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Campus Helsingborg

Comparison between statistical and lower / upper approximations rough sets models for beer can design and prototype evaluation.

Ricardo Hirata Okamoto, M.Sc., (Ph. D. Candidate).
Keisen Consultores, rhirata@keisen.com, Norte 81 No. 163, col. Clavería, Mexico City 02080, Mexico.

Tatsuo Nishino, Ph.D.
Dept. of Kansei Design, Hiroshima International University, t-nishi@he.hirokoku-u.ac.jp, 555-36, Kurose-gakuendai, Higashi-Hiroshima 724-0695 Japan

Mitsuo Nagamachi, Ph.D.
User Science Institute, Kyushu University, nagmit@za3.so-net.ne.jp, 4-9-1,Siobara, Minami-ku, Fukuoka 815-8540 Japan.

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1. Introduction.

Rough sets theory was introduced as mathematical theory to handle uncertain or inconsistent data (Pawlak, 1998). Since it is superior in dealing with linearly inseparable data, it has been used to extract the decision rules in many application areas, and its effectiveness has been shown.

On the other hand, one of the core technologies in Kansei Engineering (KE) is to identify the relational rules between design elements of products and human evaluation data such as sense and feeling (Nagamachi, 1996). Rough set methods have been used to extract decision rules between human Kansei evaluation experimental data set and design elements (Nishino, 2001, 2003). The extracted rules would enable product designer to design the products fitted to the sense of human.

The purpose of this paper is to apply Rough Sets lower / upper approximations for the definition of decision rules for the design elements of beer cans and compare them to the results obtained through statistical analysis of same experimental data set. Data sets from 2 previous studies in Japan and Mexico were used (Hirata, 2004a, 2004b).

2. General procedure.

The general procedure for Kansei Engineering application and results in these beer can studies were:

1. Selection of a product domain.
2. Collection of Kansei Words.
3. Collection of product samples.
4. Evaluation of product samples vs. Kansei Words on previously designed SD (Semantic Differential) like scales.
5. Identification of the most representative Kansei Needs of the Market using Factor Analysis and Principal Component Analysis.
6. Identification of product´s item & categories.
7. Definition of design elements (decision rules) of the product for the satisfaction of Kansei need (response variable) using Regression Analysis methods for categorical data were conducted.
8. Identification of decision rules using Rough Sets lower / upper (Nishino Model) approximations were conducted.
9. Comparison of results.

3. Statistical analysis results.

To create a beer can design, we developed 2 independent studies (Mexico and Japan), collected 37 beer cans (worldwide), recruited 32 university students to evaluate the products using a 5 point SD Scale vs. 27 Kansei words representing various emotional and affective needs.

Most representative Kansei needs were obtained using Factor analysis and Principal Component Analysis, mapping factor loading of principal components (for example see fig. 1) as follows:

1. Lightness.
2. Appealing / Unique design = “Gorgeous”.
3. Attractive design = “Cool”.

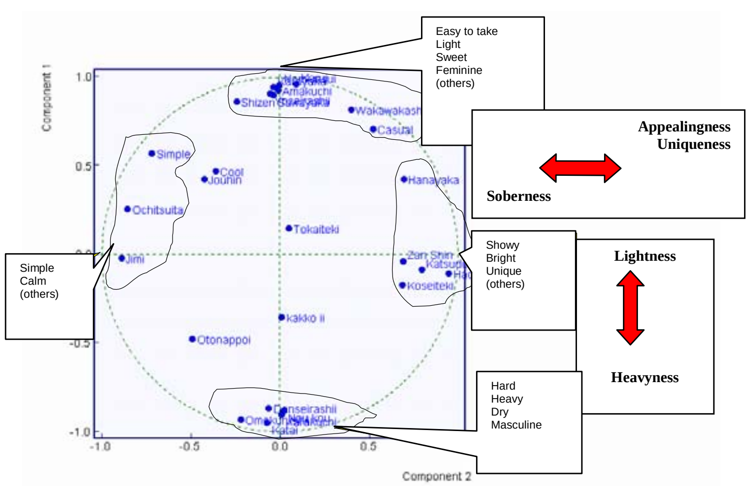

Fig. 1: Factor loading of principal components (example of component 1 “Lightness” and component 2 “Gorgeous”) – Hiroshima International University data.

Eight main items and their categories were defined as design elements:

1. Can color (9 colors).
2. Label main color (7 colors).
3. Brand letter color (6 colors).
4. Label brightness (2 types).
5. Can illustration (5 types).
6. Can texture (2 types).
7. Label Shape (3 types).
8. Information quantity (3 ranges of lines).

Our decision rules for 3 response variables such as: “Light”, “Gorgeous” and “Cool“, is as follows: (see tables I, II for “light” and “Cool design”):

Table. I: Design elements (decision rules) for “Light” (Hiroshima International University data).

For “Light”	For NOT “Light”
• A: White can and	• B: Dark can &
• K: Black label and	• M: Silver label &
• R: Black brand letter &	• S: Gold letter&
• b: Trad. Symbol &	• Z: Person figure &
• e: Lines texture &	• d: Solid texture &
• f: Oval label shape	• h: No label &
• i: Few lines	• m: Many lines

Table. II: Design elements for “Cool design” (Hiroshima International University)

For “Cool”	For NOT “Cool”
• D: Silver can &	• H: Green can
• L: Golden letter &	• W: Green letter
• B: Trad. Symbol &	• C: Modern sym.
• d: Solid texture &	• d: Lines texture
• m: Many lines	• i= Few lines.

These analyses propose design elements assuming they are all independent and that no correlation exists between them. Also, the analysis proposes the combination lf all items. So for “Light” design (see Table I), the proposed design elements would be: White can, with black label and black brand letter color, a traditional symbol and a lines textured can, as well as and an oval label shape and between 1 and 5 lines. On the opposite side, a NOT “Light” can would be proposed as: Dark can, Silver label, golden letter, person illustration, solid texture, no label and many lines.

4. Application of Rough Sets analysis.

Rough sets was used for the analysis of evaluated data in order to reduce item / category attributes, and to determine the "if-then" decision rules for the lower and upper (Nishino Model) approximation for the selected Kansei words responses such as, “Light”, “Gorgeous” and “Cool”.

We used same data set and assumed no ambiguity in human evaluations vs. one Kansei needs (if ambiguity and probabilistic properties of human evaluate is needed, see Nishino (5, 6)).

4.1.Lower approximation results.

We constructed data tables with 8 item and 35 categories relating them to categorized response variables, meaning "1 = Light can" and "0 = Not Light" values (see table III,) and "1=Cool can" and "0=not Cool" values (see Table V). Please refer to references (Pawlak, 1998, Nagamachi, 2005) about the theoretical side of the methods.

Table III. Data table of "Light" (Hiroshima International University)

Can No.	Can color	Label color	Brand letter	Label brightness	Can Illustration	Can Texture	Label shape	Info. Qty	Light response
1	C	O	T	W	Y	d	f	m	0
2	A	O	Q	W	Y	d	f	k	1
3	D	N	U	W	c	d	g	i	1
…	…	…	…	…	…	…	…	…	…
36	D	N	U	W	c	e	h	k	1
37	C	J	T	X	b	d	g	m	0

Lower approximation "if then" Decision rules for "Light" beer can, are now obtained as different combinations, for example (see table IV). Now consistent design elements for a "Light" can beer can be: White can & Red label OR White can & Oval Shinning label OR White brand letter & Red Shinning label OR a Silver can.

Table. IV: Lower Aprox. Decision rules "Light".

For "Light"	For NOT "Light"
• AO: White can & Red label OR • AfW: White can & Oval Shinning label OR • QWO: White brand letter & Red Shinning label OR • D: Silver can	• hkQ: No label shape & 6 to 10 info lines & white bran letters OR • hkd: No label shape & 6 to 10 info lines & solid texture OR • LQ: Golden label & White brand letters

On the other hand, a NOT "light" beer cans would be obtained with the following consistent combinations: No label shape & 6 to 10 info lines & white bran letters OR No label shape & 6 to 10 info lines & solid texture Golden label & White brand letters.

Comparing these results against the design elements obtained through statistical analysis (see table I) we find similar elements for "Light" such as "white can", "Oval shape", but other non similar as "Red label". The lower approach decision rules that define our objective are independent and are more reliable, because with statistical approaches, we assume all items are independent (no relation between items), but when designing a can, for example, the color of the letters of the brand are directly related to the can color itself (variables are highly inter related). Rough sets find the variables or combination of variables with higher frequency conditioned by the decision variable in the data table.

Table V. Data table of "Cool" (Hiroshima International University):

Can No.	Can color	Label color	Brand letter	Label brightness	Can Illustration	Can Texture	Label shape	Info. Qty	Cool response
1	C	O	T	W	Y	d	f	m	1
2	A	O	Q	W	Y	d	f	k	1
3	D	N	U	W	c	d	g	i	1
…	…	…	…	…	…	…	…	…	…
37	C	J	T	X	b	d	g	m	1

Lower approximation "if then" Decision rules for "cool" beer cans are:

Table. VI: Lower Aprox. Decision rules "cool cans".

For "Cool"	For NOT "Cool"
• WY: Shinny label & Animal illustration OR. • fY: Oval label & animal illustration OR • QY: White brand letter & animal illustration OR • N: Blue label.	• RiX: Black brand letter & few lines & Mate label OR • LX: Mate Golden label OR • bfA: Trad. Symbol & oval label & white can.

4.2.Upper approximation results.

Table. X: Upper Aprox. Decision rules "Light".

For "Light"	Certainty	Coverage
• RW: Black brand letter & shinning label.	0.7917	0.1230
• iXQ: Few lines, Mate label, White brand letter.	0.7422	0.1537
• XYh: White brand letter, Animal illustration, no label shape.	0.7396	0.1149
• iXh: Few lines, mate label, no label shape.	0.7396	0.1149
• Nh: Blue label, no label shape.	0.7396	0.1149
• iY: Few lines, animal illustration.	0.7375	0.1909
• gQ: Squared label, White brand letter	0.7292	0.1133
• Dd: Silver can, solid can texture.	0.7188	0.1117
• Di: Silver can, few lines.	0.7188	0.1117
• NX: Blue and Mate label.	0.6979	0.1084
• XYQ: Mate label, Animal illustration, White brand letter.	0.6979	0.1084
• Ab: White can, traditional symbol.	0.6953	0.1440
• Ai: White can, few lines.	0.6875	0.1068
• iQh: Few lines, white brand letter, no label shape.	0.6875	0.1068
For NOT "Light"	**Certainty**	**Coverage**
• B: Black / Dark can	0.8047	0.1820
• hkQ: no label shape, 6 to 10 lines, white brand letters	0.7917	0.1343
• hkd: no label shape, 6 to 10 lines, solid texture	0.7917	0.1343
• Kk: Black label, 6 to 10 lines.	0.7500	0.1272
• LQ: Gold label and white brand letter color.	0.7188	0.1219

Upper approximation contains all possible design elements and combinations which can possible belong to a set of solutions for the can design. Results are shown in tables VII, VIII ("Light", "cool"). Certainty meaning the reliability of the decision rule from the condition attributes to the Kansei need and Coverage meaning the reliability of the rule from the Kansei need to the condition attributes.

Interpretation is as follows:

- High certainty in first rule implicates that a "Black brand letter and shinning label" beer cans would affect "Light" Kansei. 79.2% of these cans are "Light".
- Coverage value in first rule implies that 12.3% of "Light" beer cans have an

RW design.

- High certainty and Lower coverage values as in third rule indicate more specific rules.
- On the opposite rules, black cans are not "light".

Table. VII: Upper Aprox. Decision rules "Cool".

For "Cool"	Certainty	Coverage
• YO: Animal illustration, Red label.	0.7604	0.1172
• fYQ: Oval label, animal illustration, white brand letter.	0.7500	0.1156
• WB: Shinny label, black or dark can	0.7396	0.1140
• WYQ: Shinny label, animal illustration, white brand letter.	0.7188	0.1477
• LQ: Gold label, white brand letter	0.7188	0.1108
• Yk: Animal illustration, 6 to 10 lines of info.	0.6823	0.2103
• NWd: Blue and shinny label, solid texture.	0.6771	0.1043
• YA: Animal illustration, white can	0.6688	0.1717
• Lh: Golden label, no label shape.	0.6563	0.1011
• Whd: Shinny label, no label shape, solid texture	0.6563	0.1011
For NOT "Cool"	Certainty	Coverage
• Ri: Black brand letter, few info lines.	0.6771	0.1159
• eW: lines texture, shinny label.	0.6563	0.1123
• QC: White brand letter, golden can	0.6354	0.1087
• RL: Black brand letter, golden label	0.6354	0.1087
• Xig: Mate label, few lines, squared label shape.	0.6042	0.1034

For the next Kansei, interpretation for "Cool" design, is as follows:

- Rule 3: 73.96.9% of Shinny Label and Dark cans are perceived as a "Cool" design. 11.44% of cool designs are Dark with shinny labels.
- On the opposite rule, 67.71% of Cans with Black brand letters and few lines are NOT Cool.

In Regression analysis we search for the effects of the explanation variables as the design parameters (design elements), in Rough Sets we find variables or combinations of variables with higher frequency vs. decision variable in the data tables (decision table). So, certainty and coverage are both frequency measures.

Differences are found between statistically obtained design elements, and rough sets "if then rules". We assume this is the result of interaction between variables and in consequence, Rough Sets approach is more reliable.

Further steps include the evaluation by design staff (experts) and by a panel or market segment comparing the prototypes derived from both approaches to validate our results.

5. CONCLUSIONS.

Kansei Engineering is open to new tools and models to translate more accurately the Kansei needs of a market in order to generate new products more efficiently.

Rough set method enables to derive more specific decision rules than traditional use of statistical regression analysis method in Kansei engineering, resulting in better approaches to the definition of design elements and its combinations.

Using Rough Sets Approach, leads also to variable design rules in one same market, which opens a new challenge and future research by using Kansei Engineering for a more detailed stratification of an already market segment we treat as homogeneous.

When analyzing data, we assume the existence of a lower approximation, which is not always true. So, the proposed method by T. Nishino (Nishino, 2004, 2005) could be suggested. Also, when interaction between explanation variables (design elements) does not exist, Lower Approximation results from Rough Sets are usually the same as the results obtained by statistical approach.

Further study is needed to validate all approaches results with design staff, and the construction of prototypes to be tested within a panel or evaluation group.

The present comparison assumes no ambiguity in human evaluation so next step is to analyze this data accepting significant differences between people (participants in a survey for instance) that affect overall evaluations, as well as to test prototypes in the market to understand the impact of the design rules, in stratified market segments.

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