# Using ontologies for data processing scenarios in aircraft designing


Javier Flores
*Department of Aircraft Design*
*Samara University*
Samara, Russia
flores.javier@yandex.ru

Kamil Osseni
*Department of Aircraft Design*
*Samara University*
Samara, Russia
ossenikamil@gmail.com

Nikolai Borgest
*Department of Aircraft Design*
*Samara University*
Samara, Russia
borgest@yandex.ru



***Abstract*—The use of Ontologies in the present is becoming very common and widely used in different education areas, some areas of the engineering such as aerospace, can improve with the application of this informatics tools. Classification of aircraft as an object and all its components has become an important research area for the statistics analysis previous of designing a new concept, in this document we are going to explain, how Fluent Editor can help the designer to improve the classification and information analysis used to choose the statistical characteristics of the new concept. On this paper databases are created for storing, processing, performing calculations, sorting, sampling and presentation of data arrays according to various criteria. Then the created array of data on aircraft wing airfoil can be further used as a basis for selecting the airfoil according to the technical task.**



***Keywords*—design, ontology, education, aircraft, airfoil**


## I. Introduction

It is known that the key element of the process of creating an airplane is its project, that is, the development of the project both in manual mode and in automated mode. To develop a modern airplane project means to develop a complete set of design and technological documentation both for paper technology and for machine carriers, which makes it possible to create an aircraft in metal and to operate it.

During the design of a new aircraft, designers and analysts create and refine several aircraft models using different software tools. Each model covers parts of the whole aircraft and usually focuses on one aspect of the aircraft. Especially during conceptual aircraft design the degree of diversity and content overlap are high compared to later design phases.

It is clear that modern design of aircraft and other complex engineering techniques cannot be created without the use of automation systems, so the degree of automation of design processes is largely determined not so much by the capabilities of modern CAD, as by the ability to formalize a particular design task, that is, the designer's ability to give a fairly strict formulation design tasks and a clear completed algorithm for solving it, using the maximum information about a typical design task, then is the use of information about the projected product (airplane).

Classically, the technical documentation is only the end result of a complex and long process of design work by the creators of the aircraft, aimed at developing a project of a previously non-existent object (aircraft), system and process.

Classification of digitized documents nowadays gains a higher significance due to the rapid growth of digital content. With respect to the growth, organizing them is a big challenge for efficient retrieval information. Therefore, finding and improving solutions for text classification has considerable importance [1].

## II. About airfoil design concepts in general

An airfoil is a surface designed to obtain lift from the air through which it moves. Thus, it can be stated that any part of the aircraft that converts air resistance into lift is an airfoil. The profile of a conventional wing is an excellent example of an airfoil. (Fig. 1) Notice that the top surface of the wing profile has greater curvature than the lower surface.

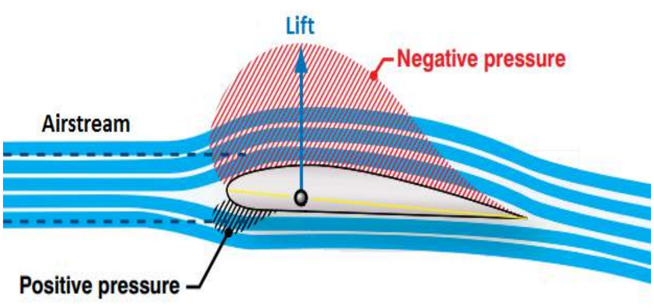


Figure 1. Airfoil flow.

The difference in curvature of the upper and lower surfaces of the wing builds up the lift force. Air flowing over the top surface of the wing must reach the trailing edge of the wing in the same amount of time as the air flowing under the wing. To do this, the air passing over the top surface moves at a greater velocity than the air passing below the wing because of the greater distance it must travel along the top surface.

This increased velocity, according to Bernoulli's Principle, means a corresponding decrease in pressure on the surface. Thus, a pressure differential is created between the upper and lower surfaces of the wing, forcing the wing upward in the direction of the lower pressure.

An aircraft in flight is the center of a continuous battle of forces. Actually, this conflict is not as violent as it sounds, but it is the key to all maneuvers performed in the air. There is nothing mysterious about these forces; they are definite and known. The directions in which they act can be calculated, and the aircraft itself is designed to take advantage of each of them. In all types of flying, flight calculations are based on the magnitude and direction of four forces: weight, lift, drag, and thrust (Fig. 2).

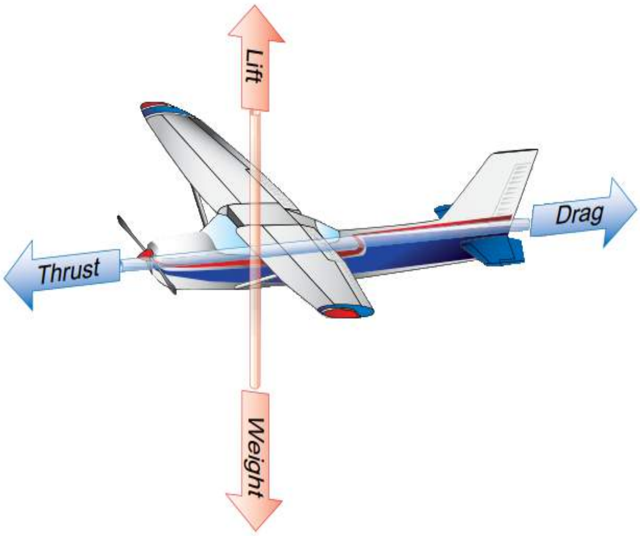


Figure 2. Magnitude and direction forces.

An aircraft in flight is acted upon by four forces:

1) Gravity or weight—the force that pulls the aircraft toward the earth. Weight is the force of gravity acting downward upon everything that goes into the aircraft, such as the aircraft itself, crew, fuel, and cargo.
2) Lift—the force that pushes the aircraft upward. Lift acts vertically and counteracts the effects of weight.
3) Thrust—the force that moves the aircraft forward. Thrust is the forward force produced by the powerplant that overcomes the force of drag.
4) Drag—the force that exerts a braking action to hold the aircraft back. Drag is a backward deterrent force and is caused by the disruption of the airflow by the wings, fuselage, and protruding objects.

## III. Ontology basics

Ontology originates from Greek philosophy, namely the study of being and existence, dealing with the questions what kinds of things exist and how they relate to one another. This concept has been adapted for use in computer science. Studer [3] define an ontology as “a formal explicit specification of a shared conceptualization of a domain of interest”, emphasizing formality which is needed for automated processing, a consensus about the contents, and the focus on a specific domain whereas the view on that domain is influenced by a certain interest for the ontology in mind.

### A. Types of Ontologies

Depending on their purpose, ontologies can be categorized into the following types [4]:

- Top-level ontologies cover general and abstract concepts, e.g notions of time and space that can be reused and refined in other ontologies.
- Domain or task ontologies cover knowledge about a specific domain (e.g. aircraft) or a specific task (e.g. cooking); since this distinction is somewhat imprecise, both are normally referred to as domain ontology.
- Application ontologies are typically developed in complement to an application and with certain usage scenarios in mind. They cover and refine specific aspects of domain ontologies for use in that specific application.
- The ontology developed in the context of this paper can be categorized as domain ontology.

### B. The Ontology Language OWL

As a language for describing ontologies, the World Wide Web Consortium W3C1 recommends the Web Ontology Language (OWL) [5], respectively its revision OWL 2 [6]. The foundations for defining semantics between concepts in OWL are logical declarations which can be evaluated by reasoners. Reasoners are programs which provide services such as checking the consistency of logical declarations in an ontology and inference of new knowledge from explicitly declared knowledge. In general, ontologies consist of concepts and roles. The concepts are organized in a hierarchical structure formed by is-a relations between these concepts. In OWL, these concepts are called classes, e.g. an Airbus A340-500 is a specialized sub-class of its superclass Airplane.

With the use of roles, more context can be added to classes in form of semantic relations. OWL expresses roles by properties which represent relations between two concepts. Possible sources and targets of these relations can be defined by the specification of appropriate domains and ranges of properties. OWL stipulates two kinds of properties: object properties relate two classes, whereas data type properties relate classes to data types.

### C. The Open World Assumption

A peculiarity of ontologies is the open world assumption. Essentially, it states that all knowledge, that is not explicitly or implicitly stated in an ontology, has to be regarded as unknown. In contrast, according to the closed world assumption, which is normally used with traditional data models such as database systems, missing knowledge would be regarded as non-existent.

Take for example a knowledge base that consists of the single statement ”Airbus is an aircraft manufacturer”, and the question ”Is Boeing an aircraft manufacturer?”. According to the closed world assumption, the answer to the question would be ”No”, whereas the open world assumption would result in ”Unknown”. According to the open world assumption, no conclusions are made until more knowledge is available which might result in an unambiguous answer. Practically, it means that in principle it always possible to add new logically consistent knowledge to an ontology without invalidating its conceptualization or content, whereas with traditional data models in a closed world this might possibly require a complete overhaul of the model or its content.

## IV. Ontology development

In the following, we provide an introduction into the ”Solution of design tasks with the help of ontological systems” methodology, show its application in our project, and conclude with the evaluation of the developed ontology.

Divide the ontology into 3 parts:

- Database of airplane (Table 1, describe the five aircraft and assign them the values of Vc)
- Database of the wing airfoil (Table 2, describe the 6 wing profiles and assign them the profile thickness values)
- The selection of the thickness and the wing airfoil (Table 3, set the conditions for selecting the wing profile for the 5 aircraft).

For symmetric profiles are selected empennage, the thickness of which is determined by the Mach number for the cruising flight regime. The most important factor influencing the choice of the wing profile is also the Mach number. Through the condition given in Table 3, the relative thickness of the profile is chosen. Based on the relative thickness of the profile, a set of existing wing profiles for an aircraft with a given Mach number is selected [6].

Table I
Five selected aircraft

| Aircraft | Vc, km/h |
|---|---|
| A 340-500 | 890 |
| Boeing 717 | 810 |
| Yak-42 | 700 |
| Bombardier Jet 100 | 786 |
| An-24 | 460 |

Table II
Six selected airfoils

| Airfoil | c,% |
|---|---|
| A-15 | 15 |
| B-14 | 14 |
| TsAGI 6-13 | 13 |
| A-12 | 12 |
| Clark-YH-11 | 11 |
| N-10 | 10 |

### A. Creating parts of the ontology

Hierarchical levels are related to each other, this characterizes the structure of the system and regulates the composition of its elements, blocks, aggregates and the relationship of the constituent structures to each other. At the same time, any structure is created to perform certain functions (useful actions, states or properties). For example, the wing performs the functions of ”lift the airplane”, ”maneuver the airplane”, etc.

Thus, all the elements of the subsystems and their individual elements over the hierarchy levels are related to each other by functional relationships.

Table III
Recommended values thicknesses bearing surfaces

| Range of numbers M | c-relative thickness, % | | |
|---|---|---|---|
| | *wing* | *horizontal stabilizer* | *Vertical stabilizer* |
| M>0,7 | 15 - 13 | 12 - 6 | 12 - 6 |
| M<0,7 | 12 - 10 | 8 - 6 | 8 - 6 |

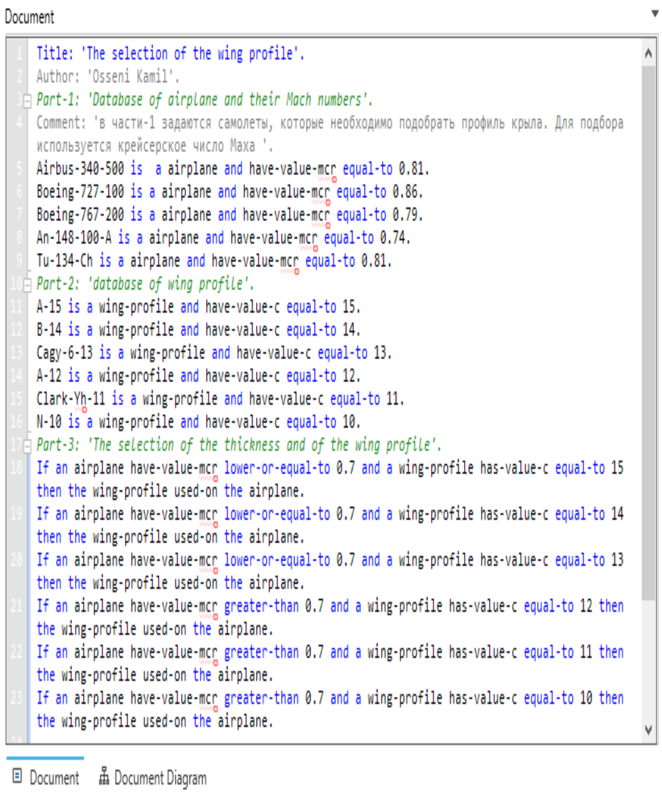


Figure 3. Fragment of the document.

Each hierarchical level corresponds to its list of tasks, the solution of which is necessary for making design decisions corresponding to this level, and even more so in the conditions of the CAD functioning when creating the aircraft design. Therefore, in the automated design of aircraft design, an important aspect from the point of view of formalization is its hierarchical structure and the multi-stage design that follows from it [7].

Figure 3 shows CNL Editor window is the main part of Fluent Editor where you can actually view and edit ontology files. It shows all the CNL phrases, both from the edited file and from the reference ontologies that correspond to every OWL statement. You can click on any phrase from the edited OWL file to modify it, or can also add new phrases [7].

### B. Taxonomy Tree

Fluent Editor shows in a way of Taxonomy Tree in for of hierarchical levels and how each of the elements are related to each other, this structure facilitates the visualization of the Database. Taxonomy tree is displayed for each OWL file being edited and is built upon data from this OWL file and all included ontologies. Selecting element on the Taxonomy tree will filter all expressions in CNL Editor window to those, which are related explicitly to the selected phrase [7].

The figure 4 shows the Taxonomy tree that helps to navigate and to search systems or subsystems in the document.

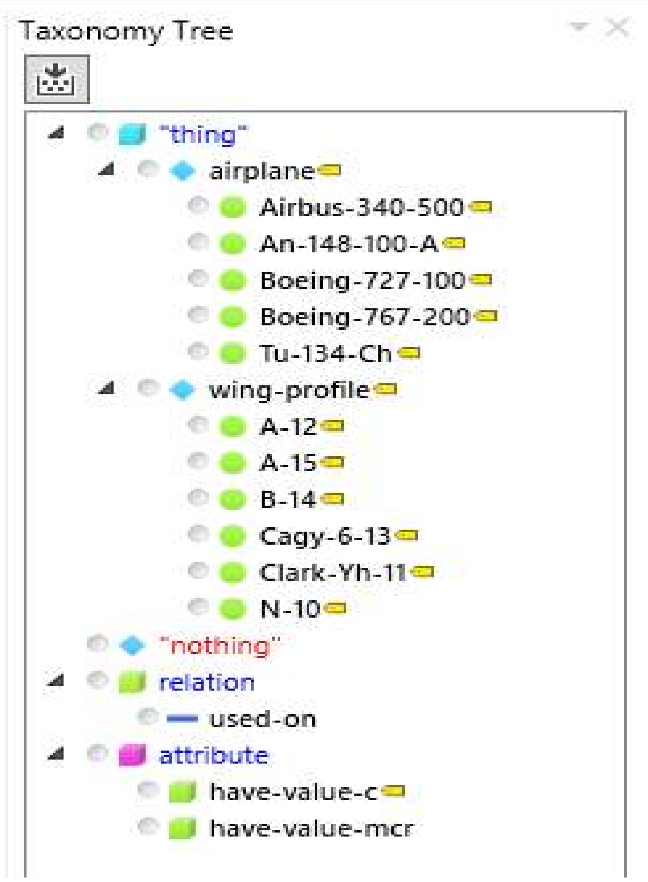


Figure 4. Fragment of the Taxonomy Tree.

### C. Presentation of ontology as a diagram

Checking the completeness and correctness of the established Database is carried out by visualization of ontology, namely, to create relationships and instances represented graphically by CNL-diagram (Figure 5). One skilled in the subject area will be easier to assess the correctness of the prepared guidance by imaging in CNL-diagram terms and relations between them [6].

The CNL-diagram help us to visualize in a more accessible way all the information, so in this way is more simple to understand the relation of every object, for example, (Figure 5) this diagram shows the 5 different airplanes,and also the 6 airfoils, and how they can relate as a thing.

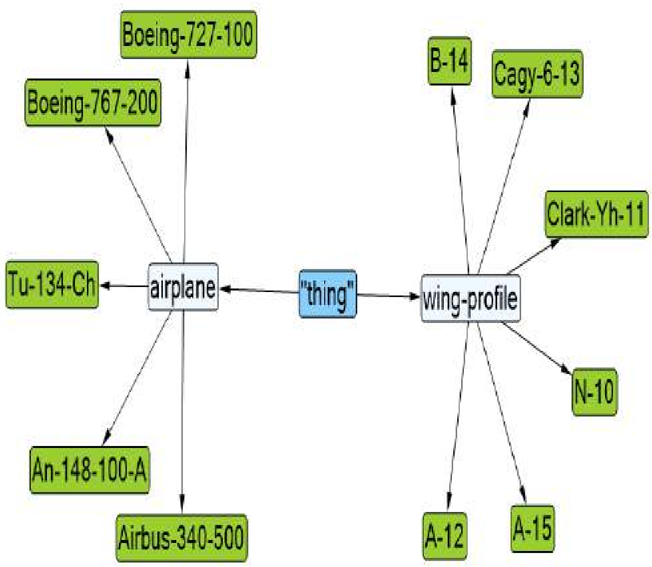


Figure 5. CNL-diagram.

### D. Reasoning

Regarding reasoning, the two most relevant benefits are consistency checks and automated classification. By using the restrictive capabilities provided by OWL, we were able to enforce rather rigid consistency constraints.

Trying to assign a value-c to a wing-profile, the subsumption service of reasoners can classify an profile that is used-on the Airplane. we use the logical selection of the thickness and of the wing profile.

- if an airplane have value-mcr lower or equal to n and a wing-profile has-value-c equal-to n then the wing profile used-on the airplane
- if an airplane have value-mcr greater-than n and a wing-profile has-value-c equal-to n then the wing profile used-on the airplane

Given an individual of an profile that was accidentally created as a direct member of the most general class Thing. When this individual is used-on the Airplane individual, the reasoner can classify it as profile.

SWRL is a powerful mechanism to build actual ontologies and express complex conditional relations for instances. Yet it is quite intractable to trace, especially for larger ontologies. In a brief it allows to inspect which rules were executed during materialization and what entities was substituted for their head clauses (and used in the body)

'Active Rules' In a brief it allows to deploy within the knowledge-base imperative code that will be executed when a certain conditions are met, expressed with the SWRL, the body of the Active Rule may perform any arbitrary action or update the knowledge base (Fig. 6).

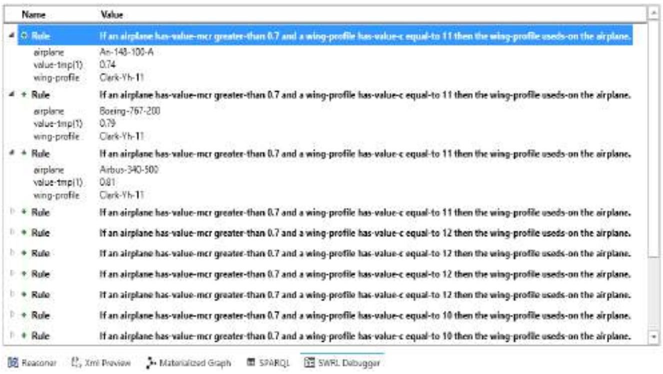


Figure 6. SWRL Debugger classification

After the running of the SWLR debugger the new CNL diagram (Fig.7) shows the relations of the wing profile and the airplane, and what type of profile is the best to use in each aircraft, acording to the relations of c and mcr values of all the items in the ontology, so we can see that there are some wing profiles that dont fit with an specific airplane and other fit with two or more, an then in an easyest visualy form this will help to chose the best of the wing profiles for the airplane.

## V. Related work

There has been extensive work on the benefits of applying semantic technologies for the efficiency of model driven systems engineering, which has been the motivational background for this ontology development project.

For example, in the development of the aircraft ontology following the NEON process model. In particular, is described the experiences from applying the NEON methodology and the resulting aircraft ontology. The aircraft ontology is an OWL ontology that covers system decomposition and component parameters of a single aisle civil transport aircraft. It can be used as a common semantic reference during model comparison and transformation [10].

Representing design alternatives as configurations of port-based objects is useful at the conceptual design stage when the geometry and spatial layout is still ill-defined. During the design process, as the designer makes additional decisions about the components and their interactions, these initial placeholders will be gradually transformed into specific port definitions. In terms of the port ontology, the incremental decisions of the designer will result in the addition of attributes to the port definitions, the sub-classing or refinement of attributes, or the addition of constraints on the attribute values [11].

Another application that would work well together with this type of ontology is the Robot Designer actually in development in Samara University, this investigated the possibility of applying methods and techniques of artificial intelligence for accelerated training of student for preliminary design of the aircraft. It is aimed to help in the process of preliminary design of an aircraft [12].

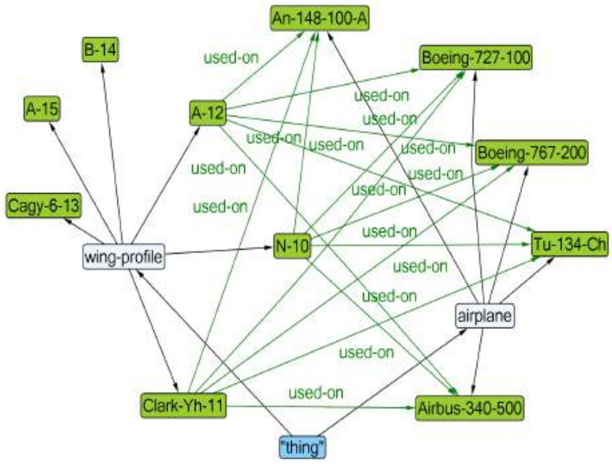


Figure 7. new CNL diagram

## VI. Conclusion

Classification of information on an easy way, effectively and fast, then working with it, will help in the future to cut times of design and research, so this will have a positive effect on the cost of development of new technology.

"Fluent Editor" has the necessary mechanisms for the implementation, conceptualization and formalization of ontology. This program facilitates the use of ontologies for classification of objects and to visualize them so the student or researcher, could do an easiest and faster conclusions on themes related to the design area.

We also intend to exploit the aircraft ontology in existing aircraft design tools beyond model consistency checking and integration. Our long term goal is to contribute to the integration of semantic technologies into system design tools and to the establishment of knowledge engineering as a natural part of systems design.

Future research is supposed to explore a more theoretical way of design concept definition than the presented one. It is empirical in that it followed a speculative way to find out the content and contextual dependencies of a design ontology and design concepts. It is also for future research how to make concept generation unique and unambiguous.

It is an absolutely open issue is how to create a population of materializable design concepts quasi automatically, if possible at all. As well, it needs further research how to further articulate possible interdependencies and conceivable interactions of design concepts, especially in unknown circumstances (situations).

## References


[1] Ch.M. Wijewickrema. Impact of an Ontology for Automatic Text Classifications, Annals of Library and Information Studies. Vol. 61, December 2014, pp. 263-272. - http://nopr.niscair.res.in/handle/123456789/30334.

[2] FAA Aerodynamics, Aircraft Assembly, and Rigging

[3] Studer, R., Benjamins, V., and Fensel, D. (1998). "Knowledge engineering: principles and methods". In: IEEE Trans. Knowl. Data Eng. 25 (1-2), pp. 161–197

[4] Studer, R., Grimm, S., and Abecker, A. (2007). Semantic Web Services: Concepts, Technologies, and Applications. Springer-Verlag New York, Inc..

[5] Zhitomirsky G.I. The design of aircraft: A textbook for students of aviation specialties of universities. / 3rd ed., And additional. / M .: Mechanical Engineering, 2005. 406 p.: Ill.

[6] Great Soviet Encyclopedia: [in 30 t.] / Ch. Ed. A. M. Prokhorov. / 3rd ed. / M.: Soviet Encyclopedia, 1969-1978.

[7] A.A. Orlova, N.M. Borgest. Text verification instruction manual using the ontologies / Proceedings of the 2016 Conference on Information Technologies in Science, Management, Social Sphere and Medicine (ITSMSSM 2016). ACSR - Advances in Comptuer Science Research. Vol. 51. 2016, pp.238-241.

[8] N.M. Borgest, M.D. Korovin. Formalization of design procedures in the engineer's educational strategy / Proceedings of the 2016 Conference on Information Technologies in Science, Management, Social Sphere and Medicine (ITSMSSM 2016). ACSR - Advances in Comptuer Science Research. Vol. 51. 2016, pp.524-527.

[9] OWL - https://www.w3.org/TR/owl-semantics/

[10] M. Ast, Martin Glas, Tobias Roehm, Creating an Ontology for Aircraft Design, Deutscher Luft- und Raumfahrtkongress 2013. DocumentID: 301356. – 11 p.

[11] Vei-Chung Liang, Christiaan J.J. Paredis. A port ontology for conceptual design of systems. Journal of Computing and Information science in engineering. Vol.4, September, 2004, pp.206-217. - DOI: 10.1115/1.17781

[12] N.M. Borgest, S.A. Vlasov, Al.A. Gromov, An.A. Gromov, M.D. Korovin, D.V. Shustova, Robot-designer: on the road to reality. Ontology of Designing, 5(4): 429-449, 2015. DOI: 10.18287/2223-9537-2015-5-4-429-449.


## ИСПОЛЬЗОВАНИЕ ОНТОЛОГИЙ ДЛЯ СЦЕНАРИЕВ ОБРАБОТКИ ДАННЫХ при ПРОЕКТИРОВАНИИ САМОЛЕТОВ


Хавиер Флорес, Оссени Камиль, Николай Боргест
Самарский Университет



В настоящее время использование онтологий становится очень распространенным. Они широко используются в различных областях образования, некоторых инжиниринговых областях, таких как аэрокосмическая промышленность, и могут улучшаться с применением этих инструментов информатики. Классификация самолетов как объекта и его компонентов стала важной областью исследований для анализа статистики, предшествующей разработке новой концепции. В этой статье делается попытка объяснить, как Fluent Editor может помочь дизайнеру улучшить классификацию и анализ информации, используемые для выбора характеристик новой концепции самолета. В работе были созданы базы данных для хранения, обработки, выполнения вычислений, сортировки, выборки и представления массивов данных в соответствии с различными критериями. Созданный массив данных по аэродинамическим профилям летательного аппарата может быть далее использован в качестве основы для выбора аэродинамического профиля в соответствии с требованиями технического задания.