Giovanni Zemella · Andrea Faraguna

Evolutionary Optimisation of Façade Design

A New Approach for the Design of Building Envelopes

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Introduction

This book is a conversation between two friends, an architect and an engineer. It is an exchange of opinions born out of a mutual interest for our disciplines and their possible connection.

After the publication of a paper on how a specific type of evolutionary algorithm could be used for the optimised design of façades, we were asked to expand the topic a bit more. We felt—and still feel—that there was a gap between the technical knowledge about optimisation and its application to the design of buildings.

We were talking about that and we both thought that we should write about optimisation as a tool to integrate the skills of engineers and architects. This topic is extremely wide and can be applied to the whole spectrum of the design of buildings. We decided to limit our discussion to building envelopes because they represent an area where the skills of architects and engineers are more evenly distributed because the boundaries between aesthetics and performance are quite loose; this is where optimisation can represent a significant step ahead towards a successful design.

The only way to approach such a problematic and at the same time overlooked subject seemed to be an informal talk. So we decided to edit a year of chats, phone calls and emails in the form of a dialogue. We hope that the result will be a useful starting point for a reflection on the task of building, as it's been helpful for us while we were writing it.

Far from being a manual on optimisation, this text aims rather to raise interest in a new vision of design and its possibilities. Only when we started to ask general questions about architecture, confronting our opinions, we realised that both our personal perspectives didn't find validation in the current practice of our professions. So instead of providing answers, the book collects a series of questions and insights. We present here a reflection in its nascent state; these are our hopes and expectations regarding the practice of building.

The book starts with a discussion about the concept of building envelopes, what we would expect from them, from the perspective of both an engineer and an architect—but does it make sense to have different perspectives?

Given the objective difficulties of producing an integrated design of building envelopes, we present an innovative approach to design based on evolutionary

optimisation techniques, that we hope will reduce the barriers preventing architects and engineers from working together properly and in an effective way.

After the presentation of a methodology to target the optimum design, we discuss how to understand and describe if a building is properly designed and, eventually, quantify its grade of ‘optimality’.

Now we have the instruments to explain our vision of designing building envelopes, how the different actors should collaborate and use the optimisation techniques to deliver good design, which can properly deal with the challenges of the future.

Eventually, we test the methodology that we taught to each other during our dialogue—with some tense moments every now and then—on a real example.

The façade is the most exposed and noticeable part of a building, but it is also a manifestation of its essence and an anticipation of its content. Balancing the relationship between content and appearance is one of the most difficult tasks of design.

How will the work of a designer change in the future? And in particular how will it be like to design a façade? An envelope? In this book, we try to give some initial answers.

We know well that the future cannot be predicted. Every anticipation is doomed to fail and will fatally lead to disappointment. But the concept of future is integral to design; in fact, when we design we envisage something that doesn’t exist yet. And after all the practise of prediction has always been helpful to improve our present, it is functional to our will and our control.

A way to conceive a prediction is by means of associations, i.e. connecting things that were not together. That’s exactly what we do in this book: we superimpose architectural ideas with a scientific computational approach. In this way, without images, but with the help of suggestions, we hope to provide some reflections of what’s to come.

Chapter 1
Envelopes

Complexity of the Design Process of Building Envelopes

I would like to focus our discussion on building envelopes, because their design represents an interesting overlap between the professions of architecture and engineering, between the categories of performance and aesthetics. This mixture of skills can represent a great design opportunity, as long as the correct approach is adopted.

The envelope is a fundamental part of buildings: it has a key part on the overall appearance of the building and on the way it performs in providing comfort conditions for the occupants. Building envelopes—and mainly façades—have to communicate emotions and the value of buildings, and therefore in there it is embedded approximately 25 % of the overall cost of projects.

In terms of performance, through façades heat transfers, air and moisture move, noise and pollution can be blocked or attenuated, daylight penetrates, etc. All these aspects are strictly connected and the way they are combined has an impact on the energy consumption of the whole building and the comfort conditions of occupants.

Appearance and comfort, we'll see if this is really the topic.

Let's start with thermal comfort, which is nowadays a requirement that is impossible not to consider: designers take a lot of care about this aspect and about energy efficiency, in order to limit carbon emissions.

How would you summarise the theme of heat transfer through building envelopes?

Heat Transfer

Heat migrates from elements which have a higher temperature to cooler ones, until equilibrium between elements is reached. Heat transfers via three means: conduction, convection and radiation. Now, without entering the very details of this

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subject, what matters to us is that, when outer and inner air temperatures are different, there is a heat transfer between the building and the external environment. This heat transfer happens through the building envelope (façade, roof, floor). In terms of building energy performance, we speak about heat losses when the external air temperature is lower than the internal one and heat gains in the other condition. The amount of heat transfer depends on the characteristics of the building envelope, on its ability of insulating the spaces. This characteristic of the building envelope is summarised in one parameter called *thermal transmittance*, or *U-value*: the lower the thermal transmittance, the less the amount of heat flowing between internal and external environments. The *U*-value is mainly defined by the amount of insulation within the opaque façade elements, the type of windows/visual elements, the amount of them, the way different elements interface and the presence of thermal bridges. Thermal bridges are due to interfaces between different façade elements, window frames, local penetrations, all the conditions where the continuity of the thermal line of the façade is interrupted. A proper design can limit the impact of thermal bridges by reducing their occurrence and by providing adequate thermal breaks. Obviously thermal transmittance influences the overall energy efficiency of buildings in different ways, depending on the use of the building and on its location: for example, for a residential unit in a cold climate it will be very important to have a low *U*-value, whilst for an office building in a moderate climate the thermal transmittance is not that important. In general, though, the lower the *U*-value the more energy efficient the building. Moreover, if walls are well insulated (meaning that the thermal transmittance is low), their surface temperature will be very similar to the internal air temperature: this is important to provide good levels of comfort for the occupants and to limit the risk of condensation or mould growth.

Low overall thermal transmittances can be achieved by having façades which are mainly made of opaque, well-insulated walls. From this point of view, it helps to keep walls and insulation layers as continuous as possible: any interruption in the insulation layer represents a thermal bridge. This means that having exposed structural elements outside the building can be extremely detrimental for the façade thermal performance. The amount of windows should be well considered, and it is key to have double or triple-glazed units, with proper buildups: the presence of low-emissivity coatings on the glass surface and gas-filled cavities between glass panes is nowadays standard practice. It is also important to avoid windows where the ratio between area of frame and area of glass is high: frames represent thermal bridges, and significant heat losses occur through them. Not all frames perform in the same way: there are timber frames with the insertion of insulation whose thermal performance is extremely good. But even if the design privileges metal frames, it is still possible to achieve decent performance with the introduction of thermal breaks.

"The lower the *U*-value, the more energy efficient the building". Is this always the case? Thermal bridges are detrimental when they are due to distraction, but external climatic conditions are not always negative for buildings. There are many situations where the internal environment can benefit from exchanges with the outside.

Having a building insulated thermally is a decision of separating the interior from the exterior, of feeling the climatic conditions as little as possible. This means that we renounce the potential benefits coming from the outside and also that we need the internal environment to be self-sufficient.

In some situations and climatic conditions, we know that thermal gains can be beneficial in terms of comfort and energy consumption, as long as they are well managed. For example, a wall facing south could be designed in a way that it absorbs and releases heat when needed.

I think it's worth talking about solar gains.

Solar Gains

When solar radiation hits glazed elements, part of its energy enters the building envelope and this leads to an increase in the internal air temperature. Solar gains can be beneficial in some circumstances: they can reduce heating energy consumption.

There are also situations (e.g. in very hot climates or in densely occupied office buildings where internal activities already provide high rates of heat) where it is fundamental to limit solar gains as much as possible, in order to avoid excessive cooling energy demand or intolerable comfort conditions. As I mentioned, solar gains occur through glazed elements only, but not all glazing types are the same and the amount of solar gains changes significantly for different products. The way glazed elements perform in terms of controlling solar gains is expressed by means of the parameter called *solar factor*, or *g-value* (in some regions it is more common to speak about *solar heat gain coefficient, SHGC*): it is the ratio between the amount of solar gains and the intensity of solar radiation hitting the glass. If a glazed unit has a *g*-value of 0.40 and a solar flux of 100 W/m^2 hits the glass, the amount of solar gains will be 40 W/m^2. The *g*-value can be reduced by adding solar control coatings within the build-up of glazed units. It is possible to achieve very low solar factors (down to 0.15), but in general coatings that reduce very much the *g*-value are also quite dark and make glazed elements reflective. When building façades are highly glazed, it is important to keep the *g*-value quite low. Another way to keep the amount of solar gains within a building under control is to introduce shading devices, which are effective when installed outside the building. They are generally fixed, but there are also some examples of movable options. It is easier to shade effectively south elevations (or north for the subequatorial regions) than east or west ones, because in the first case solar radiation is intense when the sun is high in the sky, and horizontal devices can provide good shading. Movable elements are potentially the most effective because they can track the sun position, but they are obviously very expensive and require more maintenance. A possible way to use movable shadings with reduced maintenance issues is to protect them with an external layer of glass, hence creating a double skin façade.

A clever option to control solar gains effectively is to shape buildings in a way that they can create self-shading. If this strategy is followed, it is possible to concentrate the majority of windows within shaded areas. This is not something innovative at all, even if it seems a bit forgotten: in vernacular architecture of regions highly exposed to solar radiation (e.g. in the Middle East) this is common practice. Traditional buildings have internal courtyards, which are effectively shaded by external walls: almost all windows are inserted within the elevations facing courtyards, whilst external walls are almost fully opaque, with just a few, small openings.

I should also mention the fact that what matters is not just the amount of solar gains, but also the way buildings react to them. Different types of construction behave in different ways. If façades have high *thermal mass*, they can store the heat of solar gains and re-irradiate it after a while and in a slow and regular way. This gives the opportunity to develop clever strategies, which can provide very good levels of comfort with little energy demand. For example, it is possible to use building services which cool down walls during the night, when external air can contribute to this process. High thermal mass can be achieved by thick buildups with materials having high thermal capacity (e.g. concrete). But it is fundamental to keep these materials exposed to the internal environment: internal finishes cannot be used and insulation needs to be on the outer side of façades. There are innovative products (*phase change materials*) which can be added to lightweight constructions and provide thermal mass.

In order to achieve what you say, advanced technologies are not necessarily needed. Think about Paolo Soleri's projects in Arcosanti: it's a urban system, where the energy strategy is integrated. Insolation and air movement are used to control the internal spaces, and everything is achieved with the use of concrete, glass and timber.

Light is extremely interesting: if climatic control involves mainly materials and wall buildups, daylighting is influenced also by choices about composition.

Daylighting

Having good levels of daylighting is a main target for a proper façade design: people feel much more comfortable within spaces which are naturally lit than in buildings where luminance levels rely mainly on artificial lights. Moreover, artificial lights contribute significantly to the overall energy consumption of buildings and generate heat, which increases also the energy demand for cooling. Providing daylighting is not an easy task, because it is not just a matter of quantity of natural light: its quality, i.e. the way it is provided, is extremely important. Too high levels of light generate glare and a general sense of discomfort for the occupants.

And also daylight should penetrate the internal space in order to guarantee good uniformity of natural light levels. Obviously, different uses of buildings require completely different types of daylighting: for museums it is important to avoid direct sunlight to reach artworks, for office spaces glare cannot be accepted, since it prevents people from working effectively, and so on.

Façades play a major role in controlling daylight levels. Characteristics of glazed elements can be extremely different, depending on products. The parameter describing the grade of transparency of glazed units is the *light transmittance* (*LT*): it expresses the percentage of luminous flux that goes through the glass providing daylighting. When solar control coatings are applied (to limit the *g*-value, as I mentioned earlier), also the light transmittance is affected, even if not as much as the solar factor. This is because solar control coatings are selective: they are much more transparent to solar wavelengths providing light than to wavelengths transporting heat. In this way it is possible to achieve light transmittance values which are much higher than *g*-values. For example, with the newest generation of solar control coatings, light transmittance can be as high as 60 %, for *g*-value of approximately 0.28. But LT is not the only parameter we have to consider: we also want to avoid coatings to alter the quality of light. One way of controlling this aspect is to consider the *Colour rendering index* (CRI) of glazed elements. This parameter expresses how much the colour of objects is affected by the light entering through a glazed element. A CRI of 100 means that colours are perfectly natural, therefore we should aim at products with a CRI as close as possible to 100. This parameter is obviously extremely relevant for museums and exhibition spaces, where CRI shouldn't be lower than 97.

Apart from the properties of different products, façade design has to focus on the location of glazed elements: the same window positioned in different zones can lead to completely different qualities of daylighting. For example, windows located in the top region of façades provide much deeper penetrations of light, than windows positioned just over the floor level. (On the other hand, the amount of solar gains doesn't change). Orientation of windows is also extremely important to understand how effective they are. A very interesting aspect is the presence of shading devices. A good design of these elements can cut solar radiation which would generate unwanted solar gains and glare, and, at the same time, generate good uniform levels of daylighting within the space. For example, shading devices can act as light shelves, which reflect light on the ceiling: from there light can then be re-distributed inside the rooms.

There are buildings that are completely sealed: their hyper-design doesn't allow for any changes, not even windows can be opened. This is a risk of design, imposing itself in categorical terms. We all know how important rules of thumb are, but it is also important to know that we can also adapt these rules of thumb to the specifics of our projects. At the end of the day, I think that the user should ultimately decide what comfort is.

This, in practical terms, applies to the regulation of ingress of daylight but also of external air.

Air Movement

Let me use the general, and not very scientific, term of air movement because I would like to highlight the fact that we need to consider two aspects: ventilation and air infiltration. They may look similar, but actually represent two completely different types of air movement.

Ventilation occurs through openings, which can be windows, trickle vents, air intakes, etc. It is meant to provide air exchanges to keep good air quality, or natural ventilation, to cool down the internal space. The amount of ventilation can be fully controlled, either by the occupants or automatically via a building management system (BMS).

Air infiltration (and exfiltration) occurs through joints, cracks, inadequate façade details. It cannot be controlled, and the amount of air exchanges is driven by the pressure difference between internal and external environments.

It is necessary to introduce fresh air within the internal space for several reasons. Healthy internal environments rely on adequate levels of air changes, for example for office spaces it is required to guarantee 8 l/s per person of fresh air. This is necessary to get rid of carbon dioxide and provide oxygen to the occupants. Moreover, ventilation is a way to control the amount of humidity within the environment: if moisture levels are too high, condensation and mould growth can become an issue. Air exchanges can be provided by natural or mechanical ventilation: in both cases there are pros and cons. The main advantages of mechanical ventilation are the possibility of controlling very well the amount of air exchanges and of recovering the heat of exhausted air. But, in order to take advantage of these opportunities, big ventilation ducts and plants have to be installed, and some energy consumption is required. Natural ventilation through the façade doesn't require energy for fans, ducts are not necessary and it gives the opportunity to create a relationship between building occupants and external environment, which is very important in terms of perceived comfort. At the same time, though, natural ventilation cannot be controlled as well as mechanical ventilation and it is not possible to recover heat.

Air infiltration represents an obstacle for both types of ventilation because it adds an element of uncertainty due to the fact that it is impossible to know the amount of air exchanges due to infiltration. This is the reason why it is very important to have buildings which are as sealed as possible, but well ventilated at

the same time. Limiting air infiltration requires good detailing of interfaces, high quality of windows and doors and a good continuity of the vapour control line along the building envelope.

About Efficiency

This was just a very brief summary of the levels of performance where façades have the biggest impact on the overall efficiency of the building. I like to imagine façades as filters, from a performance perspective: they act as barriers between the internal and external environment, but they don't block the natural elements, they are partially transparent to them. For example, if we want to develop a strategy of natural ventilation for the control of internal conditions, we'll have to design a façade which is "adequately transparent" to air. And the difficult part of the job is to find out what "adequately" means. In the case of natural ventilation, it is important to try to allow as much cool air as possible during summer, but we have to make sure that air doesn't enter within the building at too high a speed: this would generate serious discomfort issues to people who are next to the openings (which could be windows or other types of air intakes). At the same time, there are situations when we want to keep our building as sealed as possible. Therefore, our façade will have to be transparent to air only when this is needed, and in the way we want. A very similar thing can be said for solar radiation, light, heat, etc. Basically, we can say that the overall performance of a façade is expressed by how much it is transparent to the different elements, and how these different levels of transparency are combined.

From an Architectural Point of View

OK, so far we've considered the envelope from your perspective. The overview you have provided certainly shows how complex the subject of the envelope is in terms of energy behaviour. But now I would like to explain my interpretation, because, as an architect, I see things from a very different point of view.

As much as I like your idea of the envelope as a combination of different levels of transparency, I wouldn't consider them independently from what lies behind and in front of the façade.

Rather than seeing the envelope as a mere technical device that works as a filter or a barrier between external environment and controlled interior, I would interpret

it as a result of the building spatial conception and, more precisely, as the intersection between interior and exterior.

The form of a building is not given by its exterior, you rather comprehend it when you exit it. It is interesting when the façade suggests this idea, when its parts, like the windows, do not disclose what stays inside but instead anticipate its essence.

Besides, being the outward and most visible part, the envelope has the task to present the building, to give an overall idea of it (even if it doesn't coincide with it). Through the façade an architecture acts on the environment, engaging a dialogue with its surroundings. Therefore I would say that the façade is an externalisation of the building, the manifestation of its essence, and it should explain its *raison d'etre* in that specific place.

Since it's the part that has more to do with contingent or transient factors, the envelope has a temporary nature, like a dress. Sometimes it's short-lived, sometimes it lasts forever, but even if it disappears, by no means should it be able to destroy the building. Its disappearance should not invalidate the design.

Sometimes it seems that certain buildings are looking forward to getting undressed: they want to discard the parts that were designed to respond to a time-limited need and survive without them. This doesn't mean that the façade is a mere supplement. On the contrary it is a consequence, the overall result of the design, so it must be coherent with the rest of the building.

The design must be a unit, coherent in every part, even when the principle that rules is *incoherence*. Everything must contribute in the most efficient way to fulfil the purpose of the building.

Whether it is made of porphyry or jelly, the envelope has no value in itself, but only as part of the building. That's why, in my opinion, the best envelope is a direct consequence of the choices made on the entire building, as a whole.

Local Solutions and Global Conception

On the façade, as in the whole building, the single part can be conceived as an independent element or as something that collaborates with the rest of the system. In my opinion we should consider all the elements, even those that are specifically technical, as the result of a comprehensive design.

I would not say that a design works properly when every single problem is solved—i.e. in a kind of all-peaceful situation—but rather when each part is connected with the rest and there's some kind of equilibrium even in the presence of unbalances. When it realises some sort of a sense of unity.

That said, I would only add to your overview on the physics of the envelope some observations concerning the way architects deal with parameters and performance often considered purely technical.

Let's start by analysing the concept of façade as divider. Sometimes the partition between internal and external can be vague. The idea of putting back the transition from one state to the other can be often found in the Eastern architecture, particularly in Japan, but also in its reflections in European Architecture, like in Villa Mairea by Alvaro Aalto. In this case, for example, the filter at the entrance is particularly volatile.

Alvar Aalto, entrance to Villa Mairea, Noormarkku 1937–1939

Alvar Aalto, entrance to Villa Mairea, Noormarkku 1937–1939 (credit Francesco Venezia)

Some other times there are interiors that are handled as courtyards or transitional spaces between buildings, despite them being closed spaces in all respects—as for example the vestibule of the Biblioteca Laurenziana—and in which we are beyond the façade but not entirely inside the building. Basically, here we have an exterior which is built inside a building.

Michelangelo, vestibule of the Laurentian Library, Florence 1523-1534

Now, speaking of temperature control, I would point out that the envelope can also present different degrees of separation from the external environment: different parts of a building can have different temperatures. The border between inside and outside can be neat and coincide with the outer walls or have different degrees of thickness and porosity. Internal spaces can be heat treated the same way or present a succession of thermal stages.

When we design a window we should consider from the very beginning the solar heat gain coefficient in order to determine its behaviour in different times of day, because it's precisely through the windows that we perceive how the inner space changes accordingly to different solar conditions. In this sense, a very wide window should remain enjoyable throughout the day and under different weather conditions. This will determine, among other things, the thickness of the glazed elements, the use of space and the geometry of daylighting.

Daylighting is also important because, as you said, the way interior spaces are illuminated is often the result of choices made on the envelope. Windows are usually required to provide light and view at the same time. After all, what is a window if not light and view? But daylighting might not automatically imply an exterior view. Who said that what works well in a museum in terms of light must be wrong for a workplace? And a nice view must be necessarily a view of a park or on the street? Can not a space be powerful or moving even if it faces a wall?

Office buildings are almost always fully glazed. Usually this choice is dictated by reasons that have nothing to do with sustainability, urban planning, productivity or aesthetic. It must be a matter of tradition or, better, a repetition compulsion, because a fully glazed wall, with its generic appearance, is by no means an architectural statement and, in my opinion, if repeatedly applied to the whole building, it doesn't offer that much in terms of comfort to the people working inside.

Air movement is a parameter that must be considered when we conceive the internal space, (e.g., a room with very high ceilings), because, as daylighting, it contributes to the definition of a space.

These aspects don't define only the internal environment of buildings, but they also impact the way buildings are perceived and have to be considered as well as the materials used during the construction process. Heat, light and air are construction materials. Just think about the Moresque architecture, the extraordinary thermo-hygrometric mechanism of the Alhambra: in this building comfort conditions are achieved in such a triumphal way!

I would like to add to your technical overview one last component that in the past has consistently contributed to the shaping of façades, namely the water outlet. Beside concerning the roof, the flow of rainwater hitting the building is a more general architectural issue that can contribute in enriching the whole project.

Efficiency Versus Inspiration

I wanted to say these things to show that even technical or efficiency related problems can be interpreted as opportunities to improve the architectural quality of a design. By this I mean that when we deal with specifically technical issues we shouldn't forget the meaning of our task as architects.

Efficiency is a requirement mainly related to energy consumption: a building is efficient when it manages properly its resources according to its use and to a number of standards of comfort. But, how is a building efficient on an all-comprehensive architectural basis? As a category, it's hardly useful to describe architecture, because it's not the building that has to be efficient, but, if anything, the occupant, that has to use it efficiently. Architecture should envisage the use, without being defined by it.

Energy saving is a specific topic of our age, is the big issue, or rather our big pain in the neck. I say this because it represents perfectly the contradictions of our time. The state of perpetual crisis, the political-economic *fatigue*, environmental emergency, etc., condition and control production, dictating values and standards that have nothing to do with the conception of architecture. Architecture must be sustainable, they say. But what does it mean?

It's human beings that are sustainably problematic in the first place and architecture is just one of their manifestations. What has to be sustainable, then? Architecture or all these humans that inhabit the world and wouldn't survive without architecture?

There is also some confusion between energy saving in the short term—probably easier to achieve and to show—and in the long terms, which is, for sure, harder to apply. When we talk about sustainability, we aim to reconcile the human presence with the well being of our planet, unfortunately always from a survival point of view. In human history natural phenomena have always fostered emotions that led to the construction of artificial spaces. Buildings have always lived in natural changes. Nowadays what comes from nature is considered a hassle. The emotion of a roman, who watches from the interior of his house a torrential rain, splashing into the impluviom, is the pleasure of controlling nature, transforming it into something spectacular. While in the pouring rain today we wear high-tech waterproof fabrics, feeling the comfort of being perfectly dry, we are still in the rain.

One would suspect that sustainability is a commercial attitude. Eco sustainabilty should be accomplished as a silent and scrupulous practice and not as an architectural manifesto. The attention now dedicated to energy conservation is as much an economical factor as it was 30 years ago the energy waste, with buildings constantly illuminated. That happens as market logic doesn't pursue any logic of progress, it rather exploits the concept of progress for its own purposes.

Sustainability and comfort dictate some rules and make us forget that building is not a duty nor a right, but an opportunity to achieve something surprising, that improves our lives, and in this sense building is luxury.

Let's consider Farnsworth House, a majestic, absolute house.

Today we can't afford to live in Farnsworth House, because it's not sustainable according to our current comfort standards. It would be only if we could produce autonomously the required amount of sustainable energy but this is not possible yet.

It wouldn't help to install a wind turbine in the garden. It wouldn't solve the issue of the waste of energy. Many people think that each house should become a small power station; as Mao wanted that each Chinese farmer built a small furnace in his courtyard: millions of furnaces producing an immense quantity of very bad steel. Architecture nowadays is asked to build power stations. So, apparently, as long as we don't find some kind of inexhaustible clean energy we can't live in a farnsworth house, we can't even conceive it and plan it, we architects are not in the position to supply architecture. We can't try to do what it has always tried to do

with architecture, because our tools are all of a sudden inadequate to contemporary needs.

So far the only solution found by the construction industry to make fully glazed buildings work is a massive use of silicone, in joints, sealing of insulated glazed units, the result being some kind of 'siliconised architecture'. But if these silicones, that have now become integral to the buildings, have a 25-year life span, the structures we produce today will deteriorate in 25 years. Well, this seems a great waste of resources to me, actually, the opposite of efficiency, unless we know in advance what to do of these scraps after 25 years.

Buildings are not temporary shelters; they are the embodiment of human knowledge. It would be wiser to give less importance to transient standards, because if we turn them into the guiding principles of our designs, we risk ending up with brilliant technical solutions but no building at all. In other words, in an attempt to tailor a suitable dress for a specific moment, we would get the dress without the body. It's fascinating to think of buildings that live in real time, that adjust accordingly to small climate changes or to the presence of people inside them. Buildings that transform themselves in order to find the best configuration for a given time, without losing their architectural dignity. But unfortunately nowadays we are able to create only a parody of such buildings.

To Show and to Hide

What emerges on the surface of a building has a certain degree of emergency. It's a pun, but it's true. The building can display itself, in a self-referential way, or reflect other factors, such as context, use, etc. But it's always the answer to a substantial question raised by the design or the reaction to a prevailing problem that has overwhelmed it (in a positive or negative way).

There are buildings that display their use, buildings that show how rational they are and buildings that boast of having overcome an obstacle, mimicking a technological achievement or paying homage to it. Vernacular architecture, for example, often exhibits the solution of an issue, whether it is the shielding of sunlight or the optimisation of air exchange. The technical effort becomes representative characteristic.

Windcatchers in Yazd, Iran

From buildings that are supposed to be energy efficient we expect first of all an efficient look, even if in reality they are not in the least efficient. The same applies to computational artefacts: it must be blatant, we must understand immediately that they are computational, as if they were screaming: "Look how modern I am!". And then maybe they have nothing modern.

What is displayed is the answer or the reaction to a given problem: the more emphatic the answer, the bigger seems to be considered the problem. A fully glazed building, for example, says, if anything, that the designer has taken the issue of the outside view very seriously…

Or what if a structure shows proudly its pipes and machinery? It means that one of the major nodes of our times is technology or technocracy, right? If an architecture shows refined gadgets and complicated diaphragms to filter daylighting, it's saying: "This is the real problem! How to regulate the entry of light by means of a technical device". But why is this high-tech aspect so critical today? Don't we already know since a long time ago that we are living in a society ruled by IT?

It would be better to separate our desires from this technocratic imagery. If we go after this idea of the future, we are doomed to be never satisfied.

The notion of future, instead, is integral to the task of designing. At the end of the day, every building is the result of a long process that, as well as envisaging some problems and possibly solving them, generally raises a lot of questions. The façade should display the overall outcome to all these questions. Instead, quite

often, it just answers a single question: "What should we show?" The task of architecture is not to run after some futuristic imaginary, but to find a way to conceive in advance a desire and offering its fulfilment to mankind. Or, even better, the magic of architecture is about meeting aspirations—in fact very old—with unprecedented devices. In this way architecture should deliver a sort of retroactive forecast.

But today's most urgent question is what has to be shown, from a technological, conceptual, aesthetic and cultural point of view. And in my opinion architecture ultimately is not providing a major contribution to answer it.

Compared to contemporary art, for instance, architecture seems to be less up to speed with our times. The comparison with contemporary art allows us to focus on invention as the only criterion, ignoring the categories of technology, beauty or creativity. Contemporary art is often smart, keen and ironic. While in my opinion architecture these days takes itself too seriously to be smart. And for a reason, a new building costs a lot of money, and money is nothing to be trifled with. Contemporary artists create works that are worth lots of money, but with production costs that are often insignificant in comparison. While in the construction industry the profit margin is much narrower because the production costs are getting higher and higher and around a construction site revolve lots of people that have to be paid.

But as in the case of a worn of art, the production of a building is an open non-standardized process, whose end result is unique. In this process there is a huge disproportion between the pressure from the point of view of the profit and the non-economic value of the building. The tendency is to diversify the added value by giving more weight to features that are not directly architectural, such as the choice of materials and details, the technological aspects and comfort.

On, it seems that the social, liturgical and political nature of architecture is definitely gone. Since we've lost our sense of urban community, we are no more able to control the overall image of the city. Constructions have today a value in themselves. They are isolated, almost autistic, objects. Each building is independent from its surroundings, as some kind of virtual address. And this is totally fine by me, at least because it cannot be otherwise.

But the point is that very often this autism, this self-referential isolation, ends up showing only itself, without any added value. If there's a value is coming out from the branding.

Nowadays people are considered very important, but I think it would be more humanistic to be more focussed on ideas rather than on people. It has never been so many of us, so protected and defended, but at the same time we consider people as indexes, here fluxes. Buildings are only about their functions, they show their use in a theatrical way, as big scenographies for flowing crowds.

It seems that we've come to expect everything and nothing from our buildings. If we tolerate everything, then anything can be shown. But I think that we have already built enough in this world, there's no space left for our expectations. What we have to do from now on is to transform the built environment with some revolutionary acts. Instead it seems that today architecture is just a response to a duty; and the buildings it produces retain all the weight of this duty.

It's an enigmatic situation, because everything appears to be reversed: once architecture was the representation of power. Today it just obeys to orders. I like to imagine an architecture that is neither duty, nor power, but rather an allegory that relates to these categories.

OK, I'm digressing too much. I don't want to sound like a moaner or a fault-finder. I'm not criticising what's been done to show something better. I haven't done anything better yet, in fact I haven't built a diddlysquat! What I'm doing here, talking to you, is taking some time to reflect on our task. It's a kind of autogenic training, not a complaint. After all, neither you nor I have a reason to complain, we only have to get started and do.

Four Buildings in London

Let me be a bit more practical to clarify what I mean. What, in my opinion, makes the façade design so intriguing is the fact that there is an immediate link between performance and visual appearance. And this link occurs in two ways. The first way is very direct and it relates appearance to the parameters I described earlier on: in the case of glass, for example, if you need to achieve a pretty low *g*-value, the appearance of it will be quite dark/reflective; or, if walls need to have a low thermal transmittance, their build-up will be quite thick. And so on. The second type of link is less direct, but the effects have a considerably higher impact: if the design intent develops a strong language, then the overall performance of the façade will have to react to such an intent, and this will impact the overall appearance of the building. Let's make an example, to clarify this last sentence. Contemporary commercial buildings are required to have high percentages of glazed area, for a number of different reasons. If having a lot of glass can bring relevant benefits in terms of daylighting to the internal spaces, it also generates some issues, the main one being solar gains: it is a priority, especially in office buildings where high rates of heat are produced inside because of high density of occupants, electrical equipment and artificial lights, to control solar gains, in order to limit the energy consumption for cooling. The easiest way to do this is to apply high performance coatings that provide very low *g*-values, but this works up to a

point, after which some additional measures are necessary. Let me go through a few examples of how this can be done: I'll refer to four buildings all in the same area of London.

New Court—Rothschild Bank by OMA: in this case the way to control solar gains was to introduce a metal mesh within the double-glazed units. This solution provides a very distinctive visual effect, which is an important feature of this building, shortlisted for the RIBA Stirling Prize 2012.

OMA, New Court, Rothschild Bank headquarters, London 2006–2011

The Walbrook by Foster + Partners expresses the necessity of controlling solar gains by means of the introduction of external shading devices. The louvres are made out of fibre reinforced plastic (FRP) and their geometry is a key element of the building.

Foster + Partners, The Walbrook, London 2005–2010

In One New Change by Atelier Jean Nouvel, the solar performance of glazed surfaces has been 'adjusted' by inserting ceramic frit on them. And since frit delivers such a key contribution to the overall energy strategy of the building, it has become the main expression of the façade: it has been applied on the outer face of the glass (which was a significant innovation at the time when the project was developed) and in a variety of colours.

Ateliers Jean Nouvel, One New Change, London 2003–2010

The London Bridge Tower by Renzo Piano Building Workshop is a double skin façade, where shading devices, controlled by the building management system (BMS), limit solar gains and are protected from the external conditions. The fact that shadings are protected makes it possible to install movable elements, without having durability and maintenance issues. And movable shadings have the big advantage that they are deployed only when it is needed and can be raised at conditions of limited solar irradiance.

Renzo Piano Building Workshop, London Bridge Tower, London 2000-2012

These examples show how it is possible to adjust the way façades filter solar radiation, hence creating the right conditions for the building services to provide the right level of thermal comfort, without requiring too much energy—and hence producing high rates of carbon emissions. But this is only a very specific example, where the design has to deal only with one aspect of the overall problem. Once other elements are considered, everything becomes more complicated: for example, what else do we need to consider for the definition of the performance of the façade when the geometry of the building becomes irregular? And what are the implications on heat losses if we need to reduce the size of panels? And we could go on with a huge list of questions that have to be solved.

The Glass Paradox

If we consider the example of traditional architecture in England or Germany, we notice that the problems you mentioned—related to the internal comfort of

buildings—are totally missing. It seems that all these issues crop up with the increased use of glass surfaces, till they completely cover the buildings.

This is what I call the paradox of the totally glazed building: when architects decide to use curtain walls they tend almost automatically to concentrate all the responsibility of the design on the façade, often with exhibitionistic effects. In this case it's a matter of technological exhibitionism. Besides we have to consider that the more massive the use of glass, the more expensive becomes the building in terms of energy consumption. As you said earlier, glass isn't very efficient in terms of U-value and solar gains. Is its use the result of our cultural legacy or just of commercial reasons?

But what I really want to know is why the façade is given so much attention, as if everything was happening just there. How can the outer surface steal the show and monopolise the appeal of a building?

Somehow the façade has become the part of a building that more than others is in charge to communicate its degree of contemporaneity and economic wealth. When the envelope is given so much emphasis, it ends up defining the shape of the building as an object.

According to the logic of the market, in the attempt to maximize the profit, the added value of a building is assigned to different features of the interiors, such as comfort, degree of the finish, rationality of the system, etc., while the architectural value is all polarised on the outer surface. The effort on the façade is rewarded with maximum visibility. In this sense, a façade today not only is the surface of communication with the city and the filter between internal and external environment, but it tends to 'swallow up' the whole building.

A suitable façade in my opinion has to stay in symbiosis with the rest of the building, without monopolising the design. It shouldn't betray the building by isolating itself from the structure or betray the surroundings presenting itself as the latest thing.

Nowadays we tend to focus on the façade most of our technical cares since it is actually the place where the architecture displays itself. The rest of the building is often condemned to make shift with technological solutions that are not in the least up to date. Very often the structures that proudly support these hypertechnological façades are intricate medieval contraptions.

If we draw a parallel with the human body, what lies under the skin affects the surface, the tangle of filaments, fibres and bones contributes to the smooth and solid beauty of the bodies. But in the case of certain buildings nowadays we see Avatar skins covering Neanderthal skeletons.

This would be a very fascinating concept if it were limited to a small number of artefacts, if the contradictions were planned and well aware. But what these space age sheds show has little to do with awareness.

I believe that our world is undergoing a phase of genetic mutation. In my opinion architecture acknowledges this phase in a way that is more authentic in comparison to other fields of production. Meaning that it has gone haywire and it doesn't hide it.

Probably because of the slow pace implied by the practice of building, architecture has less the pulse of contemporaneity in comparison to other production fields, such as fashion or information technology, that move with a faster pace. But, since it's one of humanity's ancestral tasks, it can't do anything but follow every stage of human history. Probably nowadays it's easier to find architectural creativity in other fields and with different scales.

In a world doomed to become a huge limitless city, everything is architecture.

Nevertheless architectural sensibility seems to be dulled or removed.

If we are not able to build properly, if our idea of design is confused, then we are in trouble. Or maybe we are not. Perhaps we just find ourselves at a turning point. Yes, we are numb and drowsy as convalescents, but we will soon wake up.

I agree with you that the focus on the envelope is also a matter of being exhibitionist: developers want to show that they have spent a lot of money—and this is a very human weakness that has been part of our societies for centuries—and designers want to express their skills on something that everybody can see and enjoy. And these skills are both technical and aesthetical. In a way, from the point of view of the performance of a building and its level of energy efficiency, it makes a lot of sense to get as much as possible out of the envelope. If the façade reacts in the right way to the elements of the external environment, the building services will not have to work too hard to provide comfort conditions for the occupants: it is much more efficient to block solar gains before they enter the building, rather than pumping a lot of energy in the cooling system. So, in a way we can say that human megalomania can help saving the planet! Sorry for the bad joke, but I mean that we should also consider the positive aspects of such an exhibitionist attitude. But I would say that there are also important examples where the power of the developer and the skills of designers are expressed in a balanced way by both the envelope and the structure: what about the CCTV building in Beijing? Or, going a few years backwards, the Sidney Opera House? I actually find quite interesting how in many projects designers try to re-balance the relationship between structure and façade in a pretty awkward way, by 'drawing' some fake structural elements with the external cladding. This is something that I consider very unfortunate, and it also emphasises the mistake that everything is limited to the envelope, rather than re-balancing the elements.

I am not sure I agree with you when you say that this extreme attention to the envelope is necessarily linked to curtain wall. For sure it is much more important to push the performance of glazed areas, as with curtain wall it is plenty of it. But curtain wall is not around for complicated philosophical reasons: it is the façade for high-rise buildings because it is much quicker—and hence cheaper—to install. All the rest comes as a series of consequences. You say it is very high-tech, especially if compared to the other elements of buildings; but is it really the case? Are we not talking about some extrusions of aluminium, a few gaskets and glass? And because of its overall low level of technology, even if we are pushing for better and better performance, we are still far behind what we could achieve with a properly built traditional wall! Passiv Hause buildings are built with some

innovative materials, but the overall concept is fairly traditional, and curtain wall is not even considered there.

Well, we must agree on the meaning of "unfortunate". In the case of the Sidney Opera House they had to resort to an integrated design because the structure was very complex in terms of engineering, but even if the design team managed to brilliantly solve the problem the managerial organisation dominated at the expense of the final result. Which I wouldn't say was successful, at least not for Jørn Utzon, who was excluded from the project and sent back to Denmark.

I don't think that technological megalomania is the driving force of the construction industry or that it will help us save the planet. Most of the energy-inefficient structures have been already built, they are out there, and in general the damage has been done and it's too late to think in terms of remedy.

And it's not even a matter of pride, because I believe that pride is a necessary requisite to produce something: when one builds a big complex object, there are many reasons to be proud.

If designers would reason as you say, they would produce high-rise buildings in the same way as passive houses. What I'm talking about, here, is the use of technology in the construction industry.

Even race cars are made for the majority of traditional materials and produced with renown technologies, but when the latest model is advertised, they promise the buyer the ultimate experience in driving. While today's buildings, whatever is their function, are seldom intended to provide a new or more advanced experience of space. Do you agree or am I mistaken?

Getting back to the envelope, I wouldn't say that the façade is only about protection because it also exerts an action on the world. You talked about façades only in terms of security and inner comfort. I agree when you say that they are a filter. But I would add that this filter works in both directions: on the one hand it controls the entry of atmospheric agents, and on the other it conditions the external environment with its presence. If we focus too much on the protective factor we lose sight of the rest.

As to my controversy against curtain wall, well, some architects tend to focus all their attention on the façade because at least they can say they are communicating something. Cynically speaking, we might say that this something is a market value. What's not communication today!

On the other hand, however, buildings cease to arise emotions or feelings. You may argue that engineering has nothing to do with feelings. But in my opinion it does: for example, when a structure is well designed, it gives a sense of safety and augmented strength to its occupants (who feel protected inside it). While, instead, if a structure is statically impeccable but appears shaky to the eye, then it's a failure from an architectural point of view, because instead of helping men to control their surroundings, it distracts and confuses its users. We can afford to consciously love these abnormal structures as a guilty pleasure (and only when we don't have better things to think). It could have worked in the 1980s or the 1990s. But now, in a time when gimmicks have become simply boring or annoying, it

makes more sense to focus on primary issues even at the risk of looking naive or amateurish.

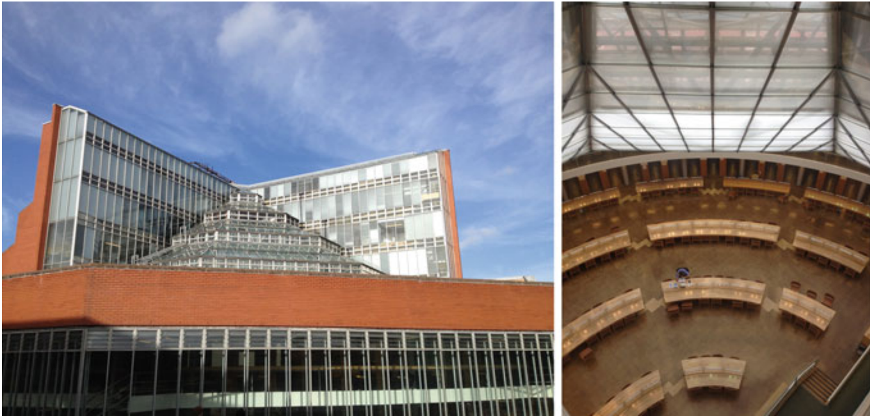
So we, architects, should take into account the presence of human beings and their emotions as the main requirement of design. Structures have no value in themselves, but only as prosthesis at the service of men. When we enter a building we must feel this, this original faith in architecture, otherwise what is the use in building? What's the point in working so hard?

OK, you said many things and I am a bit confused now. I would like to wrap up our discussion and see if we agree on the outcomes. But first, let me just say that I don't think that façades should just play a defensive role against external elements. I tend to think the opposite, actually: when an envelope shows its 'defensive tools' in a very explicit way, this probably means that something went wrong during the design process, and hence some extreme measures were necessary to correct a mistake. For example, if a façade requires very powerful shading devices to control solar gains, probably there is too much glass there. Design teams can then find extremely effective systems to cast shadows without obstructing too much of interesting views; and these shading devices can be integrated in the façade with very elegant, beautiful details. But couldn't it be possible to develop a design that doesn't need shadings in the first place? In my view we should try to take advantage of natural elements as much as possible, and not to spend energy and money in defending ourselves from them.

Unbalanced Design

All I want to demonstrate is that it is extremely hard to develop a proper design that takes into account all the different performance aspects and, at the same time, achieves the architectural intent. There is a relatively easy way to deal with this problem: ignoring it! Or, better to say, giving up in finding an adequate solution and go for what I'd call an 'unbalanced design'. Let's make a few examples, that will simplify the explanation of what I mean with this. When James Stirling designed his History Faculty Building in Cambridge, he was aware that he was ignoring many aspects that should be considered: different people raised the point that the huge amount of glazing in the building envelope would create major issues. Cleaning and maintenance would represent severe costs during the life of the building, and excessive solar gains would make the internal environment extremely uncomfortable for the occupants (Stirling knew that only a huge cooling system could cope with the solar gains). And, moreover, the use of very highly technological solutions for supporting the glass and the clay tiles would prove unreliable.

He knew that, if he had followed the indications of the other members of the design team, he wouldn't have delivered the building he wanted. And today we wouldn't have the amazing reading room of the Seeley Library—and I can only envy the students who can take advantage of the huge inspiration that only a space like that can provide.



James Stirling, Faculty of History, reading room of the Seeley Library, Cambridge 1963–1968

Passiv Haus

At the opposite extreme of the scale, I would mention the Passiv Haus buildings—and now I'm going to talk a bit in general, knowing that there could be exceptions to what I'm going to say. These buildings are engineered in an amazing way: walls buildups deliver the best you can currently have in terms of thermal insulation; windows (rigorously triple-glazing) are just the right number and located in the best position, in order to provide adequate daylighting and let beneficial solar gains. All interfaces are very well detailed in order to limit thermal bridges and avoid any avoidable air leak. Building integrated photovoltaics, finally, provide electricity in a sensible amount. The final result is that the occupants of these buildings can enjoy high levels of comfort for a minimum energy cost—and carbon emissions. But, on the other hand, it is very hard to find inspiring buildings, or to produce a good variety of architecture, because rules are very tight and there's very little room of manoeuvre to introduce something new.

Balanced Design

Personally I find myself being sympathetic to both cases, even if, obviously, for opposite reasons. You may argue that Stirling's attitude was irresponsible—even if, to be fair, we can't forget that at the time of the design of the History Faculty Building there was very little, if any, awareness about the necessity of energy savings. Yes, he was irresponsible from many points of view, but he felt that he had to deliver a very specific mission, and he did it. We can't forget that the building is still there, after that people voted to refurbish it rather than demolish

it—before the building was listed in 2000. And it is still delivering what it was supposed to deliver in accordance with the brief, even if with very relevant problems. Passiv Haus buildings are probably very boring—yes, I find them generally boring—but they are making a statement: it is possible to deliver good comfort conditions without burning tonnes of fuel! And now designers will have to take this statement into account and compare the results of their design to that. We won't be able to use any excuse any more: if we don't deliver that level of energy efficiency, we'll have to say why and explain why our solution is overall better than that. It's hard work, isn't it?

But, is it really the case that we have to choose between performance and architecture? Sir Ove Arup said that "*a balanced design can help to create a better environment*" and I believe this is a very inspiring target that we, as designers, should aim to. The term environment, I believe, should be given a comprehensive meaning: to me it should mean the overall, global environment, therefore a balanced design can contribute to its health by requiring less energy consumption and hence producing fewer emissions. But it is also to refer to the environment generated inside the building and outside: a balanced design can lead to the creation of inspiring, comfortable, beautiful places, which improve the quality of life for people. I strongly believe that only balanced designs can achieve all these targets. So, the questions are: what is a balanced design? How can we get there?

These are very big, challenging questions, and I don't know if I can give good answers to that, but I'd like to try.

Probably, before we try to define what balanced design means, it is worth trying to identify the reasons behind the origin of what we called 'unbalanced design'. The fact that it is difficult to identify solutions balancing performance requirements and architectural intent is always going to be there: if this were the only reason for the production of unbalanced design, there would be nothing we could do. Hopefully, there are also other causes that we can try to overtake. I believe that one of the main reasons is the difficult relationship between architecture and engineering.

It is frustrating that, even if everybody has been saying for decades that engineers and architects should communicate more and have a closer relationship during the design stage, we still have to deal with this issue. Building regulations are forcing design teams to make sure that buildings can meet the energy targets, therefore decisions have to take into account the effects they have in terms of overall energy efficiency of the building. This has generated the necessity of a closer collaboration between the two professions. Unfortunately, architects consider engineers some sort of soulless people, feeding their software tools with numbers in order to get other numbers, all of which simply slows down the creativity process of architects. On the other side, engineers see architects as some aloof people, floating on a theoretical world, unaware of the fact that they're losing control on the design process.

My question is: if the level of collaboration is undermined, how could we possibly expect that a balanced design will be achieved? I strongly believe that this is a huge barrier that we need to dismantle. A closer working relationship between

architects and engineers is absolutely fundamental, and actually should not be limited to architects and engineers but should also include developers, cost consultants and project managers. But let's focus on architects and engineers, for the sake of simplicity: what do I mean when I say that they should establish a closer working relationship? In fact, they already work together in design teams. Yes, this is true, but do they do that because they have to, or because they are convinced that this is the only way to achieve a better final result? That's the key issue, I think.

In my personal experience I have seen many times architects asking engineers to find good reasons why the architectural intent is a very good design solution in terms of performance and efficiency. And, at the same time, I have been involved in a lot of discussions where engineers told architects that one specific thing could not be done because the software said that it didn't work. In many situations there is no real dialogue but simply a stubborn defence of each other's positions.

Ideally every component of the design team should provide his contribution to the common effort, by being proactive, suggesting solutions that take into account the different design drivers and sensibilities. But, in order to do so, everybody needs to feel an active part of the decision-making process, should understand the importance of his/her contribution. And has to be very capable in communicating to the other members of the team the qualities of his/her suggestions: the way ideas are communicated is a key aspect.

Only if you let the other people fully understand your proposals you can expect viable contributions and suggestions to improve them. And then, obviously, mind sets are fundamental: everybody has to be open to other members' ideas and has to accept that other proposals may be better, even if they come from people specialised in a different field.

Architects Versus Engineers

The division between architects and engineers has often been depicted as a legendary contrast. But, I wonder, is there really such a sharp separation?

Or maybe this conflict has been created and fuelled by some external subjects that just want more decisional freedom. As long as architects are portrayed as creative people (living in a world of their own) and engineers as nerds (dealing with numbers and formulas), architecture will continue to be a thorny problem rather than a resource and everybody will be allowed to have their say.

As far as I'm concerned, building is not a problem to argue about, but it's a chance to use our wit and to apply it on poetic tasks. The difference isn't in terms of professions, but of aspirations. Architects forecast problems to achieve a purpose. Engineers solve problems in order to make a medium effective. These are two different tendencies, even opposite, but connected via a dependency link.

Who's really interested in making the practice of building problematic or unclear? Well, not you. And me neither. That said, I would consider solved once and for the entire old diatribe between engineers and architects. Was I fast?

Another thing I don't accept is the distinction between architecture and construction industry, between the cultured world of design and the brutality of real estate speculation. I don't feel like dividing into segments such an important process, I don't want to break it up into areas of competence and branches of knowledge.

Divide and rule, they say. What should be regulated, though, is not the practice of building, but rather what we do with our world and how we transform it.

This inversion of means and end is very common in our world. Nowadays architecture is a business just for architects. But it shouldn't be so. The same applies for engineers and engineering.

There are many other issues related to the construction industry that don't concern architecture. People tend to overemphasize the energy saving problem while totally ignoring the architectural features. If an energy-efficient building doesn't improve the lives of its users, by playing as well an important role on their perception of reality, it is a mistake, a failure and ultimately a big waste of energy, much bigger than the amount of energy that it's supposed to save.

It's not buildings that have to be regulated but, if anything, the way people use them. Why should architecture adjust to the alleged needs of the average man, when its first aim is to make the man better, when it's men that have to adapt to architecture and learn how to use it, as it is for any other tool? Personally, as a user, I expect the uttermost from architecture, and not just some boring standard.

Otherwise, for consistency's sake, we should destroy everything that's not regulated. If we were to apply the current building regulations, just think of how many masterpieces of the past would respect the standards? We would have to demolish Fallingwater because of its dangerous parapets, plug the Pantheon's dome to prevent rain to fall inside, or pierce the Great Pyramid to fix the problem of its poor daylighting.

To destroy the soul of mankind in order to consume a little less but at least to consume? No thanks, that's not for me. I'd rather freeze to death in a place that doesn't warm me, if it moves me, if it inspires me, if it makes me think, if it allows me to feel alive.

But let's get back to architecture and engineering.

Between the two there's not a difference of field but a difference of talent. They share the same areas of interest and passions.

Anyway, regardless of this division that seems fatally unsolvable—and, precisely because it's so cumbersome, I suspect it doesn't exist—what is the best way to work on a design, (whoever is involved)?

Integrated Design

In my opinion, the best way to form a design team is to develop a collaboration of ideas, rather than a partnership of people. Ideas and not defined roles should drive people to cooperate. A gathering of ideas instead of a group of professionals. The better these ideas work together, the more profitable the exchange among the team members.

Today, the most powerful ‘actors’ in the design process are the people who provide the assignations, enable the economic operations (that produce surplus value), mediate amongst clients, designers, builders and inhabitants. But it’s funny that, while the latter are the actual users of the design, these people are not even directly involved in it.

Space belongs to everybody (or at least it should). To transform it with the construction of buildings is an essential task of mankind, and—I know it sounds criminally naïve—it shouldn’t be subjected to speculations.

The real estate market—this transient limbo suspended between will and technology—has become a cumbersome presence. But how much longer will it be sustainable? And how much longer are we going to tolerate it?

In an ideal world, made only of technology and desires, we could organize the design not accordingly to business relationships (based on economy, power and performance), but by embracing ideas. And I don’t mean normative solutions or rigid theories, but open and flexible concepts that can be adapted to the most diverse situations.

In reality, though, the distance between the desire—of the client—and the gift—of the designer—has grown bigger and bigger. The client is more a nebulous entity than a well-defined presence and instead of designers we find project managers.

Building is still a strenuous task: if we want things to work we need a strong will (a desire) and a strong determination (as a result of our technological awareness). The more a member of the design team is part of an issue—that must be envisaged, solved or avoided—the stronger his contribution. From my experience, I know that we don’t need a lot of people to design a building, even a huge one. What we need is clear ideas and the skill to give them shape.

What we need is an approach.

The Ideal Design

When we look at a finished building, we immediately notice if it has been conceived clearly, because this clarity informs all of its features. That’s why clarity must be a categorical imperative of design; IT might be bold or unpretentious, but it has to be crystal clear: this is our aim, a building that doesn’t create useless misunderstandings and doesn’t need further explanations.

On these lines, the wider (more comprehensive) the initial vision, the stronger the design.

In my opinion, the ideal design doesn’t follow a method, but it’s basically a dynamic process. Rather than applying an abstract theory to a specific need, it creates a spatial means in pursuit of a general end. The means has already in itself the way this end will be accomplished.

The starting point of a design must be the definition of an idea with a capital I. This Idea is the heart of the process, something that literally gives life to it, and

then everything else will follow. Every subject has a different intellectual and cultural background and brings to the team his/her own experiences, ideas and reflections developed over time. The design offers these ideas a chance, allowing them to be implemented in a specific situation.

The best way to design is to adopt the frame of mind of questioning space.

Whether traditional or integrated, done by a single individual or in a working team, the design should be promoted not by a person (or a group of people) but by a will, a desire, or what I call the Idea. This shouldn't be mistaken for invention, though. The Idea I'm talking about is a sort of flexible concept (which is spatial rather than formal or architectural). I would say it's more a question than a solution. You don't look for it, you just find it.

In the integrated design, the Idea becomes a catalyst that gathers the different people involved in the team. I don't have experience of a collectively born Idea, but theoretically it's not important where it comes from.

It might as well come from a person who is not the architect. Anyway this person will explain it to other potential actors and if they embrace it they will become part of the design team. This way the aggregation of tasks (required to specific professionals) is replaced by the cooperation of talents (offered by people with different expertise). The members of the team will react in different ways to the Idea and give their contribution according to their area of competence.

This is how an (integrated) design should start. But in common practice design teams are often formed before the specific opportunity offered by the assignment. They already exist inside professional offices or groups of offices that work together temporarily.

An office with a fixed number of employees has a huge economic pressure, because it needs projects to pay the salaries. And, being a commercial entity, it exists for reasons that are independent from (and come before) the different works it's been assigned.

In theory an office is a guarantee for success and high quality performances. But what does it really guarantee? Shouldn't past designs and finished buildings already be an impressive guarantee?

The truth for me is that complex commercial enterprises tend to work together because the complexity of their structure allows to endlessly delegating the responsibility of judgement, till it almost magically disappears.

Beyond the Comfort Zone

I agree with the necessity of starting from an Idea, whose strength is capable of aggregating different people in a well-integrated design team. The presence of such an Idea is what will bring together the skills of everybody and will generate a spontaneous attitude of working together. And I think that the way people react to this Idea is a good indicator of its quality in the first place, so that the person proposing the Idea can immediately test it.

My first reaction when you said that this 'originative' Idea has to come from one person was that it would be even better if such Idea derived itself from a discussion among people having different backgrounds, skills, sensibilities. In a way this could make the Idea even stronger and more capable of getting the best out of the different members of the design team. But this is not that important, after all: what really matters is the presence of the Idea and the fact that people buy it.

Why should people prefer to work on projects where the design is inspired by this recognised starting point, than just get aggregated together to deliver a scheme that has been already outlined? I think this is a key question we need to address.

My answer to this is that this approach will allow the different components of the design team to exploit their skills at their best, and this will naturally generate a better piece of design. Therefore, the advantage to the different people will be that they will be part of a better project.

Let me go a little bit deeper: if everybody feels engaged in the development of an Idea and feels like his/her opinion is important in the overall economy of the project, and not just within the rigid borders defined by his/her personal skills, they will push harder and will feel the motivations to go beyond their comfort zone. If you know that a specific area of the project belongs to you and nobody can really argue with what you decide about it, then I don't think you'll be particularly motivated to try something new. But isn't it much more exciting when you feel that your opinion matters also for aspects of the project that don't necessarily belong to your personal skills? It's the feeling that you're learning something new, that you're developing your general skills as a designer: this is what motivates me and I must say that I have seen how much the quality of my contribution on projects varies depending on the level of involvement I am asked to be part of.

If a good, modern design of building envelopes should consider all the points you and I raised in the previous pages—and I think we provided a lot of good reasons proving that this is the case—can we really think to keep using the same design approach we are experiencing in our daily life? To me it seems quite obvious that we need to change our attitude and also our design tools.

Chapter 2
Optimisation

The Approach

The methodology I am going to describe is called *Optimisation*: this design approach has been already proven to be successful in several disciplines and also in engineering, but it is not popular in the building industry yet, and I must admit I find it quite surprising.

In the extreme summary, I would say that optimising means to look for the best solution: when we are facing a problem, we generally aim at solving it in the best possible way. We don't want to find an answer or a good answer; we want to identify the answer that addresses our questions more effectively than any other possible solution.

I'll first try to explain this thing in a general way, and then I'll give an example.

The first step is to be very clear in mind what you're after: you have to determine the criterion (or criteria) you are going to use to compare different solutions. In optimisation terms, this means defining the *objective function* and you have to refer to this in order to understand whether option A is better than option B. Once this has been clearly defined, then it will be possible to compare all potential solutions to your problem and determine which one is the best. Things become a bit more complicated if you want to compare options using more than one criterion, because in this case you can't find one optimum solution, but you can determine the set of options representing the best compromises between the different criteria. This approach is called *multi-objective optimisation*.

Now I'll give you an example of what I mean. Let 's say that we are designing the façade of a building and we want to determine the right combination of type of glass and percentage of vision area, in order to achieve the best level of energy efficiency of the building. This is the very generic question, from which we have to define the objective function. In order to do so, it is important that we understand how the parameters we're playing with (i.e. percentage of vision area and glass type) affect the energy performance of the building. The three major sources of energy consumption, which can be directly related to the performance of the building envelope are: heating, cooling and artificial lighting. Glazed areas lead to

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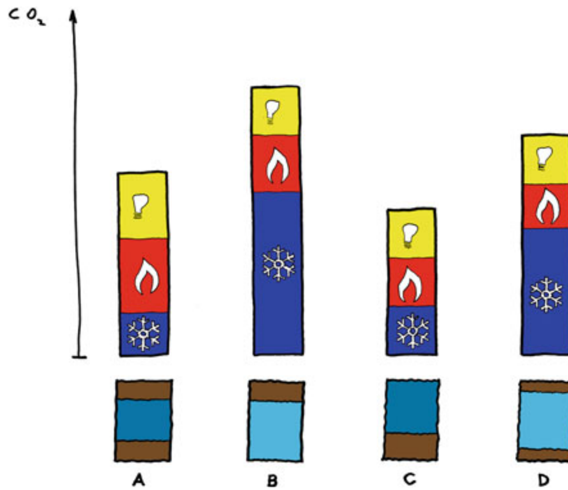
higher heat losses than the ones through an opaque, well-insulated wall; at the same time, solar radiation can enter through the glass, introducing solar gains within the internal environment, which lead to cooling energy demand. But it is also very important to guarantee a reasonable amount of daylighting, in order to improve visual comfort of the occupants and reduce the energy demand for artificial lighting. From this simple example, you can see that it's not that easy to define an objective function summarising all these aspects in an effective way. There are two possibilities: we can either make some assumptions and combine together the three sources of energy consumption in one single element, or we can keep them separate and consider three different criteria. In the first case, we will run a *single-objective optimisation*, the second case corresponds to a *multi-objective optimisation*.

Single-Objective

As I mentioned earlier, if we are to run a single-objective optimisation then we have to consider different aspects (in this example the energy consumption for heating, cooling and artificial lighting) and the objective function will have to combine the different criteria. In order to do so, we need to find a way to measure all of them and to sum up the partial results. Once this is done, it is possible to determine the overall performance of each façade option and describe it with one parameter. In this way the different façade options can be compared and we can run a single-objective optimisation. In the case of our example it is quite easy to combine the different criteria as they all represent energy consumptions. Since they are different types of energy, a good way of summing up the three contributions is to 'translate' them in terms of carbon emissions. This can be done by assuming the efficiency of the different systems (cooling, heating and lighting) and by considering some factors relating energy demand with carbon emissions—these factors differ for different countries, depending on the way energy is sourced there. The image below shows an example where four different façade options—A, B, C and D—are compared in terms of total annual carbon emissions, due to cooling, heating and artificial lighting.



Single-objective optimisation, carbon emission scheme

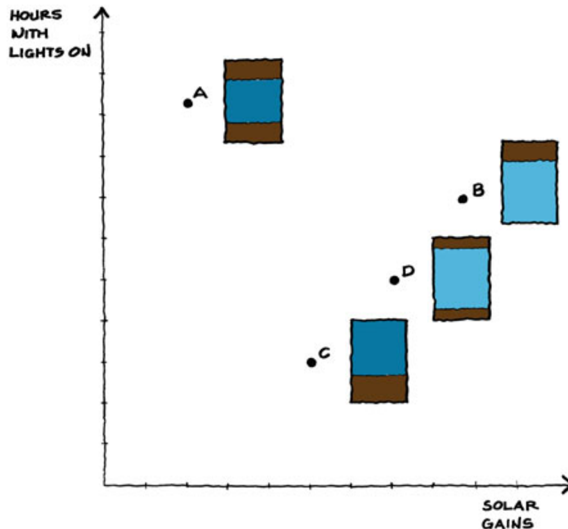
The best design will be the one corresponding to the lowest value of the objective function. It is very straightforward to understand that the best solution—among the ones considered—is C, whilst the worst one is B.

But everything becomes much more complicated if we are dealing with criteria which are significantly different. For example, if we wanted to run a single-objective optimisation where the criteria are energy consumption and internal comfort, we would have to think harder in order to find a common denominator. A possibility is to compare options in terms of cost: for energy, as we did when we assumed the corresponding carbon emission, it is relatively straightforward to assess reasonable values of corresponding costs. But what about comfort? Well, if we are designing an office building, we can say that the level of comfort is related to the employees' productivity, therefore better comfort levels will result in lower costs for the work of employees. And this cost can be combined with the one for the provision of energy. Obviously, the more 'indirect' the relationship between the different criteria, the more intricate the mechanism to combine them and the more heavily the objective function relies on assumptions.

Yes, I think I can see how difficult it can get to summarise completely different aspects in a single parameter. For example, I guess that mixing energy and space performance can become pretty academic! I'm not sure I'm convinced this can always work.

Multi-Objective

I probably agree with you: when you can't or don't want to merge different criteria in one single-objective, but you can choose to keep different aspects separate, in order to have a better understanding of the overall situation. In this case you are running a *multi-objective optimisation*. Let's come back to our example, but let's simplify it a little bit to keep things clearer: let's compare different façade options and see how they perform in terms of control of solar gains and allowance for daylighting. This is actually one of the most challenging questions for the performance design of façades: 'how can I achieve the best compromise between limitation of solar gains (and hence cooling energy) and provision of daylighting'? Answering this question can be a never-ending process, if we don't follow a proper procedure. For each of the considered façade options, let's calculate the annual amount of solar gains and the amount of hours during the year when artificial lights have to be on, because daylighting does not provide adequate levels of illuminance. In this way we can assign a quantity to each of our criteria for all our options. The image below shows how four façade options are distributed within what we can call *performance space*: options A, B, C and D are compared in terms of their performance considering the criteria we are interested in.



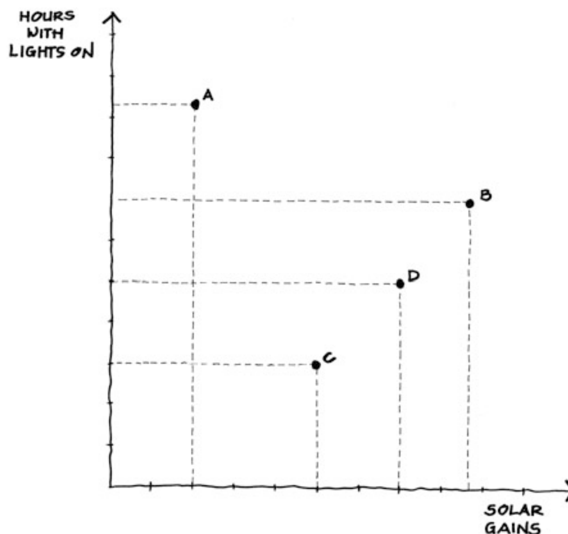
Multi-objective optimisation, performance space scheme

Option A is the one leading to the lowest amount of solar gains, but it is also the one where artificial lights will have to be on for the largest amount of time. Let's now compare options A and B: if we go for façade option B instead of A, we will have a higher amount of solar gains, but also we'll have more daylighting. Can we

say that option A is better than option B or vice versa? The answer is no because they reach different types of compromises between the two considered criteria. And the same happens if we compare options A and C or options A and D. Let's now compare options C and D: in this case option C leads to lower solar gains and better daylighting, so it is better than option D from the point of view of both criteria at the same time. In this case we can say that option C is better than option D: we should say that *option C dominates option D*. Let's define this concept properly: a solution X is said to be non-dominated by solution Y if both the following conditions are satisfied:

(a) Solution X is no worse than Y in all criteria;
(b) Solution X is better than Y in at least one criterion.

As it appears clear, we can't simply compare options separately, because we would get lost immediately if we did that: it's very important that we use an instrument that compares all the options at the same time. Let's use the concept of *domination*: we can say that all *non-dominated options are optimum solutions*. And it's easy to understand whether a solution is dominated or not: let's have a look at the image below.

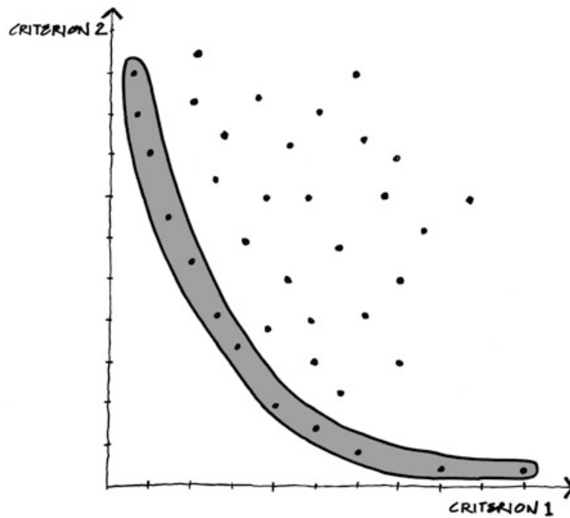


Multi-objective optimisation, domination scheme

If we draw a line parallel to each axis from the positions corresponding to the performance of each option, we'll immediately see if this option is dominated by any other options: if there are points representing other solutions between the two lines, our option is dominated. In our example, options A and C are non-dominated, option D is dominated by option C and option B is dominated by C and D.

In this case, then, we can say that only options A and C represent optimum compromises between the considered criteria: all other solutions can be dismissed.

Obviously, in a real case we would deal with a much higher amount of options, and possibly with more performance criteria. In such real cases, we aim at finding a lot of options representing optimum compromises between the design criteria: in technical terms, the scope of a multi-objective optimisation analysis is to find the *Pareto front*, which comprises all the non-dominated solutions. If we have two criteria, the Pareto front is represented by a curve, if we have three criteria, the Pareto front is a surface, and so on. What if we have only one criterion? The Pareto front will be a point, corresponding to the only optimum solution of a single-objective optimisation analysis.



Multi-objective optimisation, Pareto front scheme

Single- and multi-objective optimisation are strictly connected to each other, they are basically different interpretations of the same process. In the case of a single-objective optimisation process, we have to make some assumptions in order to connect the different criteria and determine one parameter that we use to compare different solutions. In other terms, we can say that we introduce some *weights* to combine the different criteria: in our previous example, the performance criteria were cooling energy, heating energy and daylighting availability, and we used some weights (the assumed energy efficiencies of the different systems) to calculate a total energy consumption. These weights are defined at the beginning of the optimisation process, *a priori*. In the case of multi-objective optimisation we

don't do this, but we keep the different criteria separated during our research for the Pareto front. Once we have identified all the non-dominated solutions, i.e. the optimum compromises between the different criteria, we can introduce weights to sum up the objectives. In this case we use the weights after the optimisation process, *a posteriori*, and this can give us several opportunities. If we have done things properly, the solution we get from a single-objective optimisation is within the Pareto front, and we will find it if we apply a posteriori the same weights that we applied a priori for the definition of the single-objective performance scale.

This description should make it clear why optimisation can represent a good method to achieve a balanced-design: it basically makes it possible to quantify the qualities of different design solutions and hence to compare them, in order to identify the good answers to our questions. The final result is that we can focus our attention on a limited number of options, which we know are very effective, and can exclude the ones that don't provide good value but could generate confusion for the design team. I would also like to highlight the fact that by using optimisation we are also forced to think hard about ways of describing the qualities of our design, in ways that can be compared clearly and indisputably.

Optimisation and Objective Function

Excuse me, but I have to stop you to make some comments about what you said, before it gets too broad.

As far as I know, optimisation is a mathematical procedure used in management to find the best configuration in a set of given data. So, if I had to apply it to the construction industry, I would have associated it with the management of work, resources, materials, etc. But, according to your definition, the concept of optimisation seems already entirely integral to the process of design (rather than to management).

When we design something, what are we doing if not looking for the best solution? So, when we talk about design, in a way we're already talking about optimisation.

Yet, I would point out some distinctions.

I don't like it when people talk about solving problems. We, as designers, don't solve problems, we rather foresee them in order to pursue a will. I would say that our task is to make this will possible. The will demands the most effective answer to its request. We measure its effectiveness according to the fulfilment of our expectations. So, to get an effective answer, we must know very well what we are asking.

Having design in mind, the thing I find most interesting about optimisation is the importance given to this issue: how to define the quality of the product. It's interesting that, instead of presenting optimisation as a user-friendly tool, you said right from the start that the only way to use it is to know exactly how to ask what we want.

I very much share this vision applied to design: I think that the beginning of the process has its development in itself and theoretically everything has already been decided from the very first step. This is fundamental for me. The objective function looks like the summary of a design, or, in other words, a magic formula (even if the process that it triggers has nothing magical).

I like to think that if we build a system considering all the variables and every single solution we could write an objective function for the whole design, where attentively considered requests lead to optimised results.

Sure, the procedure you present is a brilliant and efficient tool, but there's a problem: in order to use it, first we have to conceive a performance and to define its purpose. If we don't have the standards that help us decide what to expect from the design, we need a vision, a point of view, a will that requires specific performances to the project as a whole.

What I fear when I think of the word 'optimisation'—a process that leads to the optimum, the search for what's absolutely excellent—is that it might trap the design into a deterministic and irreversible process.

OK, OK, I see your point, but wait a second: so far we have spoken of optimisation in general terms, and the procedures explained earlier are applicable only if we have the possibility to evaluate all the façade options we want to consider. Obviously, in the real-world, this is not necessarily the case: the number of alternatives that we want to consider can potentially be unmanageable. Traditionally, the design team decides to analyse the performance of a very limited amount of options, which are selected because they proved successful in previous projects or because of some rule of thumbs. This approach is perfectly legitimate and for sure it can lead to very good design solutions with reasonable calculation effort. But there is a massive limitation in this design strategy: how can we find out innovative solutions if we limit ourselves to a small number of options we consider safe because of previous experiences? If we want to achieve unprecedented results, we need to adopt a new procedure! The one I want to talk to you about is *evolutionary optimisation*: this is a procedure which combines the aspiration of considering extremely wide spectra of potential solutions with the limitations of calculation effort. In very general terms, in evolutionary optimisation the research for optimum solution (or solutions if we are running a multi-objective analysis) is not a static process, but it *evolves* through different *generations* of calculations, which can test options spread along the whole range of possible solutions. The idea is that the research starts in a completely random way: some possible solutions are picked within the so-called *research space*. I want to stress the fact that these starting points are not chosen by the design team (who defines only the limits of the research space and the objective function), but are randomly selected: this is very important because only in this way it is possible to explore options that would normally be excluded a priori. These selected options are analysed and the corresponding values of the objective function(s) are calculated; in this way it is possible to start having an idea of some trends of how the objective function varies with the parameters describing the different façade options. From these

preliminary trends, the optimiser can select a second-generation of possible solutions, which are expected to achieve better performance in terms of the considered objective function, since we are interested only on good options. It may be that the preliminary trends were misleading and potentially the options considered in the second-generation could perform worse than the previous ones: never mind, because even so, this second-generation of calculations will provide more information to the optimiser. In this way, trends can be better understood and the following generation of options can be determined. This process goes on for a certain number of generations, and in general along generations the quality of tested options increases more and more. At the end of the procedure, the optimum option or the options corresponding to the Pareto front will be identified.

During the previous description, I used the very general term *optimiser* because I didn't want to enter too much detail, but actually this noun has everything in it. An optimiser could be a person who can interpret results and understand what I called trends, and in this way identify the following generation. In general, though, optimisation has to be automated, in order to be an effective design tool, therefore the optimiser is an *optimisation algorithm*. There are a lot of different types of optimisation algorithms, and this is not the place to go through all of them: I'll describe to you only one type, which is the most popular. I'll describe these algorithms in a simplified way because I don't think it is useful for our discussion to enter the very details of them. I hope in this way things will be clear.

Genetic Algorithms

Genetic algorithms take inspiration from the laws of Darwin's theory reported in his "*The Origin of Species*". In extreme synthesis, Darwin shows that in nature individuals compete for their own survival, and within populations there is a huge variation of individuals: different characteristics of individuals are inherited through generations. The key thing is that not all individuals have the same opportunities to transfer their characters to following generations: beings which are more suited to their local environment have more opportunities to survive and hence to reproduce. In this way they transmit their successful characters to following generations, and therefore populations evolve and become more adapt to the environment.

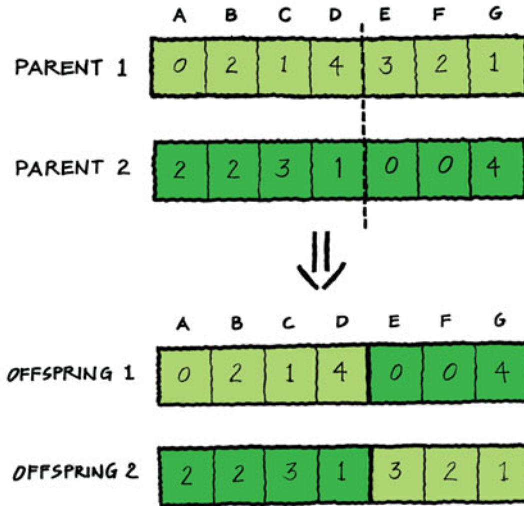
Genetic algorithms try to reproduce natural laws and apply them in the search for solutions of optimisation problems: like individuals, solutions evolve towards conditions of better fitness that make them more appropriate answers to problems. As I mentioned earlier, the research for optimum solutions goes from generation to generation of potential options. After one generation has been analysed, each option of this generation can be assigned a fitness: options can hence be compared and it is possible to determine a ranking. The following generation of potential solutions is identified by means of three different operations: *selection, recombination* and *mutation*.

Selection

As for the Darwinian's survival of the fittest, selection is the mechanism through which options with a better fitness are more likely to survive and to move to the following generation. It is important to note that, as for the natural process, we don't want to necessarily get rid of all 'bad' solutions within one generation step: we want only to give more opportunities to good solutions to 'survive'. And this is because there may be some good aspects also in options which, overall, perform badly. There are several ways we can follow to achieve this. One of them is to recreate the mechanism of the roulette wheel: we can imagine to have a roulette wheel whose different slices represent the individuals. The size of the different slices is proportionate to the fitness of the different solutions, i.e. the solution with the highest ranking has the largest slice. Depending on where the wheel stops, the corresponding individual 'survives' the selection: obviously it is much more likely that solutions having good fitness are selected. The wheel turns as many times as the number of options we are considering for each generation.

Recombination

Selecting fit individuals is clearly not enough because we want to explore new options as well. The idea is that it is likely that the combination of solutions with a good fitness can generate other fit options: the good qualities of different solutions can be complementary and their combination can lead to very successful characteristics. As for selection, also recombination can be carried out in different ways, but the most common is the mechanism called *crossover*. Let's say that we can describe the considered options by using six different characteristics (from A to G) and each characteristic can express itself in five different ways (from 0 to 4): in this way we can assign to each individual a 'chromosome' that describes it completely. Crossover cuts the chromosome of two *parents* and mixes them, generating two new *offspring* individuals. The image below describes how this mechanism works.

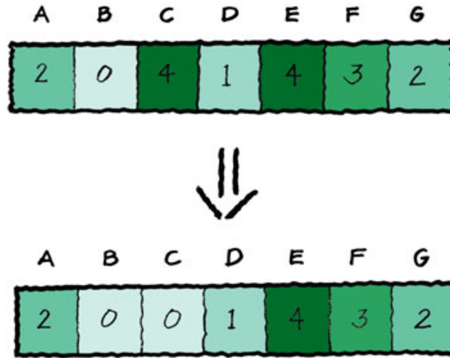


Genetic algorithms, recombination scheme

As for the selection process, also recombination is significantly driven by random, casual conditions: the location of the *cut* within chromosomes is not controlled. This allows to keep the research for the optimum more open.

Mutation

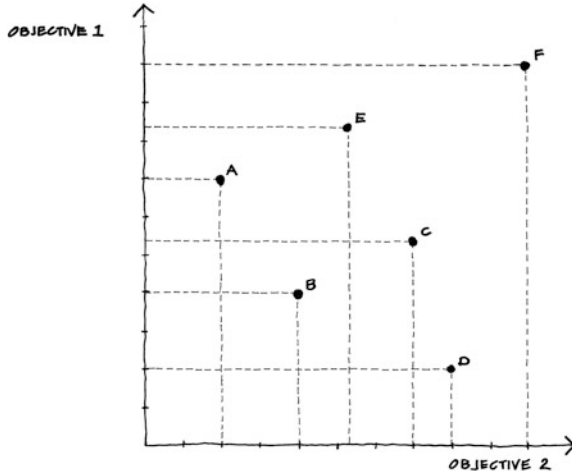
In theory, selection and recombination can make different generations evolve towards optimum solutions, because they guarantee that fit options have adequate opportunities to transmit to the following generations the character that make them successful. But along the natural selection process, another mechanism occurs and has an impact: mutation introduces some changes in the individuals' chromosomes, which are unexpected and random. Changes due to mutation are not related to the fitness of solutions and don't happen because they are expected to provide improvements. But mutation introduces an unpredictable element that allows to explore areas within the problem space that could be completely disregarded otherwise. The mechanism of mutation is very simple: a number of individuals within a generation is randomly selected and one element of their chromosome is randomly changed.



Genetic algorithms, mutation scheme

Depending on the type of problem we want to analyse, these three procedures have to be adjusted. In some cases it is preferable not to recombine all the 'survived' individuals, but to keep the fittest ones in-haltered, in order to keep their chromosomes for the following generations. And also mutation can be relatively frequent or extremely rare: in the first case the algorithm will explore a wider region of the problem space. If mutation occurs very rarely, the algorithms will find optimum solution(s) in a quicker way. Unfortunately, it is not possible to define precise rules that define how to adjust these parameters in the best way for each problem: these adjustments rely a lot on the user's competence and experience.

Genetic algorithms can be used for both single- and multi-objective optimisation problems. The three processes of selection, recombination and mutation occur in the same way. The main difference is in the way the fitness of individuals is determined, in order to initialise the process of selection. For the case of single-objective optimisation, the fitness of each individual corresponds to the level of the objective function. For multi-objective optimisation, things are slightly more complicated. In this case the fitness of the different individuals is their *domination index*: for each individual it represents the number of other options (within the analysed generation) dominating it. Let's have a look at the chart below: it shows the positions of six solutions within the solution space, defined by two objective functions. If we consider the case that both objectives are to be minimised, we can see that solutions A, B and D are not dominated and solutions C, E and F are dominated. But this is not a sufficient distinction, because we also need to differentiate in terms



Multi-objective optimisation, domination scheme

of how many options dominate each individual, in order to establish a ranking of the generation. The chart in the image shows the following ranking: options A, B and D have fitness 0, option C has fitness 1, option E has fitness 2 and option F has fitness 5, therefore will be the most likely to 'disappear' after the selection process. Now, without entering in the very details, it is important for the optimisation algorithm not just to identify as many non-dominated solutions as possible, but also to find solutions along the whole Pareto front, in order to provide adequate information for the decision-making process. There are several ways of adjusting the genetic algorithms for that, but this becomes too specialist a discussion.

Randomness and Hypothetical Logic

I think we should reflect on the connection of optimisation and evolutionary theory. Please, spare me a moment to think about what you've just said.

Somehow, it seems to me that there's a semantic contradiction between the two concepts that should cooperate in your method: optimisation and evolution. If optimisation searches for the optimum, i.e. what in a given set fulfils in the best way an external requirement, and evolution generates the 'evolved', i.e. what over time has most effectively reacted to a given environment, then what is evolved is

not necessarily the optimum and vice versa. Actually I would say they are quite the opposite: optimum is a requirement and the 'evolved' a result.

But probably this attempt to bring together the contrasts, this 'I want everything' attitude, goes well with the ideal of the architect, who wants the design at all costs.

We've already spoken about optimisation, but now I'd like to spend some words on the evolutionary process, that plays a key role in what you said.

On the basis of orthodox Darwinism, nature has no purpose, no direction and no inevitable outcomes. It evolves according to a certain randomness.

Now, every design is a statement, a declaration of will. It is a law. You will agree with me that law and randomness don't get along very well. So, I wonder, why should we leave to randomness the search for what we want? (Even if it is some kind of benevolent and friendly chance). And why should we trust this randomness right in the field of architectural design? When architecture is the realm of care, accuracy, informed decisions etc., basically the opposite of randomness?

Hence, another objection: the result we get from optimisation, through the randomness that rules the procedure, is not exactly the optimum but, more precisely, something that comes very close to the optimum: the hypothetical optimum. The logic that rules the system is a hypothetical logic. In this sense optimisation seems to embrace the principle, typical of the scientific knowledge, that there's no final or undeniable Truth.

This is the most modern, disenchanted and smartest aspect of our scientific-technological culture. No result is absolute! But, as human beings, how can we be satisfied with something that's only highly likely?

Even if we are happy with our result, we know that probably there's a better one. And this awareness, i.e. that what we got is not the best we could get, makes us unhappy.

At least, when we design and make decisions in the traditional way, we can experience some happiness in the finite and imperfect awareness that we've found, once and for all, what is for us the optimal solution. It might be a flawed happiness but it's certainly rewarding.

But I don't want to divert from the topic of our discussion. Getting back to what you've said, I must say I find very meaningful the two issues of randomness and hypothetical logic.

Enhancement Methods and the Idea of Perfection

In nature, things evolve reacting to external stimuli, changing their biology according to the environment and as far as we know the way they do it is not planned. This means that the earlier stage of an organism (or a generic being), is not necessarily worse than the latest or most advanced one. Each stage has a

certain autonomy in terms of progress, because it doesn't have necessarily a relation of cause and effect with the following one.

Every being is perfectible and tends to perfection. The result, though, is not predetermined or predictable. So, since this concept of perfection is relative (not absolute) it's impossible to assert the existence of a plan in nature. And this is precisely the main difference between natural evolution and architectural design, because the latter takes its origin from a desire and an idea.

To apply to design a method inspired by natural selection, then, means to separate the idea from its completion. Perfection only belongs to the phase of conception, while enhancement is pertinent to the following stages.

So, we can use randomness as a procedural element, functional in finding the best solution, but the thoughtful questions and planned choices that trigger the process at the very beginning don't leave anything to chance.

Anyway, the fact that we obtain the best solution through a process led by randomness is eventually an advantage for the designer: he/she doesn't have to take the final decision by choosing personally a specific solution, but still has the responsibility of asking the right question at the very beginning.

The system makes it easier to choose (doubt) and strengthen the decision (will). It lightens the means and deepens the end.

The process of optimisation seems to be extremely smooth and efficient, even seductive. Hence a few doubts: how do we question the process? Aren't we likely to twist the result, at the cost of asking the right questions? Is there a risk to bend the end to the means? In other words, could optimisation take over architects, instead of being a handy tool at their service?

Optimisation of Solutions Versus Optimisation of Decisions

Isn't it interesting that solutions evolve in the same way as species do? This way, they seem to be more like living creatures than working machines. Therefore I would speak of decisions rather than solutions (since decisions are better suited to living beings), and I would call the process *evolutionary optimisation of decisions*.

Things get even more interesting when you say that solutions are like individuals. At this point, the process appears to me like an experiment, a model of reality, even though it is obviously an abstraction. Pushing it further, we could say that thoughts behave like individuals.

The process replicates the activity of the mind. This mind, though, doesn't think like a machine, but follows closely the interaction of thoughts inside a human brain. In theory we could adopt this method every time we need to take a decision, choosing from a wide range of variables. It would be nice to have an ongoing process of optimisation in the background of our mind for all the decisions of our everyday life. It would be like having a constant technical support to our brain.

Getting back to architecture, would it be possible at some point to feed the process not only with the data from a generic situation, but also with historical

information related to the specific problems that we are facing from time to time? This could be a way to improve the decision-making process, enriching it with previous architectural experiences. It might provide us some extra tools to estimate the value of a solution.

In comparison to the past we have much better analytical skills in terms of logistics—we are able to manage and organise massive amounts of data—but when it comes to make a qualitative synthesis, we have to resort to subjective judgement. In this sense things get problematic when we have to assign a value to different solutions and determine their fitness.

In addition to comfort, feasibility, energy performance, amount of CO_2 emissions, what are the other parameters that can help us evaluate fitness?

We can define a hierarchy of values only among elements that are comparable according to some rules or standards. But how can we decide for (qualitative) features that haven't been prescribed or that are difficult to regulate?

A decision-making process is efficient as long as there is a definition of values. So if we want to extend optimisation to our disciplines, how can we determine the value of a design? I believe that we can't answer this question just in terms of efficiency and beauty.

And besides, once we have some judgement criteria and we've started the optimisation process, to me there's a big difference between the natural evolutionary process and its artificial counterpart. It's about the very concept of fitness. Because what is fittest in nature is not necessarily the strongest, the smartest or the most obedient to the laws of nature. The concept of survival cannot be reduced to a matter of fair (benevolent) chance. In other words, I find it difficult to convert the so-called struggle for life into an artificial model.

I'm not sure I agree with you when you say that you would speak about 'decisions' rather than 'solutions'. Solutions are static, they do not deliver any action: they are simply analysed, they kind of *ask for the permission to exist* but it is not up to them to give any contribution during the optimisation process. If, by chance, they are good enough and they survive the selection, they will transmit their characters to the following generation, in a way that they cannot control. Having said that, the algorithm does not take any decisions either: it works in a rigid way, relying heavily on randomness. The only decisions are taken by the design team during the definition of the problem, when the criteria to describe the fitness of solutions are established. And then, after the optimisation process has delivered the list of optimum solutions, everything is again in complete control of the design team. I think this is something very important to stress properly, because many people are reluctant in using the computational power available as they do not want to leave the decision process in control of *soulless machines*.

I don't think we should be worried about the fact that randomness is an important ingredient of optimisation. I know it can sound extremely uncomfortable to have some design decisions taken by means of a random process—but is this really the case? I'm going to explain why I don't think this is what actually happens. First of all, let's have a look at what is driven by arbitrary operations. The

first thing we cannot control is the selection of the first-generation of solutions: we define how many options there are in each generation, but then the algorithm picks the starting points of the evolutionary process completely by chance. We already discussed that it is very important that this happens, because only in this way we are sure that the whole space of potential options are explored, without limitations dictated by our previous experiences/prejudices. Once the different options of one generation have been analysed and their fitness has been assessed, the three operations followed by the algorithm to determine the following generation are strongly influenced by randomness. For selection, the dimension of each slice of the roulette wheel is proportionate to the level of fitness of each option, but then the way the wheel turns and hence the position where it stops is completely arbitrary. For recombination, randomness acts at two levels: first of all when couples of parents are formed—there is indeed no control about which option is mixing its genes with which—and also the location where chromosomes are cut and then combined is random. Eventually, mutation is the most arbitrary of all the operations, as we cannot control which option is going to mutate, which gene will change and how it will be modified.

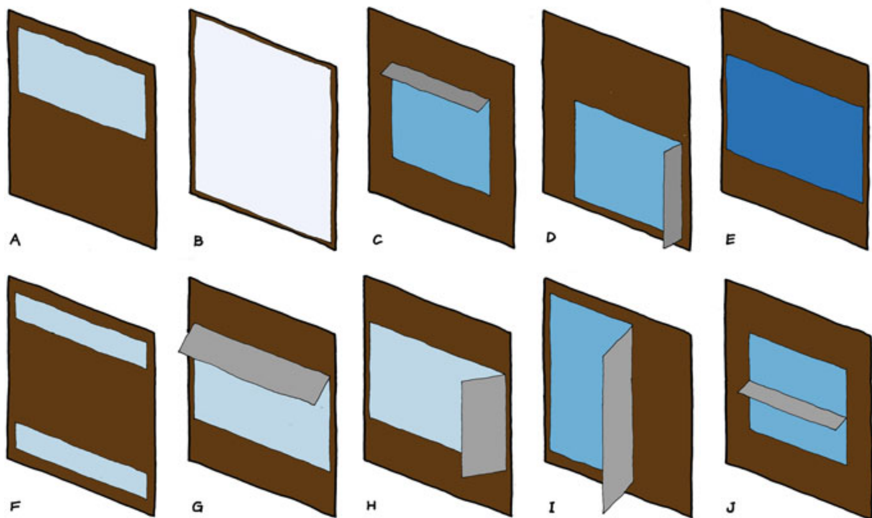
But does this mean that the final result is completely random as well? Of course not, otherwise the whole thing wouldn't make any sense. It is good practice to run the same evolutionary optimisation a number of times: if we get the same result, it is very likely that the optimisation process has been successful and that the result is the actual optimum or the Pareto front. And this is because randomness should impact only on the way the optimum is identified by the algorithm, without impacting on the final result, which is determined uniquely by the definition of the problem—i.e. the range of potential options we want to consider and the fitness function we have chosen. Since the optimisation procedure aims to find out the optimum solution without really testing the whole set of options, it is possible that the algorithm hasn't found the best solution, and we cannot be completely sure that the evolution didn't get stuck in what we called 'a local optimum'. Hence the importance of having different runs of the algorithm, because in this way we limit the likelihood that the same local optimum 'confuses' the algorithm all the times. So, in conclusion, randomness is a tool to reduce the risk of not finding the optimum, but it doesn't represent a real part of the decision-making process. Therefore we, designers, should not be worried about having our project being influenced by arbitrary, irrational decisions taken by some strange behaviour of one of the microchips within the engine of our soulless computer! Every important decision which impacts the result of our design is under our full control—which also means that we can't blame our computer if our design is wrong… Therefore, it is really up to us to define the problem, or the question we are asking the algorithm to answer, as the real answer is simply embedded in the question itself: the quality of the optimum is a direct consequence of the quality of our definition of the range of options and of the fitness function.

Let's Try to Optimise a Façade

After this brief, general description of genetic algorithms, I think it's worth understanding how they work for the façade design. As an example, let's say that we have to optimise a façade where the following parameters can be varied:

- The number of windows (within a module);
- The percentage of glazing;
- The presence of shading devices (overhangs or vertical fins);
- The geometry of the shading devices (in terms of depth and angle);
- The position of windows;
- The type of glass.

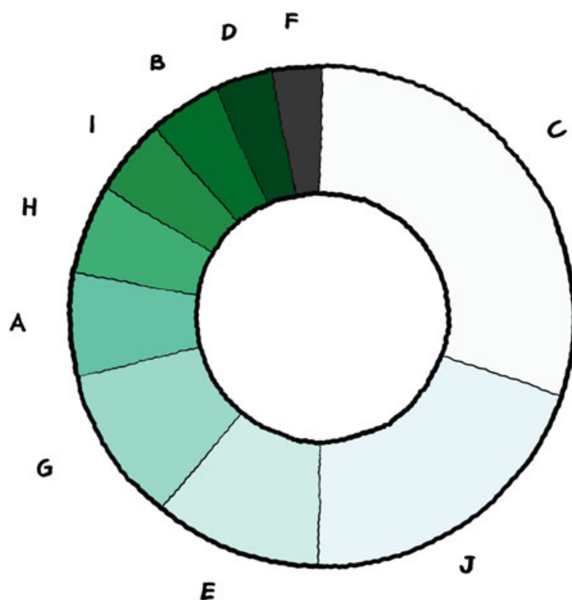
As you can imagine the number of potential solutions is enormous and it is impossible to analyse all of them, therefore genetic algorithms can represent an adequate tool to tackle this problem effectively. Just for the sake of discussion, let's say that for each generation there are ten individuals (the actual number should be larger than this, but I'm trying to keep things simple for this example). Let's imagine that, for the x-generation we are considering, the ten solutions correspond to the ones shown in the images below.



Optimisation of a façade, x-generation scheme

Let's say that the fitness of these options has been assessed and it results that option C is the best one, with the worst option being F. By knowing the fitness of each option it is possible to build the roulette wheel: option C will have the largest

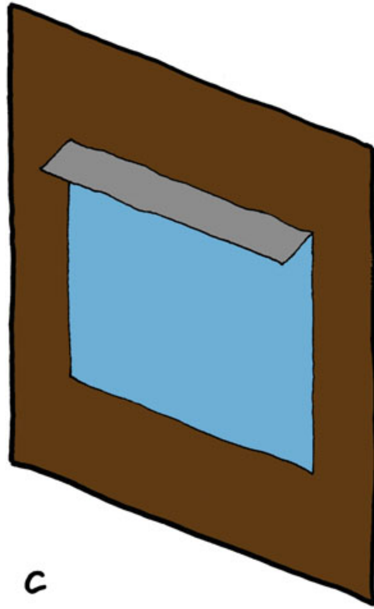
slice and option F the smallest. The size of the different slices is proportional to the level of fitness of each option: the ratio between the size of a specific slice and the size of the whole wheel represents the probability that the option corresponding to that slice is selected at each turn of the wheel. In the example, the fitness of option C is very good and it makes the slice corresponding to option C occupy 30 % of the whole wheel: this means that, for each of the ten turns of the wheel, option C will have 30 % of probabilities of being extracted.



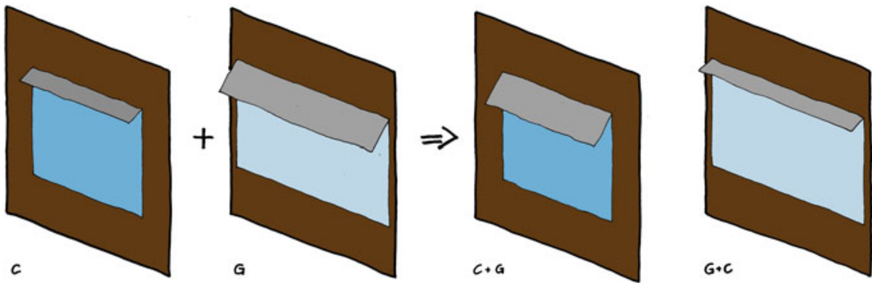
Roulette wheel, fitness scheme

I have made the wheel twist 10 times and the following options have come out: C; C; G; A; J; C; C; D; J; H.

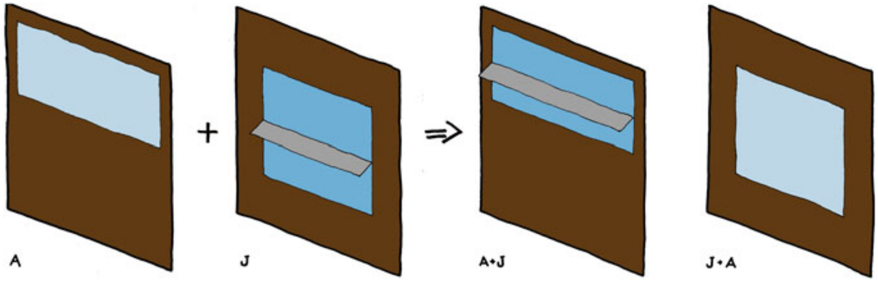
If we say that we want to keep one option in-haltered and to mutate one solution, we will have:



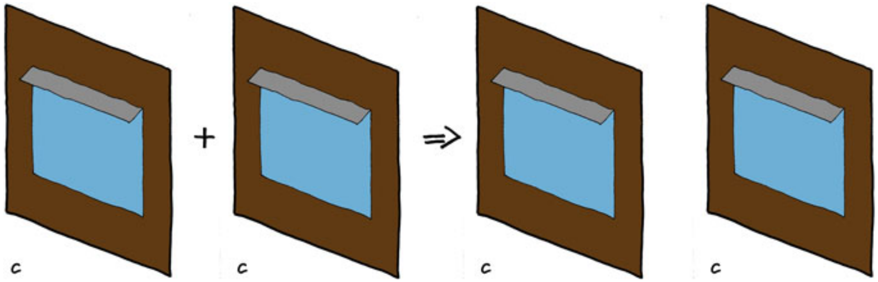
In-haltered C



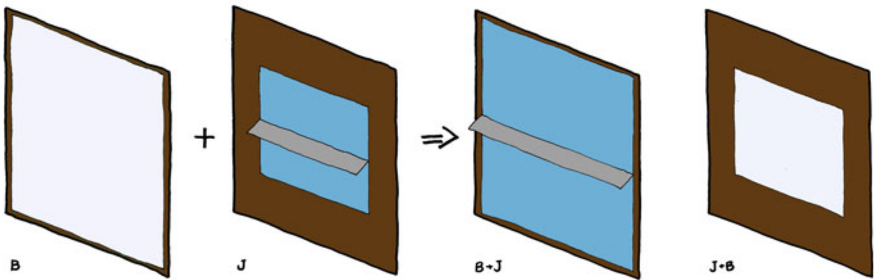
Cross-over between C and G



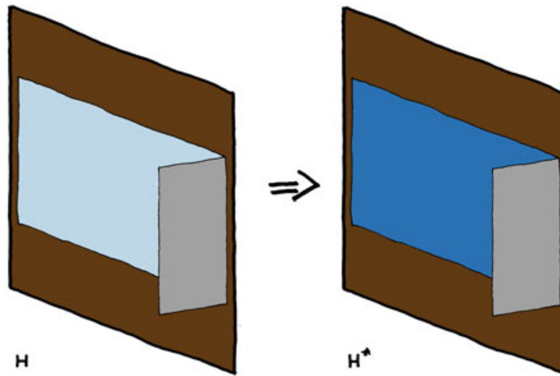
Cross-over between A and J



Cross-over between C and C

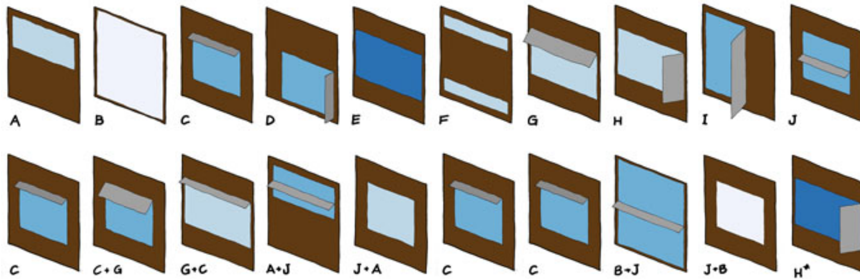


Cross-over between B and J



Mutation of H

As it can be seen, moving from one generation to the following one has led to almost a complete disappearance of vertical shading devices, and there are six options out of ten which present the same type of glass. This is just an example, but it shows how genetic algorithms pursue the research of optimum solutions.



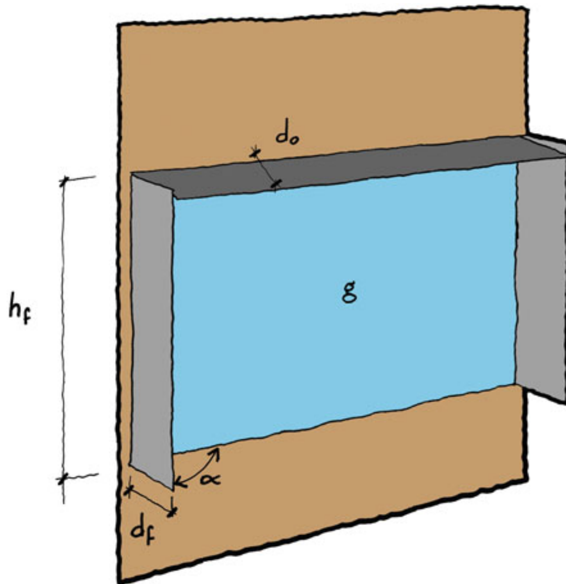
Research of the optimum solutions

So far we've seen how the genetic algorithms work in principle to evolve from randomly selected options towards the optimum one(s). This procedure will be different for the other types of algorithms that can be applied for evolutionary optimisation. What is the same for all the different versions of algorithms is what we expect from them:

Algorithms have to explore a very wide range of possible solutions;
They have to identify the best solution(s);
They have to do so within a reasonable amount of time.

Once the optimisation has run, we have a series of options: if we ran a single-objective optimisation, we'd have the best solution and the ones whose fitness is close enough to the optimum. After a multi-objective, we'll deal with the solutions within the Pareto front. Potentially, the amount of data can be really difficult to handle and generate confusion. It is important to find a good way of fully understand the results and hence take full advantage of the optimisation process. The main questions that we want to be able to answer properly are: (1) What are the specific configurations of façade (for example, percentages of glazing, types of glass, etc.) that should be avoided? (2) Reversing the question, are there some elements that have to be very prescriptive? (3) Are there parameters that don't affect the overall performance and which can therefore be designed considering only aesthetic drivers? (4) Are there ways of improving significantly the performance with little impact on the aesthetics? If we can't find a way to use the results of our analysis to answer these questions, no matter how efficient the optimisation process was: we have failed!

Let's try to answer these questions through an example, represented by the image below.



Optimisation of a façade module

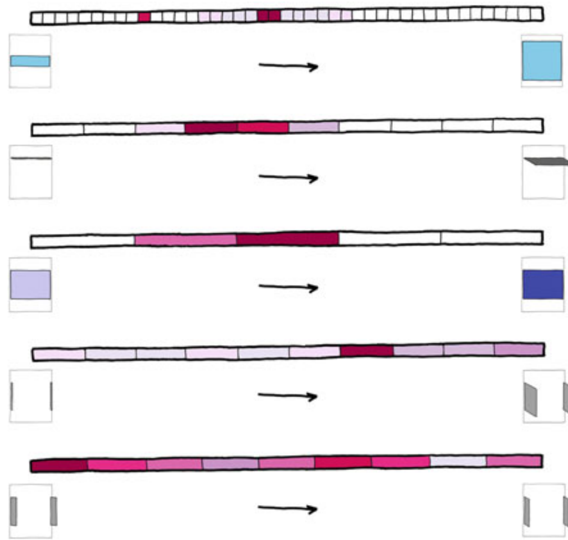
In this case we want to optimise the design of a façade module where we can vary the following parameters:

(a) The height of the glazing (h_g), which defines the percentage of vision area. We want to test a wide range (from 20 to 80 %) and we split this range in 43 steps, in order to keep the research comprehensive.
(b) The depth of the overhang (d_o), which can vary between 100 mm and 1 m at steps of 100 mm.
(c) The type of glazing (g), which can be very transparent or dark: 5 different types of glass are considered.
(d) The depth of the vertical fins (d_f), which can vary between 100 mm and 1 m at steps of 100 mm.
(e) The inclination of the vertical fins (α), which varies between 10 and 90° at steps of 10°.

In this case our research space is made out of almost 200,000 possible options. Let's say that we want to run a single-objective optimisation, where the objective function is the annual amount of carbon emissions due to cooling, heating and artificial lighting. We are considering an office building in London and the façade we are looking at is facing west.

The outcome of the optimisation exercise is a series of combinations leading to very low carbon emissions, i.e. the optimum solution and the ones leading to an increase of less than 2 % in emissions. This means that the design team is provided with a huge number of options from which decisions are to be taken. The problem is that the most immediate way of looking at the results is a long table, which has all the answers, but it's very confusing and doesn't help that much. As I mentioned earlier, we need a clever way of presenting the results, in order to have some immediate answers that can drive the design process effectively.

We need to get some rules that we can follow in order to identify a façade design that meets the aspirations of the design team and which is, at the same time, performing properly from an energy point of view. The idea is to visualise the intensity of the different levels of each parameter: this will tell us how frequently a specific type of glass or a certain depth of the overhang is present within the series of good options identified by the optimisation. This can be done in the following way: let's visualise the different variables as bars, spanning between the two extreme levels we have considered. We can use different colours to indicate how frequently the levels of the different variables are present within the series of good options we want to focus on: the more intense the colour, the more frequently that specific variable's level occurs within the optimality region. The image below shows what I mean, applied to this specific example.



Frequency of the good options

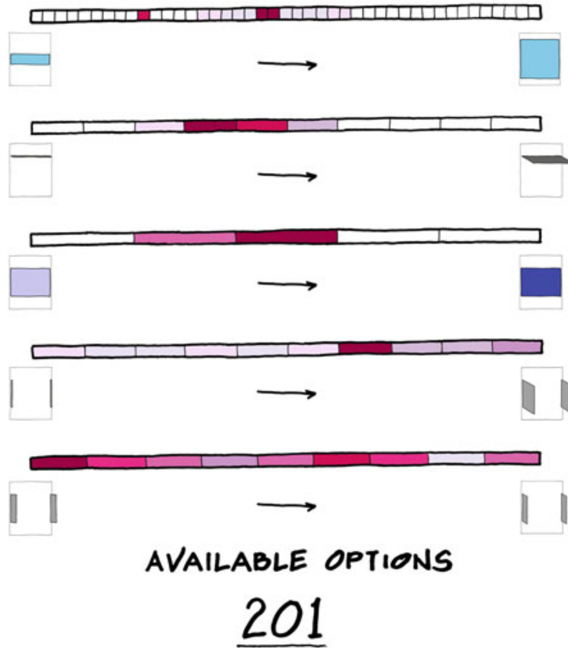
The image above is telling us that:

(a) There is a small range of glazed percentages within the optimality region, and neither very little nor a lot of vision area are beneficial;
(b) The overhang is particularly beneficial when it is in the region of 400 mm/ 600 mm depth;
(c) Only two glass types lead to good overall performance: the intermediate one and a slightly more transparent version;
(d) Vertical fins are beneficial only when they are quite deep (at least 700 mm);
(e) The inclination of vertical fins has a limited impact, since all the considered angles are present.

From the analysis of these results we can immediately understand what measures should be taken to end up with an energy efficient façade.

What this representation does not tell us is how the different variables need to be combined: what if we want to know the implications of selecting a specific level of one variable? For example, let's say that we want to understand how we can play with the geometry of the shading devices if the height of the vision area (i.e. h_g) is 2 m. Well, in this case the answer is not that immediate, because there are too many possible questions that can rise, and a 'static' representation of the results cannot satisfy all of them. We need to adopt an interactive way of selecting options. This can be done with a number of tools available in the market, for example interactive pdf can be adopted. We are not particularly interested in how to do this, but we want to focus on what sort of representation we need.

When we don't choose any level of the considered variables, the interactive tool will show us the same image shown before, and will declare the amount of 'available options', i.e. the number of combinations selected during the optimisation run. The corresponding screen shot will look like the image below:

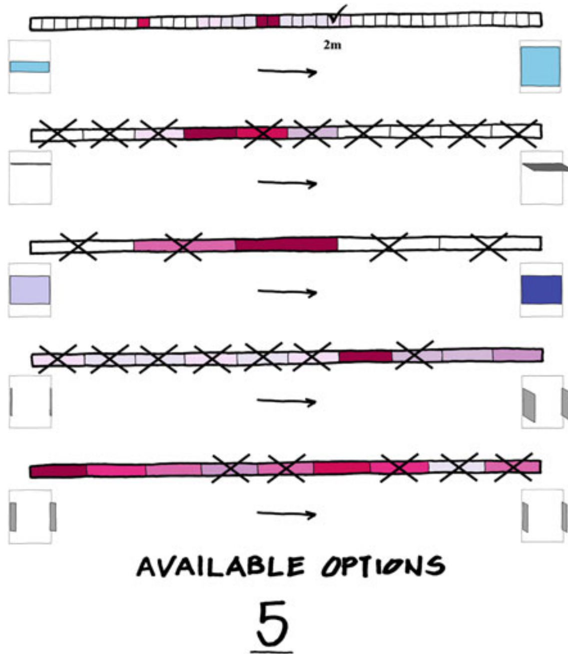


Available options

If we want to know what happens when the height of the glazing is 2 m, we click on the corresponding button and we'll have the view of the following image:

This shows immediately the implications of selecting a specific level: only a few buttons can still be clicked, and the number of available options has dramatically dropped. This has happened because we selected a level with a very low intensity.

The main advantage of this approach is that it does not refer to a specific type of analysis: we could have used it also if we had run a multi-objective optimisation with as many variables as needed.



Available options with 2m high glasing

In summary, we have seen how we can take advantage of software tools and algorithms to identify good solutions, within a huge amount of potential options and at a reasonable computational/time cost. We have also seen how the wide set of answers can be organised in a way that provides viable help to the members of the design team. In the examples above we have always referred to fitness functions based on performance/energy indicators. But this does not necessarily have to be the case. As I mentioned at the very beginning of this section, the first step to be done during an optimisation exercise is the definition of the fitness function, i.e. the scale we use to compare the different design options. This is not an easy task, but I think it is very good that the design team has to make an effort to think about how to assess whether one façade type (or, in general, a building option) is better than another: this exercise will generate a virtuous cycle for the whole design process. It will force everybody to state what they're after for the project, and to do so in a very explicit, honest way.

But this process, so dramatically honest, also requires a completely open mind-set for the designers. Because, once the objectives have been identified and properly defined, the answer we get may bring us to a solution which is very far from where we were expecting to end up. Let's imagine that the design team has worked out a solution to the design problem both in a 'traditional way' and by means of an optimisation exercise. It is possible that the two solutions coincide,

but it is infinitely more likely that they are very different. I guess there are three possible ways to deal with such a situation:

- The design team is very keen on the solution identified by means of a traditional design approach and doesn't accept to be driven by a computer (even if the computer has simply followed the rules set by the design team itself!). But, at the same time, there is the need to demonstrate, scientifically, that the identified solution is very rational and satisfies all the client's requirements in a very effective way. Therefore, the objective function is 'adjusted' in a way that an optimisation run identifies the same, preferred solution.
- The 'traditional' solution is considered more satisfactory because of some 'instinctive' criteria that the optimisation algorithm cannot perceive. Even so, the optimised solution is still taken into account and considered as a benchmark, against which the 'traditional' design needs to be compared to. It will then be clarified whether or not the improvements delivered by instinct can justify the overall lower value of the building.
- The optimised solution is deeply analysed and appraised with no prejudices due to the efforts spent for the production of the 'traditional' solution. With a complete open mind-set, the design team understands why the optimised design is better and buys it.

In principle, scenario c is the one that I think should be followed. Actually, in theory it would be better if the design team didn't develop a parallel solution in a traditional way, because in a way this will inevitably create a prejudice, which then will make it harder to analyse the optimised design. I think this is a very delicate issue to deal with: I'm fully aware that it is natural to follow the traditional route, especially during the phase when optimisation is not a common practice (yet, I'd say). And it could be beneficial, as long as it doesn't represent an intellectual barrier for the design team—and I'm very aware that this is something extremely difficult to avoid. But, let's go back to our three scenarios. As I said, situation c is the ideal one, because the final result is not just the realisation of the optimised design, but it is also a very educative process: the design team has critically understood the implications of the original decisions, which defined the objective function. And it is possible to compare the results of a fully comprehensive approach, with the ones of a traditional procedure, which we have grown up thinking it's the best one. I think this is something incredibly powerful, isn't it?

I find scenario b very interesting as well for two reasons. First of all it indicates a limitation of the optimised process, which cannot deal with some 'instinctive' criteria, and therefore can't find the actual optimum design. But, is this really the case? Or is it a matter of a mistaken definition of the objective function? This is something that we should tackle properly later on. The second reason why I find this scenario interesting is that also in this case there is a good educative process: the design team has analysed the situation in depth and there is an awareness of some mistakes or limitations in the way the objective function was defined. And there is a honest recognition of the limits of the proposed solution: the members of

the design team are aware that the proposed solution doesn't represent the best answer to the brief (represented by the criteria defining the objective function), but they know how far they are from the optimum.

What I find really disgraceful is what I described in scenario a, which, I'm afraid, is an extremely common situation. In this case the members of the design team don't accept the results of optimisation, but at the same time doesn't have the honesty to admit that and they tweak the rules until their design is scientifically proven to be the best one.

Backgrounding

In my opinion the worst and most detrimental scenario is b, because it confuses things, preferring vague 'instinctive criteria' to a logic design.

If we don't want to adopt optimisation in the architectural process, because we don't trust it or we are afraid that it might harness the design, diverting it from its ultimate aim, then it's more honest to dismiss it straight away, relying only on our traditional set of skills and ideas. It's OK to stick to what you know. But I also believe that the task of designing, either alone or in a team, is an ongoing negotiation. And design should try to bring to unity all the contributions provided by the different variables.

What fascinates me of the optimisation method is the neat distinction between conception and the decision-making stage. There's some sort of conceptual purism in this.

Being the description of the objectives, the design becomes a statement, a formula. We can follow different paths to apply this formula. Numerical analysis will help us choose the one that is probably the best.

With this I don't mean that the form will automatically create itself, in an act of self-production. No, it just remains suspended in a potential stage and will then find a solution during the decision-making process.

Nowadays there are many examples of science and technology contributions in architecture, as in all aspects of life. But I think it's evident that there's a gap between the possibilities offered by computer aided design and our present construction skills: graphic software tools give a scientific patina to our fantasies, but usually the aesthetics of the designs conceived with their help is automatically betrayed in the construction stage.

Parametric designs are beautiful and I'm waiting for the technology that will turn them into reality. On paper (or, better, on the screen) they are fascinating previews, allegories of the future, but once built they just highlight all the limitations of our materials science, and therein lies the rub.

The way scientific means are used nowadays is often just a formal statement.

By prefiguring post-Earth scenarios, computationalism seems to generate a new Nature, a nature that is supposed to be kind to men, but that ultimately might do perfectly well without them. Then, why don't we all pack and move elsewhere,

letting this self-produced architecture freely express itself on the planet? Because, what really looks out of place in the renderings of these computational designs is people: these tiny insects, these hundreds of ants going back and forth in buildings that look like huge sugary cakes.

In a moment of discouragement my professor once told me that architects put themselves into troubles from the moment they discarded classical orders. In fact, the syntax of architectural styles used to solve the problem of the form allowing architects to focus on the spatial elaboration of buildings.

The world, added my professor, needed a new Leon Battista Alberti! I've never fully understood what he meant, I just took it as a provocation detached from reality. Why should we wait for a new Leon Battista Alberti? There's no space for theories nowadays because sooner or later every theory is doomed to be proven wrong and thus to become useless.

Optimised design is not a theory but an approach, an operational framework or, better said, a *background*, that replaces the architectural as well as the technological syntax.

But on the foreground there must be an idea of space that comes from a specific desire. The stronger the initial idea of space, the more we can delegate its implementation.

In this sense I think optimisation might be an alternative to the compositional syntax, to what architectural styles used to be, a background in which syntax is left (temporarily) pending and the design can be accomplished regardless of the impositions of style and formal choices.

Today we find ourselves in front of the same tool, all of us at the same time sitting in front of the screen, as we produce and consume. When a tool is universally spread and shared by everybody, we can take its specific features for granted and finally start to compare the results, triggering that personal challenge that I mentioned before.

And I'm not saying this because I want at all costs to find a revolutionary value in the spreading of computational design.

Everyone says that an epochal change is happening, but sometimes I think that it's just a great sleight of hand, that delays the suspense and excites our anticipation. Just as when we expect the release of a new computer, that, before being a technological product is the promise of a new technological life.

Every day we are surrounded by countless signs that testify the ongoing change. But I suspect this change is slower than we think. Or maybe there's no change at all. Maybe we just want to convince ourselves that we are right in the middle of a cultural revolution.

I have this feeling because for years there's been much talk of technology, without really talking of technology. The technological society has not been fully accomplished yet. It will probably take over when we will acknowledge technology not as a mere means but as foundational feature of our world.

I believe we might take a substantial step in this direction by giving (or returning) architecture a specifically technical content. And optimisation could

help us, because it requires breaking the design into quantitative factors and features that are easily and univocally describable.

On the basis of decisions that are not stylistic but spatial, optimisation provides a technical and impersonal answer, the possibility of a form.

This is not a functionalist approach, but rather the celebration of architecture as the art of space, freed from any formal imperative.

The objective function sums up the design in a non-visual representation. This immaterial formulation, though, is very powerful because it already contains in embryo its outcome what will or might be realised. A power that's obviously proportional to the quality and accuracy of the formulation: the stronger the ability to desire, the more successful the final result.

For this reason, I would say that the objective function defines the successful building.

Chapter 3
Successful Buildings

Energy Performance and Space Performance

The technique of optimisation works well when we deal with comfort and physical performance issues. But, can we use it as well for those features that are more specifically architectural? In other words, is a quantitative survey suitable to organise and arrange architectural values? Is it possible to quantify the architectural quality of a design?

I think that in this question, more clearly than elsewhere, emerges the distance between engineers and architects. This gap, though, is based on a misunderstanding that sees at the opposite ends technology as inhuman and beauty as mysterious. But we shouldn't forget that technology is first of all a tool at the service of men and beauty the result of well-aware choices.

While, on one hand, we must acknowledge the beneficial contribution of technology in our everyday life, on the other we need to dispel the myth of beauty as a gift related to creativity and some kind of sixth sense.

Therefore, applying the optimisation technique to design might have some beneficial effect, inasmuch it forces us to handle technical and architectural features with the same means.

If the energy performance of a building, though, can be empirically measured in terms of comfort, it's more difficult to estimate architectural design with the same parameters.

If we want to evaluate architecture in terms of performance, we have to change our perspective on design, considering the building not much as a backdrop or a container, but rather as a tool connected with the bodies of its occupants.

What does it mean, then, to conceive a spatial performance? How do we express it in a scientific language? How can we consider architectural features from a quantitative point of view?

In theory everything can be quantified. If we think of the artefacts of the past, for instance the building of classical architecture, we notice that everything, from the structure to the final image, is made of numbers and proportions that obey to given aesthetic, optical, static and functional rules.

G. Zemella and A. Faraguna, *Evolutionary Optimisation of Façade Design*,
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When we design, though, what isn't, and shouldn't be definitively quantified, is the will, the desire that starts the process. This, I think, should retain a certain quota misteri. But when we move from the abstract realm of will to the actual situation offered by the design, then 'quantifiability' must rule, because the most effective praxis is the technical praxis.

I like what you've just said about beauty, as it shows a perspective for achieving aesthetics also by means of rational procedures, and not just as the result of intuition. I am not 100 % sure I agree with this, but I want to give it a try and see what happens. If you're right, this means that it is possible to take into account of not just performance-related aspects in our design procedure, based on optimisation. And that we can really perform what we called previously balanced design, as we can combine different levels of aspirations, different attitudes, without really being obliged to introduce a hierarchy of values for them. We don't have to say 'OK, let's focus on a beautiful shape and then let's see how to engineer it', or vice versa 'let's design a very high performance façade and then try to make it appealing'. New opportunities are there for us to explore. But we need to understand a bit better how we can do it. So far I have only spoken about energy performance, comfort and so on. I guess that a lot of other aspects can be considered. For example, for some buildings the view out is extremely important, because some elevations may face very interesting landscapes, and it is vital to consider it properly during the design stage. Let's say that we are designing the façade of an office facing San Marco square in Venice and we need to introduce some shading elements to limit the amount of solar gains—I know, this will never happen, but let's imagine it—well, in this case we cannot forget about the view out. We need to find a clever way of taking this into account. A possibility is to imagine *view rays* departing from a defined point of view, and running towards the main sight that we consider particularly valuable, which is divided into a grid of many 'target points'. The percentage of rays reaching the grid without being intercepted by intermediate obstacles is the parameter we want to maximise. This approach is very flexible, because it can focus on a very specific target, or the grid can be spread along wide sceneries; moreover, different points of the grid can have different weights, in order to take into account that some sight areas might be more valuable than others. It is also important to have an approach that considers the point of view of the observer: this can be adopted to tailor the design on the final user. Obviously, different areas of the façade will have different optimum compromises: a fully adapted design can be the outcome of our analysis.

We could go on with the list, but I do not think it would be very interesting; in general, as long as you can quantify something, it can be considered as a criterion of the optimisation process. But I think that this should not be enough: how can we consider aspects that cannot be described with a number but can be absolutely fundamental for the design?

I wonder how we could clarify this distance I see between your way and mine of perceiving the result of a design.

For example, what do you mean with view out?

There is a big difference between your way of dealing with the issue of allowing a view over San Marco square and the potential requirement of opening a closed environment towards a square, which is a world itself. The difference is between the technical and the poetic effect.

I guess we have a different way of considering beauty, from a cultural point of view. I think we could say that, on one hand, the scientific approach aims at solving a problem in the best possible way. On the other hand, the poetical aspiration tries to get the best possible result in the definition of the problem. Both approaches tend to the optimum. And optimum think describes beauty as the synthesis of the result of a mathematical-logical and emotional process.

But technique achieves beauty as an expression of its efficacy, with some sort of indifference for the content. Poetry uses beauty to raise a question. One tries to solve mistakes, the other springs from mistakes. Technique as science changes endlessly, poetry takes the luxury of perpetuity. Technique and poetry are enemies. They're enemies because they're competitors, as they both promise to human beings beauty and happiness, even if by means of two different approaches.

The hard task of architecture, which is at the same time technique and poetry, is to conjugate these two different perspectives.

When you look at an architectural work which is fully successful, you can't understand whether its beauty derives from aesthetical aspects or from engineering qualities: the virtuous components are mixed, they're a symphony.

How Would You Say that a Building is Successful or Not?

I fully agree with what you've just said, and that's exactly why we want to try to use optimisation in a new way, to cover a wide spectrum of design objectives, in order to overtake the existing barriers between engineering and architecture. The key part is the objective function: how can we define it, in order to have a comprehensive approach to design.

What should be the starting point of our design? Where do we want to get? I believe that we should aim at designing successful buildings, and if we want to get there we need to ask ourselves what a successful building is in the first place. This is the key question and I am afraid I cannot answer in a satisfactory way. There are so many ways in which we can judge a building: its capability in inspiring people, its longevity, its adaptability, its financial success, its level of sustainability and so on. Many of these categories are difficult to define, some of them are subjective and depend on the specific period of time they are considered. But, ultimately, this should be the fitness function we should define: the level of success.

In Nature, a successful being is quite easy to identify: its species is spread along a wide area of the world and it reproduces itself successfully. And this is applicable to animals/plants/insects of all the areas of the world and for every era. What sort of elements should we consider to judge buildings? Sustainability is a very recent criterion that wasn't considered at all until a few years ago, and also

financial success is very dependant on specific conditions. In a way I'm tempted to say that successful buildings are the ones that last for a long period of time. They must have inspired many different generations of people, which means that their qualities must lie above temporary fashions and tastes. And in some situations their capabilities of inspiring have managed to overcome some other downsides. Buildings can last for long times and survive to generations if they are not designed just to satisfy temporary criteria. I guess one of the key aspects is to create buildings which, obviously, tick the boxes of the contemporary requirements, but at the same time keep a good degree of adaptability to future needs and sensibilities.

But what does that mean? And that's where I get lost… I think this is a question that can be answered only by means of a common effort of all the people within the design team. I believe we as designers should aim at designing buildings which are successful from a global point of view, not just because of their return on investment or sustainability level or the way they look in the pictures of an architectural magazine. Therefore, we need ways to quantify the aspects defining success and then apply the optimisation techniques we have illustrated so far.

This is the key question of our conversation, since it connects success with the practice of building. If we are able to answer this question, then we can validate the whole thesis, i.e. that we can improve the quality of buildings with the help of an advanced design technique.

What lies beneath this thesis is our faith in progress.

Now, the idea of progress is at the base of any scientific knowledge. But is it integral to the theoretical system of architecture as well? And, if so, is it the same kind of progress?

Architecture is definitely a technical knowledge, but I wouldn't say it obeys to some kind of chronological progress; in fact, if we examine the history of architecture we notice that it doesn't develop accordingly to a temporal logic, following a growing trend. What we find is some development peaks concentrated in different periods of the past, in several pasts of human history.

From this point of view we can say, for instance, that today we are producing the best windows in human history, but we cannot state with the same certainty that we are producing the best buildings ever built. The windows produced in Pompeii two thousand years ago might have been a disaster, but we've never designed houses as perfect as they were conceived at that time.

That's because a building is not only made of windows and architecture is not just a matter of performance. A building is a unit, a combination of factors that fulfil different needs, pursue different aims and are regulated in different ways. Over time the connection between these factors changes, configuring a new balance. Sometimes it happens that one factor takes over. Apparently today's buildings are evaluated primarily accordingly to the mediatic performance/market value connection.

Today *utilitas* rules.

But, anyway, let's try to answer the question. It's a difficult question, as it implies that we already have a criterion to estimate success.

What does success mean? The first thing that comes to my mind is that it is a purely human priority, it's been invented by men. We could define success as the fulfilment of a desire, the achievement of a goal, something we've wanted, planned and attempted.

This leads us to another question: what's the goal of architecture? What's the desire that drives us to design and build? This brings us to analyse the practice of building and its meaning.

Evolutionary theory is based on the concept of success. You said that in nature it's easy to understand when an individual is successful. I agree with you, but I would point out that it's easy from an evolutionary point of view, which is a human point of view.

The evolution of the species is the theory that, more than all the others, has the ultimate purpose to justify the domination of man on earth. No wonder that, according to it, the most successful being in nature is ultimately man! Natural selection is selective from a human point of view: those who survive are better than those who succumb, but in the end the judge of this selection is always man. He's the one who assigns a value to lives and individuals.

Getting back to the question, if we look at the problem from an evolutionary point of view, as you've suggested, we may say that the best buildings are those that last longer. These buildings are able to adapt their configuration to new conditions and new uses, remaining recognisable, without losing their spatial essence.

To this end I'd like to point out that, being a human task, building already includes success in its definition. Each work or artefact made by men is a success in itself, as it helps men survive and improve their life. In this sense we can say that building is the most human of actions. When this original purpose emerges in the artifacts, then we experience architecture at its most.

Hence my thesis: An architecture is better than the others when it makes its user feel more human. In my opinion this is architecture's highest goal. Could we ask for more?

Anyway, the category of success belongs to men, inasmuch they transform their surroundings to their advantage. They domesticate the world, i.e. they transform into their home everything they touch.

If we want to estimate the degree of success of architecture we have to analyse it, breaking it up into all its different elements.

Divide and Rule

This analysis should help us understand the meaning of every single part and outline a hierarchy of values for the project. This hierarchy is not absolute, but needs to be revised at the beginning of every assignment.

So here's the answer to our question: a design is successful when it clearly shows the hierarchy of its values.

Buildings should reflect this order in the choice of materials: a solid and durable materiality will represent the most important values, while transient values will have a more perishable material counterpart. This way an architecture can survive for a long time, remaining intact even if it loses pieces over time.

This does not mean that a short-lived architecture cannot be powerful or meaningful. It just has to expresses its character in a clear and resolute way.

If it's true that a man's character is his fate, we can apply this also to buildings.

Solving Problems

I like the idea of making a clear statement about the hierarchical order of the different elements of the project. And I agree that this order should be defined on a project by project basis.

I think there is an interesting parallelism between this need of creating a clear hierarchy and the procedure of single-objective optimisation, where you define the objective function as a weighted sum of the different criteria you want to consider. And the weights you use are proportional to the importance you assign to each of the considered criteria.

Defining a hierarchy of values at the beginning of the project (hence before we run the optimisation) is a very honest act made by the design team.

I also find very interesting your thoughts linking evolutionary optimisation with some sort of positivistic cultural attitude. You say that believing in optimisation comes from the belief that things will always get better throughout time. Is it really the case? I don't want to look too brutal, but I actually can't see any philosophical driver in my belief that optimisation techniques can represent the way forward for tackling design problems in the most effective way. It's a purely practical thing, really. At the basis of all I'm saying there's the fact that I think that our brain is too limited to grasp all the implications of complex design decisions. And, at the same time, splitting a big problem in a series of small, simpler problems (which can be tackled even by our limited brains) is not necessarily a good idea, because it misses the implications in the big picture. Because of the huge difficulty of solving this problem, I believe that the only way to solve it is the simplest one: we have to try all the different potential solutions and find out which one is the best. And if it were possible to test all the options manually, I'd go for that. But this is not the case: we need some help to handle this huge calculation within the timescale of a project. And optimisation works quite well in doing that. Yes, it's fascinating that optimisation algorithms often take inspiration from natural laws, and that genetic algorithms specifically try to replicate Darwin's laws. But, actually, there are algorithms that are 'simply' based on statistics, and they also work pretty well. So, the term evolution doesn't refer necessarily to Darwin's selection of the species,

but it is just semantics: it describes the fact that these algorithms need to run iterations, and each iteration feeds the algorithm with additional information.

Please be as brutal as you like! But being brutal doesn't mean lacking of a philosophical imprinting. In fact, it's impossible not to have one. Yours is faith in improvement. It's the basis of your work as engineer. You can deny it, but it is so. And it's so deep-seated in your mind that you confuse it with a 'purely practical thing'.

That said, optimisation is the quintessence of scientific thinking, because it gives us the chance to apply the scientific method to any given field. You wonder at the fact that it still struggles to be adopted in the construction industry, but you say it with a certain malice, because you know (and I know too) that it's just a matter of time: the whole world is bound to be optimised in every single detail. This is our fate and our salvation.

Anyway, the point here is not whether we have to use optimisation or not, but how we should do it, after we've chosen what to optimise! In fact, if we optimise everything, we risk losing our notion of optimum. Don't you think?

Now I'd like to explain my idea of hierarchy. I would define it as the design's conceptual framework, its logical and semantic structure, the language that allows us to translate ideas into forms.

When I say that we need a conceptual organisation of our practice, I don't mean something unchangeable and given beforehand. No, the hierarchy I'm talking about is built in parallel with the design, like its mirror image. And rather than a list of desiderata or a series of solution, it's a set of design features that the design team members should have in mind to know what's more important, what deserves more attention.

A building, like a book, should show clearly what matters most and what is negligible. With this I don't mean that architecture should tell a story. What I'm saying is that design, rather than being a synonym of achievement or a given thing, fixed once and for all, is something alive. I would say that designing is a way of thinking, of reflecting on things trough architecture.

It may sound obvious, but in my perspective a design works like an organism. The development of this organism, from a bunch of cells to a body complete with limbs and organs, doesn't follow an absolute order of value, but rather the best way to form that particular kind of body. Similarly what comes first in a design is not necessarily more important than what comes after, at least not always, but just for that specific building. Otherwise we would get something else, certainly of equal dignity, but different.

So in our design we must know what comes first and what comes after, what can be omitted and what is essential.

In a human face, for example, there must be a nose. There are a thousand ways to conceive a nose: it can be a negligible detail or the main feature, it can be insignificant or peculiar, it can contribute to the regularity of the whole or create an eerie effect, often it's just a matter of millimetres, but in any case it will play a role in the composition of the face.

Our design/organism works the same way. It's a structure where all is connected. We can define the relationships among the different elements in the concept phase and we can modify or even delete some of them during the process, but when we alter the balance of the elements, we must be aware of the consequences on the whole organism. We can question everything, but not the initial idea, which represents the character of the design, because it contains all the information that we need to build the organism, as a sort of DNA. By following different paths we can obtain different results, none of which betrays the original idea. It's our task, as designers, to feed and foster this idea with our questions.

Now, if we don't want to get to the point of curing our design/organism when it's too late, we must be constantly aware of what we want to achieve throughout the whole process from the beginning to the end, till it becomes a building.

It seems to me that too often design is considered a combined operation in which different subjects gather together in order to pursue a given aim, i.e. to build. And then they decide how to do it accordingly to a schedule of deadlines.

Representatives of different professional categories join the team with their specific background and knowledge. Architects are supposed to deal with the issue of beauty, engineers to take care of efficiency and every other subject to contribute with their skills. The common goal is the finished building.

You said that design is getting more and more complex and that it's difficult for us to control the construction process as a whole. But is it true? I don't know if it was easier in the past. I don't think so. I believe that what's more difficult today is the organisation of work, maybe because the different members of the design team see their role just from their specialised point of you, and not as part of a bigger system: their contributions may be very efficient in themselves but are often disconnected from the others or in opposition with them. Hence the feuds between categories the clash between 'beauty' and 'technique' or, at the opposite end, the 'Anything is on as long as we can build!' attitude, that considers work just in terms of money.

It seems to me that nowadays complexity is a prerequisite for everything. Whatever we do we stumble into it. The best way to deal with complexity is synthesis: we must be able to sum up a complex problem and to reduce it to its elementary parts. The big picture you were talking about must be clear, albeit sketchy, to all the members of the team. Because we want to optimise the virtues of a design, not its flaws.

Now, what I want to know is: does our faith in optimisation make us less responsible?

My fear is that, with the excuse of complexity, not only are we losing sight of the big picture (the whole process in which we are involved), but we risk to forget it completely or to mistake it for an intricate summation of answers to complex problems. So let me state once again that building doesn't mean solving problems, but considering them in advance in order to pursue an ideal, big or small. An ideal of space.

Now, let's get to the point: what I think is missing today is not only an overall vision of the design, but above all a shared ideology. Every design is based on a certain ideology a system of principles and values! Each person who has joined the

team must embrace this ideology that is different from design to design. The less materialistic the ideology, the easier its fulfilment. Therefore, I think that the problem with design concerns not only the organisation of the work but every single designer right from the outset. And, second, it's not a matter of complexity but rather a lack of simplicity.

Searching for Optimum (The Perfect Ideology)

Well, there's a lot in your last intervention and I must say I agree with the majority of the things you said, but there are others I'm not sure I understood. But let me start with the little argument about my philosophical imprinting/purely practical aspects, because I don't think I explained my point of view in a proper way.

It's not that I'm trying to hide or negate my engineering background and the impact it has on my way of thinking. I must say I'm quite proud of it, even if it may sound a bit nerdy… My point is that I'm not focused on improvements, but I'm rather interested in achieving the best of what can be achieved. The fact that optimisation techniques find the optimum solution(s) by means of a path made out of steps, which represent consequent improvements, is very interesting, even fascinating. But it's not what drives me in my effort in changing the way we design buildings. What really matters is that I think we, as designers, should always try as hard as we can to deliver the best, most successful buildings. I'm not convinced that this attitude comes from my engineer's forma mentis. Doesn't everybody try to find the best solution to the problem he/she is dealing with? A surgeon aims at delivering the operation that solves the patient's problem at the best, with the smallest amount of collateral effects. A professor tries to find the most effective way to explain concepts to his/her students. And, in the same way, a design team should push the design in order to deliver the best possible space to the client—and also to the society more in general, since the building will have an impact in the environment. I've heard many people saying that they like to 'feel romantic' and accept imperfection, and for this reason they prefer not to optimise their design. I have nothing against romanticism, but I can't find anything even vaguely nicely romantic in such an attitude! I'm happy with accepting a non-optimum solution, but the choice of this design should always be an aware decision. And for this decision to be fully aware, designers should be educated about the opportunities offered by the project. The key aspect of optimisation is that it provides the design team with extremely viable information about the potential that can actually be exploited. There will then be the time to decide whether or not to go for the optimum solution. But the starting point should be the aspiration to know where the boundaries of a specific design intent actually lie. And, in my opinion, it is our duty to use all the tools we have to limit as much as possible the 'obscure area' represented by things that we don't know. There will always be aspects that we won't know, but these should be obscure because we are not able to explore them, not because we decide not to know something. This is a substantial difference.

I really like what you said about the ideology of the project, this 'arche' that all the members of the design team have to buy, to decide to be part of I agree that the big problem with many projects (the majority of them?) is that this fundamental starting point is not shared, and maybe in some situations it is not present at all! This ideology, by definition, must be very strong, and so it's very important that it is not materialistic, as you said. And if we, as members of the design team, feel the strength of this ideology, and are excited about the opportunity to develop it, then we can't be shy in interrogating and exploring it, in order to identify all its potential. Or, better to say, as much of its potential that we are able to explore. And optimisation is just a very powerful method to do so. You are very right when you say that the point is to choose what to optimise, in order to maintain the outcome of the optimisation process within the overall logic of the project. I would also add that it is important to decide when we optimise and how we do that. But I think that the risk of taking wrong decisions regarding these aspects is very low if all the members of the design team are tuned to the same project ideology.

When I say that designing is more difficult nowadays I mean that we cannot say any more that many aspects of the design are unknown and that we have to accept a high level of uncertainty; since we can limit the extents of 'obscurity', we have to do more in order to interrogate the ideology properly. The ultimate result is that decisions should be easier to take, but a bigger effort is required in the first place.

I'm not sure I understand what you say about the hierarchy of the project and the narrative order of the different design decisions. Maybe I'm a bit confused about the term hierarchy, because, by reading what you write, I'd rather use the term chronology. Please, explain it a bit more.

Challenging Progress

Imperfection might be reassuring. But the lack of accuracy, when we give up our pursuit of perfection, is not reassuring at all.

Even what we call 'romantic' or 'picturesque' has little to do with chance, because it's often achieved through a process of enhancement. A powerful ruin or an uplifting shabby building, for example, are the result of the action of time, which is itself a form of optimisation, since it selects and removes what's unnecessary.

Calculated imperfection has always been considered an important issue in architectural composition. Ancient Egyptians, for example, used to take incredible care to define their monumental structures with apparently random details: their joints were always a little irrational, their doors slightly off-axis, they were the champions of this simulated chaos.

Therefore—and here I agree with you—the search for the best result belongs to all kinds of practices, even when they seem to deny it. In this sense, science and art work the same way.

The idea of perfection is one of the founding concepts of Western culture, it allowed the creation of absolute concepts, and, more concretely, is linked to the idea of creation: if you get rid of it, everything will fall apart. What is created is

isolated, it is unity. The more it's complete and isolated, the more perfect it is. This control procedure (creative or destructive) is used in any type of human making; it's the matrix of action.

Getting to your reply, I admit that the concept of progress may be generic, but I mentioned it for a reason. Let me explain.

The aim of engineering and scientific knowledge in general is to find the best possible way to achieve a means in view of an end. They never ignore their previous achievements. Every new conquest reckons with what has been done before and takes its place at the end of a chain of efforts. Hence the strength of technology: it's ready to redefine itself but its theoretical system can't be invalidated, if a single result has been proven wrong.

This is what I call progress: an effort that's coordinated over time.

And right here I find the real difference between engineering and architecture. An engineer would never invent again something that already exists. An engineer would never reinvent the wheel! But the architect would! The architect, as we know him today, is always willing to question everything from scratch. And his/her questioning has something individualistic or anarchical.

It's funny because scientists apparently never show their connection with the past, but then they are perfectly aware of what's been done before, while architects are always talking—well or ill—of the past and their predecessors, but then they seldom acknowledge in their works the crucial parts that had already been done. In architecture we don't have a historiography of ideas.

The reason for this difference lies perhaps in the fact that scientific disciplines are more disciplined… I'm not talking about the inner structure of the knowledge but, rather, about the attitude of the single subjects and how they relate to the discipline as a whole.

Here lies the difference: whether to accept the challenge with the past or not.

Usually engineers estimate the value of a solution confronting it with previous similar solutions. That's why the choice of the best solution is easier for engineers by comparison with architects, because in science what's good is more visible.

Architects too should compare their work to similar buildings of the past and engage a challenge with ancient architects they appreciate. But when they are told so, they say: 'What we are doing now has never been done before, we can't find terms for comparison in the past, since we are now living in a completely new and mysterious age!' It may be true, but I think that, as long as our body (and mind) won't turn into something completely different, architecture will continue to be asked the same old questions.

If there is a new architecture, then it must be totally revolutionary, an alternative not to the last 40 years, but to the last 4000 years! This is what I expect from a new architecture.

And with this I don't mean to diminish the work of contemporary architects, but to broaden the horizon of what we can do. I don't understand why nowadays so much emphasis is given to ordinary residential architectures whose aim is just to increase the inhabited surface of a territory; it's just a bunch of mainstream, conventional buildings.

I wish that architects could be as determined as scientists, while pursuing their poetic ideal. Instead of indulging in vague artistic aspirations, they should give their best to achieve ideas with technical skills. An architect should be a technician first, and then, if anything, follow his/her ambitions.

When structural engineering is not conditioned by "architecture", it sometimes produces extraordinarily powerful structures and brutally pure spaces. I'm thinking about huge artefacts that defy the natural environment or technical interiors that, in their austere vigour, have something primitive or archaeological. Many great architects have been seduced by these works, because, you have to know, architects are fascinated by power. But if we try to achieve a similar effect relying only on our architectural skills, without a specific technical purpose, we are bound to fail.

Hierarchy

Getting back to hierarchy, I'll try to explain what I mean with the help of an example. A big one: the Neue Nationalgalerie by Mies Van der Rohe. It's a good example not only because it's better described in words than with drawings, but mainly because it reaches a high level of poetry by means of a rational and rigorous design. This is how I read the project.

The components are ordered in succession.

The architectural idea is to build a temple. It's up to us to figure out what rite the temple was built for, just as archaeologists that have unearthed an ancient building. A temple that houses a museum, built with primary materials, assembled with masterly proportionate elements and essential details.

The spatial idea is a very simple structure composed by a platform, eight columns and a cantilever roof plate. The hall of the temple is surrounded by a continuous glass wall, an envelope that is more virtual than physical. First the platform—then the lodge—finally the cell: it's the same order they followed during the construction.

The floor plan is originated by the superimposition of the spaces. The basement houses all the functions, the structure of the lodge and the platform represents the fixed points of the design of the plan, the rest is organised according to the use. Definition—structure—free plan.

Francesco Venezia, The Plain of the Temples, 2010

The elevation is based on the module of the glass door, its repetition and its multiples. Human scale—giant module—composition of curtain wall.

This design is not an attempt to solve some given problems. Everything has been already foreseen, as by a seer.

I find it very revealing that Mies has used only industrialised building elements. This is typical of his works. The pieces are 'given', this way the architectural creation assumes a dimension that's more imaginative rather than inventive.

As in a game, where the rules and the field are just an excuse to play and get in the game, when we play we don't invent anything, we rather find a new order of things, experimenting with distances.

There is no invention in this.

The Weight of Quality

What you've just said sounds very convincing to me. If we want to use this concept of hierarchy as our driver towards the design of successful buildings, we need to make it our objective function. Therefore we need to make the effort to quantify this sense of hierarchy. It is worth keeping in mind that there are other examples of efforts to quantify aspects which are hard to describe with numbers.

Sir Ove Arup identified a formula to 'judge the excellence or the efficiency of an architectural solution', which is based on Vitruvius' architectural theory and the triangulation of *utilitas/firmitas/venustas*:

$E = \frac{BC+EC+D}{Cost}$, where BC is what he calls 'Basic Commodity' or, in other words, the requirement of the brief, EC is the 'Excess Commodity', i.e. the desirable features not covered by the brief, and D is the 'Delight', or all the 'intangible forms of 'Commodity' which cannot be measured by a Quantity Surveyor. 'Cost' is the overall effort made to achieve the result. A big difference from Vitruvius' approach is the introduction of an economical parameter, because, as Arup said, 'cost may have nothing to do with the artistic value of the final result, but architecture is not only Art. [...] To me, the skill of an architect and the excellence of an architectural solution is measured by the ratio between what is obtained, and what is expended'. Apart from this very important addition, Arup created a way to quantify the excellence of a building, he didn't just limit his analysis to the understanding of the achievement of excellence by a building. By following Arup's approach, it becomes possible to compare different design options, and understand whether a building is better than another one.

We can say that Arup has defined an objective function, which makes theoretically possible to run an optimisation analysis. Within the terms of 'Basic Commodity' and 'Excess Commodity', I think we can fit all the parameters that can be described and quantified by proper numbers: it can be the level of sustainability, the economical requirements of the client, the parameters describing comfort levels of the occupants and so on. The difficult part is to develop a proper definition of 'Delight' and then to find a way to quantify it.

I think that one of the main issues is distinguishing between what we can quantify and what we cannot. Engineers like to describe things with numbers because in this way it is possible to compare them, to understand whether one option is better than the other. Therefore, once this 'quantifying' process can be adopted, all the decision-making is simple, up to a level that even a machine can handle it! When, on the other hand, we deal with qualitative aspects, establishing what is good or bad becomes more subjective and, in some circumstances, volatile. Maybe we could say that the border between the disciplines of architecture and engineering is the line separating what can be quantified from what is only qualitative. I don't know how 'sealed' the two compartments should be, but I believe that it is important to address the quantitative aspects of a project in a quantitative way and the qualitative ones qualitatively. I think it is a big mistake to try to describe with numbers what cannot be given precise quantities, but also it

would be nonsense to tackle subjectively what can be objectively defined. And for this reason, I believe that a big effort should be made, within the design team, to identify all the areas that can be quantified; in this way, the qualitative skills of the people involved in the project can be focussed on the areas where they can provide the most viable contribution.

Scientific research is constantly widening the field of aspects that can be quantified, and new software tools are developed to run these calculations. For example, at the time when Stirling designed his Faculty of History Building in Cambridge, engineers were able to forecast that the spaces would overheat, but they did not have the tools to say by how much. In this way they could not take a proactive role during the design process because they could not propose definitive solutions, fully backed-up. I am not sure that Stirling would have let his design be modified, but at the time it was not possible to challenge him more deeply. So we can say that the border between the two spheres (quantity and quality) is not rigid and is constantly moving. I strongly believe that architects should not be scared about the expansion of the quantity sphere, but should actually take advantage of it. If something that has always been considered to be a qualitative task is found out to be quantifiable, then it means that it was not carried out properly. And that it was sucking qualitative resources. The more we manage to identify what is actually qualitative, the more effectively we will use our intellectual resources.

What you say about the relationship with what was done in the past is very interesting. It is very important to be aware of previous experiences, and to avoid "re-inventing the wheel". This is not just a way to save time, but also a very good strategy to limit the likelihood of making mistakes. Having said that, it is also important that we don't feel too linked to previous works—and engineers tend to be quite lazy and re-use as much as possible, as the unknown is always scary for people like us who like to be conservative. Before re-using something we have to question it and challenge it, because we need to look also for new opportunities and improvements. But also we have to make sure that the solution adopted previously is applicable to the current situation; it can be 'dangerous' to expect the same effects from the same solution, if the conditions are not adequately similar. In some situations brand new solutions are necessary, but again it is important that we are not proposing something new, just for the sake of being innovative. Finding the right balance between being conservative and taking some risks to innovate is very challenging and requires a lot of care, common sense and knowledge.

So, the big question is: can we quantify everything? Is there a point where we should stop defining objective functions and adopt a more 'instinctive' attitude?

And I also agree that the process should not be restricted to the idea of a competition between beauty and performance. I am not sure that it is possible to consider every aspect of the design within an evolutionary optimisation process, because of obvious limitations of what you can ask a computer to do. I think that we cannot ask optimisation to tell us everything. If we are in a situation where some important aspects of the design cannot be considered correctly during the optimisation process, we will have to apply these criteria separately, I would say after optimisation has discarded the options that cannot be considered satisfactory

for different reasons. In general terms, I think we should ask 'machines' to help us as much as possible, by taking out of the table all the options that are not good enough from the point of view of the criteria that were identified for the optimisation process. In this way, the design team can be fully focused on the areas which can be handled only by *humans*, without being distracted by the presence of options that do not work anyway. And what if, after the optimisation process none of the available options is satisfactory because of the unquantifiable criteria? Well, I think that even in this case optimisation has told us something valuable; we need to re-consider the basics of our design.

Actually, what I have just said shows that I agree with what you said previously: the overall process is indeed an *evolutionary optimisation of choices*. Because the results of the research of the algorithm tell us the rational consequences of our original decisions, when we defined the potential solutions and the fitness function and hence the way we compared different options. If we look at this from a different perspective, we could say that the results of the optimisation procedure are a feedback of our choices. We may find out that we are going towards the right direction, or that we are getting stuck in a cul-de-sac. In both cases, we—the design team—will have it clear whether it is the case to change direction completely or to develop the design within the same frame. Therefore, we can say that choices are evolving during the process towards an optimum.

What you said runs like clockwork. But I don't understand what is this apparently very clear distinction between quantitative and qualitative aspects. At least because what we appreciate in a qualitative way is made out of quantity, what is enjoyed it is not perceived as vaguely positive but it is indeed measured and estimated.

For this reason honestly I don't understand what the use of Arup's formula is, if we can't quantify Delight? The utilitas/firmitas/venustas triangle makes sense only with an extremely schematic approach to architectural artefacts, but I don't think it might help us to define the objective function, all the more because I totally ignore how to balance the three components; do they have the same weight?

Personally I wouldn't say so. For me Basic Commodity and Excess Commodity are functional to Delight.

Anyway, the real problem is the quantification of Delight. There must be a way to estimate the purpose of the design, the degree of its fulfilment, the work that's been done and the way it is perceived.

I don't understand why you make such a sharp distinction. I believe that behind every quantitative aspect there's a qualitative feature that gives a meaning to it. Behind the physical data of heat transfer, solar gains, daylighting and air movement we find values related to our perception, that's definitely qualitative.

In Arup's formula, Cost is undoubtedly the only quantitative term, but we aren't just talking about a vague economic cost. In its definition are included the costs of resources, time, materials, production, the energy used for the construction, the energy that will be consumed by the users and, finally, disposal.

The Time of Success

I think also that the time criterion is lacking a bit in Arup's theory. Let me try to explain what I mean with a quick example. Let's assume the theoretical scenario of two buildings that are perfectly equivalent in terms of levels of basic commodity, excessive commodity and delight (for the time being let's forget that we don't know yet how to quantify 'delight'). Hence the numerator of the 'formula for excellence' is the same for building A and building B. But building A has been designed and built in a way that will not allow it to survive for more than 30 years. This can be due to the fact that it is built with cheaper, non-lasting materials, or because its design is quite rigid and cannot cope with the cultural and fashion changes that are definitely going to happen. On the other hand, building B will survive several generations, potentially 200 years, thanks to its flexible design allowing for some adjustments to be carried out during its lifespan, which will make it deliver commodity and delight for a long period of time. We can reasonably assume that designing and erecting building B will require more effort and hence a higher cost. This means that the denominator of the formula will be higher in the case of building B. Therefore, the level of 'excellence' measured by the formula will be higher for building A. Is this fair?

Well, I guess it depends on the perspective we are using to quantify the qualities of buildings. If we put ourselves in the shoes of a developer, whose interest is to achieve a return on the investment as high as possible and in the shortest period of time, then building A is definitely better than building B, and sir Ove's formula is satisfactory. But, if we adopt a longer term perspective, we can't ignore the fact that building B provides commodity and delight for a considerably longer time, with no need for dismantling and re-building. Because if six buildings A are needed to provide the equivalent commodity and delight of one building B in 200 years, then the overall cost of building A will be massively higher than the one needed for building B. Which, then, makes building B dramatically more successful. I think this could start an interesting discussion about what perspective we should assume; probably thinking long-term is more interesting and for sure it's more sustainable. At the same time, the short-term perspective is the dominant one, and the one that is much more likely to be adopted for the design of a building. I must say that I'm not sure this will still be true in a few years time when, potentially, our economic model will be different after the big crisis we're in and sustainability requirements will probably be driving more and more our decisions. Anyway, I don't think this is the right place to have this sort of discussion. What I think it's important to state is that, when we evaluate a building, we need to define the criteria we are to consider and the time-perspective we want to adopt. Depending on this, we'll define the most relevant objective function. I think that we can say that the necessity of identifying the objective function for our design process we want to carry out helps us avoiding confusion about what we are actually looking for. From this point of view, optimisation can be quite a crude methodology because it doesn't leave any space for bluff or politics. Everybody within the design team has to be fully aware of the

direction the project needs to go. And this is another reason why everybody has to be equally part of the process, with no gaps.

The concept of duration has been integral to architecture from its origins.

In the past people didn't dare to waste materials and resources to build something that wouldn't last as long as possible.

Today things are different; our feelings towards duration have changed. It seems that we have developed an aversion towards what lasts too long. Never as in our times the view of whole cities and monuments razed in disaster movies has been welcomed with such pleasure by the audience. We live in the faith that our ability to create is proportional to our ability to destroy. And we enjoy seeing buildings falling apart, because we can't accept the idea that they look always the same and that they survive longer than us, without having a specific right for it.

But this way we risk to interpret duration too literally. I'm not saying that buildings should remain the same forever, as faces mummified by plastic surgery. If a building has the luck to escape demolition, it can adapt to different uses, finding new configurations and a new life. These overlapping designs have always produced unexpected and extraordinary results. For centuries buildings have fed other buildings with their stones and more importantly with their concepts, inspiring people to design completely new buildings.

The capability of surviving is not an accident, it is often a programme, and this is true for every type of building. Let's think about the system of favelas, which are intelligent organisms, where houses are conceived in such a way they'll support future extensions above them. But this concept isn't viable only in the case of limited economic opportunities.

A Rocinha, Rio de Janeiro, credit: Philip Holzborn

A Rocinha, Rio de Janeiro, multilayering

During the construction boom, that started after World War II and coincided with the period of highest affluence of the Western world, the construction industry was driven by speculation at the expense of soil and artefacts, and durability had become an unnecessary value. In a time of such wealth, to produce something that would last was considered criminally stupid.

Probably today, from an economic, ecological and energy sustainable point of view, it would make sense to produce buildings that last and adapt over time. Nowadays the long-term design should be welcomed again.

As you said, the cost must be balanced with durability. A durable building is expensive, that's for sure, but no more than an ephemeral construction built to impress and temporarily entertain us.

The same could be applied to ideas and their duration. In a design there are immaterial features that survive and reappear in new buildings, ideas that can be reused because they haven't exhausted their efficiency, as opposed to disposable ideas with their countdown durability.

Deeper to the Surface

I think that it would be good to zoom in a little bit and focus our discussion on the building envelope, just to help our thoughts. And, as one of the main elements of building envelopes, let's focus on the window. How would you say that a window is successful? What do we want to ask windows?

In my experience, windows are often seen as a source of problems in terms of energy performance, and it has happened quite a few times to deal with the question: 'what could we do to balance the presence of this window'? I think this is quite a depressing question to be asked, and also to ask. The unfortunate answer to this is usually an estimate of square metres of PVs or a rough number of wind turbines to instal in a hidden place, where they will not disturb the view of this exciting façade… Why should we design windows that lead to problems? I think it should be the other way round: 'we might have a problem here, let's insert a window and solve it'. So, probably the definition of a successful window is exactly this: a positive window, a source of high performance—where the term performance comprises both functional and spatial perspectives.

The first design decision when dealing with windows is the definition of their size and their location, but let's assume that this has already been done correctly: I would like to focus on the window itself now.

If we go back to Ove Arup's definition for the objective function of a successful building, I guess we can use the same approach for a window.

The level of 'basic commodity' could be the amount of energy performance it provides: daylighting, beneficial solar gains during winter will be on the positive side, glare, excessive solar gains and heat losses on the negative. These aspects are quite nicely summarised in the energy rating for windows described in some standards.

The "excess commodity" is the additional energy benefit that can be delivered by a window, and this can be compared to what would happen if, in its place, there was an insulated, opaque element. An operable window can provide great advantages, because it allows fresh air when this is required. This seems obvious and not worth mentioning, but is it really the case? We are surrounded by fully sealed buildings which suffer of overheating issues during the majority of time and therefore require intensive use of cooling. I find it incredible that we have all these office buildings where the cooling system is on for almost the whole year and it could be possible to reduce a lot the energy consumption just by opening the windows when it is needed. There is quite a lot of research going on that aims at finding solutions where the insulation properties of materials can change depending on the conditions. The rationale of it is that, when the external air is cooler than the interior but solar radiation and internal gains—people, computer, artificial lighting—tend to heat up the space, having an envelope dissipating more heat is beneficial. But wouldn't it be much simpler just to circulate some fresh air from the outside?

Moreover, people would have the opportunity to control their own environment and to connect with the external world, which has been demonstrated to be very beneficial in terms of overall comfort—not just thermal but also psychological. This can be taken into account also as part of what Arup described as 'delight'.

For the last term of the equation—'cost'—there is little to say: it is sufficient to consider the actual cost of the properly designed window. If our window is helping reducing problems, then the savings due to its beneficial presence can be well accounted also here.

Future Window

I hope that in the future the window will regain its importance as architectural element and maybe, if we require from it more than we do now, we'll be able to elevate it from its current condition of mere functionality.

Windows are architectures in miniature. Once they were even represented as buildings, with columns, capitals, tympanum, etc.

We've said before that the window, being part of the façade, is the element that more than others represents the building and its degree of contemporaneity. The window of the future is the window that I hope and want to design here in the present. I don't care how architecture will develop in the future; I'm in no hurry to discover it. But the windows we are designing right now should be already the windows of the future.

The window is the contact surface between internal and external environment, the threshold between two entities, where space is compressed, that's why I would define the window a 'concentrate of space'. I like to think of it not as a mere passage (of light, air, view), but rather as a place. After all, the majority of people spend most of their life next to a window.

I imagine some kind of inhabited window.

I figure it as a space device, a miniaturized architecture, a spatial unit that might offer the chance to change the interaction with the outside world and the configuration of the interior: the threshold as a place in which to dwell.

How can we get this? When I say that we should ask more to the windows, I mean that we can ask for elaborate spatial requirements that go to characterise them. Apart from the usual requirements, windows could offer the opportunity of regulate filters and obscure daylight, as well as cut the view out with a wide range of configurations.

Moreover, we could consider a window not as a prerequisite but as an option, and make it a device that we can use when we want. There is no reason to always have a glass aperture, at night for instance—when the clarity of the window has no positive impact—it doesn't bring any light, provokes heat loss and as its inhabitants are sleeping it doesn't even provide them a view to the exterior. I imagine a window that can be filled when needed, and become thermally homogeneous with the rest of the wall. We can decide to keep the window closed and to light up the space artificially. In this way the energy consumption for the artificial lighting will be probably compensated by the savings due to the improved insulation.

Andrea Faraguna, Future Façade, 2012

From a technical point of view, the way the device, as a whole, is integrated in the design becomes more important than the way its single components are assembled.

The window has little meaning in itself, it can be considered as a generic element or it can contribute to the definition of space. It can be a hole—even if it covers the entire façade as a translucent skin—or become a place in which to spend time. It can be silent or speak; it can be neutral or trigger a reaction, an activity.

I don't know how the window of the future will look like (in terms of shape), but I think that it will be more performing and will answer to many more questions than it does now. I can imagine, for instance, a window that moves, in order to increase its power in space rather than to fulfil a specific function. I'm not talking about gadgets and performing metamorphosis, but of different postures, such as those of a body; instead of a simple protective garment architecture becomes a second body, an augmented and strengthened body.

But if we want to imagine a performing architecture, we need to consider its use in advance. If we design a space that offers an experience, there must be someone who knows how to take advantage of it. For this to happen, we have to trust the user. Hence we can give him more responsibility and freedom in order to let him own and control the space he lives.

Today we expect a lot from public spaces—be they dedicated to sports, shopping or entertainment—but we tend to forget how to inhabit more private spaces, or maybe we haven't even learnt it yet. When we buy a car we are supposed to know how to drive it, likewise when we enter an architecture we need to know how to occupy it. We should remember that inhabiting a place is an art, the art of using buildings. This is an art to learn; it used to be taught, to be part of the cultural background of everybody. Today, if someone lives in a nice house, we say that he/she has good taste. Such an essential aspect of living is considered to be related to DNA, it is considered to be a contingent factor related to lifestyle!

Delight is not an independent variable. The way we enjoy something is related to how we use it. Architecture shouldn't be a mere container of people and things, but rather a tool at the service of its occupants. And this is precisely the task of architecture, to suggest a way of living in the widest and deepest sense.

The wat we dwell is the way we design. The crisis of design is the crisis of dwelling.

What you said is definitely spot on!

I would like to add something about the importance of the occupants and of the way they use buildings, and in particular windows.

One aspect that is very hard to consider during the design of buildings is the prediction of how people will live the space, how comfortable they will feel and what they will do to improve their conditions. One of the reasons why sealed buildings are around is that in this way the people-variable can be disregarded at least in terms of ventilation and air exchanges; in this way designers are sure that 'careless' occupants don't spoil their very accurate assumptions.

But it is also widely recognised that an adequate use of buildings can lead to dramatic energy savings, and one significant example could be the use of operable windows. Apart from what I mentioned earlier—opening windows at the right time can limit the issue of overheating—it is worth mentioning that in naturally ventilated buildings it is possible to keep higher air temperatures during summer, which can reduce the cooling energy demand substantially. This is because people will relate their perception of comfort with the external conditions and therefore will be happy to accept higher air temperatures if outside it is very hot.

Our windows can become over performing—i.e. their excess commodity level can rise—as long as they are used properly. But what can we do, as designers, to make this possible? I have heard that there are attempts to drive the actions of occupants with some alerts or alarms but without limiting their ultimate freedom to do whatever they want. This is a way of introducing the Nudge Theory within the design of buildings; by means of more or less direct suggestions, we can influence the actions of people without limiting their freedom of choosing what to do.

Chapter 4
An Example

A House in Berlin

I'd like to tell you about a project I'm working on at the moment, an urban villa in Berlin.

I've been working on it for a while, some works have already started, but I'd like to use it as a pretext for our discussion and a chance to understand how it could have been designed in a different manner assuming that you would have given your contribution from the beginning.

The clients have bought a 1,000 m^2 site in a working-class neighbourhood, north of the city centre, just across the Ring.

The site is a long, narrow rectangle (15 by 67 m), which breaks the continuous façade of a typical Berlin block. The street front is not built and the property looks like an empty slot between two buildings. At the centre of the site there are two simple brick buildings, 20 m apart from each other: the first, smaller, one floor, measures 6 m by 12, the second, two floors, is 8 m wide and 12 m long.

The owners, who are both artists, want a house with large and simple spaces that can be used in a flexible way, so that they can be living and working spaces at the same time. They have clear ideas on how to organise the property: they want to leave the front on the street empty, keep the two existing buildings and add a new one, taller, between them.

The new building must have a large window on the façade. The two existing structures must be reconfigured: they will be used as working areas, as atelier, for this reason the windows must be positioned at least 3 m high from the floor.

These are the requests.

If I had to define the design in a nutshell I would say the theme is a single family home transplanted in a high-density urban site.

In my opinion, the most interesting thing is that the owners don't want to recompose the block front, a decision that somehow goes against what is suggested by the city plan of Berlin. This is the key choice and, in my opinion, the prime idea of the design. So, in this case, the initial idea has already been expressed by the client.

G. Zemella and A. Faraguna, *Evolutionary Optimisation of Façade Design*,
DOI: 10.1007/978-1-4471-5652-9_4, © Springer-Verlag London 2014

Now let me tell you how I started working on the project, which were the most important aspects and what they lead to.

Haus M, axonometric view of the site

I decided to take the model of the courtyard house and to adapt it to the shape of the site. So I tried to break up an ideal (floor-) plan into its constitutive elements and to arrange them along a straight line, in a sequence of spaces that unroll one after the other.

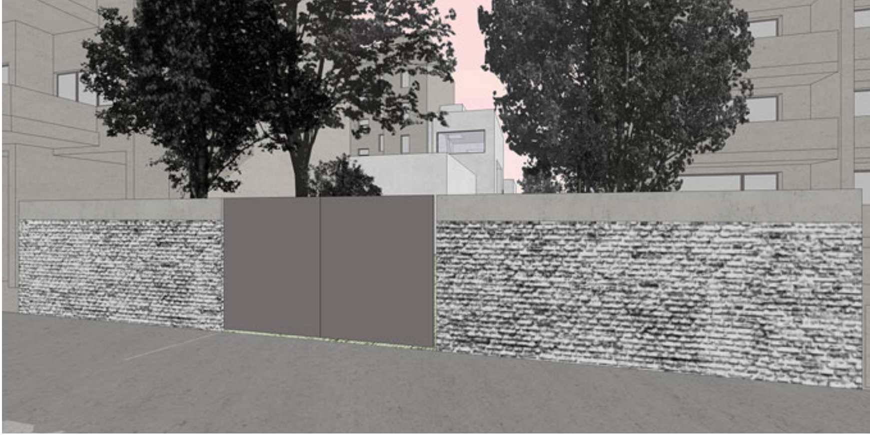
The site begins with the space that must remain empty, next to the street: I thought that the best thing to do to fill a perfectly square space with the minimum effort was to draw a circle in it: so I placed the courtyard at the entrance. From there four connected volumetric units follow one after the other.

One fundamental thing that I need to say is that the clients have decided to subdivide the construction in different phases, so that the investment can be diluted in time. Therefore it is important that during the different phases, the part of the house that has been erected is fully functional and can be used autonomously. The first part to complete is the existing structure at the back of the site: this will be the actual core of the house, the first settlement. This first volume will comprise a large working area, a kitchen, a bathroom, two bedrooms and a utility room. The second step will be about renovating the second existing structure on the site: it will be a big room to be used as an atelier with minimum furniture, just a small bathroom and a mobile kitchen (an island on wheels).

Haus M, axonometric view of the project

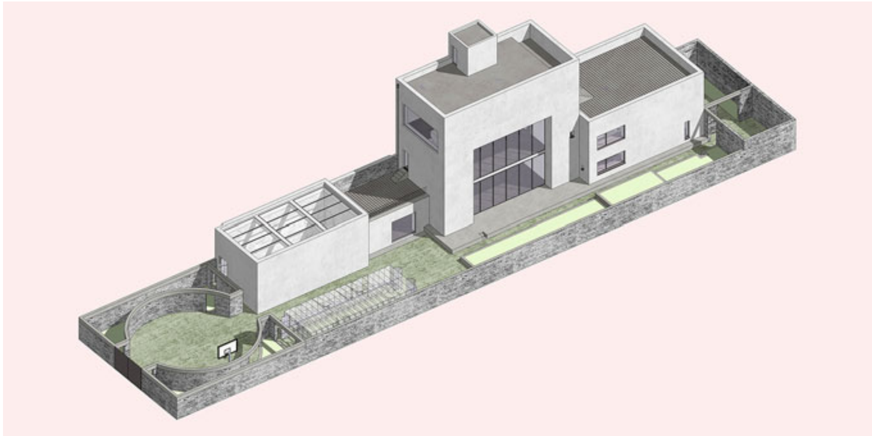
The third intervention is the construction of the *Neubau*, which will connect the two units realised previously. In it there will be the relocation of the bedrooms and a multi-usage living room at ground floor, in the centre of the system and open towards the garden. The last phase is about the finalisation of the remaining parts, with the erection of a structure protecting the cars, a sort of garage/green house, and the organisation of the garden.

Once the project will be finished, the house will keep working by following the construction sequence: the entrance will be in the building at the back of the site.

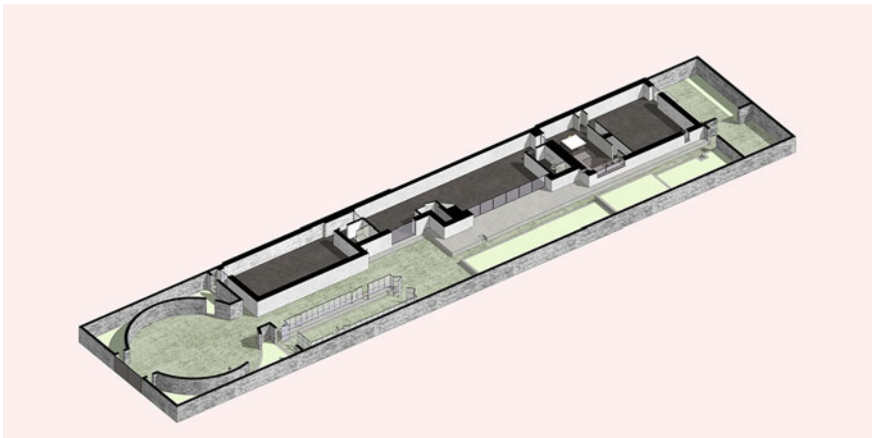


Haus M, view from the street

From the street, once you pass the gate and reach the circle shaped courtyard, to enter the house you have to cross the site in its entire length, until you reach a threshold that leads to a patio. There you find the real front door. Once inside, the sequence of spaces, lined up one after the other, brings you back to the courtyard.



Haus M, axonometric view



Haus M, cross section of the ground floor

In the end the house looks like a low cylinder and four blocks of different heights lined up in a row. The new part of the building connects on several levels the two existing structures, integrating them into a new configuration of space. But at the same time the two brick blocks are conceived in order to be used as independent units in case of need.

From the gate on the street one can see the threshold of the entrance patio.

Similarly from the front door at the bottom of the site a visual trajectory crosses the house to reach the glass door at the opposite end (one of the few exceptions to the rule of the windows over 3 m).

What a strange project. I find the shape of the site and the completely different way of occupying the space (compared to the adjacent buildings) the most intriguing aspects of the project. In what you said, I think that the two key words for me are 'transplant' (referred to the detached house in a high-density neighbourhood) and 'adapt', which refers to the concept of a court-house within a site of such geometry. For this reason I would like to focus our attention on the way the project relates to the surrounding buildings and to the relationships between the different units of the project.

Are there common characters in the other buildings of the neighbourhood? If this is the case I think it's very important to decide whether these characters should be present in this project or not. Are there other ways this building should 'communicate' with the adjacent ones? Or should we express a complete isolation? This could influence, for example, position, geometry and typology of the windows.

It seems to me that the character of this design is from the start in clear opposition to its surrounding, i.e. 5- or 6-storey apartment buildings with the fronts aligned side by side on the street and an empty space at the back, the *Hof*.

When I saw the site I was immediately fascinated by this strange situation, and I said I was willing to give it a form. So I accepted the challenge of re-evaluating this long and narrow void, an interstitial space between two high blind walls. Starting from this theme I tried to answer as directly as possible the requests and needs of the site.

I must confess that I've always been fascinated by the *Brandschutzwände*—the fire walls that divide adjacent buildings and become visible when a part of the block is missing. They mean a lot to me (I am fond of them), because they are typical of Berlin. Once you could see them almost everywhere, but first with the reconstruction and now with this mania of filling every vacant space of the city, they are becoming a rarity. I've always wanted to use them in a design and finally I was given the chance to do it.

How could I make the most of these blind walls 22 m high?

The most reasonable answer seemed to consider them as part of the property. In my view they should act as a dumb backstage protecting private spaces. In this way these walls don't define an available space, but rather a landscape within which the house has to settle in a clever way.

Rules

I want to try to explain to you the rationale that I followed in the definition of the design.

In the composition of interior and exterior spaces, I tried to balance positive and negative elements (solid and empty volumes), connecting each unit to the next one.

I tried to give a different character to each part, for example following a different principle for the openings of each building.

The matrix of the design is the right angle: I decided to apply it to the whole site, trying to include every element into the geometric pattern.

This was a way to transform the weakness of the two brick blocks, dominated by tall adjacent buildings, treating them as solid volumes. In my mind the house is one and the same with the site as a whole: some parts are complete, other are without walls and roof and other have a garden as floor.

The following issue was to combine the different elements in a system while maintaining their character and identity. So I decided to give the single units a highly symmetrical imprint and then to alter their individual regularity through their connections. So the rooms are very simple spaces, while the doors and the windows are aligned with the bisectors.

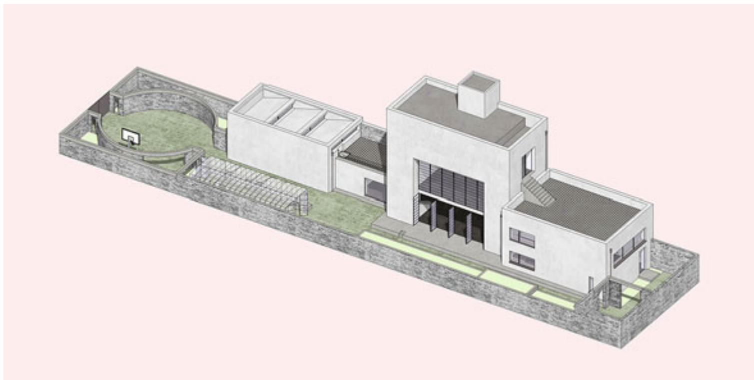
As you may have realised despite my convoluted explanation, it's a very simple and low-profile design. That's why I think it suits our conversation: we can use it as an example to confirm or disprove what we've said in the previous chapters.

At a first glance, I think that, in terms of performance, the aspects we need to look at are mainly three: heat losses, risk of overheating and good distribution of daylight. The trickiest spaces are the new building, with the huge glazed façade, and the small existing unit, with the fully glazed roof. Even if these elements are made out of triple-glazed units, their thermal transmittance will be considerably worse than the one of a properly insulated wall or roof, which will result in significant heat losses: it will be important to check that adequate internal conditions can be provided during the harsh and long Berliner winter, without the need for too high energy consumption (and hence carbon emissions). This is particularly true for the rooflight: when glazed units are in an inclined/horizontal position, their thermal performance is significantly poorer than for the normal, vertical position, because of the increase in convective heat transfer within the cavities. Moreover, both glazed surfaces are exposed to high rates of solar radiation: this will definitely be beneficial during the heating season, but it could cause some issues of overheating during summer. A proper strategy for effective natural ventilation should be implemented, in order to avoid this risk: this can be made by introducing opening vents of the right size and in the right position. Finally, I think that we need to think about how the atelier in the existing building next to the entrance is lit. Considering the use of this space, it is important to get this aspect right: for sure we want to provide the environment with daylight, but this has to be well distributed, and it doesn't have to generate glare or too strong reflections on the artworks. In this kind of spaces, daylight should be diffuse, in order to avoid too much contrast between the different areas of the atelier: this can be done either by introducing translucent films in the glass, or by orientating the rooflight towards north. I'm not sure if this is possible, but wouldn't it be interesting to establish a

little ‘visual path’ through which it is possible to see the interior of the atelier from the west-facing window of the tall building? If we want to do so, we’ll have to balance this aspiration with the other aspects I mentioned earlier.

Haus M, vertical section view

The Glazed Wall of the Atelier and the New Building



Haus M, axonometric view with the Crittal window

Haus M, zoom of the Crittal window

Let's talk about the atelier.

This room will be a work place and for this reason it needs to be considered as a tool, rather than simply as a space. It will be to all intents and purposes a work tool and its walls will be the 'workbench' of the client.

What performance shall we require? A special treatment of light, maybe. Shall we need a diffuse light with the same intensity everywhere or is it better to have a source with changes of intensity? The work surface has to be as wide as possible, smooth, continuous and without interruptions, holes or protrusions.

To get a diffused light using just the position of the windows we should orient them to the north but this seems difficult, as the north wall borders with the outside property.

Or maybe we could design a fully glazed roof, a huge skylight that could be screened by a velarium, a curtain on a movable structure. In this case we would have the widest choice of lighting, but the costs would be very high, not to mention the snow issue.

At the opposite extreme, the most economical solution would be a flat roof and two rows of long horizontal windows in the upper part of the two short walls. Sure, it's not the most refined lighting scheme and it doesn't solve the problem of the direct light, but maybe we could improve it with an adequate configuration of the space.

Another possible scheme could be a saw-toothed roof with vertical glazed units oriented towards east. This is a typical solution for industrial buildings and workplaces, but we should verify if it's the best answer to our specific design.

I understand the difficulties of introducing openings in the roof, even if I like the 'industrial' option of having vertical glazed units inserted within the saw-tooth profile of the roof: if the geometry of the roof was adequately shaped, it would be possible to have a very good distribution of light, thanks to the reflections on the inclined surface of the roof next to the windows.

Another way to limit the access of direct light is to make the windows leaning outwards along the south elevation and facing north along the west orientation. I know this breaks the rule of having only right angles along the elevations, but it could be an elegant solution to our design. Depending on how much we accept to incline the windows, we could decide to let in direct light only during specific moments of the year or of the day, hence creating a sort of light-calendar.

If we decided to go for the easiest solution of a ribbon window, we would have to find clever ways to distribute the light properly. For example, we could think of a system of lightshelves at the bottom of the windows, which re-direct the light towards the ceiling. And this effect could be improved by shaping the ceiling as a vault. Moreover, the lightshelves could integrate a rail system where the artworks can be hung and moved.

I also have doubts about the glass wall of the new part, it seems to me the weakest point of the project. The solution I've sketched does not convince me, because it's just a literal answer to the client's request. We need to find something better.

The theme of the sill seems very important to me. Such a big 'window' should have a sill with a depth proportional to its width. But it doesn't have to be just huge, a magnified window. Such a big scale requires an adequate complexity of the details and the moulding.

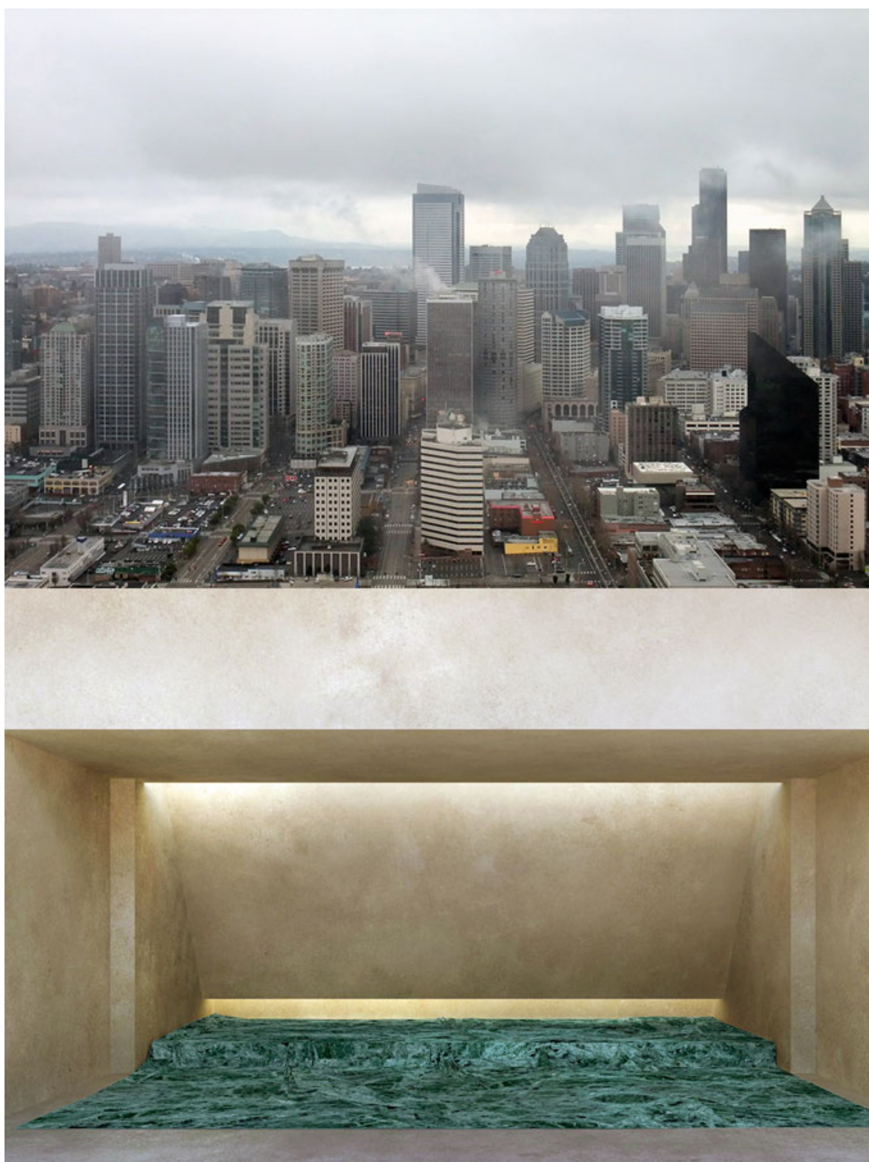
A way to increase the depth of the sill could be to provide the window with more gadgets, for example two sliding curtains to get two different shading effects, a set of moving panels or shutters to get a total blackout, or a system of side ventilation, etc.

This could be a way not only to have a deeper sill, but to make the window special, a sort of hyper-performing window. Anyway, it would be better to find a solution that has more to do with engineering and architecture than with building services. Something that isn't just an addition but rather the answer to the question: what do we expect from a special window?

Once I designed the mock-up of an architectural item to be sold on large scale, as it could be used in various contexts. I drew a space, which was a big sill, the anticipation of a window was repeated by means of a sequence of frames—as if it was the inside of a camera lens—at the end of which there was no window, but a wall. I called it *No View*.

There was no window and the view was obstructed. A mechanism allowed to slide the wall and open the space towards the outside, that obviously was to be a breathtaking view. Hence, in special occasions—say ten times a year—the view, normally obstructed, becomes the main character of the space. This is what distinguishes luxury from comfort, when you can transform something you have is a exceptional event.

Andrea Faraguna, No View, Tokyo, 2012



Andrea Faraguna, No View, Seattle, 2012

I would like the window of this house to be more than just an ordinary device that provides a view of the outside. I would like it to be a key space for the project, an active, unusual space. These details are the main character of the project that has to be a light but also uncanny anomaly of the neighbourhood.

I know that the choice of the glazed surface is a problem in terms of energy saving, but it's a specific request of the clients. They want the new building to have a large glass wall. My first attempt is the most immediate answer. Of course it could conceive it in a different way, with a different geometry, or I could separate the glass panels with wider mullions and transoms.

Or maybe we should consider the solution of a double skin façade, adding a second glass wall to the one on the front. The space between the two skins could be used in several ways, a new area of the house, with an intermediate temperature between the interior and exterior. I don't know if it's a good choice in terms of energy efficiency, but for sure the construction costs would grow considerably, and the cleaning would become demanding! But in terms of space I think it might be nice to have a veranda—a place which is neither inside nor outside—on the ground floor in addition to the large space in the centre of the house and a wintergarten for the children on the first floor, to be used throughout the year.

As far as ventilation is concerned, we could take advantage of the double height of the new building, setting up a ventilation chimney that then ramifies to the ground floor.

I am not a big fan of the double skin façade option. First of all I think it is a design that does not fit in residential projects: when you open a window you want to feel the contact with the external air, and not with the cavity/winter garden.

But also, the conditions in the space between the two skins will be uncomfortable for a large amount of time: in winter it will be often too cold and in summer too hot. Moreover, when the external air temperature is cold during winter and the windows in the internal skin are open, condensation will be likely to form on the outer skin of glass, and this is not nice.

I guess that it would be possible to interpret the big window in other ways; for example we could add a dimension by pushing the window either outwards or inwards, i.e. by having a bow-window or its opposite. In this way the window would create a space that people would be able to occupy and live, and there would be additional view perspectives.

But I think that a composed window is the most interesting way of interpreting this huge glazed element. Apart from the great appearance, this solution would allow to relate the proportions of this window with the other openings of the project, thanks to the fact that this window would become a composition of smaller windows. It would also be possible to introduce different strategies of openings, with a combination of full-height operable units at the ground floor and smaller elements at the first floor. I know that the introduction of all this framing is not ideal in terms of U-value, but with proper thermal-brakes in the frames this issue can be considerably mitigated. And I believe that the benefits due to the effective ventilation strategy that can be implemented will overcome the downsides of the higher U-value.

I also like the idea of the composed window—I guess you mean what is generally called 'Crittal'—because it offers more opportunities for the design of the façade. It alters the system of proportions by decomposing a window in smaller units and allows to play with these changes of scale. I'm a bit worried about the energy performance of such a system with all these frames, which are the weak part of windows.

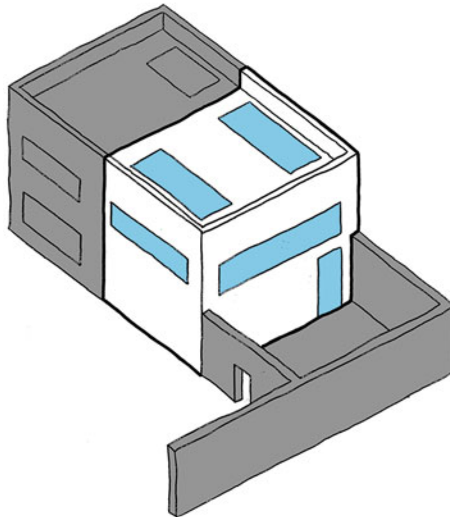
The Window Scheme of the Studio

We are already renovating the existing structure on the opposite side of the entrance, so the solutions you see in the drawings are about to be completed: we have already reconfigured the openings, purchased the windows, etc.

Nevertheless I'm curious to know what we could have done, had we used the optimisation technique from the start. Does the chosen window scheme correspond with the optimal solution in terms of energy and performance?

The arrangement you see in the drawings divides the inner space into two parts: towards the entrance there's a large double height room, that will be used as a studio, the remaining space is occupied by the kitchen on the ground floor and a bedroom on the first floor. The windows of these three spaces are aligned with the doors and, in principle, have the maximum height and width allowed.

Let's focus on the studio. In theory, openings could be located on both south-east or south-west orientations and on the roof of the studio, as shown in the image below.



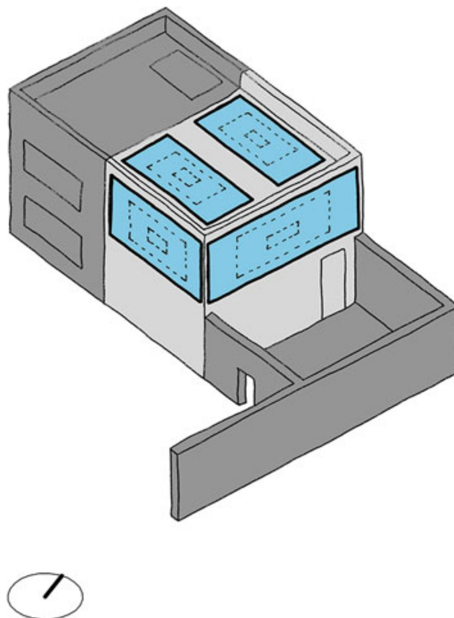
Window scheme of the studio

Since this room is an artist's studio, it is important to provide adequate levels of daylighting. At the same time, considering the climatic conditions in Berlin, heat losses through the envelope (façade and roof) should be minimised in order to limit the energy consumption for heating.

We want to explore the opportunities of varying windows and rooflights (all of them to be triple-glazed) and optimise their location and dimensions. The higher the amount of glass, the more daylighting will be available within the studio, but also the higher the heat losses. The optimisation process will have to identify the optimum balance between these two contradictory criteria. We will run a multi-objective optimisation, and the two objective functions we will consider are: the average illuminance along the space and the annual heating energy demand of the room. Our optimisation process will find the options representing the best compromise between maximising the level of illuminance and minimising the demand for heating.

The following variables can be considered:

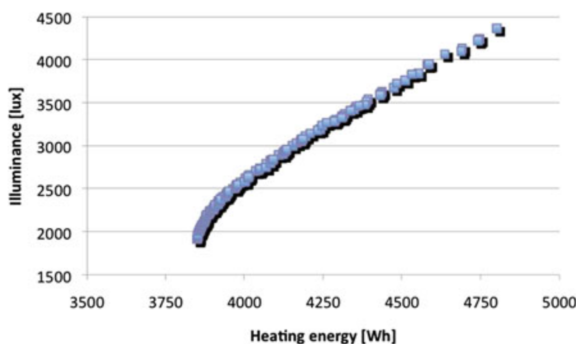
- The area of the window on the south-east elevation: this has been varied between 0 and 27 m^2, along 17 different values;
- The area of the window on the south-west elevation: this has been varied between 0 and 23 m^2, along 17 different values;
- The area of the rooflight closer to the north side of the roof: this has been varied between 0 and 8.7 m^2, along 6 different values;
- The area of the rooflight closer to the south side of the roof: this has been varied between 0 and 8.7 m^2, along 6 different values.



Window scheme of the studio

This means that there are 10,404 different potential options. A genetic algorithm has been used to identify the optimum options—i.e. the ones lying on the Pareto front—within a reasonable amount of time. The values of the two fitness functions have been calculated with the software tool EnergyPlus.

The image below shows the Pareto front of the considered set of options.



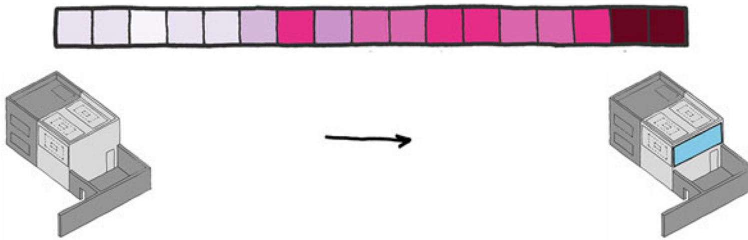
Studio windows, Pareto front

The Pareto front is made out of 113 different options, among which we need to identify the one that we consider the most appropriate, also considering other aspects. As we expected, in general options providing high levels of illuminance correspond also to high heating energy demand. Local building regulations may set clear limitations in terms of the maximum amount of heating energy consumption: this will limit the extent of the Pareto front.

But let's have a look at the relationship between performance and typology of the envelope. It is very important to understand whether some window or rooflight sizes should be completely excluded or not, or whether there are some levels of the different parameters that are considerably more present than others.

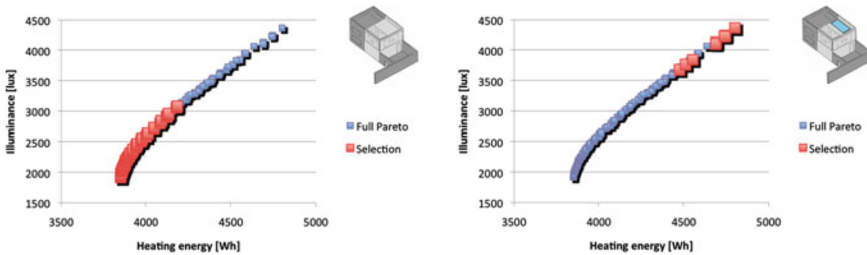
South-East Window

Within the Pareto front, there are solutions with all the values of the area of the south-east window, which means that we, as designers, are quite free of exploring different sizes and adjust its dimensions to suit the proportions of this elevation. We should also bear in mind that there are more optimum solutions for large window on this orientation. This is shown in the image below.



South-east window, size scheme

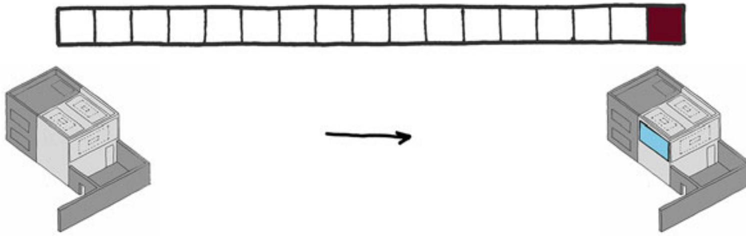
The image on the left shows the optimum solutions corresponding to the case when there is no window on the south-east elevation: they all correspond to the minimum heating energy consumption, but also to low levels of illuminance in the studio. On the other hand, when we consider the maximum considered size of the window for this elevation—image on the right—we can see that there are some options on the top-right extreme of the Pareto front (i.e. high illuminance but also high heating energy), but the majority of them correspond to an intermediate balance between the two criteria.



South-east window, Pareto front

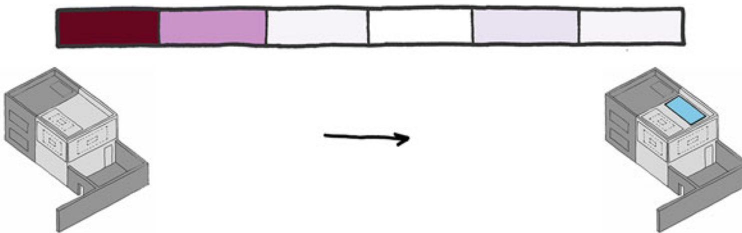
South-West Window

In this case the optimisation process provides a very clear indication: all the options within the Pareto front correspond to the case with maximum area of the window on the south-west elevation. Therefore this parameter should be considered fixed and the design cannot really play with this.



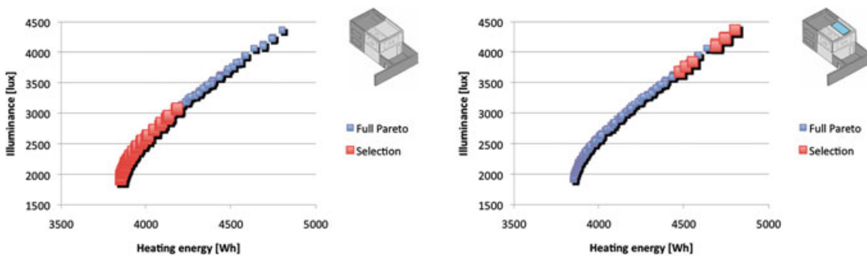
South-west window, size scheme

North Rooflight
All the considered sizes of the north rooflight are present along the Pareto front, meaning that there is some room for adjusting its dimensions considering other design aspects. However results show that there are much more optimum solutions when this rooflight is not in place.



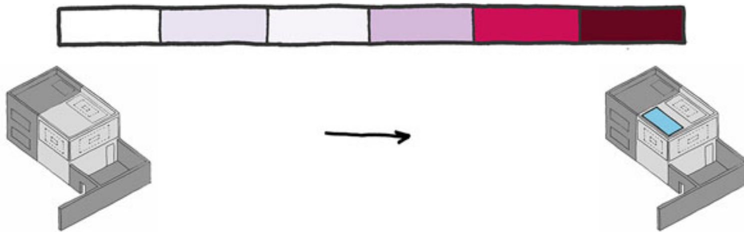
North rooflight, size scheme

The image on the left shows the optimum options when the north rooflight is not in place: these options cover all the lower left part of the Pareto front, corresponding to solutions where both heating demand and illuminance levels are low. Exactly the opposite is verified when the maximum size of the rooflight is considered (image on the right).



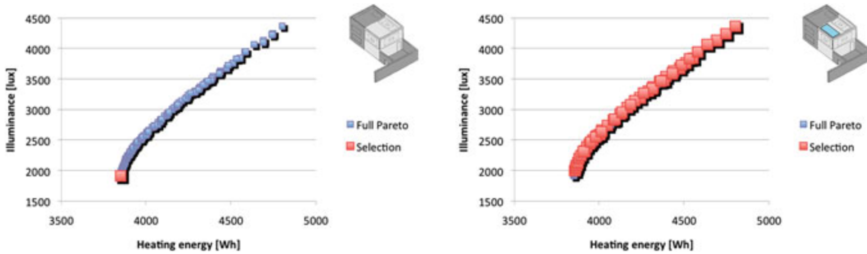
North rooflight, Pareto front

South Rooflight
Also for the south rooflight it is possible to have all the considered dimensions, but there is a significant predominance of solutions where this rooflight has the maximum dimension: actually, there is only one optimum solution where this rooflight is not in place.



South rooflight, size scheme

When the south rooflight has the maximum considered area, the whole spectrum of the Pareto front is covered.



South rooflight, Pareto front

From the results presented we can conclude that, apart from the south-west window, all variables are relatively free, therefore a wide spectrum of potential options can be considered.

Very good: this means that I got it wrong!

The decision of positioning the biggest window on the south-east façade was due to the need of characterising the wall and the small courtyard, acting as the entrance to the house. I understand the solution suggested by the optimisation process, though: if I had had these data earlier on, I would have prioritised the bigger window and positioned it on the south-west side, and then I would have thought of ways to add the other windows of the kitchen and of the bedroom. Having all the windows on the same wall saturates that wall in comparison to the

others and this imbalance has to be considered in the design of the façade. We should also consider that the south-west wall sits at the edge of the site, where there are currently many little trees, generating a green wall obstructing the light, but I guess this is a problem that can be solved.

The aim of this exercise wasn't to prove you wrong or to provide definitive solutions. I just wanted to put on the table some elements that could have been addressed successfully in the perspective of an integrated design. Let's move to a different part of the project.

The Studio Window

I wish the studio window could let in as much light as possible, maybe by means of extensions or reflective screens or lightshelves.

The glass of the window can be reached only with the help of a ladder, this means that cleaning will be very laborious. We must solve this problem. But instead of considering it a nuisance, I would use it as a chance to qualify the design. We need to find a way to reach quite comfortably the glass in all its width, without obstructing the passage of sunlight.

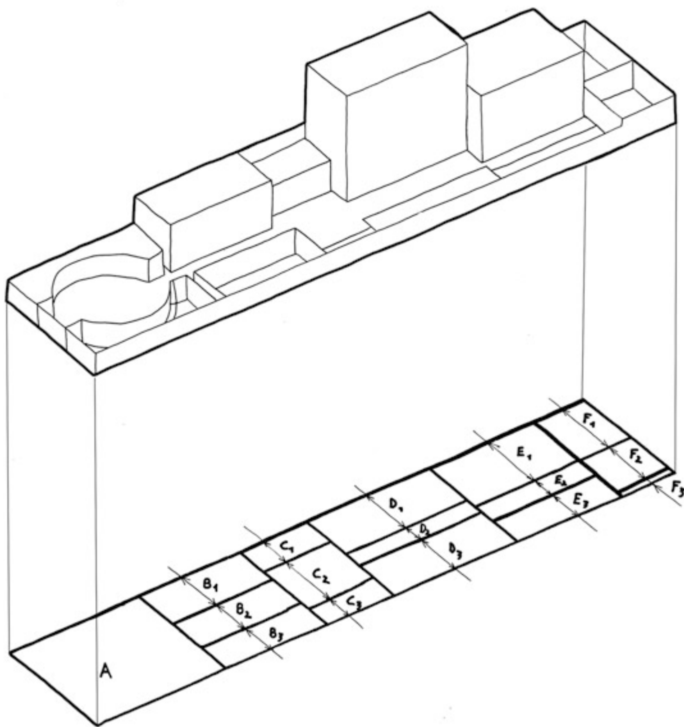
Well, this could represent an interesting challenge: in a way I would say that ease of cleaning and minimisation of obstruct of daylight are two contradictory requirements. It would be interesting to solve this problem via a multi-objective optimisation. The criterion about daylight obstruction is very easy to define; it gets a bit more difficult to quantify the 'ease of access', but I'm sure it is possible to do it. It's a matter to understand the implications of stopping a walkway (or whatever the feature to reach the window) a bit shorter or making it more or less deep. We could involve a specialist in façade access and define together a parameter to describe this. And then we would run the same type of analysis that we did to identify the ideal distribution of openings.

Proportions

As I said, the design is conceived as a system of built volumes, parts of which just happen to be outdoors or roofless. The floor plan appears as a grid of orthogonal lines. It would be great if the elements and the areas that cover the site were ruled by some inner ratio. From a qualitative point of view, the system has already its own balance, but I would like to know if there's a way to connect the dimensions of all the parts.

In fact, except for the two existing volumes and the *Brandschutzwände*, whose size is given, the dimensions of the other elements haven't been determined yet. Can we maybe apply the optimisation to find a criterion to give them a ratio, a sense of proportion?

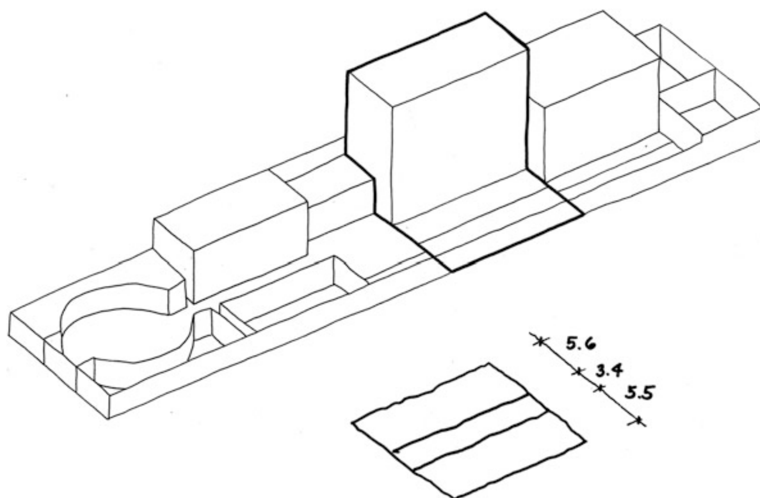
A way to create some sort of dialogue between all the elements which are part of the project is to follow the golden ratio. I don’t want to start a debate about proportions—as this discussion has been going on for thousands of years—and I am aware that the golden ratio is not the only answer for proportions, but I would just like to try what happens if we follow this rule. It is not a very straightforward exercise as there are many different variables and potential combinations to consider. There are many possible ways to implement the ratio; I propose to compare the position in plan and the height of adjacent elements and try to get the views in plan and elevation as close as possible to the golden ratio. Our objective function could be the ‘distance’ from the perfect ratio φ of plan and elevation. The sketch below describes my idea.



Proportion scheme

If we consider the positions on plan, the only elements which are fixed are the coordinates of the existing buildings (B_1 and E_1). And then there are some limitations: for the first sector, the central lane must be wider than 3 m as it has to be accessible to cars, (i.e. $B_2 > 3$ m). For the other sectors, the only rule is that the central lane must be wider than 1.2 m, as it is the walking path between the external gate and the entrance door to the studio (i.e. C_2, D_2, E_2 and $F_2 > 1.2$ m). Apart from that, let's keep our options open and try to get as close as possible to the golden ratio.

If we tried to answer this question by hand, we would have to work for very long; but, from a computational point of view this is relatively straightforward. If, for example, we refer to sector D—which is the one, together with F where we had the largest number of potential options, we get the following best result:



Proportion scheme, sector D

This combination is the one that is closest to the golden ratio: the difference from the golden ratio is only 3 %.

A very similar approach could be adopted for the definition of the height of the different elements of the project, apart from the studio and the atelier units, which are fixed as already existing. It would be especially interesting to play with the height of the new, biggest unit, to get as close as possible to the golden ratio, when considering its relationship with the Brandschutzwände at the back and the walls of the 'negative space' in front. And I would say that also the dimensions of the curtain wall could be involved in this process of optimising the sense of proportions.

In fact the same calculation could be applied to the design of façades, in order to verify the numerical ratios.

As you say for the heights, in this case we have more opportunities of choice, by deciding the inter-storey height of the *Neubau* and by increasing or reducing the height of roof line of the other volumes.

It's very important that the volumes are well proportionate on a singular basis, but also as a group. In fact, in order to contrast the fixed form of the surrounding volumes, the house has to present itself as a varying range of shapes, combined in a sculptural union.

Colours and Tones of the Envelope

The composition of the volumes takes advantage of the elongated shape of the site. If we stand at the entrance, after the gate, or if we cross the garden to reach the opposite side of the site, we see the house as a sequence of overlapping, slightly staggered, planes in the shape of a fan.

The exterior walls of the house will be insulated and treated with plaster.

But I'm afraid that the interplay of volumes will be weakened by the monotony of the colour and the dull texture of the surfaces. Besides, the house is located at high latitude and for most of the year the pale sun won't help us enhance the contrast of light and shade. The end result is likely to be a bore.

So not only must we avoid at all costs the sad view of a few monochrome shacks in a shaded narrow site, but we must overturn this unfavourable situation, and transform it into a strong point of the design.

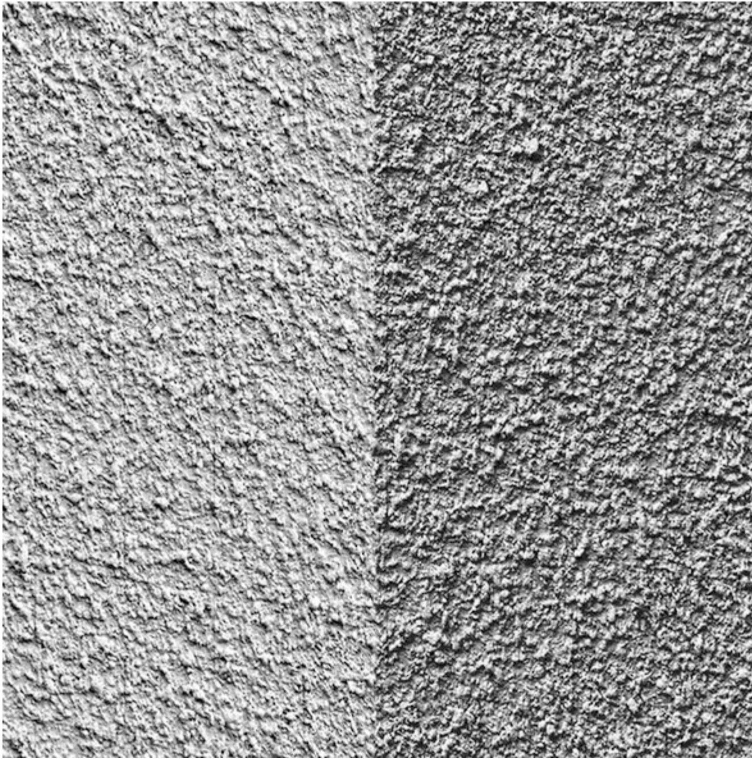
What I would do is to take advantage of the simple materials in hand to enhance the shape of the building. I want the volumes to stand out. My idea is to use the colour of the plaster to enhance the enlightenment of the bodies according to the average solar radiation during the year. I would use a different tone of colour for each face of the volume, in order to get an effect of variety, but without losing the sense of unity of the building. I'm not interested in tromp l'oeil tricks, I just want a powerful space.

Rather than overtly artificial or, worse, showy, the final effect should be hardly noticeable, as some kind of optical correction that helps us refine the form.

Bi-Colour

In addition to the tonal variety of the volumes, we could also use two different shades of colour to accentuate the two main views of the house (from the gate and from the bottom of the site), creating a shimmering effect on the whole building.

At this point it would be interesting to extend this two-tone treatment to all the outer walls of the house. We could give a certain degree of roughness to the surfaces, for example using a coarse-grained plaster. This way we could paint the façades using two slightly different colours, one for each direction.



Bi-colour, plaster detail

That's a very interesting suggestion. I can see the risk of having a very flat appearance, especially during the extensive periods when the sky is overcast and light is only diffuse—don't forget I live in London and I have a certain experience of cloudy sky.

So, just to summarise the different aspects we want to consider, we have the solar radiation, the two main views of the house and the necessity of avoiding flatness of tones. I would say that your idea of using some sort of rough render, which enables us to create a shimmering effect, can be expressed in a strong language: why don't we consider two different solar exposures—one representative of the view from the entrance of the site and one of the view from the opposite location? We could identify two specific moments when there is the maximum variation in terms of levels of solar radiation on the different surfaces of the façade. And we could say that the tone of each surface is proportionate to the intensity of the solar radiation at that specific moment. On top of it, we could check that the tones of surfaces which are adjacent—for real or in the considered perspective views—provide the maximum contrast: in this way we will avoid the risk of having a flat, boring effect.

I guess the two aspects do not necessarily lead towards the same combination of tones, therefore we will have to find a compromise between them—and we are interested in finding the best compromise. Obviously, many compromises are possible, depending on how we want to prioritise the two criteria—insolation and contrast. We could potentially keep the two aspects separate and run a multi-objective optimisation, but I am tempted to be more 'adventurous' and decide our priorities before the calculation runs, and hence having a single-objective optimisation. I am saying this because I don't want that we decide how to assign the weights to the different criteria after we know the implications of this assignment. Since this optimisation is not driven by performance requirements, but only by a design intent, I think it would be more interesting—actually, more honest for the design team—if we made the effort and decided right now if we prefer that the tones are mainly decided because of the solar intensity or vice versa if contrast is the dominating factor.

I agree with what you were suggesting: the main driver should be the solar radiation, with a little bit of contrast, acting as 'doping' to increase the movement of the façade.

In order to avoid the flattening of the volumes, I would also accentuate the perception of distance. We could lessen gradually the saturation of the colour as if seen through some kind of haze (what was called *sfumato* in the aerial perspective of Renaissance paintings).

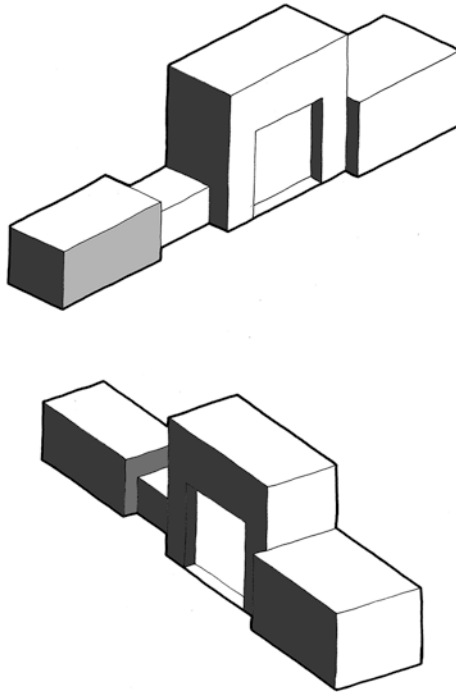
Considering the two main views, we assign to the walls of the house a different component of whiteness, that increases with the distance, starting from the two extreme limits of the property.

So, from the two positions that allow to see the whole building (at the entrance or on the opposite side of the site), the house should appear as a clear succession of volumes, their tones decreasing in intensity with the distance.

Ok, I think we agree on how to address this exercise. From each observation point, eight surfaces will be visible. I would consider that each surface could potentially have a different tone, therefore let's assume eight possible tones. This leads us to a range of more than 16 million potential solutions.

Solar Irradiance

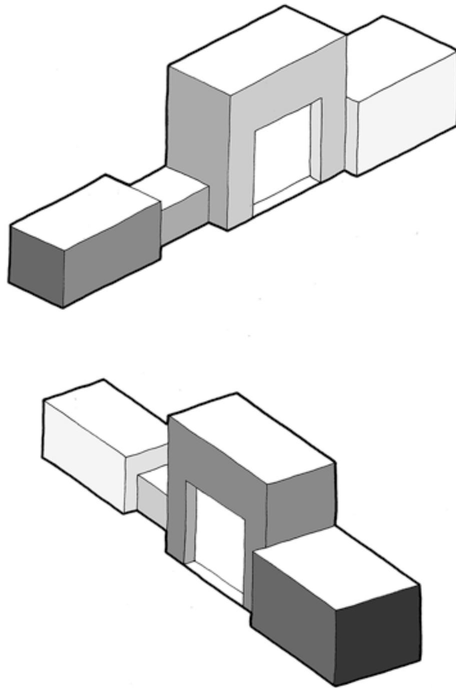
As we said previously, we need to determine the two scenarios for the different observation points in terms of solar irradiance. If we take into account the tallest building next to our site, this will cast shadows on the surfaces of our façade. A way to identify when there is a good variation of levels of solar exposure is to calculate, on a hourly basis, the intensity of solar radiation on the different surfaces and then check the hour when the standard deviation of these values is maximum, considering only the surfaces relevant to each observation point. If we assume that the surface most exposed to radiation is white and the most shadowed is black, we will get the results shown in the image below.



Solar irradiance scheme

Distance from the Observation Point

The effect of distance is quite straightforward: the closer a surface to the observation point, the darker its tone. The calculation is immediate and the results are reported in the image below. Due to the asymmetry of the site and since the observation point at the gate is more distant from the building than the observation point at the entrance of the studio, the tones are not exactly complementary.



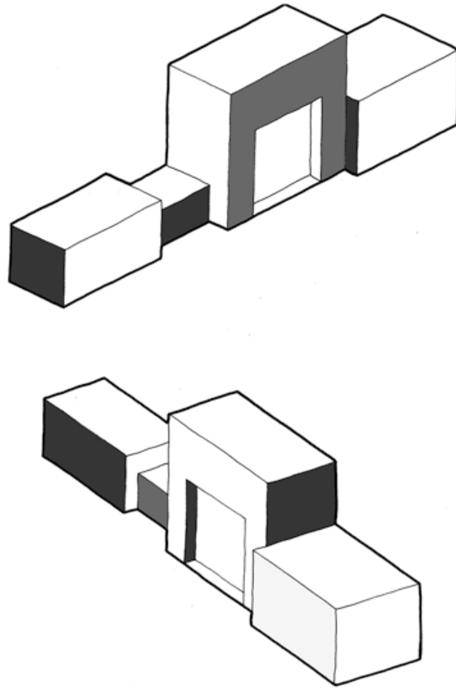
Distance from the observation point scheme

Contrast

This effect is the least intuitive to define and also the most difficult to calculate, since the result is driven by inter-relationships between the different surfaces and therefore it is not possible to assess the tone of each surface independently, as it was the case for solar irradiance and distance.

We want that the difference in tone between surfaces—which are adjacent from a geometric point of view and also from the perspective of the observation points—is maximum.

Due to the inter-dependecy of the tones of the different surfaces, a full optimisation exercise is necessary to understand how the contrast criterion drives the results, as shown in the image below.

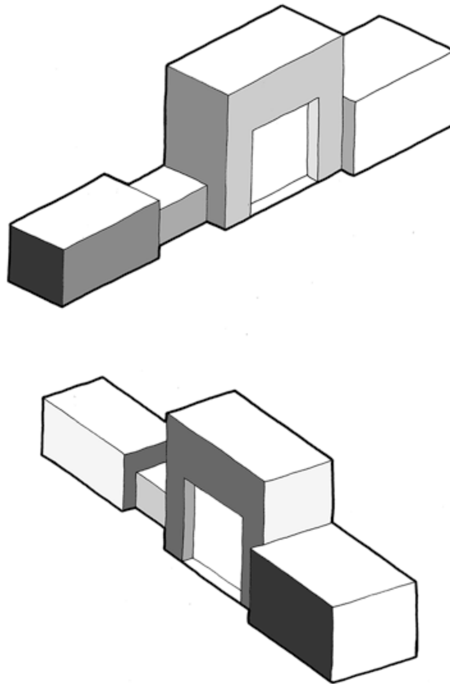


Contrast scheme

Optimum Tones

Now that we have seen how the different criteria drive the tone of the surfaces when acting independently, it is time to consider them together and to find the global optimum for our problem.

The way to determine the rating of the different criteria is completely up to us, since there are no factual performance drivers involved. We decided that we want the tones to be mainly defined by insolation and distance, with an ‘adjustment’ of contrast: the value of our fitness function is dictated by insolation and distance for 40 % each, and the remaining 20 % is due to the contrast criterion. The results are shown below.



Optimum tones scheme

I find the final result intriguing, because you can see traces of the different criteria, but at the same time none of them is completely fulfilled.

In Conclusion

The conclusion the three applications of optimisation are quite different but I guess equally interesting. The one about the distribution of glazing in the studio unit is the most 'traditional' because the objective functions express typical performance requirements. The results provide some guidelines for the design of the building envelope of this part of the project that could have been implemented if the design hadn't been already developed so much.

The other two applications were quite unique, as I had never tried to use optimisation criteria which are not linked to specific performance levels. I found it very intriguing to talk through proportions and chromatic distributions with you and the main work was the definition of the fitness function. Once this was done, the calculation itself wasn't that complicated.

Every design team would come out with a different way of describing the optimum proportion or colour variation, therefore completely different solutions would result from different approaches. This, I think, is a key aspect of the

approach we have presented in the book: the team is in full control of the design intent as the 'machine' shows the implications of the way architects and engineers interpret the building.

Speaking of Colours

What I really like of this methodology, and especially of this latest application, is the use of a scientific process, of a sophisticated calculation adopted to manage elemental materials, such as render and paint.

The apparent contrast of dealing with a simple material by means of a perfectionist attitude is the source of a sort of tension that makes the building vibrate. It avoids the steadiness typical of finite systems. This is the context where technique can give its best: by having extreme care in handling limited resources, as long as the ultimate aim is full of meaning. In this specific case, the result is a quality that is irrespective of the actual value of the product. This is what happens for the big civilisations of the past: today we admire their buildings, even if they've lost their completeness in terms of materials and shape. The perfection of the meaning stands. Now, apart from the small project we are talking about, and without doing embarrassing comparisons or analogies, I think that the high technology is visible when it survives in the meaning. From this point of view, I believe it makes sense to say that a Greek temple is authentically high tech.

Here we're talking about colours, tones and hues and we're trying to understand if this makes sense, if our effort can lead to an improvement of the project. But even if we are not fully aware of the consequences of what we're proposing, even if we are navigating in the darkness in respect of a situation, our senses get refined while we are trying to imagine it.

A Project is a War

In my view this is the direction towards which we should lead the relationship between architectural values and engineering techniques, by means of the optimisation. It has to be clear that the calculation process is not the solution of our problems—the real problems deriving from the meaning of what we're building—and it is not a *support* for the design, as in the perspective of computer aided design. It is a method to develop decisions by understanding more deeply the consequences of the (spatial) question that we're dealing with. It's up to us to decide how much to develop it, depending on the requirements of the project, and not on the resources available.

I think it's like being at war, where the effectiveness of an operation is not necessarily proportional to the means available. Where, rather than relying on help, we have to manage in the best way and with vigour what we have. And

where it's not a single, winning action that determines the final outcome, but success is dependent on strategy, coordination and overal vision.

Because designing—and even more realising a project—is exactly a war! In order to survive, the secret is not about finding allies but is about understanding what the victory is, and nobody can help us at this.

In our case our approach doesn't have to be driven by the desire of feeling strong because of the support of a methodology technically amazing. During the design process we should rather avoid help, because we can ask for help only when everything has been fully decided. We should use our energies and care in understanding what we can make out of an idea, by testing its potentials.

Because the discussion, generating from the data provided by the optimisation, drives the project in terms of intellect and spatial speculation: this is the architectural aspiration, much more than the appearance.

Now, we could keep tackling other aspects and continuing with the design. For example we could speak about the distribution of the internal spaces, about the overall energy strategy, about details, etc. What do you think?

About the Author

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