SPATIAL MODELS, DESIGN REASONS AND THE CONSTRUCTION OF SPATIAL MEANING

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ABSTRACT

Based on architectural projects which interpret literature as program we discuss design reasoning when no routine models of problem solving apply. We address three aspects of formulation: defining the design charge so that it can be retrospectively stated independent of the actual proposal; defining a language of formal operations; and defining the intrinsic aims of design that are only intimated through the proposal itself. The coherence of the project is a function of the way in which formal properties interact, and the way in which they sustain analogical or metaphorical relationships to text: how the patterns of subdivision, connection, differentiation, positioning, movement or perception associated with built space relate to textual figures, concepts, structure, or narrative. The possibility of constructing architectural meaning in this way implies an underlying model of space as a morphic language which works primarily through the constitution of generic and significant relationships rather than the combination of previously objectified elements. The gradual articulation of the design charge is mediated by a process of diagramming. Diagrams express as spatial constructions the conditions and concepts abstracted from text; also, they act as notations of constructive operations which are themselves spatial. Diagrams can be abstractive or pictorial, dense or discrete. They document two aspects of an integral process of reasoning: First, an exploration of how concepts, whether directly, analogically or metaphorically transferred from text to shape, may relate to produce a more complex idea; second, how formal properties co-vary and how an emergent design proposal engages and activates a field of formal possibility.

1. Introduction

Design and cognitive theory often navigate the relationship between language and space in opposite directions. When architectural design engages abstract ideas the aim is to translate them, at least in part, into bodily experiences of spatial relationships engendered by the occupancy

of built forms. In cognitive theory and philosophy, on the other hand, our fundamental spatial intuitions and concepts are examined as foundations for other ideas and experiences. In his study of symbolic forms Cassirer proposes that "... logical and ideal relations became accessible to the linguistic consciousness only when projected into space and there analogically 'reproduced'". (Cassirer, 1955, 200). The mutual entailment between space, language and thought has received renewed and persistent attention in recent years, both in specialized research (Bloom P, M A Peterson, L Nadel and M F Garrett , 1996) and in broader theoretical contexts (Lakoff and Johnson, 1999). We will suggest that theoretical inquiries into the metaphorical extension of core spatial concepts and relationships have something to gain from looking at architectural design. While much attention has been given to spatial metaphor as a foundation of thought, less attention has been given to its construction as the intended result of design.

The word "design" alternatively refers to an activity, when used as a verb, and to particular forms, present, represented or projected, when used as a noun. In the process of normal architectural education the success of the activity and of the pedagogy associated with it is judged through the examination, interpretation and evaluation of the produced form. We might extrapolate that learning to look at the designed object, represented or built, is also a key towards better understanding the cognitive processes involved with its creation. Thus, in this paper, we examine aspects of design reasoning and the construction of spatial metaphors, as documented, at least in part, through the products of design.

2. Design as Formulation

Looking at objects as designs involves asking whether patterns of coherence and relations of implication and consequence can be read into their diverse properties, into the manner in which their parts are configured into a whole, and into the perceptions, behaviors and experiences that the objects engender upon us. If we accept that the logical form of a thing is the way in which it is constructed and put together (Langer, 1967) we may say that to look at objects as designs involves looking at the logical form they embody or project. This is a

necessary but not a sufficient condition. To look at objects as designs also implies the retrospective attribution of intentionality to their formal structure, a reading of systematic intent into the enmeshment of their properties.

To speak of designed objects simultaneously in terms of intentionality and of logical form would seem to involve a paradox. Intentionality implies choice and contingency. Logic implies necessity and structure. The paradox is readily resolved if we suppose that design is about the harnessing of physical laws (necessity) towards the satisfaction of human needs (contingency). If however, the aim of design is the production of form which is intelligible in its own right over and above the accommodation of specific instrumental functions, as is typically the case in architecture, the relation between the ideas of intentionality and logical form gets more intriguing. The form of the object cannot merely be construed as an otherwise arbitrary choice constrained only by functional requirement, natural law and mathematical possibility. There are additional form-generating principles which are axiomatic to the design. Design decision, in other words, has to be linked not merely to the actual form but, more fundamentally, to the logic that is applied to the generation of the form. The fabrication of this logic is the three way bridge that links the study of design as cognitive activity, as an attribute of artifacts and as an exploration of possibility within geometric, physical and functional constraints. Intentionality, as studied from the point of view of the properties of the designed object and their cognitive reconstruction, does not pertain to a psychological state of mind of the designer. Rather, it pertains to the reconstruction of a problem situation which becomes intelligible in its own right by looking at the products of design and the objective traces of design reasoning, such as drawings, diagrams and models.

The activity of design has been treated as problem solving. This characterization, which we largely owe to Simon (1977), opens up interesting questions. Simon recognized that design problems are ill defined: first, there are usually no clear criteria for testing proposed solutions; second, the solution field is too loosely bounded, there are too many alternatives at the outset, and even more can arise during the design process itself; third, it is hard to predict the performance of the designed object; fourth there is a clear distinction between what is knowable in principle and the manner in which information actually flows during the

design process. He proposed that models of rational decision making are possible that allow for the decomposition of complex tasks into relatively self contained components and the continuous revision of the solution field according to information retrieved from memory or from environment. In architectural design practice, the solution field is usually restricted by recourse to historically evolved "typology" (Colquhoun, 1981), generic "solution types" (Hillier, Musgrove and O'Sullivan, 1972) or provisionally accepted "stereotypes" (Hawkes, 1976). Thus, we have to draw a distinction between design practice which is mostly informed by precedent, habit or convention and design practice which is aimed at the exploration, or creation, of new possibility. Where the ends of design are relatively well specified but new solutions are sought, design can be conceived as the critical application of scientific theory to building (Hillier, 1996). Research based theoretical principles are applied to design through processes of generation and evaluation that fit Simon's framework. Where creative design departs from less clear specifications of design ends, Simon's first two criteria for ill defined problems suggest that design can be more appropriately conceived as formulation: the specification of ends cannot be separated from the exploration of means and the criteria of evaluation are partly derived from the largely axiomatic premises established within the design itself.

We will, therefore, regard design as problem solving when it is aimed at satisfying a set of previously given requirements pertaining to use, function, performance, or form, based on previously understood principles of form and function. We will refer to the requirements that must be satisfied as the "design program". We will regard design as formulation when the axiomatic principles according to which form is constructed are established within the process of design, over and above the satisfaction of the program. As both the program that initiates design and the conception of the design involve intentions, any analysis of design as a form of reasoning must engage intentionality from both points of view. A distinction between charge and brief, drawn by Baxandall (1985), becomes relevant. The charge is the set of instructions and specifications given to a designer. It encompasses the commonly understood ways of dealing with the requirements and the circumstances leading to the initiation of a project. The brief consists of the additional intentions brought into the design by the designer. Baxandall looks upon the brief as being more specific and more localized than the charge. The

distinction between problem solving and formulation is not equivalent to the distinction between program and brief. For example, when a well known architect is asked to design a building, it is part of the understood charge that the design must be formulated as a stylistically distinctive product, bearing a personal stylistic signature. Conversely, the brief developed by a designer may include extensions or modifications of explicit requirements of function, performance or usability, in a way that affects the problem solving aspect of the design. Because of the complexities and dilemmas involved with actual design process, the design problem can best be objectively reconstructed, at least in part, after the completion of design, by looking at the result of design activity in context.

In the remainder of this paper, we will look at a particular kind of design situation, where the charge involves significant indeterminacy. We have chosen to treat literary texts as programs for architectural design, in the absence of other pre-specified instructions or physical setting. This charge requires us to look more emphatically at formulation. More importantly, it requires us to look at the relationship between language, space and the construction of meaning in architecture.

3. Diagrams of texts read as architectural programs

Over the last two years Aarati Kanekar, Ken Knoespel and ourselves have initiated parallel graduate and doctoral courses at the Georgia Institute of Technology, the National Technical University of Athens (NTUA), and the University of Cincinnati, where students have been asked to consider the questions raised above and to develop ideas for architectural designs based on literary texts. Regarding our examination of classical texts, we were assisted by lectures and comments by professor Richard Martin, Stanford University. In all cases the earlier phases of the work consist in taking "architectural notes", where the reading of text is documented through diagrams or other visual material in order to make a transition from language to visual form and to space. Here, we use the word "diagram" to refer to any 2-D or 3-D shape that is used to express a thought as a spatial construction. Figure 1, for example, shows some of the diagrams drawn by Mari who has focussed on book XI of the *Odyssey*, "Nekuia", where Odysseus makes a journey to Hades. Unlike

similar journeys in the *Aeneid* and of course in the *Divine comedy*, Homer's depiction of the Hades has neither the elaborate topography described by Dante nor the topology of boundaries identified by Virgil. It is situated at a boundary between sea and darkness. A unit square pit is dug on a shore, near the stream of Oceanus; libations of milk honey and sweet wine are offered before the pit is filled with the blood of sacrificed sheep. The dead appear through the darkness summoned by the blood. They are assigned no specific locations or elaborate settings. There is considerable uncertainty as to the geography of the place. Mari's earliest diagram sets the contour of a rectangle against a background of intersecting lines suggesting flux. Subsequent diagrams are mediated by connections that she makes between Homer's text and poems by modern Greek poet Seferis (1995). Three themes are elicited, "cabinet", "pendulum" and "mirrors". Cabinet is taken as a model of the arrangement of memory, with the ability to selectively retrieve contents. Pendulum is taken as a model for Udysseus' wondering, with a provisional position of rest and symmetry corresponding to the visit to the Hades, a visit whose impact can be conceived as a redirection of the pendulum's swing towards Ithaca. Mirror is taken as a model of the recollection and reconstruction of identity based on encounters with others: friends, family and heroes.
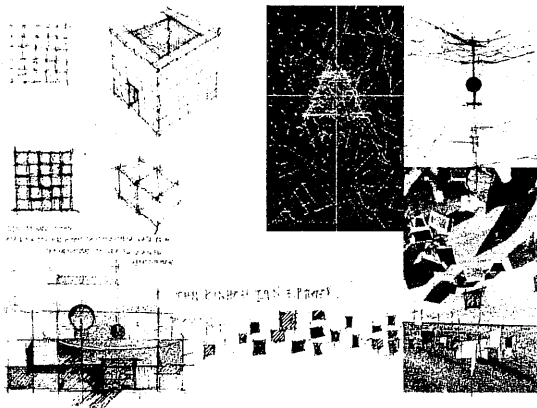

FIGURE 1: Diagrams on *Nekuia*

Instead of looking at specific narrative contents, Touloumis, also at NTUA, chose to look at the structural properties of the text, time and rhythm in particular. He focussed on book III of the Odyssey, where Telemachus visits Pylos in search for information about his father. The ascending path illustrated in figure 2 represents the three days and two nights of the narrative. The five main intervals of time are represented by equal intervals of level change. Changes of direction correspond to discontinuities, whether changes of location or major interruptions in narrative. The length of flights of ascent corresponds to the unfolding of narrative time, not the duration of events themselves, but the length of text that is devoted to them. Bounded flights stand for nights and unbounded flights for days. Thus, spatial extension acquires rhythm through qualitative demarcations, while duration is quantitatively varied according to the length of the path traversed. Movement in space is thereby potentially endowed with tempo and rhythm by analogy to the text. Earlier diagrams suggested analogies between the deployment of narrative and meandering patterns on vases; also analogies between the deployment of narrative and the spatial patterns involved with non-conventional music scores, such as the "Odyssey" by Logothetis (Karkoschka, 1966).
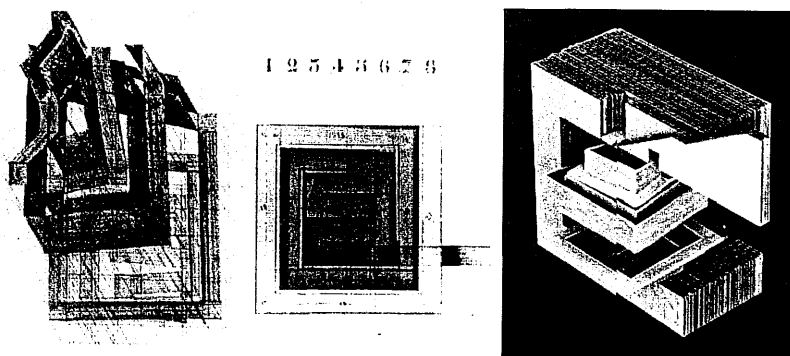

FIGURE 2: Diagram of pace and rhythm in the 3rd rhapsody of the Odyssey

From the point of view of design reasoning, the diagrams mark a shift from a condition where there is no explicit statement of what the design ends or means are, to a situation where design objectives can be articulated a bit more clearly without any certainty that it is possible to develop them. We will argue that the integration between design ends and design means in architecture is mediated by space treated as a field of movement and immersive experience, rather than by visual image or by contemplated object. We will also argue that synthetic reasoning, as an aspect of design formulation, requires more than the incorporation of several different properties or conditions in the design object. Our argument will be developed with reference to a project developed by Lycourioti independently of, and prior to the themes of inquiry addressed here[1].

4. Lycourioti's project: a case study

We will present the project in four steps. First, we will briefly refer to Carroll's *Alice Through the Looking Glass,* which was treated as a design program. Second, we will describe the largest construction built as part of the project, one which is properly architectural in that it has occupied a specific site and has been available to bodily exploration. Then, we will point to analogical connections between the construction and Carroll's text. Our third step will extend to proposing an a-posteriori metaphor which attributes some finality to design. Fourth, we will discuss several smaller constructions that can be alternatively treated as self-contained documents of the architectural interrogation of the text and as moves towards the final design. We will suggest that these 3-D constructions function as representations of aspects of the text, as diagrams of possible operations that generate built shapes and occupiable spaces, and as metaphors that establish significance and gradually formulate, in concrete terms, design intentions themselves. After this rather detailed discussion of the project, we will return to broader questions of spatial meaning, design reasoning and underlying models of thought. Consistent with the

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[1] Lycourioti's project was originally produced as a graduate design thesis, under the advise of professors Costas Moraitis and Dimitris Biris, at the National Technical University of Athens.

aim of reconstructing objective problem situations, our collective interpretative voice has an external relationship to the object of description. Lycourioti's design voice remains internal to the drawings, diagrams and constructions originally produced.

4.1 Text: knight moves

In *Alice Through the Looking Glass*, Alice dreams that she moves through the mirror in the drawing room, where she had been sitting winding up a ball of worsted; she proceeds through the reflected house and into the garden outside it. The garden is described as a chess board whose squares are divided by parallel lines of brooks, horizontally, and hedges, vertically. Alice explores the garden assuming the moves of a white pawn that crosses the board starting from position Q's 2 to be transformed into a queen upon reaching the final raw at Q's 8. The traversal is punctuated by encounters with other personified chess pieces and with imaginary creatures. While the chess board acts as a prop that supports narrative, the significance of the mirror is echoed in the recurrent theme of symmetry. When at Q's 2, Alice has to step backward in order to move forward; at Q'4 s she meets the White Queen who lives in time backwards- she experiences effects before their causes; still at Q's 4 Alice meets Tweedledee and Tweedledum, enantiomorph twins; also at Q's 4 she meets the sleeping black King and wonders whether she sees him in her dream or visits the garden as part of his; at Q's 6 she meets the Humpty-Dumpty, and egg-like symmetrical figure balancing on a fence; still at Q's 6 she meets the two messengers of the white king who bijectively personify going and coming, carrying and fetching. Gardner has suggested (Carroll, 2000, 135) that the chess game is an appropriate complement to the idea of the mirror because many chess pieces come in pairs and because at the beginning of the game, the arrangement of one player's pieces is a mirror reflection of his opponent's pieces. At the same time, however, while a mirror produces symmetries, the chess game ends with asymmetry. This opposition is not incidental to the text. The formal end to the game is Alice's check mate against the Red King and the significant event is Alice's metamorphosis from pawn to Queen.

What further significance could be attributed to the themes of symmetry and chess in the story? The mirrored world refracts and distorts the real world as in a dream. Things become fluid and prone to

metamorphoses: a garden is structured as a chess board, a shop interior, is transformed into a lake, a queen is changed into a sheep. At the same time, symmetry provides a scaffolding that conveys underlying dilemmas and paradoxes across the apparent divide between fiction and philosophy or logic (Deleuze, 1990). At Q's 4 Alice confronts questions about names, places and identity. In a wood, where things have no names and memory is lost, Alice meets a fawn that takes her to a particular open field where they both can remember who they are. The implicit question is whether identity can be carried across space. At Q's 6, the encounter with Humpty Dumpty raises the question whether proper names are descriptive of the entities they denote or arbitrarily associated with them. It also raises questions about whether named objects are always sufficiently different to allow appropriate distinctions, whether their differences depend on contextual relationships (we cannot be sure whether the Humpty Dumpty wears a belt or a cravat), and whether faces are sufficiently distinct to be recognized. The implicit question is how language and sensation interact in our perception of the world. Thus, as the tale unfolds, the question of identity is dramatized in two ways: as a transformation from pawn to Queen, with can be read as an allegory of growing up; and as an initiation into reflexive thinking, enacted through encounters, dialogues and events.

The significance of the chess game as a narrative prop is less obvious. The moves described by Carroll in lieu of a table of contents do not constitute a proper game of chess. While Carroll stages plausible chess conditions including the final chess mate, he seems unconcerned with the opportunities and challenges present at every stage and totally violates the normal sequence of white and black moves. The rules of chess appear significantly distorted by the mirror of narration. Still, the rules that apply to the moves of chess pieces are incorporated in the make up of the characters of the story; most obviously, the seemingly unconstrained movement of queens is contrasted to the constrained movement of pawns and the relative immobility of kings. More importantly, the mirror is incorporated within the narrative staging of the chess-game, with encounters bearing on identity always occurring to the right of Alice, across the vertical axis of symmetry of the board. At the beginning, when at Q's 2, Alice meets the red queen who proposes that she impersonates an advancing pawn. At the end, when Alice moves from Q's8 to K's 8, across the middle line, she takes the red queen and places

the red king in check mate. At Q's 4 Alice meets the red king who raises the dilemma of circular reference: who dreams the other person. More critically, at Q's 7 Alice meets the white knight who is sometimes held to caricature Carroll himself (Gardner in Carroll, 2000), a friendly but slightly inept figure, yet one bent upon invention; he is the last person Alice talks to before becoming queen. The effect of mirror upon the distorted game of chess can be amplified if we consider that Alice's exit from the house could be interpreted as a move out of the white castle at K. B's 1, the only pawn not otherwise evoked by Carroll during the narration. The virtual destination is presented by the white queen, at Q. B's 1, a position symmetrical to that of the castle about the vertical axis. If this interpretation is allowed, Alice's original foray from the white castle into the garden and towards Q's 2, where she meets the red queen, is a knight move, an artifice of the white knight that appropriately positions Alice for the main part of her adventure. Furthermore, the last move from Q's 8 to K's 8 brings Alice to the mirror image of the threshold of the castle, about the horizontal axis of the board. It is even possible to imagine that Alice's linear advance is conceptually equivalent to the completion of a virtual loop, back through the mirror. Towards the end of the game, Carroll proposes that Alice and the queens "castle", the only move outside the rules of chess. If we were to interpret "castling" as a reflection from the eighth row back onto the first, and if all subsequent moves were "played" as if reflected about the horizontal axis of the board, a similar check mate would ensue, except that Alice's last move would bring her back from Q's 1 to K's 1, ready to reenter the castle and wake up back in the drawing room. This possible interpretation of the game, though perhaps unconventional, further supports the hypothesis that the logic of reflections, literal or conceptual, permeates the distorted logic of the game of chess. In other words, the inherent logic of the narrative props is, at least to some extent, fused into the narrative logic of the tale.

4.2 Description: cube

Two surfaces are coiled in reverse directions and wrapped into each other so as to define a passage through the internal volume of a cube (figure 3). The cube is entered at the edge of one of its faces. The path proceeds inward between the two wrapped surfaces and leads through four

clockwise changes of direction to a central square whose side is a third of the side of the base of the cube. It then continues outward through four anti-clockwise changes of direction, to exit the cube at the rotationally symmetric edge of the opposite face. All surfaces but the ones surrounding the central space are covered by a translucent finely perforated elastic membrane. The membrane is supported by a wooden frame which divides each of the outer faces of the cube into nine smaller squares. Bracing is placed asymmetrically across successive sides of the coiled surfaces, in such a way as to enhance the perception of rotation. The height of the two coiled surfaces diminishes at alternative corners as they wrap and mesh inward, so that the height of the end surfaces surrounding the central space is half the height of the outer perimeter. The module of the frame is adjusted by half squares at corresponding intervals. The reduction of height makes it possible to look up and outward from the inner space, over the successive layers of enclosure. The inner surfaces of the central space are covered by mirrors. The cube was constructed at the center of the tilled inner courtyard of the School of Architecture in Athens. It occupied an area of 7 by 7 out of a pattern of 9 by 9 white and black tiles inscribed on the courtyard floor. Slides of the four elevations of the courtyard were projected onto the corresponding surfaces of the cube. The projected images penetrated the perforations of the membrane to also become visible, more dimly, onto the inner layers of the coiled enclosure. The second floor balcony, a major circulation space in the everyday life of the school, was made visible from the inner space, just over the stepped edges of the layers of enclosure.
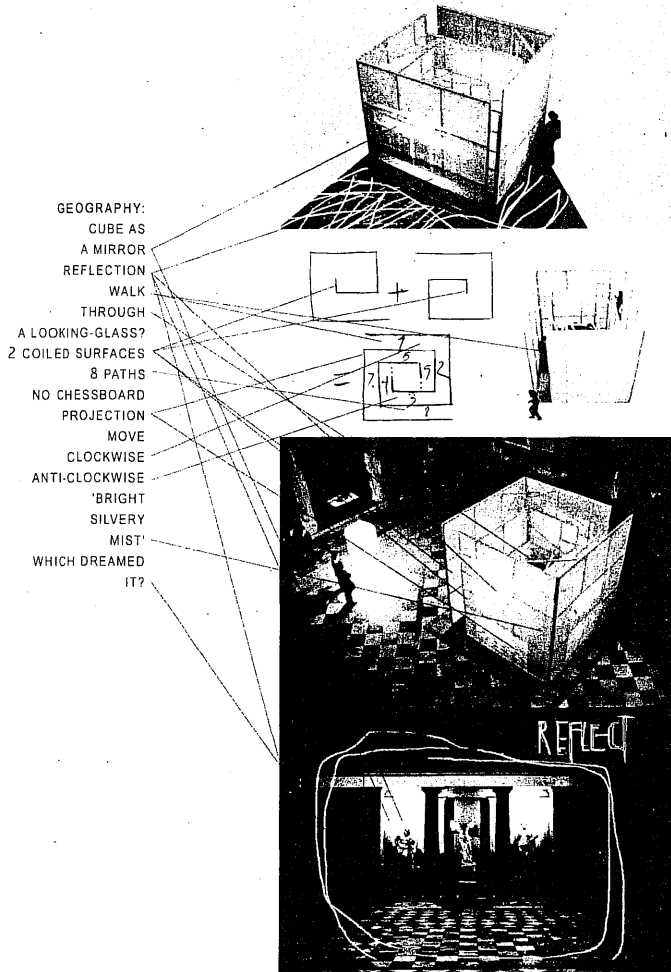
GEOGRAPHY:
CUBE AS
A MIRROR
REFLECTION
WALK
THROUGH
A LOOKING-GLASS?
2 COILED SURFACES
8 PATHS
NO CHESSBOARD
PROJECTION
MOVE
CLOCKWISE
ANTI-CLOCKWISE
'BRIGHT
SILVERY
MIST'
WHICH DREAMED
IT?

FIGURE 3: Cube - Alice Through the Looking Glass

IMAGE MOVING CAMERA:
SQUARE
CUBE
FRAME
OUTWARD
PASSAGE
INWARD
CLOCKWISE
MOVEMENT
ROTATION
LAYERS OF ENCLOSURE
LEVELS OF VISIBILITY
INNER SPACE
INFINITE
MULTIPLICATION
DISORIENTATION
OURSELVES
NO WAY OUT?
REFERENCE/THE BALCONY
TWO COILED SURFACES
TWEEDLEDEE
TWEEDLEDUM
CONTRARYWISE
LIGHT!

OOOPS!

FIGURE 4: Visibility and movement – Alice Through the Looking Glass

4.3 Analogies and underlying metaphor: Alice

The traversal of the cube obviously represents Alice's passage through the looking glass (figure 4). The translucent surfaces into which one gradually disappears stand for the glass of the mirror getting "all soft like gauze, so that we can get through... a sort of mist" (Carroll, 2000, 143). The reversal of direction built into the path stands for the reversal of orientation associated with looking at mirrors. The eight discrete linear path segments, four going in and four coming out, stand for the eight squares of a chessboard column, such as the one traversed by Alice according to Carroll's programmatic analogy between a game of chess and the moves across the checkered garden (Carroll, 2000, 132). The coincidence between the reduction of physical dimensions and the expansion of mirrored space at the center of the cube refer to the play with scale that characterizes Alice's adventure. The choice of a 3 x 3 grid on the face of the cube evokes the pattern of Knight moves: two Knight moves, rotationally symmetrical about each other can be used to define a 3 x 3 larger square comprising eight smaller squares along its perimeter –the ones traversed by the Knight moves- and one empty square in the middle. In this way, the elevation of the cube can be read as an allusion to the two inverse rotations that generate the plan. The cube, therefore, represents aspects of narrative setup, or staging, so as to make them available to direct experience.

Described like this, however, the project has limited import. It does not encompass either narrative contents or underlying meaning. We have a setting but we have no equivalent to a story. To reconstruct meaning we have to look more carefully at the spatial relationships constituted through the project and then at its siting, conceptual as well as literal. Moving through the cube produces a sense of disorientation. At the inner-most and physically confined space the expansion of the mirrored visual field is associated with confronting reflections of self, relatively still. At the same time however one is looking over the enclosure, at the upper balcony gallery, the orbit of daily movement, co-awareness and co-presence over the years of architectural education. From that space the self is now conspicuously removed. The coiled enclosure makes this familiar space appear distant, it turns it into horizon to the fore-grounded play of reflections. And yet that space provides a familiar reference to the disoriented body. One interpretative leap would allow us to recognize that

the set-up of Alice's narrative is transferred and incorporated on a new site in order to construct a ritual of, and to reflect upon, graduation: as a final project, the cube frames a rite of passage from the identity of student to that of a professional architect while absorbing the projected images of the site onto its surfaces and while circumscribing the orbit of life as horizon to a momentary reflection of self. Thus, the cube stages an unusual sensual awareness of movement and visual field to inscribe a spatial metaphor of self awareness, bodily orientation, passage and memory. Lakoff and Johnson (1999) have argued that metaphorical transfers are not limited to particular insights about the properties or attributes of the object to which metaphor is applied, but more importantly entail transfers of modes of reasoning. Here, the text has provided a framework and a language for articulating intuitions about architecture and identity that could not otherwise be expressed.

Can this interpretation of the project be linked by analogy to *Alice Through the Looking Glass*? Yes, if we treat Alice's story as an allegoric reference to growing up. The sense of wonder addressed across a threshold of age and threatened by the coming of age of the recipient permeates Carroll's staging of narration. That a cube incorporating some of Carroll's mechanisms should be linked to a metaphor of passage, memory and identity is therefore appropriate. A second analogy links the cube to Carroll's use of encounters and events as a pretext towards puzzling over our common assumptions about the world. In the case of the cube, the puzzle resides in the program that generates it. Design programs usually consist of accounts of activities, functions and behaviors, as well as requirements of space, services and equipment. That here the program is a story violates normal expectations. That the outcome is not a reproduction of narrative events prevents us to reconstruct a direct correspondence between program and outcome. While Carroll uses encounters and events to probe into the fabric of the world through dialogue, the project probes into the meaning of spatial relationships by contriving a particular sensory experience. The cube issues from Carroll's world to absorb and then transform its setting. In its relation to the school, as building and as program, the cube claims a moment of wonder upstaging normative pedagogy.

4.4 Traces of design reasoning: diagrams as products and as inputs

The process of interrogating the charge and formulating design aims is documented in a series of constructs, each also intended as a self contained object. Some of these constructs are arguably incorporated in the cube, while others seem to mark abandoned directions of inquiry.

Objects 1 and 2 (figure 5) consist in manipulations of a chessboard. Against the ground of text, the chessboard appears as object. The object is folded and sometimes cut along the folds in order to generate 3-D space, a precondition for architecture. The transformed pieces of chessboard are then arranged to suggest a direction of movement, not implied by the original square figure. Scaffolding appears as an independent support to the folded surfaces.

Object 3 (figure 5) represents the encounter with the Humpty Dumpty. A path unravels over a scaffolding and meets with a spherical shape half way along. The object is fabricated as a chess piece, with a solid body covered in text. The possibility that each encounter of the story is represented by such a figurative chess piece is then abandoned. Object 4 (figure 5) remodels the Humpty Dumpty by having an elliptical contour drawn on transparent membranes. Successive membranes represent the shape in successive positions of a fall. By arranging the transparencies in sequence the fall appears as a pattern of rotation. More importantly, the idea of movement is now interpreted not as a literal succession of occupied positions, but as a layering of surfaces. From this point of view object 4 is in clear contrast to object 5 (figure 5), which abstracts the idea of paths as ribbons of folded paper supported by wire frames, or as undulating wires supporting detached paper surfaces.

The cube shape itself first appears in object 6 (figure 5), a straightforward attempt at constructing a 3-D chess-box. In object 7 (figure 6) the cube shape is subjected to two transformations. The surfaces are folded and the edges are made to emerge as an independent framework. The interplay of cube frame and cube surface suggests an intuition of duplication, separation and enmeshing, as if in a 3-D mirror entailment. The whole structure is supported by a solid angular bracket. The bracket could be interpreted as an open book, or as a setting for endless potential mirroring. The theme of the distorted cube is repeated in object 8 (figure 6), this time in conjunction with a traversing path. Finally, the cube compositions are objectified in the paired objects 9 and

10 (figure 6), modeled as chess pieces. The surfaces of one object are plain while those of the other object bear text and a drawn face of Alice. It is possible to imagine their juxtaposition as representative of encounters between Alice and other chess pieces, specifically the other white queen whose mirror image Alice has become.

We can look at these objects it two ways, as self contained entities that carry independent meaning, and as steps in and overall process of design reasoning. Considered as self contained entities these objects are representational of aspects of the text. From this point of view, a distinction can be drawn between representations that are primarily figurative and representations which exemplify spatial relationships. Objects 3, 9 and 10 are clearly figurative. They represent actors or events as chess pieces. Objects 4 and 5 represent movement as ordered sequence and as layered transparency. It is less obvious how we can treat the objects as parts of a continuous process. We propose to look for continuities not only at the level of forms, but also at the level of design operations. The operation of folding first applied to objects 1, 2, 7, 9 and 10 is repeated in the creation of the coiled surfaces wrapped into the final cube. The final cube also conjoins the notion of a path as literal succession of folded surfaces, as with objects 1, 2, and 5, and the notion of a path as layered transparency as with object 4. Rotation, which is first explored in object 4, is also incorporated into the final project.

Thus, from the vantage point of the final project, the set of objects can be alternatively construed as formal propositions and as 3-D diagrams of operations. In this particular case, the process of interrogating objects is not unlike the activity of "bricolage" evoked by Levi-Strauss in the Savage Mind (1962). The premises of each new design move, each new reading, depend upon an expanding sense of potentiality inherent not only in the objects previously produced, but also in the evolving field of transformations that links these objects as products of similar operations.
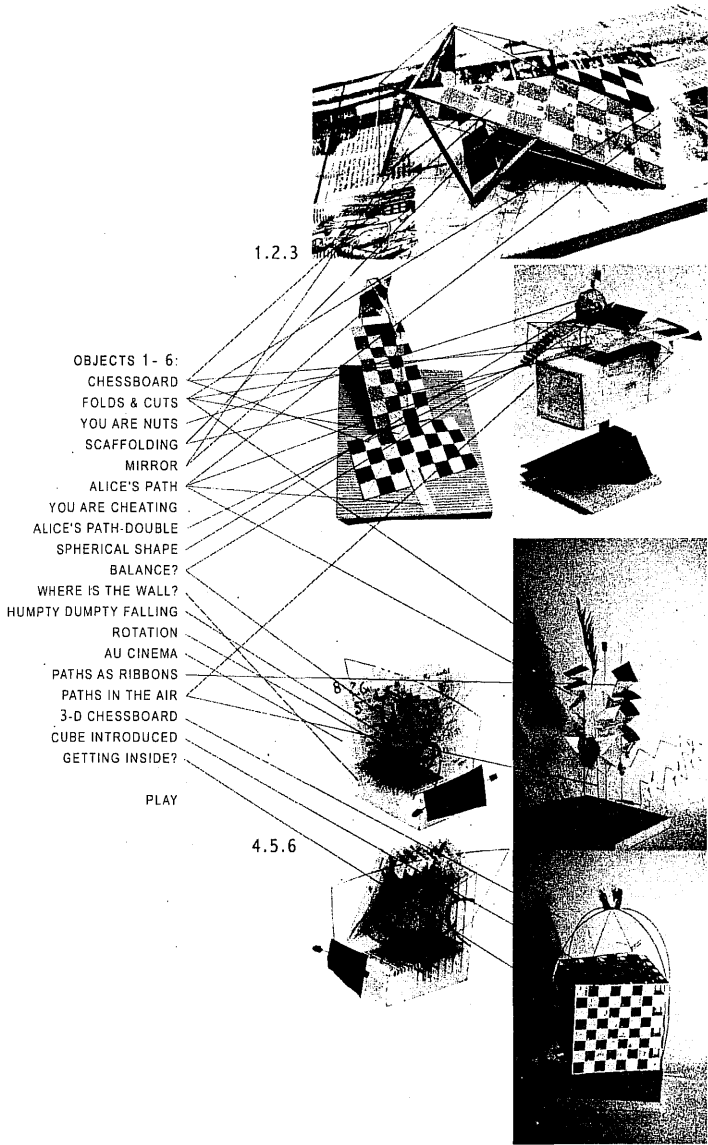
OBJECTS 1- 6:
CHESSBOARD
FOLDS & CUTS
YOU ARE NUTS
SCAFFOLDING
MIRROR
ALICE'S PATH
YOU ARE CHEATING
ALICE'S PATH-DOUBLE
SPHERICAL SHAPE
BALANCE?
WHERE IS THE WALL?
HUMPTY DUMPTY FALLING
ROTATION
AU CINEMA
PATHS AS RIBBONS
PATHS IN THE AIR
3-D CHESSBOARD
CUBE INTRODUCED
GETTING INSIDE?

PLAY

1.2.3

4.5.6

FIGURE 5: Object diagrams 1-6

OBJECTS 7-10:
SQUARE
SQUARE FRAME
CUBE SURFACE
CUBE FRAME
THE BOOK IS OPEN
DISTORTION
I FEEL DIZZY
ANOTHER PATH
IT IS BORING
NO MIRRORS
NO CHESS
YES TO
CHESSPIECES
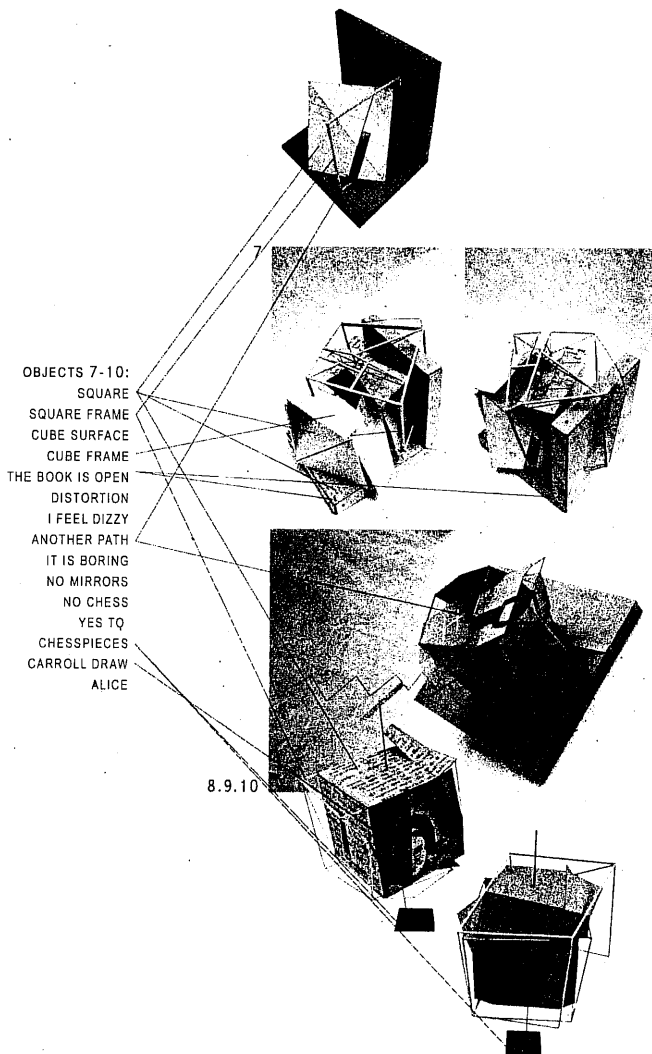CARROLL DRAW
ALICE

7

8.9.10

FIGURE 6: Object diagrams 7-10

If we shift our attention from aspects of continuity to aspects of discontinuity, we can make two fundamental observations. First, the figurative emphasis is all but eliminated in the final project. The implicit choice to abandon figure for spatial relationships is significant. Figures work iconographically, they are looked at. Spatial relationships work as settings, they can be occupied and explored. By abandoning the figurative, the final project links architectural image, the visible object, to spatial experience. Any connection to text, through analogy or metaphor, thereby becomes embodied. Second, the final cube is different from all previously constructed ones in that its surfaces are perfectly matched to its frame, and its frame remains orthogonal, with the important exception of the rotational moments created by the braces. Thus, distortion has mostly been transferred from the texture of the object to the texture of experience as we immerse ourselves into the object. We are not suggesting that folds, distortions or figurative forms are in principle inconsistent with a design emphasis upon positioning the body in space. We are simply noting a shift of emphasis in this particular case.

This shift has an obvious conceptual and operational corollary: the final construction is the only one to claim and respond to a real site. The implicit site of all other objects is the text. As a consequence the objects have no literal ground, they are self contained not merely in that they can make sense independent of each other but more fundamentally in that they can be freely moved. The siting of the final construction marks a critical conceptual transition in the relationship of text to design. In the final construction, design deploys two voices, not one. The analogy between construction and narrative set-up persists as the explicit voice. The use of text as metaphor to talk about self, context and positioning, emerges as an implicit voice. Siting marks the moment when design effort shifts from exploring analogical representations of narrative contents to assimilating these analogies into the construction of metaphor. It would seem significant that in this particular case, the conceptual dimensions of metaphor follow upon a prior stage of exploratory object making. The conceptual metaphor could be more convincingly expressed as architecture, because essential aspects of narrative setting were transferred from the means and the medium of language to architectural operations and the medium of space.

5. The logic of formulation from extraction to abduction

In introducing Lycourioti's project, we presented "making" sandwiched between two layers of "describing", or "retrieving of descriptions". First, the project was described from the point of view of a visitor confronted by the finished architectural object and gradually seeking to reconstruct the ostensive reference to the reading of text. Subsequently, we described diagrammatic constructions that did more directly document the reading of text; we traced, as much as possible, key steps in the apparent evolution of design formulation. The emphasis upon description is not incidental. Design thinking internalizes descriptions of objects and allows them to mediate subsequent manipulations of these objects.

We now shift our attention to making. The function of the constructions that punctuate the formulation of design is to extract 3-D percepts from text. These are of three kinds: first, direct manipulations of narrative references, such as the chess board, or the linear path; second, derivations and developments from original narrative references, such as the cube that initially represents a 3-D chess board; third, manipulations of different intuitions and conceptions of spatial process, such as the interpretation of motion as a layering of surfaces rather than a sequence of positions. The interaction between perceptual, conceptual and operational aspects of spatial intelligence in design is of course hardly surprising; the work of Piaget (1967) has identified and connected perception, manipulation, conceptualization and operation as dimensions of spatial understanding and learning. We would expect that these dimensions would interact, perhaps in more sophisticated ways, in the production of design constructions that project spatial formulation. For the purposes of our present argument it is sufficient to observe that the deployment of the spatial imagination initially leads to a disparate collection of 3-D diagrams that extract and present different aspects of narrative.

The crucial problem is how to interpret the proliferation of different constructions as part of a process of reasoning that ultimately crystallizes as a design. In this particular case two possible models of interpretation are patently inadequate. We are not dealing with a process of gradual elaboration and evolution, but with a process that is marked by considerable discontinuities. In Simon's terms, the solution field is continuously expanded and what is more, alternative directions of design

inquiry are not directly commensurable. Also, we are not dealing with a simple process of synthesis, where different constructs become integrated into the final product as so many parts. There are clear rejections or dismissals as well as clear transmutations and survivals of design ideas. The synthetic nature of design reasoning is more complex than either of these two potential interpretations would suggest. Would Simon's model of ill-structured problems make sense of the situation? We start by acknowledging that design interrogates diverse and perhaps disparate ideas originally explored and presented through a set of self-sufficient but different constructions. We suppose for a moment the designer to be conscious of the significant properties which allow an individual construction to stand for a given idea. We consequently suppose that alternative constructions could be projected which, through being endowed with the same property, can equally stand for the same idea: in Lycourioti's work, for example, the ideas that the design should involve cubes or that reflection should be interpreted as a pair of overlapping or juxtaposed cubes are likewise realized in multiple ways. If we thus assume potential design ideas to be associated with sets of possible constructions, the problem of the synthesis of ideas could be interpreted as a problem of finding an object which occupies the intersection of the various sets. To put it simply, one would be looking for a construction that simultaneously possesses a given number of required properties, so that it can stand for a given number of design ideas, or, which is equivalent, for a given interpretation of the design program. After a stage of heuristic search for relevant properties and for alternative ways of embedding these properties in form, the design problem would become provisionally well structured. This is a third model of design reasoning which we do not think sufficiently characterizes the process of design formulation. For easier reference we will call it the "intersection of properties" model. How then should we conceptualize the reasoning that leads to the formulation of design synthesis?

March (1976) has argued that the process whereby a proposal is produced at the earliest stages of design cannot be determined with logical rigor. March further suggested that Peirce's idea of "abduction", or "hypothesis", is closest to productive design thinking. In 1878 Peirce (1992, 188) defined abduction as the inference of a case from a rule and result, as distinct from deduction which leads to a result based on a rule and a case, and normal induction which infers a general rule from a case

and a result. March adapts this by suggesting that certain characteristics are sought which, given previous knowledge, presuppositions, or models of possibilities, lead to a design conjecture (March, 1976, 19). If we assume that the characteristics sought are analogous to the result and that design knowledge is analogous to the rule, then we would interpret the design itself as a case. This adaptation of Peirce's abduction involves a shift from interpretative to teleological reasoning. The "result", or desired characteristics, is not given as a fact, but must be brought about by creating an object, or "case". After this earliest stage of production, March argues that deductive methods are applied to predict performance and inductive methods enable evaluation, leading to further cycles of design hypothesis and testing.

We would like to adapt Peirce's idea of abduction, or hypothesis, to our account of design reasoning in a slightly different, but certainly complementary manner, one which places less emphasis on there being pre-stored models of possibilities that can directly be activated. Magnani (2001) has suggested that creative abduction, the production of new knowledge, can be distinguished from diagnostic abduction, the selection from pre-stored alternatives, without an exhaustive process of trial and error. In our example, the design hypothesis has not been arrived at through a diagnostic process. In "creative design" of the sort examined here, the aim is not to recognize the relevance of a pre-existing model but to construct a model which makes sense of an ill defined problem situation. The following quote from Peirce will serve to introduce our argument.

> Hypothesis substitutes, for a complicated tangle of predicates attached to one subject, a single conception. Now, there is a peculiar sensation belonging to the act of thinking that each of these predicates inheres in the subject. In hypothetic inference this complicated feeling so produced is replaced by a single feeling of greater intensity, that belonging to the act of thinking the hypothetic conclusion." (Peirce, 1992, 198-199)

One way to adapt this quote is to suggest that design is not merely aimed at the simultaneous satisfaction of a number of requirements, the simultaneous realization of a number of requisite properties, but rather at the production of an object such that the requisite properties seem to naturally derive from the inherent logic of the object. In themselves, the

different properties would appear like a "tangle of predicates" associated with a "complicated feeling". Once made to appear as if they derive from the inherent logic of an object, the same properties are brought under the purview of a "single conception", associated with a "feeling of greater intensity". We suggest, in other words, that one function of abduction, is turning a set of requisite properties into consequences of a more fundamental design postulate. In our particular example, requisite properties include: inverse directions of spiraling movement; movement woven across layers of spatial depth; setting an object inside another; overlapping objects; an eight-step path across a board; knight moves. This complicated tangle is simplified into a particular construction of a cube. How do the properties "derive" from the logic of the cube? The 3 x 3 grid is a classic way of composing squares, naturally lending itself to the creation of an internal object at the center of the external boundary. The inverse directions of movement are assimilated into a sub-symmetry of the square floor plan, the one preserving 180° rotation. Layering is made possible by bisecting the original 3 x 3 grid. Overlap is suggested by positioning the braces such that the overall structure seems supported by the joint effect of a primary orthogonal and a secondary rotated object, the latter present as partial frame, the former manifest as frame and surface.

According to this argument, abduction is not only applied to the original set of design requirements - here the text and in the more general case the program. It is also applied, synthetically, after a preliminary stage of diagrammatic extraction, upon material which is already spatial, not linguistic. Perhaps in more routine processes of design, spatial material is more readily, and perhaps less reflexively connoted by language. In essence we propose that the "intersection of properties" model recognizes a key aspect of design intentionality but misses its fundamental logic. The aim is not merely to incorporate properties but, more importantly, to make them appear retrospectively derivative from the equivalent of a "design hypothesis", a proposal. Our alternative model could perhaps be called a "retrospective derivation" model. Precisely because the important properties are invested into an object which can be recognized as something more than their intersection, designs are open to interpretations, or multiple readings, including readings not necessarily anticipated or intended by the designers. If we return to Peirce we note that he treated perceptual judgements, those that

allow us to recognize and characterize a given pattern, as an extreme case of abductive judgement (Peirce, 1998, 227-229). In principle, this allows that the operations of reading designs as finished products and the operations of producing designs as formulations have a common cognitive base, provided one keeps one's nose close to the object.

How then could we retrospectively characterize the process of diagramming and making which provides the inputs to design abduction? We have previously talked of "extraction". What we have called "extraction", the production of forms which stand for textual contents, would seem to combine operations of abstraction and concretion. A specific idea, image or condition is abstracted from text and then concretized in the medium of drawings, diagrams or 3-D constructions. The process is perhaps very similar to what Magnani (2001) has called manipulative abduction, it mediates between the entirely intuitive and tactile phase of design exploration and the more conscious formulation of the problem. We have argued that the transition from abstraction to concretion is made through analogy, association or similarity. However, whether the idea is concretized as an image or a spatial diagram, it is always available to be treated as a shape. Shapes have this inherent property: they can be interpreted as compositions of indefinitely many subsets. This in turns implies that they can give rise to other sets through recombination and reconfiguration (Stiny, 1999). When consisting of diagrams, drawn or constructed, concretion is inherently not static. This provides one explanation why diagrams can both articulate and destabilize particular interpretations of a problem situation (Knoespel, 2001). The transformability of shape mediates between the "extraction" of percepts and the "abduction" of designs.

6. Medium: morphic language and the transformation of spatial conditions into percepts

We now turn to the specificity of the architectural object, the creation of spatial relationships that are available to occupation. There is no architectural object until there is structured space that can be occupied. Likewise, we suggest that there is no architectural meaning proper which does not refer to the spatially situated body. For the purposes of our discussion the word "meaning" refers, quite broadly, to relations noticed

and treated as significant (Cassirer, 1955). Discussions of buildings often take off in two separate directions. First, they address the program accommodated in buildings, the overt reasons why buildings get built. Second, they address meanings that may be rhetorically inscribed in built form itself. In the latter case, an emphasis on visual image, or symbolic figure, may alternate with an emphasis on geometrical construction and the application of formal concepts to the specification of form. These three potential emphases do not directly address the modification of space as the central fact buildings are about; nor do they recognize spatial arrangement as a mediator between the experience of buildings and the activation of the imagination, interpretative or projective. The arrangement of space for human purposes, however, is the main mechanism through which buildings function to accommodate human activities. A growing body of literature which has its foundations in Hillier and Hanson's *Social Logic of Space* (1984) proposes that built space itself is a significant language; it provides an intelligible frame of reference for movement and orientation; it positions the body in a field of potential co-presence, co-awareness and communication. Hillier and Hanson (1984, 48) have defined a morphic language as any set of entities that are ordered into different arrangements by syntax so as to be intelligible. Syntax arises as space is marked, divided, enclosed, differentiated, shaped and organized by means of physical boundaries. For example, topological distinctions of interior or exterior and relationships of adjacency, containment, or sequence are fundamental to the organization of buildings for social purposes. The patterns of connectivity between lines of movement, adjacent areas, or visual fields are fundamental to the way in which space is perceived and explored through movement. So are the distinctions between integrated and segregated, central and peripheral, exposed and secluded spaces fundamental to the way in which complex spatial patterns are occupied and understood. Above all else, through their differentiation and connection, spatial patterns define interfaces between different conditions, different scales, different categories of people and different categories of use. Our concern, therefore, is to examine the way in which design becomes meaningful through the creation of spatial relationships that can be occupied and experienced.

Supposing no prior knowledge of the program that generated the design, what are the meanings that potentially arise from the design

itself? We propose that the communicative power of the design can arise from the manner in which fundamental spatial conditions are realized and intentionally transformed. Mirrors define relationships of inverted symmetry between things or spaces and their projected images. What is of interest here is the manner in which such relationships of inverted symmetry are mapped onto the asymmetric relationship of interior and exterior. The effect is to split the normal experience of the self mirrored against a background of environment, into alternative appearances of environment as projected upon external surfaces and of the self as reflected upon enclosing mirrors. On the external surfaces bodies are likely to appear as either shadows or veiled silhouettes; conversely, the building is not likely to be seen at eye level on the internal mirrors. This separation is then mediated through the sectional treatment of the cube which allows environment to become visible above the mirror, across the depth of the visual field. The two main sides of the cube, the internal and the external, are connected by the coiled path, contained within the folds of enclosure. The overall arrangement serves to create a heightened awareness of the occupancy of environment, a sense of presence and absence, of passage and envelopment. In short, there is a syntax of spatial relationships that is available to be read independently of analogical or metaphorical connections to the story of Alice. The physical sensation of disorientation (through multiple changes of direction followed by multiple reflections) serves as a trigger to direct attention to the manner in which one occupies the environment; the same applies to the physical experience of tension between physical constriction and visual expansion in the internal space of the cube. The immersive experience of spatial conditions triggers awareness of spatial relationships.

In order to account for the extension of meaning beyond our comprehension of spatial relationships, however charged, we need to postulate two things. First, that certain spatial relationships such as enclosure and interiority are already invested with fundamental significance. The definition of interior space, for example, is naturally linked to the spatial distinction of categories, whether of inhabitants of activities or of functions. It would seem that precisely because boundaries can define categories, that categories can be treated as metaphorical containers, as noticed by Lakoff and Johnson (1999, 51). Second, we need to postulate the existence of what Lakoff and Johnson have called "fundamental metaphors", which connect spatial conditions with

experiences. Thus, if passage is associated with change and if closeness is associated with intimacy, then the passage through the cube which renders the building distant can metaphorically inscribe the occupancy of the building as a mark of passage through a portion of life. We can, in other words postulate that meaning can be built upon a foundation of a syntax of spatial relationships and a set of fundamental metaphors.

Would all of this suggest that design formulation is less directly accessible to scrutiny because, more than normal problem solving, it requires us to operate reflexively upon the underlying fabric of spatial knowledge which we otherwise take for granted? Would design formulation become more amenable to systematic treatment, at least in principle, if we were willing to engage underlying structures rather than seemingly more developed building programs? We think that more than this is involved. Underlying spatial relationships, much like fundamental metaphors, can be expressed in a variety of particular ways. Regarding the linguistic mapping of underlying metaphors, Lakoff and Johnson propose that different mappings may be due to differences in the conventional images associated with languages (1999, 69). The possibility of alternative realizations of the same underlying relationships is even more obvious when we look at space. The underlying models of spatial meaning postulated by Hillier and Hanson (1984), for example, deal with topological and projective relationships rather than with affinities, similarities or isometries. Thus, they elude specific visualization, or rather become amenable to an indefinitely large number of alternative visualizations. This interaction is not simple because the same pattern of underlying connections can be realized in alternative geometries. For example, as analyzed by March and Steadman (1971), rectangular, triangular and circular plans by Frank Lloyd Wright embed the same graph of connections between functionally labeled spaces. Variations in the geometry of shape can qualify the way in which the underlying spatial relationships are perceived and understood. From the point of view of analytic theory, the task is to extract the underlying relationships from their particular realizations. From the point of view of design, however, the task is to produce an individual form. As we pointed out earlier, in normal practice, the reproduction of underlying structures into individual forms is mediated by assumptions, conventions, and an awareness of precedents or types of different sorts, whether functional, stylistic, constructional or others. In reflexive design practice two sets of

assumptions that are otherwise taken for granted can be critically revised. First, assumptions about the manner in which underlying spatial relationships determine building function and the social relations or cultural patterns associated with it (Hillier, 1996). This question is outside the scope of our present discussion. Second, assumptions about the manner in which underlying spatial relationships are imagined, projected and presented as shapes, the interaction between the syntax of space and the construction of shape.

Design formulation, therefore, not only engages underlying spatial relationships and metaphors, it also turns these relationships and their potential metaphorical extensions into percepts. The transition from underlying intuitions to percepts, images or objects, but also tactile manipulations and applied operations, occurs during both the stages of extraction and abductive synthesis described above. In design formulation, abductive reasoning operates simultaneously at two levels, the level of underlying relationships and the level of association between such relationships and particular form. Ultimately, creativity resides not only in the manner in which underlying relationships are activated or transformed but, as critically, in the way in which they are turned into percepts. The two processes, the abduction of metaphors and the abduction of percepts, seem to occur in parallel; furthermore, they seem to activate each other in multiple ways prior to the crystallization of design synthesis, almost as a prerequisite for that synthesis becoming charged with interest.

7. Concluding comments

We have approached design formulation as a production of spatial meaning over and above problem solving and have described how diagram, analogy and metaphor are engaged as aspects of it. We have looked at design abduction as the positing of a constructive principle, such that the intended properties and qualities of the design are retrospectively derivative from that principle and not arbitrarily conjoined. We have suggested that design formulation is founded upon an underlying morphic language of spatial relationships or conditions, and their associated extensions into basic metaphors. Finally, we have also suggested that the power of design arises not only from the activation and

transformation of underlying spatial structure and metaphor, but also from their reconstruction as particular percepts. We are well aware that the example used to illustrate our argument is not representative of normal design practice and that our argument does not directly illuminate design creativity as part of social or organizational process. Our aim, in engaging a rather unusual design aim, in both design and analytic mode, has been to address the foundations of the spatial construction of meaning and the interaction between space and language.

Current discussions of spatial metaphors and the manners in which they subtend thought can be enriched by considering design as an interface between symbolic forms. The potential contributions of a theory of built space as morphic language to our understanding of how spatial meaning is produced becomes evident. Without such a theory the obvious default is to subject buildings to a logo-centric discipline of interpretation, one which seeks to identify in built form some codification of ideas originating elsewhere, without equal alertness to the meanings generated as perceiving, conceiving and socialized bodies occupy structured space. Buildings are interfaces between discursive and non-discursive forms of knowledge and learning to read buildings and the languages of their design can contribute to broader theoretical inquiries over and above the theory of architecture. Our narrowly and unusually focused design exercises are probes into this larger agenda.

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