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Measurement of the perceived quality of a product

Characterization of aesthetic anomalies

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Abstract. For some companies, visual inspection has become an essential step when seeking to improve the quality of their products. The aim of this control is to be sure of the perceived quality of the product, which often goes well beyond the quality expected by the customer. For this type of control, the controller should be able to detect any anomaly on a product, characterize this anomaly, and then evaluate it in order to decide if the product should be accepted or rejected. This paper describes how this characterization can be carried out and, more specifically, how to measure the impact of the local environment of an anomaly on the perceived quality of the product.

Keywords: Perceived quality; visual inspection; anomaly; sensory profile; Gestalt

1 Introduction

The quality of a product is generally defined as the ability to meet the customer's expectations. Today, this interpretation is widely accepted and sums up the progress made over the years in the field of quality. The question now is to know what we mean by the expression "*customer expectations*". Here again, on this issue, we are dealing with the evolution of the concept of quality. These expectations have, for a long time, been focused on the key features of the product. Now, the customer also includes other expectations in his/her perception such as, for example, products which include more features than the basic model, offer access to a set of services available after the acquisition of the product and/or are perfect in appearance. The challenge for a company is now to move from looking to obtain the expected level of quality of a given product to the perceived quality of the product. A perceived quality is more difficult to evaluate because it is measured by sensory assessments of the customer.

In this context, the control of the appearance of the product plays a crucial role. This is already the case for companies whose products are meant to respect both technical and aesthetic qualities, such as luxury goods companies for example [1]. However, it is more unusual and a newer concept for other companies. Some customers of NTN/SNR for example expect that the bearing they buy meets the technical specifications defined, but that it also seems "beautiful". These customers indeed consider that the perfect appearance of a product is a guarantee of a perfect, high-quality end product.

However, looking for the perceived quality presents serious problems. Unlike expected quality which can be evaluated, at least in part, on objective criteria, perceived quality is mostly evaluated on very subjective criteria. The objectives of our research, which is part of the INTERREG IV[1] research program, are to define how to assess the perceived quality of a product better.

This paper focuses more specifically on how an anomaly on a product is perceived by a controller because this perception has an impact on the final decision he takes (the product should be refused vs. the product can be accepted).

Firstly, we show that the companies sometimes have serious difficulties carrying out the visual inspection of their products. We then describe what types of anomalies can be detected during this control. To assess the impact of a defect on the perceived quality of the product, we then detail how the controller can characterize any abnormality in appearance by using a set of generic attributes. Among these attributes, those reflecting the impact of the immediate environment of the anomaly on the perceived quality of the product is usually the most difficult to characterize. In this paper, we show how the Gestalt laws of grouping can assist the controller in characterizing this impact.

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[1] INTERREG IV program aims to define a methodology for the measurement of the quality appearance of high values products by taking account the subjective aspects of the human judgment. This project brings together industrial Swiss and French companies, the *Centre Technique du DECcolletage* (CTDEC), the *Centre Technique de l'HORlogerie et de la joallerie* (CETEHOR), the SYMME lab (*Université de Savoie*) and the LPM lab (*École Polytechnique Féderale de Lausanne*).

Table 1. R & R test on a visual inspection.

	Ctrl A		Ctrl B		Ctrl C		Experts
Part No.	M1	M2	M1	M2	M1	M2	Exact value
1	C	C	NC	NC	NC	NC	C
2	C	NC	NC	C	C	C	C
3	C	NC	C	NC	C	NC	C
4	C	NC	C	C	C	C	C
5	C	NC	NC	NC	NC	C	C
6	C	NC	C	C	NC	C	C
7	C	C	C	NC	C	NC	C
8	C	C	NC	NC	C	C	C
9	C	NC	C	C	NC	C	C
10	C	C	NC	C	C	C	C
11	C	C	C	C	C	C	C
12	NC	NC	C	C	NC	C	NC
13	C	C	C	C	NC	C	C
14	C	C	NC	NC	C	C	C
15	NC	NC	C	C	C	C	C
16	C	C	NC	NC	C	C	C
17	NC	NC	NC	C	C	C	C
18	C	C	C	C	C	C	C
19	NC	NC	NC	NC	C	C	C
20	NC	NC	C	NC	NC	NC	C
21	C	NC	NC	NC	NC	C	C
22	C	C	C	C	C	C	C
23	NC	NC	C	C	C	C	C
24	C	C	C	C	NC	C	C
25	C	C	NC	NC	NC	C	C
26	C	NC	C	C	NC	C	C
27	C	C	NC	NC	NC	C	NC
28	C	NC	NC	NC	C	C	C
29	NC	NC	C	C	C	C	C
30	NC	NC	C	C	C	NC	C

2 Visual inspection

Visual inspection is more often than not done manually because of the absence of any automated equipment to detect and to assess all anomalies which can occur on the surface of a product. This part of a production process is not problem-free. For example, Table 1 presents the data of a repeatability and reproducibility (R & R) gage test on a visual inspection carried out by experienced controllers in a famous watchmaking company.

This R & R test was done on 30 components. Three controllers (A, B and C) controlled these components two non-consecutive times. Their results (Compliant or Non-Compliant) were compared with the expected results, these having been provided by a group of experts in quality in the company (in the Exact value column).

For the experts, only two components were non-compliant (No. 12 and No. 27). None of the 30 components was found compliant by all three controllers (for example, component No. 20, judged as compliant by experts, was judged five times as being non-compliant by the three controllers).

These poor results may result from a problem related to detection. This is the case, for example, of controller A who judged component No. 27 as compliant because he did not have sufficient information about the anomaly on the product.

Fig. 1. A deviation from a reference.

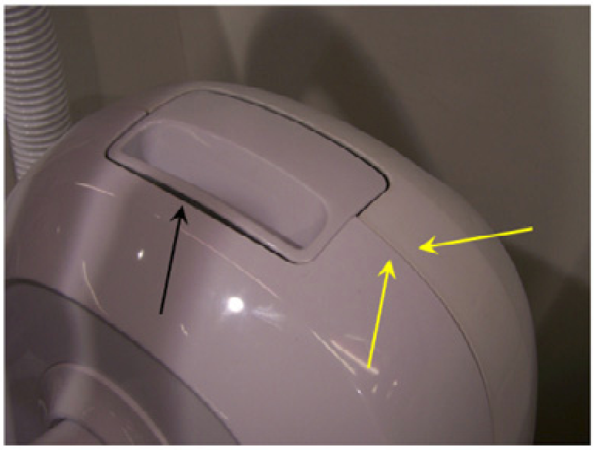


Fig. 2. A deviation from the intent of the designer [3].

The assessment of an anomaly can also cause problems. For example, controller B considered that the anomaly on component No. 25 should lead him to refuse the product. However, the experts judged the component as compliant since they considered that the anomaly would have an insignificant impact on the customer's perception of the product.

3 Aesthetic anomalies

Achieving perceived quality could mean obtaining a product with no anomalies. In reality, an anomaly-free surface does not exist since, at a given level of magnification, the controller will always detect some kind of deviation from the ideal surface [2]. This deviation is a difference in relief, in color, in shape and/or in contrast.

We consider that three types of deviation can be perceived by a controller:

- A deviation from a reference (an "ideal" product) taking the form of a difference of color, texture or contrast compared to what is expected and to what was previously defined by the company (Fig. 1).
- A deviation from the intent of the designer: a difference in the color of the part compared to the parts of the product adjacent to it (Fig. 2).
- A local deviation: the presence of a scratch, a spot, etc., on the product (Fig. 3).

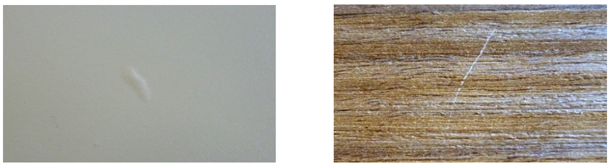


Fig. 3. Local deviation.

When a local deviation is detected, several types of aesthetic anomalies, such as a scratch, can be identified. However, the controller can also identify a "scrape", a "streak" or even a "score" that are quite similar to the 'scratch' but which have specific physical features. Guerra [4] has shown the importance of reducing the vocabulary used to describe aesthetic anomalies during a visual inspection. We therefore propose that any anomaly should be qualified by one of the four types of anomalies representative of all anomalies that may occur on the surface of any type of product:

- "*Mark*": something that damages the surface, a break in the form (scratches, scuffs, dent, etc.).
- "*Heterogeneity*": anything that will make the product lose its homogeneity (for example, a stain, a difference in colour and/or texture, etc.).
- "*Pollution*": anything that is added to a surface and which is considered undesirable (a hair, dust, a particle, etc.).
- "*Distortion*": anything that changes the shape of the surface (an overly-polished surface, an irregular line of light, etc.).

Choosing a qualification structure of any aesthetic anomaly reduced to one of the four defined types allows one to significantly decrease the detection issues, as described above, concerning the knowledge that controllers must have about what has to be detected.

4 Characterization of the impact of an aesthetic anomaly

4.1 Aesthetic anomaly attributes

Firstly, the anomaly is detected, and then qualified (according to its type: "Mark", "Heterogeneity", "Pollution" or "Distortion"); it must then be characterized.

Based on what is done in sensory analysis [4], we propose that this characterization be established by creating a sensory profile of the anomaly.

As we said previously, the attributes to use to establish this profile should clearly show the impact of the anomaly on the perceived quality. They must also meet a number of conditions, two of which are to help provide a relevant description of the anomaly and to enable one to evaluate the anomaly using a scale of intensity. They must also be accurate (easily understood by controllers), discriminative (allowing one to differentiate between anomalies) and independent from each other. Each attribute must describe a particular characteristic of the anomaly [5]. Finally, they must ideally be generic enough to be used to characterize any type of aesthetic anomaly on any type of product.

Table 2. Aesthetic anomaly attributes.

		Attributes
Factual description of the anomaly	Viewing conditions	Distance Orientation Light intensity Duration Direction
	Characteristics anomaly	Size Shape
Perspective of the anomaly	Context	Local impact Overall impact

Table 2 shows the list of the attributes that we propose for the characterization of any aesthetic anomaly. We have separated them into two groups, this distinction reflecting the manner in which the controller explores the product to characterize an anomaly that he has detected. Initially, he focuses his attention on the anomaly itself, and then considers the anomaly in relation to its local and global environment.

The viewing conditions include five attributes:

- "*Distance*" characterizes the distance required to perceive the anomaly (for example, the anomaly is only seen at a distance of less than 30 cm).
- "*Orientation*" characterizes the number of angular movements to be carried out to see the anomaly (for example, the anomaly is seen from all angles).
- "*Light intensity*" characterizes the intensity required so as to see the anomaly (for example, the anomaly is perfectly seen with less than 200 lx).
- "*Duration*" characterizes the time required to see the anomaly (for example, the anomaly is seen immediately at the beginning of exploration stage).
- "*Direction*" characterizes the direction in which the anomaly can be seen (for example, the anomaly is perceived when the product is oriented vertically).

The characteristics of the anomaly include two attributes:

- The "*Size*" attribute characterizes the size of the anomaly (e.g. the width of the anomaly makes it perfectly perceptible).
- The "S*hape*" attribute characterizes the shape of the anomaly (e.g. the regularity of the anomaly makes it hardly noticeable).

The perspective on the anomaly includes two attributes:

- The "*Local impact*" attribute characterizes how the anomaly is hidden or, on the other hand, is obviously present in its local environment (e.g. the round shape of the anomaly makes it very perceptible because it is completely the opposite to the horizontal lines of the decor in which it appears).
- The "*Global Impact*" attribute characterizes the impact of the position of the anomaly on the product in terms of the overall perception (for example, the anomaly is easily seen because it is on a visible part of the product).

Table 3. The possible attribute values.

Value	Distance	Orientation	Local impact
1	Visible using a binocular		Very difficult to perceived because it is "completely hidden by the decor"
2	Visible to the naked eye	Perceived under only one light effect	Difficult to perceive because it is "hidden in the decor"
3	Closely visible	Perceived under two light effects	Perceived because it is "isolated but in keeping with the decor"
4	Visible at arm's length	Perceived under three light effects	Easily perceived because it is NOT in keeping with the decor
5	Visible from a distance		Very easily perceived because it is "obvious for the observer"

4.2 The possible attribute values

To characterize an anomaly, the inspector must give an intensity value for each attribute. He must have a written standard that sets out all the possible values for each attribute and describes the method of awarding these values. Table 3 shows an example of a standard giving the possible values (on a scale of 1 to 5) for the three attributes "*Distance*", "*Orientation*" and "*Local impact*".

5 Characterization of the impact of an anomaly

However, the use of this standard poses some problems. This was noted in one of the companies with whom we collaborated during the INTERREG IV research program. If, on the one hand, an inspector can easily manage the evaluation of certain attributes ("Distance" or "Orientation" for example), on the other hand, he experiences more difficulties when it comes to evaluating the "local impact" attribute.

This attribute is used to characterize the impact of the anomaly on the perceived quality according to the local environment in which it appears. Figure 4 illustrates the different possible situations (same anomaly and/or same close environment). Thus, the same anomaly (a scratch of the same length, width and depth) does not have the same impact on the perceived quality depending on the local environment (strong impact in Fig. 4a, low impact in Fig. 4b). In the same decor (vertical lines), the two different anomalies (a vertical scratch and a scratch at an angle) will not have the same impact on the perceived quality (low impact in Fig. 4c and a strong one in Fig. 4d).

However, the characterization of this impact is not always so obvious. This was noted in one of the companies involved in the research program. How, for example, by using the description given in Table 3, can the inspector conclude that an anomaly is "hidden in the decor" or "betrayed the spirit of the decor"?

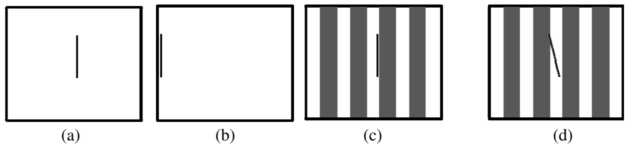


Fig. 4. Impact of an anomaly on the perceived quality [6].

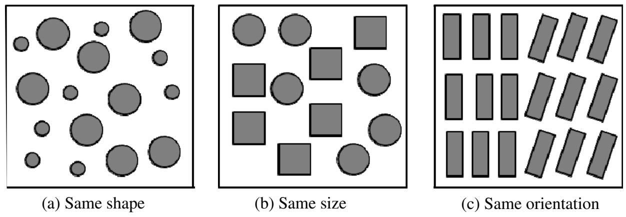


Fig. 5. Law of similarity.

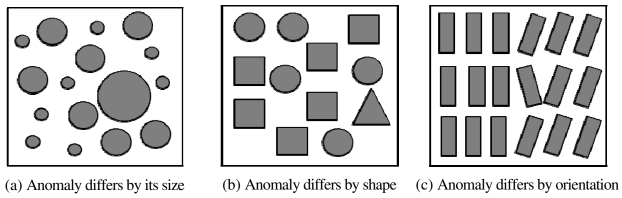


Fig. 6. An anomaly in the case of similar objects.

We can see here how the four main Gestalt laws [6] can give him some answers and how these laws can help him to assign a value to this attribute.

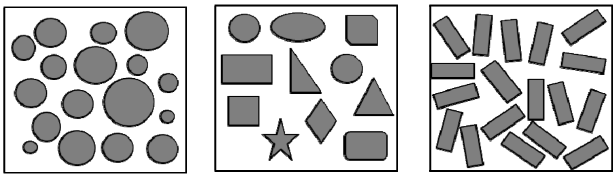
5.1 Law of similarity

When several objects are similar on the area of the part being evaluated, the observer groups them together into one object based on physical attributes (color, shape, orientation, etc.). For example, in Figure 5, the observer does not perceive a number of objects equal to the number of present shapes, but perceives two types of objects (large and small circles, squares and circles, and vertical rectangles and inclined rectangles, respectively).

Applied to visual inspection, this law leads to the conclusion that in the presence of similar objects, an anomaly is easily perceived if it differs from these objects by a particular physical attribute (size, shape or orientation). This is shown in Figure 6 where the anomaly is quickly perceived by an inspector among similar objects (the large circle, triangle and rectangle tilted 15° to the left, respectively).

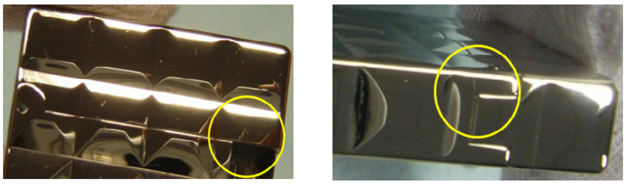
On the other hand, in the presence of non-similar objects, the anomaly is hardly perceptible. This is shown in Figure 7, in which the same anomalies as those in Figure 5 are presented. This time, they are more difficult to perceive.

When applied, this law provides guidance on the value to give to the "Impact" attribute. The impact of an



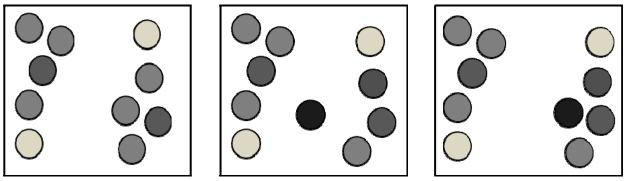
(a) Size (b) Shape (c) Orientation

Fig. 7. An anomaly in the case of non-similar objects.



(a) High impact (b) Low impact

Fig. 8. Law of similarity: anomaly impact.



(a) (b) (c)

Fig. 9. Law of proximity.

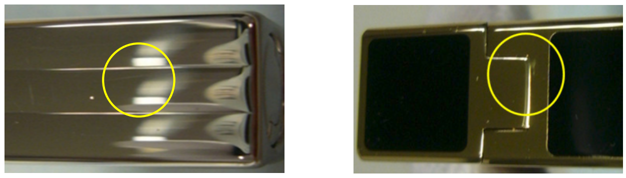
anomaly will be even higher, i.e. it will be more easily perceptible, if it is distinguished from the similar objects that surround it. It is also much lower, i.e. it is less easily perceived, if the objects that surround it are not similar. Figure 8 shows an example of an anomaly whose impact is high (a different orientation from similarly oriented forms) and an example of an anomaly whose impact is low (line among other identical lines).

5.2 Law of proximity

When several objects are close to each other on the area of the part being evaluated, the observer groups them into a single structure. In Figure 9a for example, the observer does not see ten objects, but two objects, each consisting of five circles.

If an anomaly is present (e.g. the black circle in Fig. 9), it is more noticeable when it is further away from other objects around it (Fig. 9b) than when it is close (Fig. 9c).

This law leads to the conclusion that the impact of an anomaly will be even higher if it is further away from the surrounding objects (and even lower if it is close to surrounding objects). Figure 10 shows an example of an anomaly whose impact is high (a dent isolated from other shapes) and an example of an anomaly whose impact is low (a scratch close to other lines).



(a) High Impact (a) Low Impact

Fig. 10. Law of proximity: anomaly impact.

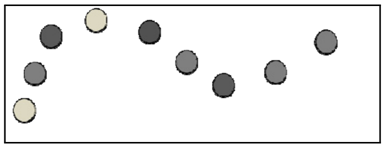
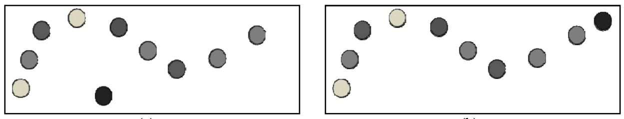
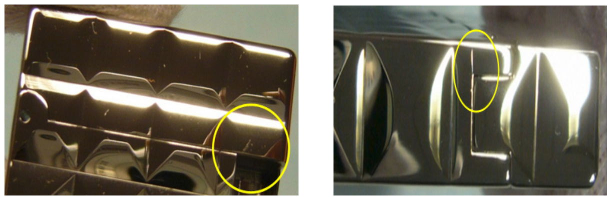


Fig. 11. Law of continuity.



(a) (b)

Fig. 12. Law of continuity: anomaly impact.



(a) High Impact (a) Low Impact

Fig. 13. Law of continuity: example of the impact of the anomaly.

5.3 Law of continuity

When the shapes are located on the same geometrical line on the area of the part being evaluated, they are grouped into a single structure. For example, in Figure 11, the observer perceives not nine objects, but a single object, formed by the alignment of the circles.

If an anomaly is present (the black circle in Fig. 12), it is more perceptible when it is further away from a line formed from other objects (Fig. 12a) than when it is in the continuity of this line (Fig. 12b).

This law leads to the conclusion that the impact of an anomaly will be lower if it is in the continuity of a geometric line formed by the other objects that surround it. Figure 13 shows an example of an anomaly, whose impact is high (a scratch that is not located in the continuity of the horizontal line) and an example of an anomaly, whose impact is low (one scratch in the continuity of another line).

5.4 Law of closure

When a geometric shape is not complete on the area of the part being evaluated, the observer tends to close it. In

Table 4. "Local impact" attribute and Gestalt laws.

	Gestalt laws		
Impact value	Similarity and proximity	Continuity	Closure
1 (very low)	Anomaly is completely hidden by surrounding objects		
2 (low)	Anomaly is similar to surrounding objects and close to these objects	Anomaly is perfectly located in the continuity of the line of other objects	The anomaly closes the geometric shape
3 (quite strong)	Anomaly is similar to surrounding objects but it is further away from these objects	Anomaly is partially located in the continuity of the line of other objects	
4 (strong)	Anomaly is not similar to surrounding objects and close to these objects	Anomaly is not located in the continuity of the line of other objects	
5 (very strong)	Anomaly is further away from the surrounding objects and is not similar to the surrounding objects		

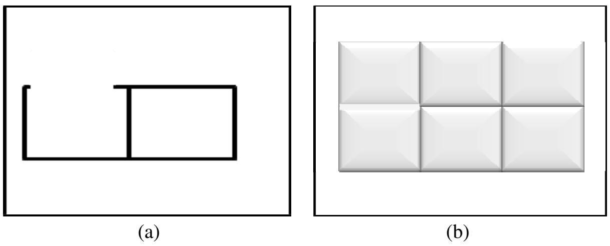


Fig. 14. Law of closure.

Fig. 15. Law of closure: impact of an anomaly.

Figure 14a for example, the observer perceives two rectangles, even though the left rectangle is not completely closed.

In the visual inspection, an anomaly resulting from an incomplete form will go unnoticed more easily. In Figure 14b for example, the two anomalies (an insufficiently clear outline on two squares on the left and on the absent contour on the upper right square) are hardly noticeable, and the inspector will perceive two squares on the left and a square on the right.

The law of closure leads to the conclusion that the impact of an anomaly is low if its geometric shape is almost complete. Figure 15 shows an example of this type of anomaly (the anomaly closes the shape of the hinge).

Gestalt laws can help the inspector to characterize the local impact of the anomaly in terms of its immediate environment. The law of similarity and the law of proximity are applied in all situations simultaneously. The law of continuity and the law of closure may or may not apply depending on the situation.

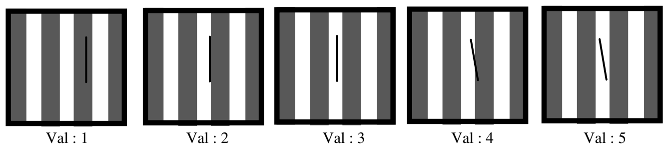


Fig. 16. Value for the "local impact" attribute – law of similarity and law of closure.

Table 4 illustrates how the written standard may include these laws. For example, if an anomaly is distinct from other objects that are very similar to each other, and it is located further away from them, a value of 5 will be given to its local impact.

Figure 16 shows some examples of possible situations where the laws of continuity and closure do not apply.

Figure 17 shows examples of products corresponding to the five situations in Figure 16.

The anomaly being characterized (i.e. a value has been given for each attribute) can then be evaluated. The calculation of the overall intensity of the anomaly is made using

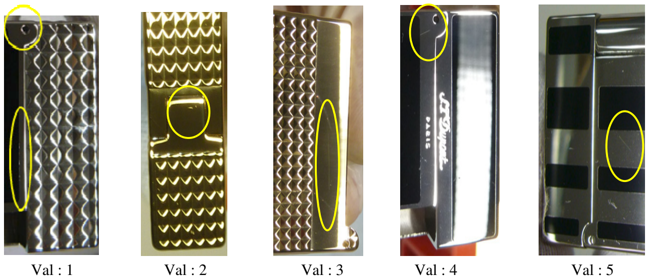


Fig. 17. Examples of value for the attribute "local impact".

all of the values the inspector gives to the attributes. This calculation is generally expressed as a weighted sum of these values. In cases where no linear relationship can be established between the values of attributes and the overall intensity of the anomaly, the neural network can be used to model this relationship. This approach is detailed in reference [8].

6 Conclusion

In order to reduce the variability of the results of visual inspection, we listed which attributes can be used to characterize an anomaly. During its visual inspection, a controller carries out this characterization by giving values to the attributes of the factual description of the anomaly he has detected (attributes "*Distance*", "*Orientation*", "*Light intensity*", "*Duration*", "*Detection*", "*Size*" and "*Shape*") and by giving values to the attributes of the perspective on the anomaly ("*Local impact*" and "*Global impact*"). We have noticed than a controller have sometimes difficulties to evaluate the "*Local impact*" attribute. As we have shown, the four main Gestalt laws (similarity, proximity, continuity and closure laws) can help him to assign values to this attribute. We have also illustrated how a written standard for visual inspection may include these laws.

Our approach has been applied in companies which are part of the INTERREG IV program. The preliminary results seem to confirm a significant reduction in the variability of the visual inspection results observed up to now.

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