UBIQUITOUS CUSTOMIZATION – UTILIZING RAPID MANUFACTURING IN THE PRODUCTION OF DESIGN AND ARCHITECTURE

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Over the past few years the term and notion of ubiquitous customization has entered the parlance and discourse of the design and architecture related research disciplines. However, whatever its guise, much of what this has entailed is usually explored and formulated through a language that still seems to persist with production processes that aren't much different than those utilized over the last half century - the 'tools of the trade', when it comes to actually implementing a building, are more or less the same, resulting in the modus operandi becoming a question of logistics rather than something more original and reflective of the digital processes we nowadays use to conceive our designs . Over the last few years, however, a number of potentially fundamentally pioneering fabrication techniques have entered the picture. One of these, Rapid Manufacturing (RM), has a number of factors that innately lend themselves for such parametrically variable production suggested by the title. This rapidly evolving branch of fabrication and means of conception, that has one foot firmly rooted in the digital realm, the other one in the analog world, is already in the process of instituting a paradigmatic shift in the way we envision and construct our built environment. The defining taxonomies and semantic patterns that allow for such pervasive variability of making and thinking about our built environment, and all that that entails, are still in the process of evolvement, however, preliminary suggestions of how such methods might operate and appear can already be observed. The projects included reflect and partake in the evolution of this still developing manufacturing discipline.

Keywords: Architecture, Design, Rapid Manufacturing, Ubiquitous Customization

INTRODUCTION

For many the term 'ubiquitous customization' is somewhat of an oxymoron, for how can something pervasive also be, as the term suggests, almost infinitely varied? The expression, in which the initial word seems to suggest a latent trait of uniformity and large scale repetition (a form of omnipresence), is seemingly capriciously combined with a term that alludes to something bespoke, subjective and one-off. The rapport between the two flanking words seems at best to be an affiliation of hovering, but tolerable, compliance, at worst a case of something disruptively discordant and nonsensical. The notion of something ubiquitously customized is potentially fraught with controversy.

Also, what exactly would the advantages be of such a process? Why would someone wish to have a product that can be seemingly infinitely diversified? In fact, isn't it exactly the consistency of a product, be this a type of Linguini or a pre-fab building component, which in this context is its valued quality? Isn't it precisely this evenness, its non-variability, and thus predictability, which is appreciated? Indeed,

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aren't our shops and warehouses stacked with countless quantities of such replicas, rows upon rows of indistinguishable products lining their identical shelves? Why would one wish to change or adjust such over centuries evolved principles and logistical systems of taxonomies?

However, when the aforementioned issues are scrutinized in a bit more detail it becomes apparent that variation is inevitable. The more complex and involved the process of conception and fabrication, the more opportunities there are for differentiation to occur. Such slippage can of course be reduced by rigorous planning and supervision, however, some level of discrepancy will always be present.

Also, if considered from a slightly different angle, as objective, uniform and effective as we would like to claim our universal products to be, the notion of what its 'function' entails can be surprisingly varied. In other words, the object might be identical, however, how we use it varies. The 'genotype' of the concept is inescapably varied in its 'phenotype' implementation. Such diversity in use can range from, say, the simple variations in mannerism regarding how, and in which hand, we hold our fork, to more complex reflections of both cultural and social peculiarities in how we perceive and occupy space, the different ways we, for instance, sleep, dine or even socialize in and around different both private and public environments and occasions. The cultural anthropologist Edward T. Hall has written extensively on the subject (Hall 1966, Hall 1983).

Such subtle, yet still premeditated, societal diversification usually appears in the details of a product that can manifest themselves in the application of a design (as in the way in some parts of the world it is the custom to leave the protective plastics on the seats of a recently bought car for considerable periods of time so as it will appear 'new' for longer) as well as in variations in the form of the design (left and right handed scissors, variations in public toilet design between the genders and cultures).

PERVASIVE TECHNOLOGY

"Recently we have witnessed a paradigm shift from cyberspace to pervasive computing. Instead of pulling us through the looking glass into some sterile, luminous world, digital technology now pours out beyond the screen, into our messy places, under our laws of physics; it is built into our rooms, embedded in our props and devices – everywhere." (McCullough 2004: 9)

The notion of ubiquity is particularly prevalent in the realm of technology (which in this context will includes building technology) in which each of us on a daily basis seem to engage with variously pervasive, yet somehow customized, interfaces and devices, be these personal computers (with customized PC shells and desktop patterns), mobile phones (with individualized ring-tones), or even Apple's iPods (with their personalized play-lists). We desire the recognizable brand (the value object), whilst simultaneously aspiring to differentiate and individualize such, still by default generic, artefacts as our own. However, such individualization is inevitably a retroactive manipulation of a standardized product. Only in the most exclusive (and thus often dear) designs is there the potential to tailor the design to befit its intended user perfectly from the beginning. This is in particular true in regards to how we conceive and build our houses. The notion of custom-built buildings is usually reserved to only the most exclusive or high-spec or prestige construction projects. Very seldom does one come across such bespoke building in more ‘ordinary’ developments such as schools or social housing. Such lack of customization is usually justified by the apparent cost such construction typically entails. Alas, at some level this type of rationalization and pseudo-validation has to be classified as a type of misinterpreted apathy, as anyone directly involved with any type of more involved building project must realize is that there seldom is such a thing as a ‘generic’ application, that the recognition, consideration and appropriation of a project’s specific nuances do matter, and if these are not recognized early enough, they will inexorably raise their ugly heads later in the lifespan of a building, usually when correcting them will require exponentially increased quantities of time, effort and finance.

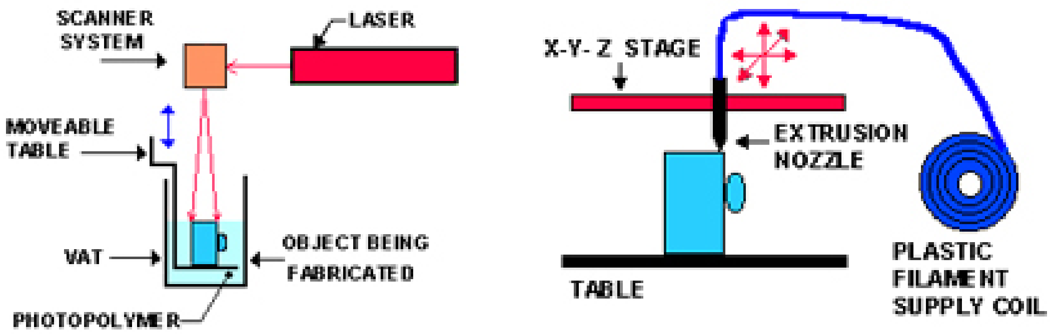
In the context of the aforementioned ‘technology’ (here interpreted in its more suggestive, utopian sense) has often been touted as the solution to the various, usually somewhat unspecified, social ills and implementation related shortcomings. However, on a directly implementational level this ‘technology’, be it the various takes of CAD (Computer Aided Design) or any of the more logistics based applications, has had only a marginal impact on the way we actually conceive, erect and realize our buildings. We’re still predominantly dependent on similar, if not the same, tools and construction mediums (cranes, scaffolding, and manual skills) that we did four decades ago, long before the ‘digital-age’ took root (http://www.freeformconstruction.co.uk/environmental_fc.htm). We still seem to be dependent on realising our three-dimensional and physical constructions based on two-dimensional technical drawing, saturated with iconic representations (abstractions) of anything from insulation to fire-hydrants; drawings through which we interpret the building to be through various standardised notion of plans, elevations and sections. At some level ‘technology’ has allowed us to up the pace of how we mechanically actualise things, be these construction drawings or even buildings, however, the means by which we do so remain more or less the same.

Alas, for those with a ‘nose’ for related matters, there’s been a distinguishable whiff of something new in the air emanating from the fringes of the associated professions over the last few years. There seems to be an evolving sense that many of the currently somewhat peripheral activities that have been taking place in the various related branches of academia and, usually more small scale, architectural practice are approaching some form of a nexus. One such node is at present known as Rapid Manufacturing.

RAPID MANUFACTURING

Raid Manufacturing (RM) is an evolved derivative of Rapid Prototyping (RP), which itself is still a relatively recent phenomenon within the design related disciplines. This process, that is a form of three-dimensional printing, is a procedure in which a virtual three-dimensional CAD model can be physically reproduced by gradually assembling the design by stacking layer onto thin, almost microscopic, layer of material (that can range from various photo-polymers, to ABS plastic, gypsum, nylon, starch, to even diverse metals) to eventually build an accurate physical replica of the initial computer based model. This technology is still predominantly used within certain sections of engineering, medicine and, within architecture, for the production of usually quite complex and detailed scale models of buildings. Similar results could potentially be achieved by other means, but it has proven to be comparatively both quicker and more precise to fabricate them through RP.

The main difference between Rapid Prototyping and Rapid Manufacturing is that whereas RP is used for predominantly conceiving a mere three dimensional representation of a design concept (that is usually used in the context of a presentation), RM aims to conceive things that are the actual, bona fide, final utilitarian thing. The technological means are still essentially the same in both RP and RM (the materials used in RM are usually more robust) only in RM the aim is to use the intrinsic pros of the processes to their advantage in the implementation of a design instead of merely creating an initial conceptual simile of a design that is to be produced by other, usually more traditional, means at a later date. The designs realized through RM use the process as a catalytic factor in the realization of the design and would be very difficult, if not impossible, to be made by any other means.



Illustrations outlining the SLA and the FDM processes

The Cons and Pros of the Rapid Manufacturing Process

Some of the current disadvantages of the RM process are:

In real time the build speed is quite slow. Depending on the required level of accuracy and the size of the design the process can take from a few hours to a number of days.

Currently there are some limits to the size of objects one is able to produce. Most commercially available machines can still only fabricate items within a roughly five-hundred millimetre cubed volume. There are, however, already a number of exceptions to this rule.

The number of materials available for additive RM is still somewhat limited, particularly in comparison to those appropriate to CNC-milling (a routing based subtractive process). Again, however, the number of suitable materials specifically designed for the various RM processes is increasing rapidly.

The final surface quality usually needs some secondary finishing, this applies in particular to smaller, tangible, objects in which finishing is of more importance.

The completed piece is usually structurally less sound compared to a cast component (Kwon 2002). Although, yet again, there are already some exceptions to this generality.

Some of the advantages of this procedure are:

Direct generation based on digital data, without the errors arising from a tradesman's interpretation of the designer's drawings (http://www.Ennex.com/~fabbers/intro.asp).

Ease of iteration. Part of a design can be changed and the object re-fabricated without the need to redo the design of the entire object (http://www.Ennex.com/~fabbers/intro.asp).

Accuracy and repeatability of dimensions on the order of 25 to 250 microns (http://www.Ennex.com/~fabbers/intro.asp).

The ability to produce complex and detailed three-dimensional forms. The additive process allows for deep undercuts as well as features such as building pieces within (even enclosed) other pieces ('Ship in a Bottle' structures), properties that would be very difficult, if not impossible, to produce directly by any other means.

Reduce lead times for unique parts Unlike in many machining operations, no jigs, moulds, or other external support devices are needed to fabricate the object (Callicott 2001: 144).

As most RM processes are completely enclosed, thus producing very little noise and waste, a clean production environment is produced that allows for the installation of the machines into non-industrial environments (Callicott 2001: 144).

TOWARDS PROTEAN TENDENCIES

There is also a financial argument for why the above notions are of importance. As our own desires are gradually progressing towards more and more personalised realm, our means for realising and accommodating such cravings need to keep pace. Or as the two Swedish economists below argue:

"Those who lack the capacity and willingness to make sense of fragmentation – to operate in an institutional vacuum of increased individualism – will have a tough time. They simply will not possess the adaptive capacity so vital for success in a fast-changing world. Both attitude and adaptability are central.

People lacking such 'protean' capabilities, as sociologist Robert Jay Lifton calls them (referring to the Greek sea god Proteus who could take any shape at any time) will be at a huge disadvantage. […] Power is being transferred from the rule-takers to the rule-breakers and the rule-makers." (Ridderstråle and Nordström: 46-47)

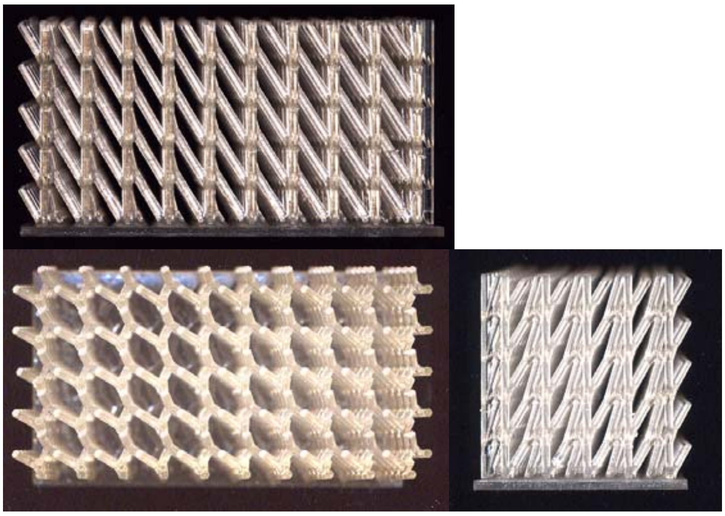
It is here, in the context of the aforesaid (quoted from a book dealing with current emerging socio-economic conditions), that Rapid Manufacturing enters the picture and gains significance. Assuming the suggestive quote above is even partly accurate, RM could provide a proposition by which such 'protean capabilities' can be achieved. With enough forethought, RM has the processes and tools by which such preordained variableness of individualistic fragmentation could be understood and realized. If our built (designed) environments are a manifestation of us as a collective of individuals, RM could provide a venue for how the things we make can become reflective of such individualism. RM already has the structures available to accommodate such parametric variability.

PARAMETRIC DEXTERITY

Some of the distinguishing qualities innate to Rapid Manufacturing are pivotal in the aforesaid assumptions:

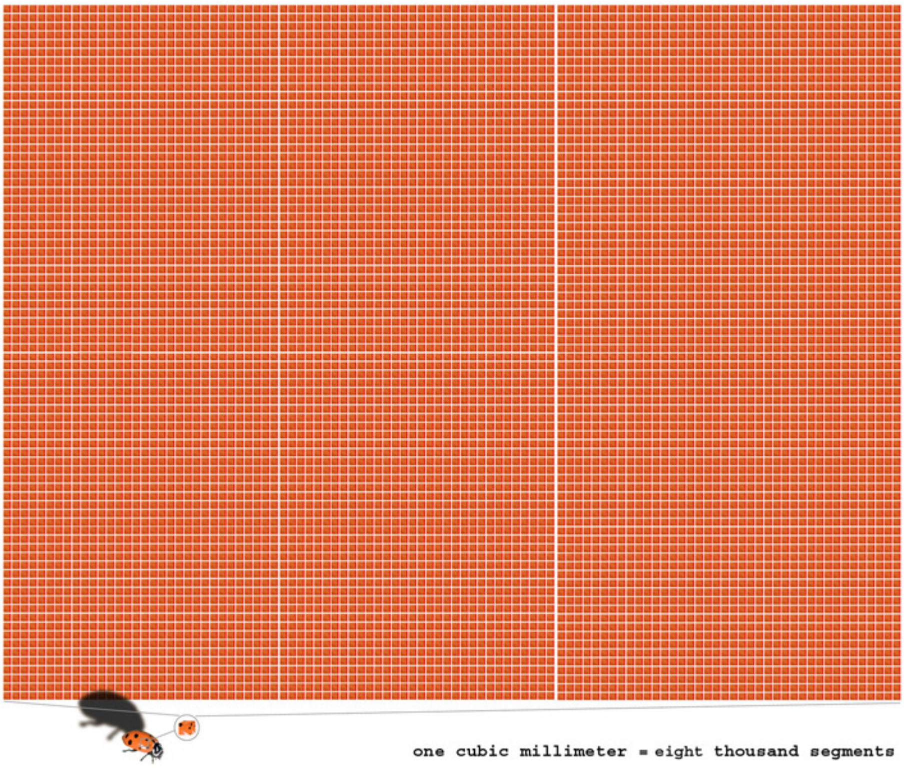
Firstly, through the RM mode of fabrication one can manipulate a (RM) material at a remarkably minute and accurate level. For example, in stereolithography, a process in which a photo-sensitive resin is cured by a laser, the machine's default resolution is a twentieth of a millimeter. This entails that if one was to make a millimeter cube (smaller than a pin-head) it could potentially be consistent of up to eight-thousand variable components. This fact introduces a whole new setting for how a design can be formulated and actualized. At this scale, which mostly surpasses beyond our somatic sensory perception, one can actually begin, not only to apply, but to design, a texture. Also, by being able to control elements at this minute scale one can actually begin to design the qualitative material properties of the design instead of having to 'collage', connect and shape different materials to fulfill the same function.

This means, for example, that if one, say, defines one of the core building components of a design as a minuscule ‘rod’, and by allowing such minute rods in a tessellated RM matrix to be thicker in one direction and a bit thinner and longer in another, or by angling the fibers into or away from the expected direction of impact, one can allow the physical model to have more strength in the one direction and more flex in the another (Assuming the innate properties of the used (RM) material allow for this). Or, by adjusting the 'density' of the tessellated matrix (the size of, and distance between, the nodes), one can control the 'solidity or how 'porous' this particular locale of the design would be. Also, by, say, connecting and shaping the fibers of this 'digital-shrubbery' to follow a weaved, spiraling, spring-like, pattern, one can provide the design with a controllable 'bounce' (or a degree of 'softness'). An early sample of such a responsive and variable structure can be seen below. Initial attempts at such minute manipulations have already been attempted and partly attained by a project done in conjunction with relevant strands of research pursued at the University College London(Hanna, S and Haroun-Mahdavi: 2004).



A tessellated variable cube, built and reflective of, the particulars of the stereolithography process and a set of simulated external constraints. The project was developed in conjunction with Siavash Haroun Mahdavi and Sean Hanna of University College London who where responsible of the programming that guided the process. The sample was built by Rapidform, London.

Now, the logistics and taxonomies guiding such metadata (data about data) is, suffice to say, a separate subject in itself (dragging an vast number of subtopics in its wake), however, the means by which one would control the arrangement of such immense amounts of data that realizing this type of design would involve would be managed by various linked networks of algorithms (Genetic Algorithms, Cellular Automata) (http://www.uel.ac.uk/ceca, as well as various simulation and optimization programs (Finite Element Analysis, Computational Fluid dynamics).



Eight-thousand manipulative components in an area smaller than a ladybug

Secondly, there is no need for templates or formwork in the Rapid Manufacturing mode of fabrication. For the RM machines it is irrelevant if two consecutively produced designs or components of a design are the same or different – if the variable design's volume and resolution remains roughly the same the technology can handle each with equal ease. Here, when considered within the context of RM, time and cost related restraints aren't an issue. This means that realizing a design is mainly limited by our own ingenuity.

Thirdly, even though the RM means of conceiving a design have a foot in both the digital as well as the analog world (a distinct advantage to most other digital, purely CAD, based modes used today for conceiving things), entailing that a number of degrees are removed between the conception of an idea and its realization, the fact remains that the resulting product, in its completeness, is also going to manifest itself as a purely digital data file. This means that the design can be, either wholly or partially, reproduced without any excessive interventions from secondary parties.

Also, as the technology is already somewhat generic (the RM machines can already be bought through relevant retail outlets) the production, or reproduction, of designs through the RM means aren't necessarily locale specific. A file can be produced in London, swiftly sent through broadband to Madagascar where it can be immediately fabricated without the involvement of intermediaries. This factor also means that no, say, spare parts would be needed in hard to reach places as only having a RM machine and some of the pertaining material would allow one to 'print' out any needed components directly. All one would need is a hard drive with all the various potentially needed spares saved as three dimensional digital files that could then be fabricated according to need.

By conceiving a design through the modus of RM a whole new realm of conception and fabrication related 'nuances' are introduced.

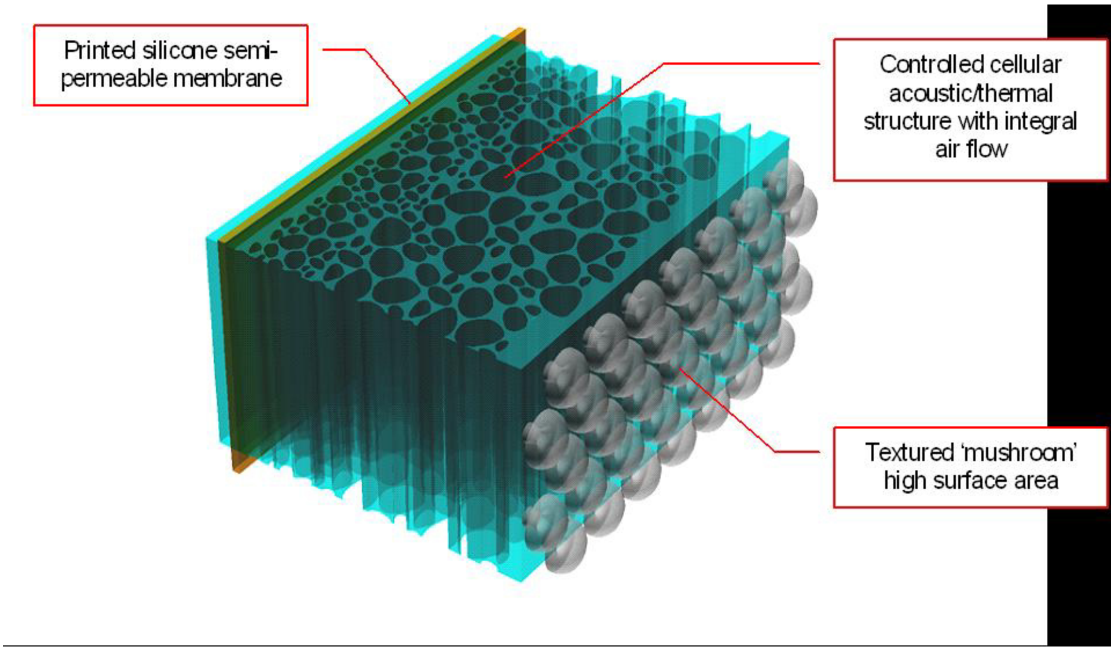
RAPID MANUFACTURINGED DESIGNS

How such matters can be formulated and implemented is provided, in brief, by the two included examples below. The initial one, devised at the Rapid Manufacturing Unit at Loughborough University, is a homeostatic wall unit that in one comprehensive go would provide all the required services and various material properties required through a singular monocoque build. The second example included is of an epidermal surface design titled 'Design Ground'. This design allows one to, through the use of a simple predetermined and intuitive 'tactile-iconography', create a customized surface that can be 'read' solely by the means of touch. Both of the included examples would not be practical to produce, due to the needed parametric variability, through any other means than Rapid Manufacturing.

HOMEOSTATIC WALL

The notion of a Homeostatic wall is one constituent of the more encompassing notion titled an 'Optimised Structure', a term used to describe a means through which a design can be realised, through the use of a single or limited amount of materials, that fulfils all the requirements of a structure - its tectonic considerations, its various services – that would all be fabricated in one go. This means that the various types of piping and ducting, even the integrated wiring and optical distribution systems, could be 'printed' simultaneously into epidermis like walls. How such various, potentially conflicting, chores would be distributed and synchronised would be determined by Computer Aided Optimisation or Metamorphic Development techniques with solid CAD (UG/ProE) software (http://www.freeformconstruction.co.uk/integration.htm).

The project is also partially inspired and derived, as the heading suggests, by various biomimetic factors, diverse dynamic systems found in nature. In this instance the workings of various termite mounds have been of particular relevance. The structure they build, within the mound, is so innately autonomous that it is able to regulate and control their environment even beyond the levels we currently expect from our own heating and cooling systems, and they achieve this without the use of any external power sources. In effect, these termites have evolved a construction method so advanced that it can control its internal environment to within fractions of a degree, regardless of how much the external environment is fluctuating (http://www.freeformconstruction.co.uk/fc_structural_homeostasis.htm). The aim is to appropriate such quite remarkable accommodating and responsive abilities in the structures we conceive for ourselves.



Section of the Homeostatic wall. (Image provided by Dr. Rupert Soar)

DESIGN-GROUND

Initially constructed around a design competition brief for a Swedish flooring company, this project was construed around two fundamental catalysts, firstly, it should try to conceive a digital design that does not solely rely or result in something purely visual; and secondly, to use Rapid Manufacturing as the means through which the design is realised.

The resulting creation, inspired by the various patterns formed by the multitudes of discarded chewing-gum found on the pavements on London's Exhibition Road, formed a tactile epidermis, a surface into which various haptic (cutaneous) relief-like signs could be embedded (somewhat similar to Braille), that could be used to both inform and insinuate various features or qualities found in the environment. For example, if the surface was shaped in a scale-like manner (as in the scales of a fish or snake) one is immediately provided with a texture that is smooth in one direction, rougher, or more resistant, in the other. Such a binary differentiation can immediately be used to fulfil a number of functions. It could be applied in, say, hospitals, hotels or airports to function as a tactile tool to inform people where the closest fire exits would be. In limited visibility, if the air is full of smoke, all one would have to do is pull ones foot (or hand) over the surface, and follow the least resistant texture to the nearest fire escape. This texture could also easily be inlaid with additional, more subtle, clues for how to proceed as well as with other environmental information - tactile dots to measure distances; make the surface texture more or less coarse to suggest how fast or slow someone should, or can, move, etc.

Even though the principals guiding the design are simple, the parametric applications of the various textural and information based layers make it almost infinitely variable. It would be close to impossible to realise this design by any other means than Rapid Manufacturing. The design is currently in its initial testing phase.

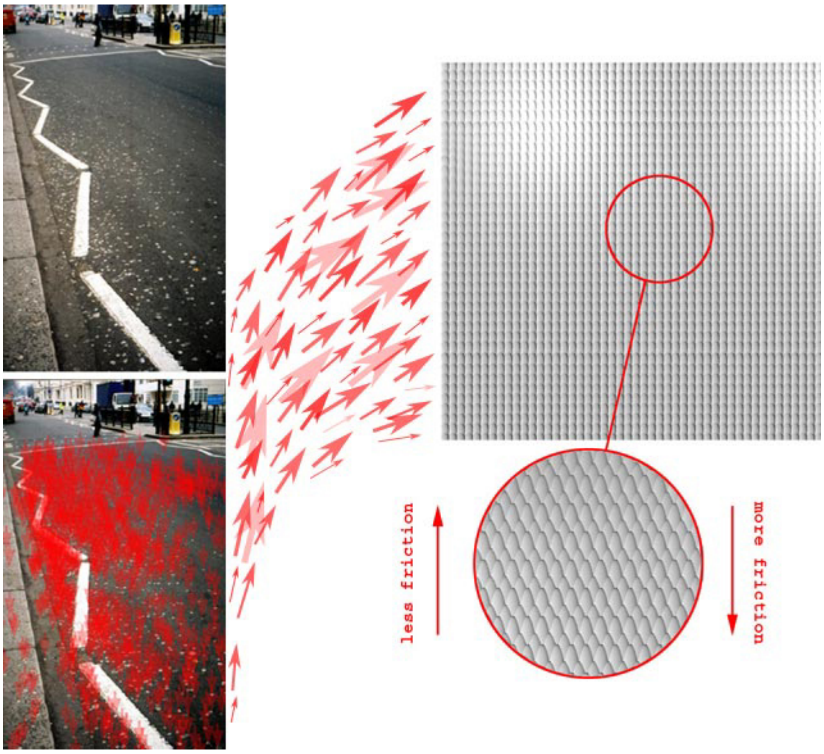


Illustration of the project catalysts - the patterns of chewing-gum on London's Exhibition Road.

CONCLUSION

As laudable as the aims suggested by the combination of such seemingly contradictory terms as ‘ubiquitous’ with ‘customization’ are, the implementation of any more involved bespoke a design inevitably entails the need for a modicum of control, usually manifesting itself through a limitation of dissimilarity, that, nevertheless, often has a habit of superseding the end aim of producing a successful customized product. Alas, idiosyncrasy always seems to hide in the corners of even the most generically applicable, researched and market tested creations.

Rapid Manufacturing as a means for both conceiving as well as fabricating something designed (for inescapably everything we do, for better or worse, is designed) introduces a paradigmatic shift in the way one can approach the whole process of actualizing a design. By streamlining and enmeshing the phases between initial tentative conception of an idea, and its final conclusive actualisation, that includes intrinsically all logistical, financial, hierarchical considerations, the process becomes more comprehensive in its formulation. The allowance for variability is an innate factor in this means of creation. By being a digital process that is intrinsically linked to (a or its) physical outcome, a number of intermediate manufacturing stages separating the idea from the final end result are removed Here there is no call for any type of batch production as the RM means allows each individual design produced becomes, in a way, its own ‘batch’.

The (not too distant) future prevalence of Rapid Manufacturing, regardless of how convoluted or altered it might appear, in whatever composite hybrid form, is guaranteed. The question is, are we going to be prime movers or vassals in the process? Originating and idea, the foundations and means for doing something in a certain way, is always difficult, and requires copious and ceaseless quantities of faith in notions that usually, at least initially, are not much more than intuitive suggestions.

How receptive we are to this and similar branches of still evolving technologies will ultimately determine our position and role in a more and more knowledge based world. To embrace something that is still being defined on a fundamental level is simultaneously a risk and an opportunity. Alas, the (still somewhat dormant) potentials of Rapid Manufacturing are too tempting to resist, and partaking in the creation of something of significance is a rewarding process in itself. One must only hope that such opportunities have a chance to bloom and that the fertile grounds for related memes (idea viruses) to germinate will continue.

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