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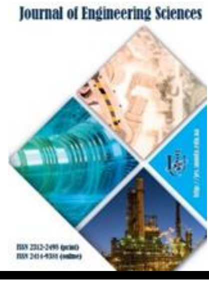

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Design in Modern Information Systems by Applying Cloud Technologies

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Abstract. In this study, the general algorithm and technology of design in advanced computer-aided design (CAD) software of the CAD-in-the-Cloud type using an information model (IM) was discussed in detail. Applying design systems of this type increases productivity and quality of the development and enables group work on the project. The proposed information model consists of three main components – working with Autodesk Fusion 360 on a computer, working with cloud capabilities, and designers' collaboration through the cloud. Nevertheless, some IM elements may be missing in a particular design, or there can be options for applying the proposed steps in the design process. Developing customized respiratory protective equipment (face masks) in Autodesk Fusion 360 CAD family was considered as an example of the suggested IM application. Modern design and producing technologies enable the creation of masks according to individual anatomical characteristics of the human face. In this paper, the protective mask was created by applying modern cloud computing technologies using information models. Information models were adapted to the process of protective mask design. The model of a human headform was developed using the 3D scanning method. After applying retopology tools, a basis of the mask frame was created on the surface of a 3D model of a head. Building a solid model and testing the mask fame configuration under mechanical stresses due to facial expression changing was carried out in Autodesk Fusion 360 CAD software. Finally, the cloud module of the generative design was applied to determine the filtering element configuration.

Keywords: information model, CAD-on-the-cloud, CAD-in-the-cloud, mask, product innovation.

1 Introduction

Software technologies are developing very rapidly. Programs are becoming increasingly important in various design and manufacturing sectors, which causes increasing numbers of different applications for them. The widespread use of computer-aided design (CAD) systems allows for simulating the development of the information technology industry, leading to new trends and evolutions. Cloud services have become the only way to get through the crisis caused by the pandemic for many companies to keep working and cooperating with clients and partners. Their expenses have risen dramatically. When using cloud technologies, a designer can work with his team partners or independently on cloud servers at any time from any location by connecting to the cloud CAD platform. Basic parameters of the future product are laid at the design stage. The design process usually involves time-consuming calculations and preparing varied documentation. There are advanced engineering tools that speed up the process and take product design to a higher level. Thanks to new technologies, it is possible to solve problems and expand design opportunities with the help of cloud CAD online platforms. The product is no longer a static object. The final product continues to evolve and expand functional capabilities after delivery. This presents new challenges for designers, engineers, and manufacturers by using cloud technologies.

2 Literature Review

Present-day design is hard to imagine without applying cloud technologies. Their capabilities extend to all the stages of project creation. The project itself is located on cloud storage as well. This increases the safety of all the project elements and access to them from anywhere. Special modules for working in this mode using cloud design technologies are provided in multiple CAD systems. There are design systems whose functions are also moved into the cloud [1].

There are two main types of cloud CAD software: CAD-on-the-Cloud and CAD-in-the-Cloud.

CAD-on-the-Cloud allows for installing current CAD software to the cloud platform. Then designers can use their CAD programs via the Internet, just like laptops. Interaction takes place through the browser or as a remote client, and there is no need to download software on a personal computer. CAD programs and project files are stored online and work effectively in one place. Applying remote client software, CAD users can work with 3D design files as they do on their desktop computers in an office.

CAD-in-the-cloud is a cloud CAD program developed from scratch. This online form of design software became possible due to significant improvements in Internet speed, network bandwidth, and advanced capabilities of cloud infrastructure providers, such as AWS and Microsoft Azure. CAD-in-the-Cloud offers completely new applications developed and created exclusively for modern cloud infrastructure. An example of a cloud CAD platform is OnShape [2], which offers software for computer-aided design through the cloud with new features such as integrated data management and tools for real-time collaboration performance.

This type of CAD system has numerous additional features, including add-ons and plug-ins for modeling, possibilities of 3D printing, PLM, and many more niche solutions.

Cloud CAD means designers can access their files and project software from any location with a reliable Internet connection. This functionality allows them to work in an office, at home, or in the client's office.

The possibilities of virtual reality have become standard functions in CAD software. 3D models can be considered to exist in physical space due to virtual reality headsets. Many software providers have started to develop their products compatible with equipment for 3D viewing.

Nowadays, numerous program products actively use cloud technologies. They include the following software.

AutoCAD Web [3] is a reliable solution with basic AutoCAD commands required for easy editing and creating fundamental projects at an attractive price. AutoCAD drawing tools online in a simplified interface allows accessing and updating DWG™ files with any workplace arranging.

AutoCAD LT® [4] is CAD software architects, engineers, construction workers, and designers use to create 2D drawings and documentation. Design and sketching in a web browser on any computer allow reviewing, editing, commenting, and making CAD drawings in a simplified user interface.

CIDEON CLOUD CAD Integration (CCI) [5] combines data and structures of mechanical engineering (for example, assemblies and parts) in advanced cloud CAD systems, such as OnShape® [2], with SAP ERP or SAP S/4HANA. CCI is developed on the platform SAP Cloud and fully integrates local and cloud SAP systems.

CMS IntelliCAD® [6] is intelligent, robust, and accessible fully functional CAD software compatible with hundreds of third-party solutions. CMS IntelliCAD also offers a complete set of tools for drawing, consistent with 2D and 3D AutoCAD®. It is a good choice for engineers, architects, consultants, and all the users of CAD drawings.

SkyCiv Structural 3D [7] is an entirely online cloud-based software for structural analysis that enables users to model, analyze and design complex 3D constructions.

Inventor® CAD program [8] provides professional-level instruments for 3D mechanical engineering, documenting, and modeling products with the possibility of using work elements in the cloud.

Creo [9] CAD software offers the most scalable packages and tools for 3D CAD product development in the modern market. Creo 7.0 includes breakthrough innovations in generative design, real-time simulation, multi-body design, additive manufacturing, and others using cloud design modules.

Autodesk Fusion 360 [10] combines design, electronics, and production into a single programming framework. This results in an integrated CAD, CAM, CAE, and PCB system on a shared development platform. Autodesk Fusion 360 CAD family includes EAGLE Premium, HSMWorks, Team Participant, and access to consumer services such as generative design, cloud modeling, and cloud rendering. Fusion 360 – Team Participant is intended for external users who can share their projects, review, and manage them through a cloud. This system contains the base kernel, which is installed on a computer, but the full advantage of many functions can be taken only by applying cloud capabilities.

The considered sources present selected examples of cloud technologies adoption to create different products. To obtain the maximum effect when using advanced methods of cloud design, it is necessary to develop algorithms and technologies for new features application in product creation and analysis.

This paper introduces a CAD-on-the-Cloud algorithm based on information model (IM) design in Autodesk Fusion 360, applying its cloud capabilities.

3 Research Methodology

Creating new objects in various spheres is currently done by applying design computer technologies using cloud platforms. Developing the algorithm for new object design with the help of computer technologies is to be based on information models. The information model generalizes the approach to design by applying different technologies. Examples of that are presented in papers [11-15]. IM allows optimizing the process of product design and analysis. Let us consider the information model for product design based on the CAD-on-the-Cloud type of CAD system. Autodesk Fusion 360 CAD family is used as CAD-on-the-Cloud software. When creating and analyzing the product model, it is necessary to perform several sequential and interconnected stages (Figure 1).

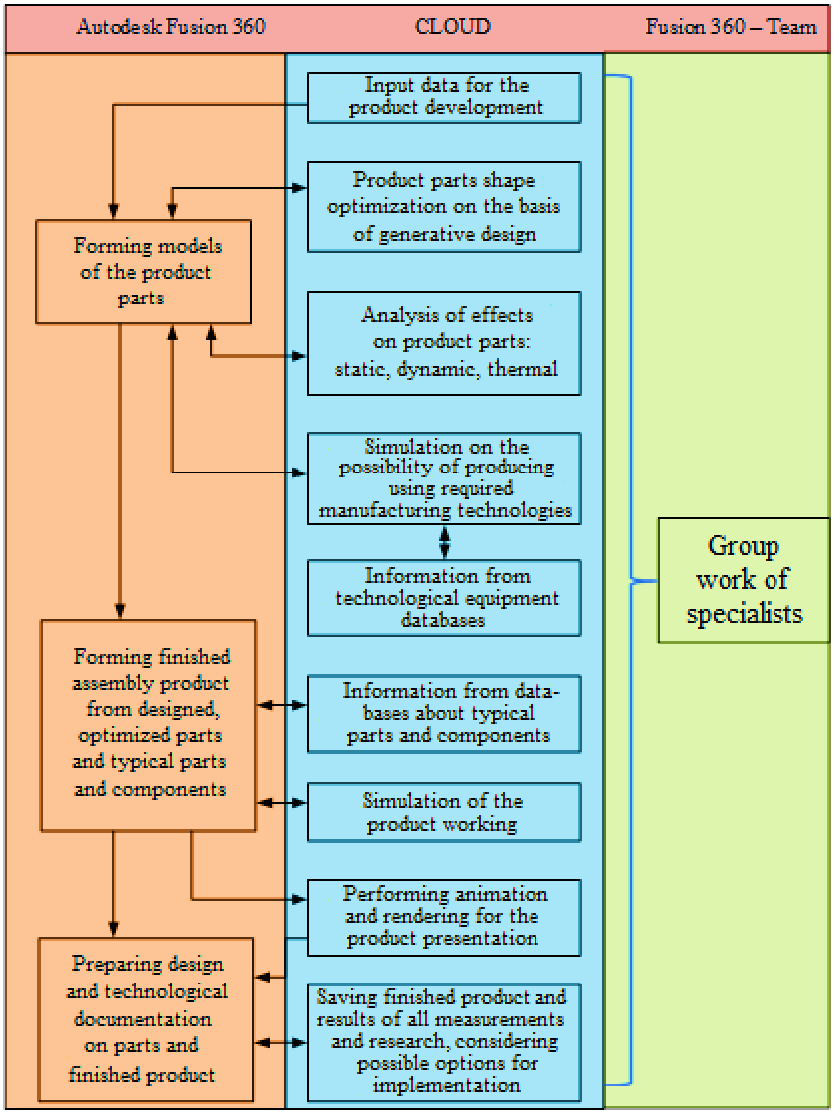

Figure 1 – Information model of design applying cloud technologies

The suggested information model consists of three major components: working with Autodesk Fusion 360 on a computer, working with cloud capabilities, and designers' collaboration through the cloud. Let us consider elements of the information model of design applying cloud technologies in detail.

1) input data for the product development should be presented in the form of an information set, for example, specifying the boundaries of an object in the form of a point cloud, the set of bounding surfaces, boundaries of the solid body. Input data is placed in cloud storage;

2) Autodesk Fusion 360 forms the required model of an object based on the obtained information;

3) the shape of the created part can be optimized in the cloud shape calculation module, which is based on generative design. As a result, the system optimizes the shape of an object the developer suggests. Otherwise, it offers its version. In this case, parts-producing technology is also considered;

4) it is possible to test the created model for the influence of different effects and stresses (static, dynamic, thermal) in cloud modules;

5) the finished model can be verified on the possibility of being produced with the help of required manufacturing technologies in the cloud module of technological processes simulation;

6) in order to carry out the creation and processing of parts simulation, it is necessary to use information about the equipment from the cloud data of the equipment manufacturers;

7) creating information about typical parts and components from cloud databases is used;

8) the finished product is assembled from designed and optimized parts and typical parts and components cloud databases;

9) working capacity of the created product is tested through its simulation;

10) to perform animation and rendering of the working product Autodesk Fusion 360 cloud service is applied;

11) results of all measurements and research, considering possible options for implementation, are saved in cloud storage of the entire project;

12) preparing design and technological documentation on parts and the finished product is made according to producing technologies;

13) in all stages of the design and research process, a group effort of various specialists in the Autodesk Fusion Team system is used.

The suggested information model allows considering the general approach to design, analysis, and simulation of production in CAD software of the CAD-on-the-Cloud type in the Autodesk Fusion 360 family.

4 Results and Discussion

Creating customized respiratory protective equipment (face masks) during the coronavirus pandemic is highly topical nowadays. Available mask configurations do not consider the individual characteristics of a person wearing it. Therefore, it is critically important to create a mask according to the anatomical features of each person. Modern design and producing technologies enable the creation of masks considering the individual anatomical features of every human. The possibility of the protective mask design is presented considering the individual features of a person. The design is performed in Autodesk Fusion 360 based on the suggested application of IM cloud technologies. In the considered example, IM is adapted to the solved problem.

At the first stage of IM development, reverse engineering technology is applied to get input data. Thus, a real human head is scanned using a modern 3D scanner. As a result, we obtained a sufficiently high-quality mathematical model consisting of a 3D point cloud. The acquired cloud is a basis for virtual headform development in the computer modeling system. An extracted mathematical model of the headform as *.obj file is imported into Fusion 360 software for further editing.

The following step in the process of 3D editing is the point phase. During this stage, it is necessary to reduce noise to decrease the number of scanned data points in homogeneous areas. The mesh model’s density should be adjusted to obtain an acceptable quality model. This design approach implies inaccuracies in an object being 3D scanned, which has the form of open polygons. With the help of Fusion 360, the deficiencies are eliminated, and the density of the mesh model is changed. As a result, the complete mesh model of a human head is finalized.

In the next stage, the mask frame design is carried out. For this purpose, it is suggested to apply a retopology instrument. Retopology allows for creating a new geometry over an existing one by modifying its structure.

After applying retopology tools, new geometry of the mask configuration is put over a face using it as a basis. It allows placing a new object quite accurately and continuing to adapt it.

This toolbox helps design a mask frame’s shape, which can be easily modified afterward. Based on the obtained mask frame configuration, the solid model of a mask is developed in Autodesk Fusion 360. This kind of work with model topology makes it possible to carry out different stress testing, select physical materials, define settings for 3D printing, and so on.

In the next stage, the mask structure is checked for reliability. The configuration of the mask frame consists of two major parts hingedly joined with each other. This allows to use of the mask regardless of changes in facial expression and speaking of the person wearing a mask. The mask frame’s lower part is tight, close to the chin, and the upper part is fixed on the nose bridge.

Strains on all parts of the mask and their connections are simulated in Autodesk Fusion 360 software. It allows verifying the configuration’s reliability under mechanical stresses along with its fixation on a face. Further, the material of the mask’s basic structure is determined and tested for external forces impact and possible displacement due to facial expression changes during a conversation. After the testing is carried out in cloud-based modules, the shape of the mask structure can be corrected.

Then we define the filtering element type and determine how to fix it to the basic structure. Let us consider the simplest version with a replaceable multi-layered filtering element. The shape of the filtering element can be modeled in the cloud module of generative design by specifying boundary conditions in the form of a mask frame and space needed for normal breathing and facial expressions of a person. The filtering element is fixed to the basic structure using a sticky layer. An additional fixing element can be applied over the filter to provide a more reliable fixation. If necessary, mask configuration is adjusted considering the reliable attachment of the filtering element. It is possible to use separate filters as an implementation option, just as in the Pitta mask with one or two filters. To achieve this, we use cloud libraries of standard variants of filters. After the filtering element construction is defined, the technology of mask frame production is developed. The experiment chooses an additive technology using a 3D printer as a core technology. The printer type is chosen from the cloud libraries of equipment manufacturers. The technological process of creating an object based on a 3D printer can be simulated in Autodesk Fusion 360 program.

After using cloud computing technologies, the parameters of the required 3D printer are downloaded, and a mask frame-creating process is simulated. If errors occur during the simulation, the program suggests appropriate configuration corrections or adding extra fixing elements.

The resulting image of a mask with a filter put on a face is demonstrated in Figures 2-3.

Figure 3 – The designed mask with a single filter

To guarantee a more secure mask fixation, its version with ear hooks like those used in glasses is proposed. Variants with separate filtering elements are presented in Figure 3 (a single filter) and Figure 4 (a double filter).

Figure 4 – The designed mask with a double filter

Thus, this study suggests the general algorithm and technology of applying CAD software of the CAD-on-the-Cloud type during the design and analysis of product creation in the form of IM. This IM can be adapted to the required work option with a particular task.

The presented information model is based on three main components – working with Autodesk Fusion 360 on a computer, working with cloud features of the software and collaboration of the designers through the cloud in Fusion 360 – Team Participant. As an example of IM applying, an approach to creating protective mask which considers individual characteristics of human face is discussed in detail. When designing a mask, an information model of the created object is used.

5 Conclusions

This study suggests the general algorithm and technology of applying CAD software of the CAD-on-the-Cloud type during the design and analysis of product creation as IM. This IM can be adapted to the required work option with a particular task. The presented information model is based on three main components – working with Autodesk Fusion 360 on a computer, working with cloud features of the software, and collaboration of the designers through the cloud in Fusion 360 – Team Participant.

As an example of an IM application, an approach to creating a protective mask that considers the individual characteristics of a human face is discussed in detail. An information model of the created object is used when designing a mask.

Information models include all the sequential stages of the mask creation design and analysis. Developing feasible options for protective masks with various replaceable filters is considered in detail. In this study of creating a mask model, cloud technologies were used: when modeling a mask frame based on retopology, when checking the mask design for reliability, a generative design module when optimizing the shape of the filter element, when developing technology and simulating the manufacture of a mask frame, when choosing technological equipment for mask manufacture, when preparing control programs for a 3D printer.

The proposed method of design using an information model can be applied to both single objects and assembled items. During the assembled items creation, it is possible to adapt IM elements for each of the product's components. Applying the presented IM reduces time and increases the constructed product's accuracy and reliability. This research is to be advanced by developing IM for CAD-in-the-cloud systems.

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