PARAMETRIC MODELING AND OPTIMIZATION
FOR ADAPTIVE ARCHITECTURE

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ADAPTIVITY IN ARCHITECTURE

- **Adaptivity**: capacity of a building to be responsive to a changing context (Negroponte, 1975)

  - adaptivity in performance oriented architecture (analysis driven design process):

- **Architectural performance** is related to:

  - architectural requirements (needs of users, investors, society, etc.)
  - environmental factors (inhabiting or facilitating the fulfilment of human needs)

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**Diagram:**

- **Environmental Factors**
  - Surroundings’ typologies (urban, rural, etc); physical conformation of built and natural environment; level of noise; climate (hot, dry, continental, tropical, etc); weather; etc.

- **Architecture’s Performances**
  - Affecting Architecture’s Performances
  - Ability to properly interface the environment

- **Human Needs and Demands: User’s Requirements**
  - Requiring defined sets of performances
  - Ability to satisfy the requirements

  Functional demands, visual perception, emotional aspects, thermal comfort, acoustical requirements, daylight comfort, etc.
FORM ACTIVE ARCHITECTURE

• **Adaptive architecture** attempts to satisfy changing needs in changing environments through:
  
  - Adjustments based on **changes in material properties**
    - Smart materials varying transparency, colour, porosity, etc.
  
  - Adjustments based on **changes in geometry**
    - Change in shape through the movement of one or more parts
    - So called kinetic or reconfigurable architecture
  
  - **Form-active architecture:** reconfigurable architecture adjusting the shape while in use
    - Movement is designed and used for performance requirements
    - Example of large roof structures responding to wind changes and to solar energy
PARAMETRIC DESIGN and OPTIMIZATION TECHNIQUES

- Adaptivity is a potential, but it also increases the complexity of the design process

  ➢ Design support

- Parametric modelling and optimization techniques

  ➢ Like for static architecture:
    ➢ Systematic generation of a large set of alternative design solutions
    ➢ GAs driven exploration based on performance evaluations

  ➢ Differently than for static architecture:
    ➢ the design alternatives can be embedded in one design solution as different configurations
    ➢ the conceptual design of form-active architecture embeds additional tasks, three of which are discussed

Identification of geometric means - Identification of suitable configurations - Identification of structural systems
Identification of geometric properties whose changes should be considered for inclusion in a form-active design

- The parameterization includes a broad range of geometric aspects

- The design exploration is structured to distinguish and group the variables that allow for improving the performance over the contextual changes from the ones that do not

a) Density
b) Inclination
c) Orientation
1 - IDENTIFICATION OF GEOMETRIC CHANGES

- Multiple optimization loops
- Comparison among optimized solutions and related values of the variables
1 - IDENTIFICATION OF GEOMETRIC CHANGES

• The output consists in a subdivision of the initial variables into two groups:
  ➢ one to be embedded into the final design solution as variables (describing the form-active properties)
  ➢ one as specified values (describing static properties)

Solar Exposure levels (W) for variable density (north-south orientation; 45 degrees inclination), inclination (density 16; north-south orientation), orientation (density 16).
1 - IDENTIFICATION OF GEOMETRIC CHANGES

• Exploration of sub-optima

➢ Integration of search filters

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peak insulation W - Average

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Identification of suitable configurations with predefined geometric properties of the design

- The parameterization is limited within a structure including variables and dependencies that have been already identified as meaningful for adaptivity
- The design exploration is structured by searching for the specific configurations required for the system under certain contextual conditions
- The outputs consist of a set of design configurations
Knowing seasonal or daily patterns of local wind, it allows:

- estimating the expected predominant configurations of the structure and determining their timing
- estimating the range of required geometric variability to support the choice of a proper structural typology
- 9 extreme load cases funicular shapes measurements
2 - GEOMETRIC CONFIGURATIONS WITHIN GIVEN PROPERTIES
(mentored graduation project - student: Yannick Liem)

- Identifying extreme configurations supports determining the range of required geometric variability and therefore the choice of a proper structural typology.

- In the specific case, Variable Geometry Trusses were chosen.
3 - EXPLORATIONS OF PREDEFINED RECONFIGURABLE SYSTEMS

Identification of technical means, to define reconfigurable systems

- The parameterization regards structural morphology and the movement
  - A taxonomy of deployable structures has been developed to facilitate parameters extraction
  - It allows further implementations, also including other reconfigurable systems

- For the chosen structure, the design exploration searches for suitable properties of the structure (such as the height of the modules)

- The output consists of a structural solution
3 - EXPLORATIONS OF PREDEFINED RECONFIGURABLE SYSTEMS

Taxonomy of deployable structures – example of pantographic structures
3 - EXPLORATIONS OF PREDEFINED RECONFIGURABLE SYSTEMS

Taxonomy of deployable structures – example of pantographic structures

- **$\beta$** - Morphology Parameter
- **$\alpha$** - Kinematism Parameter
3 - EXPLORATIONS OF PREDEFINED RECONFIGURABLE SYSTEMS

Intended support for parametric modelling and design exploration
CONCLUSIONS AND FURTHER WORK

The design of form-active architecture is addressed by means of parametric modelling and optimization techniques. Both shown beneficial advantages in supporting the design process.

• First example: Influences of various geometric properties under different conditions
  - **Benefits**: supporting the identification of useful means of adaptability
  - **Challenges**: decomposition of the problem into single factors
  - **Further work**: integration of computational clustering techniques

• Second example: suitable configurations within the boundaries of pre-identified geometric properties
  - **Benefits**: identifying the margins of required movements as well as their expected frequency
  - **Challenges**: specificity of the boundaries
  - **Further work**: implementation toward broader approach

• Third example: exploration of various reconfigurable systems
  - **Benefits**: integration of the explorations of such systems into architectural design
  - **Challenges**: modular combinations in curved structures
  - **Further work**: structural optimization across different configurations
QUESTIONS?

THANK YOU FOR YOUR ATTENTION

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