PERFORMANCE-ORIENTED DESIGN OF LARGE PASSIVE SOLAR ROOFS

A method for the integration of parametric modelling and genetic algorithms

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LARGE SPAN ROOFS

- **Performance oriented design** makes use of performance evaluations to drive the design choices

- **Large roof designs:**
  - aesthetics, structural performance and economics
  - use of on site renewable energy resources

- Most of the architectural performances is strongly affected by **geometry**
- Early integrating **performance evaluations of geometrical design alternatives** is a key point

Masdar Headquarter – courtesy of Adrian Smith+ Gordon Gill Architecture
PERFORMANCE ORIENTED PARAMETRIC MODELLING

- **Parametric modelling** is investigated as support to early integrate performance evaluations

- It represents both geometrical entities and their relationships
- Relationships are structured in a hierarchical chain of dependencies, including independent parameters
- Variations of independent parameters generate different configurations of the model
- Instances of the parametric model can be explored with respect to a given set of design criteria

1. Generate parametric design alternatives

2. Performance evaluations

3. Identification of suitable solution
INTEGRATION OF COMPUTATIONAL SEARCH SUPPORTS

- Automatically generating the alternatives to be evaluated is a key support
  
  - however a systematic evaluation of each solution is impossible due to the breadth of the solution space
  - selection of solutions to be evaluated relay on multidisciplinary knowledge

- Integrating parametric modelling with computational supports to allow a more systematic search for performance oriented optimal solutions would guide the exploration of large design solution spaces
PARAGEN

- ParaGen is a tool running software packages through a cycle based on three components:
  
  ➢ **Selection of variables**: a genetic algorithm selects values of independent parameters
  ➢ **Generation of forms**: a parametric modeler generates the geometry using the selected values
  ➢ **Analysis of the generated forms**: the geometry provided by the parametric modeling software is evaluated in terms of performance

The ParaGen Cycle

1. Select
2. Breed
3. Generate
4. Evaluate
5. Store Data
The user can browse through the database and interact to address the generation.
PARAGEN - SERVER/CLIENT CONFIGURATION

SERVER
GA - SQL - WWW

PC CLIENT

Generation & Evaluation

Designer Selection
CASE STUDY – SOLAR ENERGY TRANSMISSION: A ROOF SYSTEM

• SolSt is a free-form roof
  ➢ covering an area approximately 50m x 50m
  ➢ located in Milan, Italy

• SolSt is expected to contribute to the required thermal and daylight comfort in the covered spaces
  ➢ Focusing here on tempering the local climate to avoid the risk of summer overheating
PARAMETRIC SHAPE AND STRUCTURAL GEOMETRY

- The structural geometry of the roof is modelled based on points
- The positions of the points are mathematically described based on Cartesian coordinates
- Independent parameters regulate:
  - the density of the point grid
  - the distribution of points in the two directions
  - the height of the peaks
- The points are used to tessellate the roof based on quadrangular, triangular, hexagonal polygons or combinations
PARAMETRIC CLADDING

• The cladding is a modular system, propagated based on the structural tessellations
  ➢ it aims at limiting the incident radiations on the covered spaces by allowing the income of indirect light

• Various cladding options are explored based on:
  ➢ different tessellations
  ➢ different topologies of modules for each single tessellation
  ➢ different geometrical variations of each single topology

• Here an example based on hexagons
  ➢ with parametric height
THE PARAGEN CYCLE

• ParaGen is used to explore the parametric design alternatives looking for:
  ➢ the maximum daylight factor
  ➢ the minimum incident solar radiation
THE PARAGEN CYCLE
CURRENT RESULTS
CURRENT RESULTS

The first population has shown the emergency of two main strategies:

- High curvatures of the roof lead to increased dimensions and inclination of the South facing cladding.
- Similar performances are achieved when the flat configuration of the roof leads to homogeneously distributed highly inclined cladding panels.
FURTHER WORK

- Further work includes:
  
  - Different cladding systems: based on various tessellations and various geometries for each tessellation
  - Winter conditions: maximizing both daylight and incident solar radiation
  - Integration of structural performances
CONCLUSIONS

• The proposed method supports the evaluations of various design performances

• Advantages:

- In exploring large solution spaces:
  ➢ The support in exploring large set of design alternatives
  ➢ The parametric model can be generalized to enlarge the solution space (example: by integrating different possible tessellations)

- In addressing the generation of alternatives:
  ➢ The possibility to freely explore the generated solutions according to different criteria assists in understanding the relations between geometric variations and performances
  ➢ ParaGen demonstrated a relevant value in combining the freedom in manipulating the direction toward which the results evolve and the optimization of the selected performances

• Current limitations and further work:

- Integration of other software:
  ➢ ParaGen is open to the use of other software, both for parametric modelling (such as Rhino/Grasshopper) and for performance evaluation (such as Radiance)
QUESTIONS?

THANK YOU FOR YOUR ATTENTION

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