Advanced modelling and Digital manufacturing: Parametric Environmental Design Tools for the Optimization of UHPFRC Shading Panels

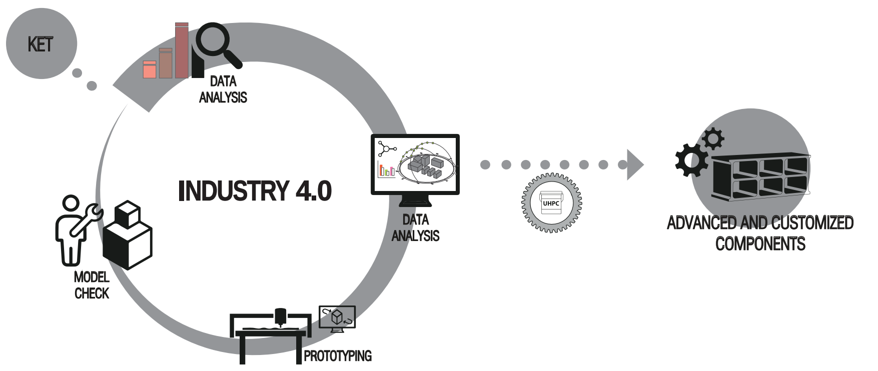
G. Nocerino[(1)], J. Principe[(1)], M. Leone[(1)]

[(1)] **University of Naples Federico II,** Department of Architecture, Italy

35th INTERNATIONAL CAE CONFERENCE AND EXHIBITION

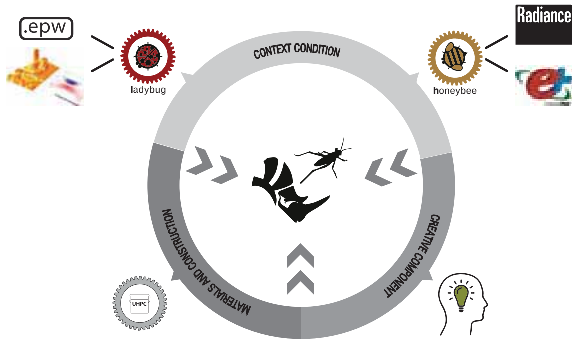
Vicenza, ITALY 2019, 28 - 29 OCTOBER

Introduction



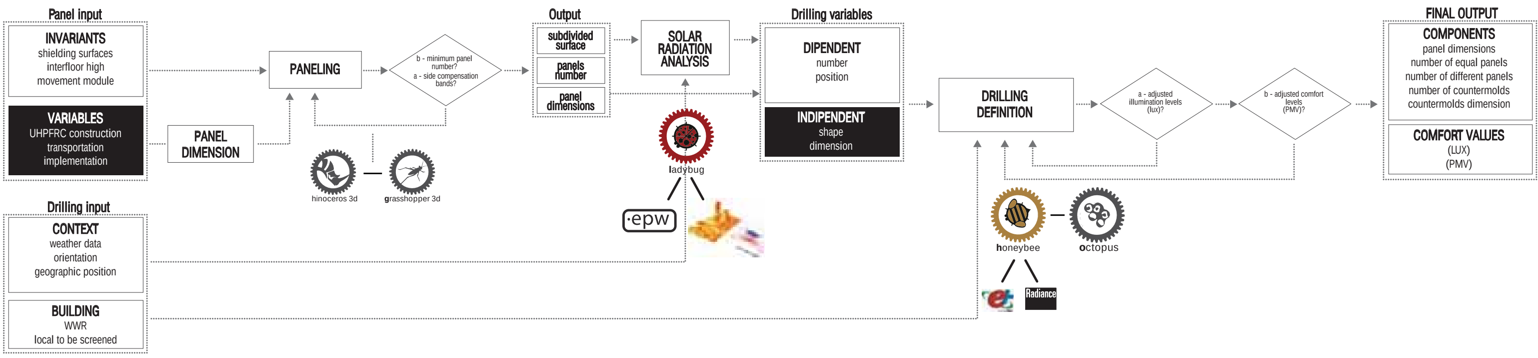
Among the many challenges that our society will have to face in the imminent future, the environmental and anthropic habitat sustainability themes will require more than just innovative technical solutions aimed at optimizing the **responsive capacities** of the built environment. In a climate-altered and highly complex reality, the intellectual and operational dimension of the project is now discovering a new **vectorial and data driven technological paradigm**. Through digital platforms capable of managing different situations and systems, the investigation of the material dimension is moving into an increasingly virtual space, in which the constant integration between environmental and material-geometric parameters identifies the meta-design phase as the "ideal place" to experiment the creative use of data. Starting from these assumptions and the experience acquired within the International Workshop "Technological and Structural Design with UHPFRC" organized by the Department of Architecture at the University of Naples Federico II (DiARC) and the Paris-Belleville School of Architecture (ENSA-PB), here the objective is to investigate the optimized design of a shading system in UHPFRC by structuring the geometric and environmental data into a set of information useful for the definition of design layouts based on a **form-finding** process.

A new approach to the design process



From a cultural point of view, the experimented process is based on a "computational thinking", able to put together design strategies and actions within a single digital development environment constituted, in this case, by the McNeel Rhinoceros software and its Visual Programming Language (VPL) platform **Grasshopper**. The correlation between strategies and actions, as well as between the information and final shape, required the articulation of the design process to be based on the typical diagrammatic logic of the computational thinking. In this way it has been possible to efficiently rationalize the façade paneling problem by using fixed shading devices and managing the different solutions proposed according to Pareto's optimum. In this way, a "flexible" design layout has been defined. A design in which the project goals are constantly related to the information aspects of the production process of the UHPFRC panels, and in which generative codes and computer programming languages (algorithmic and parametric design) blend with the creative and artistic input, now fully integrated in the production and manufacturing process. **Creativity**, therefore, still remains a fundamental precondition of technical knowledge in the age of digital revolution.

Methodology overview



1. PANELING

The first phase has the objective to optimize the material utilization, trying to minimize the final number of panels. Furthermore, to reduce production time and costs, it is important to have the maximum number of panels with the same shape and dimension. This also means reducing or avoiding side compensation bands, which will require special molds to be realized.

The algorithm utilizes **fixed and variable inputs** to calculate the dimensional data necessary for the panel production. The **fixed input** depends on the building characteristics, i.e. the windows distribution and the façade dimension. While the panel height and width are considered the **variable inputs**, defined accordingly to construction, transportation and implementation issues.

2. DRILLING DEFINITION

To have an optimal UHPFRC disposition, the drillings are organized to form a grill, in which the minimum material thickness is equal to 1.5 per fiber length. The drilling dimension is mainly linked to the solar radiation incident on the building surface, which has been calculeted using **Ladybug**, a Grasshopper add-on for the environmental design analysis. Starting from the building orientation, the environmental context, the geographic location and the meteorological data (.epw), the algorithm calculates the surface sunlight during the year. Accordingly to the average radiation values, the building surfaces are divided into "sectors" each of which having a different value of radiation. Then, for each sector the proper kind of drillings is chosen following the rule "greater the radiation, smaller the opening".The algorithm is also implemented with data related to internal visual comfort, evaluated using the add-on **Honeybee** and the software **Radiance**. The illuminance values (lux) express the indoor visual comfort.

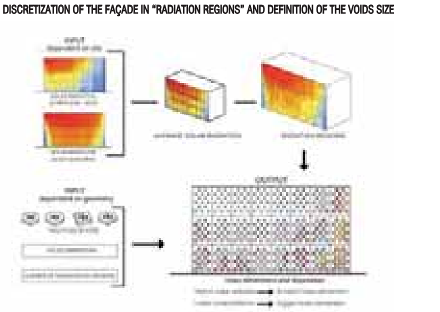
3. RESULT SEARCH AND CHECK

Using the add-on **Octopus**, a genetic algorithm is defined using as **variable inputs** the minimum and maximum opening size and the number of the intermediate drilling. The objectives are to guarantee a minimum illumination value in winter and attenuate the luminous flux in summer. The algorithm then, through an iterative process, will change the variables several times, calculating for each iteration the average illuminance values at the summer and winter solstice, keeping only the solutions that satisfy better both objectives.The process will not produce a single result, but a family of possible solutions, among which the designer choices the solution that better satisfy the project requirements.

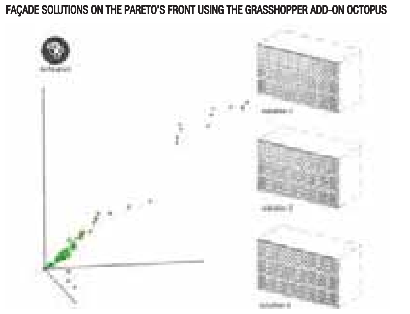
4. OUTPUT

After the last phase, it is possible to visualize, for each solution, data concerning the internal visual comfort (using the illuminance as indicator), the thermo-hygrometric comfort (using the PMV as an indicator) and all the data related to the production factors, such as number and dimensions of the drillings.

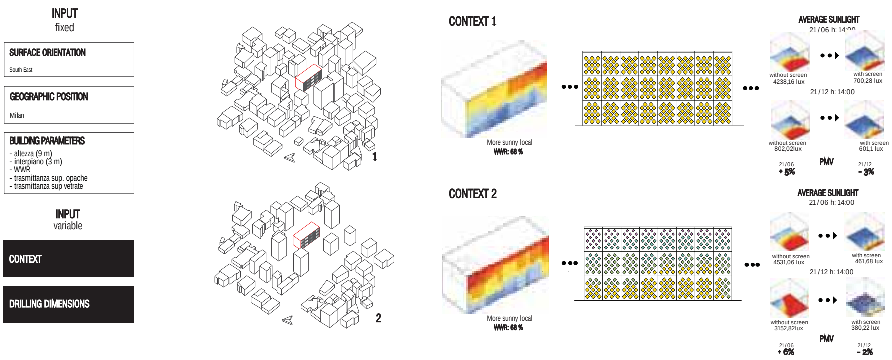
DISCRETIZATION OF THE FAÇADE IN "RADIATION REGIONS" AND DEFINITION OF THE VOIDS SIZE



FAÇADE SOLUTIONS ON THE PARETO'S FRONT USING THE GRASSHOPPER ADD-ON OCTOPUS



Results



References

Mayer-Schönberger, V. and Cukier, K., 'Big data: a revolution that will transform how we live, work, and think', (Houghton Mifflin Harcourt, Boston, 2013).
Micelli, S., 'Fare è innovare', (Il Mulino, Bologna, 2016).
Pugnale, A., '(Digital) Form-finding', in A. Tedeschi 'Algorithms-Aided Design. Parametric strategies using Grasshopper', (Le Penseur, Potenza, 2014) pp. 353-359.
Roudsari, M.S., Pak, M. and Smith, A.+ Gordon Architecture Chicago, 'Ladybug: a parametric environmental plugin for Grasshopper to help designers create an environmentally-conscious design', Proceedings of the 13th Conference of International Building Performance Simulation Association, Chambéry, August 2013 (INES - CEA, University of Savoie, CNRS and CSTB - and INSA Lyon) pp. 3128-3135
Anderson, K., 'Design energy simulation for architects', (Routledge, New York, 2014).
Menges, A. and Ahlquist S., 'Computational Design Thinking. AD Reader', (John Wiley and Sons Inc., Hoboken, 2011).