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COMPUTER AIDED GENERATIVE DESIGN OF AUTOMOTIVE SHAPED COMPONENTS

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Abstract: *Generative design as a new method of product development and innovation has become very important in the automotive industry at present. The reason for the introduction of this method into the process of development tasks solution is simple. This approach to car innovation leads to a reduction in the time spent developing prototypes. CAD software allows an approximate design to be used initially, with the ability to make subsequent changes to the aerodynamic properties and other attributes, according to the market needs. When the shape of a car is complete, styling is not closed and can be modified until the time of the final design confirmation. Now that the most important features are no longer just safety and driveability, the car's design and its saleability have become equally essential facets of the overall design process. The underlying assumption for innovation in this field is simplicity, and especially time–saving, during the development of the prototype. Since the early days of using intelligent design systems, opportunities for automotive design have expanded far beyond the boundaries of austere block shapes. These only made use of radiuses in the bending areas that were purely functional. By contrast one of the most important goals of modern car design is the shape of reflection lines. It is necessary to generate gentle and smooth curves of the car body which, under lighting, will catch the eye. Other goals include the drag coefficient, aerodynamic sound, and passive safety. Depending on the complexity of the body shell, it is possible to describe this shape by using more or fewer mathematical formulas. All these formulas are included in the special algorithm which controls the whole process. In this way, constraints can finally be generated automatically.*
Keywords: *CAD, Generative design method, Cloud of points*

INTRODUCTION

Even though they may appear similar, the fundamentals of generative design are in principle not the same as parametrical modelling. Parametric models are numerically controlled representations of design solutions which result in a new product with similar geometrical values (quantity indicators such as dimensions, weight etc.) but dissimilar in quality (e.g. aesthetic indicators, subjective user requirements, and needs). This means that generative design in new product development and innovation offers more than a geometric model. It offers the whole complex of information about a new product which has not only a deterministic, but also heuristic nature.

Practical application of generative design is part of the private policy of automotive companies. Even though it is so beneficial, they do not use it much in practice. The important role of this method is based on its time saving opportunities. A few years back it took about 4 to 5 years to start a new model production. If designers use generative developing of a new prototype, it will cut the development time to 1 to 2 years. The most important step is to reduce the routine phase during that process but also to improve the quality of the final result.

ESSENTIALS OF GENERATIVE DESIGN

The basic scheme of the generative design process is shown on Figure 1. It shows the cooperation during the prototype development.

In the first level of the development process there is just the designer, who has to make the initial design. When the draft of the shape is done, engineers start to invent the functional elements. These are in interference with all the exterior surfaces. The clay model can be checked for its aerodynamic properties, passive safety, and so on. After that, the surface is scanned by the 3D *scanning device. The output is an ASCII text file with coordinate points. A special algorithm selects, filters, and orders the points. The cloud of points is interpolated by a mesh which can be transformed into a surface. This process can be seen in Figure 2.*

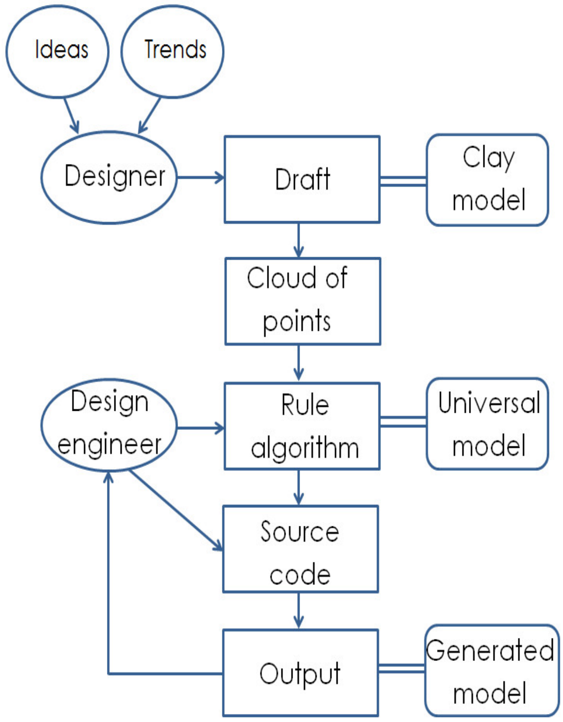

Figure 1. Basic scheme of generative developing process of an automotive prototype

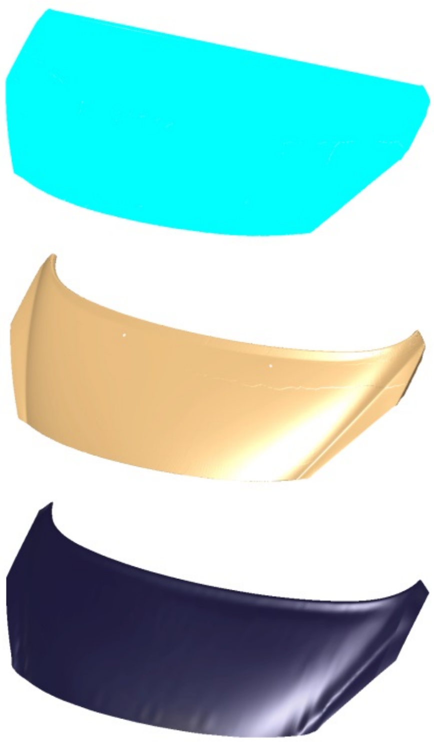

Figure 2. Process of transforming cloud of points into surface using example of a car's bonnet

This surface is then provided by the source code for the interferences between inner and outer parts. The results of the algorithms, rules, and source codes results in a generated model. In case of the draft being changed, the CAD system drives it through the process, and generates a new model.

At the beginning of a new method of development research some new terms were employed. They are important to describe this recent process. This paper uses the terminology from [1] which represents these words:

- *Genotype – generic parametric CAD model*
- *Phenotype – specified CAD data, including tree history, parameters, relations*
- *Exploration envelope – a boundary of space within which the model is generated, determined by maximum and minimum parameters*
- *Rule/algorithm – routine defining usable section from a cloud of points, the software fits the surface through this section, and then the resulting output is a universal model*
- *Source code – routine for the functional parts, based on the components interfaces and defined by the exploration envelope*

CRITERION FOR SHAPE COMPONENTS

This paper focuses especially on the generative design of automotive bodywork. Saleability is influenced by the smoothness of the shape. It is not just because of the nice curves of the body shell. Another criterion is the shape of objects reflected on the surface.

In software applications parametric equations from [2] are used. If there is a closed interval I it is possible to describe a 3D curve by the parametric relation (1).

$$K(u) = [x(u), y(u), z(u)],\ u \in I \qquad (1)$$

Firstly, the surface is as smooth as the derivation level of the curve at any point. The continuity between two curves or two segments of a curve is in (2). Here k represents the level of smoothness.

$$K^{i}(u) = N^{i}(v),\ i = 0,1\ldots k \qquad (2)$$

If there are curves with C^0 continuity this is called 'point continuity' and there is no smoothness. Using C^1 there is a 'tangent continuity'. A *minimum of C^2 continuity is necessary in order to produce a smooth surface. This is called 'curvature continuity' and using it avoids any bad edges. For the aerodynamic properties and passive safety C^2 continuity of surface in every segment is best. Of course, curves can, in principle, also be described by higher degree polynomial functions (n). In this case, it is very advantageous to change the shape of the profiles and change their aesthetic outcome by using higher derivatives order (C^{n-1}) continuity.*

Secondly, there must be a compromise between the engineer's model and the designer's draft. This is because innovation sells new products. On bodywork in particular aesthetic lines are used. In rule/algorithm there must be steps which recognize the required lines with a proper shape.

After categorization of the smoothness or lines comes a curve fitting algorithm. Splines describing the preliminary surface are used to represent the curves. After generating the surface there must be a final check. Curvature analyses are used in CAD software for the control of aesthetics, inflection lines, reflection lines etc. An example of inflection lines (red) and reflection lines (green) can be seen in Figure 3.

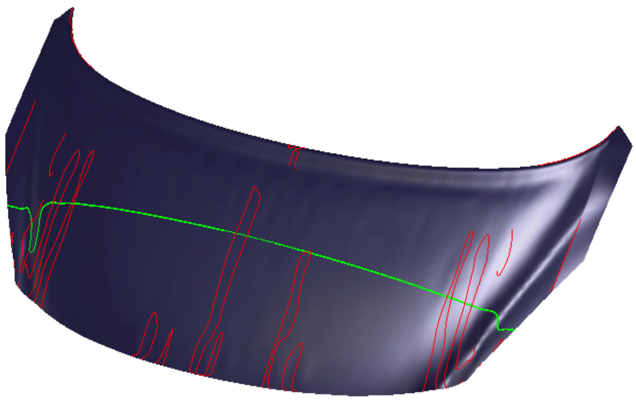

Figure 3. Car's bonnet model with analysis of reflection and inflection lines

CONNECTION BETWEEN CLASS A SURFACE AND CLASS B SURFACE

It is necessary for the assembly to fulfil certain functional relations. An A surface represents the shape, whilst a B surface represents proper position and function. Using the example of a bonnet, this means the need to fit braces, holes and other interior parts (in a broader sense to the whole car "body in white" structure). The scheme of connections in the CAD software can be seen in Figure 4. This is an example of how the source code can work to generate B surfaces. After updating the CAS (Computer Aided Style) or A surface by scanning this algorithm, B surfaces proceed to assimilate this change. This is the reason why an engineer has to prescribe the interfaces between A surface and B surface.

REASONS FOR USING GENERATIVE DESIGN IN THE AUTOMOTIVE INDUSTRY

In the past it was common for engineers to frozen the model after completing the design task. Consequently, no further changes were possible on A class surfaces after this point. In practice, generative design, based on the scheme in Figure 1, could open new possibilities in the design process. Exterior shape is active during almost the entire time of developing the new prototype.

The generative design method can also be advantageously applied to the process of automotive mechanical parts development. Here it is useful to also incorporate into the whole process the knowledge in the form of a special system. Using this method it is possible to solve problems connected with the assembly structure of complete mechanisms (changing and selecting the standardized or predevelopment parts stored in the design database), Additionally, the calculation and optimization tasks relating to the geometry and load capacity requirements can also be solved using this method. Such a task has been addressed in the design of automotive hybrid drives, where HCR gearing is used.

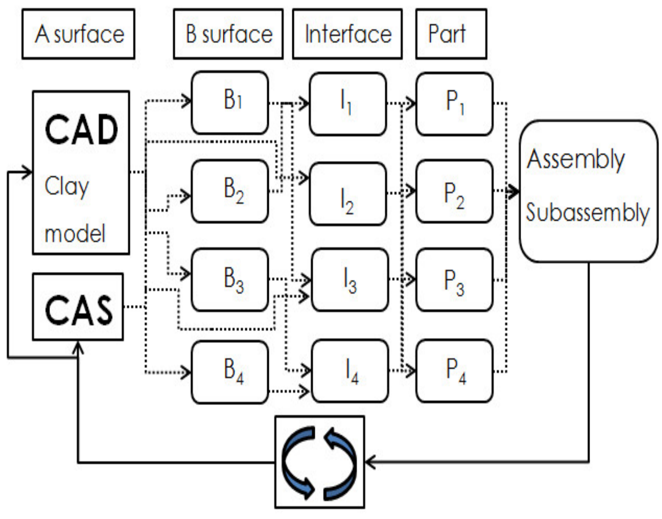

Figure 4. Scheme of CAD relations for functional parts

Finally, it is important to mention how working procedures are distributed in companies. The trend is to distribute work not just among workplaces in one firm, but also among workplaces all over the world in international concerns. Professional communication has changed from personal contact to internet connections across national boundaries. This offers employees the possibility of working in more than one place at any one time. That is why generative design is gaining ground in the automotive industry (as the next element of Concurrent or Parallel Engineering).

In conclusion, the future offers the possibility of working with simple adaptations of a model to produce changes without time-consuming procedures.

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