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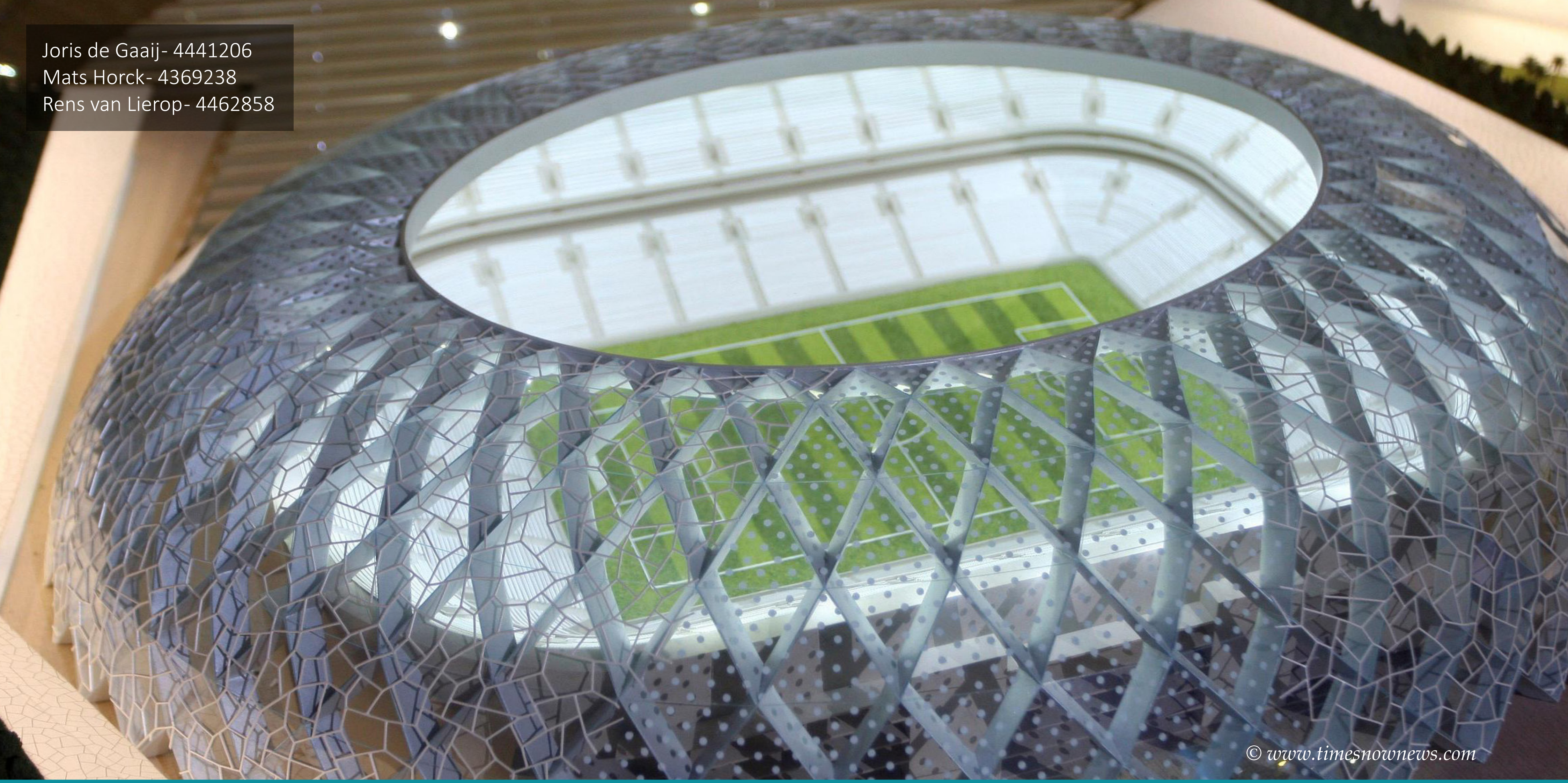

AL-WAKRAH PARAMETRIC DESIGN

This project is inspired by the Al Wakrah stadium. This stadium was one of the design options to be built for the Qatar 2022 World Cup, which is an important milestone in the country's modern history. The stadium will provide seating for around 40.000 people. The stadium is designed by Zaha Hadid Architects, who also are selected to design the new national stadium for Japan and the Olympic Aquatic Centre in London.

In the end another design option has been chosen to be built for the Qatar World Cup. Nevertheless, the Al Wakrah stadium could be an interesting parametric design project. Because of its interesting shape, the construction could be optimised in combination with the open and transparent facade. Modern parametric technologies like Rhino grasshopper can visualise the unique selling points of this stadium and could have shown the client how to overcome possible problems, like limited capacity, sight-lines problems and direct daylight issues. Parameters related to the climate like daylight are especially interesting because of the typical subtropical dry and hot desert climate in Qatar. The daily maximum temperatures can easily reach 40 °C or more. Designing a stadium in such extreme climates is truly challenging.

In this project a parametric model of the Al Wakrah stadium has been built that makes it possible to optimize the stadium considering a lot of parameters. Grasshopper, together with plugins like Karamba, Toro, Ladybug, Dodo and Colibri, has been used to create this model and could show a client a feasible and optimized design alligned with his wishes.

Parameter definition

To build a parametric model of the stadium different parameters are defined. The basis geometry is created out of a bottom ellipse plane, which is scaled and moved two times by a variable height to create an upper and middle ellipse. Those three ellipses are forming an arch. This arch is used as the basis of the whole model. See Figure 1. A facade is created by making use of the loft-function. To create the construction this basic arch is copied multiple times, afterwards the ground points of the arch are shifted to create sloped lines. Moreover, the model contains parameters to create a facade panel pattern, measure the grandstand sightlines and calculate the direct daylight entrance on the field.

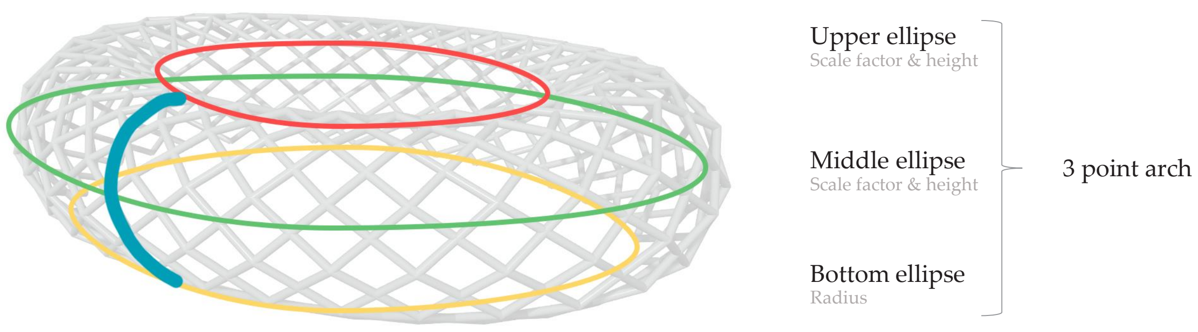

Figure 1: Parametric overview stadium

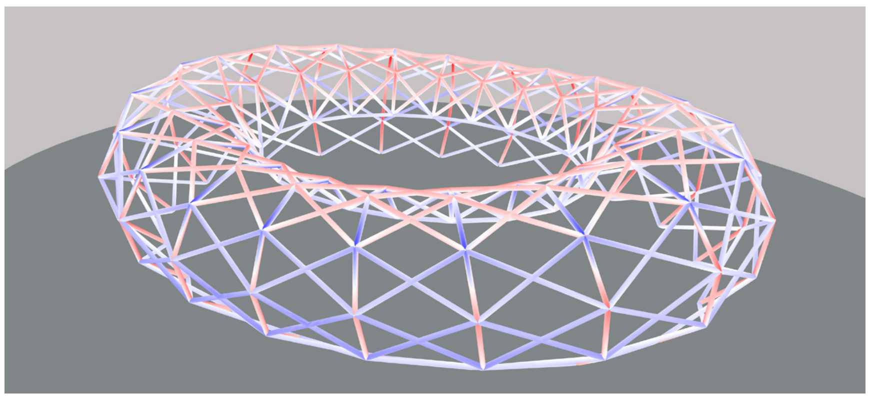

Figure 2: Stresses in construction by Karamba

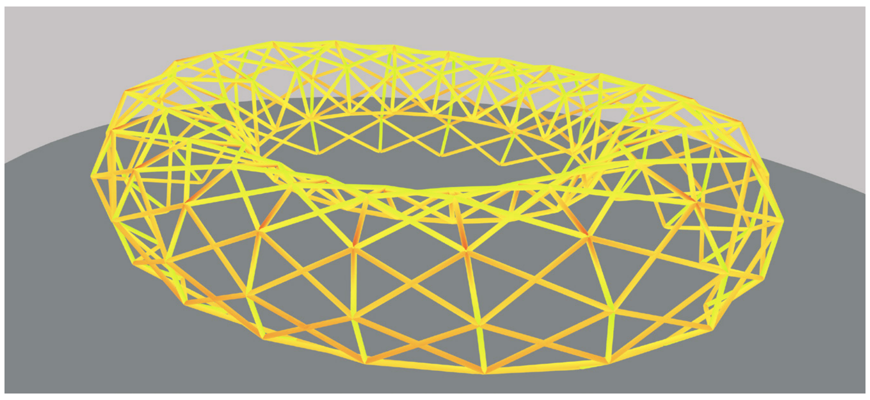

Figure 3: Unity checks displayed on the beams, closer to 1.0 = red

Analysis

karamba structural plugin

For the structural analysis of the stadium, the grasshopper plugin Karamba had been used. Due to the fact that Karamba only works with straight elements, all the polyline curves have been converted to seperate line elements in this phase. The bottom vertices of the arches are defined as the hinged supports in the model. To make an analysis the forces on the construction are split in two: gravity forces on the structure and forces due to the facade load. The facade load of 1 kN/m^2 is spread evenly over all the connection points. With the model a first and second order global analysis has been performed. The model gives as output the total steel weight, the deformations, the axial stress, the global buckling factor and unity checks, see Figure 2 and 3.

Toro stadium tool

During the project the plugin Toro for grasshopper is used. Toro is used to define geometry of stadiums and auditoriums and to analyse the spectators view. In this project it has been used to analyse the effect of the generated stadium shape on different grandstand properties as amount of seats, height and distance from the seats to the pitch. The results are visualised in a colour scaled mesh.

Besides the tools that are provided by Toro, a new tool has been created during this project to measure the view obstruction of the crowd by the stadium roof and television screens. The Toro standard stands and points (that represent the crowd) are firstly trimmed to fit inside the generated stadium. An UV grid is created at the pitch. These points are connected to the points which represent the seats of the grandstand. The amount of lines that are interrupted by the stadium geometry is measured and visualised in a colour scheme mesh at the stands, see Figure 4.

Daylight analysis & Random Facade panels

The facade is build of different panels, some of them are randomly made transparent. To determine the effect of those transparent panels Ladybug has been used to analyse the amount of daylight which is cast on the football field. This is done by adding a sun path and then defining both the transparent panels in the facades and the ellipsoidal hole in the roof of the stadium. This generates a mesh which shows the amount of direct sunlight on the field. See Figure 5.

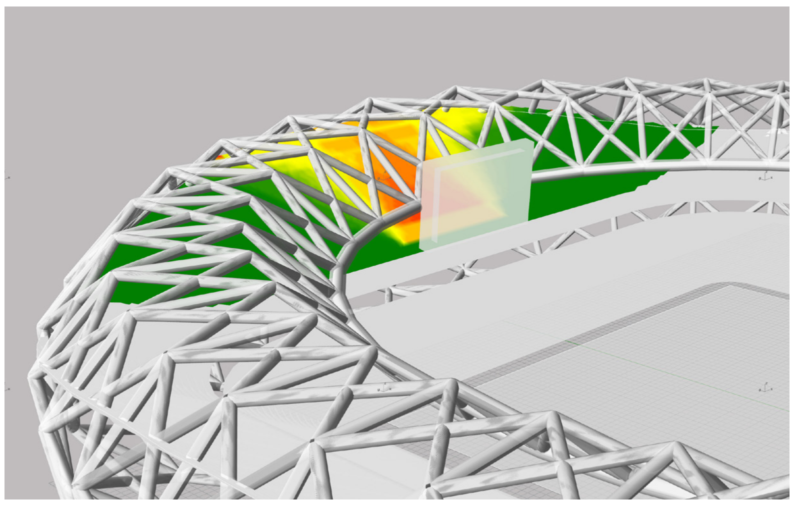

Figure 4: Sight-line analysis by custom made tool

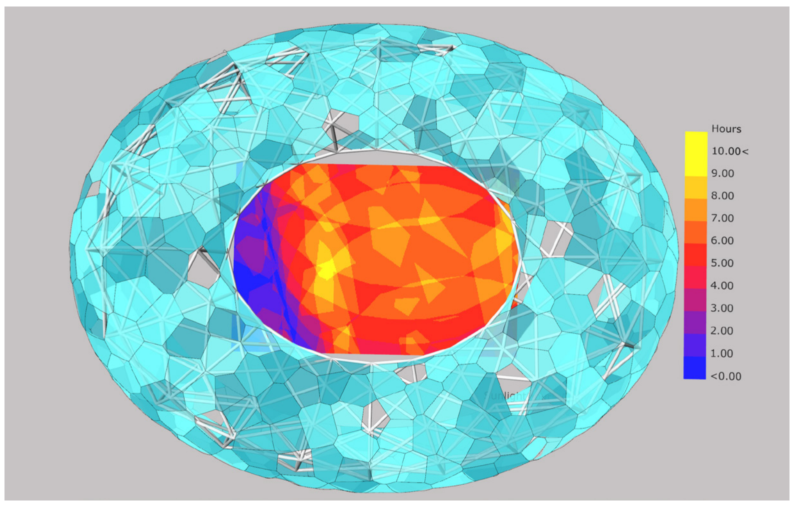

Figure 5: Direct day light analysis with Ladybug

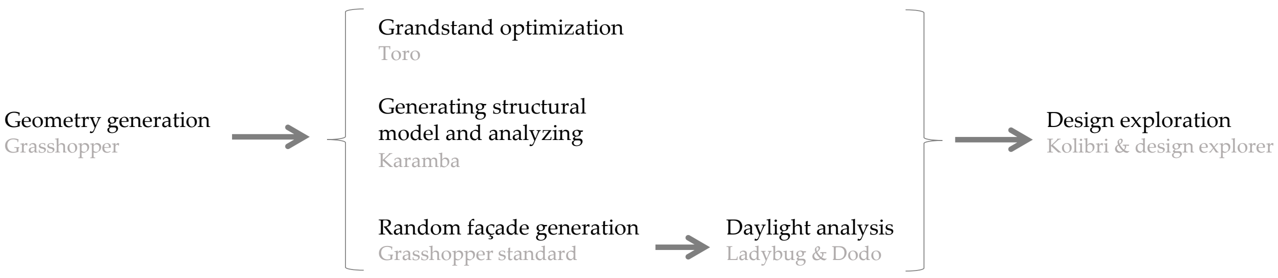

Figure 6: Parametric tools workflow

Workflow

When building the model, the main shape of the stadium and the construction were constructed together. Afterwards, three different models were made, all using the geometry as basis. One model with the randomly assigned panels and the daylight analysis. One model with the calculation of the load bearing construction using karamba. And one model which analyzes the grandstands in the stadium. In the end these models were joined in a final grasshopper file, to create a design explorer. See Figure 6.

Reflection

The Al-Wakrah stadium design is a project for which parametric design with grasshopper suits perfectly. The building has a quite complicated shape with a lot of repetitions. Moreover, a lot of analysis can be performed during the design phase, which makes it possible to optimize the building for sight-lines and direct daylight, steel weight, etc. In this way the structural engineer and the building physics engineer are able show the rest of the design team exactly what the effects of there choices are, especially with the design explorer. In a later phase more analysis tools could be used like Octopus and Galapagos to create even more optimized designs. Also more investigation on the inside climate of the stadium could be necessary. During this project it has been shown that making use of parametric tools can save a lot of time during the design phase of projects. But especially it can lead to better, optimized constructions!

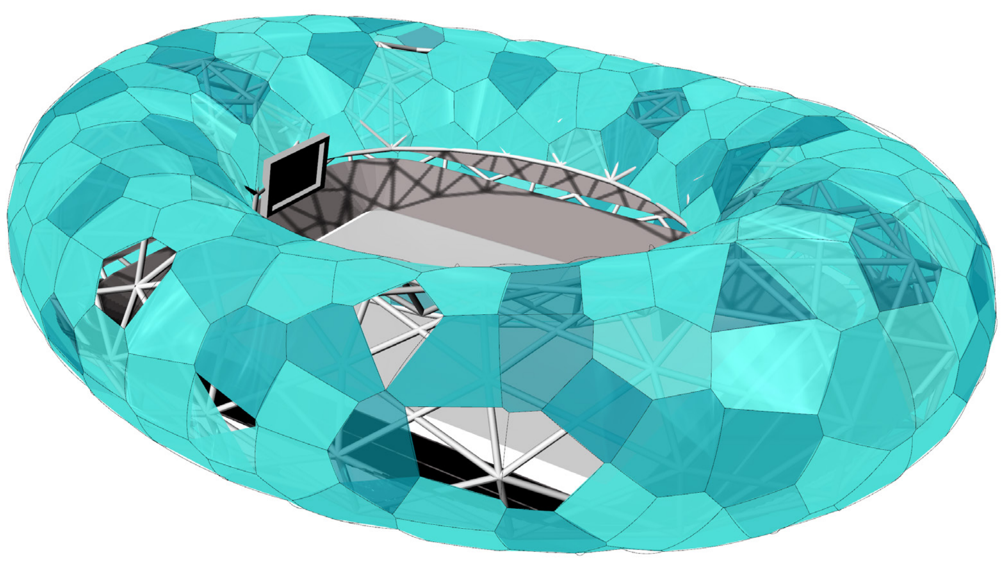

Figure 7: One of the possbile designs created with the parametric model