Generative Modelling and Electronic

Lesley Gavin
The Scott Sutherland School of Architecture
The Robert Gordon University
Aberdeen
Scotland

Abstract

Keywords: generative modelling, rule based form, random factors, shape grammars.

This paper shows work exemplifying the further extent of computer capabilities in the field of design. The work stems from a belief that for computers to be used effectively within the architectural profession their utility must stretch far beyond the process of description of geometric data, but be incorporated in the fundamental roots of design: that of conceptual design.

Computers can be used to access the knowledge we have and then formulate this knowledge into a working language of design. Computers can be used to generate space and form in accordance with any relationship the designer may choose to set. This allows them to be used from the very conception of design. It is only by working from the very beginning, the very basis of the design of a building that we can fully develop the integration of computers in the construction industry.

The work undertaken sets out primarily to explore one of the ways computers could be used in the field of architectural design. In recognition that an important byproduct of any design search is the enhanced understanding of the problem itself, the work was directed towards a particular project. This allowed each stage of thought to be to be considered as it arose and subsequently incorporated into the design model.

The work does not attempt to automise the design process but simply tries to explore some of the opportunities offered by computers and see if they can be easily incorporated into the design process offering design solutions that may not otherwise have been considered.

The exploration resulted in a simple design process model that incorporates the more accessible and useful aspects of computer technology.

The work presented here was undertaken during the winter term of 1992, at the University of East London, part of an MSc Architecture programme in Computing and Design.

The Design Project

In consideration of the time restrictions involved, decisions had to be made quickly on the type of project involved. The project chosen was a British Gas competition for an office block situated in the City of London, was chosen because it was large enough to address many issues including social interaction, the urban environment and environmental control. These factors make it useful as the basis of an experiment for computer based conceptual design.

The Design Method

The design methodology adopted was based on a generative system producing multiple possible solutions, which were then analysed and the system adjusted in accordance with the new requirements. The generati system was developed using the theories of rule-based-form generation, shape grammars and random factors.

The shape grammar element advocated the development of a set of precise generating rules, and thus established constraints on the generation of the form. However, taken as a method per se, the system did r allow the flexibility required in the generation of a three - dimensional building. To overcome this problem, initial shapes were defined but then instead of using a transformation method to create a resultant shape , a much simpler substitution / addition method was employed. This involved the addition one shape to another resulting in the creation of a new shape rather than a structural re-formation of the shape itself. The emphasis of this project was on generating form i.e. suggesting design solution ideas, without making the process unduly complicated.

The rules themselves, although precise, were not thought of as restrictive, but more as a reference to th conditions or context within which a particular action or, using a random element, a choice of actions ma occur. The system was flexible enough to allow choices made both quantitatively, say through reference t specific testing systems, or indeed subjectively, through the conscious or sub-conscious knowledge held by the designer.

The random factor was introduced to give an added element of choice in the process. Random factors are commonplace today in scientific subjects such as physics, mathematics, engineering etc. and have indeed the past been explored to a certain extent in the arts. (Monreal & De La Puente 1992) Today, the advent computer technology in the world of design opens doors to previously unexplored territory in the context architectural design. Since the computer screen is strictly ruled by logic and Cartesian co-ordinates, and random factors are mathematically based, the computer is an ideal tool for their exploration. In the case design there are many questions that do not have a black or white answer. The answers lie in some in-between area which allows a variety of possibilities. In using computers in design, random factors al for those possibilities to be explored and in this case, random factors were a crucial element in the proce simply because the vast range of possible solutions opened up could instigate the development of further design decisions.

The Concept Development

As I said previously, the methodology was developed around a specific design brief. Through analysis of tl problems set by the brief a design language should emerge. This language would be particular to this particular project in that it would reflect both the conceptual thinking and the more practical aspects of the brief.

The brief was analysed and broken down into elements. Design decisions were then made as to which elements were 'fixed'. A further decision was made to exclude these elements from the generative system as it was easy to identify optimum solutions and therefore fix their position within the design solution. Foe example, shops were to be accommodated on the ground floor, services had to be provided to the building etc. The largest varying element of the brief was also the most important: the configuration of tl office floor area. As a result it was deemed that this was the area of the brief that lent itself towards bein the subject of a generative system that could throw up multiple possible solutions.

The brief itself asked for various points to be taken into consideration:

1 . To address the fact that office workspace is of repetitious form relating to the individual, to the grour and to the whole.

2. To address the social needs of office life.

3. To address the complex question of environmental control for both human needs and energy efficiency.

4. To address the relationship of this building to the complex urban environment.

A design language was constructed within the framework of points 1 & 2 through a belief that for the building to be successful in its purpose the design must be generated from its specific needs. Once a language is defined it should then be possible to enrich it by relating it to the language of the city as a whole.

The question of environmental control and energy efficiency are indeed prominent issues in our society a need to be addressed. However, the language of design, when applied in this generative system would not result in one specific building but a multitude of buildings. This would indicate that a system of quantitative solution testing could be involved.

With these points in mind a study was then undertaken of precedent in this particular building type (in particular the work of Frank Lloyd Wright, Herman Hertzberger, Ralph Erskine & Neils Torp) and conceptual ideas were developed i.e. degrees of inter-relationships between people, between elements an between parts relating to the whole etc.

The Generative System

The generative system was subsequently developed and was based around Stiny's idea of the language of design. It was defined according to the following programme: [1]

1. The vocabulary of shapes is defined.
2. Spatial relations between the shapes are defined.
3. Shape rules can then be specified in terms of the spatial relations.
4. By applying these rules iteratively, the overall form of the building can be generated.

The vocabulary of shapes is defined in order to provide the basic building elements for the design. In this case the shapes were derived from the requirements for the units of office space. Optimum floor space areas were devised within a variety of rectilinear unit blocks.

The determination of the spatial relations involved incorporating the already established conceptual ideas in a rule based form. This primarily involved defining the degree of both the horizontal and vertical interaction. The amount of overlapping of the units directly affects the levels of both interaction and privacy within the building.

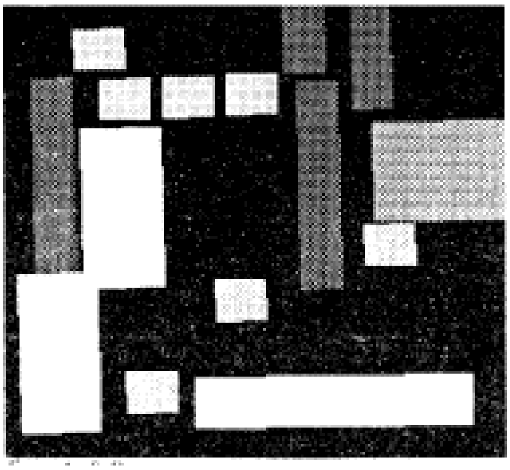
So with the brief requirements defining the 'shapes' and the conceptual ideas defining the 'rules', the nex logical step was to generate the form. The shapes themselves were created in AutoCad as blocks, allowing attributes to be easily assigned, and the rules of relationships were defined in AutoLisp with appropriate references to a random generator to allow for variety.

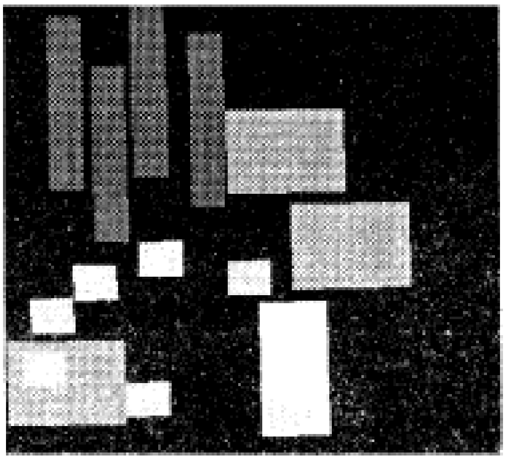
The Process

The process involved started out by creating the units in a simple rectilinear form. The random number generator was then set up and the blocks were randomly selected from a limited database, and randomly placed within a limited area. The next stage involved bringing in a level of control into the random placements and so rules were incorporated into the AutoLisp routine and applied to the blocks. The first s of rules to be employed were based on the conceptual idea of allowing flexibility in the control of the leve interaction between the office departments. This initially involved creating a rule that separated the shap (i.e. departmental areas) on pla - that is 2-dimensionally [figs.l.&.2]. The process then swiftly moved o to giving the shapes heights and therefore creating departmental volumes. The rules then began to revolv around the amount of overlap permitted within the volumes. The exploration of relationships carried on this fashion, taking into consideration vertical connections through staircases, the introduction of an atrium structure, etc.

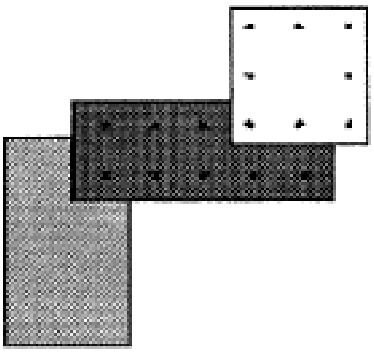
Certain strategic decisions were made early on in the process, such as the decision to have the forms generated in a constructivist way i.e. adding the elements together to build up a resultant form rather tha starting with an overall form and deconstructing the spaces within it. It should be noted that either methc would have been valid.

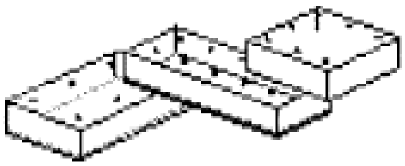
notes [1]. The underlying methodology was developed from the definitions set out by Stiny in his paper "Design Machines" (1981).



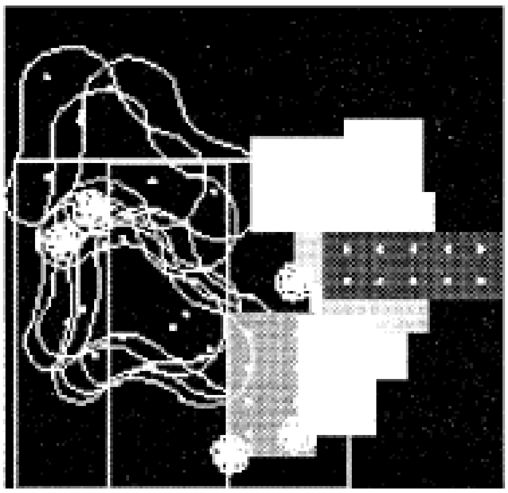


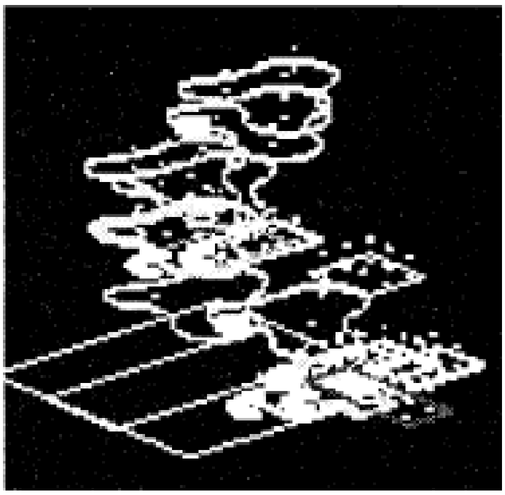
Figs. 1& 2. Random placement of shapes





Figs.3 & 4. The lego effect

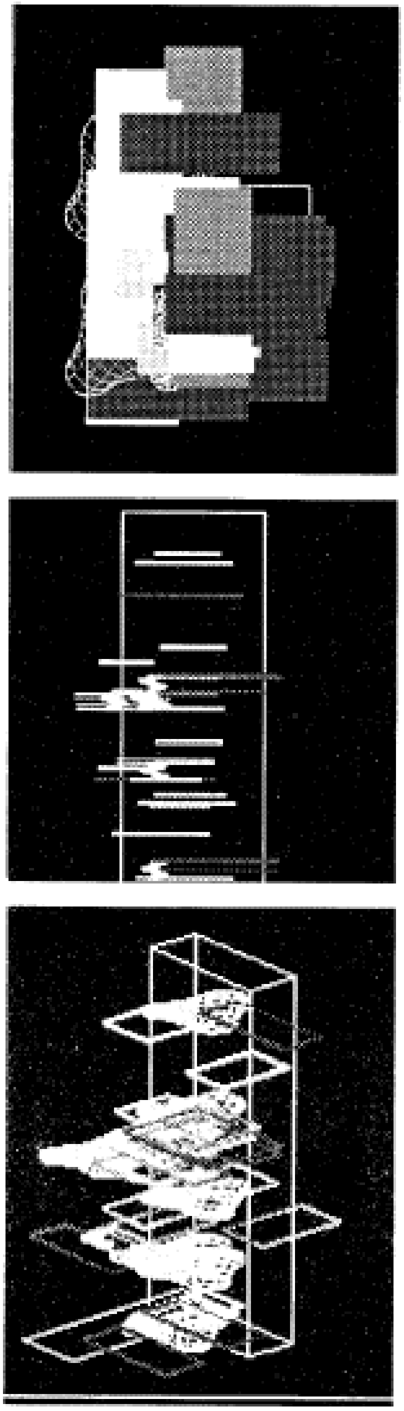




Figs. 5 & 6. Generation with rules including stairs, atrium & additional shape elements

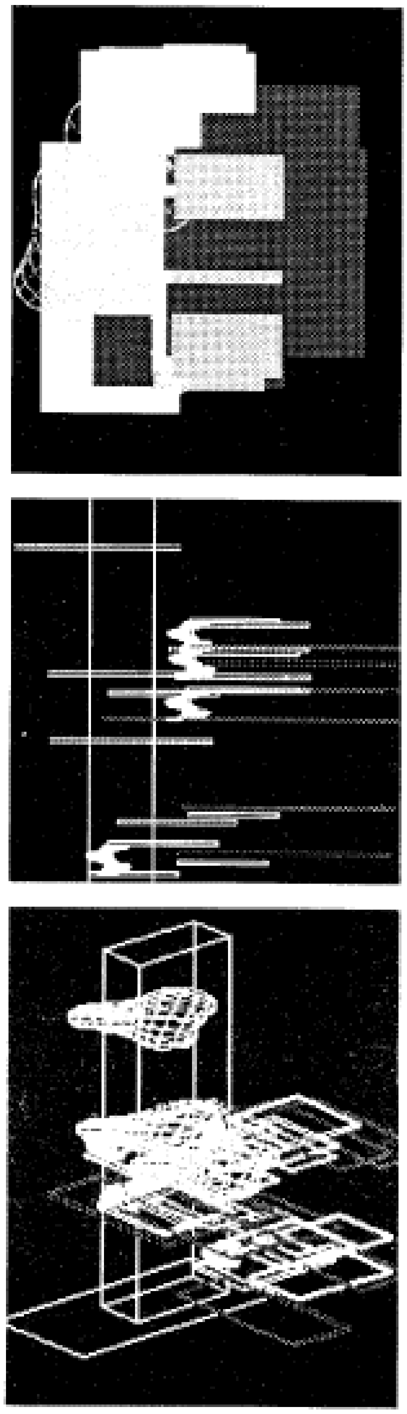
The ‘constructivist’ decision brought about a situation where a solution had to be found as to the problem of how the elements physically connected with each other in a controlled manner where, at the same time, still allowing for random placement. A solution was to assign node points within the blocks themselves [fig.3] i.e. breaking down the blocks into a series of collective elements, and reference could be made to these node points within the AutoLisp routine. This resulted in the electronic Lego effect. [fig.4] From this basis building blocks could be defined, or altered, at any stage and still be referenced by the Lisp routine as long as they had the component 'node' elements.

The routine was gradually built up through the observation and re-analysis of the generations created adding rules and shape elements whenever necessary. [figs.5 & 6]



figs. 7.1-3 example result (a)

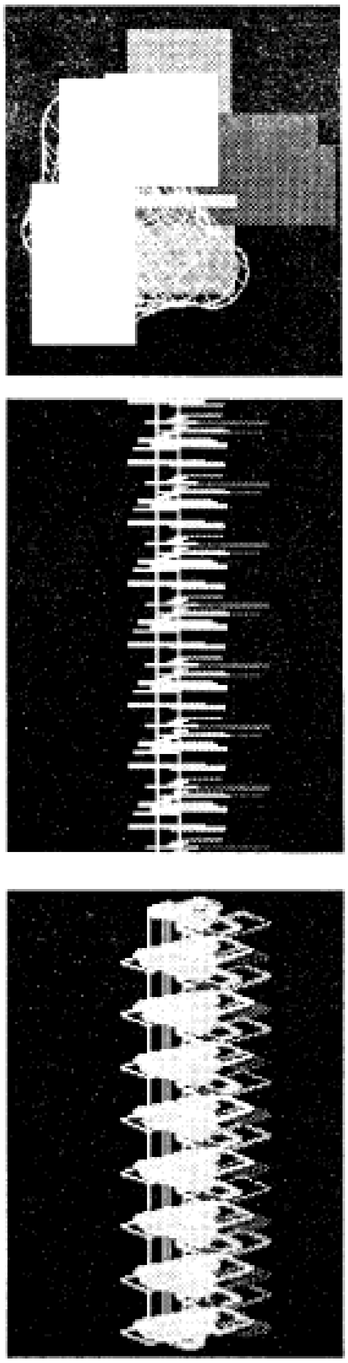
Figs. 8.1-3 Example result (b)

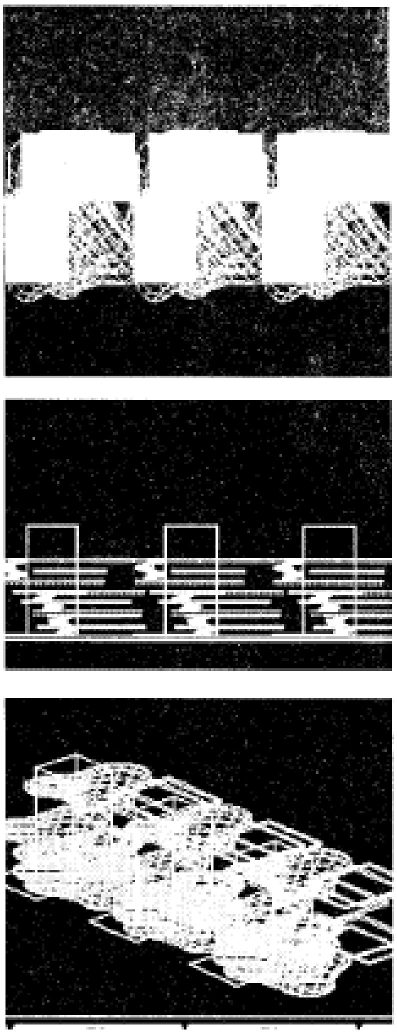


Figs. 9.1-3 Example result (c)

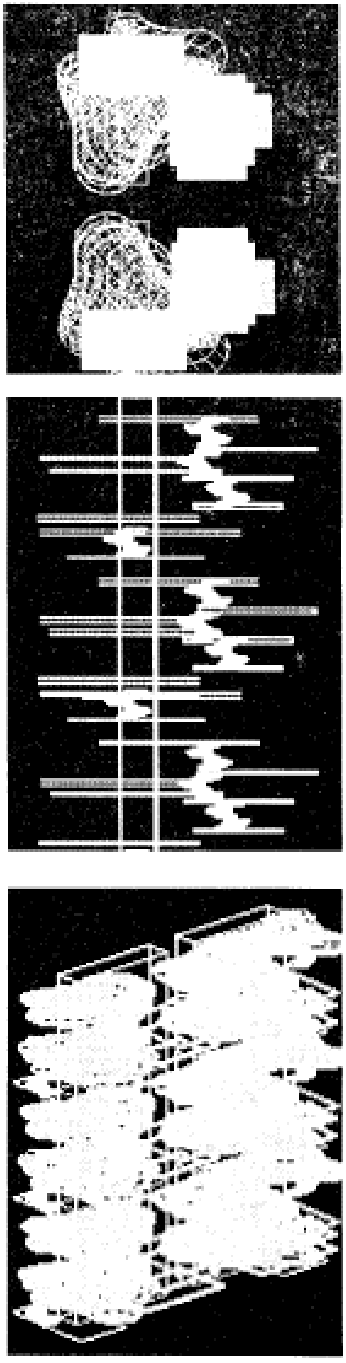
The Results

Various results were achieved in running the program some of which are shown in figs.7, 8 & 9. It was note however, that when given a large volume to work in, the resultant forms tended to be rather disjointed and produced the basis of what would become very maze-like buildings. The solution found to this particular problem was to generate the forms on a much smaller scale and use AutoCad's scale and edit commands to cop them in various ways. This resulted in much more cohesive and regular forms shown in figs. 10-12, with rendered example shown in figs. 13 - 16.





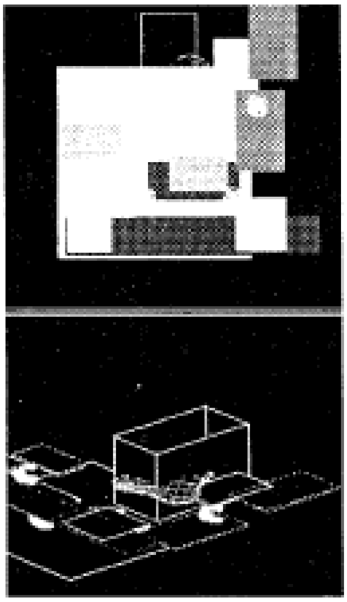
Figs. 11.1-3
Example of a generated unit
copied in a rectangular array



Figs. 10.1-3
Example of generated unit copied in the y-plane. plane.

Figs. 11.1-3
Example of a generated unit copied in a rectangular array.

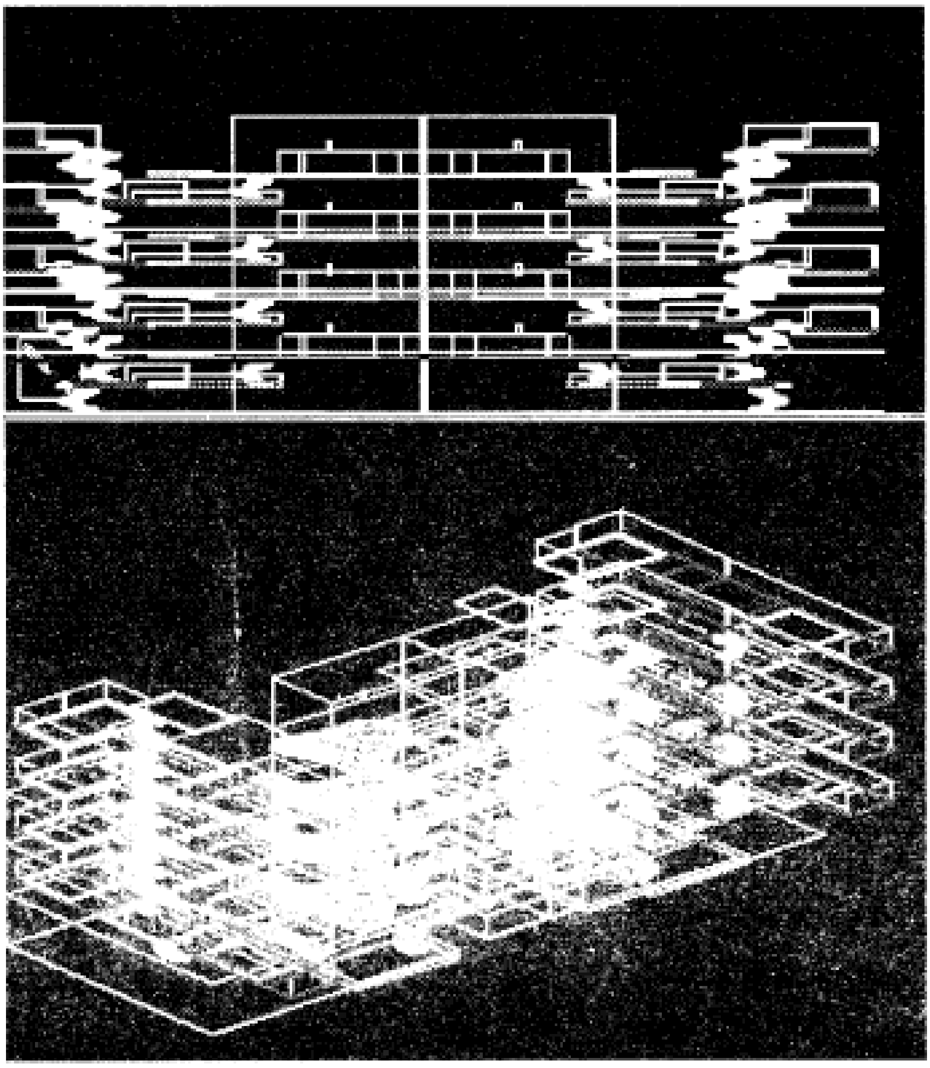
Figs. 12.1-3
Example of a generated unit mirrored then copied in the y-



Here, the plan and 3D view of the randomly generated unit is shown in fig.13. In this case the unit has been mirrored along the edge of the atrium, then copied in the y- plane by a factor of four.
The resultant form is shown in figs.14-16.

Fig. 13
The randomly generated unit plan and 3d view.

Fig. 14
Section and 3D view in Autocad.



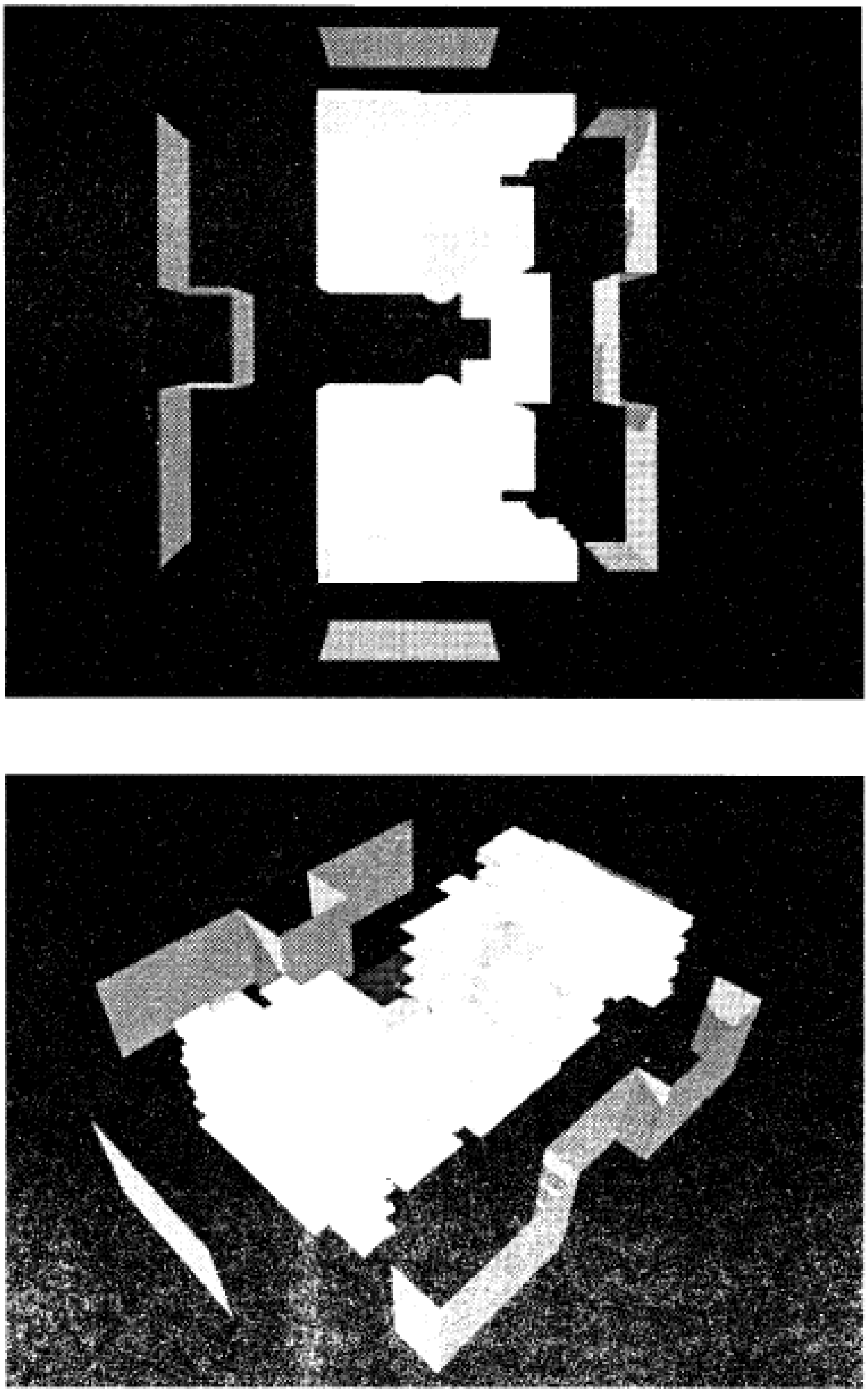


Fig. 16

Exploded plan and isometric of the building in rendered form.

The Conclusions

This pilot study has demonstrated some of the capabilities of computers as a design tool. The project could b taken further to incorporate the two remaining points set out by the brief: to look further into environmental solution testing and also to take the specific site and city context into consideration. The stu has not found one final solution but has set the framework to allow the development of such a solution.

The development of the model raised various issues. First of all, the model required precise rules from the very outset of the process. This meant that the conceptual ideas had to be clarified very quickly. The continuous generation of form at each stage gave further clarification to these ideas by pointing out any unresolved issues. The project allowed the exploration of 3-dimensional space as opposed to the more orthodox approach: that of the plan as the generator, and the resultant mazelike buildings mentioned previously identified a lack of order or hierarchy within the structure.

One of the most important aspects of the model was that it was developed in a relatively short period of tim and with a previously limited knowledge of computer technology. In order for the architectural profession embrace computer technology from its roots, it is of paramount importance that the technology is suited to the architects themselves and to already existing design methods. This project has shown that in the development of any computer aided design process, it must be both accessible and interactive with the designer at any stage of the process that the designer thinks necessary.

Bibliography

Books

Bailey, Stephen, 1990 "Offices" Butterworth
Barratt, Krome,1980 "Logic and Design" Herbert Press
Gleick, James, 1988 "Chaos" Cardinal
Kahn, Louis 1. 1974 "Louis I. Kahn" Architecture and Urbanism
Lobell, John "Between Silence and Light" Shambhala Boulder
Luchinger, Arnulf,1987 "Herman Hertzberger" Arch-Edition, Den Haag
Mitchell, W. J., 1990 "The Logic of Architecture", MIT Press, Cambridge Mass.
Omura, G. 1990 "The ABC's of AutoLisp" Sybex Inc.
Architectural Press "Hong Kong and Shanghai Bank"
Palazzolo, C. & Vio R., 1991 "In the Footsteps of Le Corbusier" Rizzoli, New York
Pipes, Alan, 1985 "Computer Aided Architectural Design Futures 1985" Butterworths Press.
PSA Directorate of Building Development "Office Space: A primer for users and designers", 1976
Schmitt, Gerhard,1 988 "Microcomputer Aided Architectural Design" Wiley Interscience
Utopica 2,1989 Raul Pantaleo Utopica.pp79 - 89
Wojtowicz, J. and Fawcett, W. 1986 "Architecture: Formal Approach ", St. Martins Press
Wright, Frank Lloyd,1975 "In the Cause of Architecture", Architectural Record Books , New York.

Periodicals and other publications:

Bridges A.H. "Any Progress in Systematic Design" Proceedings of the CAAD Futures conference 1985
Gasparski W. "Design Methodology: How I understand and develop it" Proceedings of the CAAD Futures conference 1985
Gips J. and Stiny G. "An Evaluation of Palladian Plans" Environment and Planning B 1978
Gips J. and Stiny G. "Kindergarten Grammars: Designing with Froebels Building Gifts" Environment and planning B 1980
Ho Y. S. "The Planning Process: A Formal Model" Environment and Planning B 1982
Kane A. & Szalapaj P. "Teaching Design By Analysis of Precedents" Proceedings of the ECAADE conference 199292
Knight and Weissman T. "Languages of Designs: from Known to new" Environment and Planning B 1981

Knight and Weissman I . "Transformations of Languages of Designs: part 1 to 3"
Environment and Planning B 1983
Koleichuk V. F. "Programmed Form Generation in Design"
Environment and Planning B 1980
Koning & Eizenburg "The Language of the Prairie: Frank LLoyd Wrights Prairie Houses"
Environment and Planning B 1981
Mitchell W. and Stiny G. "The Palladian Grammar"
Environment and Planning B 1978
March L. and Stiny G. "Design Machines"
Environment and Planning B 1981
March L. "Design in a Universe of Chance"
Environment and Planning B 1983
Mitchell W. and Stiny G. "Counting Palladian Plans"
Environment and Planning B 1978
Mitchell W. and Stiny G. "The Grammar of Paradise: on the generation of Moghul gardens"
Environment and Planning 1980
Monreal A. & de la Puente J. "Using Random Numbers in Layout Generation and Spatial Modeling"
Proceedings of the ECAADE conference 1992
Stiny G. "Introduction to Shape and Shape Grammars"
Environment and Planning B 1980
Stiny G. "A Note on the Description of Designs"
Environment and Planning B 1981
Stiny G. "Shapes are Individuals"
Environment and Planning B 1982