

Fractal Appropriations in Architecture: Examining Four Projects from the 1991 “Paper Architecture” Exhibition

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In twentieth century architectural design, references to fractal geometry have occurred sporadically since the early seventies. Various recent buildings designed in Australia, Germany, India, France, Holland, the United Kingdom and the United States of America have all professed a lineage derived from fractals. While the infiltration of architecture by concepts derived from Non-linear Dynamics was relatively slow and diffuse in most parts of the world, in the Soviet Union, in the early eighties, a number of theoretical design projects were proposed, within a relatively brief time period, which relied upon aspects of chaos theory, non-linearity and fractal geometry. A few of these enigmatic works were combined, along with other works, into the 1991 “Paper Architecture” exhibition which toured various parts of the world.

The aim of this paper is to look at four projects from the “Paper Architecture” exhibition and the ways in which concepts relating to fractal form and complexity theory have been used to generate architectural form largely as a response to program requirements and regional politics. While none of the designs discussed in the paper have been realised in any detail the tight cluster of projects reliant on an understanding of fractal properties is consequential for the greater study of the way in which concepts from non-linearity have been appropriated by architects.

ARCHITECTURE AND FRACTAL GEOMETRY.

Historically architecture has appropriated concepts from disparate systems of geometry and mathematics. In the past both Euclidean and non-Euclidean geometric systems have provided models which have been used for the creation of “ideal” physical forms of architecture. From Vitruvius to Eisenman the adoption of mathematical and geometrical imagery has been a prevalent strategy in architecture. Recent movements in architecture in the late Twentieth Century have similarly borrowed from contemporary systems of geometry an spatial modelling including periodic tiling, fold structures, and Boolean systems. But perhaps the most widespread appropriation has been from the realm of fractal

geometry and the associated discipline of Non-linear Dynamics. Fractal geometry is a term coined by the scientist and mathematician Benoit Mandelbrot to describe non-integer dimensions. “Fractal comes from the Latin adjective *fractus*, which has the same root as *fraction* and *fragment* and means ‘irregular or fragmented’; it is related to *frangere*, which means ‘to break.’”¹ In general terms, fractal geometry may be used to describe irregular or complex lines, surfaces and volumes which defy description through the use of Euclidean geometry. Fractal geometry appears to be significant to architectural form generation because it, in combination with Chaos Theory, provides a new way of viewing natural systems. Because fractal geometry appears capable of modelling natural structures (trees, mountain ranges, coastlines, etc.) and systems (population fluctuations, economic cycles, static, etc) it is especially seductive for architects attempting to create structures which mediate between man and nature.

Given the increasing number of claims being made every year in architecture concerning fractal geometry it is necessary to consider how this body of theory (non-linearity) has been appropriated and then, in turn, interpreted (or translated) in architecture. In this way other architectural appropriations from theory may, in time, be able to be understood and traced in future research. In terms of fractals and architecture; previous research has identified the manner in which architecture has developed its own particular theory of fractal formation and the way in which non-linear mathematicians have borrowed from architectural theory.² In each case architects and mathematicians have attempted to define the degree to which built works may exhibit fractal form. Such research has also raised basic questions of definition; can architecture be fractal?³

Claims have been made by architects, historians and mathematicians that various architectonic forms throughout history have been produced through intuitive as well as intended fractal processes. Previously, claims that certain historic works of architecture are fractal have been examined in the same way that various Modern and Postmodern works have been studied.⁴ While each of these scholarly studies has focussed on scientific definitions of fractal form and archi-

tectural appropriations, such designs have generally been singular (one-off experiments) or have occurred largely in the work of one architect (who repeatedly designs using so-called “fractal principles”). In each of these cases it is difficult to ascertain whether the conceptual forces shaping the appropriation of fractal geometry in architecture are merely coincidental or fashionable (which might be argued to be the case for the singular works) or are purely iconographic (in that they have become an individual’s chosen method of form generation). For this reason it is interesting to consider the way in which fractal geometry has been appropriated by a small, relatively isolated, group of architects in the Soviet Union in the mid-eighties. These architects, working largely in isolation, produced a series of works inspired by, or actively produced through, fractal manipulations of geometry. Unlike the singular experimental works produced by geographically and culturally disparate architects, the fractal projects produced in the Soviet Union in the mid eighties, and later collected in the “Paper Architecture” exhibition, could be argued to possess similar cultural, political and geographic influences.

FOUR WORKS OF “PAPER ARCHITECTURE”

Fractal geometry is the focus of this short paper and specifically the way in which a culturally isolated group of architects in the Soviet Union responded to the peculiar characteristics of fractal geometry. All of these projects were executed on paper between 1984 and 1987 and they were each published through the Deutsches Architektur Museum’s *Paper Architecture Exhibition* which toured North America and Europe in 1990 and 1991.

The major projects in the “Paper Architecture” exhibition which seem to possess links to fractal geometry are Turin’s *The Intelligent Market*, Bush, Podyapolsky, and Khomyakov’s *The Cube of Infinity*, Chuklov and Chuklova’s *A Stone Cast Into the Water* and Galimov’s *Temple City*. In each of these projects some aspect of fractal form has been appropriated and interpreted into an architectural expression. At its most overt, the act of appropriation may be seen in *The Intelligent Market* and *The Cube of Infinity*, each of which rely on different interpretations of the fractal icon the Menger Sponge. Similarly Chuklov and Chuklova’s *A Stone Cast Into the Water* is a lyrical design composition which is based on variations of square and triangular self-similar fractal forms and the fractal icon the Sierpinski Triad may be seen clearly in many details in the project. At a less literal level Galimov’s *Temple City* suggests an intuitive, and perhaps ironic, understanding of the fractal property of scaling. While various other projects including Brodsky and Utkin’s *Electronic Dungeon*, and Kuzembayev, Ivanov and Aristov’s *Bulwark of Resistance* might also be argued to possess some evidence of an understanding of fractal form (and Chaos Theory) they do not explicitly display, in geometric form, this understanding. Brodsky and Utkin’s and Kuzembayev, Ivanov and Aristov’s projects present a more attenuated

reading of fractal form reliant mainly on a sense of chaos and repetition within the city and bureaucracy.

In the exhibition catalogue for “Paper Architecture” Heinrich Klotz records how he initially thought that much of the Russian paper architecture grew from the era of *glasnost* and *perestroika*. Yet when he questioned the architects about their designs they suggested rather that their work had formed throughout the Brezhnev era. Klotz records;

We pointed out that it was under Brezhnev’s rule that all those rigid, large buildings that have disfigured Moscow’s image were erected—those huge fortifications of state-owned enterprises, that have even surpassed the Western disaster of “glass-box architecture.” In response, we received a quick concessionary nod: it had been precisely this Brezhnev-era architecture, with its stagnation and lack of fantasy that caused them to rebel against the petrification and to mobilize counterforces on paper. Their “paper architecture” was not the result of a stimulus arising from the new situation, but a protest against a corrupted state architecture of former years. In that regard, their projects on paper had anticipated *glasnost* and *perestroika* and we meant to announce in the inner realm of fantasy what did not stand a chance in the outer realm of reality.⁵

Alexander Rappaport has described much of the “paper architecture” of this era as a reaction against the Socialist attempts to create a utopian cityscape in Russia. The nature of a totalitarian architecture, he says, “lies not only in gigantism or in the cult of power but also in a normative monotony which evolves in the course of a systematic realisation of utopias.” For Rappaport the Russian paper architecture of the Brezhnev era was not utopian rather it was a rebellious expression of fantasy. Rappaport argued that while there appear to be similarities between fantasy and utopia the main difference is that fantasy architecture does not argue for a solution to real world social and political problems.

Fantasy proceeds from the principle of a pluralistic world and the variety of the spatial conditions of human life. The spatiality of concrete fantasy is limited. It can be valid for a dictated as well as for an agreed upon location. The theatricality of fantasy is obvious; it emphasizes its relativity, the frame and the ramp. Utopia strives to abolish this relativity ... The differences between utopia and fantasy relating to time categories are analogous. The time of utopia is either “eternity,” an era of the past (the “Golden Age”) or of the future (“the happy future”) which does not possess logical reversibility. Fantasy is, in large measure, arbitrary; it can appear and disappear. Fantasy is subject to human will, while utopia on the other hand forces humans under its will and often also under its arbitrariness. Utopia has an imperative nature; on the one hand it impresses the controlling power, while on

the other hand it incorporates in itself utopian features: the unity of totalitarian power corresponds to the unity of the author's will and derives from their combination the fictitious unity as well as the real uniformity.⁶

In attempting to break away from the totalitarian architectural impulse for monotony, both the projects by Turin and by Bush, Podyapolsky, and Khomyakov have turned towards a form of geometry which is both repetitious but is also paradoxical in its mathematics. Both architectural projects have turned to the Menger Sponge, a fractal formed by repeatedly removing sections from a cube until it is perforated to such an extent that it has an almost infinite surface area with almost no volume.⁷ The Menger Sponge is also known in mathematics as the Sierpinski Sponge (see figure 1).

The Intelligent Market

Turin's enigmatic entry to the 1987 architectural competition *The Intelligent Market* depicts a fantasy surface structure which oscillates between various states of being; at once a drawing, a house, a building and a city grid. At the top of the main display panel a Menger sponge may clearly be seen dominating the page. Various of the voids in the geometric figure are filled with bars, curtains, mullions, tension structures and trussed steel frames. Two of the main voids are also finished to imply that they are Corbusian houses, an impression amplified by the presence of a Corb-like figure at the base of the drawing and another figure reclining in chaise-lounge which recalls a famous photo of Le Corbusier. This Menger sponge structure, which appears to be a tracing from the original Blumenthal drawing used in most books of fractal geometry in the seventies and early eighties, is folded, as if it were a section of a drawing, into the lower part of the panel (see figure 2).

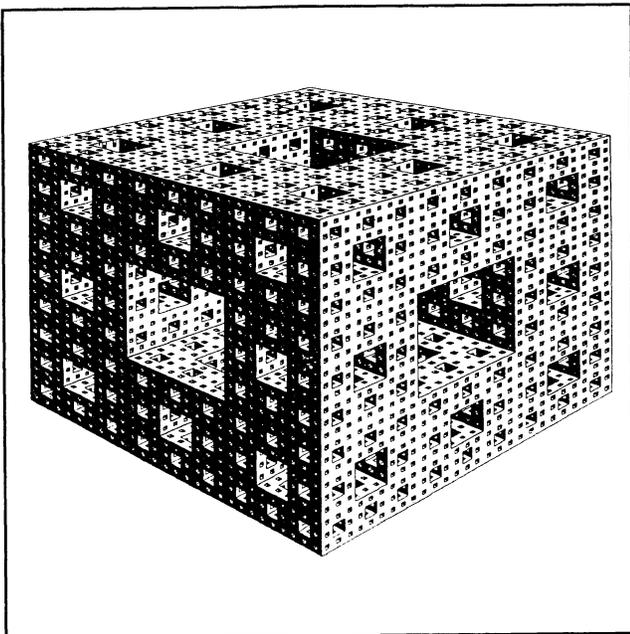


Figure 1. The Menger Sponge.

The lower sections of Turin's panel are, at their most obvious level, an elevation of the facade of a Menger sponge. However, this vision has been broken down through a process of collage so that the geometry of the sponge may be read in different ways in different parts of the diagram. To the left side of the panel the voids have been projected out of the sponge so that they cast shadows giving the impression that they are an aerial view of a city grid. The imposition of the plan of a church at the same scale (along with a few curved roads) reinforce the idea that the Menger sponge has been used as the generator of a street grid and urban space. However this impression is broken down near the middle of the panel where a figure is depicted reclining in a chair as if looking out of a window (void) in the facade. The shadows cast by the city-like projections and the form of the chair blend together further fragmenting the page and challenging the idea of a single scale in the drawing; an appropriate reading of the fractal property of scaling. Below the reclining figure one of the voids is projected into a familiar axonometric view of a Menger sponge seemingly suggesting that at this point is it only abstract geometry, not an elaborate curtain wall or an endless urban landscape. The outline of the architect's hand (and the fingerprints which are smudged across this axonometric projection) further reinforces the idea that it is a drawing at full scale. Below the reclining man another of the voids has been turned into a billboard which declares that: "The Intelligent Market develops as endlessly as our intellect. Therefore the Intelligent Market is a FRACTAL."⁸ The Corb-like figure seems to be reading the billboard which he has observed from his doorway (another extended void within the sponge). He stands on a series of folds in the paper which have metamorphosed into a ground-line. Similar folds which divide the panel resemble mountain ranges or contour lines.

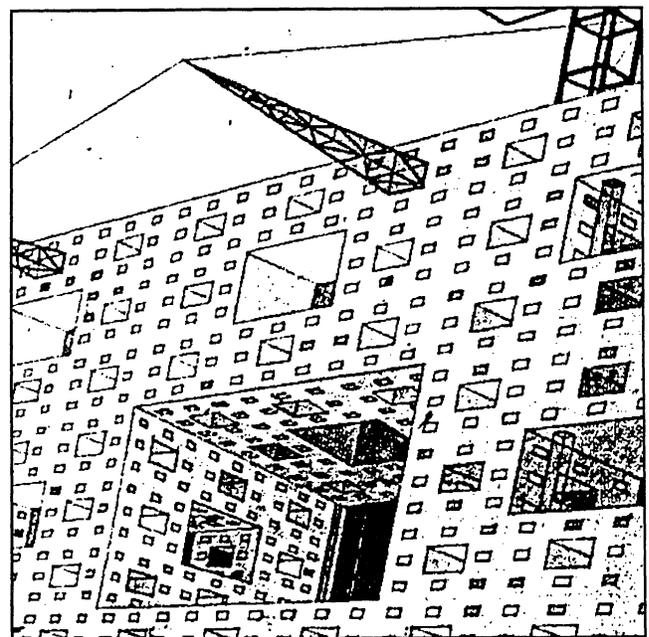


Figure 2. Detail from *The Intelligent Market*.

In *The Intelligent Market* Turin uses the idea of the surface of the Menger sponge being an ornamental facade as a means of attacking the seemingly fixed scale of an architectural work. The design fluctuates continuously between states of ornamental and structural meaning. As ornament it is a clever and subversive ploy to break down the concept of spatial certainty and predicability. As structure the fractal judiciously captures the idea that intelligence and memory can not be quantified, controlled or spatially defined. This proposed relationship between the sciences of complexity and the capacity of the mind and memory has been used in other architectural works for similar reasons.⁹

The Cube of Infinity

From the same year as Turin's transformation of the Menger sponge into a metaphor for a structure which stores intelligence, Dmitry Bush, Dmitry Podyapolsky and Alexandre Khomyakov proposed a variation on the Menger sponge as a means of overcoming the scale problems inherent in the relationship between the city and the home — a theme which resonates with Turin's project.

Bush, Podyapolsky and Khomyakov state that there is a "contradiction between the urban space of today and the requirements of organizing the urban environment. The city is an unruly, chaotic and often decaying organism. At the same time the dwelling should be a strictly neutral space free from the drawbacks of urban life."¹⁰ Their project, *The Cube of Infinity*, attempts to break down the relationship between the city, the building and the environment. The fantasy structure they propose resembles a giant cube which has had the centre third of each of its surfaces removed (the first step in the generation of a Menger sponge). The surface of the cube thus created becoming a series of facades and the gaps between facades. Each of these facades is further broken down into window openings in individual buildings and then into mullions within window openings. The buildings depicted in this way are further layered, seemingly drawn in perspective, yet really all in the same plane, simultaneously displayed at different scales. The architects' describe this complex ornamentation on the surface of the "BLOCK" as "absolutely sterile and blank;" seemingly a form of endless camouflage so that the building may blend into the urban environment. They say that it is "designed as a means of protection against the city." The facade is scaleless (or at least operates at many scales) and thus lacks true "architectural details." The facade appears to seal "off the dwelling from the unhealthy surrounding of the city and turns the dwelling into a bulwark of man's private life."¹¹ Sections and plans of the BLOCK suggest that inside an endless grid of spatial divisions breaks down the volume into tiny cells, infinitely small corridors and vast cubic voids and air-shafts. While the outside uses the metaphor of the city as the infinitely perforated facade of the Menger sponge the inside plays with the idea of an endless sequence of spaces (see figure 3).

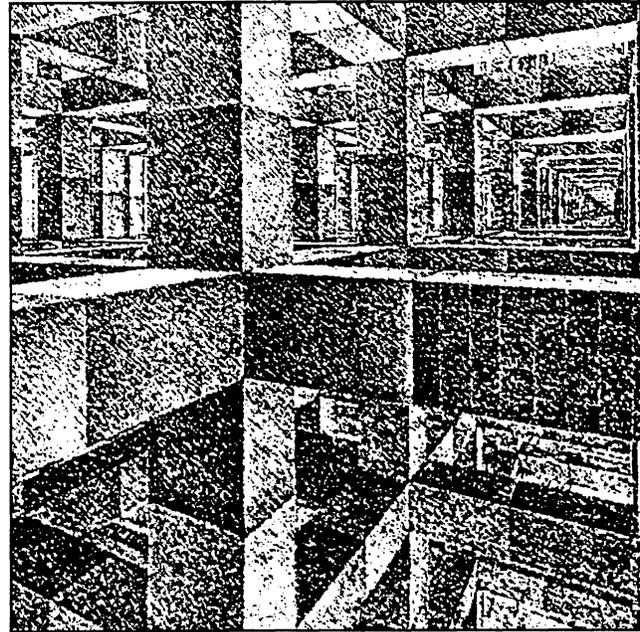


Figure 3. Interior detail from *The Cube of Infinity*.

A Stone Cast Into the Water

S. Chuklov and V. Chuklova's architectural project *A Stone Cast Into the Water* acts as a commentary on the manner in which the greater understanding of nature, afforded by modern science, impacts on architecture and spatial form. Calling *A Stone Cast Into the Water* a work of architecture though is contentious, however as a work of theoretical and geometric investigation it has relevance to architecture and to a study of fractal form and architecture.

A Stone Cast Into the Water literally appears to be an abstracted surface which has been disturbed in some way. This minor disturbance causing countless, complex, ripples to flow out into the surface. The architects' enigmatic two-line commentary suggests a series of readings of nature and geometry. They propose that while looking closely ("deeper penetrating") at nature a hidden geometrical order may be uncovered (and thus "we leave behind us a geometrical landscape").¹² Such a realisation is central to Chaos Theory as fractal form appears able to be used to describe nature. Moreover the geometry of Chuklov and Chuklova's natural landscape is repetitious and ordered; symbolically the "stone, thrown into the water makes squares." While the textural accompaniment to the project is slightly ambiguous, its relationship to fractal form is further strengthened through the graphic depiction of the ripples. Not only may a central square form be easily recognised but it is displayed at multiple scales, a common characteristic of a "self-same" fractal form. When viewed in close detail the squares are seen to be made up of smaller squares and, at their boundaries, triangles. Many of the triangles which define the edges of the ripples are moreover Sierpinski triangles (or Sierpinski Triads); an iconic fractal formed by repeatedly transforming a triangle until it has been perforated with countless smaller triangles (see figures 4 and 5).

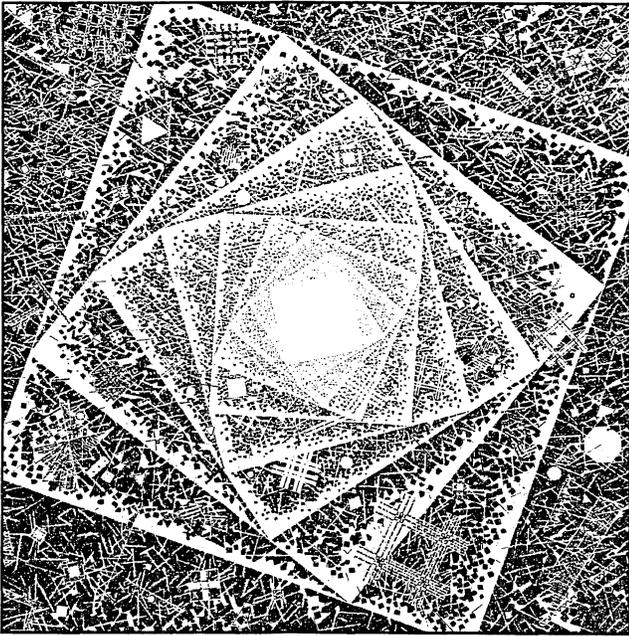


Figure 4. Detail from *A Stone Cast Into the Water*.

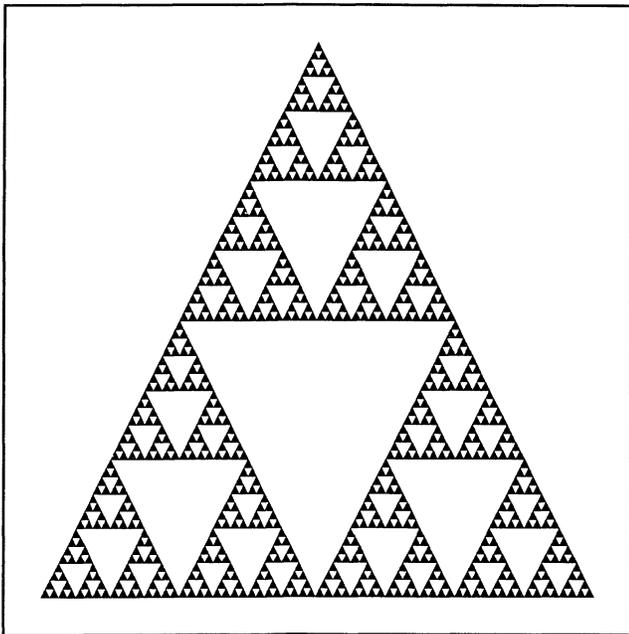


Figure 5. The Sierpinski Triangle.

Temple City

Galimov's ironic work of architecture, *Temple City*, is an urban landscape constructed in the shape of the Parthenon. Each of the gigantic pillars are made up of small accretions of tall buildings and at closer scale it becomes clear that each of these buildings has been made up of slivers of an even smaller architecture. Like *The Cube of Infinity*, *Temple City* is a work of architecture at multiple scales. Unlike *The Intelligent Market* which oscillated between states (at times architecture and at others drawing, or paper) *The Cube of Infinity* and *Temple City* present architecture itself at mul-

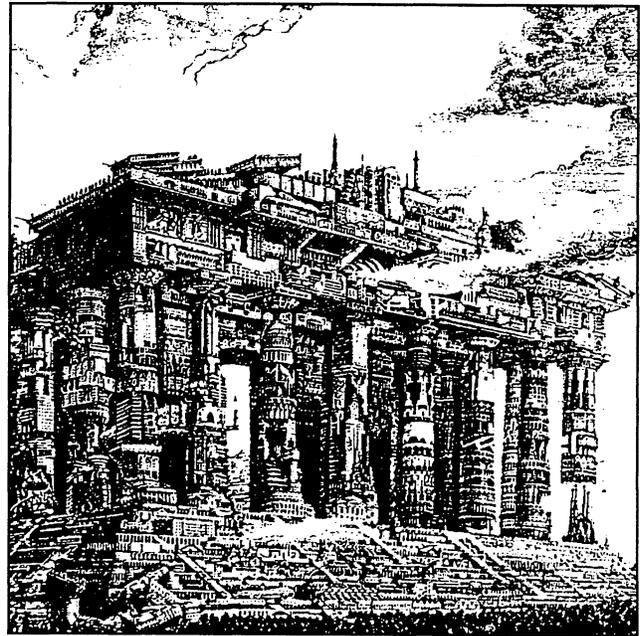


Figure 6. Detail From *Temple City*.

tiples scales. Moreover it may be possible to argue that *The Cube of Infinity* is fractally "self-same," in that its geometry is identical at multiple scales (as is the Menger Sponge), while the geometry of nature and *Temple City* are "self-similar" fractals because they possess characteristic roughness.

Galimov's project, *Temple City*, is described by the architect as a "Contemporary architectural art museum," a reference to the manner in which architecture fulfills various roles in different places. At its largest scale the project is literally a temple which functions as a city, however viewed in another way, the architectural ruin of the Parthenon is decorated with art which is in turn under magnification revealed to be architecture. Galimov's only explanation for the work is contained in a few stanzas from a poem by Anna Akmatova. The poem describes the impact on the city of time and memory. As "clocks tick on and seasons come and go" the city is broken down until it becomes, like the shades of lost "loved ones" a sight to "recoil" from "in horror." It is at this point that the realization comes that the city is not what it seems. Memory and its gradual loss, camouflage Galimov's city until it has become a single temple, yet beneath its surface, when one looks closer, the horror of its spatial complexity becomes clear (see figure 6).

CONCLUSION

Both *The Intelligent Market* and *The Cube of Infinity* project utilize the particular fractal geometric capacity of the Menger Sponge in different ways. At the same time however they each seem to understand the implications of infinite surface and almost negligible volume; a key component of the Menger sponge. Despite this geometric

understanding, the idea of using fractals as a response to a totalitarian political system, as the *Cube of Infinity* project attempts, seems paradoxically flawed. If, as Rappaport argues, the sign of a totalitarian Utopia is endless repetition, then the architects should have been seeking to use statistically self-similar fractals (those that model nature) rather than self-same forms which are infinitely repetitious. The Menger sponge, which has been used to generate an infinite variety of ornamental urban facades, acts as a form of urban camouflage which hides rigidly arborescent and monotonous architectural forms; the very forms that the project is reacting against! Whether or not this was intended as an ironic interpretation of the inevitability of utopian dreaming in Russia, regardless of how well hidden the private space is, remains unknown.

In contrast Galimov's project uses architecture itself, at multiple scales as a way of capturing conflicting memories of the city. At certain scales Galimov's city appears to be eminently ordered and controlled while at others the architecture is aleatory. Chaotic systems in nature, like Galimov's city, may often possess signs of either order or disorder when examined closely at different scales. Like the ripples in the surface of a pool the fine scale perturbations grow in influence until they have produced such a complex system that it is entirely impossible to determine its origins. In popular Chaos Theory this concept is known as the Butterfly Effect.

NOTES

- ¹ Mandelbrot, B. B. *Fractals: Form, Chance, And Dimension*. W. H. Freeman And Company, San Francisco. 1977. p4.
- ² Ostwald, M. J. Moore, R. J. "Charting The Occurrence Of Non-Linear Dynamical Systems Into Architecture". in Hayman, S. (ed). *Architectural Science: Past, Present and Future*. University of Sydney. Sydney. 1993. p223 - 235.
- ³ Ostwald, M. J. Moore, R. J. "Mathematical Misreadings In Non Linearity: Architecture As Accessory/Theory." in Linzey, M. (ed). *Accessory/Architecture*. Vol. 1. Auckland. 1995. p69-80.
- ⁴ Ostwald, M. J. Moore, R. J. "Fractal Architecture: A Critical Evaluation Of Proposed Architectural And Scientific Definitions." in Kan, W. T. (ed). *Architectural Science, Informatics and Design*. Chinese University in Hong Kong. 1996. p137-148.
- ⁵ Ostwald, M. J. Moore, R. J. "Icons of Nonlinearity in Architecture: Correa - Eisenman - Van Eyck." *Theatres of Decolonization*. 1996 University of Arizona. (In Print)
- ⁶ Klotz, H. (ed). *Paper Architecture: New Projects from the Soviet Union*. Rizzoli, New York. 1989. p7.
- ⁷ Rappaport, A. G. "Language and Architecture of Post-Totalitarianism", in Klotz, 1989. p13.
- ⁸ Lauwerier, H. *Fractals: Endlessly Repeated Geometrical Figures*. Penguin Books. London. 1991.
- ⁹ Blumenthal, L, M. Menger, K. *Studies In Geometry*. W. H. Freeman and Company. New York. 1970.
- ¹⁰ Turin, W. "The Intelligent Market". 1987 in Klotz, 1989 p90.
- ¹¹ Ostwald, M. J. "Chaos And Memory: Three Paths Around Joyce Nankivel's Museum". *Transition*. No 46. 1994. p62 - 69.
- ¹² Bush, D. Podyapolsky, D. Khomyakov, A "The Cube of Infinity" in Klotz, 1989 p105.
- ¹³ ibid. p105.
- ¹⁴ Chuklov, S. Chuklova. V. "A Stone Cast Into the Water" in Klotz, 1989 p95.