Integration: Master [Planner | Programmer | Builder]

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Abstract

The development of modern computer-based design systems and advanced manufacturing methods have progressed to the point where the promise of mass-customisation and the establishment of the 'designer as integrator' are being realised: the former implies that designers can now act as creators of systems which produce infinite possibilities, and the latter that the convergence of designer and manufacturer, through common technologies, is enabling a reunification between design and construction processes. This paper discusses the symbiotic relationships of these paradigms within design research, practice and their commercial implications, and the significance of the integration of new design tools and production methods for architects and designers.

1. The Architect as Designer

Since the Renaissance, and particularly over the last century, the role of the architect has become increasingly marginalised within the overall design and construction process. At the same time, the emancipated figure of the 'designer' has emerged, whose work is maintained pure and detached from the mundane toils of fabrication and construction. Indeed, the designer's role as a champion of aesthetics, as a virtuoso of the spatial arts, has allowed architecture to emerge beyond its roots of a trade- and crafts-driven endeavour to become the abstract art form it is today, capable of expressing abstract concepts and shaping man's environment with complex expressions of thought that go beyond simple utility. While this is highly desirable, it is equally true that this development has, over time, resulted in the architect's loss of touch with the immediacy of 'making', resulting in a linear building process in which realisation of a project is downstream, and almost secondary to, the architect's original vision. As the architect Rem Koolhaas once put it, the result is that the architect has often de-facto been reduced to a three-dimensional 'decorator', an early and marginal role in an inscrutably complex building process that is increasingly governed by developers and contractors.

This paper does not recount the history that has led to the current state of affairs, nor is its purpose to explore the current condition of the 'architect' in his present role. Instead, we are concerned with how modern technologies and practices may help the architect regain a central role in the design, fabrication and construction process, and thus return to his rightful place as the hub about which the building process revolves.

War is a useful, if somewhat grim, metaphor for the change being advocated here. Starting with Julius Cesar, during Roman times and through the middle ages generals rode with their troops into battle – their front-line contact with war was immediate, dirty and direct. There was no possibility of misrepresentation of the necessities of battle – results were tangible, and plans were drawn up in camp directly next to the battlefield, and enacted the next day. Yet this immediacy of the *Feldherr*, the strategist-warrior or field-general, dissipated as war planning became a more complex, state-coordinated affair. Drawing-room generals from the 18th to the 20th century pushed models around on giant maps or revised battle statistics, communicating with troops through an elaborated chain of command that kept battles abstract equations to be solved. Communications were slow, and wars became long, laborious, drawn-out affairs.

It has been through the employment of new communications technologies that the generals have been able to re-establish a new, if different, immediacy with the reality of war: Battle strategies are continuously coordinated through conference call, simulations and online intelligence capabilities. Real-time video of 'smart bomb' hits provides instant confirmation of attack success that accelerates the war process many times beyond that of 'dispatches' of the past, and the ability to instantly pin-point targets through the same laser-guided weapons means more efficiency and destruction with less waste of ordinance. It is this kind of transformation through technology, resulting in renewed immediacy and control, that is advocated in the architectural process.

2. Programming and Toolmaking

The architectural scholar, teacher and critic, Jeff Kipnis, has stated that the role of the architect will evolve from that of the *Master Planner* to *Master Programmer*. Programming in this context refers not to the distribution of spatial programme in the traditional sense, but to the fundamental paradigm shift in which instead of *crafting* a single solution, the designer can now create *systems*, which can produce countless variant solutions from rules, and mechanisms that respond to particular conditions or intentions.

This does not literally mean that architect becomes a *programmer* in the sense of producing computer code, although some designers today have in fact turned to producing their own computer-based tools. *Programming* in this case means the creation of a *machinic* process, which enables the generation of a solution that incorporates the designer's intent. In other words, a result-driven paradigm is replaced by a process-driven paradigm, in which results are the inevitable outcome of the process, but where the true power lies not in the product but in the system that creates it. By changing, guiding or optimizing the process, the product can be consistently improved, diversified or focused as required by specific circumstances. This emergent paradigm is becoming reality through the application of computing technologies and methodologies.

Until recently, the assistance granted by the computer to the architect has been limited to *First-Generation* design tools, otherwise known as 'CAD' systems. While these systems have been almost heroic in 'digitalising' what is conventionally a very physical profession, they have become gloriously infamous by not moving beyond their original paradigm: the electronic equivalent of physical tools such as pen and drawing board. *Second-Generation* design tools may be deemed those that are increasingly available today, permitting collaborative design processes, complex document management and increasingly complex geometric operations and representations. These are certainly a great improvement, but in general still try to emulate, while greatly facilitating, those activities which otherwise take place in the physical world. In short, computational systems are becoming great *assistants* but have yet to become real *interlocutors*, where the designer and the computer form a partnership of complements, each contributing specific abilities and knowledge to the overall task of architecture.

John Frazer, a renowned architectural scholar and pioneer of adaptive and interactive computational systems in design, often tells the story of why he became increasingly interested in computational possibilities in the 60s and 70s. According to Frazer, this was due to his lesser enthusiasm for the toil of producing architectural drawings – indeed, an architect may spend as little as 15-20% of his time doing actual *designing*, and the rest of it either producing drawings, or *representations* of that design, or *managing* these. Regrettably, any architect in practice today will know that even though drafting table and ink-pen have gone, the production time and toil is very much the same, even with the more sophisticated tools available today.

Thus Frazer was searching for the perfect architectural partner – a system that would free up his time for creative endeavours – *designing* – by understanding his (the architect's) desires, intentions and prerogatives, and respond through engaging in a *dialogue* with the architect by (1) producing plausible design solution and variants and (2) by mechanising the actual design representation process –drawings, manufacturing instructions or otherwise. In short, Frazer advocated a *systemic* design tool – one that can be instructed by the designer with rules, procedures and desirable goals, and which will proceed to generate viable options and

Frazer and several of his disciples, including the author, have gone on to further study and implement a series of these design tools. These ranged from intuitive, tactile (*haptic*) interfaces to the computer through the automation of drawing production, to the most advanced and abstract concepts drawn from nature and its form-finding processes, including evolutionary morphogenesis and generative design techniques. The latter ones, in particular, leveraged the concept of the *computer as a muse*, where the designer expresses his creativity by selecting, breeding and manipulating design constructs generated by the computer using rules specified by the designer, while converging on functional requirements specified by the design task.

It is clear, thus, that the advent of *Third Generation* design tools will require not just the ability to leverage design intention and strategy, but will emerge through the designer's expanded role as a *Toolmaker*, where the architect creates tools, which in turn generate the solution[s]. As hinted above, this will in turn require an expanded knowledge where the architect has an understanding of systems theory and principles of logic and computer programming. A new generation of tools is thus envisaged to achieve the *Third Generation* paradigm in question: these can be understood as *pure tools* in the sense that they operate on a completely different basis of understanding than conventional CAD tools. These tools will enable the architect to approach the task of design in a completely different manner; not by functioning as graphic translators or organisers, but by requiring input in the form of rules, gestures, goals and parameters, and a defining *grammar* which governs the combination thereof.

This is of course a highly idealistic scenario, even at the dawn of the 21^{st} century: most architects have difficulty in accepting the idea of having to digest computer code and produce ‘systems’, rather than having a sketchbook and producing direct design ideas. Furthermore, the problem of legacy and overhead haunts both design practitioners and the software industry: what about the existent culture (albeit a laborious and inefficient one) of AutoCAD, Photoshop and the like? The result is *hybrid tools* – conventional CAD with ‘intelligence’ or the possibility of customisation, or both. AutoCAD’s pioneering success story with AutoLISP paved the way for all kinds of customisation and modification methods, such as plug-ins, macros and embedded objects. (oo structure, parametrics).

However, the idea of ‘intelligence’, in the sense of addressable structured semantics of a represented design and not just its graphics, in the mainstream tools has only recently begun to emerge. The most powerful tool of this type available today, CATIA Version 5, requires the designer to semantically structure *every* component of the design, such that anything that is contained in a structure has its significance as part of the whole. This however still faces the arguable limitation of having to a-priori conceive the structure of the design before it is actually created, and the necessity for it to be describable within the semantic grammar provided by CATIA.

A glimpse of the next step into the future is offered by Robert Aish’s Custom Objects, an abstract semantic structuring system which permit the user to embed any type of logical functionality into geometric objects within a CAD system (MicroStation). By allowing the user to define not just an object’s *behaviour*, but also the *grammar* by which they are organised, Aish provides clues as to the first fully configurable intelligent graphic system.

3. Learning from Engineering

The Moderns and the Modern Movement were the first to advocate the use of automated and ‘machinic’ production methods for design. Le Corbusier was fascinated by ships and aircraft, and in how their design was a direct result of their functional requirements. Mies van der Rohe made extensive use of industrial steel, showing an early application of ‘systemic’ design – the creation of structures through rule-based (repetitive) use of steel beam and girder patterns. However it was the architect and theoretician R. Buckminster Fuller who specifically approached his designs as systems where geometric structural rules combined to generate complex form. The ideals shared by these visionary men were often derived by a fascination with technology-driven making – engineering.

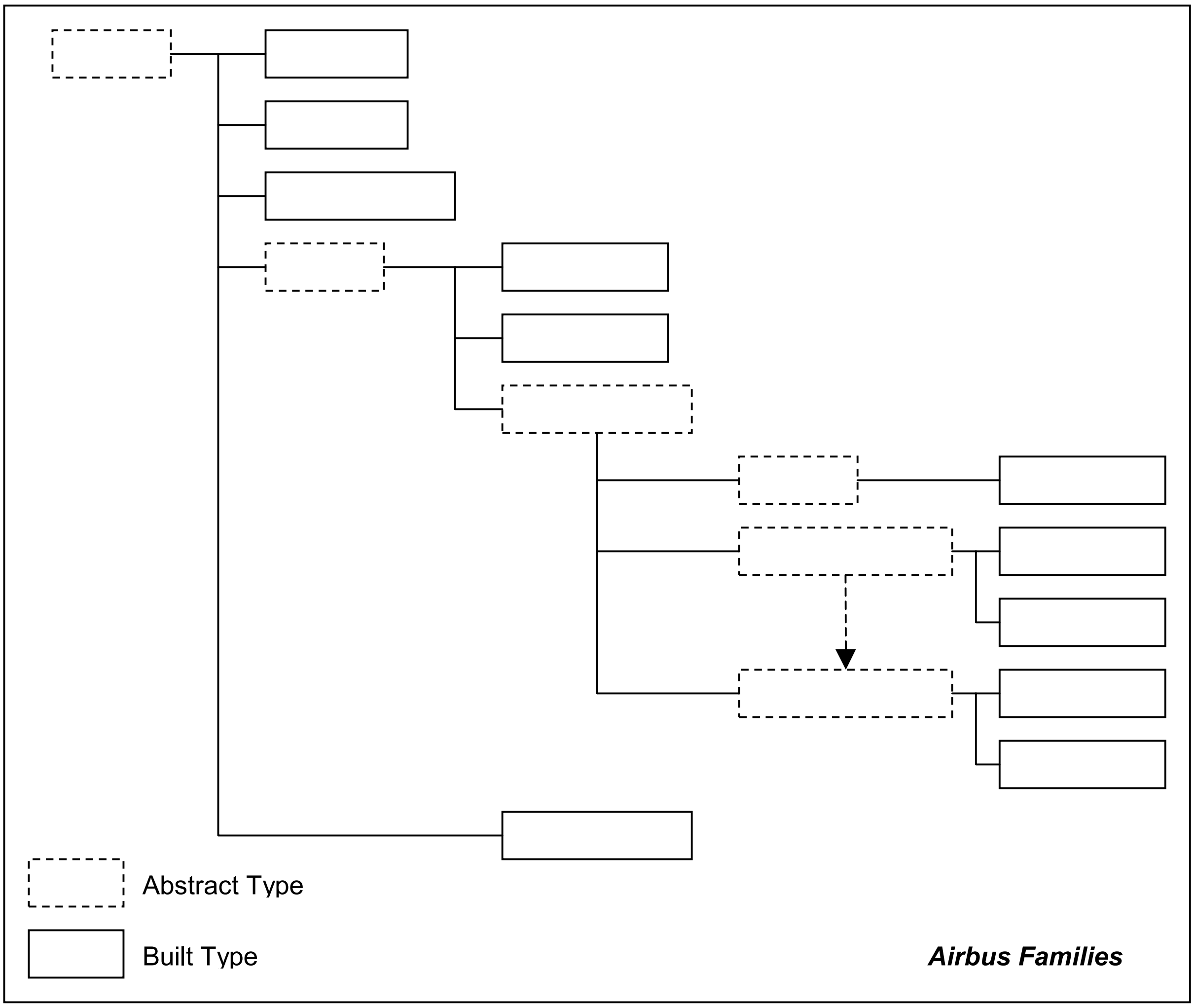
Engineering is not driven by aesthetics, but by economic criteria bound to manufacturing and fabrication capabilities, and the ability to produce designs which are achievable with available technology plus some percentage of necessary innovation. The management of these forces means that engineering practice invariably pushes the boundaries of technology in a feasible manner, resulting in small but significant achievements which create consistent progress.

Industrial companies have understood the power of embedding common design features into collective *families* of related, yet uniquely tailored design, and combining this with flexible production means to produce as wide a range of products as possible while keeping design, development as well as tooling and production re-configuration costs at a minimum. In fact, the former is achieved through parametric design tools while the latter is accomplished using robotic technologies and reconfigurable manufacturing methods.

In the 1980s, four European automobile manufacturers understood the possibility of producing a 'generic' or *abstract* design with enough *potential* to be developed into distinct products with a common root. SAAB, FIAT, Alfa-Romeo and Lancia formed the Euro-4 consortium to produce an abstract prototype car chassis which was subsequently developed into distinct cars by each company, each with very distinct design and market-fitting traits and yet each very much the *descendant* of that abstract parent:

SAAB	9000i	High-end luxury sedan
Lancia	Thema	Elegant town car
Alfa Romeo	164	Sporty mid-range sedan
FIAT	Croma	Affordable family sedan

Similarly, but arguably to greater effect, is the story of Airbus Industrie, the European aircraft consortium that in less than 30 years has grown from zero to the biggest commercial aircraft vendor in the world. Airbus began with a single twin-engine multi-purpose widebody design, the legendary A300, which proved to be a *root* design with so much *potential* in it that over 30 years it has stretched, shortened, re-winged, re-engined and, in the case of the A300T Beluga, distorted into a giant transporter. Except for the last instance, all the aircraft listed in the table below share a common fuselage cross-section which can be ‘extruded’ as necessary, tail assembly, nose and internal systems. With every major version change, Airbus introduced innovations and improvements in contained doses, notably in new wing designs, different engine combinations and flight systems.



Airbus Families

By using and re-using the common root elements, Airbus was able to leverage an existing design framework while constantly improving up on it. The sheer design potential of the original A300 *formula* was such that Airbus was able to meet changes in market requirements and fill emergent niches by tailoring, or *customising*, the design quickly and with minimal research and testing expenditure. This has equally proven effective for operators of the aircraft, in that maintenance and flying knowledge gained on one type could be transferred to the next – in fact, the A330/A340 family was certified as one 'type', with pilots being qualified on both models directly, thus reducing training and necessary knowledge. The question is, how can architects make treasure of these ideas when developing and re-exploring related design problems?

The construction industry has also begun to explore new paradigms. In the early 1990s, the Japanese construction giant Obayashi introduced the first workable robotic 'construction system': a series of 'climbing cranes' would erect a structural steel skeleton for a tower, deriving their assembly instructions from the design data of the building. The robotic cranes worked 24 hours a day, continuously climbing the very structure they were erecting, and building the tower with greater speed, efficiency and accuracy than human builders.

In short, the digital process from start to finish, from design through manufacturing to assembly, can be considered 'open for business' – it is at this stage that the architect must become fully aware and fully immersed in this process, in order to leverage its potential to push design possibilities to new, as-yet unexplored limits. Certainly the most successfully innovative architects today have developed a powerful understanding of computing, and leverage this knowledge in how they structure both their design and their practice. In most cases, this translates into an architectural practice's achievement in finding as much common ground as possible between the architects' ambitions and the possibilities awarded by existing design technologies. More often than not, this is a messy practice in which the tools are almost never entirely used as originally planned, and where often the practice's goals and the tools' capabilities must be shoehorned into each other to achieve workable results. The 'tool-making' scenario envisioned above is still remote in most practices, and yet many of the more progressive practitioners today are understanding that a *symbiotic* relationship between the designer and his tool – and the processes these tools enable – open up new possibilities for new designs, but for the architect to keep *control* of those designs as they move from inception to realisation.

4. The Integrator

"For hundreds of years before the Renaissance, the integrative knowledge required for the processes of design and construction was typically embodied in one individual — a generalist architect/master-builder — who was dependent on and collaborated with fellow guild workshop cohorts. These were typically specialized craftsmen such as stonemasons and carpenters." (Barrow)

The complexities of today's building process and the sheer vastness of the required knowledge from start to finish mean that the role of the 'Master Builder' in the medieval sense is gone forever. Yet it is conceivable that the essence of the role of what may be deemed the 'ancestor' of the modern architect may find its reflection in the renewed centrality of the architect today – *The Architect as Integrator*. This new central figure leverages the complementary roles of *Planner, Programmer* and Builder to create a next-generation architect that is able to recapture that central role in the building process, a role that is currently vacant, and insidiously being annexed by the hegemony of contractors and manufacturers.

Many of today's more advanced architects are beginning to advance beyond the conventional constraints of traditional practice, either consciously by choice, or because of a greater desire to see a design intent carried through to the final product. While these firms are heroic in their efforts, they are still few in number and have yet to claim the total *integrator* role described in this paper.

The Italian architect, Renzo Piano, is often referred to as a 'high-tech' architect – indeed, his designs tend to push the usage of materials and structures to the limit. Yet his office employs digital technology primarily at the production level – the designs themselves are still largely *crafted* by hand according to the designer's intent – by sketch and model. By comparison, the office of Sir Norman Foster and Partners, also commonly dubbed 'high-tech', is very much more advanced down this path than Piano. Foster employs parametric design tools and form-generating methods very early on in the design process, including Aish's Custom Objects. Geometric, aesthetic, structural, economic, and environmental performance criteria all equally drive design development. Foster's designs are tuned towards industrial production while leveraging the notions of flexible manufacturing.

Mark Burry's work on Gaudi's Sagrada Familia and his collaborations with Mark Goulthorpe show how the same sets of tools (CADDS 5, parametric manufacturing) can be employed to achieve entirely different results: the former is a sort of 'archeology of the future', in which Gaudi's parametric design is computationally regenerated and converted to stone through the combination of CAM and traditional stonemason techniques, while the latter is an exercise in generation of abstract form types through mathematical operations. In both cases, the architect Mark Burry acts as an integrator of design intent and design process through design technology, with equally spectacular results.

The author's own collaboration with the office of Frank Gehry is entirely focused on *integration*. Gehry's design process is such that it can *only* exist through (1) the use of the most sophisticated modelling tools available, in particular CATIA and (2) by developing designs in strict collaboration with some of today's most advanced architectural fabricators such as C-Tek (USA) or Permasteelisa (Italy). By leveraging the concept of *technology transfer*, the office is able to *exactly* reproduce Frank Gehry's sculptural designs in built form – this can be described as *integration*.

In conclusion, it is unavoidable that (1) advanced computational technologies will continue to pervade the design profession and (2) that the architect must readdress his role within the architectural process if his centrality is to re-emerge. Powerful process-driven design tools are becoming the norm, and advanced manufacturing and assembly techniques allow for any kind of design to be built. To harness and exploit these powers, the architect has a window of opportunity – that of the integrator.

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