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Problems with designing of unfolding surfaces in the context of generative modelling

Problematyka modelowania powierzchni rozwijalnych w kontekście modelowania autogenerującego

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This paper is an attempt to deal with problems related to designing of unfolded surfaces in CAX systems. In the paper main problems during a modelling process of such type objects are described. Additionally, some way of how to deal with this task are shown. Authors' main focus is on using the generative modelling techniques in order to automate the designing process of the unfolded surfaces.

KEYWORDS: generative modelling, distributed system, unfolded surfaces, surface modelling

CAX systems have become an indispensable tool for every constructor. The continuous development of such systems allows creating simple models of objects in a simple, quick and effective way. A multitude of special modules, including designed for modeling sheet metal parts, relieve the designer of the need to continuously check many parameters, e.g. associated with sheet metal bending. In addition, at any point in the design process it is possible to check whether the model is technologically correct (whether it can be unfolded). These modules work perfectly in the case when we are dealing with metal materials, with a very well known and relatively simple description of the deformation process during bending, but with respect to materials with completely different properties, they cease to fulfil their task.

There are objects having so-called unfold surfaces, i.e. such surfaces that can take on more than one form due to their importance. This form can be enforced by a framework on which the surface is unbuttoned or by material properties. An example of a simple technical object with elements being unfolded surfaces is an umbrella. As part of its operation, one can distinguish two basic states - a folded and unfolded umbrella (fig. 1) - and all intermediate states. An umbrella is an object in which the membrane is stretched over a suitable skeleton.

The problem with the modeling of this object in the CAD system is reduced to the appropriate modeling of the membrane - so that it is possible to present the object in at least two extreme states. The surface of the diaphragm before folding and after folding must have the same value, and the model should, as far as possible, accurately reflect the way the membrane is laid after rolling up.



Fig. 1. Umbrella in two extreme states

In the further part of the article, the authors outlined the basic problems associated with modeling unfolded surfaces and proposed a solution to such a task using a distributed system, whose main element is the Generative Model created in the CAX class system.

Problems associated with the modeling of unfolded surfaces

As already mentioned, the main problem in modeling objects with unfolded surfaces is to obtain the same surface area before and after unfolding. This can be achieved by trial and error, but it is a time-consuming and inefficient process [1]. The most-suitable way seems to be the use of a mathematical apparatus based on an integrals calculation. Namely, the equation must be met:

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$$\iint_S f(x, y, z) dS_u = \iint_S f(x, y, z) dS_f$$

where: S_u - unfolded surface, S_f - folded surface

To calculate the surface area using integration, it is necessary to know the equations of the curves that this part describes. An example of a surface in two states and with the curves that describe it are shown in fig. 2.

The determination of the function of the curves describing the surface presents problems related to the manner of predicting the behavior of the material during folding [1]. How the material will be arranged depends - directly or indirectly - on many factors, such as:

- rigidity of the material,
- number of fixed points resulting from the skeleton form, on which the surface is spread,
- the direction of forces (including gravity).

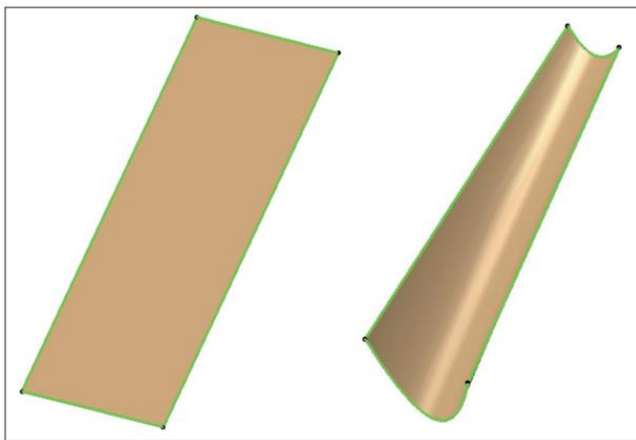


Fig. 2. Flap surface with marked curves describing it

If it is known how the surface will be arranged, the equations describing the individual boundary curves and thus calculate the area of the surface can be adjusted. In order to meet the condition of equality of surface areas, it is necessary to carry out optimization in order to select the appropriate values of the curves parameters describing a given surface. When the form of equations and parameter values is known, it is possible to model a surface in a CAD system. Each manual entry of equations into the CAD system and generating surface based on them would take a lot of time, therefore a better way is to automatically send information about the surface. This can be done by generating point cloud with coordinates that would then be imported into the CAD system (fig. 3). At such points, the surface can be undone, and the accuracy of this surface is controlled by the appropriate selection of the number of points. An additional advantage of this method is the ability to automate the process by using macros. Another way is to use an Generative Model whose input geometry would be a point cloud or parametric boundary curves. The use of boundary curves in the parametric form allows the generation of a surface in a larger number of intermediate states.

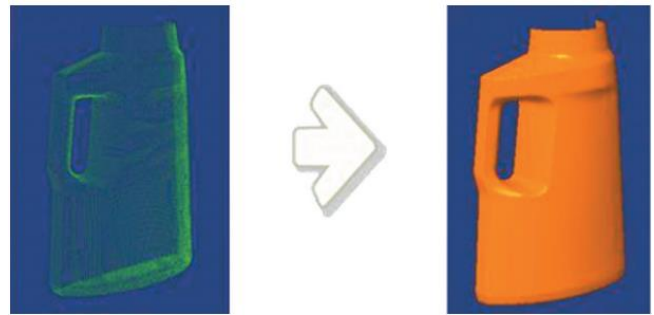


Fig. 3. Transforming a point cloud into a surface

Proposal of a distributed system for generating unfolding surfaces

Fig. 4 shows a schematic of a distributed system with the main stages of the process specified. This system is an attempt to solve the aforementioned problems with the modeling of unfolded surfaces [2].

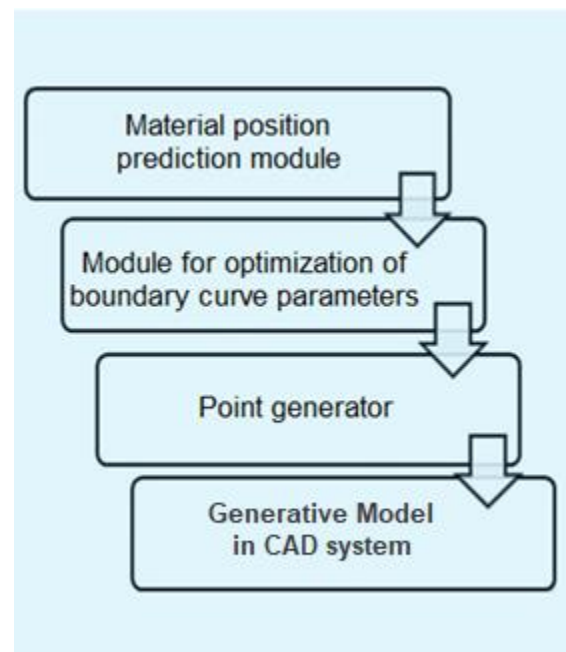


Fig. 4. Scheme of a distributed system

The first element of the presented distributed system is the material positioning prediction system, which is designed to estimate the probability of the material stacking depending on the imposed input data [3]. It is assumed that this system will be based on the Bayes network (fig. 5), which will allow to easily develop a network capable of assigning the probability of material composition for predefined schemes. Due to the complexity of the issue, it will be necessary to develop a network suitable for a specific application case. Other material arrangement diagrams must be taken into account in the case of an umbrella, and others, e.g. for a truck tarpaulin [3]. It is anticipated that the developed system will be a specialized tool supporting the design of a specific element. The result for the schematic layout of the highest probability will become the basis for the next module.

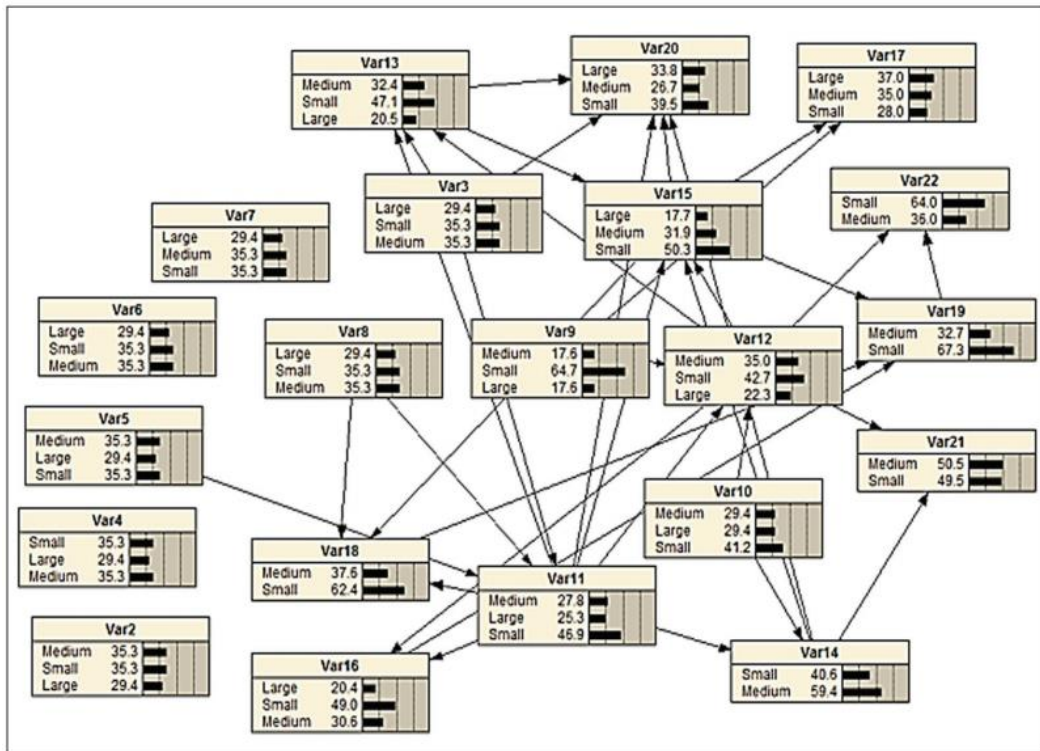


Fig. 5. Example of a network of beliefs

Based on the results from the prediction module, the parameter optimizer module will be able to select such parameter values describing the individual boundary curves so that the condition of evenness of the surface areas of the surfaces in both forms is met. This module can be based on a script created using the SciLab, MATLAB software, etc. [3, 4] This will allow cascade optimization of individual parameters to obtain satisfactory results. However, it should be borne in mind that the optimization process will only be completed if the equation quoted at the beginning is met. This may be associated with a very long program run time, so it seems necessary to apply the permissible deviations between the results depending on the requirements and type of the modeled element [4].

When the exact form of equations describing boundary curves of the surface is known, it is possible to generate a certain number of points - either in the form of a cloud covering the entire surface or only in the form of coordinates of points located on the edges of the surface - which will be used to generate the model using CAD system tools.

The last element of the system is a model prepared in the CAD system. The advisors propose the use of a Generative Model to automate the process of generating forms of specific surfaces [2, 5]. This model would be able to carry out a surface modeling process on the basis of information imported in the form of coordinates of points, which would ultimately result in a surface model of the object in a folded or unfolded form - depending on the needs (fig. 4) [5].

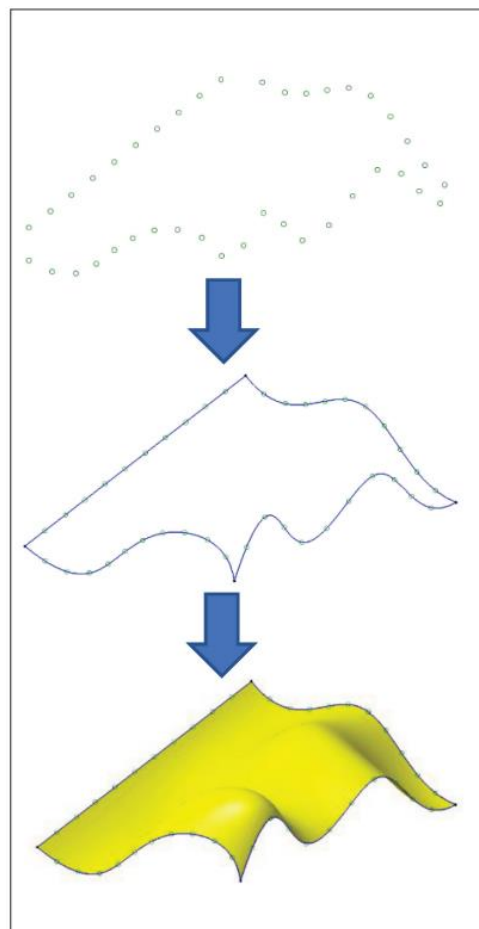


Fig. 6. Diagram of transforming a set of points into a surface

Conclusions

The proposal of a distributed system presented in this article is an attempt to solve the problem with the modeling of such surfaces that change their form during operation, but maintain the continuity of the material, the process being completely reversible. Available modules for modeling objects created in the folding or unfolding process are invaluable in the case of modeling sheet metal parts, but they do not cope with the specific requirements of the surface presented in the article.

It would seem that the discussed surfaces are of marginal importance and there is no need to model them. The problem with modeling the umbrella membrane presented at the beginning is just one example of the use of unfolded surfaces. Meanwhile, they are used in many areas, including in the automotive industry (airbags, folding roof skins, tarpaulins of trucks), cosmic (expandable solar panels, solar sails) or medical (heart valve implants, stenoses). The possibility of modeling the manner in which a given surface will behave during folding can be invaluable, e.g. in the case of the need to carry out more accurate FEM simulations or generate a more detailed technical documentation of the object.

Next, the authors intend to develop the subsequent modules of the presented distributed system, finally to obtain a tool allowing for quick and accurate modeling of developed surfaces.

REFERENCES

1. Węlyczko A. „CATIA V5. Sztuka modelowania powierzchniowego”. Helion, 2009.
2. Rzydzik S. „Rozproszony system komputerowego wspomaganie procesu projektowo-konstrukcyjnego”. Gliwice: Wydawnictwo Politechniki Śląskiej, 2013.
3. Koski T., Noble J.M. “Bayesian Networks. An Introduction”. Wiley, 2009.
4. Cees B. “Multidisciplinary Design Optimization: Designed by Computer” Concurrent Engineering in the 21st Century. Foundation, Development. Challenges. Springer, 2015.
5. Jałowiecki A., Skarka W. “Generative Modelling in Ultra-efficient vehicle design”. Transdisciplinary Engineering: Crossing Boundaries. IOS Press, 2016. ■

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