SHADING DESIGN WORKFLOW FOR ARCHITECTURAL DESIGNERS

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Motivation of the project

- Architects with **NO ACCESS TO CLIMATE SPECIALISTS** that can endorse their **SHADING DESIGNS**, therefore the **UNCERTAINTY ON PERFORMANCE** becomes an issue.
- Useful tools are available for designers to implement, the **LACK OF BACKGROUND** on the subject of climate **LIMITS THE USE OF THIS TOOLS** and their benefits.
Currently, forms of exploration in architectural design are evolving, and sustainability should not be left behind.
WHAT?

WORKFLOW:
- Based on valid **INDICATORS**
- **DESIGN OBJECTIVES** - DAYLIGHT QUALITY and SOLAR GAIN
- With the use of a **FRIENDLY INTERFACE**

GOALS:
- Making **INFORMED DESIGN CHOICES**
- **USE OF VIRTUAL REALITY** as a form of exploration.
HOW?

TOOLS

PARAMETRIC DESIGN TOOLS + DAYLIGHT AND ENERGY SIMULATORS + OPTIMIZATION TOOLS

METHOD

WORKFLOW

INTERFACE

USER FRIENDLY INTERFACE

VIRTUAL REALITY
Focus of this presentation
WORKFLOW

**PARAMETRIC DESIGN ENVIRONMENT**

**Purpose:**
- Building and shading design parametric modelling.
- Parametric tools for environmental simulations.

**OPTIMIZATION SOFTWARE**

**Purpose:**
- Multi-objective optimization process.

**VR RENDER ENGINE**

**Purpose:**
- Generating VR interface.

**VR RENDER SIMULATOR**

**Purpose:**
- Create an interactive an immersive experience for a designer as resource for design decision making.
**INDICATORS**

**DAYLIGHT QUALITY**

**DAYLIGHT FACTOR**

The use of this indicator is to inform about evenly natural light distribution on a room. It is measured through percentages.

**SOLAR GAIN**

**G-VALUE**

The purpose of this indicator is to demonstrate the reduction of the G-Value, the goal is to prove the effectiveness of a shading device, through an index resulting of a relation between the energy outside the room and the resulting infiltrated energy.
DESIGN OBJECTIVES

ENERGY
G-Value reduction factor

DAILIGHT FACTOR
Maximize DF

USEFUL AREA
Maximize the amount of usable space regarding the DF.
USER FRIENDLY INTERFACE

Complex Grahopper Environment.

Simplified User Friendly front-end environment.
MAKING AN INFORMED DECISION

EXPLORING

Using VR to have a broader perspective of on the shading performance.

ASSESSMENT

Through the observation and analysis of the results in a VR environment. The user can support a decision or decide to make changes in the project.
USE OF VIRTUAL REALITY

ADVANTAGES:

1. Decision making process is not only supported by analysis data and user experience.

2. Possibility to explore variations of results and the effect of the indicators on a room in real time.

3. Exploration through realistic point of view.

4. Visualization and study of detailed mock-ups of shading device modules.
1 - Model of envelope.
2 - Slab subdivisions generated in the envelope.
3 - Subdividing the slabs into a module(s) to fit the glass is part from the architectural program in the facade.
4 - Location of the architectural program in the envelope.
5 - Locate architectural program behind the window subdivision of the envelope.
DESIGN - Conceptual shading design

DESIGN ACCORDING TO ORIENTATION

- OVERHANG
- FINS
- LOUVERS
- EGGCRATE
- AWNINGS
DESIGN - Location and program selection

1. The Torgenza dome > Daylight factor
2. Energy flow and window total energy > C-Value
3. Sunpath and drybulb temperature graph > Ray-tracing
DESIGN - Parametric Shading Design

SHADING PARAMETERS

DESIGN ACCORDING ORIENTATION

PERFORMANCE FUNCTIONALITIES

SIMULATION PARAMETERS

MATERIAL

COLOR

DESIGN SIMULATION OPTIMIZATION VISUALIZATION ASSESSMENT
SIMULATION - Daylight simulation

MODEL ROOM

SIMULATION

RESULTS

Daylight simulation recipe:
Based on Radiance Material Library

DAYLIGHT FACTOR GRID

USEFUL AREA
SIMULATION - Energy simulation

Energy simulation recipe:
Based on ASHRAE code library material
OPTIMIZATION - Multiobjective optimization

INPUTS: DESIGN PARAMETERS

OUTPUTS: DESIGN OBJECTIVES

OPTIMIZATION MAP

PROCESS

RESULTS

DESIGN SIMULATION OPTIMIZATION VISUALIZATION ASSESSMENT
OPTIMIZATION - Process for parametric optimization

PARAMETRIC DESIGN ENVIRONMENT

PARAMETRIC MODEL  →  PARAMETRIC SIMULATIONS  →  BRIDGE TO OPTIMIZATION TOOL

ESTECO GH COMPONENT

D-EXP: EXPLORATION TOOL

OPTIMIZED PARAMETRIC RESULTS

EXTERNAL SOFTWARE

OPTIMIZATION TOOL

PRE-OPTIMIZATION  →  POST-OPTIMIZATION
OPTIMIZATION - Results for optimization in 3D

DAYLIGHT FACTOR

USEFUL AREA

G-VALUE

DESIGN  SIMULATION  OPTIMIZATION  VISUALIZATION  ASSESSMENT
VISUALIZATION - Optimized result exploration
Three levels of a discarding process will help the user decide which optimized results will be explored with Virtual Reality.

1. Level 1: Analysis and selection of post optimization results, directly from the statistical data presented from the optimization tool, that best suit the design objectives.

2. Level 2: The selected sample of results, are submitted to the daylight and energy simulation software in order to retrieve the 3-D models for the pre visualizations of the optimized results. Through visual and analytical process it will be determined which of the optimized results work better according to the model room and the design objectives.

3. Level 3: Selected results from level 2 can be analysed in deep detail through post optimization features through Virtual Reality, with immersive exploration giving a deeper insight that will have the added value of experience.
What is expected from the added value of VR is:

EXPERIENCE with DIRECT FEEDBACK on DESIGN DECISIONS.
CASE STUDY - The Esplanade (Singapore Opera House)

CLIMATE ZONE: 1-A
VERY HOT AND HUMID
CASE STUDY
CASE STUDY - Background

Total of shading devices: 7140
Shading devices in Lyric Theatre: 3840
Shading devices in Concert Hall: 3300

Estimated time to accomplish the analysis: 18 months

Design objectives: Maximum shading

Climatic indicators taken into account: None

Total of customized designs: 12
DESIGN - Parametric model of building

- Envelope Model
- Envelope Section
- Division of Envelope according to model room expected height
- Possible of position of model rooms in envelope
- Locations in envelope of model rooms according to the envelope geometry
DESIGN - Reference point

MODEL ROOM SELECTION

ROOMS WITH NO SHADING

AVG. DAYLIGHT FACTOR = 6.25%
G-Value = 1
Energy infiltrating = 349 kW/hr m²
DESIGN - Conceptual Shading Design

SHADING SAMPLE

Basic Window
BASIC SHADING MODULE

Basic Shading
DESIGN - Design parameters

VISIBILITY
- Mean visibility 50%
- Minimum visibility 25%
- Maximum visibility 70%

HEIGHT VARIATION
- Height variations are possible

LENGTH CONSTRAINTS
- x = 0.3m
- x = 1m

DESIGN SIMULATION OPTIMIZATION VISUALIZATION ASSESSMENT
DESIGN - Design parameters

VISIBILITY
Mean visibility 50%
Minimum visibility 25%
Maximum visibility 70%

HEIGHT VARIATION
Height variations are possible

LENGTH CONSTRAINTS
x = 0.3m
x = 1m

DESIGN | SIMULATION | OPTIMIZATION | VISUALIZATION | ASSESSMENT
DAYLIGHT TERGENZA DOME - direct daylight influencing the model room.

POINT PROJECTION - from the dome patches that relate to the window of the model room.
DESIGN - Parametric Shading Design

Amplitude = 0.3 > 1m

Point projected in window

Amplitude
DESIGN - Parametric Shading Design

VECTORIAL PULL POINTS GENERATE PERMUTATION OF SHADINGS
DESIGN - Parametric Shading Design
SIMULATION

ROOF
DAYLIGHT = Gypsum: 255,255,255
ENERGY = ASHRAE 90.1-2004 EXTOOF
IEAD CLIMATEZONE 1-4

GLASS
DAYLIGHT = Low-e Argon glass, TVis_.714
ENERGY = Alum2 Frame, Low-e Argon

SHADING
DAYLIGHT = Aluminum: .900,.880,.880,.800
ENERGY = Aluminum

WALLS
DAYLIGHT = Gypsum: 255,255,255
ENERGY = ASHRAE 90.1-2004 EXTWALL
MASS CLIMATEZONE 1-2

FLOOR
DAYLIGHT = Parquet: .309, .165, .083, .03, .1
ENERGY = ASHRAE 90.1-2004 ATTICFLOOR
CLIMATEZONE 1-5
SIMULATION

SHADING WORKFLOW

EPW File
C:\Users\localadmin\Desktop\LuisELopez\P4_2\frontend_c

Facade Orientation:
West

Program West
Location in facade 0.
Facade Location 0

Office

Daylight Factor
G-Value

SITE SELECTION
OPTIMIZATION

SUMMARY:
19 total optimal results out of 300 simulations.

At location No.24: 7 total optimal results 6, 10, 22, 29, 49, 57 and 92.

At location No.2: 7 total optimal results 1, 16, 21, 28, 29, 55 and 82.

At location No.46: 5 total optimal 19, 23, 31, 44 and 74.
SPECIAL ATTENTION WAS GIVEN TO PARETO FRONT RESULTS. FRONT FOR ALL DESIGN OBJECTIVES AND RELATIVE STRENGTH BETWEEN DESIGN OBJECTIVES TOWARDS DESIGN PARAMETERS.
VISUALIZATION - Optimized result exploration

The average Daylight Factor for all model rooms give results within the expected values between 2% and 5%.
Every model room shows a value variation within its sample results, showing that every model room has optimal results to choose for G-Value reduction.
Only result samples for position 24 and 46 show a relevant result with an acceptable Useful Area above 23m².
VISUALIZATION - Optimized result exploration

Relative strength chart for position No. 2

Relative strength chart for position No. 24

Relative strength chart for position No. 46

As it is shown, not all design objectives were influenced in the same way by the design parameters. Useful area was the least affected, whereas daylight factor and g-value performed almost equally.
VISUALIZATION - Optimized result exploration
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Result 22 at No. 24:
Daylight factor: 4.32 avg. %
G-val reduction: 0.71
Energy infiltrating = 102 kW/ hr m²
Useful Area: 23.14 m²

Result 19 at No. 48:
Daylight factor: 3.39 avg. %
G-val reduction: 0.60
Energy infiltrating = 139 kW/ hr m²
Useful Area: 23.14 m²
VISUALIZATION - Optimized result exploration

**With no shadings:**
AVG. DAYLIGHT FACTOR = 6.25%
G-Value = 1
Energy infiltrating = 349 kW/hr m²

**Result 22 at No.24:**
AVG. DAYLIGHT FACTOR = 4.32%
G-val reduction: 0.71
Energy infiltrating = 102 kW/hr m²
Useful Area: 23.14 m²

**Result 19 at No.46:**
AVG. DAYLIGHT FACTOR = 3.39 avg. %
G-val reduction: 0.60
Energy infiltrating = 139 kW/hr m²
Useful Area: 23.14 m²
VISUALIZATION - Optimized result exploration in Virtual Reality

(Click on image for video)
VISUALIZATION - Optimized result exploration in Virtual Reality
ASSESSMENT

ROOM 24:

Daylight factor: 4.32 avg. %  
Higher avg. percentage of  
Daylight distribution

G-val reduction: 0.71  
Higher rate of  
efficiency in blocking  
energy

Useful Area: 23.14 m²  
when DF = 2% to 5%
IMPACT OF VR ON DESIGN PROCESS (demonstration in P-5)

- Exploration of sets of optimized results per model room.
- Visualization of environmental features for: daylight (sun) and context.
- Experience of light differences according to model room position in the building, towards the context.

DESIGN
- Parametric model of building
- Location and program selection
- Conceptual shading design
- Parametrized shading design

SIMULATION
- Daylight simulation (Daylight)
- Energy simulation (G-Value)
- Multi-objective optimization

OPTIMIZATION
- Maximize Daylight Factor
- Minimize G-Value
- Optimized Design exploration (VR)

Visualization
- Visualization and comparing simulation results for optimized results in real time.
- Shadow-casting effect on the room in real time throughout specified dates.
- Manipulation and interaction with detailed shading device mock-ups.
- Interaction and impact visualization on testing different layouts for architectural programs.

ASSESSMENT
- Satisfying design
- Decision making
WHAT ELSE CAN BE DONE?

ANALYSIS FOR MULTIPLE TYPOLOGIES AND PROGRAMS

ANALYSIS FOR MULTIPLE OBJECTIVES IN ONE SINGLE SPACE
WHAT ELSE CAN BE DONE?

ROOM

RATIONALIZATION OF THE SHADING ELEMENTS

FACADE