# LAYOUT OBJECTS OF COMPLEX SHAPE

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**Abstract.** In this paper, I present a method of prototyping large-size objects with complex surface. The developed method is based on the existing strengths in areas of modeling large objects, and offers new approaches. A preliminary analysis of existing methods for the rapid prototyping and the feasibility of their use in the aviation were been, as part of the paper. The basic principles and approaches to the formation of a framework were produced. The range of the application of this method was found.

**Keywords**. Modeling, rapid prototyping, framework.

## 1 Introduction

Wide possibilities of modern computer technology can't replace full-size models. In some cases, full-size models need for driven by the requirements of technology, as in the composite industry, where, before you make a product, it is necessary to make a full-size model. Another purpose of the experimental model may be rendering any ideas or solutions layout decisions.

### 1.1 Topicality of the work

Models are used as a technological instrument and for a componentry in aviation. The large size and complexity of the required prototype surface are the peculiarity of the aviation industry, this becomes especially important, when we make modern aircraft.

In the past, the standard template lofting methods used to create the full-size models, achieved the required accuracy by a large number of tooling and drawings. Other methods use for the experimental and pilot production, that methods include a high degree of a manual labor and a long period of completion products, the quality of which is entirely dependent on the skills of the worker. But the modern industry is impossible without information technology. The introduction of new equipment into production is characterized by reducing the innovation period and by high rates and an avalanche-like development. Rapid prototyping, or modeling, is one of the key technologies that have a significant impact on the pace of industrialization.

The current technology of rapid prototyping is a very vast concept, which includes all variety of methods to receive a prototype from a computer model. There are a wide range of technologies of rapid prototyping: systems for the synthesis of layered parts from wax or plastic, powder materials, vacuum casting on investment models, silicone molds. Names of technology prototypes are different, but the principles of creating identical: the prototype is the foundation of any solid-state model, and the result is detail.

The problem is that in addition to the high cost of consumables and prototyping facilities themselves, these technologies have another drawback - the inability to manufacture large-sized products.

## 1.2 Main problem

We need to create a model of a light multipurpose aircraft for composite matrix and produce a mandrel for a composite matrix and a fuselage of the airplane. The purpose is: development a scientific method and programs to decide prototype question. This purpose is guided by deciding the following tasks:

- Analyse the methods of prototyping;
- Develop a method for creating a framework;
- Develop algorithms and programs and include them in the subsystem aided layout frame product surface;
- Conduct on the basis of established subsystem design studies to determine the rational values of the parameters of the framework model;
- Develop design recommendations;
- Research methods.

The object of research is the design of the product. Subject matter is the process of manufacturing the layout of the product. Decomposition of tasks, development of models and algorithms are based on the principles of system approach.

Identification of rational design solutions implement on the basis of simulations using the formal heuristics method. The mathematical problem of finding the rational values of the parameters set was presented as a problem of the multicriteria discrete optimization.

Scientific innovation is to develop a set of formal-heuristic methods, models, algorithms and procedures for solving the problem of full-size prototyping subjects, based on virtual models.

## 1.3 Method of attack

A mathematical model of a parametric task to create the optimal framework can be represented by the methods of dynamic programming as a problem of a discrete multi-criteria optimization.

Decomposition is constructive and technology division of a model for units in accordance with next principles.

F (x) - a continuous, differentiable, piecewise-smooth function in the target segment.
F (x) - a function describing the surface of the unit of model

If the above conditions fulfilling on the entire surface, we don't have to divide model into units. Introduce the vector X * design parameters

$$X^{*} = \underset{\substack{x \in X \\ u \in U}}{\mathrm{Arg\,Min}}\, F(x;u).$$

Vector design parameters of the function consists of elements which correspond to the minimum value of the objective function F (x, u), linking the parameters and characteristics of the project on a set of constraints U.

This problem has a multi-criteria: a criterion of minimum weight, complexity, in this case objective function is the total length of the contour in a plane cutting parts during laser cutting.

Optimization is conducted by minimizing the length of the cutting laser.
F (x, u)-a single-valued and integer-valued function.
X = X (S1; S2, δ) - vector of parameters.
Where, S1-Longitudinal step,
S2-Cross-step,
and δ-thickness of the elements of the framework.
Definition of the error of a model.
The production error in the model can be defined as the sum of errors, appeared at various stages of

the process.

$\Delta = \Delta program. + \Delta las. + \Delta mat. + \Delta\ prod.$

Where,

Δ program. - programming error in the software product ,

Δ las .- accuracy of laser cutting ;

Δ mat .- accuracy of the material;

Δ prod.- error of the assembly and final processing (variable parameter);

Δ program.- accuracy of software product using Solid Works is 0,001 mm;

Δ las .- the average for different laser machines is 0,01 mm;

Δ prod = F (Δprogram.., Δ las .., Δ mat ..) – Error of the final assembly and processing within 1 mm.

Δ mat . - Accuracy of the material is depending on the material and temperature conditions for the plywood 10 mm-0, 5 mm to 4 mm plywood-0, 25mm, sheet of Plexiglas 3 mm-0.1 mm, ΔH Plexiglas 3 mm thick at Δt = 60 is 1 mm at 1 meter.

The summation of components enables us to obtain the error Δ = 1,5 mm dimension of the manufactured model of about 6 meters and framework made of plywood 10 mm thick. The accuracy of the obtained model depends on the accuracy and precision frame subsequent refinement. The cost of the finished product also includes the cost of manufacturing the frame, which depends on the length of cut (optimized parameters), and the cost of the subsequent refinement of the product.

## 2 The method of comparative analysis of rapid prototyping technologies

We use the concept of performance modeling in evaluating methods of modeling, ranked set of private efficiency criteria, i.e. set (Ai, Bi), where i = 1, n-total number of individual performance criteria. The concept is based on the method of expert evaluations.

We introduce the following set of criteria:

A1-precision manufacture of the product;

A2-cost manufacture of the product;

A3-maximum size of the manufactured product;

A4-time manufacture of the product.

A criterion, that is most important, is assigned score 10 points, score other criteria determined sequentially as a percentage of the more important.

The thus obtained values of normalized scores: summarize the points and determine T.

$$T = t1 + t2 + t3 + t4 + ....$$

Then each of the estimates divided by the received amount.

$$bi = ti / T$$

The priority criterion is given by its rank-bi, the value of which can be judged on the degree of importance in improving the efficiency criterion as a whole. In this case, the most important criterion is the accuracy (criterion A1). ti-tenths of each criterion (Table 1)

| Criterion | ti scores | bi ранг |
|---|---|---|
| A1 - manufacturing precision of the product | 10 | 0,5 |
| A2 - manufacturing cost of the product | 5 | 0,25 |
| A3 - maximum size of the manufactured product | 2 | 0,1 |
| A4 - manufacturing time of the product | 3 | 0,15 |

Table 1: Ranking performance criteria.

Calculate the existing methods of rapid prototyping efficiency criteria A1, A2, A3, A4 on a ten-point scale. The method, witch has the best Ai property, gets 10 points (Table 2).

| Modeling method | Efficiency criteria | | | |
|---|---|---|---|---|
| | A1 | A2 | A3 | A4 |
| Stereolithography | 10 | 2 | 2 | 8 |
| Selective Laser Sintering | 6 | 3 | 3 | 7 |
| Laminated Object Modeling | 5 | 6 | 4 | 6 |
| Fused Deposition Modeling | 7 | 3 | 3 | 7 |
| 2D milling | 7 | 10 | 5 | 4 |
| 3D milling | 8 | 4 | 9 | 5 |
| 3D+ milling | 9 | 3 | 9 | 4 |
| 2D Laser Cutting | 9 | 9 | 10 | 10 |

Table 2: Analysis of the modeling techniques.

I concluded, that existing technologies do not meet the requirements of accuracy, the dimension of production of parts, time and cost of production, which leads to the need for a new method of modeling, after analyzing the existing methods of modeling.

In addition, analyze showed, that modeling techniques do not allow the automated form to obtain the necessary roughness, i.e. surface requires manual modifications in the form of polishing, this one can conclude, that the alternative method can be also only partially automated.

# 3 Creation of large prototypes using information technology

The scientific research analyzed of the possibility of applying the developed method for civil passenger planes of different dimensions. The analysis showed that the method appropriate to apply for the light aircraft for several reasons:

- The surface of the light aircraft has complex shapes and contours.
- This is not only the requirement of design, but also is an important basis for good aerodynamics.
- The series of a light aircraft often small. Often this is experimental production.
- The use of expensive special equipment is not justified.

## 3.1 Applied the application of modeling techniques for aviation objects

When we made the project of the light commercial aircraft, we needed, that produced technology was easily scalable, fast, inexpensive prototyping to production tooling elements.

In the first phase, studies were conducted on a model airplane at a scale of 1:4, after successful testing and completion of necessary procedures, full-size model aircraft had been made, for removal of the matrix (rear surface of the product) and further production of products made of composite materials (Figure 1) .

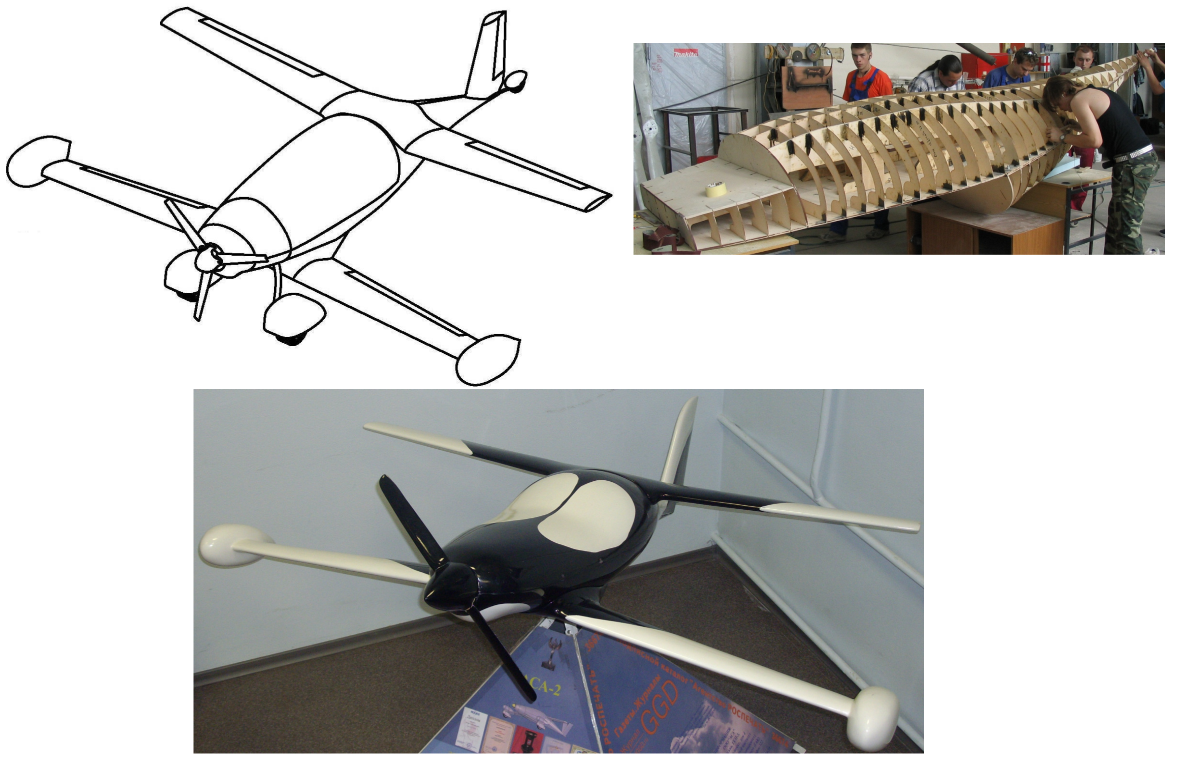

Figure 1: Light aircraft in the different scales.

The second subject matter is long-haul aircraft, designed by a group of students and postgraduate students due to large dimensions (80m wingspan) studies were conducted on a model at a scale of 1:50 (Figure 2).

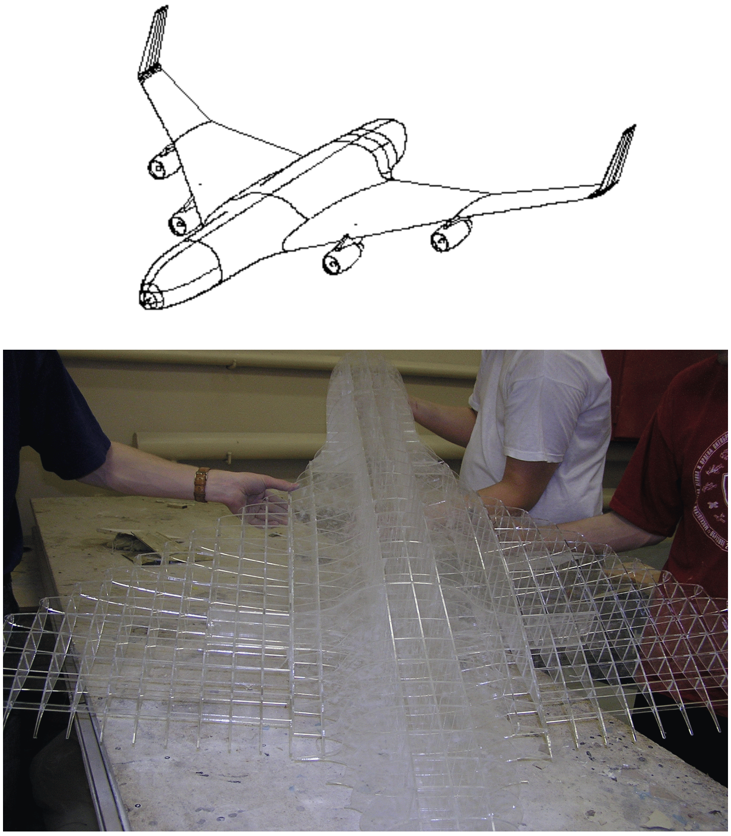

Figure 2:Model of the long-haul aircraft.

### 3.2 Principle of method

The idea was, that a framework of future technological to create using by the equipment solid-state model of the aircraft fuselage, tail fairings, the central compartment. Next requirements make for details:

- The high precision in manufacturing;
- Easy to assemble products;
- The sufficient accuracy of product assembly, no need for additional tooling.

Formulated requirements were met by the fact that some parts of a framework of the model, regardless of the original external shape of products, flat, and they can be manufactured using low-cost 2-coordinate CNC machines. The product builds on the principle resembles the well-known puzzle game, i.e. the components should be carefully approached to one another and are held together without extra effort.

Special program was written to automate the process of obtaining an electronic model of the framework on the Visio Basic. The program will help to reduce the routine stage of a design. It independent cut solid-model into segments of desired thickness and with a given step and creates the necessary gaps. Each element of the assembly will correspond to file containing the 3D-model. Assembly with longitudinal and transverse elements created from the solid model, using the technological division an products.

### 3.3 Turn-based method for the establishment of large prototypes

Methodology for modeling can be represented as a sequence of several stages (Figure 3):
1. Creating a solid model;
2. Creating framework of the model;
3. Creating gaps to build models;
4. Creating a scheme of the laser cutting;
5. Making elements of the frame by the laser;
6. Assembling framework;
7. Final processing.

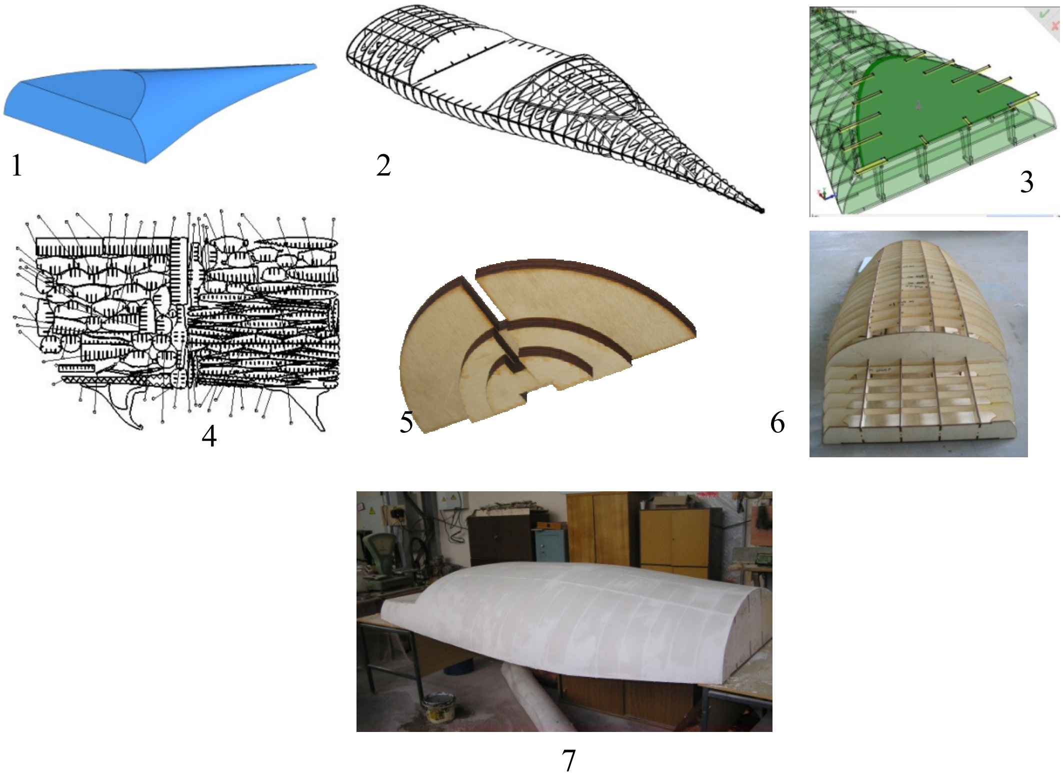


Figure 3: Sequence of stages.

### 3.4 Technology features a large-size prototyping and development prospects

The advantages of the developed technique to existing methods of modeling are that:
1. The developed technology for prototyping large objects combines the traditional approach and new information technologies;
2. We have seen the shortening of the task time in 4 times, in our own experience;
3. The range of application of this method is very wide. It is: the automobile industry, shipbuilding, education, design, and aviation, of course.
4. We can make not only technological models using followed method of the modeling, but also create the exhibition frameworks models.

I can see the prospects for the development of technology in:

- Automation of processes of distribution-based grooves and facilitate the elements of the prototype framework, for receipt easy-to-assemble product, does not require additional design modifications;
- Expanding the scope of the technology at the expense of refinement of the software and the possibility to simulate the counter-surface of the product, we will obtain matrix of the products, for subsequent production of parts made of composite materials;
- Development of more detailed mathematical model that takes into account more then one criteria.

## 4 Conclusion

The problem of the surface reproduction is one of the main tasks of the technological equipment, the correct solution for playing surface.

The problem-solving of the surface reproduction with a given accuracy was considered in this paper.

The results of the work may be considered:

1. Developed scientific methodology and software to address prototyping questions of large objects with a surface of double curvature, ensuring accuracy to 0, 003% of the product size.
2. The algorithms and programs were included in the subsystem aided layout framework surface of the product, which reduce the cost of more than 300 times.
3. Design studies that were conducted on the basis of established subsystem determined the rational values of the parameters of the framework model, design recommendations developed.
4. The use of CAD has helped to significantly reduce and modernize the standard processes, which led to shorten the task 4 times.
5. There are possible to produce a wide range of products (screws, car tuning parts, columns of buildings and other architectural elements).
6. Successful testing of technology were on real products:
   - creation of a matrix model of a light aircraft on a scale of 1:1
   - creation of a model for the matrix of a light aircraft on a scale of 1:4
   - creation of an exhibition aircraft model by plexiglass on a scale 1:50.

## References

[1]. Arepiev AN Conceptual design of main line passenger planes. Selection schemes and parameters. Moscow 1996.

[2] Bulanov VV Sparrow IM. Technology missile and aerospace structures from the CM. MSTU 1998.

[3] Zlenko M. Rapid Prototyping Technologies - layer-by-layer synthesis of physical copies based on 3D-CAD-model. CAD / CAM / CAE Observer # 2 (11) 2003 .

[4] Kuprikov MY Structural and parametric synthesis of the geometric shape of the aircraft with "hard" constraints. Moscow Aviation Institute in 2003 .