Erhan Karakoç

Performative Architecture with an Adaptive Building Facade

Topic: Architecture

Author:
Erhan Karakoç
İstanbul Kültür University, Department of Architecture,
Turkey

Main References:

[1] Ghamari H. ve Asefi H. (2010). Toward Sustainability by the Application of Intelligence Building Systems. The Second International Conference on Sustainable Architecture, Amman, Jordan.

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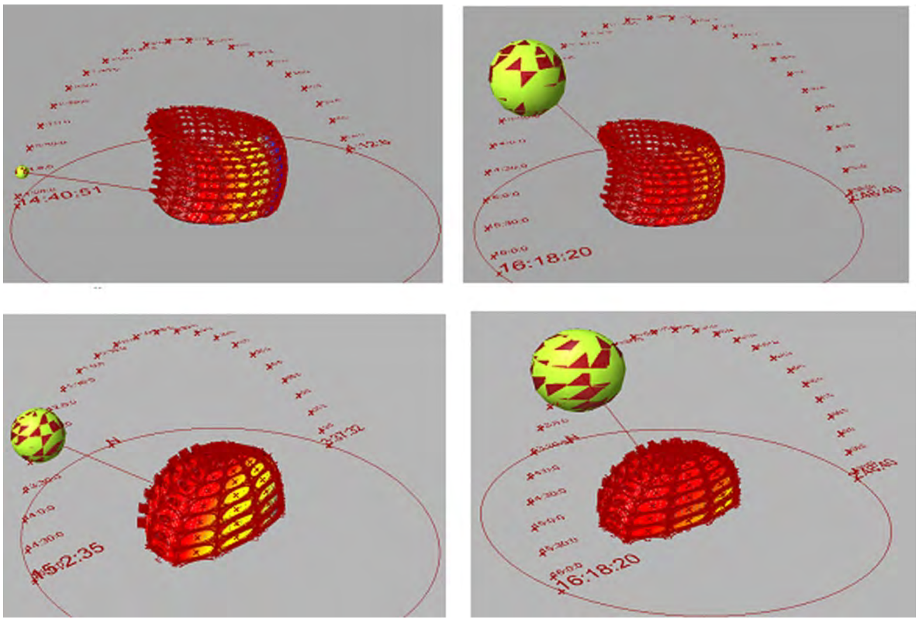
[3] Oxman R. (2008) "Performance based Design: Current Practices and Research" Issues IJAC

Abstract:

Performative and adaptive architecture is very popular nowadays. Especially, environmental problems such as climate changing and air pollution is increasing by the non-technologic buildings. So, designers are interested on the adaptive building to stop this environmental problems as soon as it is possible by some technological methods as performative and adaptive architecture. In this article, performance based adaptive building envelop design criteria and methods will be explained with a building envelope (model suggestion), that has adaptation ability to sun.

Within this article, it is evaluated that the theoretical works and application data. The performative, adaptive and pneumatic architecture which are explained in theoretical part of the article, are examined in terms of the place in architectural medium, design strategies and project examples. At the end of these examinations, some deductions are made. In the application part of the article, it is examined how the adaptive envelope reacts in the different time zones and different places and seasons. Also the algorithm is applied on different geometries to analyzed the forms which emerged according to the sun. These output are collected and evaluated to understand how the algorithm works. Outcome is affected differently according to the parameters. In terms of model proposal, the computer programs which related to the computational design are used.

For the method of the proposal, nature inspired approach is used. The opening and closing of the stomas which are the pores of the plants are analyzed. These systematical pressure changes which are observed in the plants provide to use a different analogy technic for the application of the model. Thanks to the nature inspired design approaches, the optimization of the building envelope according to the sun is ensured and the algorithms which are led to the changes in building morphology are created.



Model suggestion: facade and sun orientation with performative and adaptive systems

Contact: erhankarakocitu@gmail.com

Keywords: Performative Architecture; Adaptive Architecture; biomimicry; Optimization.

Performative Architecture with an Adaptive Building Facade

MSc. Arch. Erhan Karakoç, R.A.

Department of Architecture, İstanbul Kültür University, İstanbul, Turkey

e-mail: erhankarakocitu@gmail.com

Professor of Architecture Gülen Çağdaş

Department of Architecture, İstanbul Technical University, İstanbul, Turkey

e-mail: glcagdas@gmail.com

Premise

Performative and adaptive architecture is very popular nowadays. Especially, environmental problems such as climate changing and air pollution is increasing by the non-technologic buildings. So, designers are interested on the adaptive building to stop this environmental problems as soon as it is possible by some technological methods as performative and adaptive architecture. In this article, performance based adaptive building envelop design criteria and methods will be explained with a building envelope (model Proposal), that has adaptation ability to sun.

1. Introduction

Within this article, it is evaluated that the theoretical works and application data. The performative, adaptive and pneumatic architecture which are explained in theoretical part of the article, are examined in terms of the place in architectural medium, design strategies and project examples. At the end of these examinations, some deductions are made.

In the application part of the article, it is examined how the adaptive envelope reacts in the different time zones and different places and seasons. Also the algorithm is applied on different geometries to analyse the forms which emerged according to the sun. These output are collected and evaluated to understand how the algorithm works and evaluates. Outcome is affected differently according to the parameters. In terms of model proposal, the computer programs which related to the computational design are used (Karakoç, 2015).

For the method of the proposal, nature inspired approach is used. The opening and closing of the stomas which are the pores of the plants are analysed. These systematically pressure changes which are observed in the plants provide to use a different analogy technic for the application of the model.

Thanks to the nature inspired design approaches, the optimization of the building envelope according to the sun is ensured and the algorithms which are led to the changes in building morphology are created.

2. Performative Architecture

Performance based adaptive buildings have become much more important in case of the changeable climate parameters. Performance based adaptive building envelopes, which can change according to the environmental factors, enhance the living comfort of the users, ensure the sustainability, reduce the operation costs and extend the life of the building thanks to integration the other disciplines with the architecture (Karakoç, 2015).

The architectural design has different methods. Performance based adaptive architecture is one of these methods. Because the architecture issues are related to lots of variables, it has become necessary to examine these issues with the other disciplines like engineering, natural and social sciences. In this article, it has been evaluated severally in regarding to performance based adaptive architecture and these evaluations are shown via the example analyses.

The inputs of the performance based design are examined and the effects of these inputs upon the adaptive building envelope are explained by evaluating the data (Oxman, 2008).

The important part of the article is derived from the recently developing issues according to the changes in architectural approaches like the performative, adaptive and pneumatic architecture. “Form follows performance” is a new tag for today’s architectural style (Hensel, Menges, 2008).

In this article, it is explained that the effects of computational design tools upon the design of the adaptive systems by authors. In the design process of the project which is proposed, it is examined that the effects of the parametric based design tools upon the performance based adaptive and pneumatic systems.

It is clarified that the software which are used in constitution of the different systems, morphologies and geometries, the methods and the researches in regards to algorithms providing the control of the performance based adaptive and pneumatic morphologies within the project.

3. Adaptive Architecture

Adaptive buildings and facades are emerged at the beginning of the 1980’s (Wiggington, 2002). Adaptive buildings can process the conditions inside and outside of the envelope and change its forms according to effect or turn some passive climatic systems on.

For adaptive architecture, environment must be harmonious with architecture and other natural and artificial elements must be harmonious with building envelope (Ghamari, Asefi, 2010).

Adaptive architecture provides the user to live under the comfortable and ideal conditions in the building by forming the architecture with environmental factors. Addition to this, adaptive architecture is important regarding the protecting the environment and sustainability.

In the world which the conditions change constantly, the environmental factors play an important role. It is necessary to design adaptive buildings in which the climate changes occur permanently.

Adaptive architecture as discussed in this research proposes a new strategy for performative architecture defined as a multi-layered system that communicates with environment, in this case humans, through both software and hardware and has the ability to change its rules during its interaction with the environment (Karakoç, 2015).

Adaptive building have many advantages when we compare to traditional buildings. This advantages that is during life-cycle are more comfort for building users, more stable buildings, less management expenses and sustainability.

Adaptive buildings also have some potentials for future and nowadays. These potentials are developed “decision support mechanisms”, material technology (nano- technology etc.), computer aided design and computer aided manufacturing tools.

In this article, definition of adaptive buildings, advantages and potentials of adaptive buildings and design process of performance based adaptive building will be explained.

4. A Model for Designing Performance Based Adaptive Building Envelope

Sun is the most important parameter for environment and climate, especially for a model that is performance based and adaptive. In this chapter, design process of a model that is react to the sun and its data in a simulation with different software will be explained.

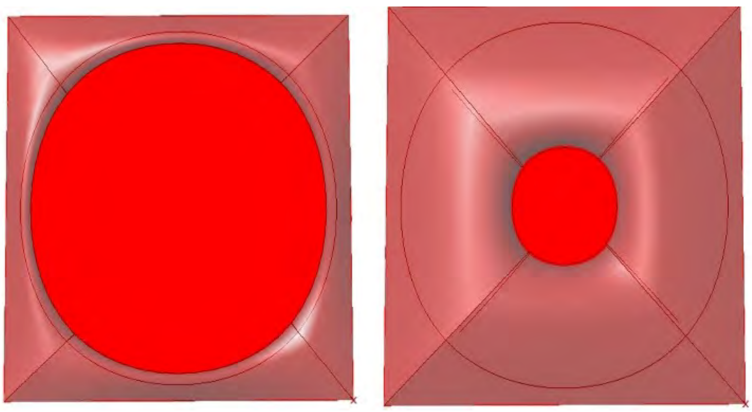


Figure 1: Sun orientation of the modules as the proposed model (Module: Left hand side is opened, right hand side is closed)

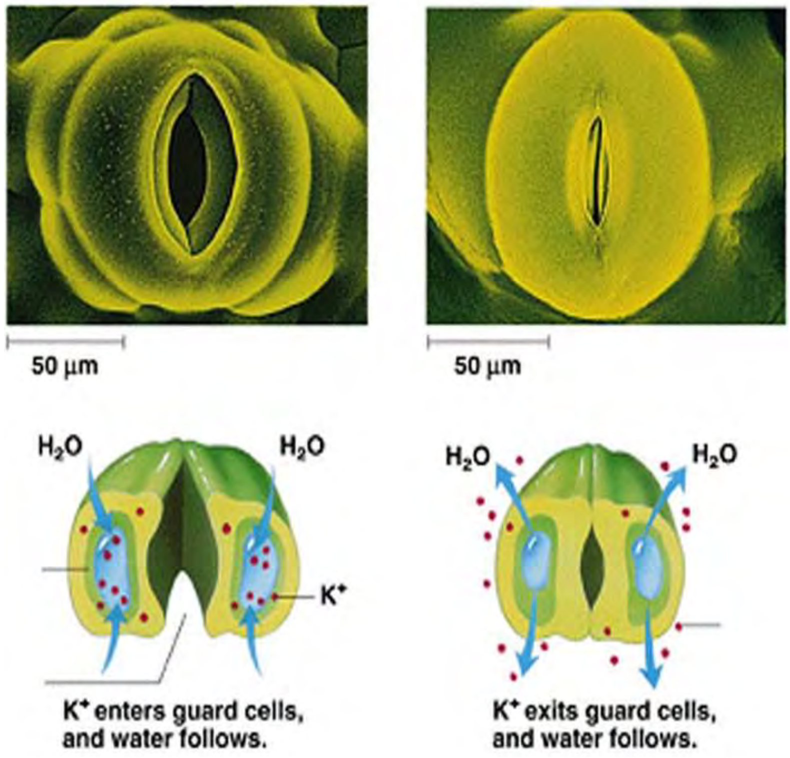


Figure 2: Sun Orientation in the nature with inner pressure of plants (plant stomata: Left hand side is opened, right hand side is closed)

Nature inspired design is really suitable to create and design optimized buildings and its envelopes. Optimization in architectural design can be used for understanding the adaptive building and performance based design (Figure 1).

Plants can optimize water levels, air quality and pressure on the stomata with a specific system. In this module design, it is aimed to reach the similar system with the "stomata optimization" (Figure 2).

Nature inspired design that is used for optimization is evolved to pneumatic design and adaptive design with a performative inputs. These performative inputs can be analysed easily by this visual code (Figure 3) and can provide a reaction to climate and especially sun.

Performance based adaptive building envelope is designed with the "Rhinoceros" and "VB.net scripts" and by the data of suns position changings as the seasons and times during the day.

Solar radiation is calculated with a parametric software script in VB.net and building envelope is changed according to sun and its data such as solar radiation, angle, latitude, longitude and other parameters (Figure 3).

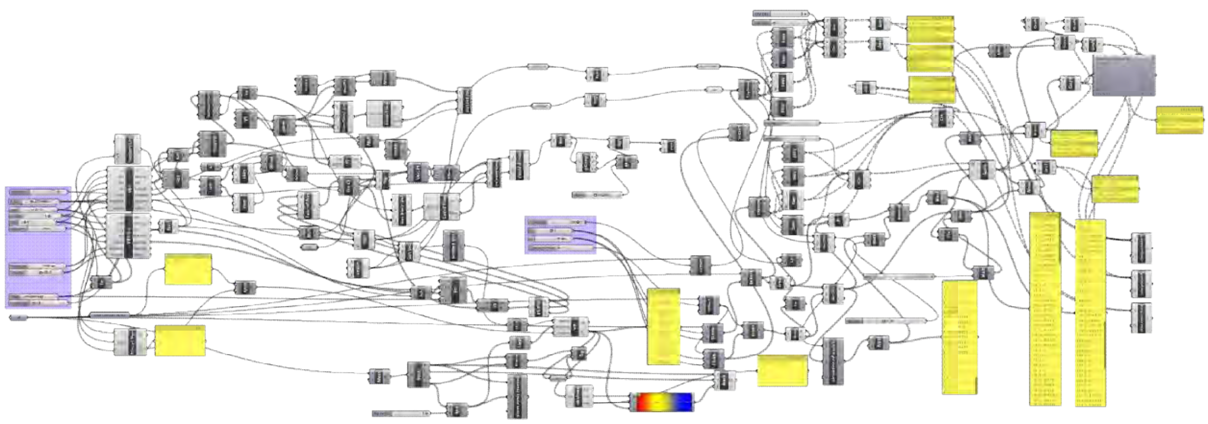


Figure 3: Visual Code part of "the model for designing performance based adaptive building envelope"

In this model design, there is a grid systems that include some modules uniquely designed and react to environment by its own data. Some parameters for this model are simulated first as a solar radiation and then angle and the other parameters and then it optimize the all modules. After all modules are calculated oriented to sun, porosity of the modules can be change by the data and this envelope control system by an decision making algorithm (figure 3).

4.1 Model Proposals on the Seasons

As the model data input changings forms can be change as the angle of the sun, solar radiation, sun direction and other parameters in the shape and modular organisation. Under this title four different experimental shapes in winter and summer results will be explained.

4.1.1 Model Proposals on the winter season (January)

The four different experimental shapes will be shown in this section as the winter seasons (January) (fig.4-7).

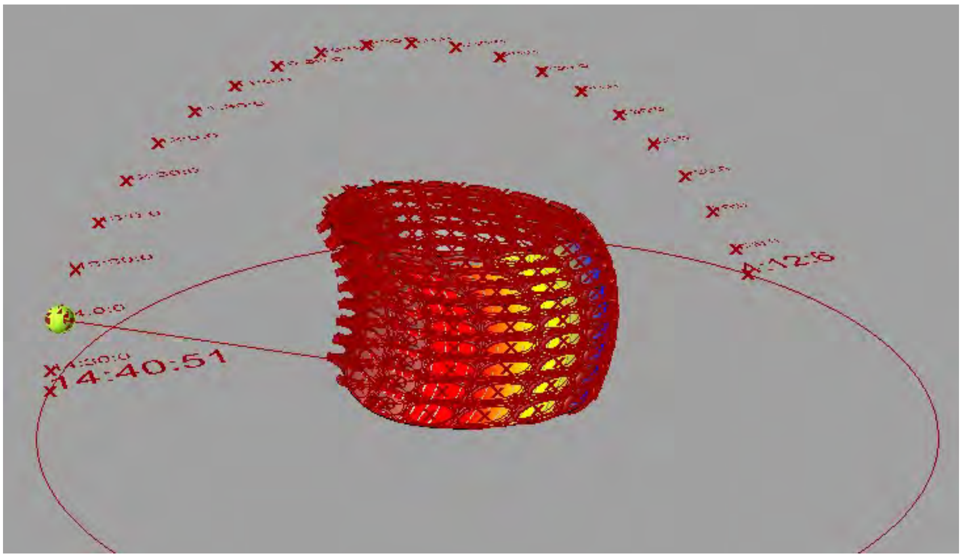


Figure 4: Example 1 form in winter (January)

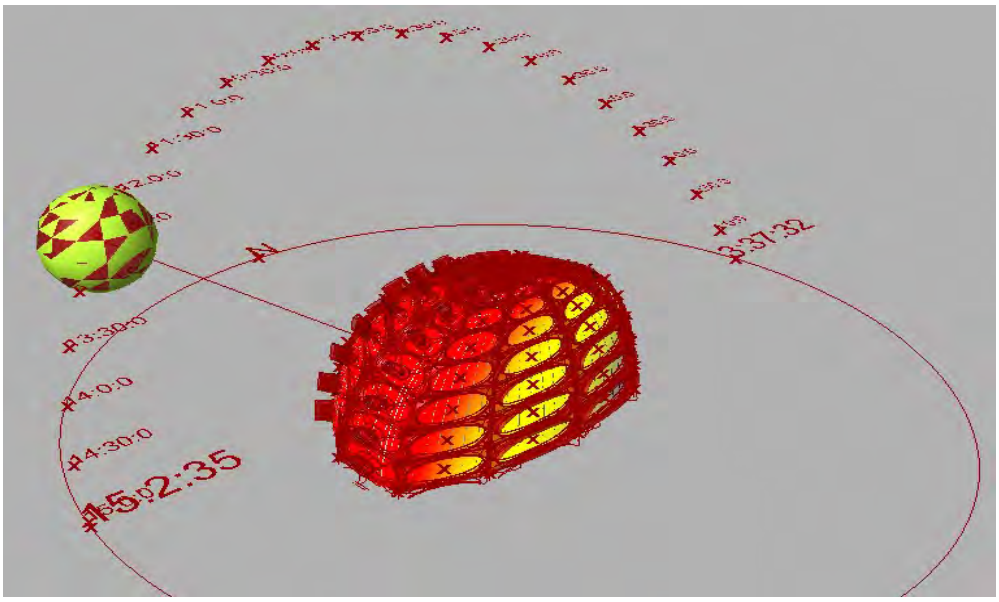


Figure 5: Example 2 form in winter (January)

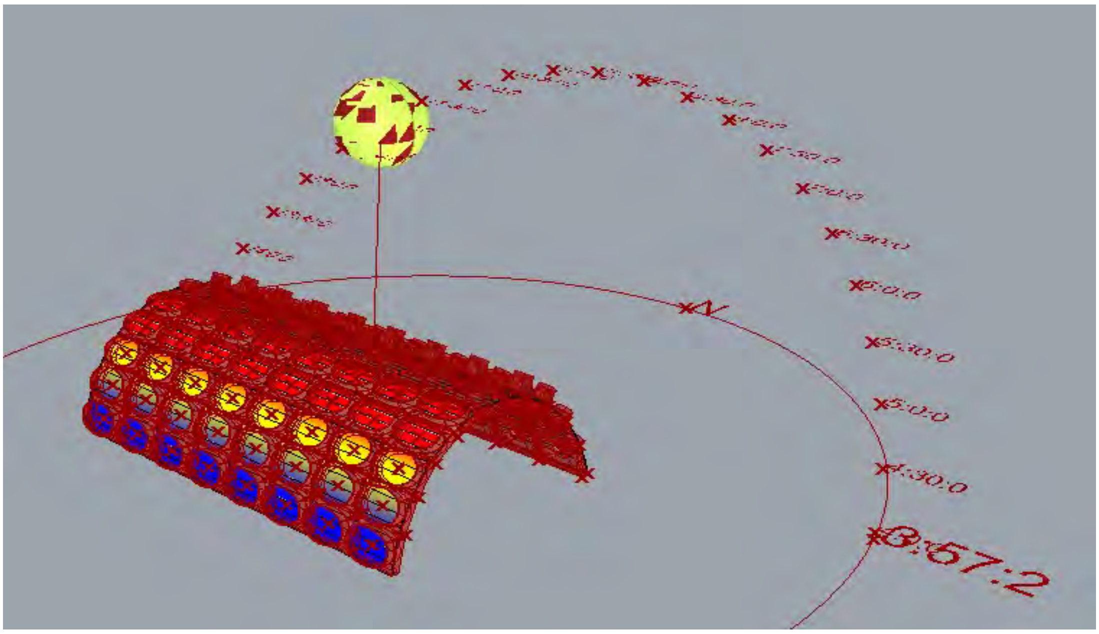


Figure 6: Example 3 form in winter (January)

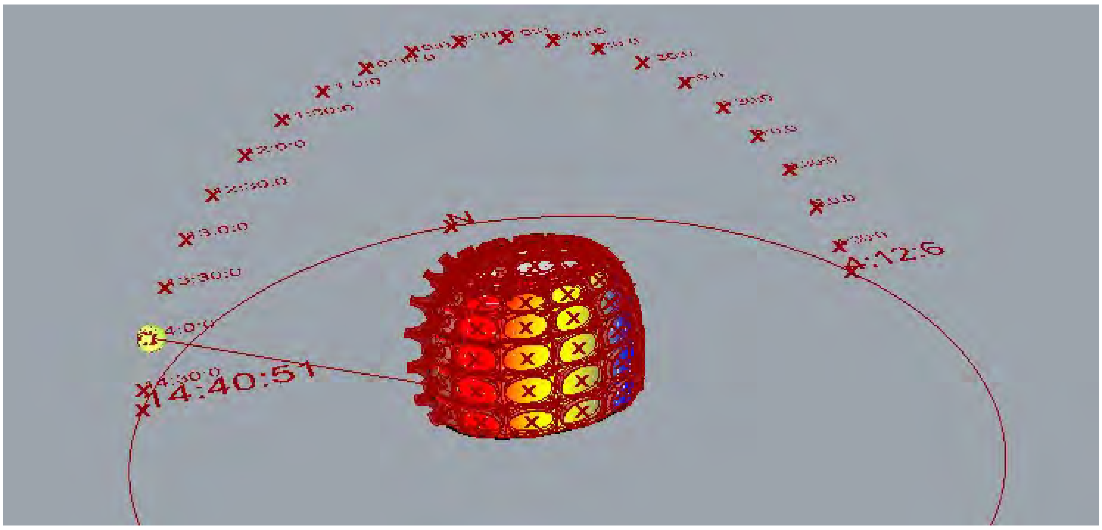


Figure 7: Example 4 form in winter (January)

4.1.1 Model Proposals on the summer season (June)

The four different experimental shapes will be shown in this section as the winter seasons (January) (fig.8-12).

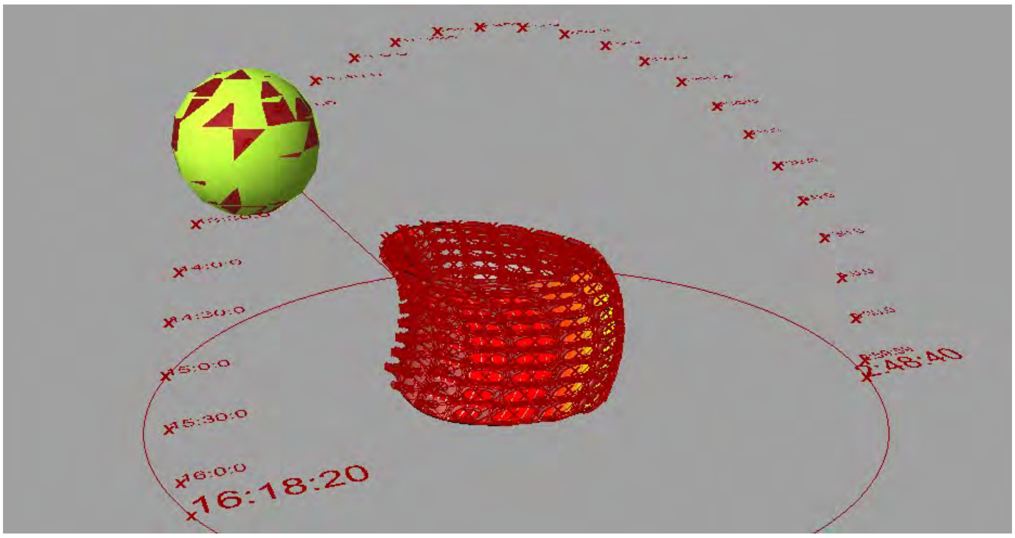


Figure 8: Example 1 form in summer (June)

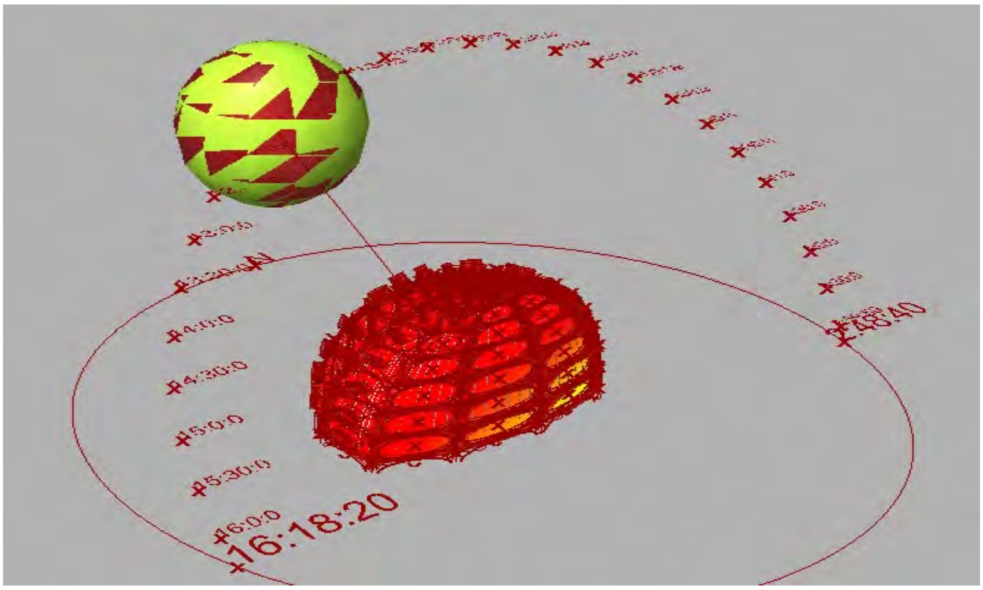


Figure 9: Example 2 form in summer (June)

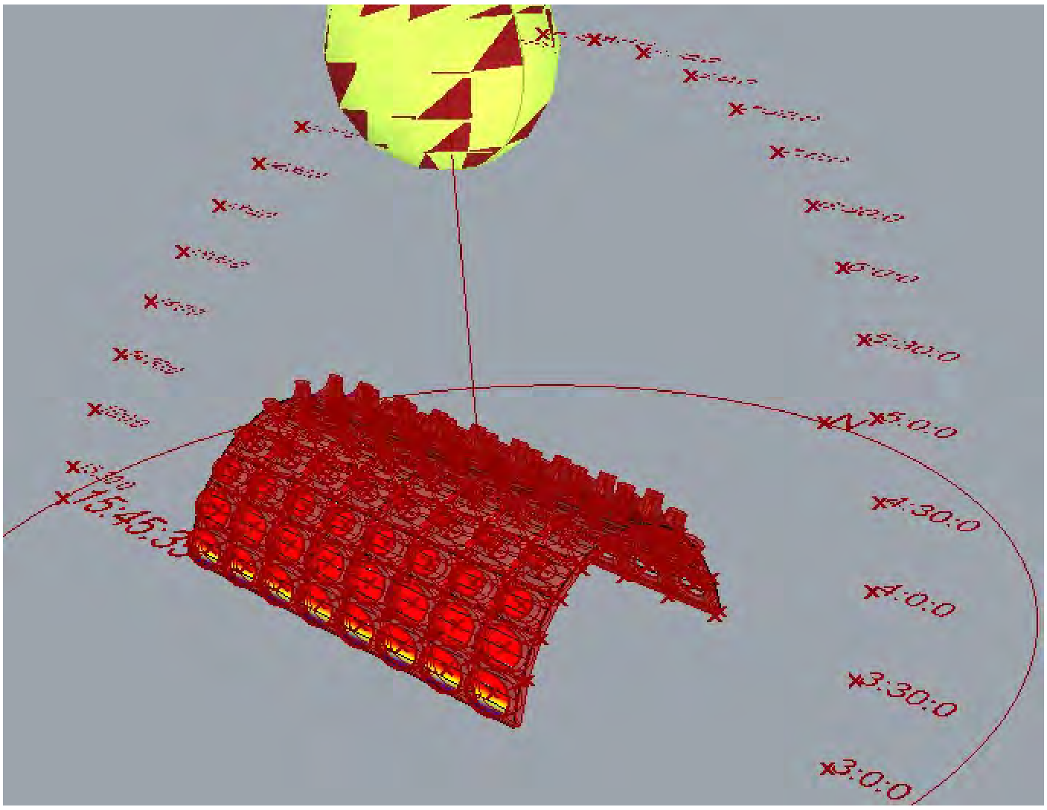


Figure 10: Example 3 form in summer (June)

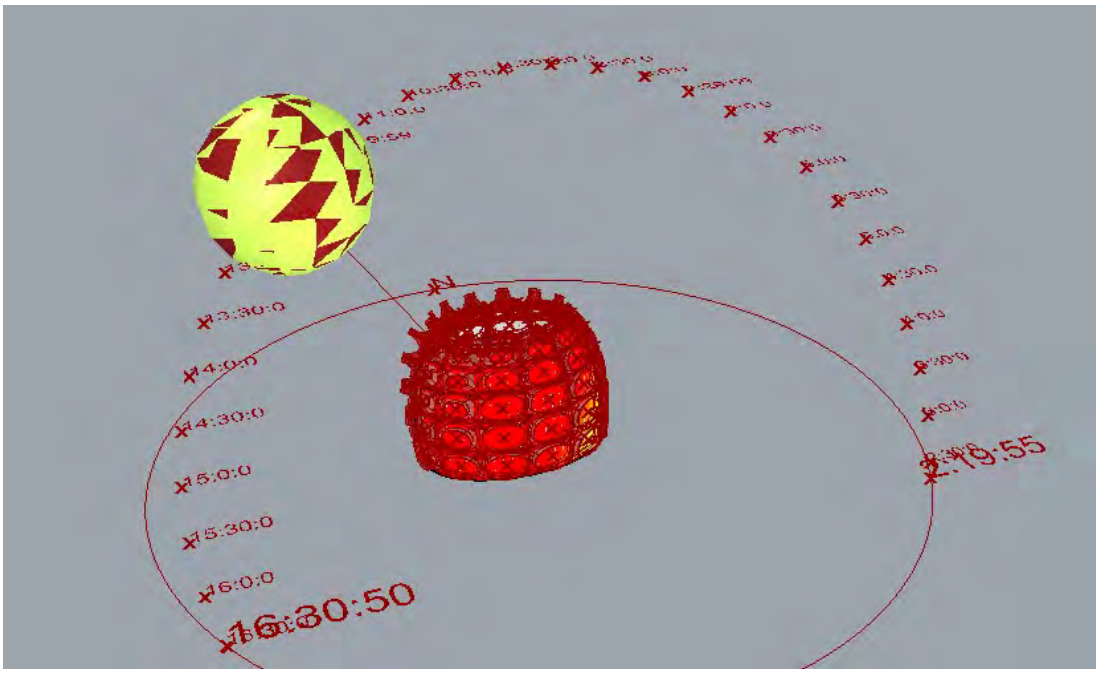


Figure 11: Example 4 form in summer (June)

4.2 Model Proposal on the Different Hours on the Daytime

As the model data input changings forms in the daytime can be change as the angle of the sun, solar radiation, sun direction and other parameters in the shape and modular organisation. Under this title four different experimental shapes in morning, afternoon and evening results will be explained.

4.1.1 Model Proposal in the morning

The four different experimental shapes will be shown in this section as the morning (fig.12-15).

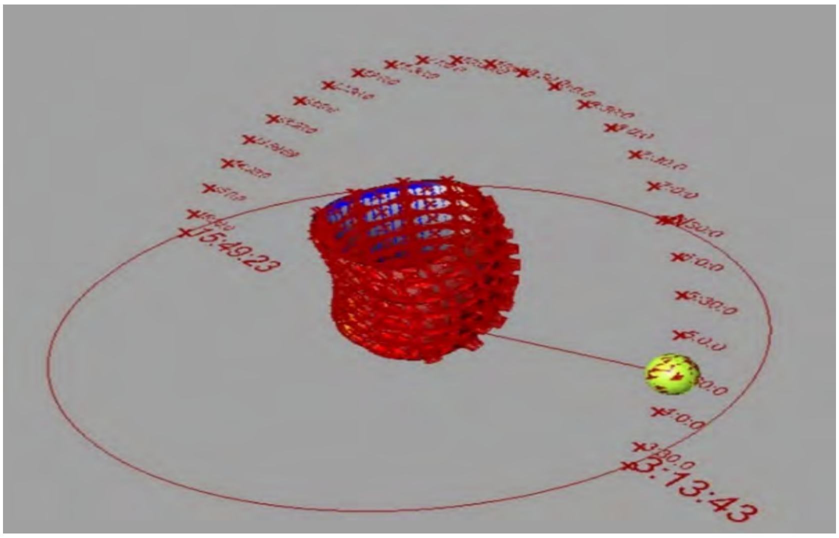


Figure 12: Example 1 form in morning

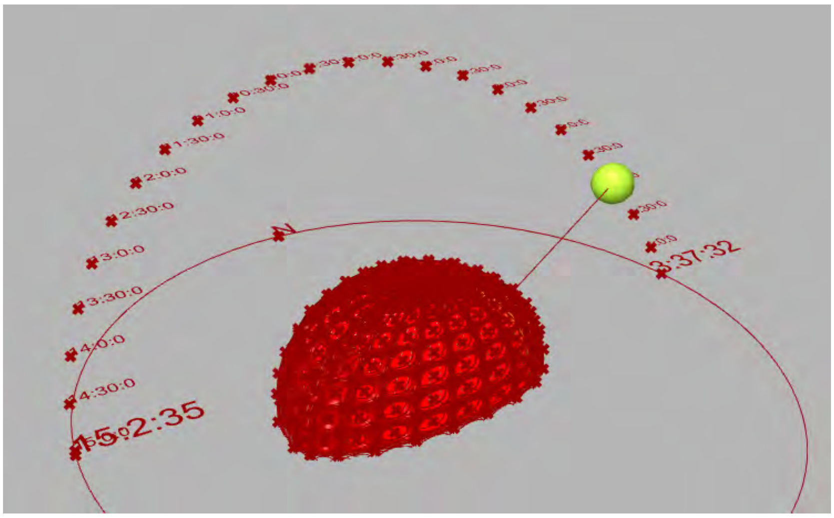


Figure 13: Example 2 form in morning

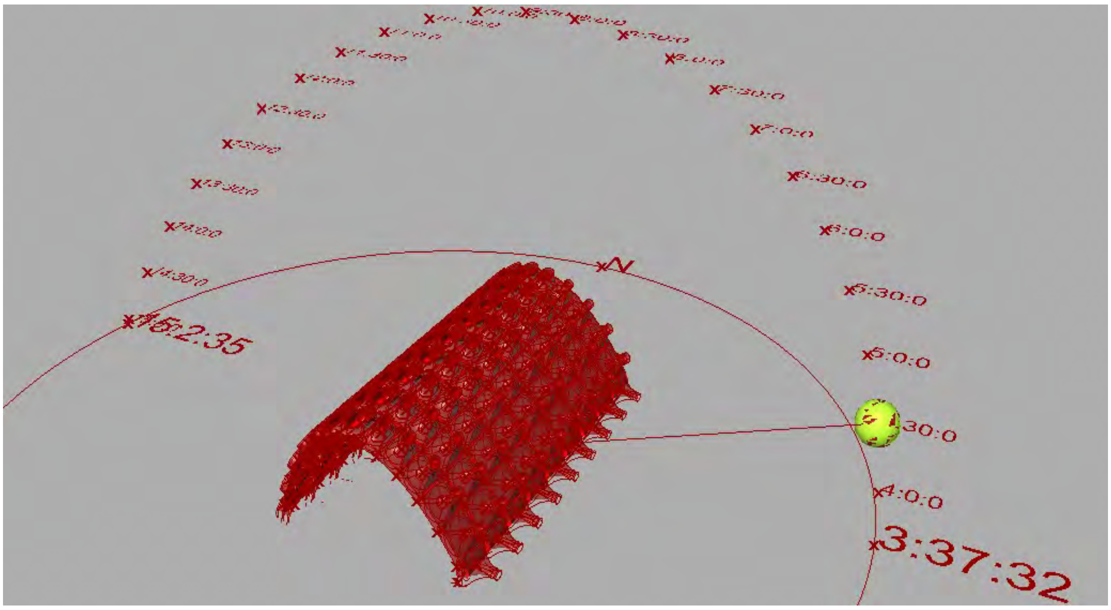
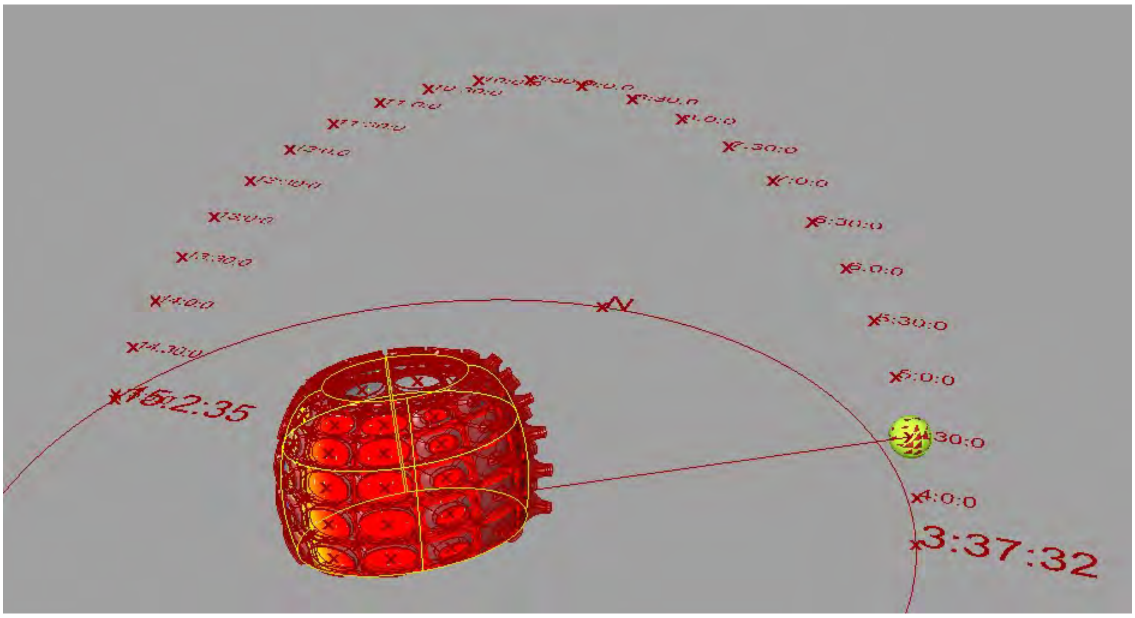


Figure 14: Example 3 form in morning

Figure 15: Example 4 form in morning



4.1.2 Model Proposal in the afternoon

The four different experimental shapes will be shown in this section as the afternoon (fig.16-19).

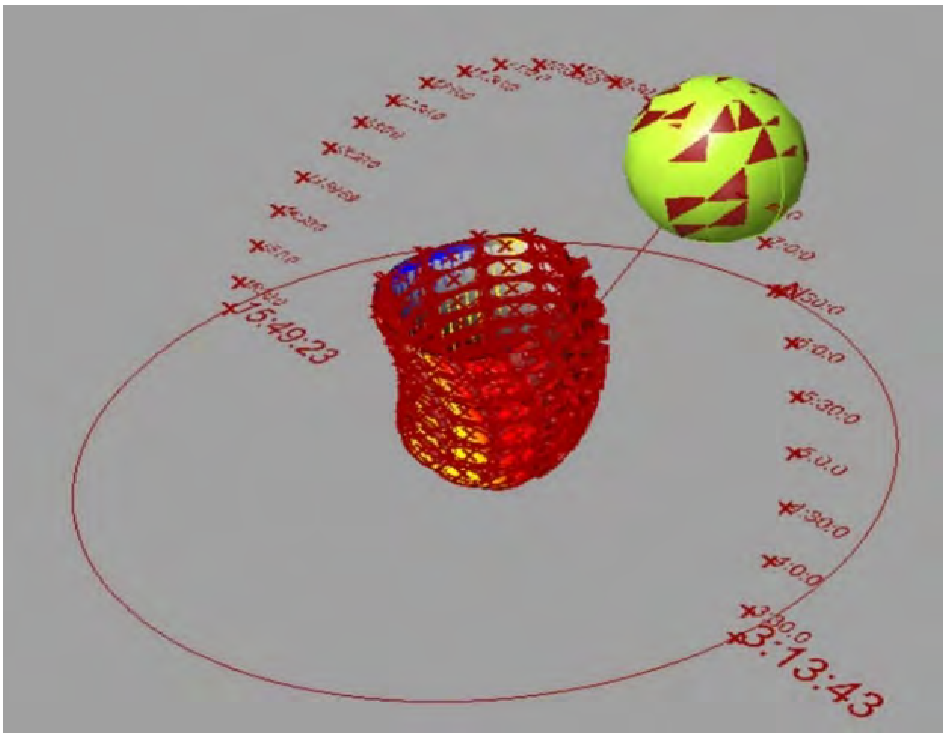


Figure 16: Example 1 form in afternoon

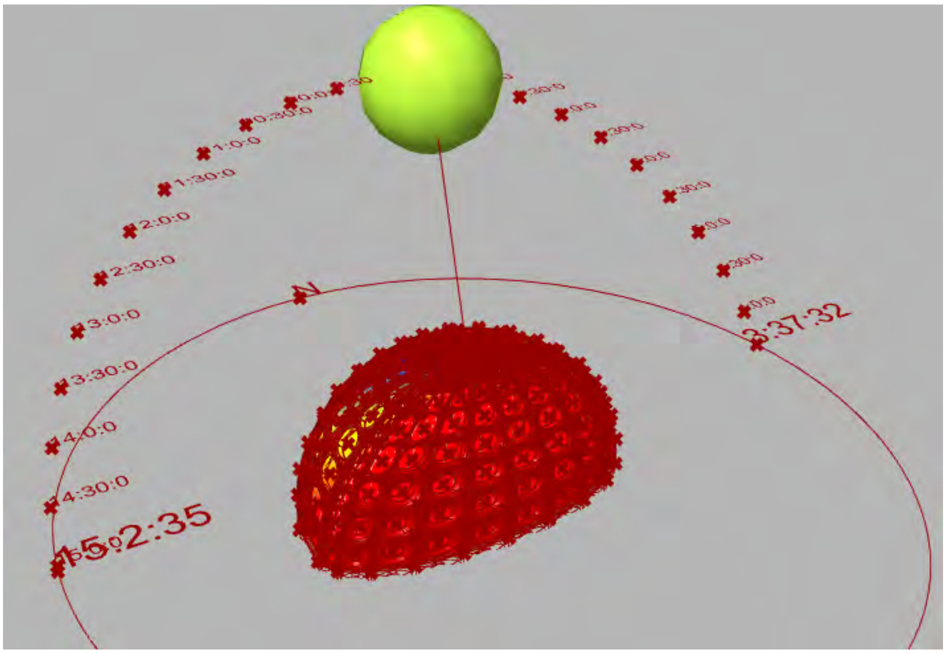


Figure 17: Example 2 form in afternoon

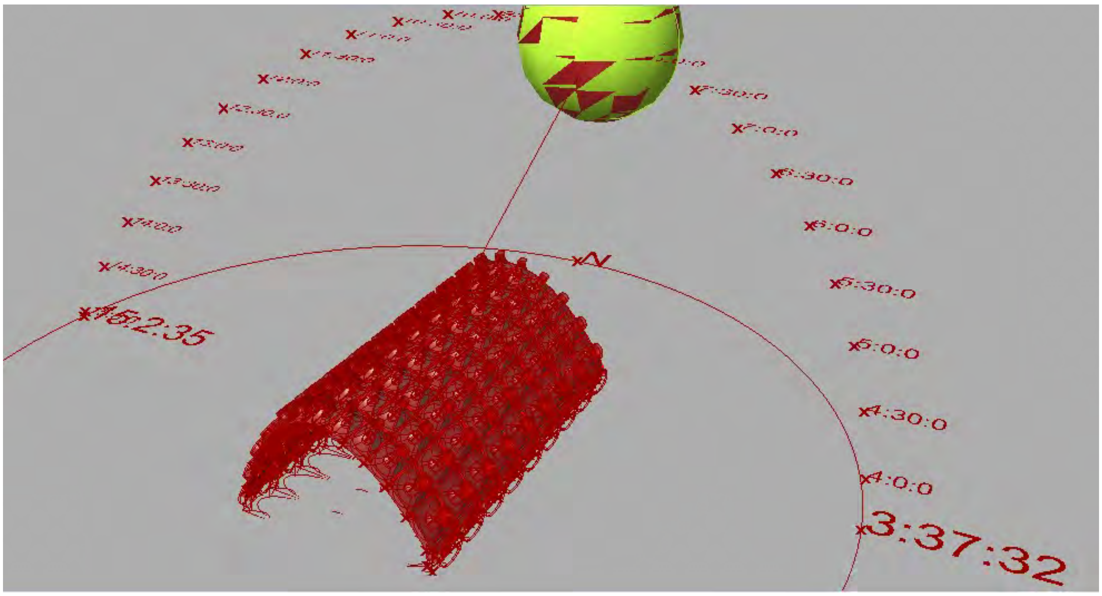


Figure 18: Example 3 form in afternoon

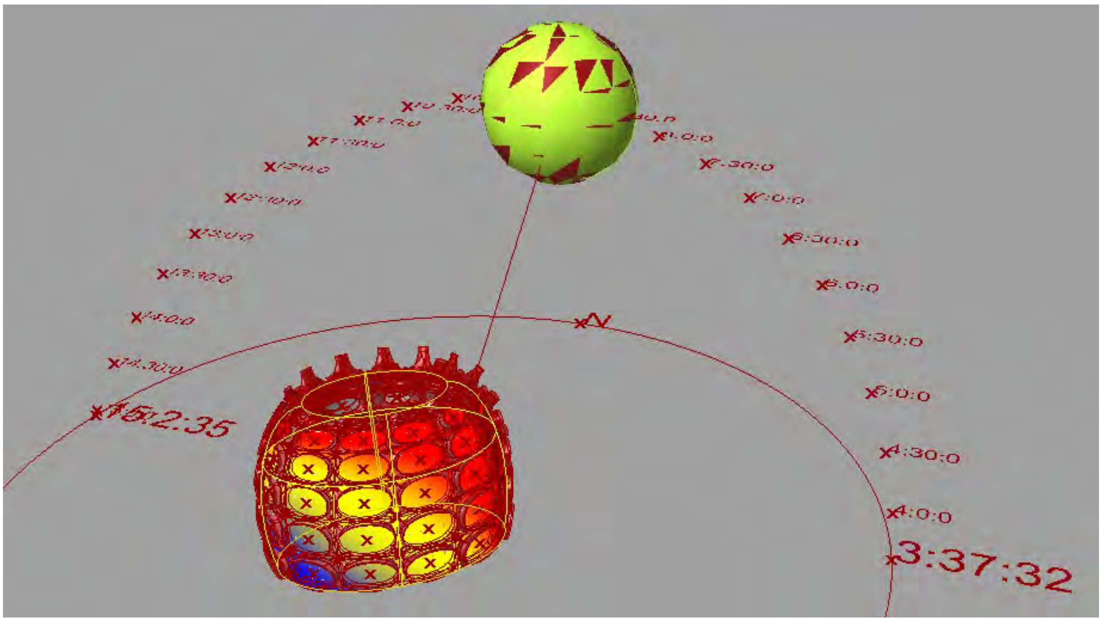


Figure 19: Example 4 form in afternoon

4.1.2 Model Proposal in the afternoon

The four different experimental shapes will be shown in this section as the evening (fig.20-23).

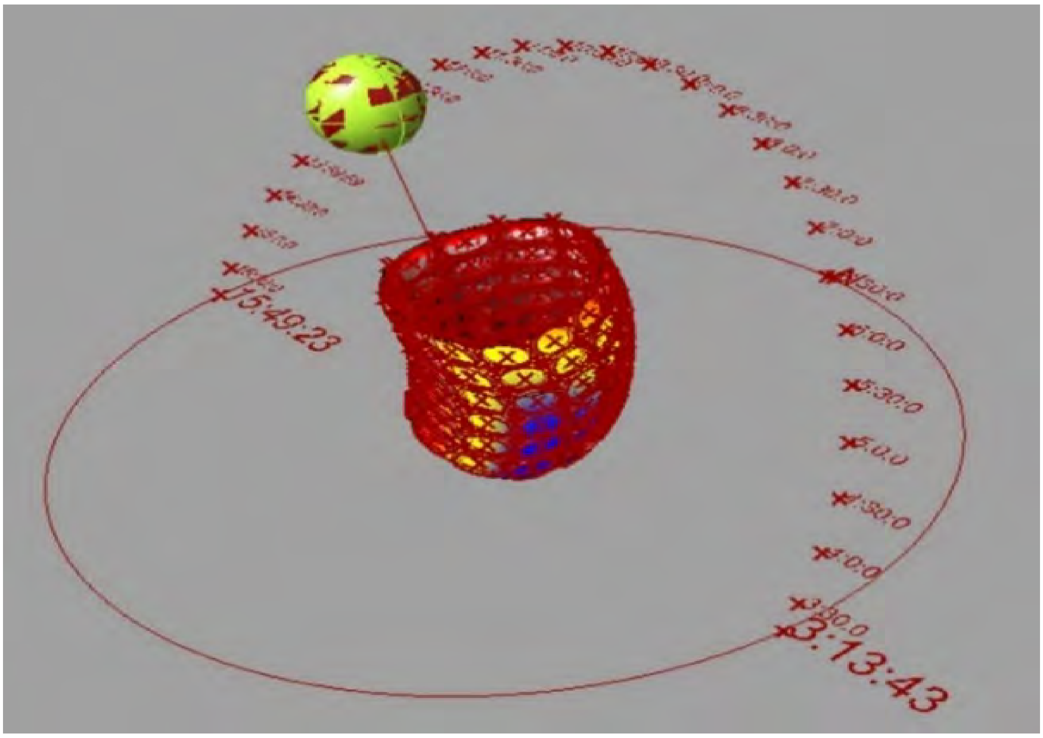


Figure 20: Example 1 form in evening

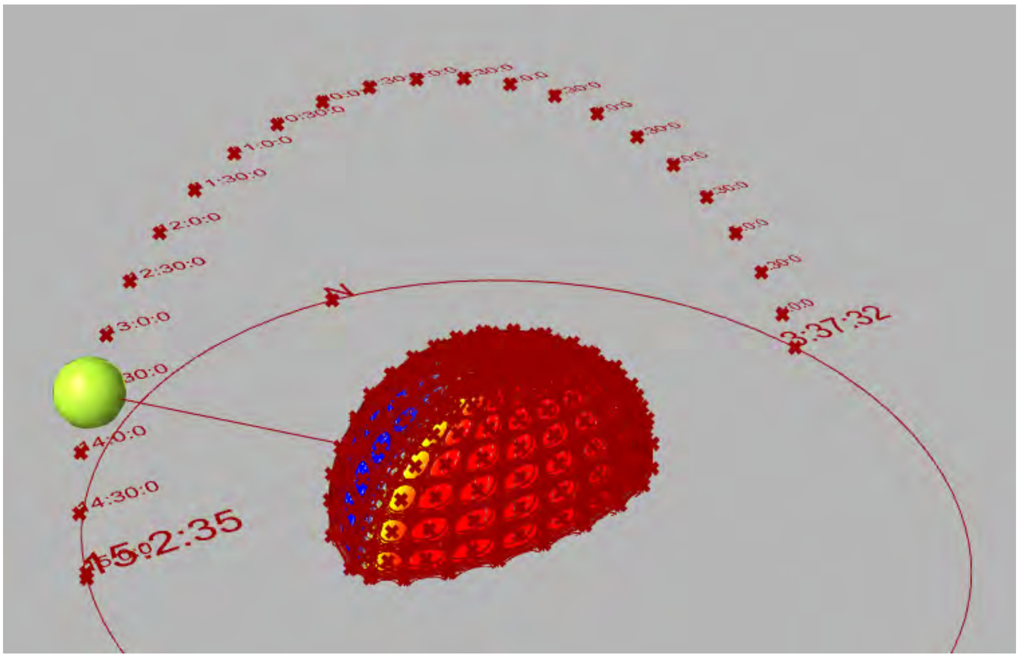


Figure 21: Example 2 form in evening

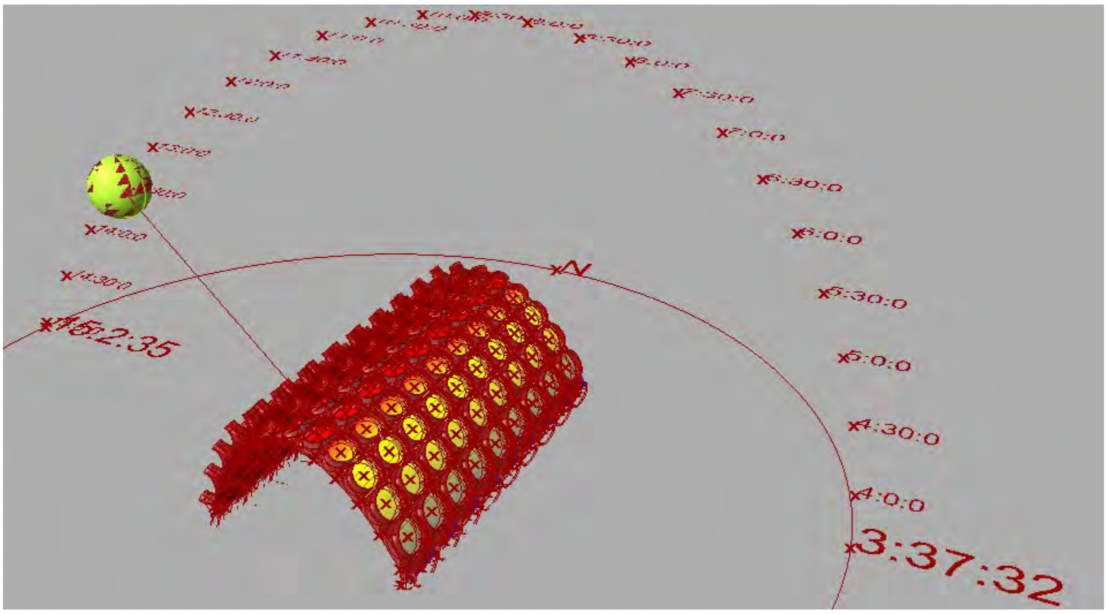


Figure 22: Example 3 form in evening

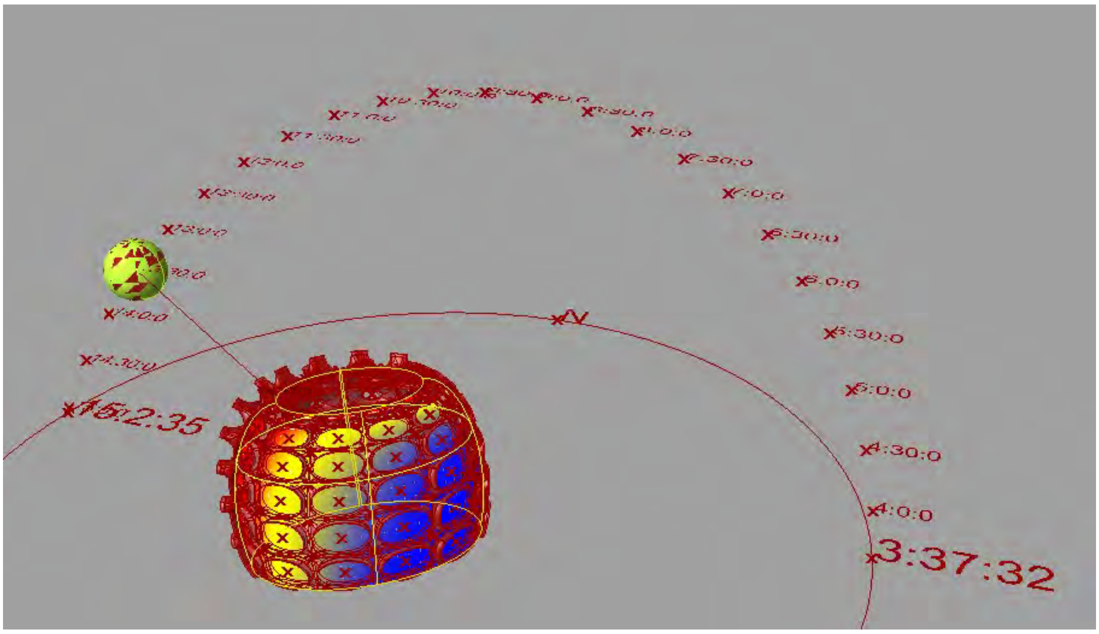


Figure 23: Example 4 form in evening

4.3 Parameters of The Model Proposals

The basic parameters of the model is shown on the figure 24. Another parameters that is used for creating basic shape (curvature degree, pressure for the modules etc.) and modules location optimisation algorithms are calculated by the computer with the Rhino and its plugins (grasshopper, heliotrope, Diva, gEco and vb.net) and visual basic. These algorithms are optimised to have most efficient form of the building envelope.

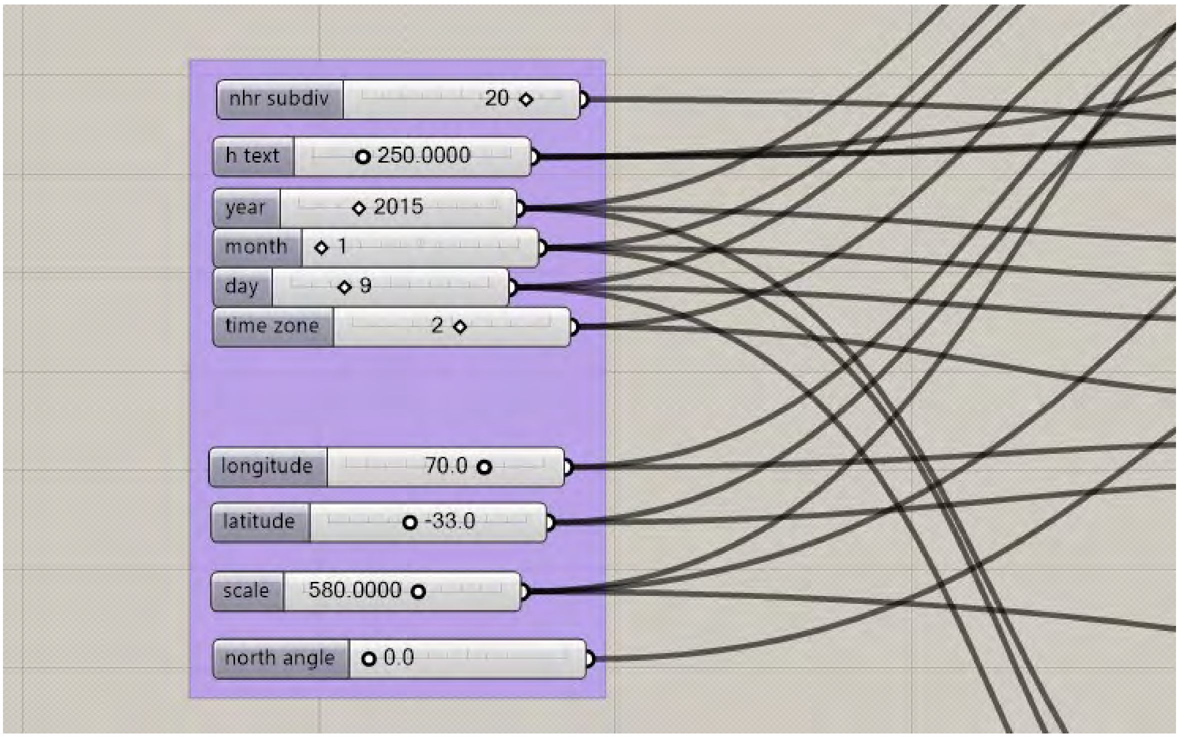


Figure 24: Parameters of the model

4.4 Potentials and Future of The Model Proposal

The proposed model of the performance based adaptive and pneumatic building has many potentials. This software and forms can be improved by the computers. Especially, Artificial intelligence is an important and innovation for the model proposal. Because computers can manage buildings as the parameters like sun, wind and so on.

For the future applications and advantages of the performance based adaptive building envelopes that can be oriented to the sun is really an opportunity for a sustainable environment. Because, by using adaptive buildings, people spent less natural resources and provide building users more comfortable spaces.

Economic reasons are the important for the building users. If architects use performance based adaptive building, building users can have all these opportunities.

Outcome is affected differently according to the parameters. In terms of model proposal, the computer programs which related to the computational design are used.

5. Conclusion

As a result, building envelopes in the future will be more optimized and more functional and it will be controlled by the decision making algorithms. After these algorithms developed in a high level, building users can give control of their spaces and their buildings. Probably, in the future by the artificial intelligence researches, people will talk their building about all the situation of the house about climate. Performance based adaptive buildings can be the solution for the healthier environment and more efficient architecture.

In this article theoretical information and a model application is explained and some details of the model are shown with graphics as a data, model and simulations and potentials, advantages of this model for the future are explained.

References

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Annex
Code Examples From The Model Proposal

Visual Basic Code Piece 1

```
.................
  Private Sub Print(ByVal format As String, ByVal ParamArray args As Object())
    __out.Add(String.Format(format, args))
  End Sub
  Private Sub Reflect(ByVal obj As Object)
    __out.Add(GH_ScriptComponentUtilities.ReflectType_VB(obj))
  End Sub
the Script component. </summary>
  Private Sub Reflect(ByVal obj As Object, ByVal method_name As String
  End Sub
#End Region
```

```
  Private Sub RunScript(ByVal pts As List(Of On3dPoint), ByVal riseSet As List(Of On3dPoint), ByRef A As Object)
    Dim i As Integer
    Dim newPtArray As New List(Of On3dPoint)
    Dim tempPtArray As On3dPoint
    newPtArray.Add(riseSet(0))
    For i = 0 To pts.Count - 1
      tempPtArray = pts(i)
      If tempPtArray.IsValid Then
        If tempPtArray.z > 0 Then
          newPtArray.Add(tempPtArray)
        End If
End Class
..............
```

Visual Basic Code Piece 2

```
.................
  Private Sub Print(ByVal format As String, ByVal ParamArray args As Object())
    __out.Add(String.Format(format, args)) component. </summary>
  End Sub
  Private Sub Reflect(ByVal obj As Object, ByVal method_name As String)
    __out.Add(GH_ScriptComponentUtilities.ReflectType_VB(obj, method_name))
  End Sub
#End Region
Private Sub RunScript(ByVal year As Integer, ByVal month As Integer, ByVal day As Integer, ByRef doy As Object)
    ''' algorithm based on OnlineConversion.com http://www.onlineconversion.com/day_week_number.htm
   If year Mod 4 = 0 And year Mod 100 <> 0 Or year Mod 400 = 0 Then
      doy = day + accumulateLY(month)
```

```
    Else
       doy = day + accumulateNY(month)
</my vb4>
    End If
  End Sub
End Class
```

....

Visual Basic Code Piece 3

....

```
  Private Sub RunScript(ByVal yr As Double, ByVal mth As Double, ByVal day As Double, ByVal hrs As Double, ByVal tzone As Double, ByVal longitude As Double, ByVal latitude As Double, ByRef zenAng As Object, ByRef azi As Object, ByRef hrAngle As Object, ByRef solarElev As Object, ByRef eqaTime As Object, ByRef solDec As Object)
    ' The Solar Position algorithm is based on National Oceanic and Atmospheric Administration's Solar Position Calculator http://www.srrb.noaa.gov/highlights/sunrise/azel.html
    'Code is ported into vb.net and integrated into Grasshopper by Ted Ngai
     Dim hourAngle, haRad, csz, zenith, azDenom As Double
    Dim azRad, azimuth, exoatmElevation, refractionCorrection, te As Double
    Dim solarZen, elevation, coszen As Double
    'timenow is GMT time for calculation
    Dim timenow As Double = hrs - tzone
    longitude = longitude * -1
     Dim JD As Double = calcJD(yr, mth, day)
    Dim T As Double = calcTimeJulianCent(JD + timenow / 24.0)
    Dim R As Double = calcSunRadVector(T)
    Dim alpha As Double = calcSunRtAscension(T)
    Dim theta As Double = calcSunDeclination(T)
    Dim earthRadVec As Double = R
```

....

Visual Basic Code Piece 4

....

```
     Dim solarTimeFix As Double = eqTime - 4.0 * longitude + 60.0 * -tzone
    Dim trueSolarTime As Double = hrs * 60 + solarTimeFix
     While trueSolarTime > 1440
      trueSolarTime -= 1440
    End While
   hourAngle = trueSolarTime / 4.0 - 180.0
    If hourAngle < -180 Then
      hourAngle = hourAngle + 360
    zenith = radToDeg(Math.acos(csz))
    azDenom = (Math.cos(degToRad(latitude)) * Math.sin(degToRad(zenith)))
  If Math.abs(azDenom) > 0.001 Then
  'Basic Functions
  'Convert radian angle to degrees
  Function radTodeg(ByVal angleRad)
    radTodeg = (180.0 * angleRad / Math.Pi)
  End Function
  Function degToRad(ByVal angleDeg)
    degToRad = Math.Pi * angleDeg / 180.0
  End Function
```

....