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A survey to evaluate how non designers perceive aesthetic properties of styling features

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ABSTRACT

World-wide market competition and the need to create products that better satisfy the expectations of the customer require a more comprehensive involvement of the customer in the product definition loop. It is therefore crucial to provide customers with very easy-to-use shape definition and modification tools, allowing them to verify and evaluate possible shape alternatives without requiring specific knowledge on geometric modeling. A set of aesthetic properties guiding the shape characterization and appraisal have been identified together with measures for their evaluation and shape modeling methods for their direct modification. Since these properties are those indicated by stylists, this does not guarantee that they are usable in a context which involves the customer in the product definition loop. To verify the extent to which the terms indicating the properties, their meaning and their measures are significant and understandable by non-expert designer people we carried out a survey. This paper describes the methodology adopted and the outcomes of this survey.

Keywords: geometric modeling, styling, aesthetic features, semantic-oriented 3D modeling.
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1 INTRODUCTION

Designers conceive a new product by making sketches of some essential curves that are an abstraction of the product model and strongly affect the product impression. These curves may be structural lines, like profiles, but also meaningful lines that have no explicit representation in the product model, but can nevertheless be perceived and strongly affect the product impression, such as the lines originated by the reflection of the light on the object.

These lines may be regarded both as properties or as features of the model: on the one hand they reveal properties of the underlying surface (all surface points on the lines share the same geometric property, e.g. same angle between the normal to the surface and the light ray), on the other hand they are feature lines with their own set of properties.

Given the importance of these styling features for the final product appearance, there has been a growing interest in the research community towards the exploitation of these aesthetically relevant product elements for improving the design process [1]; research works in different fields (cognitive psychology, computer science..) have been carried out, aimed at exploring the possible links between shape characteristic and elicited feeling with the final objective of exploiting these possible relationships for the creation of computer assisted tools able to support modelling functionalities, driven by the design intent [2-4].

In particular, in the frame of an European project involving stylists from major companies both from the automotive and consumer appliances fields, the styling features have been characterized in terms of aesthetic properties guiding the shape characterization and appraisal and some measures for their evaluation are proposed as well as shape modeling methods for their direct modification . Since these properties are those indicated by stylists, this does not guarantee that they are usable in a context which involves the customer in the product definition loop.

On the other hand, the importance of putting the user at the centre of the design loop is widely recognized. User-centered design [5] is a broad term to describe design processes in which end-users influence how a design takes shape. There are many ways in which users can be involved, typically during requirements gathering and usability testing but also at the product concept stage. In the ideal scenario the customer would be able to define and personalize aesthetic characteristics of shapes by means of spontaneously expressed terms. In this scenario, users' creativity finds a direct way of representation, and ICT design tools become really creative tools accessible to a larger community and not only for experts.

In this perspective, to allow the involvement of the customers in the product design process, making possible they express their own ideas on the product shape they wish, first of all we have to understand to which extent the terms indicating the aesthetic properties, their meaning and their measures are significant and understandable by lay people. To this aim we carried out a survey, structured to collect the necessary feedback from a group of people with different cultural background and not skilled in product design.

The paper describes how the survey was structured and performed and the achieved outcomes. The paper is organized as follows: section 2 summarizes the aesthetic properties whose perception by lay people has been investigated in the survey. Section 3 and 4 focus respectively on the methodology adopted for the survey and the related outcomes. Section 5 concludes the paper discussing the results.

2 THE AESTHETIC PROPERTIES

To identify an appropriate characterization of shapes in terms of styling features and to understand which features properties stylists consider, the design activities carried out in different industrial design fields have been deeply analyzed within the FIORES-II project [6]. Among the other results, the project showed that different languages are adopted in different phases of the product design process (marketing, concept design, Computer-aided styling modeling). In particular, during the creation and modification of the product model, stylists express detailed directives when they work with surfacers at the definition of the 3D digital model using a limited number of terms strictly linked to shape properties: with these terms they provide instructions for the modification of the product shape (e.g. "making a curve a bit more *accelerated"*, or " decreasing curve *tension*").
The terms referring to these properties represent a first link between low-level CAGD descriptions and the high level character of a product. Properties' characterization and measures (or more generally shape descriptors) play a key role: they are useful tools to formally characterize the property of the shape which has to be modified focusing on the possibility of translating the concepts linked with the aesthetic properties in an environment able to treat the geometrical entities from a mathematical point of view. Meaningful measures for property evaluation may allow the control of the shape; by monitoring these values and correspondingly acting on the associated geometric properties, it could be possible to obtain a required modification of the shape.

In [7] authors illustrate the meanings and the measures of the above listed properties and the implementation of the corresponding modification operators. In [8,9] authors present the definition and implementation of semantic operators for curve deformation based on the shape characterization provided by some of these aesthetic properties, namely convexity, acceleration, straightness. The research presented in this paper is based on the measures of these aesthetic properties defined and implemented in the above mentioned works.

In the following we briefly illustrate the meaning of the properties used in the survey:

- **Straightness.** While in engineering a curve is either straight or not, for a stylist a curve can be more or less straight, depending on the dimension of the overall curvature radius in relation to the curve length. The bigger the radius is, the straighter the curve. Even curves having inflection points and consequently variable radius can appear straight.
- **Convex.** A (non-linear) curve is convex or concave if the curvature along the curve has the same sign. Whether a curve is convex or concave depends on the context in which the curve is viewed. When designers are making a curve more convex, they are moving towards the enclosing semi-circle; i.e. considering the chord between the two extremes of a curve , the most convex curve on that chord is the semicircle with diameter equal to the chord. Thus the ideal convex curve is the semicircle, or an arc of circle, if the continuity constraints at the endpoints are compatible with, otherwise it is the curve presenting the lowest variation in curvature that satisfies the given continuity constraints. Conversely the least convex curve on that cord is the cord itself. Judging a curve more or less convex depends on several factors: above all the symmetry, the roundness, and the curvature variation.
- **Acceleration.** A curve without any acceleration is a straight line or a true radius, i.e. a circle. If in a curve the tangent deviation changes too slowly it may show no acceleration at all. Acceleration is sensitive to the orientation of the curve on which it applies. There is no unique definition at which point a curve starts to accelerate, but acceleration always starts in a rather flat area and leads into a high curvature region; moreover stylists say that symmetrical curves have no acceleration.

3 SURVEY OBJECTIVES & METHODOLOGY

To understand if the identified aesthetic properties are usable by laypeople to express their ideas on the product shape, it is necessary to

- Verify if these terms are easily understood and if there are characteristics of curves that are easier captured than others;
- Verify if the provided measures reflect the perceived property ranking;
- Verify if there is the possibility to give also a commonly shared qualitative characterization of the measures.

To answer to the above questions, a questionnaire has been formulated and circulated to acquire feedback from non-designer persons. Our target users are persons with some basic expertise in using computer technologies, having an age corresponding to active working period, thus representing a sample of potential buyers. To overcome the possible cultural limits, related to the original country, the questionnaire has been developed by using Google Docs pages supported by MS Powerpoint presentation, that allows a web distribution, in two languages: French and English.

The questionnaire has been structured in three parts. The first section aims at collecting general information about the interviewed sample, such as age, profession, knowledge on surface modeling. The other two sections are finalized to collect the required information to answer to the above questions.

In particular, the second part is aimed at discovering if:

1. there are properties that are better understood than others;
2. the ranking provided by the defined measures reflects the ranking the user would give to the curves according to a specific property;

3. the perception of an aesthetic property is affected by the type of curve, such as symmetric or non-symmetric curve and/or with or without curvature extrema.

Thus, we set up a MSpowerpoint presentation in which each slide presents a curve (see Fig.1). There are in total 27 curves: they include both symmetric and non-symmetric curves, either presenting 0 or multiple curvature extremum points. To each curve a matrix is associated, where rows correspond to the analyzed properties, and columns indicate a qualitative connotation (*very not*, *not*, *fairly*, *very*). People are then asked to assign an appropriateness score (from 1 to 3, where 1 indicates the most appropriate) to the qualitative connotation that better applies to each property. In this way, we expect that people assign the score 1 to the qualified properties in which they are more confident. Moreover, if the property is well understood we can find a correspondence between the values evaluated by the aesthetic property measures with the selected appropriateness score set to 1 (e.g. low value in case of appropriateness qualification set 1 for *Very not*).

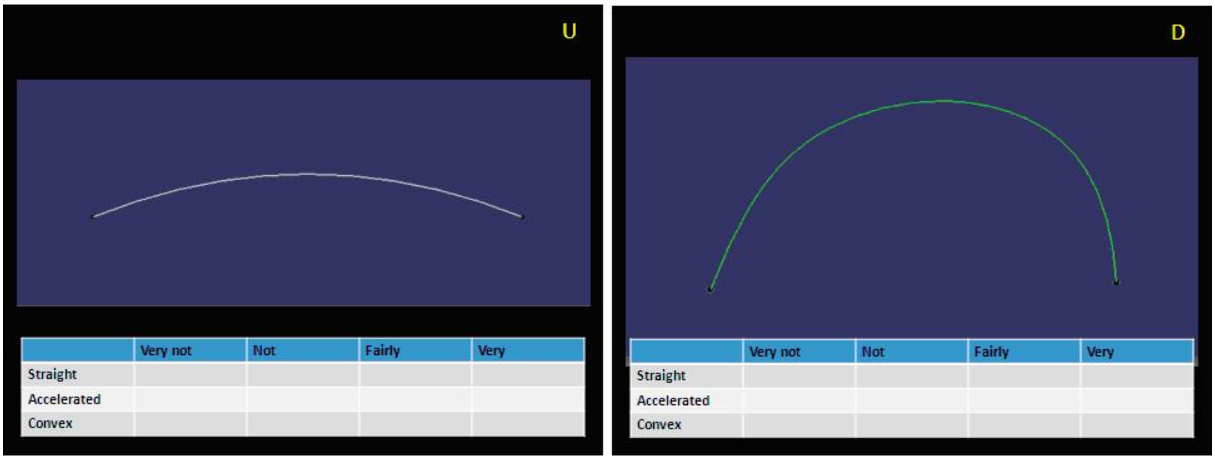


Fig. 1: Examples of the power point slides used for the questionnaire.

Once selected and scored a specific cell of each row of the matrix under the curve drawing, we asked to put the slides in descending order from the most to the less convex, straight or accelerated respectively. This step aims to check if the ordering provided by the defined measures is reflecting the ones perceived by non-professionals.

It must be noted that the ordering is somehow non-restrictive in the sense that being the aesthetic properties conceived for performing rather small adjustments on curves already showing a given aesthetic characteristic, they are not so selective in distinguishing curves (i.e. the same value of a specific property can be associated to different curves). In addition, being these properties strongly related to perception we still have to accept some fuzziness in the measures, i.e. we must accept that for curves having slight differences in the property measures, the order assigned by different persons can slightly be different among themselves and with the computed measures.

The third part of the questionnaire is once more dedicated to verify the qualitative evaluation of a specific property. To this aim a sequence of curves are shown, each curve being a modified version of the previous one obtained by slightly increasing the value of a given property. For each property different starting curves have been selected already characterized by the property under evaluation. All the curves are numbered. Users are then asked to indicate which curve number better represents the shift from the qualitative attribute *Very not* to *Not* and from *Not* to *Fairly*. Fig. 2 shows an example of two curves (the 7th and the 10th) of the slide show for the convexity property.

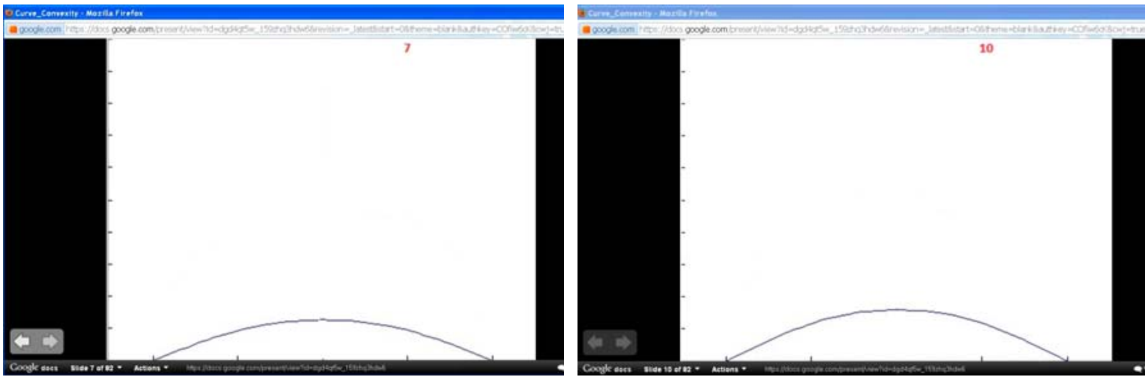


Fig. 2: two slides extracted from the slide show for the verification of the qualitative range limit for the convexity property.

The above described part of the questionnaire was realised in three versions, one for each of the aesthetic properties analysed, i.e. convexity, acceleration and straightness. This split was necessary to reduce the time required for answering to the questionnaire questions. Being the interviewed people not paid for the time spent on the questionnaire we couldn't expect them to consider all the properties together. In order to a have a variety of cultural background we contacted mainly academic staff and students and students from France, Italy, Netherlands and Malta, from Mathematics, Design and Engineering schools.

4 SURVEY RESULTS

Being the interviews carried out remotely, we had the questionnaires answered at different levels of completeness. 38 persons answered at the whole questionnaire in a first time. The 47% performed all the requested steps, while the 17% forgot to organize the slides according to the decreasing property appearance in the first part of the survey. 30% were doctors and 58% had engineering school or equivalent degree and a reasonable balance between male and female was obtained (more than 30% were female).

All the results were then collected in an MSExcel file. Fig. 3 shows a part of the MSExcel table reporting the results of the weighted qualitative aesthetic property selection for the various curves inserted in the MSPowerPoint slides. Each row corresponds to a specific curve. The first column shows the name of the curve indicated in the corresponding slide. On the second column of the table the actual values of the properties evaluated with the implemented measures are reported; it also indicates whether the curve is symmetric (S) or not (NS) and the number of inflection points in the curve. Each row is then split into three parts in turn containing two rows. They correspond to the selected description (e.g. *Very Not Straight*) and rank for the considered three aesthetic properties. The rank corresponds to the ranking of this association between the three possible for this curve. Then columns list the answers obtained: here only few are depicted. Then for each curve, answers are summarised to give the percentage corresponding to each qualitative attribute considered (*very not*, *not*, *fairly* and *very*). The rightmost column depicts in a graphical way the percentage distribution of the answers among the qualitative values. As you can see from the fifth column on the right side, the answers are generally falling into two consecutive values, for instance in the case of curve B the 85% are in *Very Not* and *Not* (40% and 45%), while only the 14,29% indicate the curve as *fairly straight* but no one is judging it *very straight*. We noticed that in general these proportions are respected normally presenting at least the 40% of the answers indicating the same attribute, and the sum of the two consecutive attributes is more than 80%. We can then conclude that there is quite a good convergence among the received answers.

				Answer 1	nswer 1	nswer 1	nswer 1	Very Not (%)	Not (%)	Fairly (%)	Very (%)
		Straightness	Description	F	N	VN	VN	50,00	41,67	8,33	0,00
B	0		Rank	2	1	2	2				
		Acceleration	Description	N	VN	N	F	12,50	41,67	37,50	8,33
Straight=	0,4582		Rank	3	2	3	3				
Acc=	0,0301	Convexity	Description	F	F	F	VN	16,67	8,33	45,83	29,17
Conv=	0,5118		Rank	1	3	1	1				
		Straightness	Description	F	N	V	VN	16,67	29,17	50,00	4,17
C	1		Rank	2	1	1	3				
		Acceleration	Description	F	VN	F	VN	12,50	12,50	50,00	25,00
Straight=	0,7232		Rank	1	2	2	1				
Acc=	1,0031	Convexity	Description	N	N	N	N	20,83	50,00	20,83	8,33
Conv=	0,223		Rank	3	3	3	2				
		Straightness	Description	N	N	VN	VN	62,50	37,50	0,00	0,00
D	0		Rank	1	2	2	3				
		Acceleration	Description	F	N	N	F	4,17	37,50	54,17	4,17
Straight=	0,3244		Rank	3	1	3	2				
Acc=	0,1242	Convexity	Description	V	F	V	VN	8,33	4,17	29,17	58,33
Conv=	0,6885		Rank	2	3	1	1				
		Straightness	Description	VN	N	N	N	40,00	52,00	8,00	0,00
E	0		Rank	1	1	2	2				
		Acceleration	Description	F	N	VN	N	16,00	44,00	36,00	4,00
Straight=	0,4714		Rank	3	2	1	3				
Acc=	0,1097	Convexity	Description	V	F	V	VN	12,00	8,00	32,00	48,00
Conv=	0,4704		Rank	2	3	1	1				

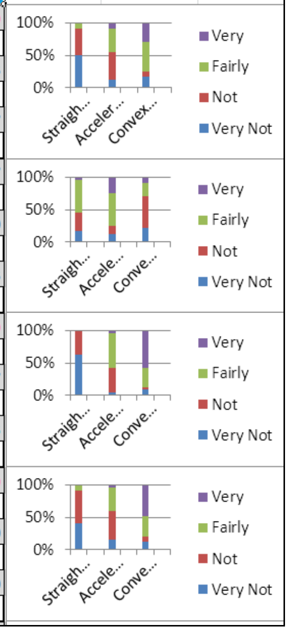


Fig. 3: A fragment of the MSExcel table summarizing the results of the first part of the survey.

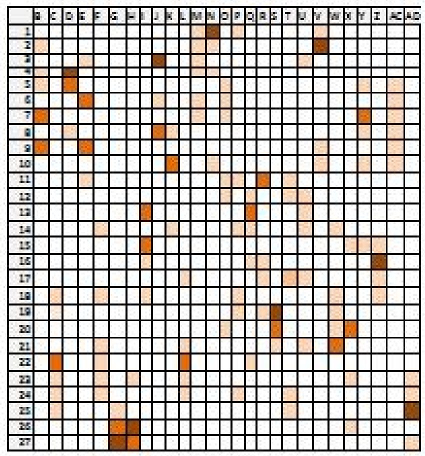
While all the interviewed persons had to select and rank the aesthetic property qualitative value for all the presented curves, we asked to each one to put the curves in descending order according to only one of the three analysed properties knowing that this activity may require some time.

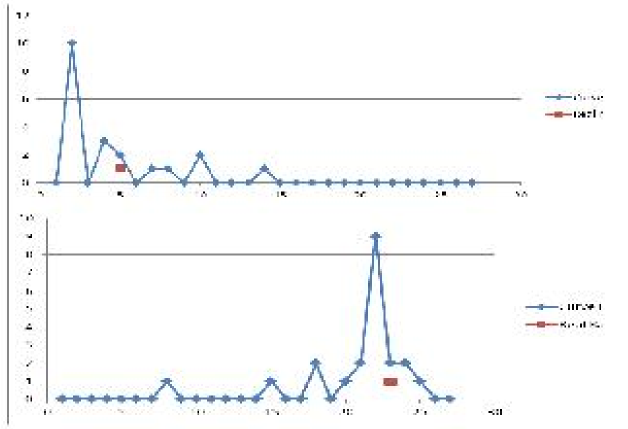
To verify how much the perception differs from the measured values for each curve, we compared the position indicated in the answers with those given by the implemented property modifiers. The results obtained indicate that the given ordering does not always coincide with the one provided by the measures (see Fig. 4.b and Fig. 5) , anyhow the answers tend to have acceptably consistent ordering This can be seen by looking at Fig. 4.a, where the position selected (rows) for each curve (columns) are indicated by the coloured boxes, the darker colour corresponds to more recurrences of the same position for the curve.

Fig. 5 shows a part of the excel table presenting all the ordering positions selected for each curve according to the straightness property, together with the standard deviation, their real positions and the difference between the medium value indicated and the real one.

Here we only report few tables and plot results, but similar differences are obtained for the convexity property, whereas for the acceleration property the difference between the ordering indicated and the one corresponding to the actual measures is more evident for several curves. In summary, the average difference between the real position and medium position is equal to 2 for straightness, 2,6 for convexity and rise to more than 6 for acceleration, where we have less concentration in the ordering position for the same curve.

The final part of the questionnaire was aimed at verifying the possibility to identify a widely recognised measures' threshold for switching the qualitative perception (from *Not very* to *Not*, from *Not* to *Fairly*, from *Fairly* to *Very*) of a specific property. In Fig.6 part of the answers obtained for the straightness property are shown. On the right, curves are depicted showing the selection distribution, the x-axis corresponds to the number of answers obtained, while the y-axis corresponds to the selected slide number. As we can see the range of the values are somehow contained in relatively limited interval. Thus, we are confident that some *fuzzy* threshold generally acceptable can be identified, probably close to the medium or to the barycentre value of the obtained answers. Further investigations with larger number of answers and curves are then needed to verify if the interval range can be reduced to thresholds generally acceptable.





(a) (b)

Fig 4: Ordering distribution for the curves according to the convexity property (a) and a visualiasation of the ordering distribution according to the straigthenss for two curves shown in Fig. 1 compared to the actual values (b).

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AC	AD	
	x	19	6	21	17	7	24	25	13	18	15	8	23	26	22	2	11	12	3	14	10	27	4	1	20	9	16	5	
	x	21	6	22	18	10	15	27	11	20	16	7	24	26	23	4	13	9	2	12	14	25	8	1	17	5	19	3	
	x	8	14	22	20	13	23	27	10	7	6	12	19	24	26	1	5	16	4	18	2	25	17	3	21	15	9	11	
	x	20	7	24	18	10	26	27	21	19	23	6	15	25	14	1	3	12	9	13	4	17	11	5	16	8	22	2	
	x	18	9	22	15	11	26	27	12	19	17	7	23	25	20	1	4	14	6	13	2	24	8	5	21	10	16	3	
	x	18	6	23	20	7	21	27	11	19	15	12	24	26	22	1	9	13	3	14	5	25	10	2	16	8	17	4	
	x	17	7	22	19	15	25	27	11	18	13	10	23	26	21	1	6	12	4	14	5	24	9	3	20	8	16	2	
	x																												
	x	18	5	22	15	4	25	24	13	14	17	7	23	26	21	9	12	8	2	16	10	27	11	1	20	6	19	3	
	x	19	10	21	13	18	17	27	12	20	16	11	22	26	23	1	3	8	5	15	2	25	7	6	24	9	14	4	
	x	19	11	23	13	12	14	27	16	20	17	9	24	26	21	1	5	10	7	15	2	25	6	3	22	8	18	4	
	x	14	8	20	26	11	18	27	15	16	13	9	23	21	22	1	6	12	3	17	4	25	7	2	24	10	19	5	
	x	15	4	22	11	10	14	16	18	12	21	1	6	19	3	2	5	26	23	17	7	9	13	25	8	24	20	27	
	x	20	7	22	17	6	27	25	12	21	13	8	18	24	16	1	3	11	5	14	2	23	10	4	15	9	19	26	
	x	19	9	22	15	12	16	27	13	20	18	8	23	26	24	1	7	10	6	14	4	25	5	3	21	11	17	2	
	x	21	13	18	17	14	26	27	16	22	12	4	25	19	24	5	9	6	3	15	8	20	10	1	23	7	11	2	
		11	24	8	4	21	15	27	16	12	17	22	7	13	6	1	3	19	26	18	2	9	23	25	10	20	5	14	
		17	4	24	13	3	16	27	6	11	21	5	14	23	25	7	8	12	1	20	10	26	9	2	15	19	22	18	
		8	25	18	5	24	23	27	7	16	9	22	19	26	21	1	3	13	11	15	2	20	10	12	17	14	6	4	
		16	4	15	10	5	25	27	18	17	19	3	9	22	26	1	8	20	7	23	2	21	13	6	11	12	14	24	
		16	8	25	15	7	26	27	13	17	22	6	19	24	18	1	3	12	5	14	2	23	10	11	20	9	21	4	
		15	10	22	12	11	19	26	13	21	17	8	23	24	20	1	3	5	6	14	2	25	7	27	18	9	16	4	
	x	15	4	22	11	10	14	16	18	12	21	1	6	19	3	2	5	26	23	17	7	9	13	25	8	24	20	27	
Minimum	x	8	4	8	4	3	14	16	6	7	6	1	6	13	3	1	3	5	1	12	2	9	4	1	8	5	5	2	
Maximum	x	21	4	25	26	24	27	27	21	22	23	22	25	26	26	9	13	26	26	23	14	27	23	27	24	24	22	27	
Standard Deviation	x	4	4	4	5	5	5	2	4	4	4	5	6	3	6	2	3	5	6	3	4	5	4	8	4	5	5	8	
Moyenne	x	17	9	21	15	11	21	26	13	17	16	9	19	24	20	2	6	12	7	15	5	22	10	7	18	11	16	8	
[redacted]																													
Real Rank	x	19	9	23	18	15	12	27	13	20	16	6	24	25	22	2	8	11	4	14	5	26	7	3	21	10	17	1	
Diference	x	2	0	2	3	4	9	1	0	3	0	3	5	1	2	0	2	1	3	1	0	4	3	4	3	1	1	7	2

Fig. 5: Table showing all the ordering positions indicated for each curve according to the straigthenss property.

Quelle est votre situation actuelle	Connaissez vous les courbes de Bézier, les B-Splines et les NURBS ?	passage de "très raide" à "assez raide"	passage de "assez raide" à "peu raid	passage de "peu raide" à "très peu raide"
Etudiant	J'en ai quelques souvenirs	8	21	32
Etudiant	J'en ai quelques souvenirs	10	21	55
Etudiant	J'en ai quelques souvenirs	10	38	72
Etudiant	Oui	8	22	45
Researcher		0	10	34
Researcher		2	8	12
Researcher		8	15	58
Researcher		5	10	55
Etudiant	J'en ai quelques souvenirs	1	5	50
Etudiant	Oui	5	34	54

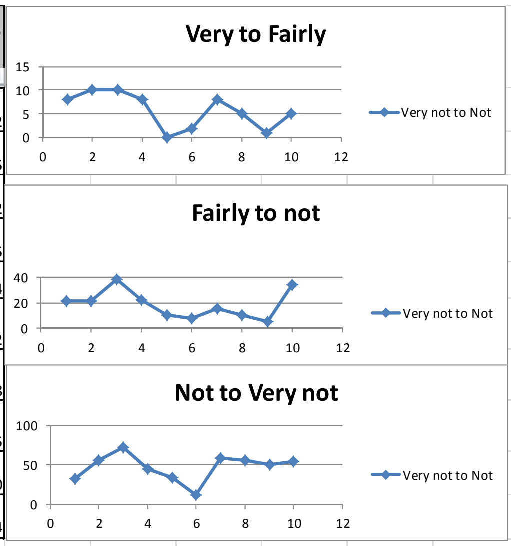


Fig. 6: visualization of part of the choices for the switch between two qualitative assessments of the straightness property.

5 CONCLUSIONS AND DISCUSSION

It is worth to notice that we got more answers from people who were asked to concentrate on Straightness and Acceleration. This can depends on several factors: these notions were new for the interviewed people and so they were interested in it, or simply the group of people chosen for answering on convexity was less reactive even if we tried to achieve a comparable sample of people. Moreover, since most of the contacted population are non-designer students, for them Convexity is a mathematical concept: "A curve is convex or not". This might have affected their judgement. Despite of this, the obtained results are more in accordance with the measures for straightness, then for convexity and finally for acceleration.

We can say that, depending on the curve shape characteristics, there is an acceptable consistency in the property comprehension and categorisation that can give us some opportunities to find common vocabularies for describing curves. In fact we classified the curves used according the presence of curvature inflections and of their symmetry with respect its medium axis. Then we analysed the closeness of the answers obtained with the results of the measures. From this analysis we can deduce that people have more problems in assessing curves symmetric with no inflection points and curve non symmetric with a single inflection point. On the contrary they have more facility in dealing with non-symmetric curves with no inflection points. This is a quite important result in the view of automatically splitting curves in pieces to be judged or described in terms of aesthetic properties.

The survey carried out demonstrates that while for convexity and straightness we can say that are correctly recognised properties, possibly because terms normally used, the same does not happen for acceleration, whose ranking is frequently different from the measures obtained.

Despite the promising outcomes of the presented survey, to have more definitive conclusions a larger number of interviews should be considered. Also the quality of the filled questionnaire should be improved. In fact, some of the received questionnaire were not fully completed, mainly in the curve ordering activity.

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