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Aplicability of golden ratio rule in modern product design

ABSTRACT

This paper presents research regarding application of golden ratio rule in field of product design. The rule was applied to the design on vacuum cleaner, as it is a common and widely spread product. The aim of this paper is to research possibilities of applications of the rule in modern design. In order to determine consumer's subjective aesthetic judgment of products designed by directly applying golden ratio rule, one vacuum cleaner was designed in that manner. Results for consumer's subjective aesthetic preference were compared to results for other differently designed vacuum cleaner models present in the market today. Factors used were age, gender and level of education of participants (typical consumer). The results showed no statistical influence of age or gender factors. Statistically significant differences were noticed for level of education factor, between participants with high school diploma and university diploma. It was observed that product designed using golden ratio rule received higher marks regarding aesthetics in case of participants with university diploma. It can be concluded that golden ratio rule can be applied in field of product design, equally successful as in the other art fields where it is commonly used, but consumer demographics must be taken in to consideration, especially education level.

KEY WORDS
golden ratio, industrial design, aesthetic preference

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Introduction

Today manufacturers place their products on highly competitive and dynamic markets. Products life-cycle span is often uncertain and it is difficult to achieve long lasting popularity of the product. Not only fast and efficient production and functionality of the product is required for the market success, but the product also has to be enriched with highest possible creativity to make it more interesting and appealing to the consumer. Using design elements wisely designers can achieve solutions superior to the competition and therefor ensure bigger market share for the product. Creativity plays big role in process of product development (Hsiao & Chou, 2004). Having that that in mind, while using innovative ideas it is necessary to know the fundamental principles of design to achieve optimal results. With combination of commonly known rules and new ideas it is possible to get a harmonious yet innovative product form. In modern marketing a good product design is recognized as an opportunity and advantage. Product appearance affects customer choice in several ways: aesthetic communication, symbolic, functional and ergonomic information, attention attraction and categorization (Creusen & Schoormans, 2005) (Markowsky, 1992) (Crilly & Clarkson, 2004).

The golden ratio, also called the golden mean, divine proportion, golden section, golden number and etc. is precisely defined in mathematics and thoroughly examined discussed in many books and articles as a rule of achieving the pleasant and aesthetic form (Stakhov, 2005). Rule of golden ratio have achieved the status of common knowledge in art and design. The use of the golden ratio is not rarity even in design of today's industrial products and it is proved that those rules contribute to improve-

ment of aesthetic impression that a product can have on potential consumer (Hsiao & Chou, 2004) (Disneya et al., 2004) (Bloch, 1995) (Noble & Kumar, 2010) (Khalid & Helander, 2006) (Crilly & Clarkson, 2004). On the other hand there is ongoing discussion about misconceptions about golden ratio rule as a result of the repetition of the same errors by different authors (Markowsky, 1992).

The golden ratio is the result of dividing a line segment so that the ratio of the whole segment to the larger piece is equal to the ratio of the larger piece to the smaller piece, called division in extreme by Euclid (Smith, 1953).

In case of rectangle with height h and width w, the h to w ratio is the same as ratio w to sum (h, w) (Emery, 2006):

$$\frac{h}{w} = \frac{w}{h+w} \quad (1)$$

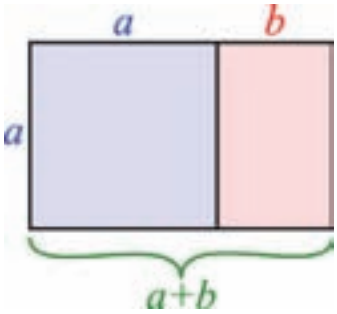
With assumption that h=1,

$$\frac{1}{w} = \frac{w}{1+w} \quad (2)$$

By solving the equation 2, golden ratio (equation 3) can be calculated (Noble & Kumar, 2010) (Emery, 2006).

$$\varphi = \frac{w}{h} = \frac{1+\sqrt{5}}{2} = 1.68033988749895 \quad (3)$$

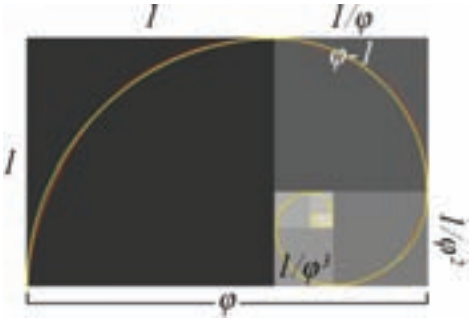
Figure 1 shows an illustration of the relation presented in equations 1 and 2, while Figure 2 shows some shapes constructed by applying golden ratio rule.



» **Figure 1:** *Golden rectangle page relation*

a)

b)



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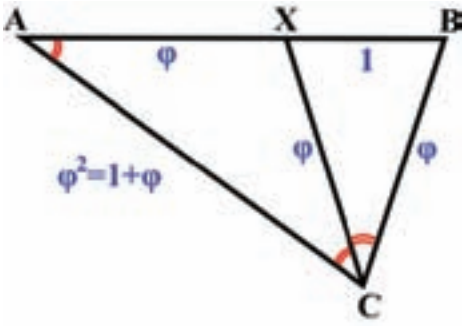

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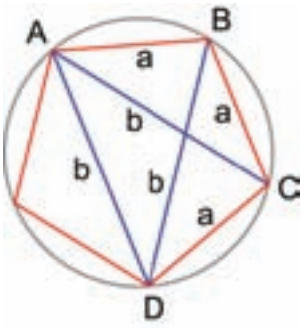


» **Figure 2:** *Golden ratio examples: a) Pentagram, b) Golden spiral, c) Golden triangle, d) Ptolemy pentagon*

As a result of quick fashion changes and coexistence of multiple different styles simultaneously lifetime of the product is reduced. Aesthetic value of the product and the ability of the product to attract consumers' attention during the first contact is gaining increasing importance in the market (Crilly & Clarkson, 2004). The external appearance of the product is primarily responsible for the first impression that customer gains for the product.

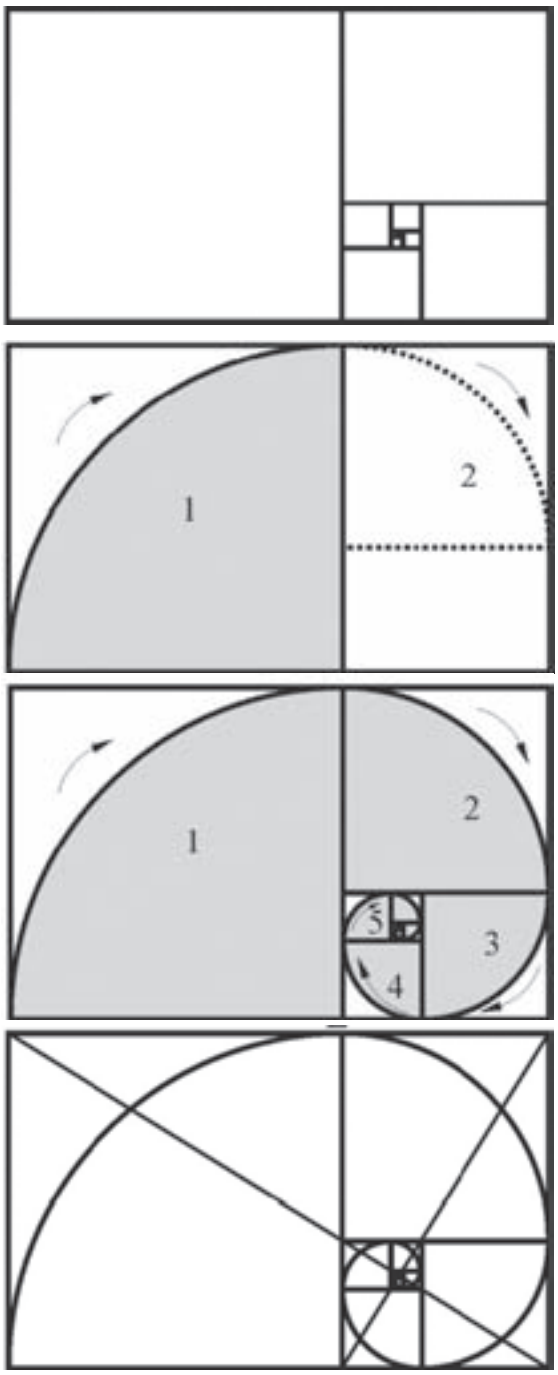
Vacuum cleaner was chosen as a typical industrial product that can be shaped in variety of forms. Large number of these devices is present on the market today, some of them achieved market success by emphasizing the functionality and on the other hand some emphasize aesthetics of the product. According to traditional attitude- success of a product depends on its functionality, usability, but nowadays it is possible to find a group of products whit aesthetics is a priority, but that does not ratio that it shall result in reduced functionality. Some products fail to do either and usually fail as a product all

together, costing the manufacturer not only the invested resources but also damaging their reputation. The most successful products combine these two features and provide a sense that the product is completing and enriching the living space while retaining seamless functionality. Two extreme examples are Dyson and Dirt Devil vacuum cleaners designed by James Dyson and Karim Rashid respectively. Dyson vacuum cleaner is designed in such a way to highlight functionality and features of the device. Dirt Devil is a completely different end of the spectrum where the design is absolutely subordinate to aesthetics of the product (Figure 3).

» **Figure 3:** *Dirt Devil (up) and Dyson (down) vacuum cleaner renders*

The aim of this paper is to determine the consumer's preferences regarding aesthetics of the product and exploring possibilities of using the golden ratio rule in the design of modern industrial products. Golden spiral, which is derived from the golden rectangle (Figure 3), was directly applied to the design of a vacuum cleaner to be used in the experiment.

By drawing arcs 1, 2, 3, etc., and their bonding, golden spiral is constructed as shown in Figure 4. The starting point (pole) of the spiral is located at the intersection of the diagonals AC and DF of two largest rectangles: ABCD and CDEF (Sharp, 2002). Design of the vacuum cleaner derived from this process is shown in Figure 5 with orthogonal projections in black and white colors. Main objective of this paper is shape of the device so influence of the device colours are not examined, but it is possible to use various colour combinations in satisfactory manner.



» **Figure 4:** *Golden spiral construction*

» **Figure 5:** *Vacuum cleaner design proposal using golden spiral*

Figure 6 shows typical design solutions of vacuum cleaner from worldwide recognized manufacturers present in the market today. All vacuum cleaners fall under the same category¬ floor vacuum cleaners of contemporary design and none of them was designed using golden ratio as a main design element. Those designs were used as a stimuli for construction of the survey instrument used in the experiment. Experiment was devised so that it offers insight in to the typical consumer subjective aesthetic judgment. Consumer's aesthetic preferences were compared between the vacuum cleaner design dominated by golden spiral shown in Figure 5 and vacuum cleaners designed without significant influence of golden ratio rule shown in Figure 6 numbered 1 to 5.

» **Figure 6:** *Typical models of vacuum cleaner solutions: 1) Dyson dc19t2i (United Homestores [Online], 2012), 2) Hoover xarion tav1620 (Appliancist [Online], 2012), 3) Philips marathon vacuum cleaner (InventorSpot [Online], 2012), 4) Samsung vcd-9451s32 (TechnoMarket Serbia [Online], 2012), 5) NEO fc 218 red (TechnoMarket Serbia [Online], 2012), 6) Proposed model*

Method

In this paper, a study was conducted with the purpose to determine the subjective aesthetic preferences of consumers with regard to household appliances, vacuum cleaners in this case. Subjective aesthetic judgment for the proposed model (figure 5) was compared to the 5 existing models of the same class vacuum (figure 6).

Participants

The study was conducted by interviewing 48 participants of whom were 21 men and 26 women, aged between 22 and 62 years (one participant was eliminated because it did not complete the survey). Participants provided information about their level of education as follows: ue – university education and he – high school education, age and gender.

Procedure

Instrument for survey was one a4 size paper containing survey question and printed images of 6 vacuum cleaners used as stimuli, all of them shown in figure 6. All images shown to participants were printed in gray scale, in order to eliminate the effect of colour preference and isolate effect of the product shape. Products were striped of any manufacturer trademarks also. Random arrangement of stimuli was assured for all of the surveys participants. Each participant evaluated aesthetic appeal of all 6 vacuum cleaner models, the existing 5 and the sixth designed strictly applying the golden ratio rule. Participants graded the products according to subjective aesthetic preferences ranging from 1 to 7, where 1 is the lowest and 7 the highest grade.

Collected results were placed in the matrix suitable for statistical analysis. Dependent t-test for paired samples and one way anova test were used. Dependent t-test was used in case of analyzing aesthetic judgment of all existing vacuum cleaners paired with proposed design, while one way anova test was used in case of age and gender impact analysis.

In the results section of this paper, existing models of vacuum cleaners will be presented using numbers 1 to 5 and proposed vacuum cleaner design will be marked with number 6, as shown in Figure 6.

Results and discussion

Using dependent t-test for paired samples, variances from the subjective aesthetic judgment for the proposed and existing models of vacuum cleaner were compared. The results are presented in Table 1. Statistically significant differences between the proposed vacuum cleaner model and other models, the level of confidence set at $p < 0,05$. Table 1 shows the mean values and it can be noted that the approximate each other, but still are statistically different.

Table 1
Summary of statistical differences between the subjective aesthetic judgment of vacuum cleaner pairs

	Vacuum cleaner model	Mean	St. dev.	p
Pair 1	6	4.30	1.08	0.001
	5	3.36	1.21	
Pair 2	6	4.30	1.08	0.012
	4	3.68	0.95	
Pair 3	6	4.30	1.08	0.020
	3	4.98	1.29	
Pair 4	6	4.30	1.08	0.003
	2	4.98	1.05	
Pair 5	6	4.30	1.08	0.011
	1	4.96	1.21	

Table 2
Mean values and standard deviation of subjective aesthetic grades for University educated and High school educated participants

	Stimulus 1		Stimulus 5		Stimulus 6	
Education	HE	UE	HE	UE	HE	UE
Mean	5.29	4.5	3.77	2.81	3.85	4.9
St. dev.	1.16	1.11	0.98	1.17	1.13	0.76

ANOVA test determined the effect of participant's education level on subjective aesthetic preferences of different models of vacuum cleaner. In case of education level statistically significant differences between University educated and High school educated participants were noticed in the case of a vacuum cleaner 1 $F(1, 47) = 5.41$, $p = .003$, vacuum cleaner 5 $F(1, 47) = 8.85$, $p = .005$ and vacuum cleaner 6 $F(1, 47) = 5.41$, $p = .001$. Mean values and standard deviation are shown in Table 2. Vacuum cleaners 1 and 5 received higher grades by the less educated participants, while in the case of a vacuum cleaner 6 opposite can be noticed.

It may be noted that participants with higher education level have given higher grades to aesthetic value of the design that uses directly golden ratio rule. This is not the case with lower educational level participants. They gave the highest grades to design that emphasizes functionality. The explanation may be sought in the fact that during the education process the value of the golden ratio in art and other fields is emphasized and the knowledge is now transferred into evaluation of aesthetic appliances. Less educated participants may not be, or are in lesser extent, familiar with golden ratio rule, its application and value.

Analysis of the significance of gender factor on the subjective aesthetic preference showed statistically significant differences only in case of the vacuum cleaner 5 $F(1, 47) = 7.61$, $p = .008$. By comparison of grade mean values, it can be noted that the score of the male population of the participants ($M = 2.86$, $SD = 1.17$) is significantly lower than the score of the female population ($M = 3.77$, $SD = 1.04$). This can be explained by the fact that male participants gave the highest grades to the vacuum cleaner models 1 and 3 which design is purely function oriented, while vacuum cleaner model is not. This is questionable if we take in to consideration that the design of vacuum cleaner models 4 and 6 is not function oriented also. These differences noticed between genders and their causes are not the subject of this study, but they should be explored further in future studies, with specially designed survey.

Age of the participants showed no statistical significant effects regarding subjective aesthetic preference of the presented vacuum cleaner models.

Conclusion

Using vacuum cleaner design as a case study, the direct application of the golden ratio rules in the design of home appliances was explored and illustrated. The result is a modern, aesthetically pleasing, harmonious and innovative product form capable of attracting the consumer's attention. It can be concluded that this rule holds its importance even today and it can be applied to the design process of modern products. Results show that the rules of good form are deeply rooted and significant today as they have been hundreds of years ago. The analysis of the education level effects shows that the use of the golden ratio achieved higher scores in terms of aesthetics from the participants who have had more opportunities to come across the explained applications of golden ratio rule. This indicates the importance of previous experience in assessing the consumer's aesthetics preferences of the products. As for the golden ratio rule, it can be concluded that it is not directly and unambiguously related to the assessment of product aesthetics, rather it can be used as a tool to increase aesthetic appeal of the product to certain groups of consumers. Having this in mind it is necessary to have good insight in to demographics of the potential consumers of the product. Unconditional use of the golden ratio rule will not ensure the success of the product or the high aesthetic appeal all across consumer population. Gender and age did not show a statistically significant effects in the case of subjective aesthetic preference when applying the golden ratio rule.

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References

1. Appliancist. (2012) [Online] Available from: http://www.appliancist.com/vacuum_cleaners/hoover-xarion-bagless-vacuum-cleaner-airvolution-tav1620.html [Accessed 7th August 2012].
2. Bloch, P. H. (1995) Seeking the Ideal Form: Product Design and Consumer Response. Journal of Marketing, 59(3), 16-29
3. Creusen, M. E. H. & Schoormans, Jan P. L. (2005) The Different Roles of Product Appearance in Consumer Choice. J PROD INNOV MANAG, 22, 63–81
4. Crilly, N. Moultrie J. & Clarkson P. J. (2004) Seeing things: consumer response to the visual domain in product design. Design Studies, 25(6), 547–577,
5. Disneya, S. M. Towilla, D.R. & van de Veldeb, W. (2004) Variance amplification and the golden ratio in production and inventory control. International Journal of Production Economics, 90, 295–309
6. Emery, J. (2011) Fibonacci Numbers and the Golden Ratio. [Online] Available from: http://stem2.org/je/fibonacci.pdf [Accessed 7th April 2013].
7. Hsiao, S. W. & Chou, J. R. (2004) A creativity-based design process for innovative product design. International Journal of Industrial Ergonomics, 34, 421–443

8. InventorSpot, (2012) Copyright ©2006-2012 AhaCafe LLC. [Online] Available from: http://inventorspot.com/articles/philips_marathon_vacuum_cleaner__10017 [Accessed 7th August 2012]
9. Khalid, H. M. & Helander, M. G. (2006) Customer Emotional Needs in Product Design. CONCURRENT ENGINEERING: Research and Applications, 14(3), 197-206
10. Markowsky, G. (1992) Misconceptions about the Golden Ratio. The college mathematics journal, 23, 2-19
11. Noble, C. H. & Kumar, M (2010) Exploring the Appeal of Product Design: A Grounded, Value-Based Model of Key Design Elements and Relationships. J PROD INNOV MANAG, 27, 640–657
12. Sharp, J. (2002) Spirals and the Golden Section. NEXUS NETWORK JOURNAL, 4(1), 59-82
13. Smith, D. E. (1953) History of Mathematics, Vol. it Special Topics of Elementary Mathematics, Dover, New York,
7. Stakhov, A. P. (2005) The Generalized Principle of the Golden Section and its applications in mathematics, science, and engineering. Chaos, Solitons and Fractals, 26, 263–289
8. TechnoMarket Serbia. (2012) [Online] Available from: http://www.technomarket.rs/products/09110780/samsung-vcd-9451s32 [Accessed 7th August 2012]
9. TechnoMarket Serbia. (2012) [Online] Available from: http://www.technomarket.rs/products/09082401/neo-fc-218-red [Accessed 7th August 2012]
10. United Homestores. (2012) [Online] Available from: http://www.uhsonline.co.uk/products/Dyson-DC19T2i-Multi-Floor-Cylinder-Vacuum-Cleaner.html [Accessed 7th August 2012]
11. Xah Math. (2012) [Online] Available from: http:// http://xahlee.info/math/top_math_wonders.html [Access 7th August 2012]