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LOGICAL CLASSIFICATION OF GEODESIC SHELLS AND DOMES

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ABSTRACT

In this paper consideration of given to problems of classification of geodesic shells and domes. Here the article contains a description of existing classification of geodesic shells and domes and revealed their shortcomings. This classification considers only single contour plate geodesic domes. In order to remove the limitation of existing geodesic shell's classifications was built their logical classification. For the building of the logical classification of geodesic domes were picked out several classification attributes. A logical classification of geodesic shells and domes was built. It was constructed a grammar for notation of geometrical models of geodesic shells which shown types of geodesic shells. The logical classification reveals 48 classes of geodesic domes (if double-contour domes with the second contour with the same configuration are ineffective). New GEODOME library of parametrical objects of ArchiCAD was implemented. Here the article contains a description of existing forms of classification. Classification of geodesic shells and domes is in form of paper document. At present, there are electronic classifications which based on modern information technologies. The electronic document can be displayed to show investigated objects, phenomenon and process. An interactive electronic classification of geodesic shells and domes was built. The interface of a program of electronic geodesic domes classification is based on buttons which show classes and subclasses of geodesic shells. Classification of geodesic shells and domes has information, systematising and predictive function.

Keywords: modelling, geodesic shells, geodesic domes, classification, grammar symbols, parametrical objects, electronic interactive classification.

INTRODUCTION

Geodesic shells (Domes) - it is a class of space structures which are used in construction. Elements of such shells are got by a breakdown of spherical shell surface with geodesic lines - the central section of the sphere. Researchers are conducted in such fields as developing and using libraries of parametrical objects for CAD systems (HBIM - a library of information modelling of historical buildings) [1], geodesic breakdown of surface [2] , architectural design of geodesic domes [3], strength and stability analysis of these structures [4]. There are research papers which generalise all these works, including classification of geodesic domes and shells [5].

In J. Clinton's classification 4 classes of geodesic domes are picked out [6]. They differ with a peculiarity of the breakdown of Mebius triangle into elements. This classification considers only single contour plate geodesic domes. G. Coxeter's classification [7] considers a system of notation of surface breakdown into polygons in form of (N, M), where N - number of polygons sides, M - number of polygons meeting at the vertex. For example, a notation for icosahedron is (3, 5). This classification can be used only to single contour geodesic domes. It doesn't take combine systems and algorithms of breakdown into consideration. The further development of Coxeter's notation for consideration of combined systems with different shape elements (triangular, pentagonal, hexagonal) and for consideration of the frequency of breakdown is fulfilled in classification M. Wenninger [8]. A new element added in the notation of Coxeter: $(N, M+)_{b,c}$, where M+ means M and more polygons in vertex, b - a number of the vertex in one direction of Mebius triangle, c- a number of the vertex in direction $+60^0$. For example $(3, 5+)_{2,2}$ - for the icosahedron. This classification can be used only for present variants of geodesic domes. The classification of Pavlov G.N. [9] picks out 5 systems of geodesic domes (3 single contour systems and 2 double contour systems). This classification doesn't show the shape of initial geometrical elements.

LOGICAL CLASSIFICATION OF GEODESIC SHELLS AND DOMES

In order to remove the limitation of existing geodesic shell's classifications was built their logical classification which has such properties: 1) includes single contour and double contour geodesic shells, 2) is based on shape of initial geometrical elements which form the shell, 3) includes the principal combinations of classification attributes for revealing of unimplemented classes of geodesic shells.

For building of the logical classification of geodesic domes were picked out such classification attributes as: 1) Type of polyhedron (icosahedron, octahedron, tetrahedron), 2) Number of contours (single-contours - double-contours), 3) Kind of shell surface (flat plates - pyramids), 4) Shape of plates (triangular, quadrangular, pentagonal, hexagonal) 5) Shape of pyramids (trihedral, tetrahedral, pentahedral, hexagonal), 6) Type of the second contour (internal - external), 7) Configuration of contours (different - same), 8) Number of elements of sphere breakdown.

It was constructed the grammar for notation of geometrical models of geodesic shells which shown types of geodesic shells. Non-terminal symbol shown such construction as: S - geodesic shells (first symbol of grammar), A - part of types of polyhedrons (icosahedron, octahedron, tetrahedron) and types of shells (single-contour, double-contour), types of second contour (d-

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different, s - same configuration), B - part of types of plates and types of pyramids, C - part of variants of breakdown,

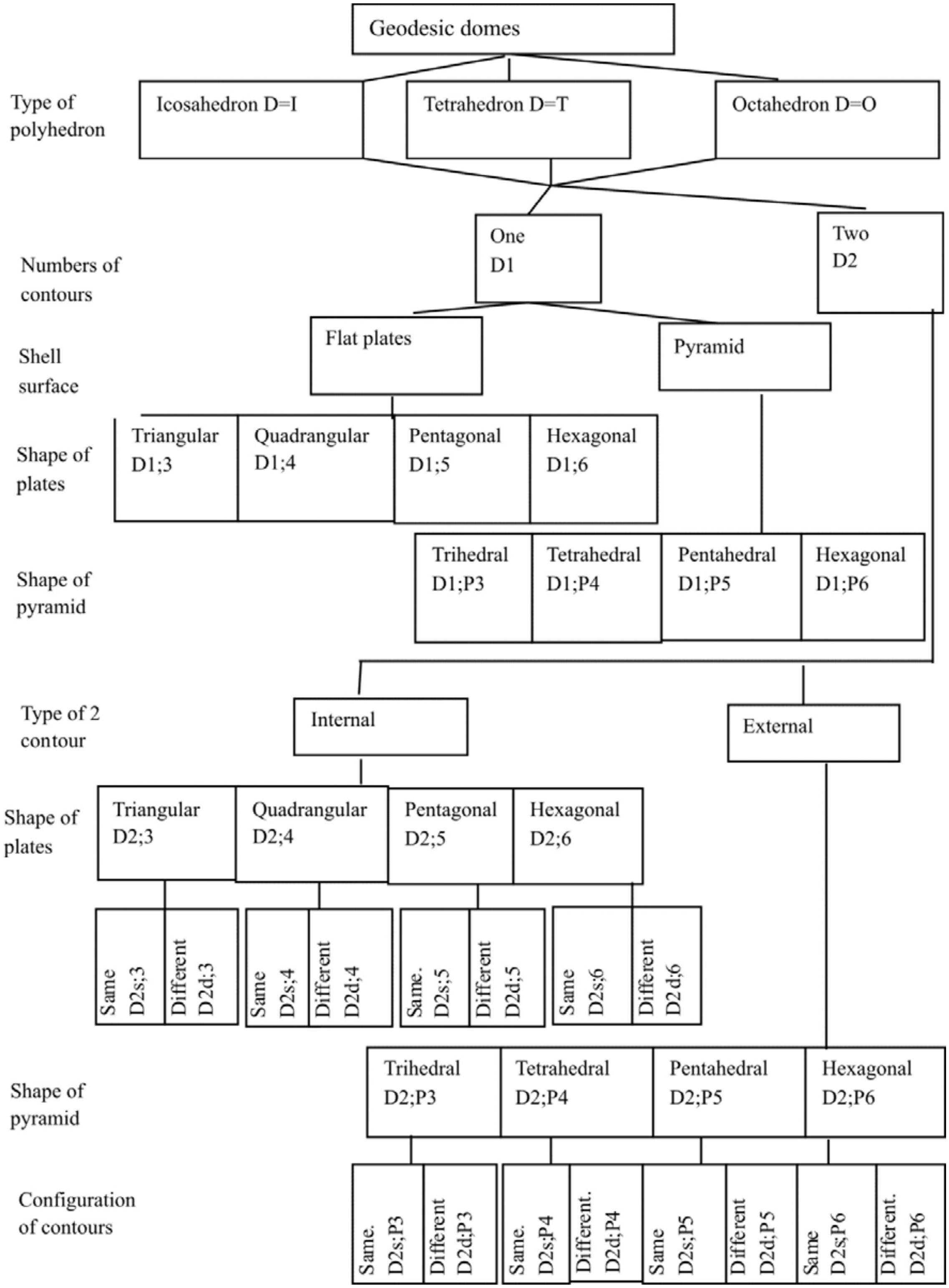

Figure-1. Logical classification of geodesic domes.

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D - polyhedron {I - icosahedron, O - octahedron, T - tetrahedron}, E - plate {3 - triangle, 4 - squad, 5 - pentagon, 6 – hexagon}, P – pyramid {P3 – trihedral, P4 - tetrahedral, P5 - pentahedral, P6 - hexagonal}, K - constant.

Grammar G is
G: S →ABC // notation of types of geodesic shell
// consist of part of types of shell, part of type of
// element and part of variant of breakdown
A→DK // contains type of shell
B→E|E, PK// contains type of plates and type of
// pyramid
C→K // contains type of number of elements of
// shell breakdown
D→{IK|OK|TK}
E→{K|K,E}
P→{PK}
K→d|Kd
Terminal symbol d - figure.

Figure-1 shows a logical classification of plate and pyramid geodesic domes. A logical classification reveals 48 classes of geodesic domes (if double-contour domes with the second contour with the same configuration are ineffective).

At the moment classes on the basis of icosahedrons are implemented as parametric objects of ArchiCAD: I1; 3, I1; 6, I2; P3, I2; P6, I1; P3, I1; P6, (Pavlov G.N.), I2; 3, I2; 6, I1; 4, , I1; 5, (Lakhov A. Ya.). Classes are not implemented: I2; 5, I2; P5, I1; P5, I2; 4, I2; P4, I1, P4. Analogous classes based on octahedron and tetrahedron are not implemented too. Data Base GeoDome has an open architecture, that is it can be completed with new geodesic shells classes.

DB GeoDome is realised in the form of ArchiCAD library. This library represents a set of folders and external files which can be used in projects. Library elements contain geometrical models of geodesic shells.

IMPLEMENTATION CLASSIFICATION IN ELECTRONIC FORM

Classification can have different forms. For example, there is a classification in form of graph [10] as in ASTM Uniformat II of the classification which is used for the building of knowledge management systems in AEC projects. There is a classification in the form of the table [11] as in the classification of software hazards used by software testing. There is a classification in form of graphic tag cloud [12], when keywords of text visualised, a size of words proportional to a frequency of using these words in the text. Classification can be in electronic form [13] like in SNOMED system (system of nomenclature of medicine clinical terms), which is a part of medicine information systems.

Classification of geodesic domes is in form of paper document. At present more modern forms of classifications are used, they are based on modern information technologies [15-16]. An electronic document is a document on the magnetic disk, which must be used on the computer. The electronic document can be displayed to show investigated objects, phenomenon and process. Electronic documents can be researched and used for scientific investigations.

That's why it was necessary to build an interactive electronic classification of geodesic shells and domes. This electronic classification of geodesic shells and domes is used for getting, keeping and demonstration of the information about geodesic shells, designing or building objects, authors of geodesic shells breakdown and about an implementation of parametric objects of ArchiCAD for these classes.

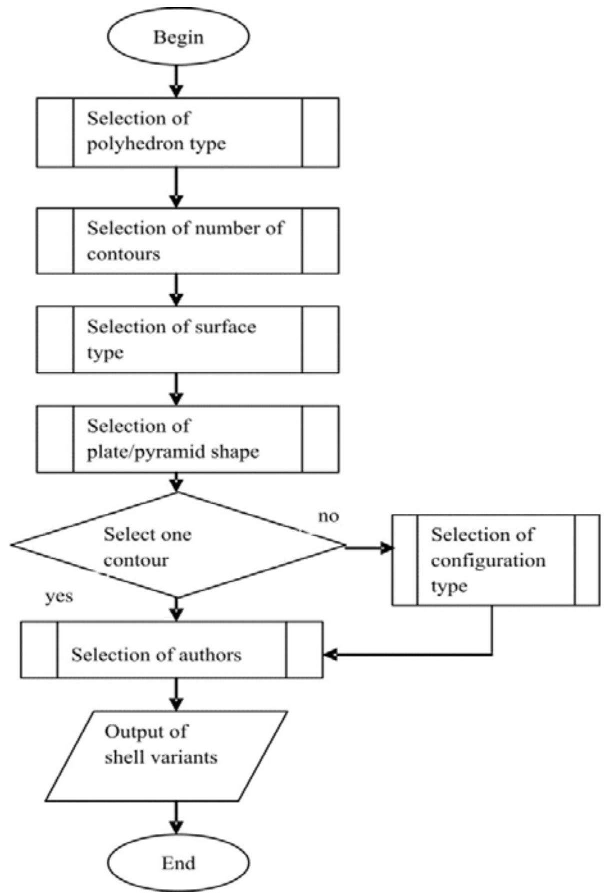

Figure-2. Flowchart of ECGEOD program.

Electronic classification of geodesic domes (ECGEOD) is a well- regulated structure including geodesic shells classes. Electronic classification implemented in form of the Visual Basic program with .NET Framework. Algorithm of this program is in the form of a flow chart (Figure-2). At the beginning of the work with the program type of polyhedron which is used for sphere breakdown of elements (tetrahedron, octahedron or icosahedron) is chosen. Then numbers of shell forming contours (single-contour or double-contour) is chosen. After that type of shell surface (of plates or of pyramids) is chose.

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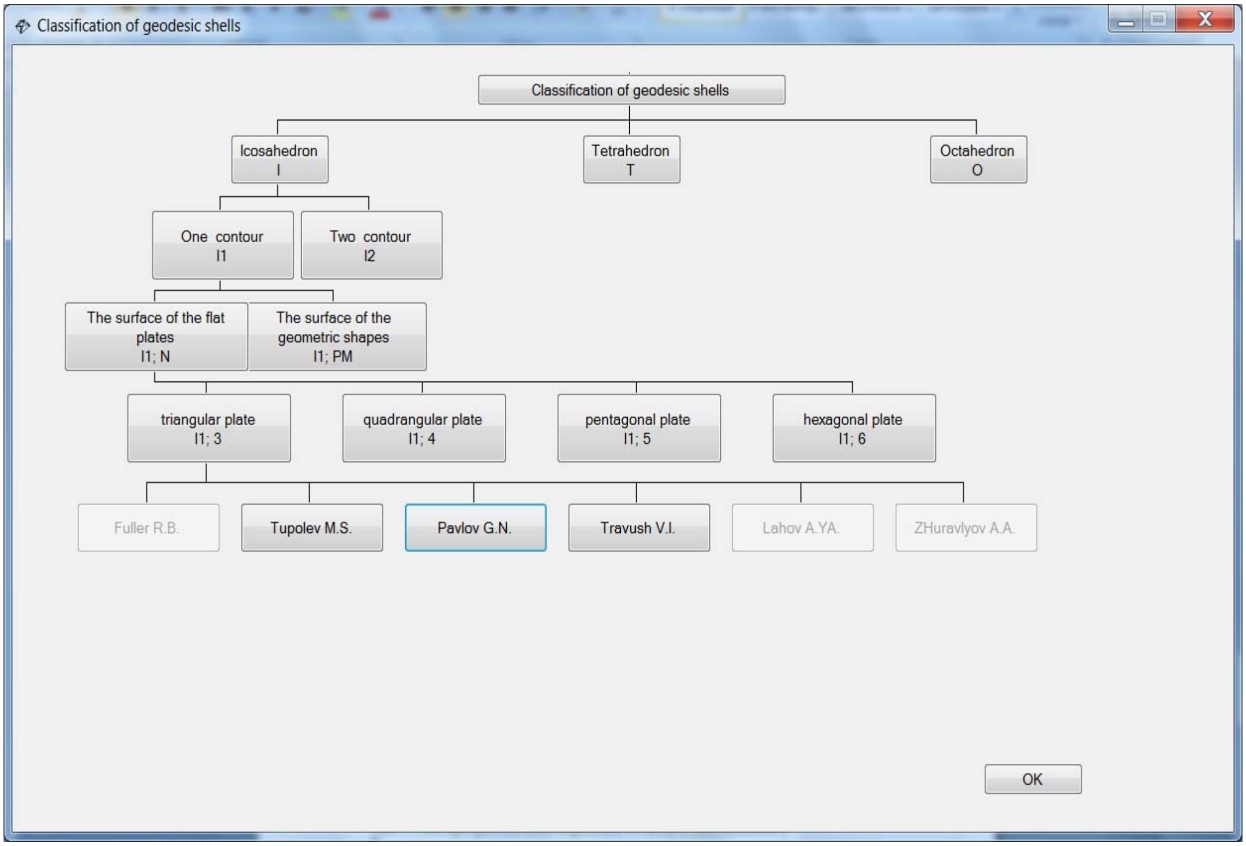

Figure-3. GUI of ECGEOD program.

Then the shape of a plate (triangular, quadrangular, pentagonal or hexagonal) for plate surface or shape of a pyramid (trihedral, tetrahedral, pentahedral or hexagonal) for pyramid surface of the shell is chosen. Finally using of single contour or double-contour shell is examine. If double-contour shell is chosen the type of the second contour (the same configuration or different configuration) will be used. If a single contour shell is used then go to next stage. Then the possible author of breakdown method for formed class of geodesic shell is chosen. On the last stage of algorithm visualise of geodesic shells variants.

The interface of the program of electronic geodesic domes classification is based on buttons which show classes and subclasses of geodesic shells. Classes form a hierarchical structure. Every level is defined with some classification attributes. The first level is defined with a type of polyhedron. The second level is defined with a number of contours; the third level is defined with a type of shell surface. The fourth level is defined with a shape of plate or pyramid. Objects realising classes of geodesic shells are shown on the lower level (Figure-3).

If some class is implemented, additional form with information about the author of breakdown, main characteristics, the image of the shell, information about implementation of a parametrical object of ArchiCAD for this class will be shown. You can see the program name in language GDL and variants of breakdown. If you choose another variant of breakdown you will see its image.

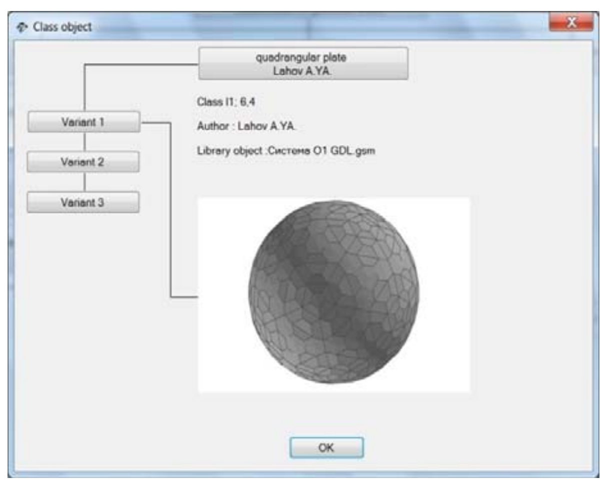

Figure-4. Additional form with information about the object of class I1; 4.

The additional form with the information on the object is shown in Figure-4 for a one-contour shell of quadrangular plates.

If you make double click under the image you will see it in large scale for studying of details. If you

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make click under the image again you will return to the previous form.

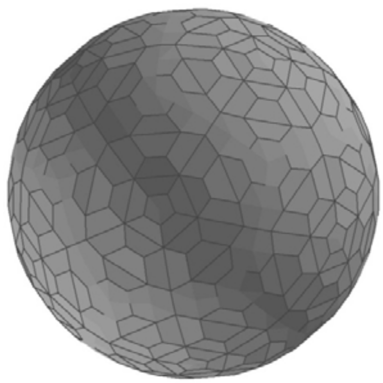

Figure-5. Additional form with the object of class I1; 4 in large scale.

The additional form with the information on the object is shown in Figure-6 for double-contour shell of triangle plates with internal second contour. The parametrical object for the given class of geodesic domes has been described in [17]. The new type of a double-contour geodesic dome with a plate space enclosing contour and a lattice internal load bearing contour is described in this article. Here the article contains a description of a principle of a duality for geodesic networks, questions of a breakdown of domes of plain hexagonal elements and of mainly plain hexagonal elements. New reusable parametrical objects on embedded programming language within ArchiCAD software GDL are described too.

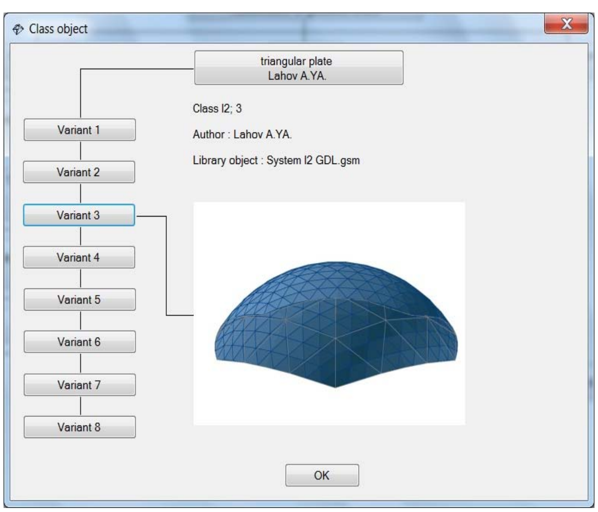

Figure-6. Additional form with information about the object of class I2; 3.

The additional form with the information on the object is shown in Figure-7 for a single contour shell of a triangular pyramid.

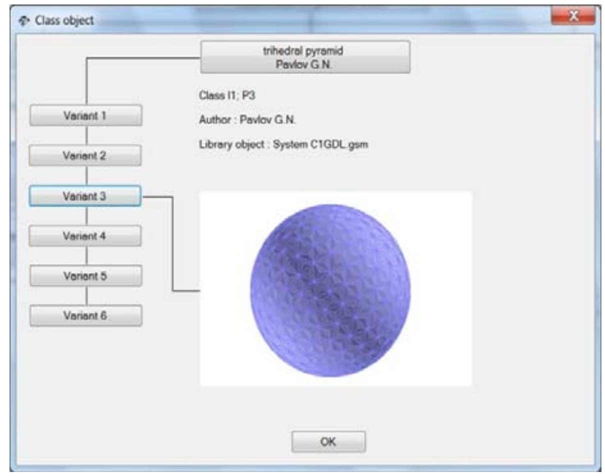

Figure-7. Additional form with information about the object of class I1; P3.

The additional form with the information on the object is shown in Figure-8 for double-contour shell of a hexagonal pyramid with external second contour.

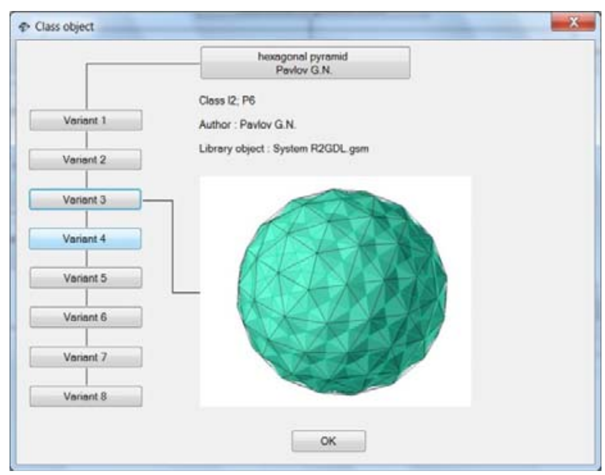

Figure-8. Additional form with information about the object of class I2; P6.

Parametrical objects for a one-contour shell of triangular plates, of pentagonal plates, of hexagonal plates, are presented in electronic classification also. Parametrical objects for a double-contour shell of hexagonal plates are presented. Parametrical objects for a single contour shell of a hexagonal pyramid are presented in electronic classification. Parametrical objects for a double-contour shell of a triangular pyramid are presented.

In electronic classification, Fuller's geodesic shells are presented also. For example, Golden dome at the American exhibition of 1959 in Moscow, a Pavilion of the USA on the World's Fair Expo 1967 in Montreal, Climatron in the Botanical garden of Saint Louis (the State of Missouri, the USA)(Figure-9).

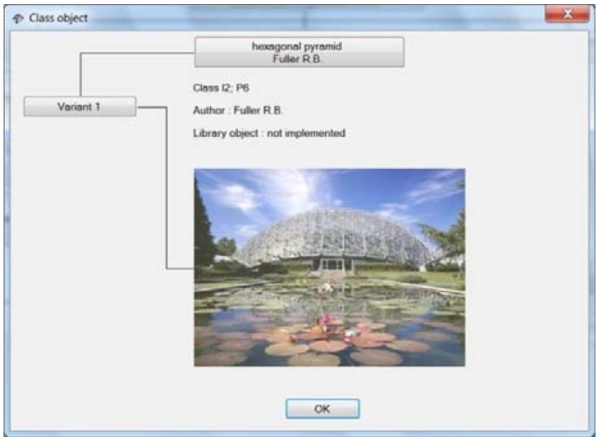

Figure-9. Additional form with information about the Climatron (class I2; P6)

If this class is not implemented information about it will be given (Figure-10).

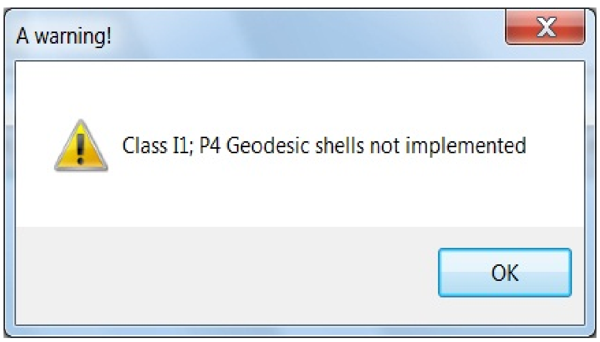

Figure-10. Additional form with information about the not implemented object.

CONCLUSIONS

Classification of geodesic shells and domes was built. This classification visualises subject domain of geodesic shells and domes, gives information about possible classes of geodesic domes. New types of single-contour and double-contour geodesic shells and domes have been revealed. They differ from already known types. This new type of geodesic domes can be developed as plug-ins for the ArchiCAD software. Using classification in interactive form (ECGEOD) it is possible to define how this class is realised: as an algorithm of breakdown or as a parametric object of ArhiCAD. It's possible to learn characteristics and see an image of built or virtual geodesic domes. Thus classification of geodesic shells and domes has information, systematising and predicting function.

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