Paint Appearance - Perception, - Acceptance and Preference
What’s common?

Source: NASA, South polar region of Epimetheus Saturn moon photographed on 12.03.2007 by Cassini
Objective of the experiment

► Development of a perception based structure space.

► Fitting the coordinates by Wave-Scan values.

► Estimation of limits for structure harmony.

► Analyzing the preference behavior.
Sample Selection

► Complete pair test.
► Reasonable number of assessable pairs is 190.
► How to select 20 representative panels out of 101 different structure panels?
► We used Principle Component Analysis to select representative panels.

Importance of components:

<table>
<thead>
<tr>
<th></th>
<th>PC1</th>
<th>PC2</th>
<th>PC3</th>
<th>PC4</th>
<th>PC5</th>
<th>PC6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard deviation</td>
<td>15.24</td>
<td>7.00</td>
<td>2.94</td>
<td>2.31</td>
<td>1.73</td>
<td>1.10</td>
</tr>
<tr>
<td>Proportion of Variance</td>
<td>0.78</td>
<td>0.16</td>
<td>0.03</td>
<td>0.02</td>
<td>0.01</td>
<td>0.00</td>
</tr>
<tr>
<td>Cumulative Proportion</td>
<td>0.78</td>
<td>0.94</td>
<td>0.97</td>
<td>0.99</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>
Structure Spektra of selected Samples

<table>
<thead>
<tr>
<th>du</th>
<th>&lt; 0.1mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wa</td>
<td>0.1 – 0.3 mm</td>
</tr>
<tr>
<td>Wb</td>
<td>0.3 – 1.0 mm</td>
</tr>
<tr>
<td>Wc</td>
<td>1.0 – 3.0 mm</td>
</tr>
<tr>
<td>Wd</td>
<td>3.0 – 10 mm</td>
</tr>
<tr>
<td>We</td>
<td>10 – 30 mm</td>
</tr>
</tbody>
</table>

| SW     | 0.3 – 1.2 mm |
| LW     | 1.2 – 12 mm  |

![Graph showing structure spectra of selected samples](image-url)
Viewing Conditions

► Single fluorescent lamp.

► Triple reflection due to reflector.

► Viewing distance approximately control distance of cars.

► 43 test persons in total.
Assessment Tasks

► Rate the resemblance of the two structure on a scale of 0 to 10.
   0 = no difference,
   10 = no resemblance.

► Would you accept the presented difference between two adjacent car parts?

► Which structure do you prefer?
Multidimensional Scaling

We used MDS to unfold the perception space from the estimated distances of the 190 pairs. Doing this an equidistant space is to be obtained.

To link the perception space to physical parameters, we used linear regression to combine the perception coordinates with the Wave-Scan values.

If MDS is applied on city distances the coordinates of the cites can be reconstructed.
Results
Perceptional Structure Space
Structure Space of the Average Test Person

Very good fit of dimension 2.  
$R^2 = 0.97$

Poor fit of dimension 1.  
$R^2 = 0.66$

Diagnostic graphs show curiosities.


- No homogeneous reconstruction for all panels. #60 and #51 unusual.
Looking for Group Effects

Applying a cluster analysis on the scoring of the test persons yields two groups.

S1 - linear rating
S2 - non linear rating

Ward linkage
Perception Spaces of Group $S_1$ and $S_2$
Structure Characteristic M-Type And A-Type

![Graph showing the comparison between M-Type and A-Type structures over time (du, Wa, Wb, Wc, WD, We).]
Perception Space $S_1$ and Property Fitting

\[ D_2 = a_2 W_a + a_5 W_d - a_1 du - a_6 W_e + a_0 \]

\[ D_1 = b_4 W_c + b_6 W_e - b_1 du - b_5 W_d + b_0 \]
Perception Space $S_2$ and Property Fitting

\[ D_2 = a_2 \, W_a + a_5 \, W_d - a_3 \, W_b - a_6 \, W_e + a_0 \]

\[ D_1 = b_1 \, d_u + b_4 \, W_c - b_2 \, W_a - b_5 \, W_d + b_0 \]
Summary Perception Space

► The structure perception is different to all known transformations.
  ► The dimensions are:
    Total waviness
    Structure characteristic

► The new structure space can be described by Wave-Scan values du, Wa…We.

► A description by balance and waviness was not significant!

► Even distance rating is highly subjective!
  ► Part of the test persons score small differences more severe than bigger ones.
  ► Another part of the test persons score homogeneous.
Structure Harmony Acceptance
Structure Harmony Tolerance

Harmony Acceptance G1

Harmony Acceptance G2

configuration distance
fitted space

configuration distance
fitted space
Example: Harmony Tolerances for Independent Processes

Configuration Space incl. Harmony Acceptance for Group 2

Example: Structure Space $S_2$

Only structure differences within a circle would be accepted between adjoining parts.
Summary

► Based on the new structure space it is easy to specify tolerances for adjacent car parts.

► The assessment showed that the tolerances are much smaller than tolerances established at the moment.

► This would imply the necessity of specifying a reference structures similar to color references.
Structure Preference
Example: Different Preference of Test Persons
Preference Groups
Preference

- Persons of group 3 prefer smooth surfaces with a high DOI and therefore with low shortwaviness.

- Persons of group 2 are the counterpart of group 3. They detest visible longwaviness and accept high amounts of shore waviness. Even a certain dullness is accepted as.

- Group 1 is somewhere in between the two groups. The test persons prefer harmonic structures without much dominance of either longwave or shortwave. Up to a certain degree they accept some shortwaviness and are therefore closer related to group 2 than to group 1.

- All groups have one thing in common: the smoother the surface the higher the preference.

- The preference only shows up if the total waviness is approximately the same.

- The preference probability for every group can be calculated with high accuracy using the Wave-Scan values du, Wa...We.
Preference and Production Monitoring
Example: 2 different paint lines – horizontal parts

The figure show the preference probability for the 3 group of every measured horizontal part.
Preference and Production Monitoring
Example: 2 different paint lines – vertical parts

The figure show the preference probability for the 3 group of every measured vertical part
Preference Probability and Perception Space

Group 1

Group 2

Group 3
Summary

- 3 different structure preference types:
  - Smooth structures with high DOI (G₃) (~10%).
  - Visually smooth, but high shortwaviness (G₂) (~50%).
  - Harmonic structures - not too dull yet no obvious longwaviness (G₁) (~40%).

- For parts of the test persons the claim Wb helps to hide longwaviness is proven.

- All preference type can be described by Wave-Scan values

- All types have one in common: the less the waviness the better the structure is rated! In case of similar waviness the preference decides.
Thank you.