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STATISTICAL EVALUATION OF AESTHETIC SHAPES

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Abstract: *Aesthetics is an important criterion in choosing most products. Aesthetic standards defined mathematically and implemented in evolutionary algorithms in order to obtain aesthetically optimal products are sometimes not enough to obtain a unique optimal product. In those cases the human factor plays a decisive role. This paper is focused on investigating the human perception of the optimal vases generated using circular arcs or Bézier curves and criteria defined based on the harmonic ratio or the golden ratio. Moreover the paper presents different correlations that exist between the human perception and several classes of people obtained with respect to different aspects such as age, gender, educational background, and urban/rural typology.*
Key words: *aesthetics, optimal shapes, golden ratio, harmonic ratio, statistics.*

1. INTRODUCTION

Aesthetics has become an area of increasing interest in the recent years. The aesthetic shape of products is very important even in engineering due to the general tendency of satisfying the emotional needs of the user. Therefore, the goal is to obtain design elements (geometrical dimensions, curves, proportions etc.) that are optimal with respect to several aesthetic criteria. This implies the use of computers leading to the development of domains such as Computer Aided Aesthetic Design where new criteria or definitions for aesthetic curves have been proposed (see [1], [8] and [9]).

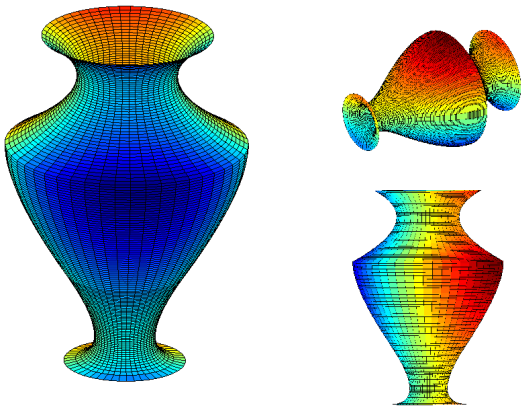
The problem of defining aesthetic criteria for different design elements has been addressed since Antiquity. For example, the aesthetics measure has been defined as the ratio between the order and the complexity of the aesthetic object Birkhoff [2] in 1933. Other authors have used the famous five sacred geometry constants: $\pi, \sqrt{2}, \sqrt{3}, \sqrt{5}, \left(1+\sqrt{5}\right)/2$ in order to define some aesthetic standards. The last constant, known as the “golden number", "golden section", "golden ratio, "divine proportion" or „extreme and mean ratio” is one of the most used constants and many authors have focused on it (see for example [3], [4], [5] and [6]). The second constant, known as the “harmonic ratio”, has been less exploited than the golden ratio during the years. However, this constant is found when analyzing some natural aesthetic forms [7].

The previous work of the authors has addressed the issue of generating aesthetically optimal vases using circular arcs [10] and Bézier curves [11]. Several aesthetic criteria regarding the generated vases were defined using the golden ratio and the harmonic ratio, respectively. Four types of optimizations were performed for this paper: using circular arcs and the golden ration, using circular arcs and the harmonic ratio, using Bézier curves and the golden ratio and using Bézier curves and the harmonic ratio. The optimization was conducted in each case using evolutionary algorithms. The number of aesthetic standards used in the conducted optimizations varied between three and six. However, without using an additional economical standard or the human factor, the optimizations lead to several classes of aesthetically optimal vases with different shapes. For each optimization the obtained vases were divided into classes and representative vases from each class were

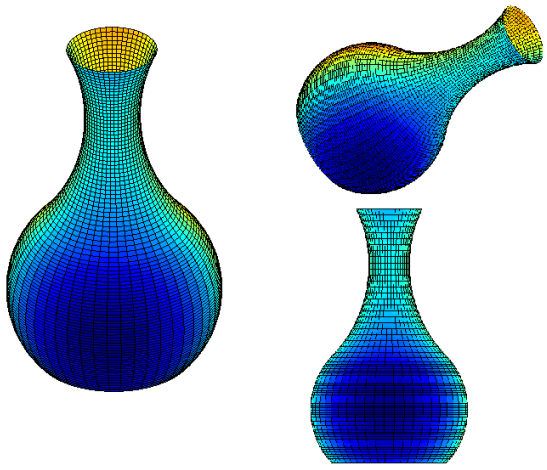
included in a questionnaire which will be briefly presented hereinafter together with the obtained results. A similar questionnaire whose purpose is to investigate the influence of basic geometry on user perception is presented in the paper [12].

2. QUESTIONNAIRE STRUCTURE

The questionnaire contained 19 questions from which the first four referred to age, gender, educational background, and urban/rural typology. The four questions allow determining the influence of the four mentioned aspects on the perception of aesthetics. The other 15 questions refer to the 15 representative vases chosen from the classes of optimal vases obtained after performing the four optimizations. An example of two optimal vases included in the questionnaire is provided in Figure 1.



a) Optimal vase generated using Bézier curves



b) Optimal vase generated using circular arcs

Fig. 1. Examples of optimal vases included in the questionnaire

For each of the 15 vases the question was the same: "How would you characterize the vase using the adjectives presented below and grading it from 1 to 5?". The adjectives and grades were the following for each vase: 1 - beautiful … 5 - ugly; 1 – harmonious … 5 - disharmonious; 1 – proportionate … 5 - disproportionate; 1 – modern … 5 - classic; 1 – artistic … 5 - common. Each participant evaluated each vase using the five pairs of adjectives. For example, for the pair beautiful/ugly 1 means very beautiful, 2 means beautiful, 3 means so and so, 4 means more ugly than beautiful, while 5 means ugly. After finishing the questionnaire the answers of each participant are saved in a data base and ready to be statistically processed.

3. STATISTICAL INTERPRETATION OF THE RESULTS

For each question the results were first counted with respect to each adjective and the mean and dispersion were computed. An example for question 5 is provided in Table 1.

The questions were divided corresponding to the vases obtained using as aesthetic standards the harmonic section and the golden section, respectively. The results were statistically processed by computing the mean and dispersion in each case. As it can be seen in Table 2 the vases obtained using the golden section are considered more beautiful, more harmonious, and more proportionate than the ones obtained using the harmonic section. They are considered less modern and less artistic but the differences of the means are really small.

The questions were then divided corresponding to the vases obtained using Bézier curves and circular arcs, respectively. The results were statistically processed by computing the mean and dispersion in each case. As it can be seen in Table 3 the vases obtained using Bézier curves have been better evaluated than the ones obtained using circular arcs for each considered aspect.

The correlations between the studied aspects and age, urban/rural typology, gender, and educational background, respectively, have been determined for each optimal vase.

Table 1

The statistics regarding question 5

Question 5	1	2	3	4	5	Total answers	MEAN	DISPERSION
1-beautiful…5-ugly	30	45	22	5	3	105	2.1048	0.9319
1-harmonious…5-disharmonious	30	37	21	12	5	105	2.2857	1.2898
1-proportionate…5-disproportionate	31	28	20	21	5	105	2.4381	1.5224
1-modern…5-classic	22	21	19	27	16	105	2.9429	1.9015
1-artistic…5-common	28	24	33	13	7	105	2.4952	1.4309

Table 2

Statistics regarding the vases obtained using the harmonic section vs. the golden section

	Harmonic Section		Golden Section	
Features	**Mean**	**Dispersion**	**Mean**	**Dispersion**
beautiful	2.6583	1.2335	2.5116	1.4084
harmonious	2.6881	1.1660	2.5170	1.3765
proportionate	2.7667	1.2665	2.5279	1.3149
modern	2.7464	1.2333	2.7605	1.4639
artistic	2.7440	1.2096	2.7755	1.4133

Table 3

Statistics regarding the vases obtained using Bézier curves vs. circular arcs

	Bézier Curves		Circular Arcs	
Features	**Mean**	**Dispersion**	**Mean**	**Dispersion**
beautiful	2.2735	1.2299	2.8027	1.5348
harmonious	2.3891	1.1875	2.7088	1.4510
proportionate	2.5660	1.3261	2.5891	1.4258
modern	2.5605	1.5223	2.9592	1.5513
artistic	2.4041	1.3206	3.0544	1.6642

Table 4

Correlation coefficients for question 7

	Beautiful	Harmonious	Proportionate	Modern	Artistic
Beautiful	1	0.811103595	0.674661314	0.927401	0.839328
Harmonious	0.811103595	1	0.882055421	0.932997	0.933656
Proportionate	0.674661314	0.882055421	1	0.769891	0.668983
Modern	*0.927400588*	*0.932996953*	0.769891431	1	0.955672
Artistic	0.839327538	*0.933655812*	0.66898341	*0.955672*	1

For example, for the vase corresponding to question 7 it can be seen that the perception of the vase as beautiful increases with age (Fig. 2 – lower grade means more beautiful). People between 30 and 40 years old consider the vase less modern than others. However, they consider it more harmonious and artistic than everyone else. The slight drop corresponding to a better perception of people between 30 and 40 years old has been noticed at most questions for most features.

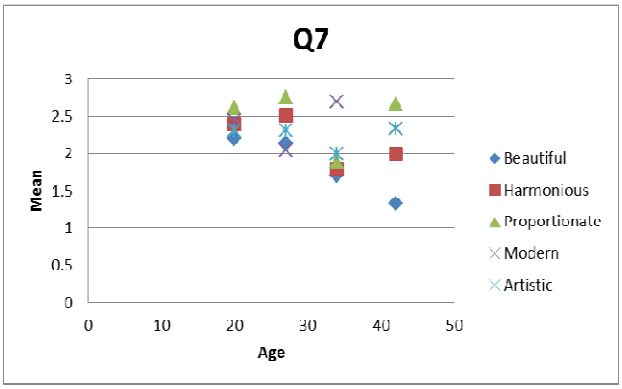


Fig. 2. Feature-age correlation for question 7

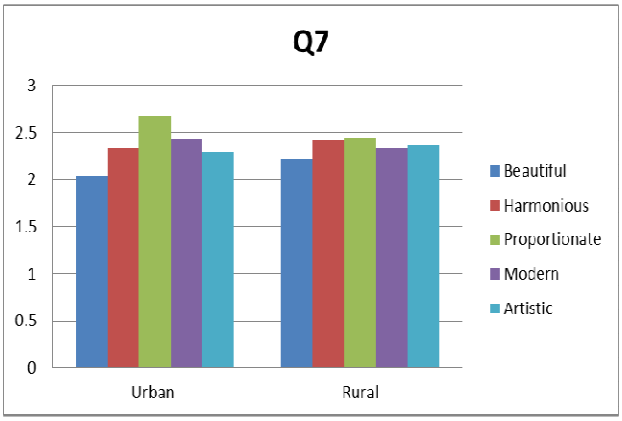


Fig. 3. Feature- urban/rural typology correlation for question 7

The feature- urban/rural typology correlation reveals for the same question (Fig. 3) that the people from a rural area consider the vase more proportionate and more modern than the ones from an urban area. The means of the grades corresponding to the rural area regarding all 5 studied aspects are very close suggesting a correlation in perception. However, this is not true for all questions. The feature-gender correlation for the same question is presented in Fig. 4. As it can be observed women are more exigent at all studied aspects except proportionality, men considering the vase corresponding to question 7 less proportionate than women. Regarding the feature-educational background correlation presented in Fig. 5 it can be mentioned on one hand that the people who come from a technological high school or "other" high schools consider the vase better at all studied aspects. On the other hand the people with an economical or arts background are more critical than the others. This observation is true for more than half of the vases included in the questionnaire.

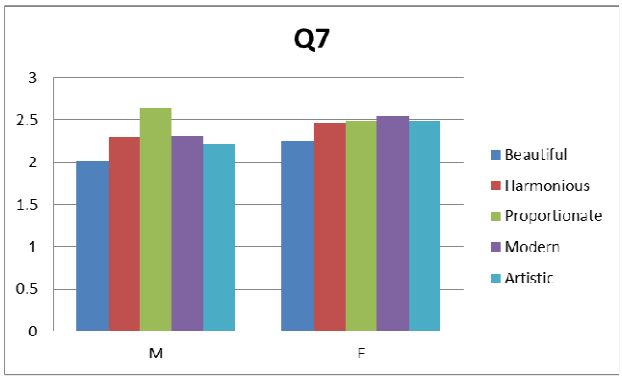


Fig. 4. Feature-gender correlation for the question 7

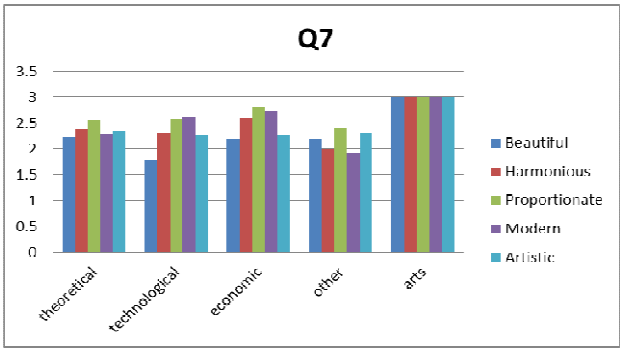


Fig. 5. Feature-educational background correlation for question 7

As mentioned before, the means for the studied features were computed for each question (see Table 1). Even if the means of the features are close that does not mean that there is a correlation between the features. In order to determine if such correlations exist, the correlation coefficients were determined for each question.

An example is provided in Table 4 for question 7. The values were obtained using the function CORREL() from Excel. It has to be mentioned that the values between 0.5 and 0.7 are considered a medium correlation, the values

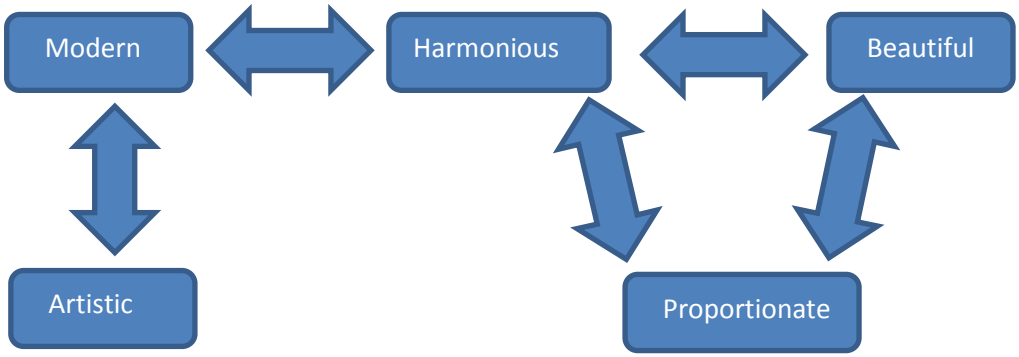


Fig. 6. The global connection between the analyzed features

less than 0.5 correspond to a weak correlation, while the values larger than 0.7 signify a strong correlation. However, only the values larger than 0.8 were taken into account when studying the global correlations due to the fact that these values reflect more fidelity and a stronger correlation. As it can be observed in Table 4, the pairs beautiful-modern, harmonious-modern, harmonious-artistic, and modern-artistic have really strong correlations.

In a similar manner, the tables with the correlation coefficients were determined for all questions. The data was centralized in a global table by adding all values larger than 0.8 corresponding to all possible pairs of adjectives and the ones less than -0.8. The results revealed five strong correlations between pairs of analyzed features (see Fig. 6). In other words, artistic means modern, modern means harmonious etc. However, only three adjectives form a closed loop, which means that only those words are considered to have the same meaning. Thus, the word "harmonious" means "beautiful" and "proportionate" and it can replace the words "beautiful" and "proportionate" in the study, reducing the complexity of the approached problem and allowing to include other features without complicating the completion of the proposed questionnaire.

4. CONCLUSION

The aesthetic design has a significant role in the success of products nowadays. The aesthetic standards used to obtain aesthetically optimal products (vases in this case) have to be complemented by the human factor.

The human perception regarding different features of the optimal vases was analyzed in this paper. The data was collected through a questionnaire which included 19 questions: 4 referring to age, gender, educational background, and urban/rural typology and 15 measuring the visual impact of 15 aesthetically optimal vases on the user.

The results showed that at 3 out 5 studied aspects the vases generated based on the golden ratio were preferred to the ones generated based on the harmonic ratio. However, the differences were small. Larger differences were noticed between the vases generated using Bezier curves and the ones using circular arcs, the first ones being better rated than the latter at all 5 studied aspects.

The correlations between the adjectives proposed to be used in order to characterize the optimal vases showed that three of them are strongly correlated and can substitute one another in the questionnaire. In a further approach just one adjective from the three correlated ones can be kept and other aspects can be included in the questionnaire in order to perform a better evaluation of the human perception regarding the optimal vases.

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6. REFERENCES

[1] Kuragano, T., Yamaguchi, A., *NURBS curve shape modification and fairness evaluation for computer aided aesthetic design*, In Proceedings of the 7th WSEAS International Conference on Signal Processing, Computational Geometry & Artificial Vision, pp. 38 – 44, 2007

[2] Birkhoff, G., *Aesthetic Measure*. Cambridge: Harvard University Press, 1933

[3] Dunlop, R.A., *The Golden Ratio and Fibonacci Numbers*, World Scientific, 1997

[4] Livio M., *The Golden Ratio: The Story of Phi, the Worlds's Most Astonishing Number*, Broadway Books, 2002

[5] Stakhov, A. P., *The Generalized Principle of the Golden Section and its applications in mathematics, science, and engineering*, Chaos, Solitons and Fractals, Vol.26, pp. 263-289, 2005

[6] Crăciun, I., Inoan, D., Popa, D., Tudose, L., *Generalized Golden Ratios defined by means*, Applied Mathematics and Computation, Vol. 250, pp. 221–227, 2015

[7] Falbo, C. *The Golden Ratio-A Contrary Viewpoint*, The College Mathematics Journal, 36, 123–134, 2005

[8] Gobithaasan, R. U., Miura, K. T., *Aesthetic Spiral for Design*, Sains Malaysiana, Vol.40, No.11, pp. 1301-1305, 2011

[9] Harary, G., Tal, A., *3D Euler Spirals for 3D Curve Completion*, Symposium on Computational Geometry, pp. 107-108, 2010

[10] Crăciun, I., Rusu, F., Tudose, L., *Aesthetic optimization of a basic shape*, ACTA TEHNICA NAPOCENSIS – Series : APPLIED MATHEMATICS AND MECHANICS, ISSN 1221-5872, Vol. 58, Issue II, pp. 257-262, 2015

[11] Rusu, F., Crăciun, I., Tudose, L., *Aesthetic shapes generated by piecewise continuous Bézier curves*, Annals of the Tiberiu Popoviciu Seminar of Functional Equations, Approximation and Convexity, ISSN 1584-4536, Vol. 13, 2015, in press

[12] Achiche, S., Maier, A., Milanova, K., Vadean, A., *Visual Product Evaluation: Using the Semantic Differential to Investigate the Influence of Basic Geometry on User Perception*, In Proceedings of the ASME 2014 International Mechanical Engineering Congress & Exposition (ASME IMECE 14), November 14-20, Montréal, Québec, Canada, 2014

EVALUAREA STATISTICĂ A FORMELOR ESTETICE

Abstract: *Estetica este un criteriu important în alegerea majorității produselor. Standardele estetice definite matematic și implementate în algoritmi evolutivi cu scopul de a obține produse optime din punct de vedere estetic nu sunt întotdeauna de ajuns dacă se dorește a se obține un produs optim unic. În acele cazuri factorul uman joacă un rol decisiv. Această lucrare se axează pe investigarea percepției umane asupra vazelor optime generate folosind arce circulare sau curbe Bézier, precum și criterii definite pe baza secțiunii de aur și a secțiunii armonice. Mai mult decât atât, lucrarea prezintă diferite corelații care există între percepția umană și diferite categorii de oameni determinate în raport cu aspecte precum vârsta, genul, background-ul educațional și mediul de proveniență.*

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