Alter EVO: an interactive evolutionary computation tool for instant architecture processing.

Renato Saleri Lunazzi, architecte DPLG, DEA informatique et productique, master en industrial design.
Laboratoire MAP aria UMR 694 CNRS – Ministère de la culture et de la Communication.
e-mail renato.saleri@lyon.archi.fr

keywords: 3D modeling, generative approaches, automatic texturing, building design, formal grammars.

model: a simplified representation of an actual system.
modelisation: knowledge structuration process.
IEC: Interactive Evolutionary Computation

Abstract

This paper briefly describes a bio-mimetic principle used to solve a simple spatial allocation problem. We define an initial set of bidimensional figures by specifying their respective dimensions. An initial spreadout creates 144 random solutions, each with a multiple set of optional possibilities: the inner evaluation function points the best pattern combination in terms of compacity and/or non overlapping occurences. Henceforth user can choose - following the evaluation function or not - to rebuild a fresh set of combinatory patterns within a mutation range preset: according to the visual result of the prior refinement process, user can indeed choose to "gently nudge" the present combinatory set (simply by flipping an occasional random bit in the chromosome) or - on the contrary - to "smash badly" its phenotype by a full recasting of its genotype. The purpose of this experimental implementation is to substantially reduce computation or evaluation time to produce plausible solutions, according to initial spatial constraints and considering that human attention tends to rapidly decrease its efficiency.

Cognitive paradigm

Conventional Artificial Intelligence aims to model human or biological cognitive schemes. We certainly consider as an embedded property of the human mental faculty the ability to process in parallel huge amounts of data but most of all the aptitude to merge order and disorder to enhance creativity.

The computer efficiency - and therefore its velocity - is broadly overhelmed by human ability to treat and solve - in a parallel manner - nonlinear or conflictual contexts. Human creativity is - above all - unpredictable and emerges from a complex comportamental paradigm: a typical "black box" function with an indeterminate causality. Architecture design often follows such a similar scheme, and its creative process follows a non-deterministic pattern. Intuition, individual preferences, subjective evaluation, perception and knowledge define an individual cognitive context that leads data inputs interpretation to a very personal possible expression.

Scientific context

In architecture design, we believe that - in most cases - the more discriminant model able to represent the distributive complexity of present architecture is the horizontal plan. Thus, this very property will be exploited to improve a pluridisciplinaric integration process.

Interactive evolutionary computation (IEC) or Aesthetic Selection is a general term for methods of evolutionary computation that use human evaluation. Usually human evaluation is necessary when the form of fitness function is not known (for example, visual appeal or attractiveness) or the result of optimization should fit a particular user preference.

IEC methods include Interactive Evolution Strategy [Herdy 1997], Interactive genetic algorithm [Caldwell, 1991], Interactive Genetic Programming [Sims, 1991] [Tatsuo, 2000], and Human-based genetic algorithm [Kosorukoff, 2001].The application areas of IEC have been spread widely. IEC is a technology that joins human and evolutionary computation in order to optimize target systems based on a cooperative interaction between feature parameters and psychological spaces.Conventional approaches for these human evaluation-based systems have frequently modeled the human evaluation characteristics and embedded the substitute evaluation model in optimization systems. The analytical approach is a common approach in AI research, but it is difficult to perfectlt model, for example, a personal preference model. [Takagi 2001]

The number of evaluations that IEC can receive from one human user is limited by user fatigue which was reported by many researchers as a major problem. In addition, human evaluations are slow and expensive as compared to fitness function computation. Hence, one-user IEC methods should be designed to converge using a small number of evaluations, which necessarily implies very small populations. Several methods were proposed by researchers to speed up convergence, like interactive constrain evolutionary search (user intervention) or fitting user preferences using a convex function. IEC human-computer interfaces should be carefully designed in order to reduce user fatigue (Takagi, 2001).

There is a history of research relating to interactive evolutionary computing which, in the main, relates to partial or complete human evaluation of the fitness of solutions generated from evolutionary search. This has generally been introduced where quantitative evaluation is difficult if not impossible to achieve. In this research task, we quote as a "good idea" the solution provided by those individuals with an higher fitness value, an appropriate response to our initial constraints, set as "compacity value" and "non overlapping property". This means that top rated individuals respondoptimally and simoultaneously to compacity and non-overlapping needs. After very few recursive steps, we notice that not only upcoming individuals tend to enhance their inner fitness but the generative process also improves the fitness value of the whole population.

<u>Programming environment</u>

The briefly described system works within a HTML/javascript - MAYA/MEL gateway. Prior data inputs are gathered in a simple HTML-FORM descriptor and subsequent values passed and processed by a javascript runtime. In this very first trial we store 12 numerical values acting like position descriptors for every single figure, and there are 144 new generated individuals for every single generation step. For its first spreadout, the program generates random figures, according to initial input values given by user – respective height and width of 5 coloured squares - and plots them over a fixed size surface. Notice that the color-code of input parameters display (X1 Y1) match the resulting output color of displayed figures: 7x8 for the white square, 6x5 for the grid-filled etc.

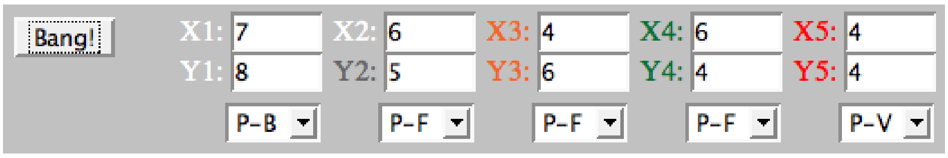

Fig 1: initial input values.

User could either anticipate the respective openings of future geometries; they won't be visible at this point but will be successively generated within the upcoming Maya 3D post-processing.

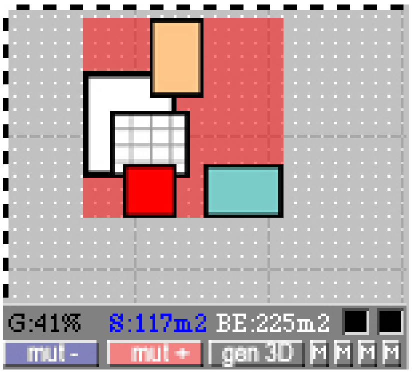

Fig 2: 1 out of 144 first generation of meaningless generated figures.

User is supposed – at this step – to pick his favourite figure in this randomly-generated cluster of possible solutions. The program gives a help, designating with a green flashlight the “best response“ in terms of surface optimization VS non overlapping occurrences (fig. 3).

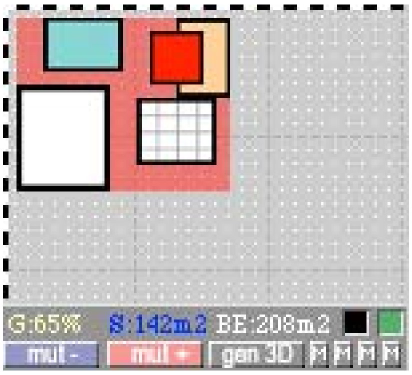

Fig 3: the first generation champion, with a 65% ratio between resulting squares surface (142m2) and the red bounding box surface (208m2).

Following the program suggestion could not only rapidly improve single best individuals performance but either globally enhance the common fitness ratio, as the recursive computation encloses part of parent phenotype. Next step reorders the general framework of upcoming figures but their expression obviously ensues their parent's.

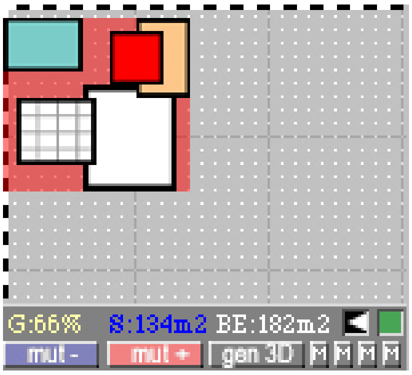

Fig 4: performance is still weak but rapidly improving, according to figure 7.

The full re-deployment button – labeled “mvt+“ - shifts the position of each square all the way through X **or** Y axis, as the local re-deployement button – “mvt-“ - gently nudges each square not more than 1 single snap per axis. In this very case, and only after 5 generations – yet following the program suggestion - the emerging system appears to be a “77% efficiency ratio“ cluster of squares. This means by the way that a “100% efficient“ figure would be a perfect lay-out of colored squares over the underlying red bounding box.

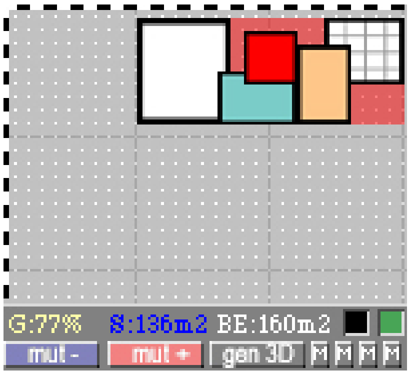

Fig 5: 5th step of this generative sequence with a 77% efficiency ratio.

Next figure shows the complete bio-mimetic arrangement sequence through a 12 generations process – in this case, for each generation the user follows the computer suggestion. The 12th step generated object displays a 80% efficiency ratio: as a matter of fact, its good fitness response breeds a compact self-organization.

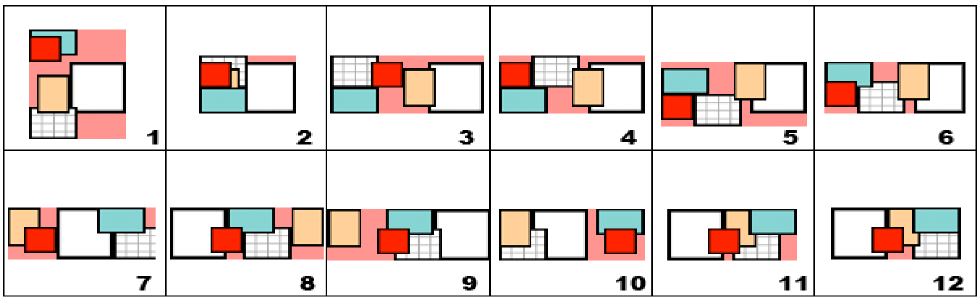

Fig 6: 12 generations refinement.

What we quote as a "good idea" is often the solution put forward by those individuals with an

higher fitness value, an appropriate response to our initial constraints, set, as seen above, as "compacity value" and "non overlapping property". For the computer, top rated individuals respond simoultaneously to compacity and non-overlapping needs. Recursive replacement not only tends to enhance the inner fitness of single individuals but improves the intrinsic response of the whole population, as stated in the following spreadsheet, displaying a 13 steps computation.
The fitness peak of an IEC response is hard to localize: similar subsistems tend to be considered subjectively congruent, even if they are not: visual similarities may actually be broadly different, from a structural point of view.

<u>Generative response</u>

Besides a moderate general fitness improvement we notice a fast championship ratio growth, which means that most of the generated color clusters ensures a satisfactory response to spatial allocation needs. To provide a best variety spreadout we believe that generating a wide variety of average-satisfactory individuals is preferable, rather than locally optimize a little collection of super-items. We could roughly affirm that this peculiar aspect of this technology provides a faster average enhancement of generated objects aptitudes, giving more choice through collections diversity and providing a better spatial response to selected elements.
Any time, user can obviously diverge from the computer-based “best“ response – the most interesting aspect of IEC paradigm. Choosing another arrangement will clearly redefine the following reassembly of subsequent descendants, offering a new bunch of rearranged solutions, closely related to their “new rebel“ forerunner.

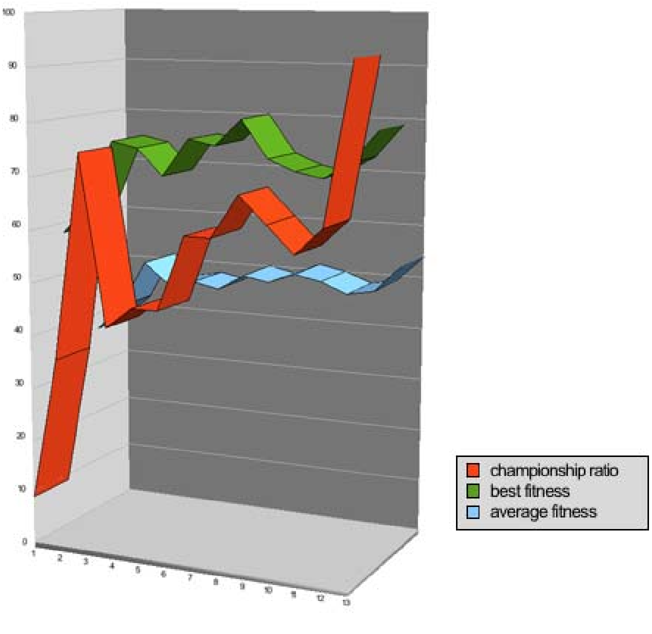

Fig 7: monitoring the generative behaviour.

This digression from traditional genetic algorithms causes radical rather than gradual change in the populations. This is most likely useful to accelerate somehow the interactive generative process as we stated that it could be tedious and rapidly boring. As stated above, specific mutation operators combat the tendency of genetic algorithms to converge on a few super individuals by insuring genetic diversity in the populations. The individuals spreadout offers a wide visual variety of “plausible“ solutions. When an interesting combination is reach, a fine-tuning process can be achieved to adjust preferred spatial combinations.

Experimenting with 3D

Since early stages of generation, user can export the well-liked combination toward an Autodesk Maya 3D environment. This can be achieved by a simple embedded runtime in javascript from the former HTML environment. At this point, according to prior openings designation and the specific positioning of surface elements, the program computes an input-geometry-based boolean transformation. First of all, the creation of cubic primitives, related in size and position to their respective referent in the 2D representation. The pertinence of the openings positioning is drived by a simple comparison between the positioning of square edges comparatively to the center of the global bounding box. The selected opening is automatically positioned on center of the most remote edge of the square; in any case, a door is consistently placed across the closer one (figure below).

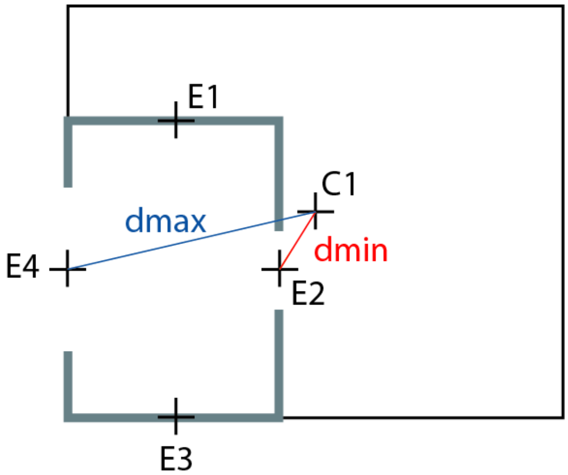

Fig 8: the openings positioning according to the distance of the support-edge to the center of global bounding box (C1).

This process is accomplished recursively for all the generated subspaces. Roof obliquity is obtained putting into practice the same principle: the closer-to-the-center (E2 in the above figure) edge of a square component is elevated vertically.

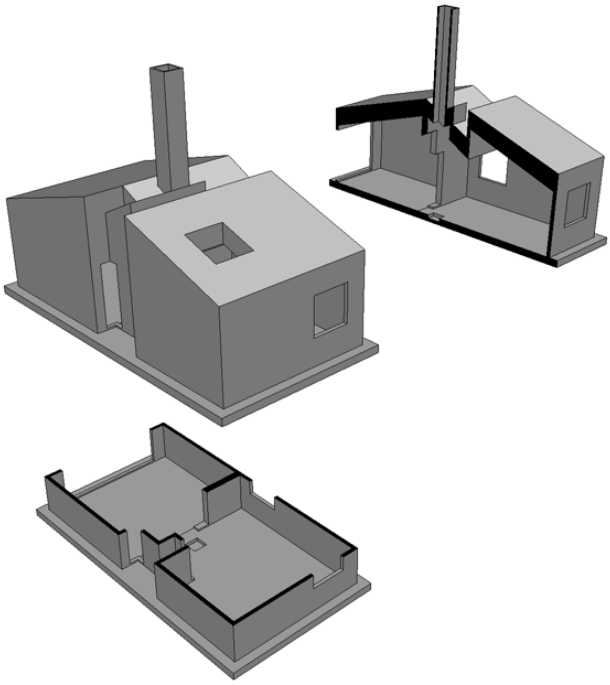

Fig 9: plan and cross-section of a 3D MEL-generated object

.

Results

Experimenting with IEC techniques and 3D objects gives the opportunity to quickly produce interesting 3D standalones. Performing tests involving various parameters and extensible surfaces brings to life hundereds of plausible architectural objects, all different. At the moment the general framework is quite simple, our goal with this research task was only to validate some initial generative conjectures, thus experimenting with bio-mimetic interactive evolutionary computation tools. Next step of these generative technique could match closely architectural design process needs; according to specific inputs, i.e. topographic or climatic outsets.

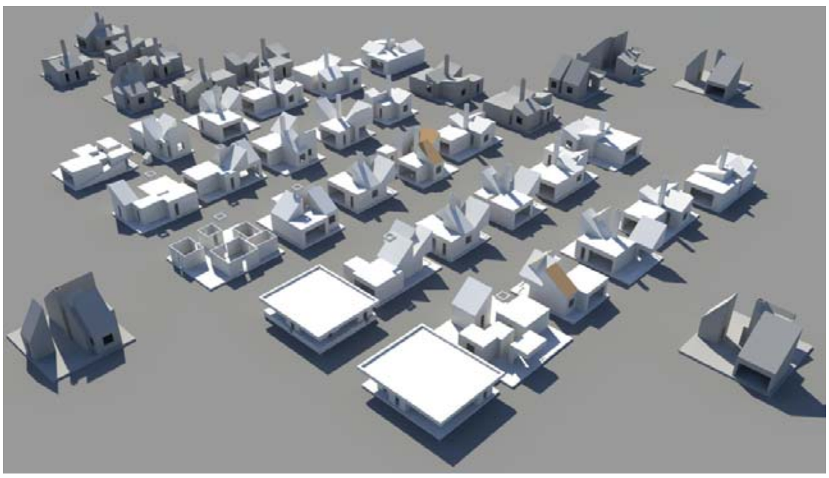

Fig 10:multiple objects created with the depicted program.

Conclusion

Present computer aided-design tools should be able to assist the former exploration that leads the entire design process. However, present software often calls an immediate actualization of geometrical intentions by forcing the user with pre-set intentional clusters - geometric primitives, textural resources, design procedures... - often uncompromising, with poor intuitive feedback and generally restraining imagination spreadout: "*most of CAD software act like over-equipped hand-drafting assistants, assuming the maturity of the designer as much as the maturity of the project itself*." [Chupin - Lequay 2000]

Fig 11:final textured rendering of a generated "architectone".

Recalling Nature with efficient generative paradigms seems to be relevant to discriminate the exponential spreadout of possible solutions of artificial growth approaches. However, the drawback of such processes consists in its unpredictability or its poor response to domains where it is hard or impossible to define a computational fitness function.
Interactive Genetic Algorithms (IGA) or Aesthetic Selection uses human evaluation for the fitness function, tipically when the form of fitness function is not known, such as visual appearance or aesthetics evaluation.
What we aim to achieve is a computer-assisted interactive generation approach for creating architectural plausible geometries. This semi-automated process is intended to act like an "imagination enhancer" serving early conceptual exploration and improving IGA techniques in the domain of architecture design.

Related bibliography

[Caldwell 1991] **Caldwell, C. and Johnston, V.S.**, "Tracking a Criminal Suspect through Face Space with a Genetic Algorithm," *ICGA-4*, pp. 416-421, 1991

[Chupin - Lequay 2000] **Jean-Pierre Chupin – Hervé lequay** (2000) "Escalade analogique et plongée numérique" Entre l'atelier tectonique et le studio virtuel dans l'enseignement du projet – pp 21 à 28 in "Les cahiers de la recherche architecturale et urbaine"

[Herdy 1997] **Herdy M**. "Evolutionary optimization based on subjective selection" - Evolving blends of coffee, Proceedings of the 5th European Congress on Intelligent Techniques and soft Computing, EUFIT'97, 1997, pp 640-644.

[Korsukoff 2001] **A. Kosorukoff and D. Goldberg** "Genetic algorythms for social innovation and creativity" IlliGAM Report 2001005, University of Illinois, Urbana Champaign 01-2001.

[Sims 1991] **Karl Sims** " Artificial evolution for computer graphics" ACM Computer Graphics 25(4), SIGGRAPH91 Proceedings.

[Takagi 2001] **Hideyuki Takagi** "Interactive evolutionary computation: fusion of the capabilities of EC optimization and human evaluation" Proceedings of the IEEE Volume 89, Issue 9, Sep 2001 Page(s):1275 - 1296

References

Barber, C.B., Dobkin, D.P., and Huhdanpaa, H.T. "The Quickhull algorithm for convex hulls," ACM Trans. on Mathematical Software. 1996

Batty M., Longley P.A., "Fractal Cities: A Geometry of Form and Function", Academic Press, London and San Diego, CA. 1994

Ben Saci, A. "Théorie et modèles de la morphose", Thèse de la faculté de philosophie sous la direction de B. Deloche, université Jean Moulin. 2000

Berger V. , Saleri R. "Instrumentation du hasard numérique dans la conception architecturale" Travail personnel de fin d'études – Ecole d'architecture de Lyon – 2005.

Biles J. A. "GenJam in Transition: from Genetic Jammer to Generative Jammer" *Information Technology Department, Rochester Institute of Technology* Generative Art Milan Italy 2002.

Burks A. W. in: William Aspray and Arthur W. Burks: *Papers of John von Neumann on Computing and Computer Theory, chapter Von Neumanns Self-Reproducing Automata* , pages 491–552. MIT Press, 1987.

Dr Colakoglu B. Ph.D. - An informal Shape Grammar for Interpolation of Traditional Bosnian Hayat Houses in a Contemporary Context - *Yildiz Technical University, department of architecture, GA, Milan Italy, 2002.*

Chupin J-P, "Le projet analogue: les phases analogiques du projet d'architecture en situation pédagogique" *Thèse présentée à la faculté des études supérieures de l'Université de Montréal, janvier 1998.*

Codd. E. F. *Cellular Automata* . Academic Press, New York, 1968.

Corcuff M. P. Architecture: Forme, Space and Order? *Actes du 7th International Conference Generative Art 2004, Milan, 13-16 décembre 2004*

Pr. Duprat B. LAF Lyon - Connaissance Morphologique, morphose et sémiose des conformations des édifices - *Colloque AISE, Lyon 5/6 juillet 2004*

Pr. Duprat B. LAF Lyon - La connaissance objective des formes architecturales et ses médiations: calcul des traits distinctifs vs sélection d'indices significatifs - *Colloque INSA LaRA / AISE, INSA de Strasbourg 15-16 mars 2004*

Pr. Duprat B. – Pr. Paulin M. LAF Lyon - Le système de la façade et de la baie: maisons à loyer urbaines du XIXème siècle - *Ecole d'Architecture de Lyon, Laboratoire d'Analyse des Formes*

Ebner M. A Three-Dimensional Environment for Self-Reproducing Programs. In: *Advances in Artificial Life: 6th European Conference* , ECAL 2001, Prague, Czech Republic, Berlin and New York: Springer, 2001.

Fischer T. Computation-Universal Voxel Automata as Material for Generative Design Education. In: Soddu, Celestino et al. (ed.): *The Proceedings of the 5th Conference and Exhibition on Generative Art 2002* . Generative Design Lab, DiAP, Politechnico di Milano University, Italy, 2002.

Frankhauser P. La Fractalité des Structures Urbaines, Collection Villes, Anthropos, Paris, France. 1994

Frankhauser P. "L'approche fractale : un nouvel outil de réflexion dans l'analyse spatiale des agglomérations urbaines ", Université de Franche-Comté, Besançon. 1997

Frazer J. H.. *An Evolutionary Architecture* . Architectural Association, London, 1995.

Gaildrat V. "Modélisation déclarative d'environnements virtuels: Création de scènes et de formes complexes par l'énoncé de propriétés et l'emploi d'interactions gestuelles" HDR Université Paul Sabatier Toulouse III - IRIT Toulouse. 2003

Killian A. Embodied Intelligence - Using Genetic Algorithms To Generate Developable Strips From Free Form Surfaces - *Dep of Arch. MIT*

Krawczyk R. J. Experiments in form generation using cellular automata. In: Koszewski, K andWrona, S. (eds.): *Design e-Ducation. Connecting The Real and the Virtual. Proceedings of the 20th eCAADe Conference* . Warsaw University of Technology, Warsaw, Poland, 2003.

Heudin J.C. "L'évolution au bord du chaos" Hermès Editions. 1998

Horling B. "Implementation of a context-sensitive Lindenmayer-System modeler" Department of Engineering and Computer Science and Department of Biology, Trinity College, Hartford, CT 06106-3100, USA. 1996

Khamphang Bounsaythip C. "Algorithmes évolutionnistes" in "*Heuristic and Evolutionary Algorithms: Application to Irregular Shape Placement Problem*" Thèse - Public defense: October 9, (NO: 2336) 1998

Henry H. Achten, Bauke de Vries, and Joran Jessurun. DDDoolz - A Virtual Reality Sketchtool for Early Design. In: Tan, B.K., Tan, M. and Wong, Y.C. (eds.), *CAADRIA 2000: Proceedings of the Fifth Conference on Computer Aided Architectural Design Research in Asia* , National University of Singapore, 2000.

Herr C. M. Generative Architectural Design and Complexity Theory - *Issues of Generative Arts under Digital Environment - GA, Milan Italy, 2002.*

Lindenmayer, A. "Mathematical models for cellular interactions in development", parts I-II. Journal of Theoretical Biology 18: 280-315. 1968

Y. I. H. Parish and P. Muller. Procedural modeling of cities. In Proceedings of ACM SIGGRAPH 2001, pages 301--308. ACM, 2001.

Prof Liou S. R. BSc MArch. DArch. Design from known to New - *Issues of Generative Arts under Digital Environment - GA, Milan Italy, 2002.*

Marsault X. – “Application des IFS à la Composition de Tissus Urbains Tridimensionnels Virtuels“ - *UMR CNRS MAP, "Autosimilarité et Applications, CEMAGREF, avril 2002.*

Meyer A., Fabrice Neyret F. “Textures Volumiques Interactives“ - *iMAGIS, laboratoire GRAVIR/IMAG-INRIA.*

Salingaros N. A. - Urban Space and Its Information Field - *Journal of Urban Design, Volume 4 (1999) pp 29-49.*

Donald Schön , A . "Kinds of seeing and their functions in designing" Design Studies 13 [2 avril 1992] pp. 135-156

Saleri R. “Pseudo-Urban Automatic Pattern Generation“ in Chaos and complexity in Arts and Architecture – Nicoletta Sala editor, Università svizzera italiana 2006.

Soddu C. “La citta ideale – Generative codes design identity“ in Generative arts 2002, politecnico di Milano 2002.

Sikora S., Steinberg D., Lattaud C., Fournier C., Andrieu B. (1999) “Plant growth simulation in virtual worlds : towards online artificial ecosystems. Workshop on Artificial life integration in virtual environnements“. European Conference on Artificial Life (ECAL’99), Lausanne (Switzerland), 13-17 september.

Takase N. Y. Sho A. Sone K.Shimiya Automatic Generation Of 3D City Models and Related Applications - *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences Vol XXXIV - 5/W10*

Tannier C. Simulation spatiale et cartographie participative in "Cartographier Aujourd'hui les Espaces d'Aujourd'hui" - sous la direction de Jacques Lévy 2002

Torrens P. “How cellular models of urban systems work” , CASA. 2000

Turing A. M. The Chemical Basis of Morphogenesis. *Philosophical Transactions of the Royal Society* , 237:37–72, 1952.

Woloszyn P. “Caractérisation dimensionnelle de la diffusivité des formes architecturales et urbaines“ Thèse de Doctorat – Université de Nantes 1998.

Wonka P. Wimmer M. Sillion F. Ribarsky W. - Instant Architecture - *ACM Transactions on Graphics, Volume 22, Number 4, page 669-677 - july 2003*