PERFORMATIVE COMPUTATIONAL DESIGN

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1. INTRODUCTION

Human is the most advanced being in the universe so far. The objective of science is the well-being and prosperity of mankind as a whole and consequently all scientists are responsible to mankind and their function is essential for future generations. Science and technological developments bring advantages and disadvantages, but when used with consciousness, science and technology is able to yield solutions for almost all problems. The goal is to maximize the advantages and minimize the disadvantages.

Concerning the building sector in which we operate, Architecture is an important part of a culture because the buildings, settlements and the cities are the most enduring elements of the culture. Culture is the complex of everything related to the way of daily life and the patterns of behaviour of a certain group or a society correlative to a certain human environment. Belief, art, food, shelter, law, moral, custom, religion, government, social structures, knowledge and *architecture* are all part of a culture. In this respect, there is no cultureless society and the culture is a dynamic and creative phenomenon which becomes apparent in the long period.

The aim of the scientific Research and Developments of the building sector is to provide better buildings and living environment for the human being thus the whole society. Populations of cities overtake those of rural areas, and the majority live in cities**.** Up to the estimations 2/3 of the world population is going to be living in the coming decades in metropolitan areas, mega cities. *Built environment* in cities consume 75 percent of the world's energy and responsible for 80% of the greenhouse gas emissions. Especially in developing countries, the cities and living environment is getting over populated, almost no green and recreation areas and play ground for children in the cities. More and more citizens are being dependent on anti-depressive pills.

This all bring additional problems with, such as social, economical, physiological, health, safety, technical, cultural and the sustainability. As engineers and architects dealing with building science, we are urged to tackle also these material and immaterial issues in an integral approach to provide solutions to the contemporary problems.

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Due to the rapid technological developments of the last century and today's worldwide digital communications and the Internet brings us to a new era where the sustainability issues in urban and built environment demands urgent innovative approaches from the building sector in relation to the ICKT (Information, Communication & Knowledge Technology). As academics involved in this sector, our challenge is: how can we support environmental sustainability and enhance the quality of life as architects and building engineers, using ICKT?
The building sector and the built environment show increasing new demands. Contemporary cities require also recognizable, prestigious buildings as an icon of the city. Cities require new identities. In architecture, not only the design of an innovative form of a building (such as free form, fluid architecture, dynamic architecture) but also in aspects such as comfort, safety, wind, energy efficiency, health, indoor climate, building services and the new requirements on logistics, innovative construction techniques and materials, which fulfils the overall performance of a building.
Besides these economical, historical and cultural aspects in relation to sustainability issues needs attention in our buildings and contemporary cities.
Above mentioned complex aspects in the building sector brings new challenges which the existing knowledge can be captured with the new knowledge, to be progress as an integral part of design & engineering processes. Integral approach in design & engineering is partial solution to deal with complexity to reach sustainability as well.
General definition of science is the "Knowledge about the structure and behaviour of the natural and physical world, based on facts that you can prove, for example by experiments" (Oxford dictionary). In its essence, the scientists are trying to discover everything what we can experience and observe, which already exists in the universe and the nature. An exact scientist discovers the material world and the soft scientist mainly deals with immaterial world, such as psychologist, sociologists. In the exact science generally the immaterial aspects, such as intuition, perception, comfort, cultural, spatial perception and the spiritual values are neglected and considered as not existing, since they cannot be observed or measured by traditional measurement means.
The Architects are dealing with the design of the future reality of the living environment. In this respect we have a big responsibility for the society where we live in but also for the generations to come.

2. ARCHITECTURAL DESIGN

Design is the Description (projection or model) of the (future) reality. Everything we see around us is designed. In architectural design, we deal with Alpha, Gamma and Beta sciences. **Beta** mind scientist deals with the objective world of facts & logic represented by rational mind. **Alpha** mind scientist deals with the subjective world of beauty & moral represented by artistic intuitive soul and the **Gamma** mind scientist considers the interest of society and culture. The mixture of these sciences makes the designer and the design task unique. While processing the design, the

designer uses her/his intuition and logic. The successful designers and architects are the ones who use the mathematical and intuitive intelligence in their design work. Up to Pascal, human being has 2 types of intelligence, namely *mathematical* and *intuitive*.
It is very hard to define exactly what a design is and how architects design, because every single design is as unique as the designer her/himself. There are no general, unanimous rules applicable to each process and each designer. The starting point is always different, although there are certain questions every designer will have to face. In the design task, whether it is a bread toaster, teapot, mobile phone, bridge, off-shore work, settlement, a district design or a building, each design starts with fulfilling *program of requirements*, independent of an object. All objects have functional requirements where then the form qualities added.
In this case different added values will be expected, in particular those regarding quality of form. Of this design of the architect people will expect even more, namely the perception of space. Not only should a new building look attractive, but people should also feel good inside the building and in its immediate surroundings. In this respect there is a fundamental distinction between architectural design and the designs in most other disciplines.
In the eventual realization of a design various disciplines will play a role, and in the completed design, function, technique and form should be expressed as integral parts. The concept of an architectural design shows similarities with the real object, the building itself. At the end of the design process a virtual object is created, showing the same geometrical and morphological qualities as the real object, both in space and in time.
Emeritus Professor Helmut Emde of the 'Technische Hochschüle Darmstadt' ('Darmstadt University of Technology') explains the notions of space and time in his book 'Simulation und Wirklichkeit' ('Simulation and Reality') by placing the ideas of Kant, Newton and Leibniz next to each other. According to Kant, space and time are: "The two ways human consciousness beholds", by which he means the forms of insight of human consciousness. Newton postulated: "Space is God's sensorial area", with which he wanted to indicate that it is in *space* where we can sense God.
Leibniz' concept: "Space is the arrangement of the being-togetherness" connects the statements of Kant and Newton, which relate to consciousness and the material being respectively. In this sense: "Time is the arrangement of things that come after each other", also applies.

3. ARCHITECTURE, TECHNOLOGICAL DEVELOPMENTS & GLOBALIZATION

Architecture refers to the science of designing and constructing buildings and built environment to meet people's physical, **moral** and **spiritual** needs, and **cultural values** making use of alpha beta and gamma sciences as it was stated earlier. Therefore it encompasses soft and hard aspects. It is the combination of arts and sciences.

Famous innovators and architects such as Buckminster Fuller in the history was also a man of many trades: engineer; architect; mathematician; poet; teacher; and philosopher. He is best known for his invention the geodesic dome which is extremely light and almost indestructible. He was also a person very concerned for humanity in many respects.
The most significant difference between the other designer's discipline and the architect is the additional spatial value of an object, thus the spatial design qualities. For example the Rotterdam Erasmus Bridge was designed by the Dutch architect Ben van Berkel of UNStudio NL Amsterdam, who was asked to bring the additional design qualities to that bridge which should be considered as an signature or an icon of the city of Rotterdam. Santiago Calatrava is another example who built bridges in many countries as an architect. The bridges he designs have also become world famous which is breaking tradition and symmetry is truly unique. Calatrava's designs are ambitious, intricate and innovative. It is due to these architects integrated approach and the spatial perception abilities that they have been asked to design all over the world, internationally recognized. In contemporary architecture, Santiago Calatrava is one of the most successful architects of the world. He is an Engineer, architect and an artist. Calatrava's most obvious contribution to the contemporary architecture is the Combination of expressionism and mathematics. He integrates the Design and Engineering in a spatial context, by exploring the creativity.
In the design task of an architect, it is expected that the architect brings additional qualities next to the spatial perception qualities. Those are the material and immaterial-spiritual, physical and non-physical values. The most successful and enduring architects are the ones who are able to realise this balance of physical and non-physical values in their buildings. But how can we make these values explicit due to their soft nature?. The physical values are possible to process in design by various methods, by calculating structures, firmness, detailing etc. But can we make these soft aspects such as non-physical, emotional, spiritual and beauty aspects explicit?
Technological developments have always influence on human behaviour and in the long term culture. Since the ongoing developments on internet and visual media and ICT technology, we see also the other side of the medallion. Some scientist are concerned about the visible disadvantages in social behaviour, such as the Founder and director of the MIT Initiative on Technology and Self, sociologist, anthropologist, and psychologist prof. Sherry Turkle in her best seller book entitled *Alone Together. Why we expect more from technology and less form each other* she says: "We've gone through tremendously rapid change, and some of these things just need a little sorting out. I believe we shouldn't applaud the existence of technology without criticizing which is not showing respect to traditional values…".
Another award winning journalist, ethicist and communications specialist prof. Michael Bugeja claims: "We have forgotten how to respond ethically, emotionally and intellectually to the challenges, desires and opportunities of life at home and at work" .
Prince Charles at the opening lecture of the Islamic Centre, at Oxford University, entitled "İslam & Environment", (10 June 2010) points out that the blind pursuit of

the exclusively material oriented values is the source of the environmental sustainability problem. He emphasized the value of the sacred traditions of the world as a creative resource to solve this problem. In particular he mentions the unexplored potential of the sacred geometrical knowledge in arts and sciences.

Globalization and technology have indeed positive and negative effect on human behaviour and therefore on the sustainability issues as well in broader term. The societies are becoming more and more a consumer society, which we only consume without producing. This includes also the production of new, novel knowledge.

One of the most significant negative effects of the globalization in architecture is that:

- Too little attention paid for people's moral and physiological needs,
- Disappearing vernacular, traditional building technical knowledge,
- Disappearing cultural identities and values.

"First we shape our dwellings, and then our dwellings shape us", as Winston Churchill stated. This statement reminds me the situation of many cities in Turkey as well.

The figures underneath are the examples of how we dealt with our building cultural heritage and the values in the contemporary cities and buildings in Kayseri Turkey. It is an example of my hometown Kayseri, which the history of the city goes back to 4000 years BC. It show the cultural lost and the lost of the old city grid which is now filled with the bad copy of the western architecture which does not fit in the culture of the people and life-style. In this respect, we believe that the academics and architects should find solutions for this lost try to find the balance between old and new. We believe that the partial solution will be also returning back to the soul, to self origin and cultural historical values, which needs academic research and new knowledge to capture.

Figure 1. The house of Ataturk and the interior in Kayseri-TR
Figure 2. The so called modern city of Kayseri

Figure 3. Traditional house architecture
Figure 4. Modern architecture building in Kayseri-TR

4. COMPUTATIONAL DESİGN & DEALING WITH COMPLEXITY

Integration of various academic disciplines with architecture also takes place in our subject area, computer science in architecture. The old craftsmanship which we had in the past has been complemented with a new kind of craftsmanship, in which the knowledge used in the architectural design process is coupled with the machine, namely the computers.

Computers have been used till now in architectural spatial design, for sketching, 2D drafting and later for 3D modelling as a tool but they haven't really been used in a computational sense with algorithms.

In his lecture at the Delft University of Technology, Robert Aish stated: "Necessity is the driving force behind the innovation". Indeed, when there is a need, human being is able to find innovative solutions. In another interview Aish talks about the migration from handcraft to industrial craft to digital craft. He says it is not so much about how to use digital tools but how a user can program tools and present algorithms in order to realize the design intent.

We are now in the stage of being use computers as a partner, by transforming our requirements to algorithms for their support as partner.

Then we can define the term Computational Design as: Computational tools, methods and techniques, which enable designers to formulate their design needs, requirements and rules, and translate them into algorithms that generate designs for buildings, a design approach which exceeds the use of computation as a representational or drafting tool.

Robert Aish describes Computational design as an emerging approach to design that uses the power of the computer to aid the design's progress. Traditionally the designer would create and document drawings or a model as a representation. Computational design provides a framework where various design ideas can be quickly generated and evaluated. It does require some different thinking, for instance the designer would have to consider what variables would need to be driven by the system prior to design, assess what elements depend on one another and identify the desired performance criteria. With these identified a script can be written to provide a framework for the design creation and assessment. So by putting in a little more time at the start, many more design variations can be created, tested and assessed.

5. PERFORMANCE DRIVEN COMPUTATIONAL-INTEGRAL DESIGN

Malkawi defines Performance driven design in their book Performative Architecture as:" Performance-driven design is based on the recent advances in engineering, simulation, computation and construction to provide with most suitable solutions for the contemporary complex demands for the built environment. It could be argued that this approach is steadily gaining ground and will soon become the norm in the architectural practice."

In our understanding and handling, within the complexity in a building, overall aspects, such as social, economical, cultural, safety and sustainability till the form, aesthetic, functional, constructional, climate and energy aspects which can be considered during the conceptual phase of the building design process which aims the maximum optimality of a building, using ICT tools, techniques and methods.

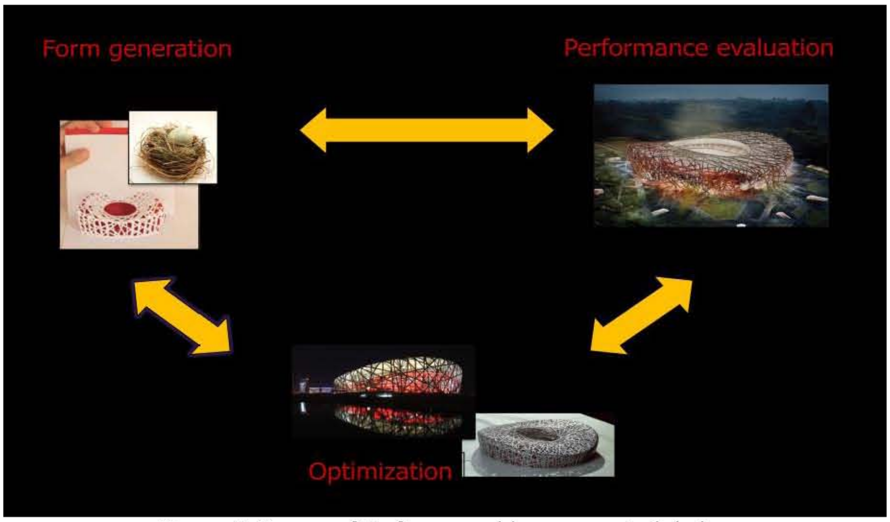

Figure 5. Process of Performance driven conceptual design

It is common knowledge that a computer is very appropriate to check exact criteria, but in the conceptual phase of the design process there are hardly any exact data. In the consecutive phase, the materialization, however, data become more and more exact. To date, materialization has been achieved through a time-consuming procedure, according to traditional methods, which often fails in effectiveness and consistency and does not offer all the possibilities from which to select. The development of methods by which three-dimensional materialization can be supported by means of computer science technology is largely unexplored territory.

During the conceptual (initial) design process, the emphasis is shifting to the processes of form generation, based on performative strategies of design such as structure, acoustics or environment design and the technology has opened up new possibilities for designers to assess certain performance aspects of their designs as it becomes realistic.

The well known contemporary Dutch architect of Ben van Berkel- UNStudio, Amsterdam states: "Architectural practice has expanded over the years and become much more complex. It's no longer the case that a project simply involves the architect and the client. These days the architect works not only with the client, but also with a large network of specialists and advisors. At the same time, not only building and design techniques have expanded, but also the conceptual arrangements of projects; the practice no longer involves only pure architecture, but politics, fashion and the sciences also play an important role. Teaching architecture today means that you have to help students to focus on developing their individual talents on the one hand, but also teach them to choose very carefully within the range of pragmatic possibilities on the other."
(http://www.staedelschule.de/architecture/interview_ben_van_berkel0.html)

Contemporary architecture and engineering practice is working in an integral and collaborative manner, which they handle the complexity as an interactive process where the form and the performance outcome interact with each other to come to the optimal solution. The architects, computational modellers and engineers are working in close collaboration to create most extra-ordinary impossible structures. The leading offices such as ARUP Associates, Bollinger+Grohmann Engineers, and Foster & Partners are working in this manner. Hugh Whitehead, who set up the Specialist Modelling Group in Foster & Partners: "I run the specialist modelling group, which is a research and development group. We relate very closely to all the support groups, so even if we are known as the specialists, we actually deal with modelling in its broadest terms. It takes into account physical processes as well as computer modelling, and also analysis, digital fabrication and rapid prototyping."

At the same office, prof. Stephan Behling (teaching integrated design at the University of Stuttgart -Germany) leads the practice's research into sustainable design and the use of new materials and methods in construction, and established the Material Research Centre (MRC). He is also responsible for the Specialist Modelling Group (SMG), a multi-disciplinary, project-driven research team consisting of architects, engineers, mathematicians, building physicists and environmental scientists who are experts in all aspects of environmental analysis, computational design and digital fabrication.

Figure 6. Foster & Partners office studio in London where they work in an integral approach for the form and performance evaluation, with physical and digital modelling. (http://www.earchitect.co.uk/images/jpgs/products/foster_partners_desks_q191011_5.jpg)

The current concern for the environment evokes fresh challenges for the building industry, such as the necessity of developing building materials that can be recycled and re-used, buildings which can offer maximum comfort and minimum energy use even plus energy buildings as it is already being built in Germany. PlusEnergy is a coined concept developed by Rolf Disch that indicates a structure's extreme energy efficiency so that it holds a positive energy balance, actually producing more energy than it uses.

Figure 7. The Solar Settlement with the Sun Ship in the background: two Plus Energy projects in Freiburg (http://en.wikipedia.org/wiki/PlusEnergy)

Figure 8. Efficiency House Plus with electromobility, Berlin-Germany
(http://downloads.german-pavilion.com/downloads/pdf/exhibitor_28292pdf)

The Institute for Lightweight Structures and Conceptual Design (ILEK) at the University of Stuttgart has won First Prize in the architectural planning competition *Efficiency House Plus with electro mobility* issued by the German Federal Ministry of Transport, Building, and Urban Development. The proposed design is developed under the leading of Professor Werner Sobek, which demonstrates the potential of actively coupling energy flows between the emerging fleet of electric vehicles and our built environment. This concept is architecturally embodied through a striking glass showcase in which all of the core technical systems are laid out prominently to form a full-scale living display. The project not only illustrates the feasibility of building future single-family homes which generate a significant surplus of energy – enough to power the electric vehicles of their occupants – but also demonstrates how future buildings can be designed and built to allow for complete disassembly and recycling at the end of their life cycle.

Added value of computational performance means is the Interaction and integration among various knowledge disciplines and involved actors. This yields deep knowledge; so that optimal solutions can be reached that satisfy the broad range of goals at the same time. Indirect contribution of these means to the environment and sustainability is the Modelling and *collaboration* in: design, construction, realization and operational services, *visualization* and *analysis* of the *sustainability performance* of buildings and built environments and search for optimal solutions as an enabler for data, information and knowledge processing, re-use and communication.

Due to the developments in computational design tools, techniques and methods where architects are able to design complex forms, there is increasing new demands on performance aspects of sustainability such as comfort, safety, wind, energy efficiency, health, indoor climate, building services and the new requirements on logistics, innovative construction techniques and materials during the conceptual phase of the design and the interaction between the form and performance aspects.

Figure 9. Serrenia residential resort and hotel complex-Egypt, by Foster & Partners

An example of a performance driven design from the practice is the Serrenia's Marina 'Hub' which is one of the focal points of the development, with an extraordinary wave shaped floating roof and a vast airy, cool space below. A central pier, yacht marina and beach club extend from the hub.

6. COMPUTATION & PERFORMANCE RESEARCH PROGRAM OF THE CHAIR DESIGN INFORMATICS

At the Faculty of Architecture, Delft University of Technology, one of the 6 research programs which run under our leading is the Computation & Performance. The aim of the program is to improve the performance of buildings by using computational methods for model generation and analysis, decision-making and design communication and collaboration in an interdisciplinary environment. Performance in this context refers to technical performance as well as qualitative performance – physical, psychological and cultural. We deliberately do not define performance in any strict manner; comfort and safety, visual attractiveness and iconic quality can be considered performance aspects in the same way as structural integrity, energy efficiency and sustainability, etc. Computation and performance go hand in hand in the aim of this program: computation serves as the means to reach the goal of performance. At the same time, performance is in itself a means to reach better buildings and a better built environment, from urban and regional planning till the building design which we strive for as an ultimate goal.

Few examples of ongoing Phd research projects:

• **Du XIAOYU:** Building Form Generation for Passive Cooling: Digital Generation of Contemporary Rural Residential Building Based on Passive Cooling Strategies of Chinese Vernacular Building

This research focus on digital approach for building form generation and performance evaluation. General objective is to clarify the principle of Chinese traditional vernacular building form design for passive cooling and integrate the current digital design approaches for building form generation based on building performance in the early stages of architectural design. Then, applying this integrated design approaches to the generation of Chinese contemporary rural residential building in hot summer areas based on passive cooling strategies of Chinese vernacular building.

Sub-objectives:

- Clarifying the relationship between Chinese traditional vernacular building form and passive cooling.
- Finding the main characteristics of climate in hot summer area of China and the suitable passive cooling strategies.
- Finding the available techniques from Chinese traditional vernacular building which can be utilized for passive cooling in contemporary building.
- Finding the main characteristics of the new contemporary Chinese rural residential building and the suitable way for its improving.
- Finding the suitable parametric design software for form generation
- Finding the main parameters of building form which can influence the passive cooling effect.
- Finding the suitable evaluation method for passive cooling.
- Integrating the digital environment for the design process.
- Final Products will be the *Guidelines* for new contemporary Chinese rural residential building design with passive cooling system and a Method for *Integrated architectural design approaches* for building form generation based on performance evaluation in a digital environment.
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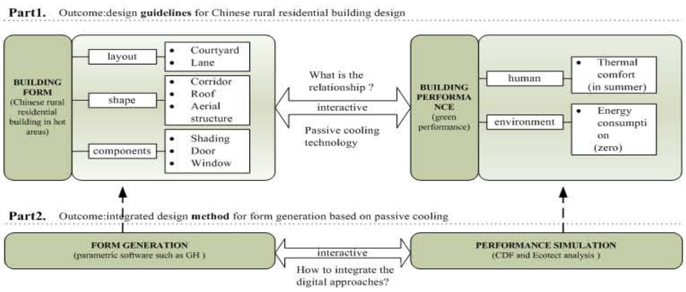

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- **Abdul BIN IMADUDDIN:** Bioclimatic design in Vernacular Architecture.

The main reason for the existence of vernacular architectures that are different between regions in the world is due to the different climatic condition in the region which they are dealing with. It was known that climate was the main factor that influences the shape and the technique of building constructed before man has a good knowledge on technology and materials. Buildings that have the most economic, most useful and have most effective solutions to the climatic conditions of the region in which they exist are best examples of vernacular architecture (Engin, Vural et al. 2007). Vernacular buildings are the architectural products that

come out as a response to the requirements of local climate and as a result of the interaction between human and experience collected by seeing natural environment. Vernacular buildings, either individually or a whole settlement, are the best examples of the harmony between human behaviour, building and the natural environment.
In the studies of the thermal comfort of buildings, they are mainly referenced under bioclimatic design or the vernacular, with the emphasis on basic and good design principles. Relating to bioclimatic design with features of the local vernacular; it aims to create a digital design method for an appropriate domestic architecture for the popular suburban settlements of growing cities around the world.
Bioclimatic design can be defined as a design of an indoor, exterior and outdoor building and space by considering the local weather and climate. The aim to apply bioclimatic design in building preferably to provide a thermal and visual comfort to the building occupant by utilizing natural and environmental source such as wind and solar. The basic element of bioclimatic design is passive cooling which integrate the building with the environmental source for cooling, heating and lighting such as wind, solar, air, vegetation, water etc. to create indoor and outdoor thermal comfort. Hence, bioclimatic design studies on the whole more technical and scientific in nature, while vernacular architecture highlight the issues of culture, tradition and aesthetics as well as comfort. In this writing, both bioclimatic and vernacular designs are discussed for the various setting of the region and different world climate.
Passive cooling means cooling building by utilizing the efficiency of building envelope / fabric without mechanical device assistance. It is only rely on natural ventilation to provide indoor thermal comfort by evaporation, convection and radiant without using electrical device. Passive cooling relay on daily temperature changes and relative humidity thus it will depend on the climatic conditions. Some design strategies to reduce heat gains into internal spaces is natural ventilation, wind towers, courtyard effect, earth air tunnels, evaporative cooling and roof spray.

- **Michela TURRIN:** Performance oriented design of adjustable modular roofs

Performance oriented design of modular roofs
By focusing on modular wide span roofs, the research refers to the field of performance oriented design and relates it to integral design as a way to approach the complexity of architectural processes; the use of parametric modelling is investigated in combination with performance simulation software and genetic algorithms in order to support such design process and the integration of reconfigurable structures is investigated in order to allow roofs for adjustability. By referring to this context, a first concept that needs to be discussed concerns performances in architecture; and this leads to the interrelated concepts of, on one side, complexity and, on the other side, adaptability.

Performance and kinetic architecture
The concept of performance in architecture takes into account the impact that the built environment has on human life, both from a daily and long term perspective,

and confronts human needs and wants in their various levels, from basic to high. As a consequence, in order to define and asses a range of performance requirements, data sets need to be identified and managed both for the human needs to be satisfied and for the environmental conditions that may either inhabit or facilitate the accomplishment. Given a specific data set describing the context in its parts, identifying a design solution which satisfies the expected performances is already a challenging task. The complexity of this operation increases even more when considering that the data set does not offer a fixed frame. Human needs and demands change over time, in the short and long term use of the space; and the environment also changes both in the short and long term. Therefore, while traditional buildings are quite static and are usually designed based on the average satisfaction of the most common or predictable conditions, the idea of a building able to properly react to changing needs and environmental factors should be considered.., Possible ways to satisfy changing needs in changing environments include changes in geometry (based on geometrical reconfigurations of elements) and changes in material properties (without implying geometrical variations). The first one requires a change in shape through the movement of one or more elements or parts of them; it is here called kinetic architecture, and has been closely investigated according to the key influence of geometry upon architectural performances.

Parametric geometry and reconfigurable structures for modular roofs

This context gives emphasis to the importance of early integrating performance simulations during the design process, in order to evaluate different geometrical alternatives. On one side, this process refers specifically to the concept of performative architecture, defined by Branko Kolarevic as the one in which building performance, broadly understood, and becomes a guiding design principle (Kolarevic, 2003). On the other side, it requires a network of interdisciplinary interrelations and recalls the concept of integral design by referring to the simultaneous integration of various and interdisciplinary aspects. Such process has been explored based on the combination of parametric geometry and performance simulation software, where the first ones allow the algorithmic creation of geometrical design alternatives that are meaningful for the investigated performances, and the second ones allow their performance evaluation; the use of genetic algorithms has been made in order to guide the search process and to converge the generation of design alternatives toward a set of well performing solutions. Further, the use of reconfigurable structures has been investigated to allow the design switching between different geometrical configurations of its components, aiming at embedding variable geometrical configurations each of which optimized for different contexts.

The process has been developed by specifically focusing on the design of modular large roofs. When focusing on large roofs, aesthetics, structural performances and economics often dominate the design process. However, the current increase in attention to energy-related aspects generates new challenges which require special attention. Particularly, the use of renewable energy resources needs to be confronted in the design. Based on this, structural morphology and solar energy transmittance have been selected as key research subjects. Within this context, special attention is given to the use of (eventually adjustable) components to make the envelope able to use on-site energy resources, like wind and solar energy. Focusing on passive thermal comfort (passive heating and cooling) and daylight, large modular structures are investigated with respect to the ability of being responsive to the daily and seasonal changing climate factors. The use of responsive geometries leads to investigations upon reconfigurable structures as systems responsive to different climatic conditions, including the possible integration of deployable and foldable modules.

The Vela Roof: an example of performance oriented parametric design

Though a first case study, the potentials of parametric modelling for performance oriented design have been explored. The case study is a large span roof (here called "Vela"), part of a project active in Bologna (Italy). Since the risk of summer thermal discomfort was expected under the roof, various strategies have been investigated considering passive systems and their effect on the thermal comfort. With respect to the investigated strategies, the geometry of the roof plays a key role and its exploration was integral part of the performance oriented process. In this context, parametric modelling was used in order to jointly investigate the overall shape, the structural morphology (with eventual integration of openable modules) and the cladding system of the roof. In particular, the models aim at parametrically generating three integrated families of geometric instances. The first one concerns alternatives of the overall free-form shape of the roof, to drive the airflow for cooling. This includes alternatives of the structural morphology, which were studied according to previous choices that favoured a space frame typology. The second one concerns the integration of openable modules in order to allow summer heat extraction. The third one concerns the sun shading properties of the cladding system, which play a fundamental role to prevent thermal discomfort. Specifically, this third investigation was based on ETFE pneumatic cushions with a north-south printed shading system aimed at reducing the direct solar radiation by allowing the income of indirect light. Figure 10 shows an example of performance evaluations for shadow effect (and direct solar exposure) and daylight of various parametric alternative solutions, generated to explore different opening angles of the printed shading.

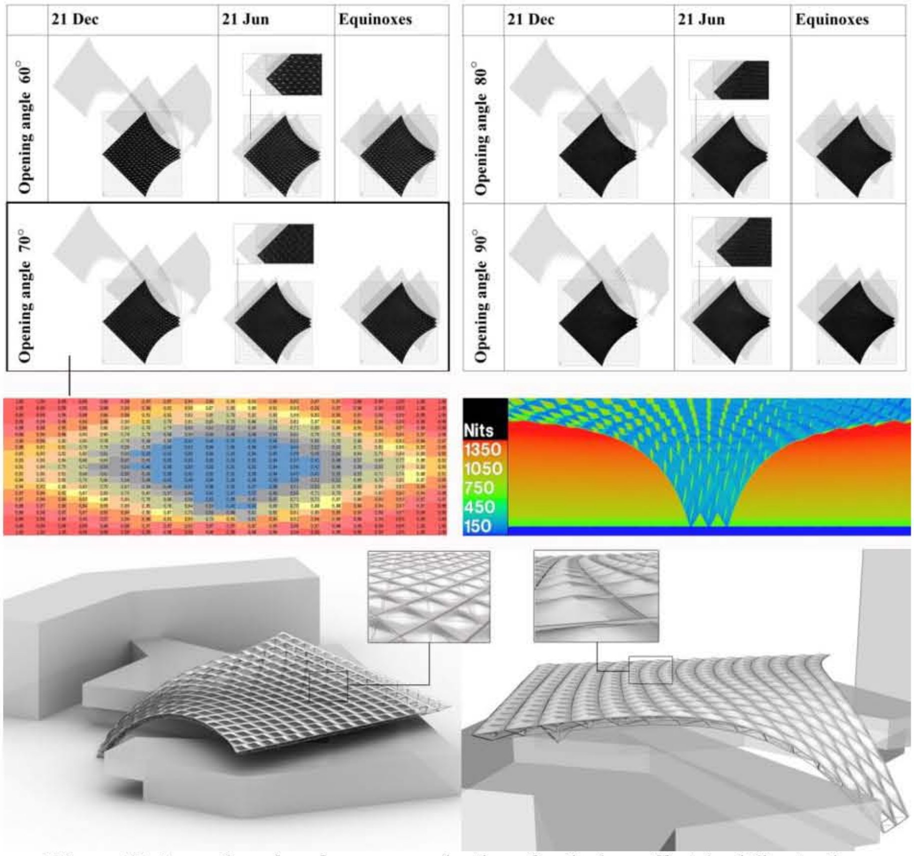
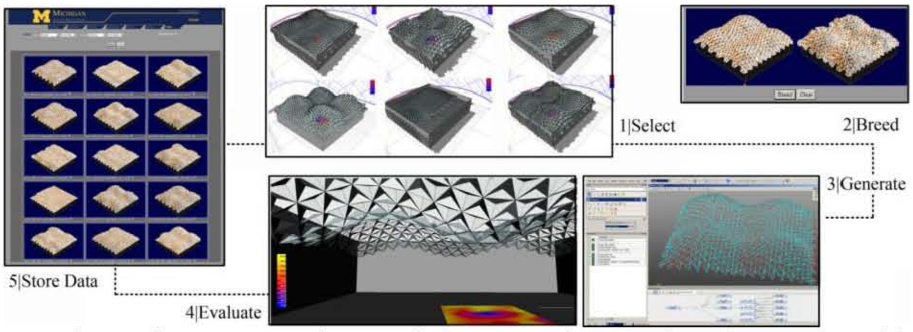


Figure 10. Examples of performance evaluations for shadow effect (and direct solar exposure) and daylight of alternative solutions parametrically generated.

SolSt: an example of performance oriented parametric design based on genetic algorithms

The Vela roof case study shown the potentials of parametric modelling in generating large range of design alternatives, which can be evaluated based on various performance criteria. The exploration of such a large design solution space remained however unsolved. In order to provide support in this phase, a tool (ParaGen) initially born for structural optimization was further developed to include energy related performances, based on a collaboration between TUDelft and Michigan University. ParaGen loops parametric modelers (at the moment Generative Components, Bentley Systems), performance evaluations software (at the moment STAAD for finite element analysis in structural design and Ecotect for energy related performances) and a genetic algorithm system. The tool is currently being tested on SolSt, a large span roof conceived for a location in Milan (Italy).



Note: The work on ParaGen is part of PhD research currently under way at Delft University of Technology and is performed in collaboration with the University of Michigan, where ParaGen was born on an idea of Peter von Buelow. As part of the same PhD research, the work on the Vela roof has been developed in close collaboration with Axel Kilian and Eric van der Ham.

- **José NUNO BEIRÃO**: City maker. Designing Grammars for Urban design

The main aim of the research was integrating information flow in the design process in order to support design decisions. For that purpose three main things were developed:

1- The integration of a parametric design platform with a geographic information system;

2- Urban design patterns, i.e., modular algorithms generating small design moves which combined may produce designs;

3- Embedding calculations in the design in order to obtain indicators on diverse properties of a design and in an interactive way.

The design environment above described allows designers to better deal with the complexity of the urban form and related information, thus strengthening design decisions. The platform also benefits strategies based on adaptable models with linked properties rather than definitive layouts.

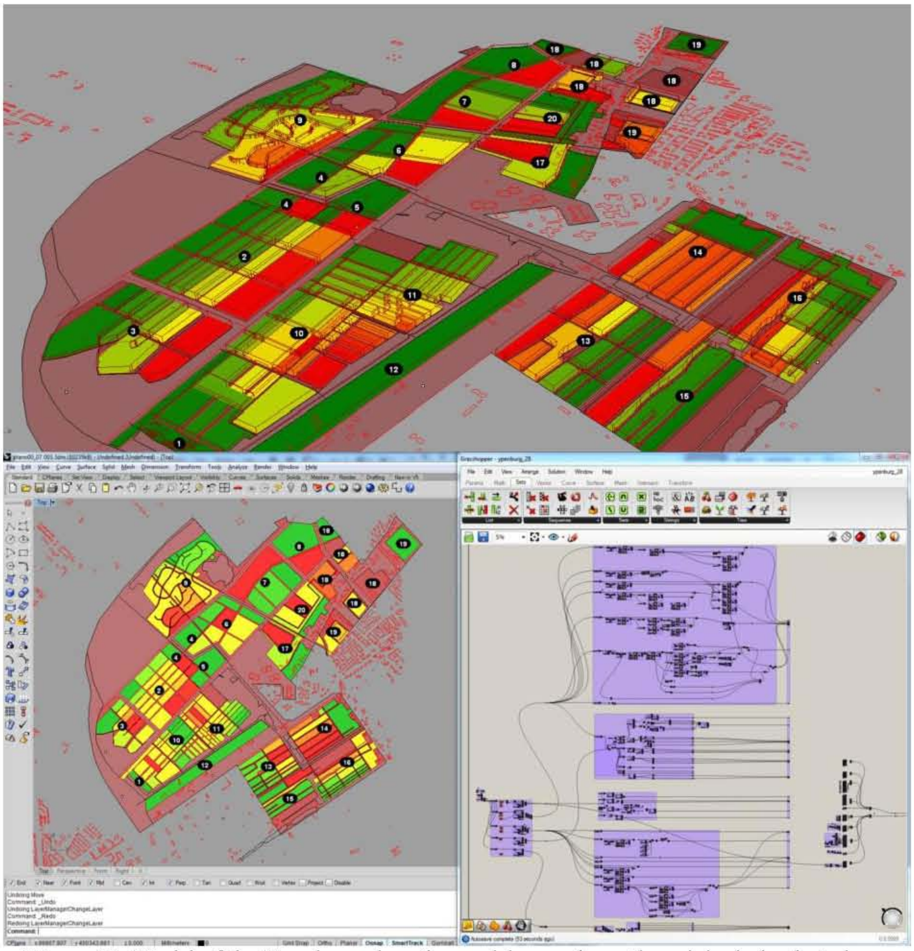


Figure 11. Model of the Ypenburg plan; the model reproduces the original plan but plays with density variations - colors show different building intensities determined at block level and also at district level. Districts are numbered. Different density variations will allow designers to visualize the impact on the plan appearance and to establish possible density regulations for the plan.

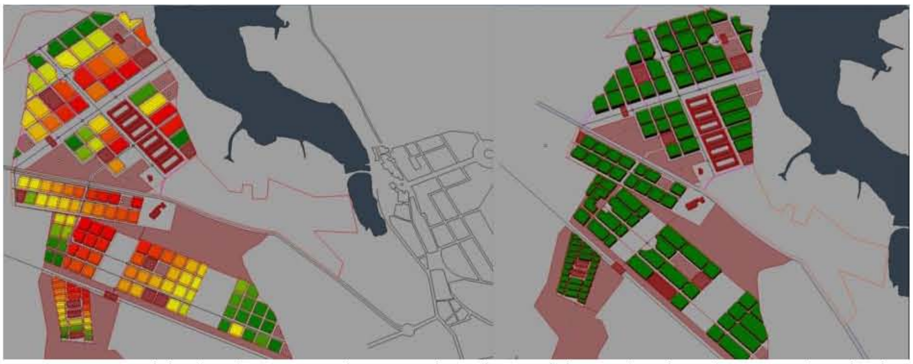


Figure 12. Model of Quinta Fonte da Prata plan; the model was developed more or less in the same fashion as Ypenburg but using a distribution of density defined as a function of proximity to selected elements of the design such as main streets or squares. We call this function attraction. The distribution calculations are done at district level but indicators defined at block level. Image on the left shows intense distribution and image on the right shows the situations when attraction is zero.

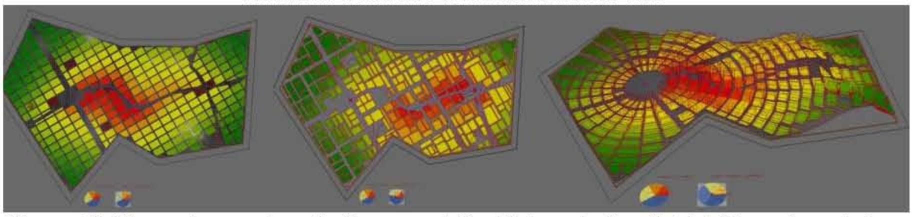


Figure 13. Shows three automatically generated grids in a similar district. The only variation is the input on grid type; the other variables (geometric and numerical) are the same. The grid on the right also shows the mapping of the plan into topography.

- **Pirouz NOURIAN**: Configurative Design Methodology and Technology.

A proposal for applied computational methods for built environment configuration Concisely, in this PhD research the main focus is on devising computational methods for configurative design: that is explicit design of spatial arrangements. This issue has three key aspects: Configuration, Computational Design and Design Methodology. Configuration here refers to the so called “hidden structure of space” or major aspects of spatial arrangements, including massing (density distribution), land-use allocation and topological relationships of spatial elements. Computational design methods and techniques are being used to make software applications for built environment design. These software applications are to support design and decision making processes in built environment design.

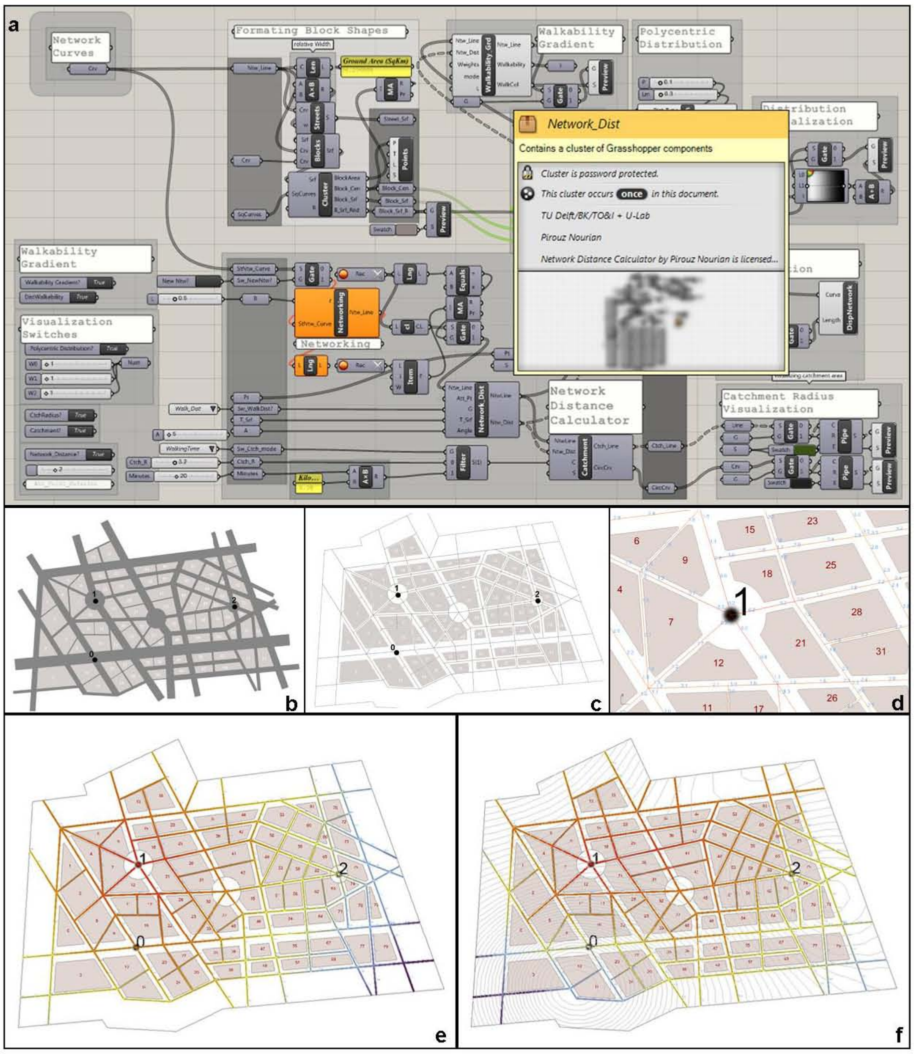


Figure 14. The computational design system made for Grasshopper® Visual Programming Interface. (b) a typical imaginary neighborhood; (c) street centerlines (d) network distances from an attraction point; (e) gradient of network distances from attraction point number one, considering a flat landscape; The bluer the colour the farther the distance (f) gradient of network distances from the same point considering a topographic landscape.

Sub topic: Computational Intelligence for Enhanced Decision Making in Engineering and Design

Human beings have the remarkable capability to make best decisions although the environmental information is ample, comprehending many obvious and hidden relationships among the detailed properties of an environment. Establishing computational models that simulate the human abstraction, reasoning and creation capabilities is the subject matter of the research presented here. This is important for two reasons. The first aspect is that the computational models permit to better understand the processes occurring via human mind, so that a deeper understanding of what design/decision-making is and how it works is gained. The second aspect is that it permits to support a human designer/decision-maker by means of powerful, 'wise' assistance during difficult tasks that are beyond human comprehension. In particular decisions in design and engineering are difficult to take due to increasing complexity that generally arises from the following three issues:

The first issue is the involvement of multiple decision criteria, which are conflicting and generally have a soft character, such as sustainability, operational certainty, financial certainty, or attractiveness. The softness stems from the need to represent many detailed features of an environment by means of a few quantities, so that models involve many non-linear relations among variables. The second issues is the involvement of multiple, stiff constraints that must be satisfied, such as time, money and space restrictions. The stiffness refers to large numerical difference among several constraints subject to minimization. And finally, the third source of complexity is the involvement of several independent variables constituting a solution, which implies an excessive amount of possible solutions to be investigated within limited time.

These issues make it formidably challenging to reach most suitable solutions. It is emphasized that this difficulty is alleviated when advanced computational methods are used to deal with the complexity, which is the subject matter of the computational intelligence-based work presented here. In particular methods from the domain of computational intelligence, such as evolutionary, neural and fuzzy computation, are employed to deal with soft and conflicting objectives, stiff constraints and vast solution domains. As result, solutions are guaranteed to satisfy the objectives at hand as much as possible, while they satisfy the constraints at the same time. This quality assurance is highly desirable in the face of depleting resources and increasing demands imposed on engineering and design products, and it will become more and more relevant in the future, in proportion with the increase in complexity of the real-world decision-making problems.

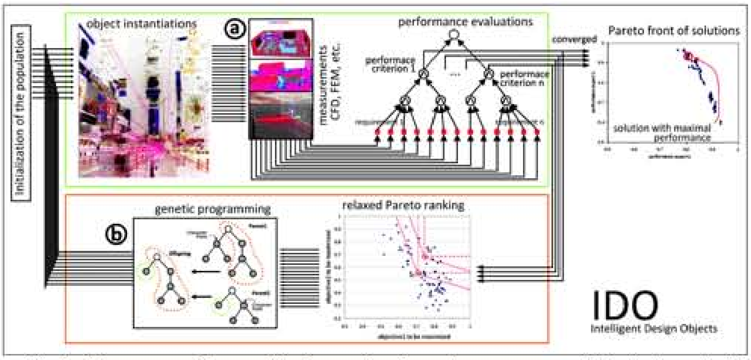


Figure 15. In this approach a multi-dimensional performance model is integrated into a computational search process.(PhD thesis M.Bittermann)

Energy-Neutral Neighborhood Engine (ENNE)

By the researchers Michael BITTERMANN, (post-doc) Ioannis CHATZIKONSTANTINOU (PhD,) Ozer CIFTCIOGLU (senior researcher-guest professor) recently completed project deals with the energy performance measurement of a buildings/series of buildings which can be use during the conceptual phase of the design.

Energy sources are scarce and therefore expensive. There is a necessity to use these sources as carefully as possible. Therefore we developed a tool that supports design and renovation of buildings, so they will have a low heat-energy demand. Using the Energy Neutral Neighbourhood Engine (ENNE) this can be achieved at minimal investment costs and without compromising the architectural quality. In ENNE the energy demand will be computed with satisfactory integrity throughout the early design stage.

Design-software with real-time energy computations

ENNE is a design software with real-time energy computations and a user friendly 3-D interface. It is a design tool for project developers, architects, and urban planners, who wish to know about the heat energy demand of their designs from on the first design stage. The computations are based on appropriate models of energy behavior. Therefore the annual heat energy demand and monthly costs for heat energy are computed with accuracy per house or for a whole building complex. This is considered an important feature for marketing a design, because house buyers are interested in the information on permanent costs of a property. Also municipalities may value the insight provided by ENNE regarding the implications of design decisions. Using the tool, the time required to accomplish an energy demand analysis with appropriate emphasis on integrity is significantly reduced. With ENNE the energy demand is computed in real-time throughout the design process.

In ENNE the following factors are taken into account:

Influence of the orientation	Influence of the location
U-values of walls, windows, roof, and floor	Dimensions
Percentage of windows	Different house types
Influence of the ventilation system	other influences

Further levels of computations

ENNE is an advanced design-software having three levels of computations that meet the demands of design complexity. *Level 1* is the basic heat energy and cost computations with minimal design input requirements as described above. *Level 2* considers additional soft design issues, like visual perception, environmental safety and comfort, and so on. *Level 3* provides optimization of the energy design aspects, with respect to the trade-offs among them. For example reaching low energy demand at maximum architectural quality.

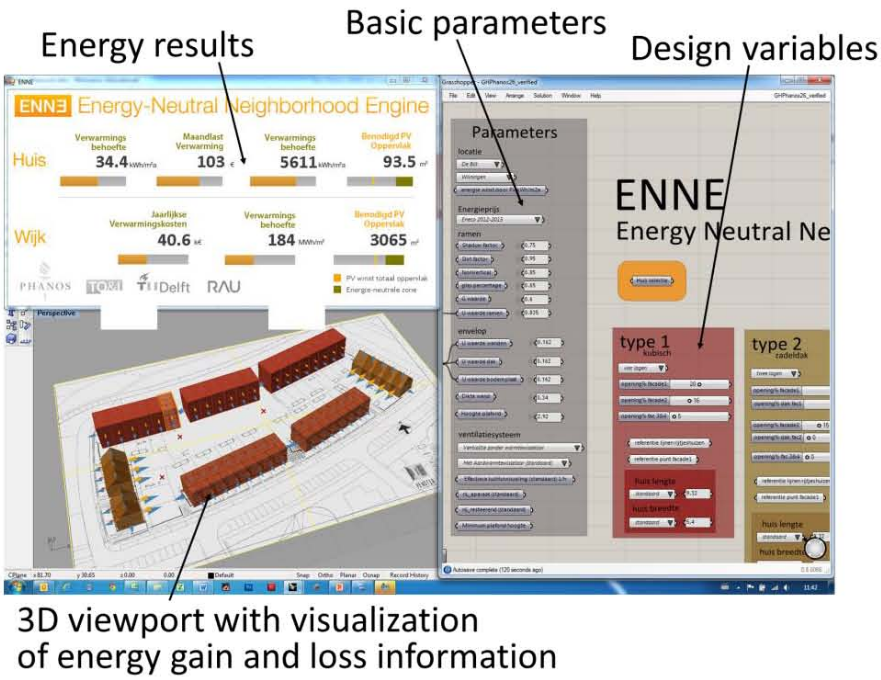


Figure 16. Components of the ENNE software interface

• **Ioannis CHATZIKONSTANTINOU:** Computational Comprehension for Treating Complexity in Architectural Design and Engineering.

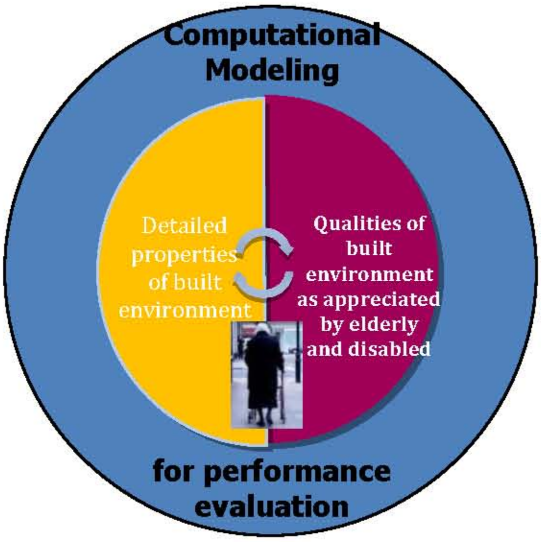
The task of architectural design is characterized by a large degree of complexity. The complexity comes as a result of the conflicting nature of the demands that the design is usually called to respond to, as well as the excessive amount of design decisions that it entails and which are related to design objectives in intricate ways.
The complexity comes from the fact that most real-world problems concern complex systems, which involve multiple, conflicting objectives, and multiple decision variables that are interrelated with the objectives in intricate ways. This generally gives rise to an excessive amount of possible solutions, so that identifying a most suitable solution among them is a formidable challenge. Such problems are encountered in all fields of science, ranging from the social sciences to engineering. In such cases human comprehension is not suitable to arrive at a best decision, and it should be supported with machine comprehension. Therefore machine cognition and consciousness is high on the modern scientific research agenda. The aim of the research is to investigate and develop a computational cognition and comprehension methodology in accordance to this demand, so that machine support can point to design decisions that reflect the at the same time the satisfaction of design demands as well as the preferences of the parties involved in the design.



The images are result of an investigation in the application of computational search (using evolutionary computation) for facade shading configurations that may provide shading for desired interior areas while minimizing material cost of the facade and subject to manufacturing constraints. The two different sets of images belong to solutions that are characterized by different performance in terms of shading efficiency and use of material.

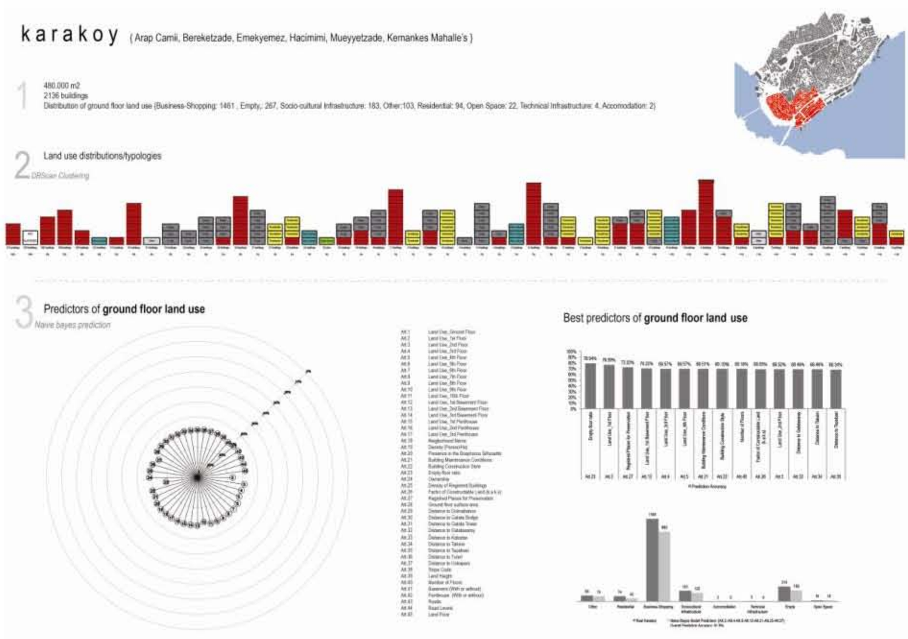
- **Tijjani ZUBAIRU:** Assessment of building Performance from the standpoint of elderly and disabled persons using neural computation.

Assessment of the performance of a building from the view point of its suitability for elderly and disabled is a complex matter, because it concerns not only measurements of detailed properties of a building, such as the width of doors, or the height of door steps, but it also involves psychological assessments in terms of security, safety, privacy, visual comfort etc. In order to deal with this complexity, assessment of experts, as it is conventionally exercised, without support by means of appropriate computational means is insufficient. Ageing and disability as used in this context refer to all forms of impairments limiting the functioning of both physical and mental attributes of human, that make the daily use and interaction with the built environment challenging. Developing a computational model for the precision assessment of the performance of institutional and public buildings is the objective of this research. The performance assessment concerns particularly the degree of suitability of a building for usage by elderly or disabled people. The methodology employed for this purpose is from the domain of computational intelligence, because it is uniquely able to deal with the complexity of the performance being assessed, namely the methodology emulates the ability of human to establish appropriate abstractions despite abundant information that contains many non-linear interrelations among multiple detailed attributes. This is in contrast to the methods from statistical analysis that presuppose independence among variables, which is a gross simplification in the present case, where a subject matter of great complexity is investigated. The result from the model being pursued will be an understanding as to the relative importance among the building features taking their simultaneous interrelation into account for the satisfaction of the demands of elderly and disabled. This way the information on performance being modelled is acquired by means of questionnaire supported where expedient by physical measurements, which will be integrated into a neural model.

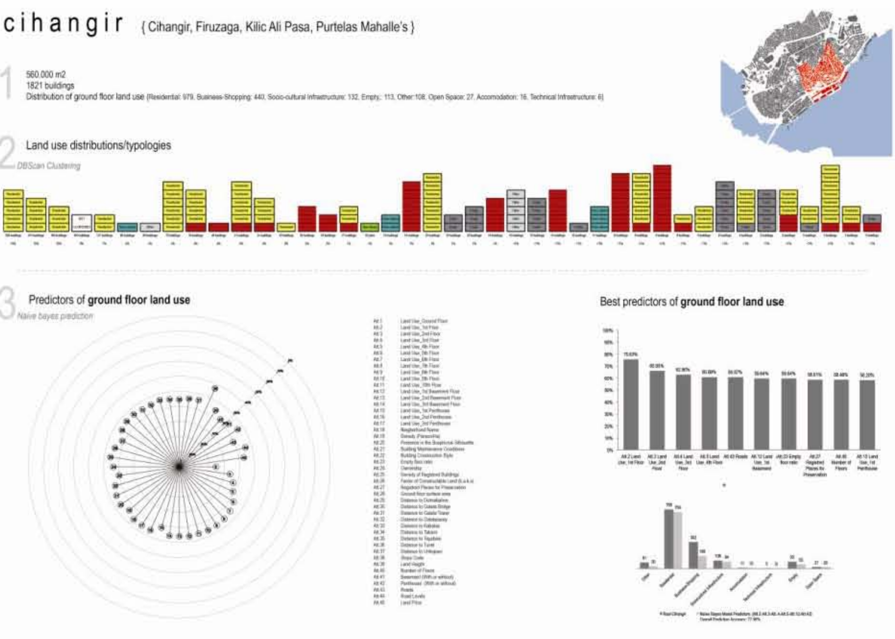


- **Ahu SÖKMENOĞLU**: Exploring patterns and relationships of a complex urban system; The case of Beyoglu (joint PhD with Istanbul Technical University-Turkey)

This research applies data mining methodologies in urban analysis to explore patterns and relationships of micro-scale data in Beyoglu-Istanbul and proposes a framework integrating data mining analysis results with evolutionary computation to demonstrate how these patterns and relationships can assist in decision-making in urban transformation.



These images depict the results of the analysis of buildings' attributes of two major districts in Beyoglu, Cihangir and Karakoy by means of data mining methodologies. Clustering analysis is done to detect how land-use of buildings is clustered within the districts, and Naive Bayes Prediction is applied to find the predictive power of different attributes of buildings over land-use of ground floor which indicates a certain probabilistic relationship among them. The patterns and relationships found in this step are further analyzed by means of Association rule analysis and integrated into evolutionary computation.



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- **Irem ERBAS**: Description of a decision support tool - based on Knowledge Modelling - for energy and comfort performance improvements of existing houses.

The main objective of this research is to contribute to energy efficient (re)design processes of the existing housing stock within the context of sustainability. The research aims to search for and present an approach to provide integrity to deal with the growing amount of information and processing of this information in energy efficiency and indoor climate relationship during a (re)design process of existing housing. The focus of this practical problem of energy efficiency is to ensure good indoor climate on several energy levels, from the less ambitious one till the most ambitious one. Based on these, two main questions are raised:
How can architects be better guided to achieve the ambitious energy goals without neglecting comfort? How to organize the complex and extensive information and how to present it to the architects in a meaningful way so that they are simultaneously informed about how their design choices affecting several performance criteria?
It is asserted that there is a need for a better support for architects in the process of energy and comfort upgrades of houses, particularly looking at early stage of (re)designing. In order to understand why one design performs better than another requires an integral approach looking closely to the interrelationships among the various aspects. Therefore there is a need both to better understand how conditions of good indoor climate are correlated with measures to improve the energy use of a building and to make this knowledge available to the architect in the design process in an integrated way.

According to findings, a knowledge model is established showing the interrelations between the performance criteria and their sub-aspects. This model has been considered to be a generic one which can be expanded with adding in further information. It is considered to be link to decision support tool development. By means of information/knowledge modelling and embedding such a model within an existing architectural tool, it is intended to make performance assessment an inherent part of design process.

7. CONCLUSIONS

Universities are the places where the *universal knowledge* is being discovered, developed and shared, without national borders. As Santiago Calatrava says; universities are the places where the *minds* collaborate and communicate. Therefore universities as scientific institutions besides preparing students for their professional life should educate and stimulate students to develop a critical, scientific, and innovative way of thinking. It is our aim to train young first-rate designers and researchers in order to upgrade the excellent reputation both nationally and internationally, also in the field of computational design, with the aim to be able to optimize the design performance to enhance the optimum building quality and built environment for the human wellbeing and prosperity of mankind.
As scientists and professionals concerned with built environment, from our professional ethics and social responsibility point of view, we are urged to develop new knowledge, and novel technologies which are able to capture this knowledge. This must systematically be disseminated to the new generations besides retraining the practicing professionals.
While doing this, next to the physical, material more attention should be paid to *human centred* immaterial values as well, such as social, cultural, moral and spiritual needs of the societies.
Integrating these soft issues with the environmental sustainability targets in the design process can be accomplished using the ICKT technologies. To make it happen we need to set up the appropriate strategy and policy for this goal.

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