ALGORITMOS, FORMATIVIDAD Y ABSTRACCIÓN PARAMETRIZADA

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Las herramientas informáticas aplicadas a la arquitectura o simplemente a lo gráfico, en su estadio más avanzado, permiten desarrollar geometrías generadas a partir de lenguajes de programación, lo que supone una modelización no gráfica sino paramétrica de las mismas. Es el caso de lenguajes desarrollados dentro de programas como Rhino, Autocad o 3dMax, como son el Rhinoscript, el Autolisp o el 3dMaxScript respectivamente, o lenguajes como Processing. Dichos lenguajes de programación son, en realidad, metalenguajes porque aún teniendo su propia gramática y lógica internas están orientados hacia la manipulación, edición y desarrollo de lo gráfico como representación e ideación de la arquitectura.

La utilización de ***algoritmos*** para definir estructuras formales y geometrías complejas ha irrumpido como un nuevo campo dentro de la arquitectura digital, un campo distinto de lo que tradicionalmente se presuponían como cuestiones básicas para el diseño arquitectónico. Kostas Terzidis **1** se ha referido al uso de algoritmos en el contexto de la arquitectura de la siguiente forma:

> Algorithms can be used to solve, organize, or explore problems with increased visual or organizational complexity. In its simplest form, a computational algorithm uses numerical methods to address problems [...] ramdom variables or conditions can be inserted into an algorithm, further increasing the degree of unpredictability of the final outcome and magnifiying the level of complexity. Contrary to common belief, algorithms are not only deterministic processes developed to explain, reason, or predict a humanly conceived problem, but can become venues for addressing complexities that exceed human ability to explain, reason, or predict.

Los algoritmos en arquitectura pueden ser utilizados para aprovechar la potencialidad de los ordenadores para barrer una casuística imposible de abordar con las limitaciones inherentes al ser humano. Obviamente no resuelven los proyectos de forma automática, pero pueden emplearse para desarrollar y explorar infinidad de soluciones formales. En este sentido la utilización de algoritmos entraría de lleno en lo que denominamos ***conciencia digital***. María Fullahondo **2** se ha referido con este término al uso de las herramientas digitales no como simple sustituto de las tradicionales herramientas de dibujo y representación de la arquitectura, sino como nuevo paradigma en la consecución del lenguaje arquitectónico:

> Probablemente, desde el nacimiento de la perspectiva, no haya existido ninguna época en la que la herramienta utilizada condicione la producción arquitectónica de una manera tan determinante.

La representación del espacio arquitectónico desde el Renacimiento ha influido enormemente en la consecución del propio lenguaje arquitectónico; la perspectiva o la imprenta han sido dos descubrimientos que revolucionaron dicho lenguaje de forma considerable. En este sentido, la concepción del espacio como receptáculo con cualidades propias del espacio geométrico ha determinado buena parte de la producción arquitectónica a lo largo de los siglos hasta fecha muy reciente. Kerchove y Tursi **3** se referían a esta cuestión en los siguientes términos:

> However, to understand time as composed of aligned, regular elements and space as a void and neutral container required a process of significant abstraction of the

1 / TERZIDIS, Kostas, *"Algorithmic Complexity: Out of Nowhere"*, en *Complexity. Design Strategy and World View*, Ed. Gleiniger, Andrea y Vrachliotis, Georg, Birkhäuser Verlag AG, Berlin, 2008, p. 79.

2 / FULLAONDO, María. *Conciencia digital*. XI Congreso Internacional EGA, Sevilla 2006.

3 / KERCHOVE, Derrick y TURSI, Antonio, *"The Life of Space"*, Architectural Design, V. 79, I. 1.

bodily experience. Not the body in terms of the totality of its senses, but as that part of it that defines what it sees –the eye– has determined the experience of modern man. Perspective represented an immediate demonstration of the working of this process of abstraction, based as it was on the complete mathematisation of space. In this way, it established an indisputable "symbolic form".

Una concepción más moderna del espacio –la que ha caracterizado la modernidad arquitectónica durante el siglo XX y quizás está ahora consiguiendo una mayor identificación con la arquitectura reciente– está ligada a la idea del espacio como campo, como sistema dinámico, permanentemente permeado por líneas de fuerza, y por una ligazón mucho más estrecha con el tiempo, esto es: por el propio devenir que caracteriza la existencia del mundo material. La arquitectura parametrizada puede constituir un nuevo paradigma en la concepción del espacio arquitectónico y es probable que establezca una mayor afinidad con dicha concepción espacial. Así Kerchove y Tursi **4** describen este cambio de concepción como sigue:

> Space is no longer an empty and neutral container that can be described on a flat surface using the arithmetic-geometric relations of perspective. Rather, it is continuously generated and regenerated by the networks that structure it, by the conflicts that vivify it, by the living beings that inhabit it. This new definition of space is naturally tied to the development of 20th–century physics and its notion of the 'field': space becomes a field of forces and counter forces, a field that emerges from the actions taking place within it.

La formalización de geometrías generadas a partir de algoritmos puede asumir más nítidamente una caracterización dinámica del espacio, y con ello una representación arquitectónica de la idea de espacio como campo o del propio espacio-tiempo de la física moderna. Marcos Novak ha acuñado el término ***transarchitectures*** refiriéndose a ese nuevo imaginario arquitectónico generado en el ciberespacio, una nueva frontera a explorar dentro de la arquitectura: acaso una nueva abstracción formal que nace de la propia arquitectura. Novak **5** ha escrito en los siguientes términos respecto a la parametrización de la geometría arquitectónica definida a partir de algoritmos (las imágenes anteriores de Marcos Novak se refieren a este texto):

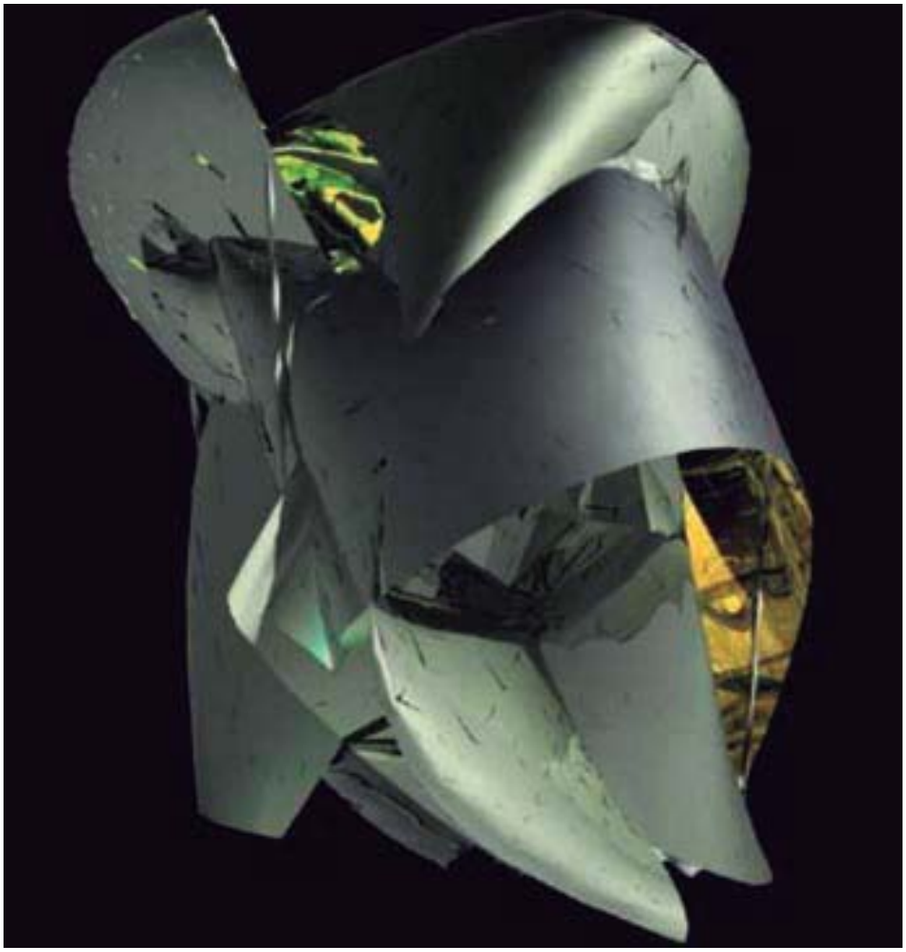
Marcos Novak, *Trans Terra Firma*, 1995.

> The algorithm that produces these forms works as follows: data is interpreted as two sets of points in 3D space in bodyspace, an instance of output of the algorithm becomes a form of a material architecture [...]

Esto supone otro paso más en la evolución del lenguaje arquitectónico bastante radical que deviene de lo digital. Y no nos referimos a la relación entre el dibujo de ideación y las posibilidades ilimitadamente plásticas del modelizado tridimensional. En efecto, en este caso la editabilidad como propiedad de lo virtual deriva de su inmaterialidad. Las construcciones virtuales son ilimitadamente plásticas en la medida en que su constitución a partir de *bits* no es material y por ello, sus formalizaciones sólo adquieren existencia real durante el tiempo en que el código es ejecutado por un programa de ordenador. Por esa misma razón, los programas de dibujo informatizado están en cierto modo limitados para el arquitecto que los utiliza porque no tiene acceso directo al código del lenguaje que viene desarrollado por otros. Interponen una cierta distancia entre el arquitecto y el objeto de su diseño –tal vez la distancia que molesta a Gehry–; el arquitecto no puede controlarlo con la naturalidad a la que estaba acostumbrado con los medios convencionales. Polyxeni Mantzou **6** subraya este problema:

> El hecho de que el arquitecto depende de otros para suministrarle medios para proyectar [*software*], es decir, se encuentra alejado de la creación y la estructuración de un nuevo metalenguaje el cual sirve como base para su trabajo, crea una nueva condición de distanciamiento, igual de importante como aquella que en el pasado le apartó de la obra y le trasladó al estu-

4 / KERCHOVE, Derrick y TURSI, Antonio, *"The Life of Space"*, Architectural Design, V. 79, I. 1.
5 / NOVAK, Marcos, *"Transarchitectures and Hypersurfaces: Operations of Transmodernity in Hypersurface Architecture"*, AD, 133, 1988.
6 / MANTZOU, Polyxeni y BITSIKAS, Xenofon, "*Proyectar en la era del código digital"*, Actas Congreso Internacional EGA XII, Madrid, 2008, p. 490.



Marcos Novak, *Data Driven Forms*, 1997-1998.

dio. El dibujo como lenguaje ha estado enteramente en las manos del arquitecto mientras que el *software* puede ser abierto a la utilización pero viene como un lenguaje hecho por otros y a cuya estructura él no tiene acceso.

En los programas convencionales de C.A.D. el arquitecto dibuja y modeliza virtualmente en la pantalla del ordenador el objeto arquitectónico que está diseñando. La pantalla es, pues, un interfaz que grafía su objeto arquitectónico según va cobrando forma y es lo que se interpone entre el arquitecto y su objeto de diseño. No puede ser de otra forma por la virtualidad implícita en el proceso. No obstante, el arquitecto *dibuja en 2D*, o *construye modelos 3D*, y lo hace *sobre* la pantalla del ordenador introduciendo órdenes ya sea a través del teclado o por medio del ratón (y en el futuro próximo por otros procedimientos actualmente en fase experimental).

Sin embargo, los programas que permiten escribir códigos que se transcriben gráficamente, como los anteriormente citados, sí introducen una nueva posibilidad de desarrollo para la arquitectura que puede entonces ser "algoritmizada". Es decir, el dibujo no es, entonces, un acto gráfico en el sentido de correspondencia entre la orden dada al ordenador (trazado de huellas) y lo que éste grafía en la pantalla (soporte). El dibujo es una formalización de un código que se ha escrito en un lenguaje informático capaz de generar dibujos parametrizados. En su breve pero conciso texto, *Algorithmic Architecture,* Terzidis **7** se ha referido a este salto cualitativo en el proceso de diseño en los siguientes términos:

> By using scripting languages designers can go beyond the mouse, transcending the factory-set limitations of current 3D software. Algorithmic design does not eradicate differences but incorporates both computational complexity and creative use of computers. For architects, algorithmic design enables the role of the designer to shift from "architecture programming" to "programming architecture"[…] For the first time perhaps, architectural design might be aligned with neither formalism nor rationalism but with intelligent form and traceable creativity.

Esto sí que es una revolución de revoluciones porque los *scripts* son tan abstractos como puede ser el lenguaje que utilizamos para comunicarnos y, al menos en este sentido, podemos hablar de ***abstracción parametrizada***. La "arquitectura algorítmica" puede ser considerada, pues, como el estadio más avanzado en el ámbito de la utilización de herramientas informáticas aplicadas a la ideación arquitectónica. En cierto sentido constituye una *abstracción* de la abstracción.

En efecto, la inevitable mediación del dibujo o incluso de la modelización tridimensional –como maquetación en el espacio virtual– introduce una distancia entre el arquitecto y lo diseñado pero éste tiene un control de algo que se materializa en una forma –aunque sea en la pantalla del ordenador por medio de la cual se puede visualizar la forma–; el control sobre la forma de lo diseñado es formativo y equivalente a lo que sucede cuando se utilizaban medios de representación gráfica convencionales; es decir, cambia la herramienta pero el proceso de

diseño es equivalente. La consecución de la forma implica en estos casos un desarrollo formativo en el que lo diseñado y el autor establecen una base dialéctica que va conduciendo a la definición progresiva de la forma. Pareyson **8** escribe en este sentido:

> …cuando propongo el término "formatividad", no pretendo aludir solamente al arte como actividad de formar o a la esencia del proceso artístico en la que creo que reside el aspecto más propiamente original […] Esta teoría es la distinción-unidad de forma formante y de forma formada, por la que la obra misma, aun antes de existir como formada, actúa como formante, guiando el proceso de su formación, sin que por ello se pueda decir que la forma formante sea algo distinto de forma formada, sino que, por el contrario, son absolutamente la misma cosa.

Sin embargo, los *scripts* que generan la geometría arquitectónica no son gráficos y tampoco son materialidades plásticas. No son, por tanto, equivalentes a un dibujo o a una maqueta; esto es: no guardan una relación formativa entre el autor y lo diseñado por él, entre su propia estructura –un código escrito en un lenguaje informático– y la forma geométrica resultante. En otras palabras, el dibujo bidimensional o el modelo virtual con los que habitualmente se trabaja en los estudios de arquitectura en la actualidad no dejan de ser una ***emulación*** de las herramientas a las que el arquitecto ha estado acostumbrado: los dibujos y las maquetas. El dibujo parametrizado, en cambio, es un no-dibujo porque carece de grafía. Dennis Dollens **9** se ha referido a esta nueva herramienta nada intuitiva introducida por la arquitectura digital:

> Un impedimento para el desarrollo de una arquitectura electrónica híbrida o puramente digital es la necesidad de que los arquitectos reorienten, al menos parcialmente, la base conceptual de la arquitectura que practican; en concreto, la necesidad de que acepten la programación por ordenador como un acto de colaboración arquitectónica y de que se adapten al espacio y a la producción virtuales como lo han hecho al espacio físico en 2D y 3D. Cuando la comunión entre los procesos de proyecto y electrónico sea más firme, el acto de escribir, proyectar y utilizar un código electrónico para generar formas podrá conceptualizarse totalmente como parte del papel creativo del proyectista.

Llama poderosamente la atención el paralelismo que encontramos entre la imaginería de algunas de las propuestas de Novak y el *Merzbau* de Schiwtters (comparar imagen de Novak –*Variable Data Forms*– y la obra de Schwitters). Pero resulta más sorprendente si pensamos que las geometrías de Novak se han generado a partir de algoritmos y el Merzbau (mitad arquitectura-mitad escultura) fue construido entre 1923 y 1936 con sus propias manos, es decir, perfectamente material. Esto nos da una primera idea de que los algoritmos se dirigen formalmente, lo que explica que las investigaciones puedan "buscar" en determinadas direcciones. Es decir, el que utiliza sistemas algorítmicos no lo hace sin ningún criterio formal, sino que dirige la "investigación" formal implícita en el código o "script". Pero ¿qué es realmente un algoritmo? David Berlinski **10** lo define genéricamente:

> Un algoritmo, por decirlo de algún modo, es un grupo de reglas, una receta, una prescripción para emprender una acción, una guía, un mandato vinculado y dirigido, una adjuración, un código…

Esto significa que el algoritmo como lenguaje no gráfico es completamente ajeno a la arquitectura –al menos tal como la entendemos hoy–, es

Kurt Schwitters, *Merzbau,* 1923-1936.

Marcos Novak, *Variable Data Forms*, 1999.

7 / TERZIDIS, Kostas, *Algorithmic Architecture,* Architectural Press, Oxford, 2006, p. XII.
8 / PAREYSON, Luigi, *Conversaciones de Estética*, Ed. Antonio Machado (Visor, Colecc. La balsa de la medusa), Madrid, 1987, pp. 130-131, (Tit. Orig. *Conversazioni di Estetica*, Ed. Mursia, Milán, 1966).
9 / DOLLENS, Dennis, *De lo digital a lo analógico, Ed. Gustavo.Gili,Barcelona, 2002* (Tit. Orig. *D·2·A Digital to Analog*, Ed. Sites Books, Lumen Inc., Santa Fe, 2001)., p. 104.
10 / BERLINSKI, David, *The Advent of the Algorithm: The Idea that Rules the World, Harncourt, Brace, Nueva York, 2000,* cit por Dollens, Dennis, *Op. cit.*, p. 98.

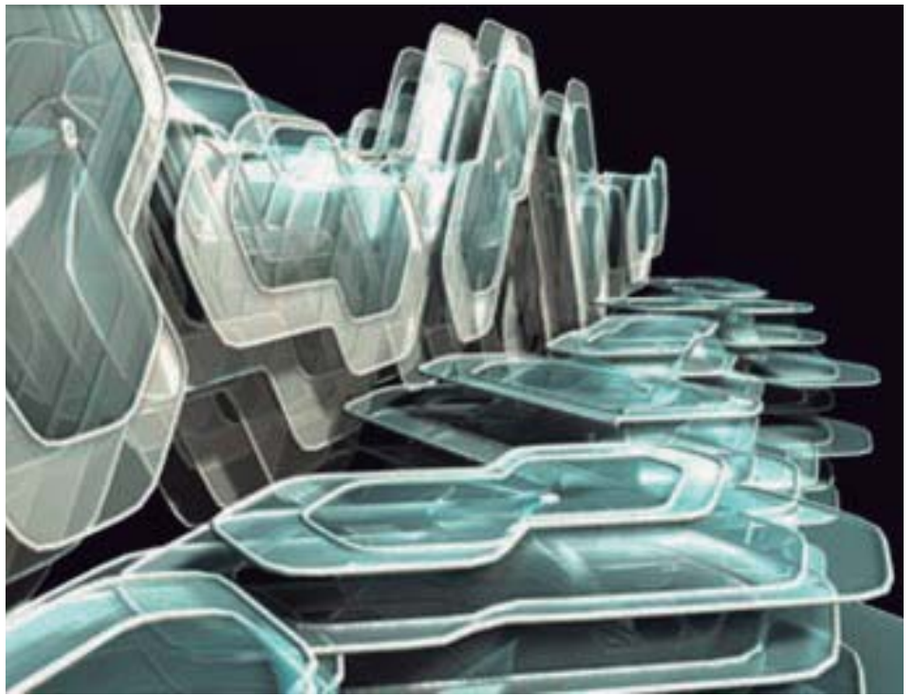
el lenguaje propio de los ordenadores y de lo ***maquínico***. Así como la máquina se asocia al mecanismo y a la repetición mecánica de la actividad para la que ha sido diseñada, el ordenador, como sistema abierto, obedece a una concepción maquínica; su constitución permite aperturas porque está basado en códigos, y éstos pueden ser todo lo distintos que se quiera, incluso pueden generar iteraciones y aproximaciones sucesivas. Guattari **11** escribe sobre esta variabilidad de lo maquínico:

> Rather than having an opposition between being and the machine [that is, between being and becoming], or being and subject, this new notion of the machine now involves being differentiating itself qualitatively and emerging onto an ontological plurality, which is the very extension of creativity of machinic vectors.

Eisenman **12** añade a esta distinción su propia interpretación en lo que se refiere a la idea contemporánea de un espacio arquitectónico que está más cerca de la idea de campo en Física:

> Thus, in architecture such a process might be iterative, might have directions and energy, and might, deal with forces and flows which could be multiple, reversible, and deformative rather than linear and transformative.

Dado que los algoritmos permiten definir estructuras formales generadas desde un código o *script* que posteriormente pueden ser grafiadas y modelizadas virtualmente, la idea de orden –necesaria en toda arquitectura– está implícita en la propia concepción estructural del algoritmo. En efecto, esta es una propiedad de los algoritmos que abre nuevas perspectivas a la investigación arquitectónica. Puede que la "mecanicidad" implícita en la lógica iterativa del algoritmo genere una cierta repetitividad pero en realidad esto sólo depende de la complejidad del propio algoritmo o de su encadenamiento con otros que puedan transformar la estructura formal definida previamente. Obviamente, una vez obtenido el modelo, el arquitecto puede manipularlo a placer y conseguir introducir en el modelo algorítmico alguna dosis de "imperfección subjetiva", acaso para dejar una leve impronta de "humanidad" en el perfectamente estructurado y repetitivo diseño.



Michael Hansmeyer, Lindenmayer Systems in Architecture (arquitectura algorítmica).

La forma parametrizada de la arquitectura introduce una variabilidad inimaginable de alcanzar por medios convencionales. Una pequeña variación en el código puede transformarse en un enorme cambio en la forma definitiva. Y lo que es casi más importante: se introduce el factor de la aleatoriedad en el diseño, lo que supone una doble paradoja. En primer lugar porque una forma aleatoria arquitectónica no tiene sentido y, en todo caso, carecería de un orden. Y en segundo lugar porque la pretensión de generar un código completamente aleatorio es una paradoja autorreferente. Kostas Terzidis **13** se ha referido a este problema del siguiente modo:

> Randomness is a term used to describe a lack of an identifiable pattern, purpose, or objective. In its formal manifestation, randomness can also be defined as a meaningless pattern. While this defini-

11 / GUATTARI, Felix, "*On machines", en The Journal of Phiilosophy and Visual Arts,* no. 6 ("Complexity"), ed. Andrew Benjamin, cit. por Eisenman, Peter, *Written into the void: selected writings,* 1990-2004/Peter Eisenman.
12 / EISENMAN, Peter, *Written into the void: selected writings,* 1990-2004/Peter Eisenman, p. 57.
13 / TERZIDIS, Kostas,, *"Algorithmic Complexity: Out of Nowhere",* en *Complexity. Design Strategy and World View*, Ed. Gleiniger, Andrea y Vrachliotis, Georg, Birkhäuser Verlag AG, Berlin, 2008, p. 75.

14 / TERZIDIS, Kostas, *Op. cit.*, p. 76.

tion can be applied to the description of a pattern being random, it becomes problematic when it is applied to the act of creating a random pattern. The claim itself involves a self-referenced paradox: how can one create something that is meaningless? Wouldn't the mere act of creation assign meaning automatically? […] In other words, the creation of randomness involves intention, which is contrary to randomness. However peculiar this may sound, by definition one cannot create randomness.

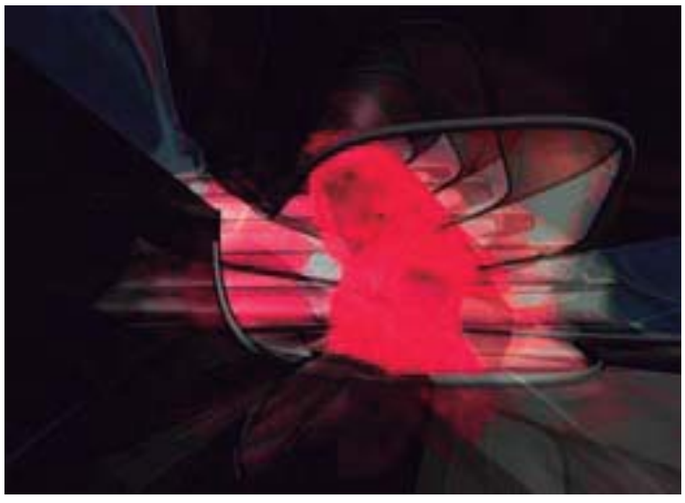
Así, los algoritmos que desarrollemos pueden crear una cantidad enormemente variable de formalizaciones pero todas ellas estarán gobernadas por un cierto orden que se deriva del propio algoritmo, de su estructura intrínseca. Las formas que genere el algoritmo tendrán algún sentido, estarán orientadas en una línea de investigación formal y por lo tanto tendrán un orden en común. Kostas Terzidis **14** ha relacionado complejidad y aleatoriedad del siguiente modo:

Complexity, as defined earlier, is associated with randomness as follows: if a pattern is very regular, it is easy to describe, and so it is simple. In contrast, if it is irregular, then it is difficult to describe, and so it becomes complex. If it is so complex that the information it contains cannot be compressed at all, we say that it is random. So randomness is characterized as the maximum of complexity, and the opposite of regularity and simplicity.

Sin embargo, la relación que establece entre aleatoriedad y complejidad Terzidis no es necesariamente biunívoca. Los algoritmos como operadores de la forma pueden generar geometrías enormemente complejas en tanto que su grado de aleatoriedad sea mayor. Pero no todo lo complejo tiene porqué medirse en términos de aleatoriedad; podemos encontrar arquitecturas complejas cuyo orden y cuya regularidad sea más o menos sencillo. La propia arquitectura de la molécula de ADN está basada en la combinación de 4 elementos que constituyen la base nitrogenada **15** –el eslabón básico dentro de toda la cadena– que repetidos de forma sistemática alterando su orden pueden definir algo tan complejo como la constitución de un ser humano.

Eisenman **17**, por su parte, se ha referido a la hipercomplejidad en la definición del espacio arquitectónico generado a partir de estrategias de *spacing* reconociendo la dificultad implícita en la explicación de conceptos como ***spacing*** o ***conceptual blurring***, y así escribe:

La complejidad normal puede entenderse a través de la consistencia lógica. Un cubo es una forma simple, pero un paraboloide hiperbólico es una forma más compleja. Requiere una explicación más compleja. La hipercomplejidad es algo que no se puede explicar a través de la complejidad normal, de las ecuaciones lógicas matemáticas. El espaciamiento puede ser explicado, pero requiere un nivel de complejidad que no se encuentra en las geometrías convencionales. Es ya otro nivel de descripción.



Michael Hansmeyer, Lindenmayer Systems in Architecture **16** (arquitectura algorítmica).

15 / En realidad las unidades básicas están precedidas por un azúcar –desoxirribosa– y sucedidas por un fosfato que sirven de enlaces respectivos con los sucesivos eslabones dentro de la cadena. Dado que el azúcar y el fosfato no cualifican el eslabón sino que son las piezas de enganche necesarias únicamente los 4 elementos (adenina, timina, citosina y guanina –A,C,T,G–) determinan la cualidad del eslabón, a su vez su posición y su constitución dentro de la cadena determina la calve genética contenido en el código.

16 / http://www.mh-portfolio.com/ (visitado el 10_05_2009).

17 / EISENMAN, Peter, "*Procesos de lo intersticial*", El Croquis: Peter Eisenman 1990-1997, 83 , 1997, p. 30.

18 / "In a similar, almost humorous fashion, the *Dada Engine* is a computer algorithm that produces random text based on recursive rearrangement of elements in a grammar. The resulting text, while allegedly based on random processes, is readable, occasionally makes sense, and is sometimes surprisingly intelligent", Terzidis, Kostas, *Op. cit.*, p. 77.
19 / LEACH, Neil, *"Digital morphogenesis",* Architectural Design, V 79, I 1, p. 34.
20 / LEACH, Neil, *Op. cit., Ibidem.*
21 / NOVAK, Marcos, *"Transarchitectures and Hypersurfaces: Operations of Transmodernity in Hypersurface Architecture",* AD, 133, 1988, p.89, cit. por Dollens, Dennis, *Op. cit.*, pp.110-111.

Marcos Novak, *Turbulent Topologies,* Istanbul, 2008.

Aparentemente la complejidad de los sistemas algorítmicos no tiene límite. Las formas que podemos manejar, por tanto, tampoco lo tienen. La aleatoriedad y la complejidad son lo opuesto a la regularidad y a la simplicidad, lo que significa que la sencillez que la modernidad imponía en la arquitectura como paradigma miesiano no es un valor propio de este tipo de arquitecturas. La variabilidad de la forma está ligada a un determinado factor de aleatoriedad. Considerando que el algoritmo es un código que está diseñado con arreglo a un patrón, a un determinado orden, puede servir también como investigación formal en sí misma aprovechando la enorme capacidad maquínica de los ordenadores para procesar códigos y obtener resultados. De este modo, podemos explorar muchos campos con arreglo a unos parámetros de partida que nos ayuden a formalizar el proyecto. Como el ordenador es capaz de producir una innumerable cantidad de resultados la labor del arquitecto será entonces la de alguien que elige y desecha lo que el ordenador produce. Al igual que la *Máquina Dada* **18** es capaz de generar un sin fin de frases articuladas correctamente desde un punto de vista gramatical –la mayoría de ellas sin sentido– habrá algunas de todas ellas que –por casualidad combinatoria– tengan significado. De modo análogo, el diseño parametrizado introduce en la arquitectura la oportunidad de resolver problemas que superan la capacidad de análisis de las personas en el tiempo.

De este modo, el papel del arquitecto pasa a ser el de analizar y evaluar la geometría obtenida más que el de generar directamente la forma arquitectónica. Y es en este sentido en el que el control de la forma deja de ser formativo dado que el arquitecto confía en la capacidad maquínica de los ordenadores para encontrar soluciones formales utilizado estrategias proyectuales basadas en procesos de ***form finding***. Neil Leach **19** se ha referido a esta cuestión en el ámbito de la *morphogenesis:*

> Used initially in the realm of biological sciences, the term refers to the logic of form generation and pattern-making in an organism through processes of growth and differentiation. More recently it has been appropriated within architectural circles to designate an approach to design that seeks to challenge the hegemony of top-down processes of form-making, and replace it with a bottom-up logic of form finding. The emphasis is therefore on material performance over appearance, and on processes over representation.

Desde un punto de vista literal –el análisis de ciertas formas de la naturaleza y la apropiación de dichas formas como optimización de la forma ante un determinado problema por parte de la arquitectura– escondería tras de sí una cierta dosis de figuración en tanto que imitación; dicha actitud entra de lleno en lo que se ha dado en llamar *Biomimetics* **20**. Pero si es el orden de la naturaleza el que se pretende imitar, es decir, su capacidad para elaborar patrones de formación, entonces el camino está más próximo a la abstracción a partir de la preexistencia, a partir del referente material que encontramos en la naturaleza. La ***morphogenesis,*** bien entendida y aplicada a la arquitectura entraría así en el ámbito de la arquitectura algorítmica como copia de los modos de hacer de la propia naturaleza y no de la copia literal de la forma natural por la pura forma o de ésta como fuente de belleza.

De esta manera, nos encontramos ante un nuevo reto que consiste en generar algoritmos que puedan tener sentido arquitectónico en algún contexto y de este modo abordar la arquitectura partiendo de la base de que hay un cierto grado de arbitrariedad en la elección de la forma de ésta tal y como han sostenido Tafuri o Moneo. Marcos Novak **21** habituado como está al empleo de algoritmos para definir sus *transarquitecturas* escribe:

> Construyo maquetas matemáticas y procedimientos generadores que están limitados por numerosas variables sin relación inicial con preocupaciones pragmáticas […] Estos modelos son matemáticos y algorítmicos. Si la maqueta se alimenta de datos temporales, la forma se vuelve animada, la arquitectura líquida […] Una vez que la arquitectura de los objetos se ha apartado a favor de una arquitectura de relaciones, los conceptos de hiperespacio e hipersuperficie se vuelven naturales.

El problema, pues radica en cómo articular el algoritmo para que la forma tenga sentido arquitectónico. Es cuestión de tiempo el que la programación se convierta en una herramienta más del proyecto. La capaci-

22 / TERZIDIS, Kostas, *"Algorithmic Complexity: Out of Nowhere"*, p. 79.
23 / MARCOS, Carlos L., *Espacio material: la arquitectura como extensión topológica*, Tesis Doctoral, E.T.S.A.M., 2009.
24 / PALLASMAA, Juhani; *Los ojos de la piel*; G. Gili; Barcelona; 2006; (Tit. Orig. *The eyes of the skin*, Wiley-Academy, Chinchester (West Sussex), 2005), p. 43.

Tarbell J., City Traveler Variation A, Enero, 2004 (sketched with Processing).

dad de los ordenadores de "buscar" soluciones formales a partir del desarrollo de algoritmos es enormemente ágil; contra ella no podemos competir. Sin embargo la capacidad de discernimiento de los ordenadores, hoy por hoy, no está muy desarrollada. Una serie de investigaciones formales desarrolladas a partir de un determinado algoritmo debe ser analizada críticamente por el arquitecto. En este sentido Terzidis **22** ha escrito:

> Dannenberg and Shusta developed an algorithm that produces all possible combinations of skyscrapers for a given site. Their strategy involves physical and geometric parameters to script a computer modelling code that builds, renders, and organizes an infinite number of skyscrapers possibilities, from which emerges a formal pedigree categorized in texture and performance. What is remarkable about this –or any other combinatorial analysis– is that they are able to produce computationally any possible form ever created or any yet to be created.

En suma, los algoritmos nos proporcionan una posibilidad de manejar niveles de complejidad superiores a los que seríamos capaces de resolver por medio de estrategias proyectuales convencionales. La imposición de la forma por parte del diseñador contrasta con la enorme variabilidad de un sistema generativo basado en los algoritmos que, al igual que los diagramas de Eisenman, es un sistema que implica ***apertura***, pero a diferencia del proceso de extracción de la forma desde el ***diagrama*** en el caso de Eisenman, el ordenador tiene una capacidad virtualmente ilimitada de generar formas a partir de algoritmos dependiendo del nivel de complejidad que éstos contengan y su grado de variabilidad o aleatoriedad.

En todo caso, la arquitectura, una vez construida seguirá siendo una **extensión topológica** definida por un **espacio material 23,** y la experiencia sensorial que de su vivencia se deriva resulta y resultará insustituible. Por mucho que evolucione la tecnología y varíen las formas que estamos habituados a ver en la arquitectura los invariantes del lenguaje de ésta seguirán formando parte de ella. Así, la arquitectura del futuro no podrá obviar el problema del orden, o de la escala, o la relación entre el espacio y la materia que lo conforma, todos sus elementos seguirán estando "cohesionados" por el campo gravitatorio terrestre o su ineluctable verticalidad, arrancará del suelo de una u otra forma, habrá de protegernos de los meteoros, deberá relacionar el espacio interior con el espacio exterior, y seguirá modificando el lugar, pasando a formar parte de él como un objeto arquitectónico más. Asentimos con Pallasmaa **24**:

> En las experiencias memorables de arquitectura, el espacio, la materia y el tiempo se funden en una única dimensión, en la sustancia básica del ser que penetra nuestra consciencia. Nos identificamos con este espacio, este lugar, este momento, y estas dimensiones pasan a ser ingredientes de nuestra misma existencia. La arquitectura es el arte de la reconciliación entre nosotros y el mundo, y esta mediación tiene lugar a través de los sentidos.

ALGORITHMS, GENERATIVITY AND PARAMETRIC ABSTRACTION

by Carlos L. Marcos

Computer tools used in architecture or more generally speaking in the graphic media, in their ultimate stage, can develop geometries generated from programming languages. This means the modelling of those geometries is non-graphic, instead it is parametric. For example, scripting languages developed in programs like Rhino, Autocad or 3dMax, such as the RhinoScript, Autolisp or 3DMaxScript, and even open software used in specific graphic media such as Processing. These languages are, in fact, metalanguages because they have their own internal logic and grammar but are designed towards the manipulation, editing and development of graphic inventiveness, as well as the representation of architecture itself.

The use of *algorithms* to define formal structures and complex geometries has emerged as a new field within digital architecture, a field rather different from what are traditionally expected to be core issues in architectural design. Kostas Terzidis[1] has referred to the use of algorithms in architecture as follows:

> Algorithms can be used to solve, organize, or explore problems with increased visual or organizational complexity. In its simplest form, a computational algorithm uses numerical methods to address problems [...] random variables or conditions can be inserted into an algorithm, further increasing the degree of unpredictability of the final outcome and magnifying the level of complexity. Contrary to common belief, algorithms are not only deterministic processes developed to explain, reason, or predict a humanly conceived problem, but can become venues for addressing complexities that exceed human ability to explain, reason, or predict.

Algorithmic architecture can be used to take advantage of the computers' potential to analyse a casuistry impossible to deal with the inherent limitations of human beings. Obviously, algorithms are not able to automatically design an architectural project; however, they can be used to develop and explore an extraordinary wide range of formal solutions. In this sense, the use of algorithms fully enters into what we call *digital consciousness*. María Fullahondo[2] has referred with this term to the use of digital tools not as a mere substitute of traditional drawing tools and for the representation of architecture, but as a new paradigm in the pursuit of an architectural language:

> Probablemente, desde el nacimiento de la perspectiva, no haya existido ninguna época en la que la herramienta utilizada condicione la producción arquitectónica de una manera tan determinante.

The representation of architectural space since Renaissance has greatly influenced architectural language itself; both perspective and press were two breakthroughs that transformed architecture considerably. In addition, the concept of space as a receptacle with the qualities of geometrical space has determined architectural production over the centuries until very recently. Kerchove and Tursi[3] have addressed this issue on the following terms:

> However, to understand time as composed of aligned, regular elements and space as a void and neutral container required a process of significant abstraction of the bodily experience. Not the body in terms of the totality of its senses, but that part of it that defines what it sees –the eye- has determined the experience of modern man. Perspective represented an immediate demonstration of the working of this process of abstraction, based as it was on the complete mathematisation of space. In this way, it established an indisputable "symbolic form".

The modern conception of space that has characterized architectural modernism in the twentieth century -and perhaps is at present getting a greater identification with today's *avant-garde* architecture- lies on the idea of space as a field. That is to say: as a dynamic system constantly permeated by forces and with a much closer connection to time; hence, with the distinctive flow of life found in the material world. Parametric architecture can constitute a new paradigm in the conception of architectural space and is likely to establish a closer affinity with such notion of modern space. Kerchove and Tursi[4] describe this conceptual shift as follows:

> Space is no longer an empty and neutral container that can be described on a flat surface using the arithmetic-geometric relations of perspective. Rather, it is continuously generated and regenerated by the networks that structure it, by the conflicts that vivify it, by the living beings that inhabit it. This new definition of space is naturally tied to the development of 20th-century physics and its notion of the 'field': space becomes a field of forces and counter forces, a field that emerges from the actions taking place within it.

The formalization of geometries generated from algorithms can more easily take on a dynamic characterization of space and, therefore, an architectural representation of the notion of space as a field or of the space-time based in modern physics. Marcos Novak has coined the term *transarchitectures* referring to the new architectural imagery generated in cyberspace, a new frontier to explore within architecture: perhaps a new formal abstraction architecture-borne. Novak[5] has written regarding the parameterization of architectural geometry constructed from algorithms on the following terms (the earlier images by Marcos Novak refer to this text):

> The algorithm that produces these forms works as follows: data is interpreted as two sets of points in 3D space in body-space, an instance of output of the algorithm becomes a form of a material architecture […]

This represents a further and radical step in the evolution of architectural language that is originated out of the digital world. We are not referring here to the relationship between drawing inventiveness and the unlimited plastic possibilities of three-dimensional modelling. Indeed, in this case, the editability as an attribute of the virtual is derived from its immateriality. Virtual constructions are unlimitedly plastic to the extent that their constitution from *bits* is not material and therefore their formalization acquires real existence only during the time the code is being executed by a computer program. For the same reason conventional computerized drawing programs are somewhat limited for the architect who uses them but does not have direct access to the code of a language developed by others. Thus, they introduce a certain distance between the architect and the object of his design -perhaps the distance Gehry bothers about-; the architect is no longer in control of his design in the way he had been in the past with conventional tools, used as he was, to the materiality of his own production. Polyxeni Mantzou[6] points out this problem in these terms:

> El hecho de que el arquitecto depende de otros para suministrarle medios para proyectar [*software*], es decir, se encuentra alejado de la creación y la estructuración de un nuevo metalenguaje el cual sirve como base para su trabajo, crea una nueva condición de distanciamiento, igual de importante como aquella que en el pasado le apartó de la obra y le trasladó al estudio. El dibujo como lenguaje ha estado enteramente en las manos del arquitecto mientras que el *software* puede ser abierto a la utilización pero viene como un lenguaje hecho por otros y a cuya estructura él no tiene acceso.

In conventional CAD programs the architect virtually draws and models on the computer display the architecture he is designing. The display is thus an interface which graphs the architectural object as it takes shape, and therefore it is what stands between the architect and his design. It can not be otherwise because of the virtuality implied within the process. However, the architect either *draws in 2D* or *builds 3D models on* the computer screen either by entering commands through the keyboard or the mouse (and in the near future by other procedures currently in pilot phase).

Nevertheless, programs that do allow writing scripts that are graphically transcribed such as those cited above introduce a new opportunity for the development of architectural design that can be then referred to as "algorithmic". That is: the drawing is not any longer a graphical act in the sense of the correspondence between the order given to the computer (marking of traces) and what is displayed on the screen (a support). The drawing is more the formalization of a script written in a computer language capable of generating parametric designs. In his brief but concise text, *Algorithmic Architecture*, Terzidis[7] has referred to this qualitative change in the design process as follows:

> By using scripting languages designers can go beyond the mouse, transcending the factory-set limitations of current 3D software. Algorithmic design does not eradicate differ-

1 / Terzidis, Kostas,, "Algorithmic Complexity: Out of Nowhere", in *Complexity. Design Strategy and World View*, Ed. Gleiniger, Andrea y Vrachliotis, Georg, Birkhäuser Verlag AG, Berlin, 2008, p. 79.
2 / Fullaondo, María. "Conciencia digital". XI Congreso Internacional EGA, Sevilla 2006.
3 / Kerchove, Derrick y Tursi, Antonio, "The Life of Space", Architectural Design, V. 79, I. 1, p. 49.
4 / Kerchove, Derrick y Tursi, Antonio, "The Life of Space", Architectural Design, V. 79, I. 1, pp. 49-50.
5 / Novak, Marcos, *"Transarchitectures and Hypersurfaces: Operations of Transmodernity in Hypersurface Architecture"*, AD, 133, 1988.
6 / Mantzou, Polyxeni y Bitsikas, Xenofon, "*Proyectar en la era del código digital"*, Actas Congreso Internacional EGA XII, Madrid, 2008, p. 490.
7 / Terzidis, Kostas, *Algorithmic Architecture*, Architectural Press, Oxford, 2006, p. xii.

8 / Pareyson, Luigi, *Conversaciones de Estética*, Ed. Antonio Machado (Visor, Colecc. La balsa de la medusa), Madrid, 1987, pp. 130-131, (Tit. Orig. *Conversazioni di Estetica*, Ed. Mursia, Milán, 1966).
9 / Dollens, Dennis, *De lo digital a lo analógico, Ed. Gustavo.Gili,Barcelona, 2002* (Tit. Orig. *D·2·A Digital to Analog*, Ed. Sites Books, Lumen Inc., Santa Fe, 2001)., p. 104.
10 / Berlinski, David, *The Advent of the Algorithm: The Idea that Rules the World, Harncourt, Brace, Nueva York, 2000,* cit por Dollens, Dennis, *Op. cit.*, p. 98.
11 / Guattari, Felix, "*On machines", en The Journal of Phiilosophy and Visual Arts,* no. 6 ("Complexity"), ed. Andrew Benjamin, cit. por Eisenman, Peter, *Written into the void: selected writings*, 1990-2004/Peter Eisenman.
12 / Eisenman, Peter, *Written into the void: selected writings*, 1990-2004/Peter Eisenman, p. 57.
13 / Terzidis, Kostas,, *"Algorithmic Complexity: Out of Nowhere"*, en *Complexity. Design Strategy and World View,* Ed. Gleiniger, Andrea y Vrachliotis, Georg, Birkhäuser Verlag AG, Berlin, 2008, p. 75.
14 / Terzidis, Kostas, *Op. cit.*, p. 76.

ences but incorporates both computational complexity and creative use of computers. For architects, algorithmic design enables the role of the designer to shift from "architecture programming" to "programming architecture"[…] For the first time perhaps, architectural design might be aligned with neither formalism nor rationalism but with intelligent form and traceable creativity.

This is indeed a revolution of revolutions because the *scripts* are as abstract as the language we use to communicate may be; at least in this sense, we may speak of *parametric abstraction.* Algorithmic architecture can hence be seen as the most advanced stage in the field of computer aided architectural inventiveness. To a certain extent it constitutes an *abstraction* of abstraction.
Definitely, the inevitable mediation of the drawing or of the three-dimensional modelling –in the virtual space- introduces a distance between the architect and his object of design, however the architect has control over something that he is able to see and manipulate on the computer display regardless of its virtual existence. Thus the control over the architectural form is equivalent to what happens when conventional tools for graphic representation are used; there is a change of the tool but the design process is alike. The achievement of form involves in both cases a generative development in which the designer and his production is established on a dialectic basis which leads to the gradual definition of form itself. Pareyson[8] writes regarding this subject:

…cuando propongo el término "formatividad", no pretendo aludir solamente al arte como actividad de formar o a la esencia del proceso artístico en la que creo que reside el aspecto más propiamente original […] Esta teoría es la distinción-unidad de forma formante y de forma formada, por la que la obra misma, aun antes de existir como formada, actúa como formante, guiando el proceso de su formación, sin que por ello se pueda decir que la forma formante sea algo distinto de forma formada, sino que, por el contrario, son absolutamente la misma cosa.

However, the *scripts* that generate architectural geometry are neither graphic nor plastic entities. Therefore, they are not equivalent to a drawing or a model, that is: they do not hold a generative relationship between the designer and what is designed by him, between their own structure –that of a written code in a scripting language- and the resulting geometrical shape. In other words, the two-dimensional computer drawings or the virtual 3D models currently used in architectural offices at present are not very different from an *emulation* of conventional design tools the architect has traditionally made use of: drawings and models. In contrast, parametric drawing is a non-graphical tool because it lacks graphicness. Dennis Dollens[9] has referred to this not very intuitive new tool introduced by digital architecture:

Un impedimento para el desarrollo de una arquitectura electrónica híbrida o puramente digital es la necesidad de que los arquitectos reorienten, al menos parcialmente, la base conceptual de la arquitectura que practican; en concreto, la necesidad de que acepten la programación por ordenador como un acto de colaboración arquitectónica y de que se adapten al espacio y a la producción virtuales como lo han hecho al espacio físico en 2D y 3D. Cuando la comunión entre los procesos de proyecto y electrónico sea más firme, el acto de escribir, proyectar y utilizar un código electrónico para generar formas podrá conceptualizarse totalmente como parte del papel creativo del proyectista.

The parallels between the imagery found in some of the proposals by Novak and Schiwtters' *Merzbau* are certainly striking (compare the images by Novak - *Variable Data Forms* - and the work by Schwitters). But it is still more surprising if we consider the fact that Novak's work was generated from algorithms and the *Merzbau* (half sculpture-half architecture) was built with his own hands and was therefore perfectly material. This gives us a preliminary idea regarding the fact that algorithms may be formally driven, something which justifies how algorithmic formal investigations can be *lead* in certain directions. That is to say, anyone using algorithmic procedures does not lack of a formal criterion, instead he will drive the formal search implicit in the code or script trying to explore new possible geometries. But, what is really an algorithm? David Berlinski[10] has defined it generically as follows:

Un algoritmo, por decirlo de algún modo, es un grupo de reglas, una receta, una prescripción para emprender una acción, una guía, un mandato vinculado y dirigido, una adjuración, un código…

This means algorithms constitute a language completely foreign to architecture -at least as we understand it today-, it is in fact the language of computers and of the *machinic.* Being machines related to mechanisms and the mechanical to the repetition of the activity for which it has been designed as they are, the computer as an open system follows a machinic conception. Its constitution allows openness because it is based on codes and these may differ from one another as much as we want to; they may even generate iterations and certain randomness. Guattari[11] writes about this variability of the machinic:

Rather than having an opposition between being and the machine [that is, between being and becoming], or being and subject, this new notion of the machine now involves being differentiating itself qualitatively and emerging onto an ontological plurality, which is the very extension of creativity of machinic vectors.

Eisenman[12] adds to this distinction his own interpretation in regard to the contemporary idea of an architectural space that is closer to the idea of field in physics:

Thus, in architecture such a process might be iterative, might have directions and energy, and might, deal with forces and flows which could be multiple, reversible, and deformative rather than linear and transformative.

Provided algorithms define formal structures generated from a code or script that are then graphed and modelled virtually, the idea of order required in all architecture is implicit in the structural design of the algorithm itself. Indeed, this is a property of algorithms that opens new perspectives for architectural research. Unquestionably the mechanical inherent to the iterative logic of an algorithm may generate certain repetitiveness but it just depends on the complexity of the algorithm itself, and to its embedment within other algorithms that can transform the formal structure previously defined. Obviously, once the model is generated, the architect can manipulate it at his will and may introduce in the algorithmic model some degree of "subjective imperfection", perhaps to leave a slight imprint of "humanity" into the otherwise perfectly structured and repetitive design.
Parametric form in architecture introduces a degree of variability unimaginable to be achieved through conventional means. A slight variation in the code can entail a huge change in the final form. And what is even more important: introduces randomness as a new factor into the design, something which involves a double paradox. Firstly, because random architecture makes no sense since it would imply a lack of order. Secondly, because the intention of generating a completely random code is a self-referential paradox. Terzidis Kostas[13] has referred to this issue as follows:

Randomness is a term used to describe a lack of an identifiable pattern, purpose, or objective. In its formal manifestation, randomness can also be defined as a meaningless pattern. While this definition can be applied to the description of a pattern being random, it becomes problematic when it is applied to the act of creating a random pattern. The claim itself involves a self-referenced paradox: how can one create something that is meaningless? Wouldn't the mere act of creation assign meaning automatically? […] In other words, the creation of randomness involves intention, which is contrary to randomness. However peculiar this may sound, by definition one cannot create randomness.

Thus, algorithms have the potential to create an enormous quantity of different formalizations but all of them must be governed by a certain order implicit within the algorithm itself, its intrinsic structure. All the forms generated by the algorithm will have some sense, will be formally oriented and, therefore, will have a common order. Kostas Terzidis[14] has associated complexity and randomness on the following terms:

Complexity, as defined earlier, is associated with randomness as follows: if a pattern is very regular, it is easy to describe, and so it is simple. In contrast, if it is irregular, then it is difficult to describe, and so it becomes complex. If it is so complex that the information it contains can not be compressed at all, we say that it is random. So randomness is characterized as the maximum of complexity, and the opposite of regularity and simplicity.

However, the relationship established by Terzidis between randomness and complexity is not necessar-

15 / Actually the basic units are preceded by a sugar-deoxyribose- and succeeded by a phosphate serving as a link with successive respective links in the chain. Since the sugar and phosphate are only the necessary attachment parts and they do not qualify the link only 4 elements determine the quality of the link (adenine, thymine, cytosine and guanine -A, C, T, G-), in turn their position and their constitution within the chain determines the genetic key in the code.
16 / http://www.mh-portfolio.com/ (visitado el 10_05_2009)
17 / Eisenman, Peter, "*Process of the interstitial*", El Croquis: Peter Eisenman 1990-1997, 83 , 1997, p. 30.
18 / "In a similar, almost humorous fashion, the *Dada Engine* is a computer algorithm that produces random text based on recursive rearrangement of elements in a grammar. The resulting text, while allegedly based on random processes, is readable, occasionally makes sense, and is sometimes surprisingly intelligent", Terzidis, Kostas, *Op. cit.*, p. 77.
19 / Leach, Neil, *"Digital morphogenesis"*, Architectural Design, V 79, I 1, p. 34.
20 / Leach, Neil, *Op. cit., Ibidem.*
21 / Novak, Marcos, *"Transarchitectures and Hypersurfaces: Operations of Transmodernity in Hypersurface Architecture"*, AD, 133, 1988, p.89, cit. por Dollens, Dennis, *Op. cit.*, pp.110-111.
22 / Marcos, Carlos L., *Espacio material: la arquitectura como extensión topológica*, Tesis Doctoral, E.T.S.A.M., 2009.
23 / Pallasmaa, Juhani; *Los ojos de la piel*; G. Gili; Barcelona; 2006; (Tit. Orig. *The eyes of the skin*, Wiley-Academy, Chinchester (West Sussex), 2005), p. 43.

ily biunivocal. Algorithms as operators of form can generate highly complex geometries as their degree of randomness is greater. Nevertheless, complexity does not necessarily need to be measured in terms of randomness; there can be found complex architectures whose order and regularity is more or less straightforward. The very structure of the DNA molecule is based on the combination of four different elements constituting the nitrogenous base[15]. -the basic link in the chain-; repeated systematically but altering their order they can define something as complex as the architecture of human beings. [16]
Eisenman[17], has referred to hypercomplexity in the definition of architectural space generated by *spacing* strategies implicitly recognizing the difficulty in explaining concepts like *spacing* or *conceptual blurring;* thus he has written:

Normal complexity is one that can be understood through a logical consistency. A cube is a simple form, but a hyperbolic paraboloid is a more complex form. It requires a more complex explanation. Hypercomplexity is something that is not explainable through the normal complex of logical mathematical equations. Spacing can be explained, but it requires a level of complexity not in conventional geometries. It is already another realm of description.

Moreover, the complexity involved in algorithmic systems has no apparent limits. The geometries we can handle, therefore, neither do. Randomness and complexity are the opposite of regularity and simplicity; this means that the simplicity modernity imposed as a Miesian paradigm in architecture is not a valuable attribute of algorithmic architectures. The variability of form is related to a certain randomness factor within the algorithm; considering the fact that it is a code designed according to a pattern -a particular order- it can also be used to pursue a formal search taking advantage of the enormous machinic capacity of computers to process codes and obtain results. Consequently, we can explore many possibilities simply modifying the starting parameters as an aid to formalize our design. Since the computer is capable of producing a countless number of results the work of the architect will then shift to choosing and discarding the computer output. Just as the *Dada Machine*[18] is capable of generating an endless amount of correctly articulated sentences from a grammatical point of view -most of them meaningless- there will be some of them that -by combinatorial chance- may have meaning. Analogously, parametric design in architecture introduces the opportunity to solve problems beyond the human capacity of analysis over time.
Accordingly, the architect's role becomes that of analyzing and evaluating the obtained geometry rather than directly generating the architectural form. It is in this sense that the control over form is no longer generative. Neil Leach[19] has addressed this issue in the field of *morphogenesis:*

Used initially in the realm of biological sciences, the term refers to the logic of form generation and pattern-making in an organism through processes of growth and differentiation. More recently it has been appropriated within architectural circles to designate an approach to design that seeks to challenge the hegemony of top-down processes of form-making, and replace it with a bottom-up logic of form finding. The emphasis is therefore on material performance over appearance, and on processes over representation.

From a literal standpoint, the analysis of certain forms in nature and the application of such forms as shape optimizations for a particular problem in the field of architecture would imply a certain figuration understood as simple imitation; this attitude falls squarely within what has been termed *Biomimetics*[20]. However, if the order of nature is what it is sought to imitate, i.e. the capacity to develop generative patterns, then the path is closer to abstraction from the pre-existent, that is: a process of abstraction triggered out of the material reference found in nature. *Morphogenesis* properly applied to architecture would then enter in the realm of algorithmic architecture as a mimesis of nature's generative processes instead of plain verbatim copies of the natural form for the sake of it or simply because the consideration of nature as a source of beauty.
In this way, we face the challenge to generate algorithms that may have an architectural sense in some context, thus addressing architecture on the basis that there is a degree of arbitrariness in the choice of architectural form as Moneo or Tafuri have argued. Marcos Novak[21] accustomed as he is to the use of algorithms to define his *trasnarchitectures* writes:

Construyo maquetas matemáticas y procedimientos generadores que están limitados por numerosas variables sin relación inicial con preocupaciones pragmáticas […] Estos modelos son matemáticos y algorítmicos. Si la maqueta se alimenta de datos temporales, la forma se vuelve animada, la arquitectura líquida […] Una vez que la arquitectura de los objetos se ha apartado a favor de una arquitectura de relaciones, los conceptos de hiperespacio e hipersuperficie se vuelven naturales.

The problem is then circumscribed to the articulation of the algorithm so that it becomes a meaningful architectural form. It is just a matter of time before programming becomes another tool of architectural design. The ability of computers to "seek" formal solutions based on algorithm definition is extremely agile; we can not compete against it. On the other hand, the discernment of computers nowadays is not yet well developed. Consequently, a large number of formal investigations developed from a given algorithm must be critically examined by the architect. In this sense Terzidis[21] has written:

Dannenberg and Shusta developed an algorithm that produces all possible combinations of skyscrapers for a given site. Their strategy involves physical and geometric parameters to script a computer modelling code that builds, renders, and organizes an infinite number of skyscrapers possibilities, from which emerges a formal pedigree categorized in texture and performance. What is remarkable about this –or any other combinatorial analysis- is that they are able to produce computationally any possible form ever created or any yet to be created.

In all, algorithms give us a chance to handle higher levels of complexity as compared to those we would be able to manage through more conventional design strategies. The traditional imposing of form by the designer greatly contrasts with the enormous variability of generative systems based on algorithms. Like Eisenman's *diagrams*, algorithms involve openness, but unlike the process of extracting the shape from the diagram that we find in the case of Eisenman, the computer has a virtually unlimited ability to generate forms from algorithms depending on the level of complexity that they contain and their degree of randomness.
In any case, once built, architecture will remain a *topological extension* defined by a *material space*[22]; the sensory experience of architectural space cannot be replaced. As technology evolves and the forms we are used to experience in the architecture may vary the invariants of architectural language will remain. Accordingly, the architecture of the future cannot ignore the problem of order, or that of scale, or the relationship between space and the matter that conforms it, neither will architecture be able to unleash itself form the fatality of gravity and its ineluctable verticality, nor will its elements cease to remain cohesively bonded by such gravitational field, it will necessarily raise from the ground, will have to protect us from weather, and shall connect its inner space with the *locus* becoming part of it as another architectural object. We affirm together with Pallasma[23]:

In the memorable experiences of architecture, space, matter and time are merged into a single dimension, the basic substance of being which permeates our consciousness. We identify with this space, here, right now, and these dimensions become ingredients of our very existence. Architecture is the art of reconciliation between us and the world, and this mediation takes place through the senses.

FIGURES

Fig. 1. Marcos Novak, *Trans Terra Firma,* 1995
Fig. 2. Marcos Novak, *Data Driven Forms* ,1997-1998
Fig. 3. Kurt Schwitters, *Merzbau,* 1923-1936
Fig. 4. Marcos Novak, *Variable Data Forms,* 1999
Fig. 5 Michael Hansmeyer, Lindenmayer Systems in Architecture (algorithmic)
Fig. 6, 6 bis Michael Hansmeyer, Lindenmayer Systems in Architecture (algorithmic)
Fig. 7 Marcos Novak *Turbulent Topologies,* Istanbul, 2008
Fig. 8 Tarbell, J., City Traveler Variation A, January, 2004 (sketched with Processing)
http://www.complexification.net/gallery/machines/citytraveler/ (17_02_2010)

IDENTIFICATION OF ARCHITECTURAL DRAWING AND DESIGN (*) AS METHODOLOGICAL PROCESSES OF SCIENTIFIC RESEARCH IN ARCHITECTURE

by Javier Fco. Raposo Grau

(*) In Spanish, the usual term applied to designing architecture is the verb form *proyectar*. It means "to plan", "to project", "to cast", "to throw", and "to design" (T. N.).

1 / Ernst Mach (1838-1916) and Pierre Duhem (1861-1916) were prominent physicists. They could be considered parallel figures, although there are some important differences between them. Both lived during the same time period, they passed away in the same year, they carried out research within the field of history of science, and they linked their work with their conceptions about philosophy of science. As if it were not enough, they both asserted that scientific theories are not true or false.

E. Mach is one of the most important empiricist authors who ever existed. From the beginning of his career, his research was focused on psychophysical problems. He considered them fundamental to determine the value of knowledge in general and of science in particular.

2 / Pierre Duhem's interest was always focused on psychophysical problems, that he considered fundamental to determine the value of knowledge and science. The German edition of his *The Aim and Structure of Physical Theory*, where he defended his general epistemological views, was published in 1908. E. Mach wrote the foreword to the book, which largely contributed to qualify Duhem as a positivist physicist. The Austrian author had already mentioned the book in the preface to one of his works, pointing out that he had added some footnotes in the text with references to related works which had been published simultaneously or a bit later. Two other works were briefly mentioned, and the rest ? almost a half ? of the introduction was devoted to Duhem's book, which had been published in the same year. He wrote that he had experienced great pleasure from reading it and that he did not expect to find himself in basic agreement with a physicist's position. He gave special value to the concordance with the French author because both of them independently had reached the same conclusions. He

Introduction

The present essay is focused on the question of what is and should be considered research in architecture, and more specifically in architectural design. The aim is to clearly identify the graphic processes inherent to the practice of architecture, particularly to research activities linked with higher education, and to prove that the nature of such activities remains constitutive of the character of scientific inquiry.

Background. Research. Scientific Method.

It seems appropriate to begin by making a few points about concepts in the traditional approaches to scientific research, their validity nowadays and their application to architecture-related activities. We will examine the work of professionals involved in architectural training, more precisely in architectural design. The main objective of this essay is to promote reflection on the way research is and should be conducted in schools of architecture, and on the connections between inquiry/education and practice, so as research may be clearly distinguished and determined particularly in this field.

First of all, let us analyze the etymology and current meaning ? both general and restricted to our domain ? of the Spanish word for research. *Investigación* is the action and effect of researching. The term comes from Latin *investigatus,* past participle of *investigare*, and means to search for, to inquire, to investigate, to track, to follow by vestiges, to find out, to discover. Etymologically, the word traces back to *in-* + *vestigium*, footprint, track, trace or sign, the vestige of someone or something. In an etymological sense, research is thus an activity that leads us to acquire knowledge about something.

Every inquiry arises as the result of a process with precise goals and a purpose. In general terms, research is as a process where the scientific method is applied in the quest for relevant and reliable information that is useful in order to understand, to verify, to correct or to put knowledge into practice. A series of steps towards a determinate end must be followed to get the intended goal. Scientific inquiry is a systematic method of continuing investigation of phenomena. This form of knowledge includes a body of techniques for observing evidence, rules for reasoning and prediction, some principles on planned experimentation, and ways to share both experimental and theoretical results.

Scientific inquiry is the intentional quest for knowledge or solutions to problems of scientific nature. The scientific method indicates the path to follow and techniques show the precise way to do it. The process allows us to get in touch with reality so this can be deeper known. It also stimulates creative intellectual activity, and it helps us developing an increasing curiosity about solving specific problems. There are two levels of inquiry, namely, everyday or common inquiry, and rational or critical inquiry. The former is related to the search for knowledge and is inherent to human activity. It is based on questions that are answered through daily mechanisms of investigation, and on their corresponding solutions. The latter is the reflective, systematic and methodic activity of questing aimed at acquiring knowledge and solving scientific, philosophical or empirical/technical problems. It is fulfilled through a process, it has some specific goals and it is intended to formulate new theories or to change the previous ones to make knowledge advance.

Research is a kind of reflective activity that involves the profound, careful and exhaustive analysis of different elements: the knowledge sources or empirical evidence, the assumed problems, the models in hypothesis testing, and the plans to develop each and all related activities.

Research is systematic because the most important goal is not to find isolated data, but to link our thoughts with the information derived from the critical examination of the knowledge sources. The acquired knowledge gets connected through coordination or subordination relations, and it gets integrated within the body of organized knowledge or existing verified theories.

Research is methodic because logical processes are required to gain, to systematize and to share knowledge. The study of some objects of inquiry makes it necessary to develop specific ways, i.e. methods to properly investigate phenomena.

From the structural point of view, any inquiry has four elements, as follows: a subject, an object, a medium and a purpose. The subject ? the researcher ? develops the activity. The object is the matter or topic of investigation. The medium is everything required to fulfill the activity, that is to say, the set of appropriate methods and techniques. Finally, the aim or purpose lies in the solution of specific problems.

Research is pursued through a process that arranges a series of activities in several stages: 1. Selection of the subject matter and preliminary bibliographic consult. 2. Formulation and definition of problems. 3. Formation of hypothesis. 4. Data collection and recording. 5. Testing of hypothesis. 6. Publication of results.

A properly conducted inquiry involves the development of reflective thought and undoubtedly requires persistence. This kind of quest allows us to search and find our own and original answers to the questions formulated by ourselves, therefore to generate new knowledge. It provides suitable methodologies to approach reality in different ways, it stimulates creative and intellectual activity, and it helps us developing an increasing curiosity about solving a variety of problems. This feature is inherent to the scientific mind, which considers that research never comes to an end because results have to be constantly reviewed.

It should be emphasized that some of the qualities of a good researcher are inherent personality traits, while other skills are gained by education and training. The researcher must be aware of his/her strengths and weaknesses, so as the latter may be overcome through work and determination.

Researchers should pay attention to the following issues: dogmatic positions must be set apart; the supposition that the researcher is in possession of the absolute truth should be avoided, it is necessary to keep a constant and insatiable desire for searching the essence instead; ignorant attitudes should not be assumed, a moral position allows the researcher to be honest and responsible in the exercise of his/her duties, as well as to value the contributions of individual members of the research team; a critical attitude should be held on analysis and hypothesis verification; new approaches to future research should be proposed; impartiality and lack of prejudice and preconception are indispensable to judge information and reasoning of others; self-criticism is important to recognize and correct mistakes; skills to manage methods and techniques, and the ability to adapt them to processes under way are necessary; the researcher must be a very willing worker and also a persistent and patient person to face the difficulties that may arise.

The studious inquiry or examination is pursued through a methodology or process determined by the context itself. This fact must be taken into account to assure the dissemination of research results. The outcomes have to be reported and published to be fully considered scientific knowledge, and to become a real contribution to the general knowledge of society and of other researchers in particular.

Crisis in the traditional model of scientific research

It can be proved and justified that the classical concept of scientific research in the framework of Natural Sciences is in question nowadays. It should also be accepted that a new approach to research has been introduced from a methodological point of view, and architecture-related activities are clearly ascribed to this view.

There are remarkable constraints on scientific research in natural and even social sciences. Limits on each and all fields of knowledge are imposed by