A Process-Oriented View of Complex Architectural Forms

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Throughout the history of architecture building forms have tended to reflect the technologies and processes tat have been within the designers reach. Today we are on the threshold of a new era where liberation from linear processes by digital technology is enabling us to devise and construct complex architectural forms efficiently. Buildings no longer have to reflect the planar, orthogonal and repetitive processes of the traditional assembly line but can respond to and express the non-linear forces of Nature so critical in any sustainable approach.

There has been much discussion in the last few years about the relationship of architecture to the "New" Sciences. To he more precise the developments in the science of Complexity, the study of chaotic systems and the emergent morphology. Much of the debate has concentrated on the visual aspects of these phenomena and perhaps this is not surprising since we, as architects are visually aware people. In some ways this could he seen as an extension to the many visual and stylistic references to Nature that have been present in architectural development throughout this century. Beautiful as some of these forms and spaces may be they inevitably tend to he 'one-dimensional' visions of Nature, perhaps verging on the picturesque. The structures and forms found in the natural world are staggeringly beautiful and show limitless variety, the true beauty however is forever being uncovered the deeper we dig like an endless series of Russian dolls. The Cosmic Onion principle as some have put it. The study of living organisms is the study of the processes that reflect the systems dynamic organization. It is these processes and the ingenuity with which problems are solved that are truly remarkable.

The changes in and perhaps the evolution of a new architecture will not come about through a dogmatic or prescriptive interpretation of complexity in Nature hut in the understanding of how its processes and systems tackle problems to produce such an awesome array of beauty. The principle of form follows function might then he reconciled with current ideas if one were to include the full spectrum of problems that require solving including cultural and commercial aspects. Perhaps the great cathedrals could fall into this category.

Some of the best and simplest examples of this process-oriented approach can be seen in indigenous vernacular buildings. Most as striking as any natural form, not only remarkable structures demonstrating complete understanding of the (usually) limited materials used but ingenious low energy passive environmental solutions - all this and rich in cultural significance. This architecture can be thought of as a real extension of Nature and its lineage can be traced from primitive times to now, albeit very faintly for the majority of time.

With the turn of the century fast approaching we are becoming increasingly aware of the need for Sustainability in society and in particular the built environment which uses 5O% of natural material resources, produces over 50% of national waste and consumes 40% of our total energy production. These figures clearly demonstrate the inappropriateness of our current activities and the need for a dramatic change in attitude if the globe is to sustain a projected 8 billion people in 2050. As architects we are in an ideal position to instigate these changes with the perhaps unique ability to straddle the cultural and technological aspects of society.

The use of advanced techniques and technologies now puts us in a position once again where truly Naturally aligned architecture can blossom and sustain a dynamic equilibrium between Nature and a large global population. Efficient means of collecting natural energy sources is it solar or natural ventilation can be passive or active. Both can be driven by advanced technologies for increased efficiency. Mono-crystaline silicone cells now have upwards of 25% efficiency in converting sunlight to electricity. The ever-increasing power of computers is set to double each year. Computational Fluid Dynamics now allow incredible calculations to be made where the visualization of the invisible becomes possible. The study and comprehension of natural phenomenon can now be undertaken producing sky scrapers that are naturally ventilated and building geometry's and forms can he generated from the local environment. These calculations not only rely on advanced hard technology hut also on the understanding of 'process' in the form of algorithms and software, again extending Natures 'soft' side such as genetic algorithms and DNA coding. Perhaps the combination of computational power and traditional materials like bearing stone will open up new horizons.

At Nicholas Grimshaw and Partners we produce products that are expressive and dynamic in their form. We try to express the processes that are involved in their generation. When we talk about these processes we cover an enormous range of influences and forces and it is their management that is crucial to our work. The large span structures we have worked on perhaps best demonstrate these principles.

Our recent entry for the Stockholm Olympic Stadium was our response to an intriguing brief. The organizers had implied that they wished to have an 80,000-seat stadium for the 2004 Olympics. After 3 years they proposed that they would like this structure to be removed and replaced with a 20,000 seat indoor arena where possible re-using as much of the original stadium. We found this to he a challenging problem but eventually we produced a design that re-used all the original components without altering them. The resultant arena building was very much an evolved form. By using our computers we were able to in effect fold the stadium closed much like flower petals. Once the arena roof was finely tuned it was opened hack out and the stadium structure was then re-evaluated and fine tuned once more. This series of iterations eventually produced two distinctly different buildings using one set of components.

The Waterloo International Terminal is perhaps the most intriguing example of process-oriented architecture. As an extension of the evolution of large glass buildings the Terminal roof structure once again establishes a morphology that has been little seen since the latter part of the 19th century. The glazing of complex 3D surfaces relies heavily on the understanding of the limitations of manufacture and construction techniques. Some of the early glass houses such as Bicton (1820) are highly crafted buildings that have pushed and indeed express the limitations of the glass manufacturing processes of the time. The 'crown' process of glass manufacture produced only limited sizes of glass pane, approximately 0.75m x 0.5m hut generally much smaller and it was only after manufacturers began employing the new 'cylinder' process in the 1830's that glass sheet size increased to around 1.Om x l.3m. The fact that each sheet of glass could he cut in-situ allowed these complex forms to he erected. The morphology of these early glass houses was largely established by physical and environmental requirements or the understanding of these requirements ~t the time. Indeed most glass houses were conceived without the input of architects who tended to produce glass houses in Grecian or Gothic styles. In an effort to produce minimal structures, greatly reducing interference with light, composite-shell construction was pushed to the limit and used to great effect albeit with catastrophic consequences at times. All these structures were only possible because of J. C. Loudons revolutionary iron sash bar design, ground breaking technology of the time. Harsh corrosive internal environments however eventually saw a return to the use of timber:>

As the glass manufacturing process changed and standardization became the norm so the morphology shifted hack to being planar, Paxtons Crystal Palace perhaps being the pinnacle of this type. The staggering nine-month programme was only achieved because of this shift in technology from craft to mass production. Very little has changed in building form as the processes are still highly standardized. Perhaps the biggest change has been the development of toughened glass allowing greater clear spans. The flip side to this benefit has been the loss of cutting in-situ perhaps severing all craft base approaches. Most glass houses designed to day still display planar forms.

The roof at the International Terminal was no exception and indeed was to be constructed in nine months. From very early on in the design stages it became obvious that the site profile, dictated by the track alignment, would influence all our subsequent decisions. Because of this complexity and the unknown knock-on effects further down the design and construction process it became clear that the wisest course of action would he to flow with the problems as opposed to forcing them into a pre-determined solution. Geometry, flexibility and buildability were to become the key to success and it was a through a thorough understanding of fabrication, manufacturing and building processes that enabled lateral solutions to be had. Standardization was to he critical for success and the key problem was to reconcile this to a very irregular morphology. A solution was reached that enabled 230 'standard' rectangular glass panels out of a total of 1680. Each panel overlapped each vertically adjacent panel much like snake scales. The key to eliminating geometric twist was the incorporation of a standard neoprene concertina gasket, which could accommodate out of plane variances of approx. +/- 80mm. Each panel was fixed to the external steelwork via a series of standard interconnecting stainless steel castings. These connections were assembled from four independently rotating components allowing a variance in position of +/- 180mm in each axis.

The achievement at Waterloo was the production of a complex 3D form out of standard components. In this case the geometry was unavoidable and was dictated by the site constraints. Our Eden Project for Bio-climatic 'glass' houses in a disused clay pit in Cornwall further develops this process hut in this case the form of the structure emerges not only from the complex site hut complex environmental criteria as well. The project aims to he a show case of Bio-diversity in the plant world and as such give us a greater understanding of Mans relationship with Nature. In effect a demonstration of Sustainability, which at one end of the scale requires maximum use of solar energy and light for plant cultivation. The Biome structures are on a massive scale with a total length of over 1km and a maximum span of 120m, this is required if the project is to allow the study of whole plant populations, essential in understanding Bio-diversity.

The structural form capitalizes on the scarce southfacing slopes within the clay pit. All the 'Biomes' are connected by restaurants and visitor facilities using the same structural and cladding systems. Complex geometrical problems are eliminated by faceting the volumes. However as the structure follows the pit levels, large variations in plane occur which in turn causes twisting within the envelope. Maximizing on solar gain and minimizing heatloss is essential as is cost and lifespan. Upon analysis double glazing on this scale and form has proved to be less than satisfactory and the design is being developed using a transparent Teflon foil system which is fabricated into a triple skin pillow inflated to 300psi. These pillows allow greater penetration of low frequency ultra-violet light, have better U-value figures and weigh substantially less than double-glazed glass panels. Maximum panel size on the 'Biomes' is loom x 3m thus greatly reducing the weight of primary steel structure. The down side of this system is life span, which is estimated at 30 years fairly low relative to glass. However the weakest link in a double glazed panels the silicone seal, estimated at about 20 - 25 years, which can only he replaced under factory conditions. A quick calculation actually shows that the volume of foil used to enclose the 'Biomes' is almost that of the double-glazed silicon joints when flattened to 0.3mm.

Perhaps the most interesting factor is the ability of panel fabricators to design the foil surfaces to have varying degrees of warp to accommodate the complex surface form. Sophisticated pattern making software and CNC machinery are now able to produce sheets that are as complex a form as sailing spinnakers. Once again the building envelope will he a 'craft' based process made possible by powerful and sophisticated tools. This technology is non-linear and information based much like the craftsmen who erected Bicton hut at the same time highly efficient. The Eden Project utilises this technology to produce a morphology that responds to its environment like a living organism.