ON DETERMINING HUMAN DESCRIPTION OF TEXTURES

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ABSTRACT

The TEXRET-System, a texture retrieval system based on soft-computing technologies is being developed at University of Chile. One of its main features is that texture queries using human-like or qualitative description of textures are allowed. This human-like description of the textures was the subject of a psychological study that is described in this article. To our knowledge this is one the first studies on that subject.

As a result of the study were selected 12 adjective pairs to be used in TEXRET. Another aspect considered in the study was the evaluation of 100 textures using the selected adjective pairs. This evaluation was very important to train a neural network that translates qualitative description of textures into quantitative ones. This last part of the study was performed in the Internet, with the participation of more than 100 persons.

1. INTRODUCTION

Textures are homogeneous visual patterns that we perceive in natural and synthetic scenes. They are made of local micropatterns, repeated somehow, producing the sensation of uniformity. Texture perception plays an important role in human vision. It is used to detect and distinguish objects, to infer surface orientation and perspective, and to determine shape in 3D-scenes [3]. An interesting psychological observation is the fact that human beings are not able to describe textures clearly and objectively, but only subjectively by using a fuzzy characterization of them. On the other hand, with the new advances in communication and multimedia computing technologies, accessing mass amounts of digital information (image databases) is becoming a reality. In this context, textures, due to their esthetical properties, play today an important role in the consumer-oriented design, marketing, selling and exchange of products and/or product information. For this reason, systems that allow the search and retrieval of textures in image databases are of increasing interest [3, 5]. One very know example of such kind of systems is QBIC [9] (from IBM).

This work is part of a main research effort, whose aim is the construction of the TEXRET-System, a texture retrieval system based on soft-computing technologies [3, 5-6]. The TEXRET-System has the following features: (i) direct access from the Internet, (ii) texture queries using human-like or fuzzy description of the textures, and (iii) synthesis or generation of the requested textures when these are not found in the database, which allows a growing of the database. This article is centered on the second feature of the system, which correspond to its most innovative characteristic.

Until now, the lack of intuitive interfaces for the retrieval of textures has been an important drawback of texture retrieval systems. The work described in this paper overcomes that. It should be mentioned that a related approach was used in the development of "ART MUSEUM" [8], a system for the retrieval of impressionism paintings using qualitative features.

The article is structured as follows. The TEXRET-System is outlined in section 2. In section 3, the determination of human description of textures is described. Finally, in section 4 some conclusions are given.

2. THE TEXRET-SYSTEM

The TEXRET-System, whose block diagram is shown in figure 1, is made of the *FI* (Fuzzy Interface), the Q^2TPT (Qualitative to Quantitative Textural Properties Transformation), the *TR* (Texture Retrieval), the TG (Texture Generation), and the EPA (Evolutionary Parameter Adjustment) modules.

The on-line phase of the texture retrieval process works as follows: A human user makes a query of a texture using a subjective, linguistic or human-like texture description. The FI module enters this description into the system using a fuzzy representation of it. The Q^2TPT module interprets the query and translates it into a quantitative texture description that is implemented using Tamura Descriptors [7]. This quantitative description is used by the TR module to search the texture in the database (see description in [5]).

In the case that the texture is not found in the database, the user can choose the automatic generation of it. The TG module generates the texture using Markov Random Fields (MRF) [2]. The parameters of the MRF are calculated from the Tamura descriptors and then the textures are generated. As a result of this generation process a set of textures is presented to the user. If the user considers that one of the generated textures satisfy his query, the process finishes here. If not, the user enters into an iterative process. The iterative generation of the textures is implemented using interactive evolutionary computation (EPA module). The TG module is described in [6].

The subjective or human-like texture description that the system accepts was determined by a psychological study in texture perception. This study, one of the firsts in this subject, is described in this article.

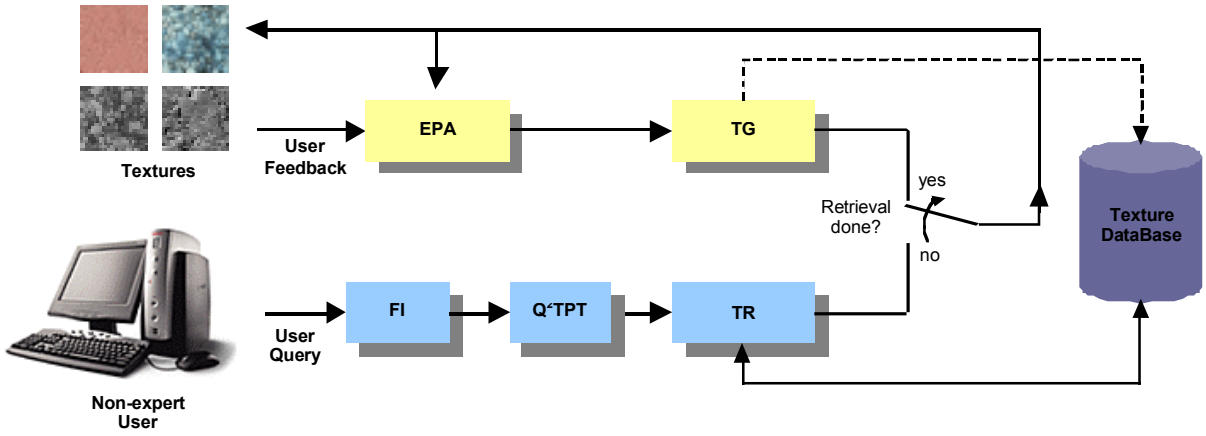

Figure 1. Block diagram of TEXRET.

3. HUMAN DESCRIPTION OF TEXTURES

As mentioned, the Q²TPT module should translate a human-like or qualitative texture description into a quantitative or mathematical description. This last description is then used for either the retrieval or the generation of the corresponding texture.

The quantitative descriptors or features we use are the Tamura ones (coarseness, directionality, contrast, line-likeness, regularity and roughness). Tamura gave a mathematical procedure to calculate them. A description of our own implementation can be found in [5].

The human-like texture description that TEXRET accept was determined by a psychological study, described in the following two subsections (surveys I and II). In these surveys we asked directly to humans how they describe textures. As a result of this study, we found a set of 12 adjective pairs to be used in our system.

It should be mentioned that this study was performed in Chile (Spanish spoken country), using Spanish words. Each of the used adjectives has a direct translation into English. For this reason we believe that the results obtained in the Spanish language can be directly applied to English. In appendix 1, the original Spanish adjectives we used are listed.

To that point a question is still open. How can the Q²TPT module make the translation from qualitative to quantitative description of textures? That is, how can it relate the both mentioned kinds of texture descriptions?

To solve this problem we took 100 textures and we obtained both kinds of descriptors from them. Then, we trained a neural network to relate both kinds of descriptors (see description in [5]). This network perform a kind of association between these descriptors (see figure 2). The quantitative description of the 100 textures was directly obtained using the Tamura equations. To obtain the human-like description of the textures was necessary to ask humans again. This study was the subject of our last survey, performed in the Internet, and described in section 3.3.

In the next subsections surveys I, II and III are described.

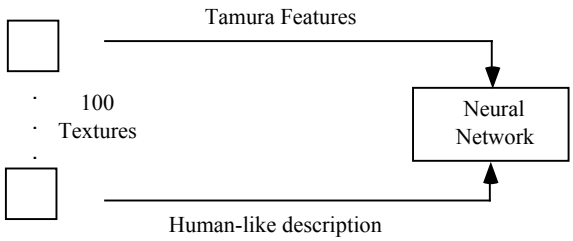

Figure 2. Association between qualitative and quantitative texture descriptions.

3.1. Survey I

The aim of this first survey was to get an overview of the subjective description of visually perceived textures using open answers, as well as to perform a selection of the found characteristics for Survey II.

The survey was divided in three parts. In the first part the subject should imagine a texture in her/his mind and to describe it in such a way that somebody who had not seen the texture before could also imagine it. The reason for beginning with this task was that persons were not be influenced by having seen textures. In the second part, a series of single textures were shown on a computer screen. The textures were to be described according to impression, effect and characteristics. In the third part, pairs of two textures were shown to the subjects on a computer screen, and they had to compare them with respect to their similarities and differences. Textures were taken from standard texture databases (see figure 3). Ten persons participate in this survey, all of them university students.

During the evaluation it turned out that the methodology used for part one was not very useful, because it could not be proved what texture the subjects had in mind while describing it. Therefore, the results delivered little information.

In parts two and three emerged a multiplicity of answers in non-adjectival form because open answers (free reply) were allowed. From this fact, a suggestion was given in order to improve the next test. It was to use only close-ended or partly close-ended answers. As mentioned, the information obtained in this survey was the basis for the next one.

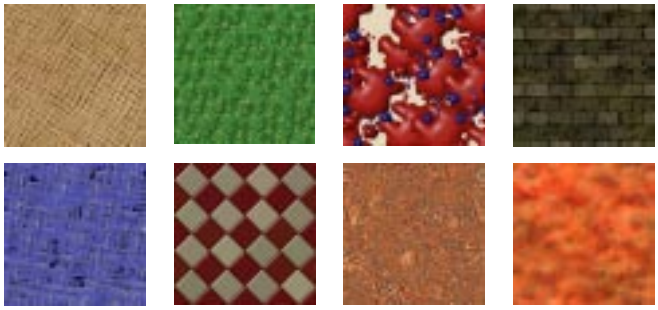

Figure 3. Examples of textures used in Survey I.

3.2. Survey II

The purpose of this survey was to investigate the most relevant and most frequently human-used characteristics for the qualitative description of textures.

Supported on characteristics derived from Survey I and on knowledge obtained from technical literature [1, 4, 7], a list of adjective pairs was composed (see Table 1). Of course, the selection of the adjectives was subjective and thus potentially dangerous. Nevertheless, to us this procedure seemed to be the most appropriate to begin with.

The adjective pairs 4 ("tasty/insipid"), 7 ("fragile/robust"), 14 ("loud/quiet") and 19 ("soluble/non soluble") were inserted additionally into the list in order to observe the concentration/attention of the subjects. According to our opinion, none of these pairs represent a characteristic that could be used when describing textures.

The survey was comprised by three parts A, B, C. In part A (= Characteristics) the subjects had to evaluate the given list of adjective pairs (see table 1) and to say which pairs they would use to describe textures and which ones they would not. In part B, the subjects could add characteristics that they considered important, but which did not appear on the list. Finally, in part C also called "Relevance of the Characteristics", the most important characteristics from the given and added ones (parts A and B) should be named, up to a maximum of ten.

To give the subjects an impression of textures, a sheet containing 72 textures from standard texture databases (like the ones shown in figure 3) was provided to them. These textures were shown only for a short moment (a couple of minutes), because while answering, the subjects were supposed to evaluate the adjective pairs without being influenced by the texture images.

The sample consisted of 50 subjects. From this sample, 26 were male and 24 female; 32 were university students and the rest non-students. The average age was 28.8 years.

In figure 4 is shown a chart with the distribution of the answers given by the subjects for part A. Named is only one adjective of each pair. In part B the subjects could name new adjectives. The variety of the answers was very high and no adjective was named more than 2-3 times. For this reason these adjectives were not further considered in our study. In figure 5 is shown a chart with the distribution of the answers given by the subjects for part C. Named is only one adjective of each pair.

Table 1.Characteristics used for Survey II.

Identifier	Characteristic
1	homogeneous / non homogeneous
2	geometrical / non geometrical
3	pleasant / non pleasant
4	tasty / insipid
5	soft / rough
6	fine / coarse
7	fragile / robust
8	with lines / without lines
9	flat / non flat
10	happy / sad
11	regular / irregular
12	symmetrical / non symmetrical
13	with circles / without circles
14	loud / quiet
15	periodical / non periodical
16	clear / dark
17	simple / complex
18	transparent / non transparent
19	soluble / non soluble
20	natural / artificial
21	defined / diffuse

As it can be seen from figures 4 and 5, all subjects named items 5 and 6 most frequently. Items 4, 7, 14 and 19, the ones that had been inserted in order to observe answer behavior, were rarely chosen. For this reason they were not considered anymore.

The adjective pairs 3 ("pleasant/non pleasant") and 10 ("happy/sad") were also taken out. The reason was they are too subjective and their further use in the TEXRET-System was considered very difficult.

For the remaining 15 adjective pairs a ranking considering the frequency distributions of the answers was made, each for parts A and C (see table 2). It this table is also shown the percentage of subjects (from the 50 under study) that uses this adjective pair.

Afterwards, a so-called fulfillment degree (FD) was calculated. FD was defined as a percentage number, which indicated how well a certain quantity of adjective pairs filled what the single subjects considered as important. The calculation was as follows. First, the sum of the frequencies of the first 5, 6, 7, 8, 9, 10, 11, 12, 13, 14 and 15 pairs in the ranking, were each divided by the sum of the frequency of all 15 pairs. From these calculations resulted percentage numbers that corresponds to the FDs. The FDs are shown in the graph of figure 6.

The question now is how much percent (FD) should be taken as a criterion to decide which characteristics are to be selected.

We decided to eliminate the pairs 3 ("transparent/non transparent") and 18 ("with circles / without circles"). The reason was the low percentage of fulfillment degree and the very complicated mathematical translation of these features into Tamura features. Furthermore, "periodical/non periodical" was canceled, because the subjects rarely used it. We wondered why. A reason could be that although "periodical/non periodical" and "regular/irregular" are somehow similar concepts, the words "periodical/non periodical" are less common in everyday language than "regular/irregular".

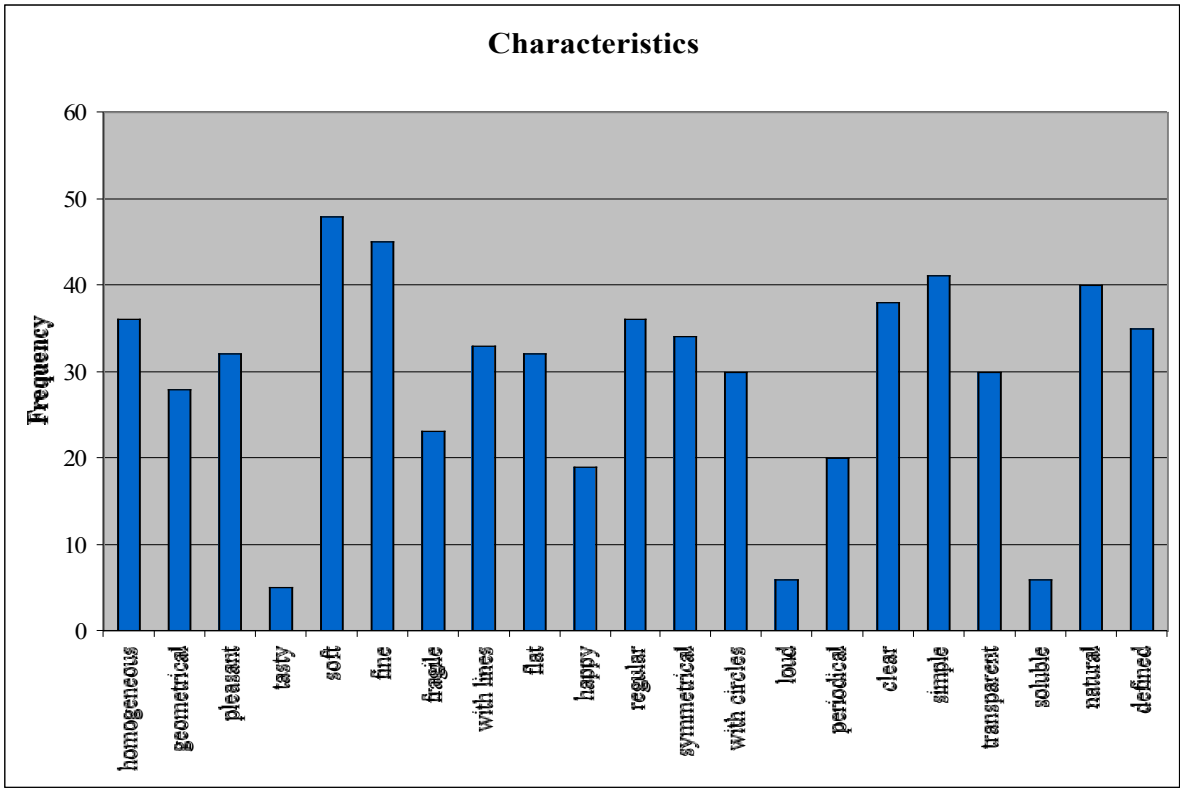

Figure 4. Frequency table of part A.

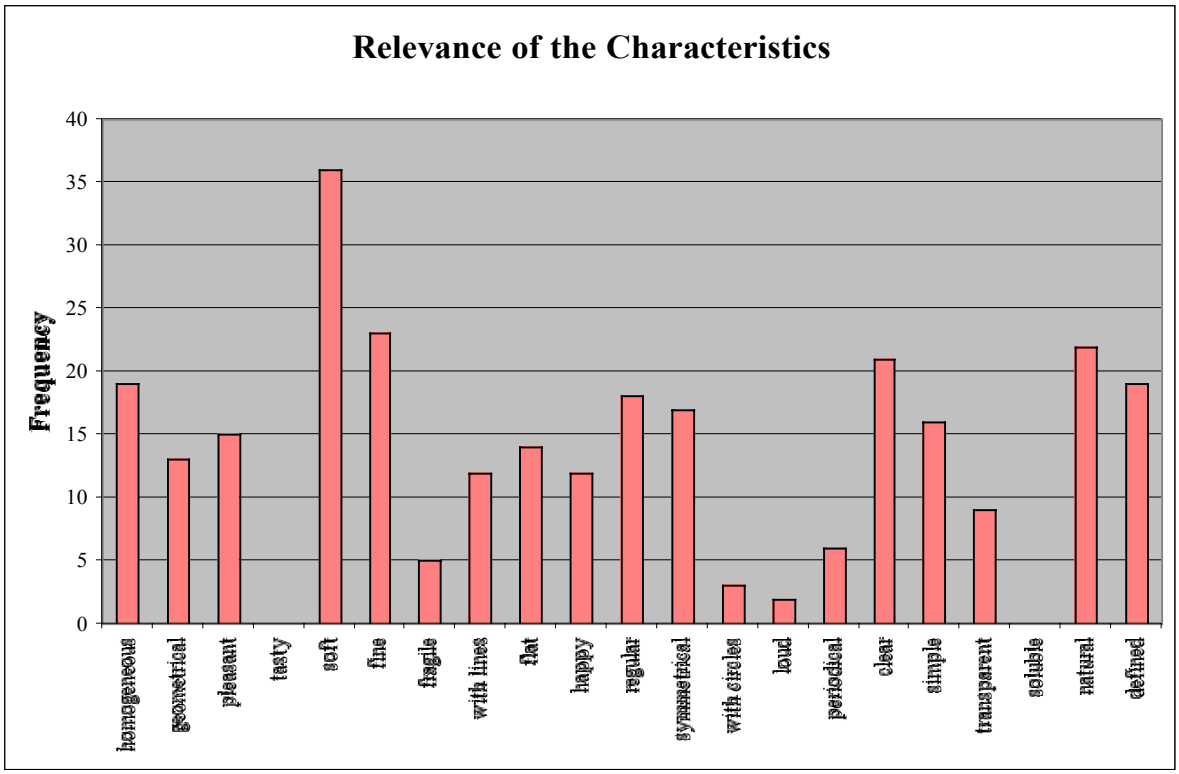

Figure 5. Frequency table of part C.

By considering all this aspects, the selection of the remaining 12 characteristics resulted in a FD of 92.8% (in reference to part C: "Relevance"). The selected adjective pairs are: "soft / rough", "fine / coarse", "natural / artificial", "clear / dark", "homogeneous / non homogeneous", "defined / diffuse", "regular / irregular", "symmetrical / non symmetrical", "simple / complex", "flat / non flat", "geometrical / non geometrical", and "with lines / without lines".

According to our opinion, this corresponds to an excellent solution because it represents a good compromise between a high FD and a low number of characteristics.

3.3 Survey III

As mentioned, using both qualitative and quantitative description of 100 textures (see figure 7), a neural network is trained to learn the association between both kinds of descriptions. The quantitative description of the 100 textures is obtained using the Tamura equations. The qualitative description of the same textures should somehow be determined.

The aim of this last survey was to find this human-like or qualitative description of the 100 textures, using the 12 adjective pairs selected in surveys I and II. The way to obtain these descriptions was asking humans again. The requirements this third survey should fulfill were:

- the number of texture images that each subject evaluates should be small (<15),
- the number of asked subjects should be high (>50),
- the subjects should see the texture images in a computer screen,
- the subjects should have the possibility to give gradations of the adjective pairs (for example: "almost flat" or "very regular"), and
- the interface that the subjects use to evaluate the texture images should be the same that the final users of the TEXRET-System would use to retrieve textures.

This last point is very important to perform an appropriate training of the neural network.

Taking into account all mentioned requirements it was decided:

- each subject will evaluate 10 textures,
- the number of subjects will be larger than 100, that means each texture will be evaluated at least by 10 different persons, and
- the survey will be performed in the Internet using the interface shown in figure 8.

Table 2. Ranking of the 15 selected features.

Part A: Characteristics	%	Part C = Relevance	%
soft / rough	96	soft / rough	72
fine / coarse	90	fine / coarse	46
simple / complex	82	natural / artificial	44
natural / artificial	80	clear / dark	42
clear / dark	76	homogeneous / non homogeneous	38
homogeneous / non homogeneous	72	defined / diffuse	38
regular / irregular	72	regular / irregular	36
defined / diffuse	70	symmetrical / non symmetrical	34
symmetrical / non symmetrical	68	simple / complex	32
with lines / without lines	66	flat / non flat	28
flat / non flat	64	geometrical / non geometrical	26
with circles / without circles	60	with lines / without lines	24
transparent / non transparent	60	transparent / non transparent	18
geometrical / non geometrical	56	periodical / non periodical	12
periodical / non periodical	40	with circles / without circles	6

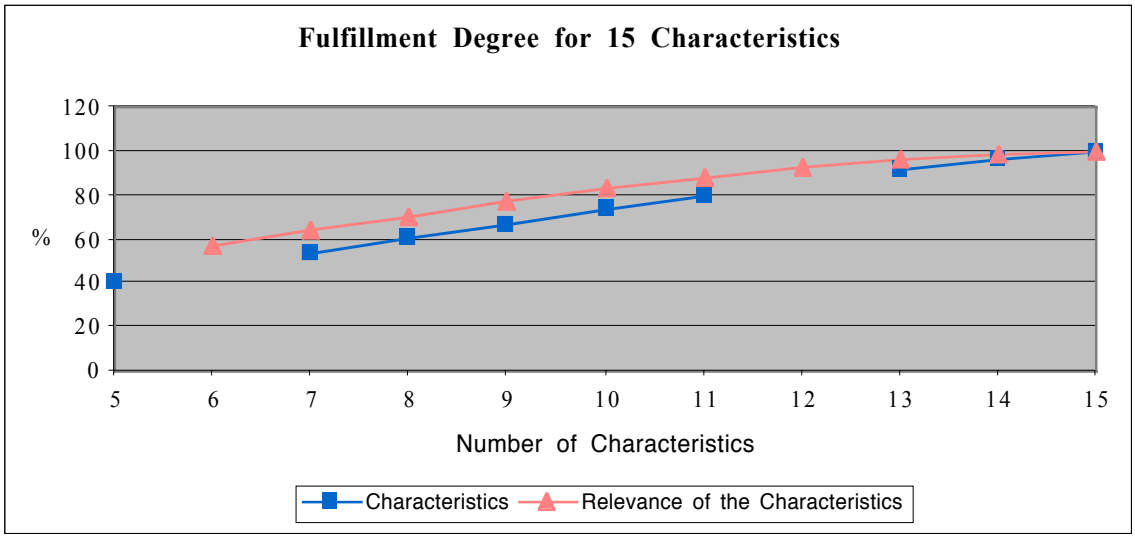

Figure 6. Fulfillment degree for 15 Characteristics.

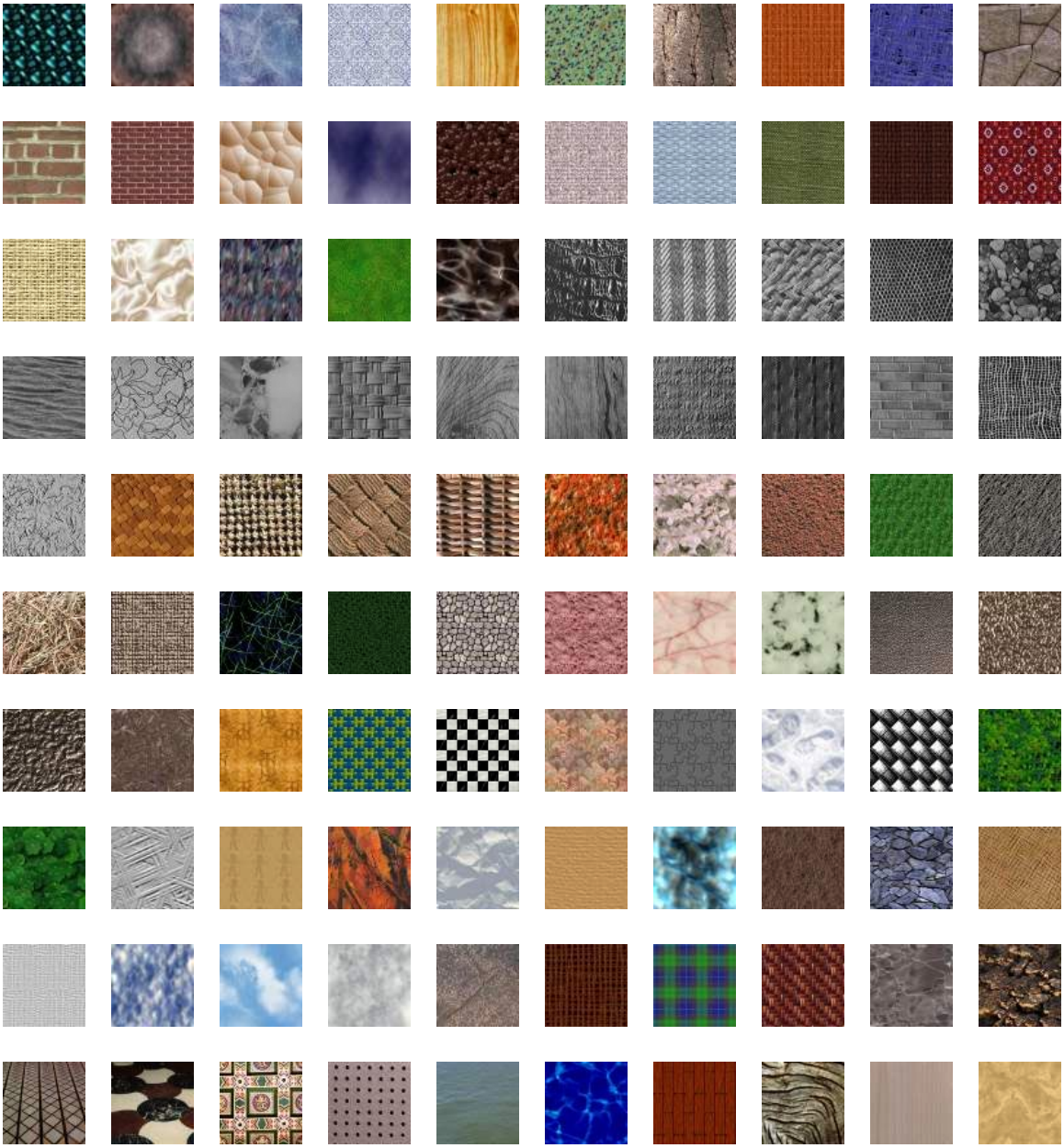

Figure 7. The 100 texture images used in Survey III.

As it can be seen in figure 8, the interface allows the users, for the evaluation of each texture, to choose gradations of the adjective pairs using “slide bars”, and also to enable/disable each of the adjective pairs by means of the “yes/no” button. This Internet interface was programmed in JavaScript, and till the moment the number of persons that has answer the survey is 109.

4. Conclusions

Providing the facility of a user-friendly texture retrieval system comes out to be a very complex task. With this objective in mind, the TEXRET-System has been developed in the last years. One of its most innovative and important features is the possibility to perform texture queries using human-like or qualitative description of textures. In this paper was described a psychological study, which was developed to determine the qualitative description of textures that TEXRET accepts.

As a result of this study were selected 12 adjective pairs to be used in TEXRET: “soft / rough”, “fine / coarse”, “natural / artificial”, “clear / dark”, “homogeneous / non homogeneous”, “defined / diffuse”, “regular / irregular”, “symmetrical / non symmetrical”, “simple / complex”, “flat / non flat”, “geometrical / non geometrical”, and “with lines / without lines”.

Another aspect considered in the study was the evaluation of 100 textures using the selected adjective pairs. This evaluation was very important to train a neural network that translates qualitative description of textures into quantitative ones. This last part of the study was performed in the Internet, with the participation of more than 100 persons.

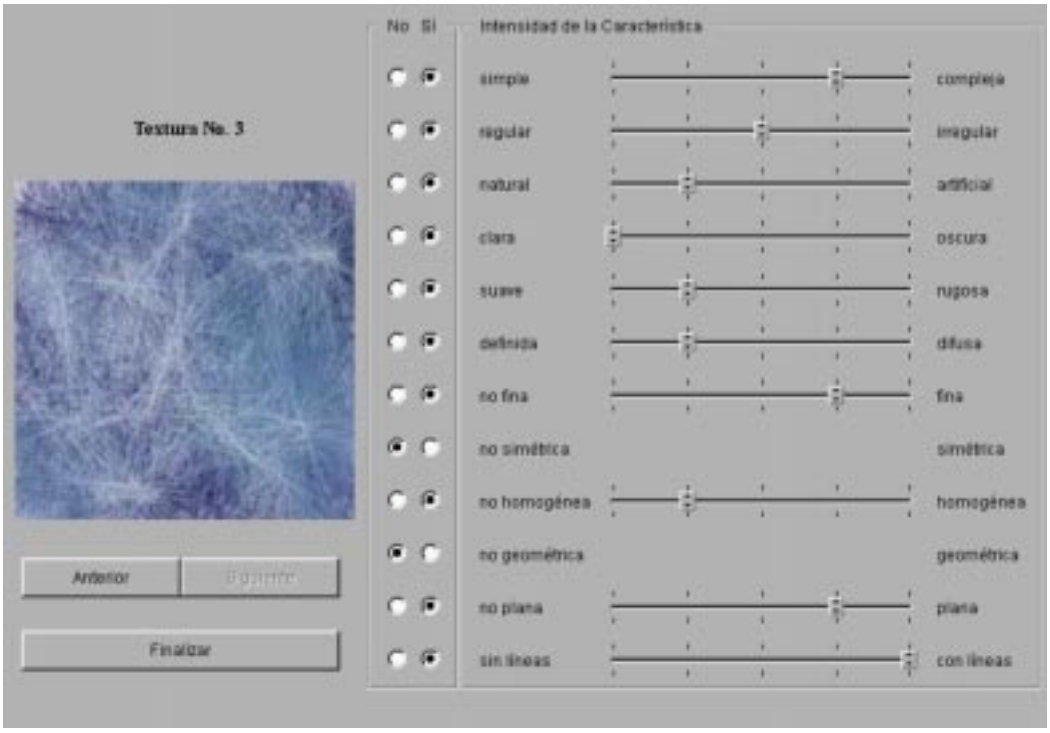

Figure 8. Layout of the interface used in Survey III.

At the moment we are evaluating how to consider different user profiles in TEXRET, specifically in the qualitative-quantitative translation process.

Acknowledgements

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Appendix

Original adjective pairs, in Spanish.

Identifier	Characteristic
1	homogénea / no homogénea
2	geométrica / no geométrica
3	agradable / desagradable
4	sabrosa / insípida
5	suave / rugosa
6	fina / no fina
7	frágil / robusta
8	con líneas / sin líneas
9	plana / no plana
10	alegre / triste
11	regular / irregular
12	simétrica / no simétrica
13	con círculos / sin círculos
14	sonora / callada
15	periódica / no periódica
16	clara / oscura
17	simple / compleja
18	transparente / no transparente
19	soluble / insoluble
20	natural / artificial
21	definida / difusa