A BIM APPLICATION ABOUT COMPUTATIONAL DESIGN: AN APPLICACION ABOUT SPATIAL MESH INTERSECTION

Bincaz-Calvo Jacques*, Manchado-del Val Cristina, Gómez-Jáuregui Valentín, Otero-González César

Departamento de Ingeniería Geográfica y Técnicas de Expresión Gráfica.
Universidad de Cantabria. España

*jacques.bincaz@alumnos.unican.es

ABSTRACT

This work is focused on the design of spatial meshes by the intersection of parallel trihedra (Otero 2000). This work develops methods to composition of spherical isosceles triangles. This issue has been developed before by (Otero 2000) and (Togores 2003) but without developing any software to create and handle spatial meshes.

This work carries out this task by 3 ways: 1º by using pre-existing families in BIM environment, 2º by creating new families and 3º creating spatial meshes through computer programming.

The methodology consists on creating spatial meshes on spherical triangles. These triangles can be isosceles or equilateral and can be grouped to create different shapes. The key of is to find an efficient way to calculate all the nodes and all the bars and replicate this structure all around.

To optimize the algorithm and solution it is necessary to characterize the geometry problem. The second part of the algorithm consists on creating the bars and to duplicate them, so at this point the algorithm has to be efficient to create a solution in a reasonable time.

KEYWORDS: Geometric design, spatial meshes, computational design, computational morphology.

1. INTRODUCTION

Structural meshes design involves several stages. The first one is purely artistic and architectural. The second stage consists on translating the ideas into a realizable project.

This work focuses on the last stage which means an engineering approach without putting aside the artistic approach of the engineer who has to translate the idea to beams, columns, spams, etc.

Recently, computational design of spatial meshes has evolved a lot because computers are able to manage a great amount of data and perform many calculations quickly and efficiently. The consulted bibliography shows that modern techniques in that matter are included into the computational structural analysis and finite element analysis. These techniques have brought improvements in shape optimization and meshing.

On the other hand, there are geometrical techniques that in common cases can only manage simpler shapes as spheres, domes, etc.

This works focuses on spatial meshes design by composition of spherical scales, which are created by intersection of parallel trihedra. This technique can be applied to create many type of covers and especially to create meshes and its application in BIM environments. This technique implements optimal meshing in some cases when possible; in other cases the uniform element distributions are justified.

2. RESULTS OF THE RESEARCH LINE

The principal idea in this work is to find an optimal mesh on a spherical surface, so it is necessary to define the surface geometry. To define this geometry it is necessary to choose a circumscribed polyhedron to the sphere. The tetrahedron (4 faces) and the icosahedron (20 faces) are good options because they have triangular faces. It is important to define the trihedron generated by the three edges of the faces and the center of the polyhedron (see figure 1). In the first part of this work we will only work with the icosahedron. The icosahedron cuts the sphere in 20 spherical triangles, in which we are going to find a mesh with optimal element distribution.

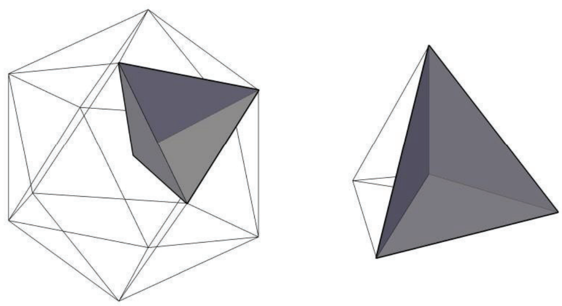


Figure 1. Icosahedron and tetrahedron trihedra.

The meshing process starts with what is known as ”cut by parallel trihedra”, that consists on cutting the spherical triangle by parallel plane to the original trihedra planes. Their cuts concur at the bisector planes of the trihedra (see figure 2). There are 3 degrees of freedom in this construction, the sphere radius “R”, the number “n” of subdivisions in the arcs of the border and the angle “λ” between first node of the “k” cut and the second node of the “k-1” cut. To simplify the degrees of freedom, λ takes the value of α/2, being α the subtended angle of the border arc from the center of the icosahedron.

The first executable program is written in VBA environment of AutoCAD due to the ease of the debugging process for the graphic results.

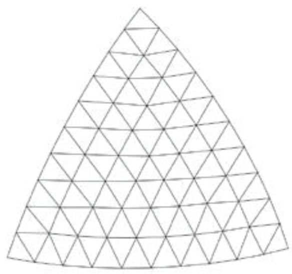


Figure 2. Spherical triangle (icosahedron).

The next step is to define new scale geometries, by moving the trihedra along the axis “OO’” (see figures 3 and 4). This axis is defined by two points, the center of the polyhedron and the 3- order rotation axis of the icosahedron face. By moving the trihedra, it cuts the sphere at different locations, generating lowered domes if the displacement is negative and globular domes if it is positive (see figure 3). The displacement along the axis “OO’” is a new degreof freedom “ΔR”.

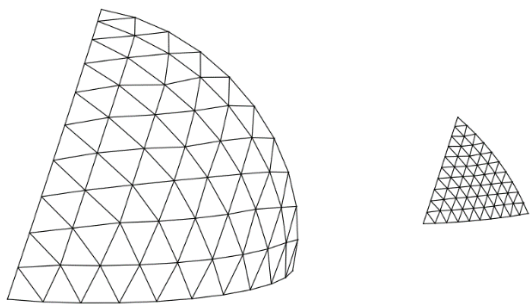
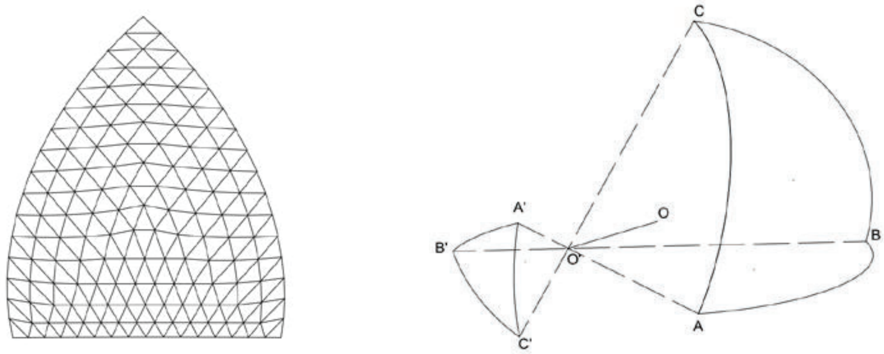


Figure 3. Globular dome (left) and lowered dome (right).

The last construction shows a possibility in terms of finding a new shape. The globular dome (type A) is defined by 3 points A, B and C and the lowered dome (type D) is defined by 3 points too, A’, B’ and C’. There are two more type of trihedra, type ABC’ (type B) and A’BC (type C) (see figure 4). These new trihedra have isosceles triangular faces so the 4 type of trihedra can



be put together to create new shapes. The rule to compose the trhihedra is that the total solid angle of them has to be equal to 4π. Figure 5 shows an example of different compositions of trihedra type A, B, C and D.

Figure 4. Isosceles triangle mesh and trihedra A, B C y D.

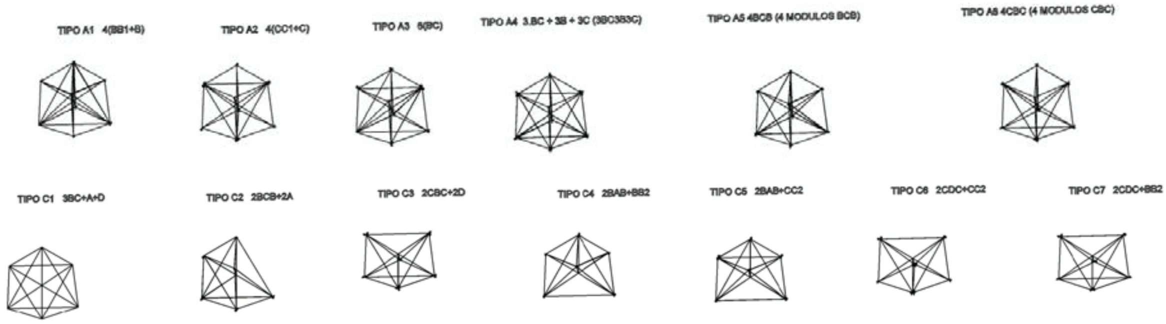


Figure 5. Compositions of trihedra.

The models that have been created in CAD environment are exported to BIM. The creations of the joints is made by specific software by parametrizing them so they can adapt to every single node.

3. RESEARCH TEAM

Name: **César Antonio Otero González**
Center: Universidad de Cantabria
Department: Departamento de Ingeniería Geográfica y Técnicas de Expresión Gráfica
Category: Professor.

Name: **Cristina Manchado del Val**
Center: Universidad de Cantabria
Department: Departamento de Ingeniería Geográfica y Técnicas de Expresión Gráfica
Category: Professor.

Name: **Valentín Gómez-Jáuregui**
Center: Universidad de Cantabria
Department: Departamento de Ingeniería Geográfica y Técnicas de Expresión Gráfica
Category: Porfessor.

Name: **Jacques Bincaz Calvo**
Center: Universidad de Cantabria
Department: Departamento de Ingeniería Geográfica y Técnicas de Expresión Gráfica
Category: Student.

4. REFERENCES

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NUEVOS MODELOS DE INVESTIGACIÓN Y COLABORACIÓN EN INGENIERÍA GRÁFICA

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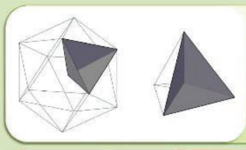
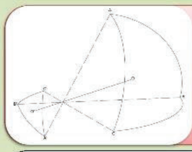
OBJECTIVE

Creating optimal meshes on triangle contours from spherical surfaces. These surfaces came from a procedure called “intersection of parallel trihedra”. These meshes can be composed to create more complex shapes.

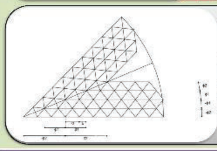
INTRODUCTION



Trihedra obteined from an icosahedron (left) and from a tetrahedron (right)



The trihedra moves along OO’ (both points are the circumcenters of triangles ABC and A’B’C’) axis creating a large amount of different compositions ➔ Parallel trihedra (Otero 2000)



Then the mesh is composed by using R1 element distribution. R1 distribution is a way to obtain a pattern of bars from nodes.

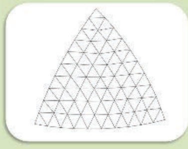
METHODOLOGY

DEFINING MODEL GEOMETRY VARIABLES (STARTING POLYHEDRON,RADIUS...) → INTRODUCING GEOMETRY INTO A PROGRAMMING ENVIRONMENT (VBA) → CREATING NODES AND BARS ACCORDING TO R1 DISTRIBUTION → EXPORT DATA TO A BIM MODEL (REVIT AND INVENTOR). REVIT CREATES THE BARS AND INVENTOR DESINGNS THE JOINTS.

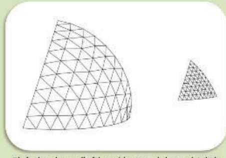
RESULTS

THE RESULTING SHAPES OF MESHES ARE:

1. SPHERICAL TRIANGLES
2. GLOBULAR AND LOWERED DOMES
3. ISOSCELES TRIANGLES



Spherical isosceles triangle



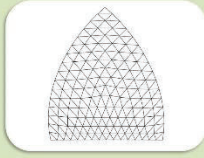
Globular dome (left) and lowered dome (right)

There are 4 different shapes appearing :

- 2 Globular domes/lowered domes/spherical triangles (type A and type D)
- 6 Isosceles triangles (type B and C)

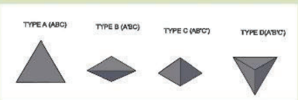
The 4 type of trihedra allows to create different shapes. The conditions are:

1. Adjointing faces must be equal.
2. Solid angle must be 4π (to be a closed shape)



Isosceles triangle

The next images show how it is posible to create different shapes from 4 basic shapes. The name of each composition tell how the trihedra have been combined.



Type of trihedra

Shapes composition

[1] Otero C. “Diseño geométrico de cúpulas no esféricas aproximadas por mallas triangulares con un número mínimo de longitudes de barras”. Ph. D. University of Cantabria. Santander 1990.
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