figures (Figs. 1.3, 1.4). Scenes, on the other hand, represent human sacrifices, offering rituals, processions of warriors with prisoners, sat rulers guarded by floating serpents, and anthropomorphic figures kept in architectural structures (Fig. 1,2).

Each of those themes is repeatedly observed, although in each occasion slight variations are introduced in the elements conforming the image. This *exploratory* creativity constrained by rigid conventions, common in most forms of religious art, is the one modeled by GGTS.

4 Formal Structure of GGTS

GGTS comprises an **I**nferential mechanism (I) for the generation of relieves, a list (*P*) of 1267 **P**roductions hierarchically arranged, a start symbol (Sculp), a list (*N*) of 1125 Non-terminal symbols, a dictionary (*T*) of 2140 Terminal symbols, a set (*KV*) for the storage of **K**nown **V**aluable images, and a set (*KR*) for the storage of **K**nown **R**ejected images $(GGTS = (I, P, Sculp, T, N, KV, KR))$.

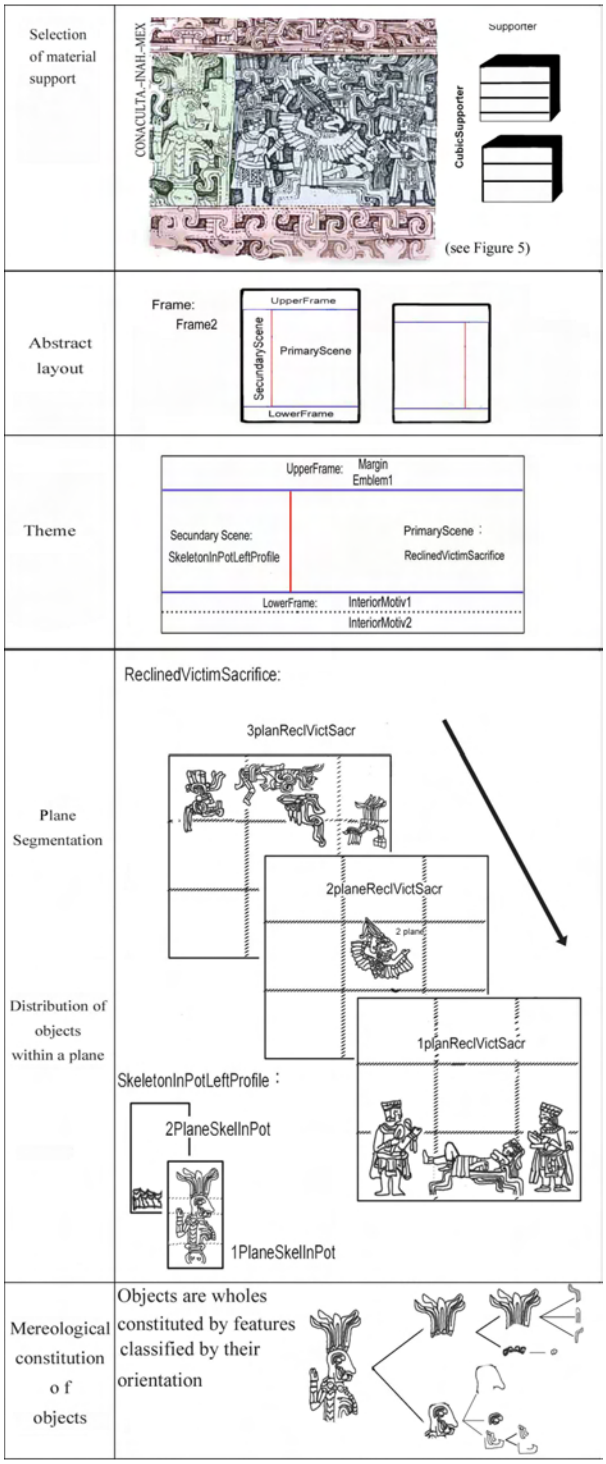

Figure 2: Levels of composition within a relieve

I is a non-monotonic system based on *Closed World Assumption* $(CWA\,(S) = ((S \nvdash \mathrm{P},) \rightarrow (S \mid\!\sim \neg P)))$ and *Modus Ponens* $((P, P \rightarrow Q) \vdash Q)$.

The productions in *P* have the form:

$$IconName \rightarrow Preposition < IconName//IconName >.$$

Here, *Preposition*, as in many natural language grammars, refers to a symbol that specifies the spatial relation that articulates two objects, in this case icon names. There are non-terminal and terminal prepositional symbols.

[2]Pascual Soto (1990: p208) describes the relieve in Figure 2 with the formula: *'(97.)(.?)(?:) /(1004 +, 414)/ (.)(.97)'*. This formula says that the *base* symbol (/ + /) is the *association* (,) of the symbols *1004* and *414*; that *over* (:) the *base* symbol there's an *unclassifed* symbol (?); that symbol *97* is to the *right* (.97) of an *unknown* symbol located *at the right* (.) of the *base* symbol; that symbol *97* is to the *left* (97.) of an *unclassified* symbol located at the *left* of the *base* symbol.

Table 1: Prepositional symbols. Every prepositional relation has a terminal symbol (`cls_1`) and a non-terminal symbol (`cls`)

Looks like this	Is described by this	Is formalized by this
	□ is contiguous to ○	C(□, ○)
	contacts from below	CB(,)
	□ contacts left extreme of —	CLE(□, —)
	○ contacts left side ▯	CLS(○, ▯)
	○ contacts top of ▭	CT(○, ▭)
	the nodes of ∩ contact the nodes of ∪	CN(∩ , ∪)
	the concavity of holds ○	CV(,○) CV(,○)
	■ is behind of ■	B(■,■)
	▭ encloses △	ENC(▭, △)
	presents △	P(, △)
	supports	S(,)
	▭ is over △	O(▭, △)

The angle brackets represent the punctuation marks that limit the scope of a prepositional symbol, and the double slash represents the marks that separates the names of the two elements participating in a topological relation. Both kinds of marks have a non-terminal and terminal version. Non-terminal parentheses are"[" and "]", and the terminal ones are "(" and ")"; whereas non-terminal separatrix is "/", and terminal separatrix is ",".

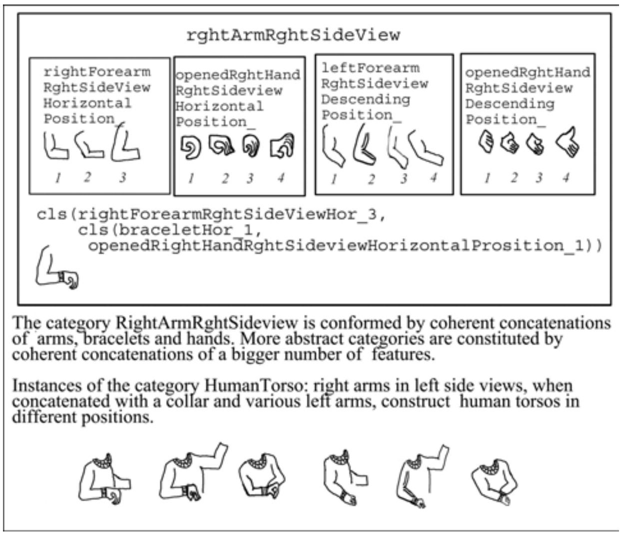

Figure 3: Examples of feature categories

IconName symbols may refer to terminal icon names (names of a basic features), or to non-terminal icon names, where a non-terminal icon name is that which can be transformed into a terminal icon name or into a chain of non-terminal symbols of the form $Preposition < iconName//iconName >$.

The terminal and non-terminal icon names are abbreviated phrases describing the *asymmetric geometry* of an icon category or icon feature. This is, the terminal and non-terminal icon names of the grammar describe the orientation of an object, as is perceived from a vantage point (Fig. 3).

The two types of icon names are distinguished by a typographical mark. Feature names end with the suffix "_n", where *n* could be any natural number.

As an example, take the case of the symbol `rghtArmRghtSideview`; it means *right arm seen from its right side view*. But given that it has no suffix, then it is a non-terminal icon name. Hence, it is not possible to associate a specific drawing to `rghtArmRghtSideview`. In order to be instantiated, it must be transformed into a topological relation sustained by two or more icon names.

The abstractness of a non-terminal icon name is represented with groups of productions with equal symbols on the left side of the arrow, but different chains of symbols on the right side of the arrow. Consider the following examples:

(1)

```
rghtArmRghtSideview →
cls[rghtForearmRghtSideviewDescend/
cls[braceletDescend/
opnRghtHndRghtSideviewDescend]].
```

(2)

```
rghtArmRghtSideview →
cls [rghtForearmRghtSideviewHorizontal/
cls[braceletHor/
opnRghtHndRghtSideviewHoriz]].
```

These productions express that the category `rghtArmRghtSideview` includes two subcategories. Thus, every time a *right arm seen from its right side view* has to be constructed, it might end up with the appearance of a:

> *(1) Right forearm seen from its right side view in descending position, contacting the left side* (CLS) *of a bracelet in descending position*, which *contacts the left side of an open right hand seen from its right side view in descending position*.

Or it might look like a:

> *(2) Right forearm seen from its right side view in descending position, contacting the left side* of a *bracelet in horizontal position, that contacts the left side* of an *open right hand seen from its right side view in horizontal position*.

Given this set up, it is possible to describe GGTS as a hierarchical collection of compositional conventions. In this hierarchy, the most abstract formulas associate a material support and a surface with a general scene distribution. Less abstract formulas define which icon types are to be located in which positions. And the most concrete formulas describe the way in which observable features (terminal icon names) conform a coherent and valuable image (Figs.2 and 3).

5 Derivation of Relieves with GGTS

The constitution of an image is a compositional process. And it is precisely this fact what allows both to recognise known instances of the El Tajín Style as well as to create new ones.

5.1 Production of Novel Images

The production of a novelty always begins with the introduction of the start symbol (Fig.4.1), and ends up with the construction of a formula describing the position of every basic feature conforming the image (Fig. 4.19). In Figure 4 (Fig.4.2- 4.4), after its introduction the start symbol (`Sculp`) is substituted by a formula that articulates a support (`stele`) with a rectangular surface and an unframed layout (`board1`). Afterwards, a drawing plan is decided by picking out a general theme: `unusualAnthropomorphicFigure`. This last decision causes the image to be segmented into three sections (Fig 4.5), one over the other: `unusualHead`, `unusualTorso`, and `belt`. Subsequently, `unusualHead` is expanded into, or rewritten as, the main sections of a head: an `unusualBeard` below an `unusualFaceCountour` that `encloses` an `unusualFace1`. Then `unusualFaceContour` is transformed into `unusualFaceCountour_1`(Fig 4.6). Afterwards, `unusualFace1` is subdivided into four sections: `leftUnusualEye`, `rightUnusualEye`, `unusualNose`, and `unusualMouth`: the first next to the second, the third below the former two and above the fourth one. Subsequently (Figs. 4.7- 4.11), the four subsections are filled out with the terminal icon names `leftUnusualEye_1`, `rightUnusuaEye_1`, `unusualNose_1`, and `unusualMouth_1`. Once this is done, the symbol `unusualBeard` is transformed into `unusualBeard_1` (4.12). At this moment the head has been finished.

The torso is constructed likewise. The symbol `unusualTorso` is transformed into a topological relation sustained by three non-terminal icon names: a *left arm*, a *necklace* and a *right arm*. Afterwards, a torso is instantiated by transforming each of those non-terminal icon names into suitable terminal icon names (Fig. 4.13- 4.16). Finally, the non-terminal icon name `belt` is substituted by a *decoration* inside the *contour of a belt* (Fig. 4.17).

Given that the image has been constructed by strict fulfilment of accepted rules, the value of the image is granted. It is a well formed object. Nevertheless, its novelty still has to be evaluated. This is done by searching for a copy of the constructed image in *KV*, which is nothing more than a list of previously constructed descriptions. If there is no such copy, then the image will be taken as a novelty and will be included in *KV* (this process is explained in section 5.2).

This criterion may be considered a naive instance of what may be called creative. However, the approach here presented is tied to create new things out of a language, and also tied to comply with a set of internal rules. In any case, an image thus created is totally new with respect to what ever was known before, and this is why we call it a novelty. Withal, the archaeological evidence found at El Tajín seems to show that, at least in certain societies, a novel and valuable artistic piece can be obtained by an *exploratory strategy* interested in very slight variations.

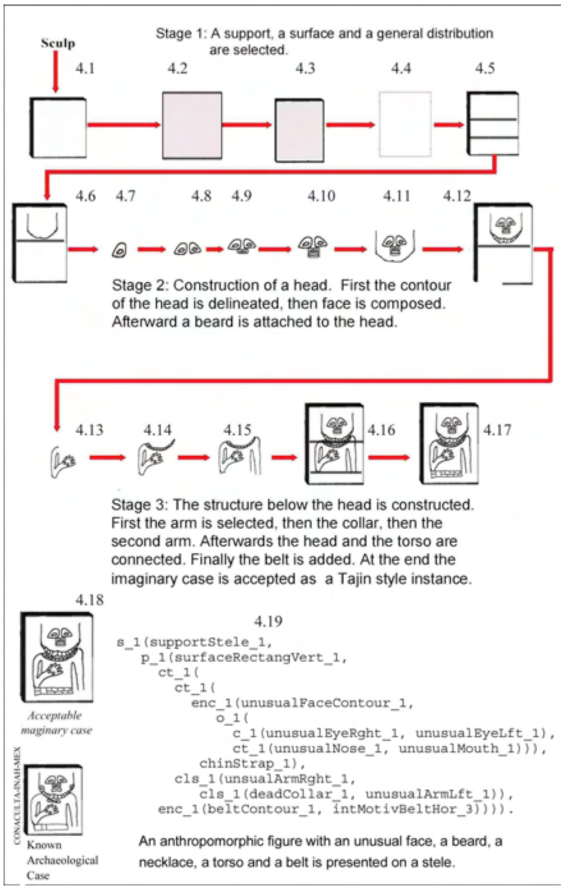

Figure 4: Construction of a new image

5.2 Recognition of Novelties

The recognition process is a compositional sequence too. As shown in the example of Figure 5, the process starts with the reception of an input formula describing an image. This initial input is taken as a “what is this?” question. This sets out the production of a hypothesis about its general layout (Figs. 6.1, 7.2). But, given that the hypothesis is a non-terminal icon name (`s[quadrangularSupport...]`), it cannot be contrasted with the input formula, which is entirely composed of terminal symbols. Thus, the non-terminal icon name is recursively transformed until the structure of a frame is selected(Figs. 6.2-6.4, 7.2-7.5).

Later on (Figs. 6.5, 7.6), , `SuperiorMargin2` is transformed into a `TopDelimitationMargin2` that encloses an `Emblem1`. Then `TopDelimitationMargin2` is transformed into `topDelimitationMargin2_1`, which is, as its typography attests, a terminal icon name that can be matched with the input formula .


```
s_1(quadrangularSupport_1,
p_1(quadrangularSurface_1,
s_1(
enc_1(topDelimitatioMargin2_1,
c_1(
cls_1(rearDecoAbstIconHorRghtSideviewUp_8,
cls_1(ct_1(
skelEyebrowRghtSideview_7, jawAbstIconFront_1),
ct_1(leafLftSideviewHorUp_1,
supDentitionRghtSideviewHorUp_6))),
cls_1(cls_1(
cls_1(supvoluteBagRght_4, InfVoluteBagRght_1),
...)...)..)..))))
```

Figure 5: Reclined Victim Sacrifice and Input formula depicting the highlighted fragment

After a successful first matching (Fig.7.6), the compositional process continues until the icon described in Figure 5 is accepted as a valuable El Tajín style image. Finally, the novelty of the image is confirmed by checking that there is no record of it in *KV* (7.16).

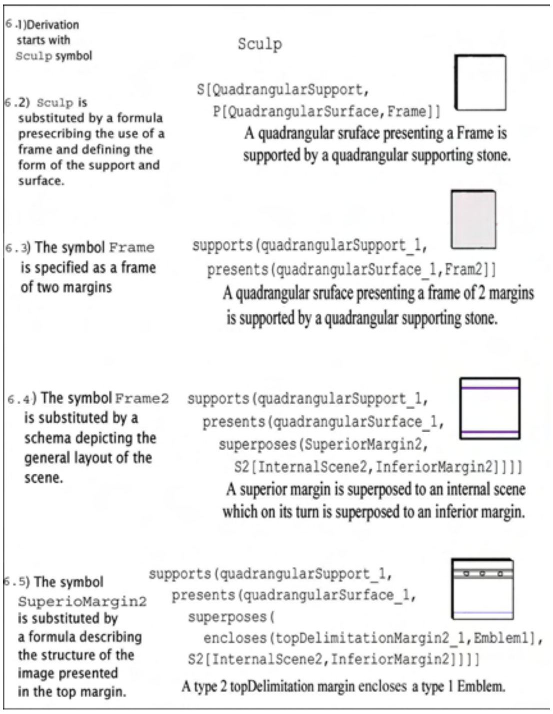

Figure 6: Initial steps of a derivation sequence

An alternative scenario would be that in which no successful hypotheses could be derived from the productions of the grammar. In this case, the absence of an applicable production would enable the storage of the formula into the set *KR*, although this conjecture could be retracted after the acquisition of new knowledge. In this last case, it would suffice to search in *KR* for formulas that could be recognised as valuable, despite its previous rejection.

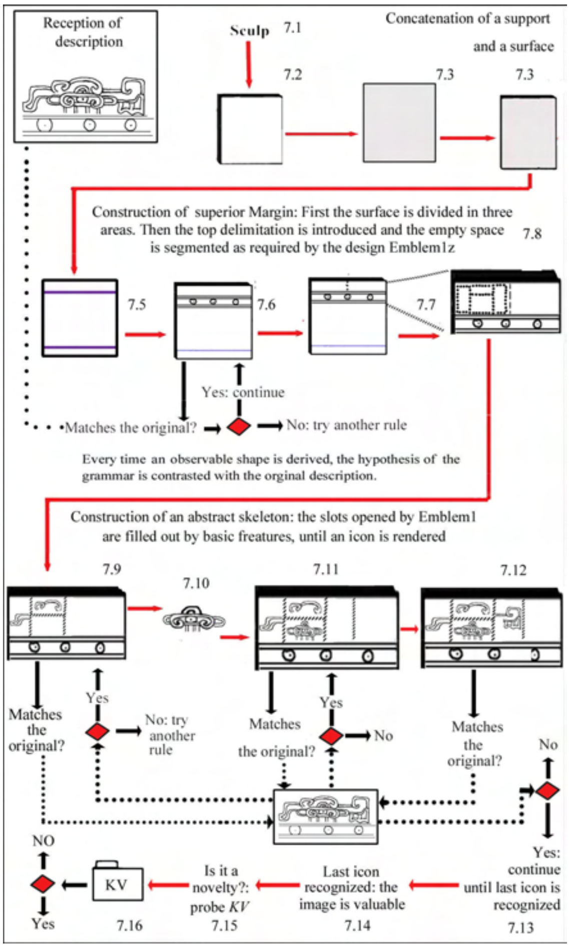

Figure 7: Recognition process

6 Prolog implementation

The Prolog version of the grammar (GGTS.pl) runs as a *depth-first search* that traverse a searching space from left to right. This basic mechanism always starts a search in the same point (`Sculp`) and may follow an exhaustive route. However, if the user introduces a query specifying a type of theme or the exact position of a feature or chain of features, the search is done differently. In these two cases, GGTS.pl starts in the same initial node and derives part of an image, but if the created segment does not suit the conditions stated by the user, the image is cancelled and a whole category of similar images is discarded, thus preventing the exploration of certain regions of the searching space.

A second manner in which the searching process is hastened is through a modular structure. GGTS' productions are sorted in accordance to their level of abstraction and general subject. This set up lessens the number of lines to be read when searching for a rule.

The productions of GGTS.pl have one of two forms:

(a)

nonTerminalIconName(A,F):-
Preposition (A,B),
OpeningParenthesis (B,C),
NonTerminalIconName(C,D),
NonTerminalIconName(D,E),
ClosingParenthesis(E,F),
ParsingProcess.

(b)

nonTerminalSymbol([terminalSymbol | Tail],Tail).

In (a), the lines ending with two variables inside a parenthesis are list constructors. They introduce terminal icon names into specific positions of a list, enabling the transformation of the `Sculp` symbol. The line "*parsingProcess*" is the call for a procedure that registers the successful use of the production. On the other hand, the form (b) is used to define a terminal symbol. In this way, at the end of a successful search, the list constructors compose a chain of basic features, while the registration process gives an interpretation of that chain.

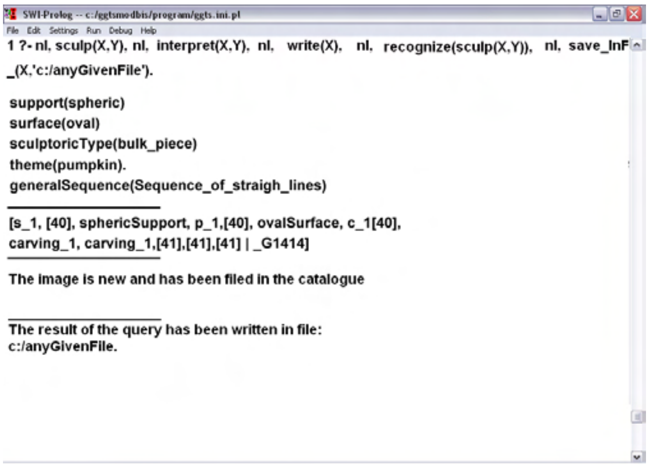

Figure 8: Example of a query

Besides the productions of the grammar, there is a set of seven predicates that allow the user to 1)print or save the formulas generated during a session, 2)run test suites, 3)sort formulas into the sets *KV* and *KR*, 4)decide if a given formula is valuable and new, 5)revise the set *KR* (retract conjectures), and 6)obtain an interpretation for a given formula. Figure 8 illustrates some of these predicates. The query tells GGTS.pl to construct and describe a sculpture, intepret it, save it in KV (if possible), and store a copy in "*a given file*". The result of each command is separated by horizontal lines.

The accuracy of GGTS.pl has been partially contrasted against the official catalogue of the Mexican National Institute of Anthropology (Castillo-Peña, 1995). The productions now registered in the program are reliable. They accept what they are supposed to, and reject paradigmatic examples of the styles created at other related cities (Teotihuacan, Tula and Tecnochtitlan). On the other hand, the grammar is still an incomplete model and the rules are somewhat rigid. Nevertheless, given the non-monotonic structure of the program, when the missing compositional conventions of El Tajín style get to be included, it will be possible to update the sets *T, N* and *P*, revise the set *KR*, and expand the set *KV* (section 4).

7 GGTS as an Anthropological and Cognitive Model of Creativity

Cognitive archaeology studies the human ability to construct and use symbols (Renfrew et al., 1994; Preucel, 2006). Its principal interests are design, representation (production and utilisation of iconic embodiments of reality), planning, measurement, religion and symbolic social control (preservation of social alliances). In accordance with these objectives, it has been shown that GGTS.pl has access to a set of possible symbols quite similar to the one accessed by the inhabitants of El Tajín city. But for the sake of anthropological adequacy, it is also of interest to see if the functional sequence of the compositional process done by the grammar has any similitude with the functional sequence of the human brain.

Psychological experiments interested in eye movements have shown that visual scenes are scanned in a piecemeal manner, following the guidance of mental schemata that predict the general layout of a scene (Henderson and Ferrerira, 2004; Cowan and Moorey, 2006). Likewise, it seems to be the case that the same mental schemata are used to guide bodily movements, such as the motion of a sculptor's arm (Mushiake et al., 1999; Carmena and Nicoleli, 2003). In this respect, the step-by-step scanning of a formula, coupled with the sequential construction of a descriptive formula, are thought of as a simulation of the process by which those abstract maps direct attention.

Also, neurophysiological evidence seems to show that the abstract maps just mentioned are stored in modules located at the motor areas of the parietal cortex, separated from the modules that recognise particular shapes, which are located at ventral areas of the brain (Colby and Merriam, 2005). It seems, as well, that the visual knowledge of the ventral area is organised in accordance with the asymmetric geometry (viewpoint) of the known shapes (Tanaka, 2003, 1997). Hence, the modular set up of GGTS.pl, and the classification of the symbols in accordance with their asymmetric geometry are understood as a partial representation of the functional anatomy of the brain areas dedicated to *high-level vision* (Wandell et al., 2005).

Fourth, linguistic studies have shown that the use of prepositional expressions suggests that human mind abstracts spatial relations with the aid of a topological geometry in which the location of an object is relative to the location of other objects in the scene (Talmy, 2001; Herskovits, 1997). Thus, describing an image as an assemblage of basic features, and the use of prepositions to describe the abstract connections sustainable by any pair of parts conforming a whole, are considered to be a plausible representation of the *mental language* that allows human cognition to perceive coherent wholes made up of discernible parts.

If those correspondences are accepted, then it could be thought that GGTS.pl gives a plausible functional account of the basic mechanisms used by the human mind during the processing of visual representations, including the design of *novel valuable images*. Having said that, GGTS.pl allows to argue that creativity is not an exclusive feature of productive activities, but an essential element of perception. Many of the cognitive abilities used during the production of novel objects are used as well during the recognition of valuable and novel objects. In the case of El Tajín relieves, both, sculptors and spectators, most probably employed a set of compositional conventions internalised as abstract maps. Sculptors probably used these maps to select the position of each shape, and to plan the movements of their limbs. Observers, on the other hand, probably utilised the same maps to plan the movements of their eyes and to check if every feature was located in the correct position. Likewise, sculptors and spectators probably had to explore a space of possibilities before deciding whether a particular combination of features correctly instantiated an accepted convention. Both, also, probably had to compare a well formed object with previous creations in order to know if a totally new object was witnessed.

8 Discussion

As a cognitive functional model, GGTS simulates four aspects of visual knowledge: 1)the application of a topological geometry, 2)the use of a mereological ontology organised in accordance with the asymmetric geometry of the forms conforming visual experience, 3)the flow of the process known as *active vision*, and 4)the design of symbols. The first two aspects are embodied by the symbols of the system and the modular organisation of the productions. The other two are simulated by the derivation process of the grammar: the most abstract schemata predict the layout of a complex scene and activate a chain of modules that predict the shape of the features composing complex wholes. When the aim is the production of a formula, the corroboration of every foreseen consequence guarantees the quality of the object; and when the task is to give sense to a formula, the confirmation of anticipated outcomes explains away many possibilities assuring the plausibility of the final categorization.

As a creative mechanism, GGTS is a well-known tool. Boden (1998) and Wiggins (2005) classified generative grammars as exploratory mechanisms and subordinated them to transformational systems, which not only explore structured conceptual spaces, but distort their boundaries in order to discover new compositional possibilities. Accordingly, GGTS only explores a fixed conceptual space.

Notwithstanding this limitation, a shape grammar can still bring about some surprises. Generative grammars implemented in Prolog generate variations with backtracking as its only aid. However, in the case of GGTS.pl, a slight improvement was obtained by introducing two sets: one for the storage of valuable products (*KV*), the other for the storage of rejected products (*KR*). With this set up, the grammar not only generated valuable objects, but was able to detect the novel ones, even when the formulas where not created by it, or were generated during independent sessions. Other programs have used analog solutions. The problem with GGTS is that it makes this evaluation only on finished objects, where as other programs do it on earlier stages of the production process (Pérez y Pérez and Sharples, 2004; Pérez y Pérez, 2007).

Like most generative grammars, GGTS cannot extrapolate general rules from particular instances. The only way to expand its knowledge base is by manual introduction of information. However, it is worth to consider that the plain addition of features (terminal icon names) in the appropriate categories creates a whole new set of novel and valuable complex images.

Despite its negligibility, the afore mentioned improvements are useful, once applied in the proper situation. In many occasions, archaeologists and art historians advance competing definitions without giving a mechanical procedure for the testing of their theories. In cases like these, the exploratory creativity of shape grammars might be the objective tool that could evaluate the predictive power of competing style definitions. As any other archaeological theory, every time new sculptures were associated to indubitable archaeological contexts, each style definition would have the opportunity to be tested, being better the one accepting the biggest number of legitimate cases and rejecting the biggest number of unacceptable objects. Accordingly, a shape grammar could also be considered a tool for scientific discovery. Every time a legitimate archaeological finding could not be recognized by the best grammar, this finding would have to be considered a real scientific discovery, since the best theory did not predict it and scientists were forced to revise and, perhaps, reject earlier inferences (Aliseda Llera, 2006). Finally, a shape grammar with the sets KV and KR, is a catalogue capable of accepting only new instances of a certain style. This catalogue, given the parsing mechanism of the grammar, would also be capable of interpreting and sorting out the images stored in it, assisting archaeologists not expert in iconography in the elaboration of accurate field reports.

A final archaeological potential is related to the expanding conditions of a grammar. If the set of terminal symbols (*T*) was transgressed, so that some features were incorrectly sorted, then the new grammar would *create* a set of new but illegitimate variations, that, nonetheless, would look very similar to well formed images. In this case, teachers training archaeologists would have a mechanical way to produce expert appraisal drills.

At this point, two shortcomings of GGTS.pl should be reminded. First, it does not process pixel patterns. The user would have a better experience if she/he could avoid the writing of the formulas. Second, the productions of the system could be more flexible, enabling the designer to introduce a smaller number of them. These flaws are expected to be surpassed in subsequent versions of GGTS.

To summarise, GGTS and GGTS.pl have the limitations known for every generative grammar, but this condition did not forbid the generation of things that were not there from the beginning. Also, it should be reminded that slight changes enhanced the performance of a classical formal system. Therefore, GGTS and GGTS.pl show that generative grammars, if put in a convenient context, are still useful instruments for scientist and students.

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