

CONTROL HIERARCHIES  
IN  
COMPLEX ARTIFACTS  
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## ABSTRACT

When we examine the composition of complex artifacts we are likely to see a hierarchical structure. The kind of hierarchy we find depends on the criteria we apply for the decomposition of the configuration under scrutiny. One criterion can be to consider the whole composed of parts that lend themselves for control by separate agents in charge of the design or maintenance of it. We will seek for such *control units* in the complex artifact. Hierarchies composed of control units tell us about the ways we can partially transform the artifact and how different designers may best distribute, among themselves, their design joint efforts. Hierarchies composed of control units we will call *control hierarchies*.

Three kinds of control hierarchies are distinguished. The first, called *assembly hierarchy*, is commonly known and predominantly technical in nature. It tells us that a unit on a higher level of the hierarchy is composed of parts we find on the lower level. Control is one of assembly of smaller parts into a larger one and the process is a sequence of assemblies.

In the other two control hierarchies the entities we find on a lower level do not assemble to form a higher level unit. The relation between the levels is not one of assembly but of 'dominance' where the transformations on the lower level are constrained by the higher level. Of these two, one has to do with the control of physical elements and is called a *dependency hierarchy*. The other has to do with the control of spaces in which we distribute our physical parts and is called a *territorial hierarchy*.

The paper also discusses the relation between these different hierarchical structures. It particularly touches upon the relation between dependency hierarchies and territorial hierarchies and considers how the same physical configuration can have different territorial interpretations.

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## INTRODUCTION

Designing is a social activity in which various parties seek consensus about what to do: the professional designer, the client, and other consultants must work together in the design process.

Looking at the design process in this way, we must consider the interaction between, on the one hand, the parties who act and, on the other hand, the configuration shaped under their action.

Studying this interaction we see, in the configurations we make, the hierarchical structures that are the subject of this paper. When we look only at the forms and not the parties who act, we learn little about designing. When we look only at the people and not at the forms that result from their efforts, we may remain equally ignorant about designing: but when we study the interaction between the two, new perspectives emerge.

My paper is based on experiences and studies about the design of environmental forms: buildings, neighborhoods and other settlement forms, but I will try to formulate as generally as I can the principles I found because I believe they can be applied to the design of any kind of complex artifact.

What I have to say has nothing to do with functional or aesthetic objectives. The function we attach to the object we are designing and the purposes we attach to our designing make us a designer of a certain kind of artifact: e.g. architect, mechanical engineer, etc. When, therefore, we seek to discover what is of interest to designers of different disciplines, we must disregard specifics of function and purpose and focus on the interaction between the designer and the form as such.

## 1. AGENTS AND CONFIGURATIONS

1.1. I will call an agent P, any person, or group of persons acting as one, capable of transforming a configuration C. I will write PP for a combination of such agents, each transforming their own configuration, and P or Px for a single agent.

Suppose there is an agent P acting to transform a configuration called Ca.

For P to transform Ca there must be parts of Ca to be taken away, to be added, or to be displaced. (I do not consider the displacement of Ca as a whole to be a transformation of it, but such displacement can be the transformation of a larger whole of which Ca is a part.)

Thus P may see Ca as composed of parts b.

We can write:

$Ca \Delta b, b, b, \dots$  1)

in which  $\Delta$  may be read as 'composed of'. On each side of  $\Delta$  we see the same whole described in a different way. On the left we see the whole as a single object. On the right we see it as a *configuration* of parts. We do not define  $Ca$  as a set of parts but as a configuration of parts. The same set of parts can yield a different configuration when  $b$ 's are differently positioned in space relative to one another. Thus there is implied in  $\Delta$  a set of parts and a set of position relations among the parts.

1.2. There are many ways in which  $Ca$  can be seen as composed of parts. What parts an agent  $P$  decides to see is for it to decide and may have to do with convention, function, preference, or convenience. The important thing is that, to act at all,  $P$  must agree on what parts  $C$  is made of. We will therefore say that the expression 1) is correct for a particular  $P$ .

1.3.  $P$  can see each part  $b$  as a configuration in itself; thus a particular part  $b_1$  becomes  $Cb_1$  and

$Cb_1 \Delta c, c, c, \dots$  2)

and again, this way of seeing  $Cb_1$  is a matter of choice for  $P$ .

1.4. Looking at 1) and 2) together, we have a description of  $Ca$  as a *part-whole hierarchy*. We are accustomed to seeing complex things as part-whole hierarchies. We may see, for instance, a wall as composed of bricks, a window as composed of a frame and other parts that fit the frame, a door as a frame that holds a part that moves, etc; and a house as composed of walls, windows, and doors, etc.

## 2. MOVES

2.1 In this paper, however, we want to look at  $Ca$  not just as a composition of parts, but we are interested in  $P$  acting on  $Ca$ .

Whatever  $P$  does will be a combination of three basic acts:

Take away a part: elimination  
Add a part: introduction  
Put a part somewhere else: displacement or re-arrangement.

But  $P$ , we may assume, will act with purpose and seek to establish certain relations between parts  $b$  in a sequence of basic acts. Such purposeful combinations of basic acts are intended to 'arrange' parts and we may call them 'arrangement moves' or 'moves' for short. Connecting parts, putting parts on a distance from each other, stringing them along an imaginary

line, or making them conform to certain geometric patterns, are all arrangement moves.

### 3. CONTROL

3.1. Control is the ability to decide on moves. When agent P can decide to transform a configuration Ca, by moving ( displacing, introducing, or eliminating) all and any of the parts Ca is composed of, we can say that P is in full control of Ca.

When Ca is controlled by an agent we will write:

PCa

Because we do not know anything about P other than that it controls Ca, we really have identified P by Ca and, therefore PCa stands for an agent as well as for a configuration Ca under control.

3.2 We have seen that Ca can be composed of parts b. Thus, by way of demonstration we may have:

Ca  $\Delta$  b1,b2,b3. 3)

We have also seen that b1 and b2 and b3 could be configurations by themselves composed of parts c.

That means that Cb1 and Cb2 can be under control of their own agents PCb1 and PCb2. And we can write:

PCa  $\Delta$  PCb1, PCb2, PCb3. 3.1)

We can think of the house Ca which is composed of walls Cb1 and windows Cb2, and doors Cb3. And there is an agent PCb1 that assembles the windows out of smaller parts c, and another agent PCb2 that assembles doors out of other smaller parts c, and an agent PCa that assembles doors, windows, and walls into a house.

3.3 To have a situation as given in 3.1) it is necessary that the four agents involved see the whole configuration PCa in the same way. These agents must *agree* on the way they will see the whole Ca and its parts. We begin to see the complex whole as the result of a *social agreement*. Thanks to this agreement the different agents can act meaningfully on their own.

### 4. ASSEMBLY HIERARCHIES

4.1 Part of the agreement implied by 3.1) is that the configurations PCb1, PCb2, and PCb3 can be independently composed of smaller parts c in different ways because otherwise no agent could exercise control over them. If that is the case, we can say that b1, b2, and b3, are *control units*. And if Ca can be transformed by combining b1, b2, and b3, it is also a contro unit.

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for instance, we may see the porches of different houses in a street as a configuration by itself, but that configuration of porches cannot be a control unit. The larger control unit a porch is part of is the house it belongs to.

In case of the porches along the street we can identify a configuration composed of other configurations:

$$Ca \Delta Cb1, Cb2, Cb3, \dots \quad 4)$$

And we know that the porches are control units so we can write:

$$Ca \Delta PCb1, PCb2, PCb3, \dots \quad 4.1)$$

But there is no agent PCa.

4.2 In this paper, while any spatial distribution of control units Pb1, Pb2, etc... can be seen as a configuration, we will be particularly interested in a configuration Ca which itself is a control unit as well, so that we can write:

$$PCa \Delta PCb1. PCb2. PCb3, \dots \quad 4.2)$$

Which means that agent PCa can decide which configuration Cb will be part of it and where a configuration Cb will go in the configuration Ca; while each PCb, as a configuration by itself and as a control unit, will have similar control over its own parts.

4.3 In expression 4.2) we have, from among all the possible configurations we may see as part-whole hierarchies identified one that is, at the same time, a *control hierarchy*. That is to say, a hierarchy in which all parts are control units. Control hierarchies are the hierarchies we normally tend to consider when designing and building complex artifacts.

4.4 In a control hierarchy each agent can assemble its own configuration from parts it can select and arrange. There are different kinds of control hierarchies that we will discuss later on. In the control hierarchy of expression 4.2) PCa is an assembly of several configurations PCb. And each configuration PCb is an assembly of configurations PCc. When this is the case, we will speak of an *Assembly Hierarchy*. An assembly hierarchy is a part-whole hierarchy in which the parts are control units.

( the expression 4.1) we see a part whole hierarchy as well, but it is not a control hierarchy and therefor not an assembly hierarchy.)

4.5 In these general expressions we are not interested in the identities of the agents involved. The individuals who control the parts Cb may be in joint control of Ca, forming together a PCa. Or a different individual, or group of different individuals forming one agent, may be PCa. In the latter case this agent PCa may or may not, be mandated by the Pb's to take care of Ca. Regardless of identities, PCa will always be an agent distinct from those on the lower level of the assembly

hierarchy because it has a different control responsibility. PCb's only control parts, PCa controls the combination of these parts.

## 5. DOMINANCE

5.1 Now let us consider two parts b that together make a configuration Ca.:

Ca  $\Delta$  b1, b2.                      6)

Suppose we do not know what control situation is at hand but that we can observe, over time, transformations of Ca; that is to say, we can observe the results of control exercised on Ca.

Let us use an abstract example and take two rectangles of the same shape marked b1 and b2 respectively in a field F. Let the field F with the two rectangles in it be the configuration Ca ( see figure 1)

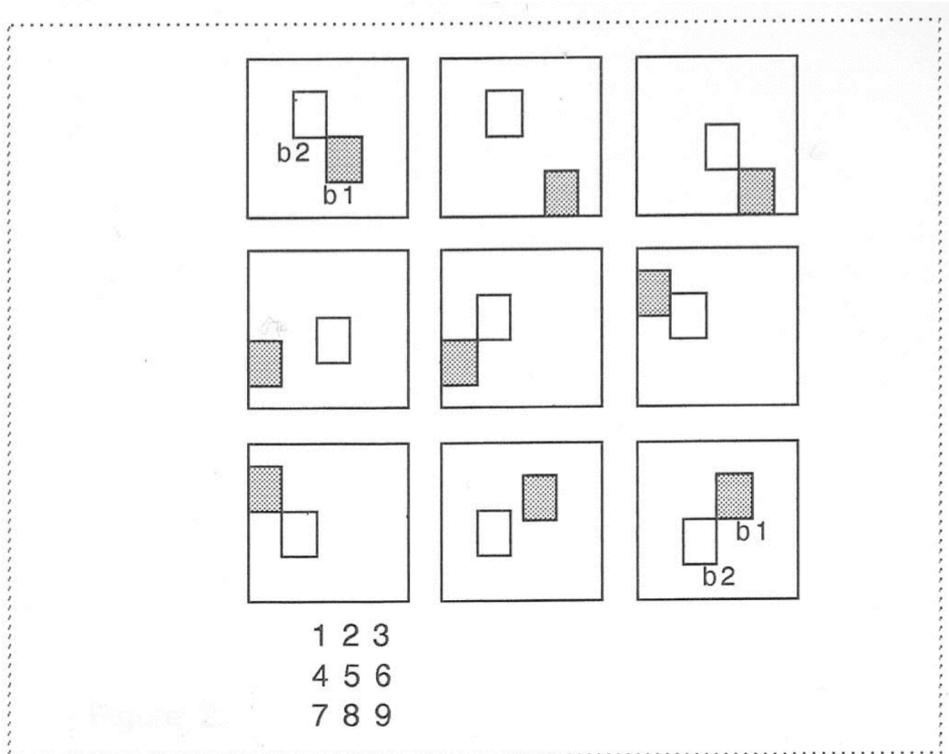


fig.1

5.2. Suppose we now observe a sequence of transformations as, for instance, given in figures 1.1. through 1.9. The configuration Ca consist of two rectangles located in a square field. Ca transforms because the rectangles b1 and b2 change their location within the square they inhabit. The transformations should be read from 1 to 9 in figure 1. We see that each time, when b1 moves, b2 moves to connect itself with one corner to a corner of b1. Apparently, b2 wants to maintain a relation to b1, while

b1 is free to disturb that relation by displacing itself. When we see a pattern like that we can conclude that b1 *dominates* b2.

5.3. Dominance is defined as follows:

If there are, in a configuration, two parts b1 and b2 and we find that, when b2 is displaced or transformed, it does not force displacement or transformation of b1 but, when b1 is displaced or transformed, it may force displacement or transformation of b2, then b1 dominates b2.

5.4 Because our example consists of abstract rectangles we cannot see why dominance takes place. We will see later on that reasons for dominance can vary. Perhaps b2 needs to connect to b1 for functional reasons ( say, b2, to function must plug into b1) in which case the configurations determine dominance independent of the agent in control. It may be that agent P in control of the configuration just likes b2 to be in a diagonal relation to b1, and that another agent controlling this configuration would not follow the same pattern. The dominance situations we find in real life are of both kinds. Sometimes function demands it, sometimes it results from human preference or habit. Often the distinction is not so clear. Our interest is in the behavior of forms under control of agents, not the motivation of agents. We are looking at dominance relations among configurations and parts rather than dominance relations among agents.

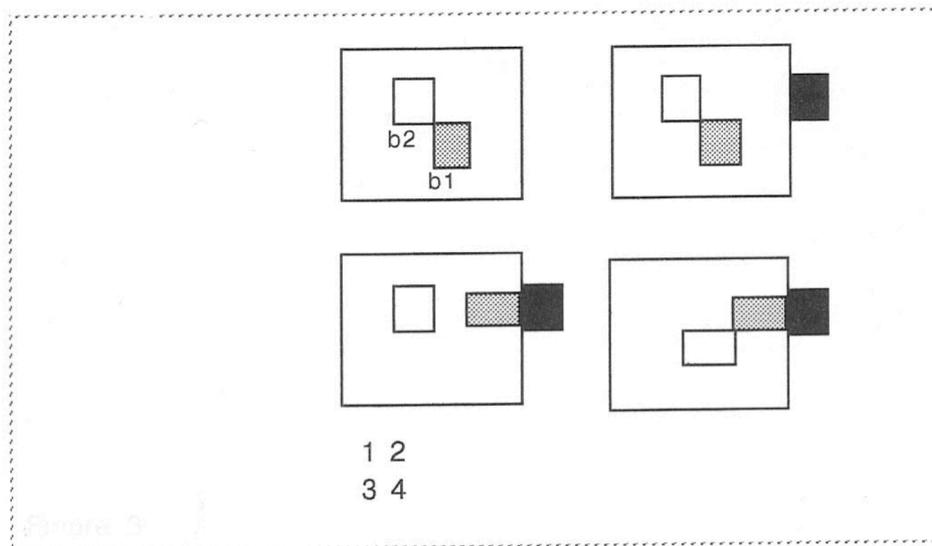


fig.2

5.5 Figure 2 suggests that b1 is, in turn, dominated by a part outside Ca: b1 seeks to place itself adjacent to that third, outside part. In that case, we find a chain of dominance among three parts. It is not difficult to see that complex situations can result from such chains of dominance.

## 6. DEPENDENCY HIERARCHIES

6.1 Hierarchical structures based on dominance among control units can be seen in many artifacts. We will call them *dependency hierarchies*.

For an example that is rather similar to that given in fig.2, but less abstract, think of a chair relative to a desk and of the desk relative to a wall against which we want to place it. When, in our design, we move the desk, we want the chair to come with it and when the wall is shifted, we will also adjust the table to stay with it.

Once we know dominance, many examples can be found in real life.

For another example a wall may contain a window. The designer can give the window different positions in the wall while the wall stays in place, but when the wall is displaced, we expect the window to come with it. Buildings may line up along a street. The buildings can be taken down, altered, or newly built while the street remains the same. But when the street must be widened, or even shifted in its course, buildings must adjust. We take it for self evident that the street pattern dominates the positioning of buildings. Similar examples will be discussed in more depth later on.

6.2 If we take the symbol  $\supset$  to mean 'dominates' we can write, when two parts b1 and b2 of a configuration have a relation of dominance:

$$b1 \supset b2 \quad 7)$$

and it may also be that b1 and b2 are control units:

$$PCb1 \supset PCb2 \quad 7.1)$$

6.3 As we can see from the examples given and from the figures 1 and 2, lower level entities (b2 in expression 7) in a dependency hierarchy cannot combine to make the higher level entity (b1). A combination of chairs does not make a table. A configuration of buildings does not make a street. Even when we would have, in the situation of figure 1, two parts b2a and b2b wanting to connect to corners of b1, these two lower level parts could not combine to make a b1. Unlike with assembly hierarchies, in a dependency hierarchy configurations on the lower level are not parts of a higher level configuration.

We therefore cannot write:

$$b1 \Delta b2 \quad 8)$$

there is no way to make a desk out of a number of chairs, or a wall out of windows.

But we can write:

$$Ca \Delta b1, b2$$

For instance: my work station (Ca) consists of a desk(b1)

and a chair (b2). Or: the facade (Ca) consists of a wall (b1) and a window (b2).

So, where b1 and b2 are on the same level in an assembly hierarchy, they are on different levels in terms of dominance.

## 7. SHAPE AND DEPENDENCE

In the example of figure 1, b1 and 2 are exactly the same shape and inhabit a free field; nothing in the shapes of figure 1 makes dominance likely; we recognize it only in the sequence of moves.

In many cases, however, we find the forms themselves of such shapes and composition as to suggest the distribution of control we call 'dominance'.

7.1 Consider the series of figure 3. We see a configraton Ca. In it we can distinguish two configurations that are themselves composed of smaller parts: on the highest level of assembly we have:  $Ca \Delta Cb1, Cb2$ . Here Cb1 is made of 'pegs' (p) and forms a cluster of enclosures:  $Cb1 \Delta p1, p2, p3, \dots$ , while Cb2 is a distribution of squares (s):  $Cb2 \Delta s1, s2, s3, \dots$

We can see, therefore, an assembly hierarchy of three levels: The lowest level parts are pegs and squares ( p and s), the middle level parts are Cb1 and Cb2, and the highest level is Ca, the combination of these two.

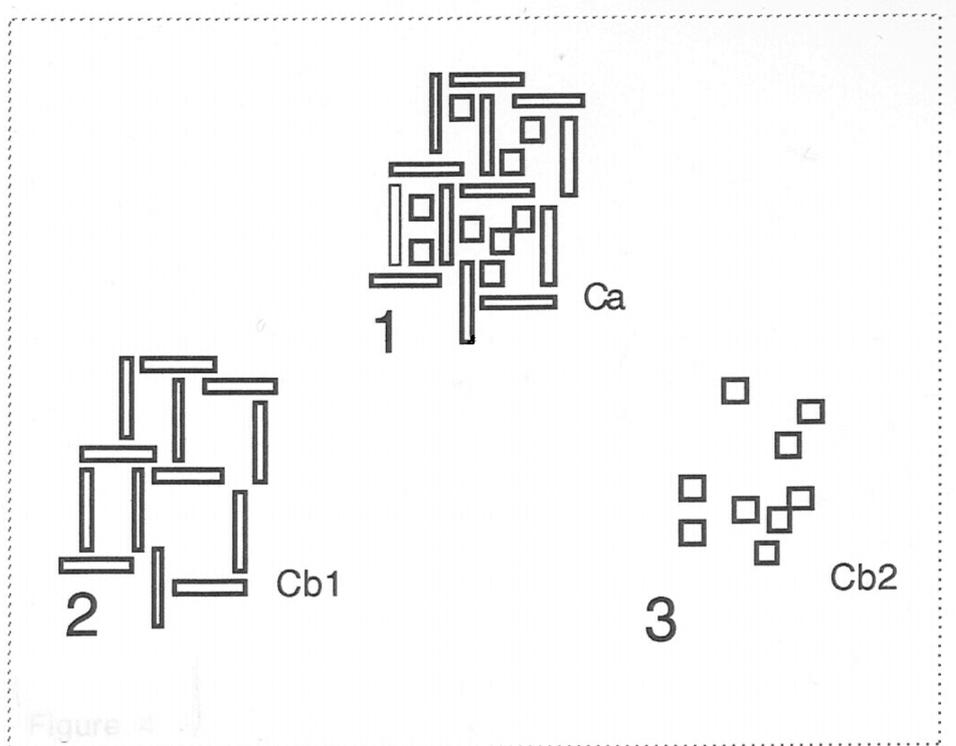


fig.3

7.2 Let us assume that Cb1 and Cb2 are control units so that we can write PCb1 and PCb2.

Let us further assume that, by agreement among agents

PCb1 and PCb2, the relation between Cb1 and Cb2 is such that the squares must be located in an enclosure formed by pegs. No square may be found outside such an enclosure.

Figure 4 gives an example of a sequence of moves under the assumed circumstances. In figures 5.2 and 5.4 squares move. In figure 4.3 pegs are moved. We find that the agent in control of squares can take out and bring in and displace parts without forcing transformation of the configuration of pegs. On the other hand, we find that transformation of Cb1 (the pegs) easily disturbs the configuration of squares (Cb1). To open an enclosure or to shift the boundaries of an enclosure, it may be necessary for PCb1 first to 'evict' the squares inhabiting it: that is to say it must force PCb2 to move its squares a certain way.

Of course, when PCb2 refuses and gets away with it, PCb1 is no longer in control of Cb1; it must dominate to exercise control. Thus, the systemic and morphological conditions are such that whoever controls Cb1 will dominate Cb2 or, to put it differently, the condition for control of Cb1 is to dominate Cb2.

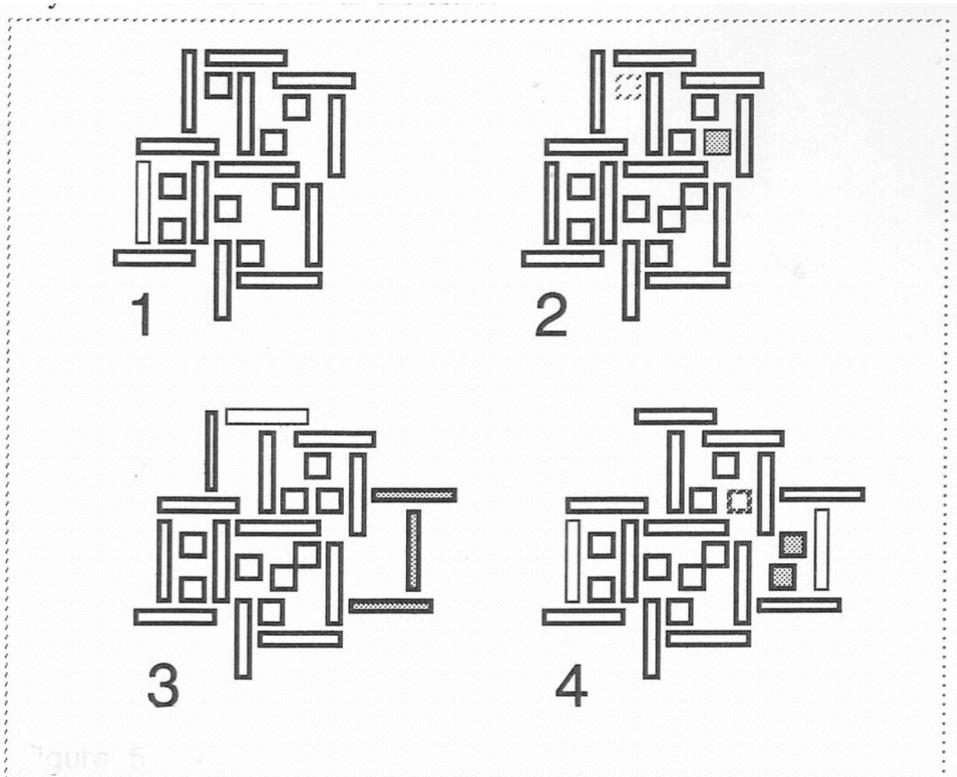


fig.4

Configuration Ca, behaving under transformation as it does in figure 4, makes us see a two-level dependency hierarchy. We can, from there, begin to construct a dependency hierarchy of greater depth.

7.3 Once we have seen configurations like those given in

figure 4, we may guess, next time when we see a similar configuration , that there is a dependency hierarchy there. It is so familiar that we have a name for it: dominance by forms of enclosure. Of course, we can only be sure when we watch such a configuration transform, because it need not follow the assumption of enclosure figure 4 is based on.

When we deal with complex artifacts, we often 'see' dominance in this way. We do not need to watch the transformations of the artifact to predict its 'behavior' under transformation, because we are familiar with it and recognize it in the shapes of the configurations at hand.

But while it seems that morphology determines dominance we may find, on closer scrutiny, that convention also plays a role. It is 'natural' that the chairs 'follow' the table because their use is habitual. It is 'self evident' that the street dominates the buildings but one can imagine a case where the distribution of buildings determines where the streets go. Thus dominance is closely related to form, but that relation may be conventional as well as formal.

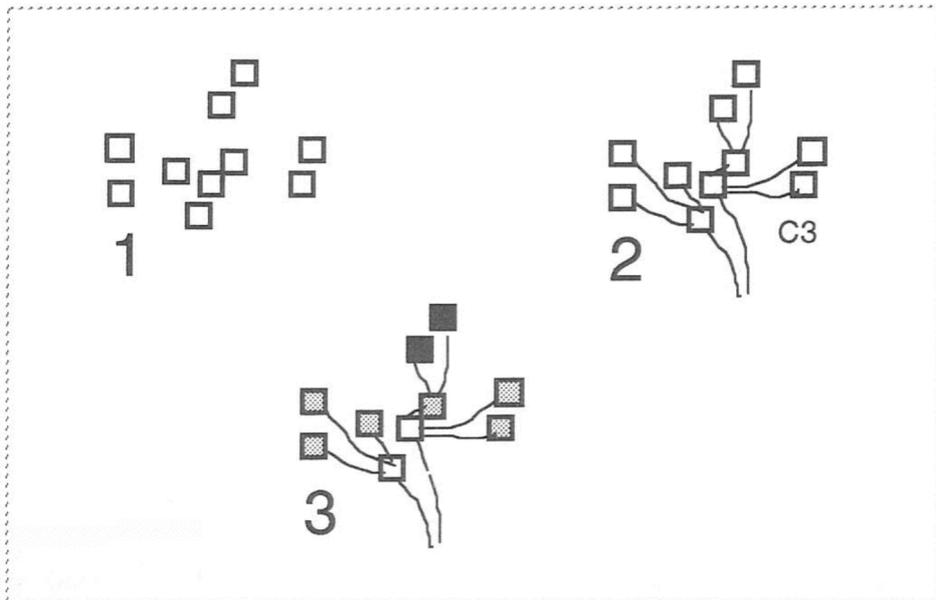


fig.5

7.4 Common vocabulary tells us that we have an innate sense for dominance relations in complex forms. When a higher level form transforms and lower level forms must yield, we speak of a 'structural' problem. What we call 'frameworks' or 'infrastructures', are usually higher level forms in a dependency hierarchy. The framework allows us to attach a diversity of objects to it. We can change and rearrange these objects without disturbing the framework, but, when we redesign the framework, the distribution of lower level objects is disturbed and must follow the new arrangement.

7.5 Be it convention or morphology, there are shapes that we easily recognize in terms dominance relation. Among them, different shape-families can be identified, suggesting different

kinds of dominance relations between levels. Three are suggested here:

7.5.1 The *relation of enclosure* gives us one family of dependency hierarchies. Figure 3 is of that family and the relation was established in the case of 7.2.

7.5.2 A *relation of supply* usually yields tree-like higher forms by means of which lower level configurations are served. In figure 5.2 we see an example of two tree-forms together. In figure 5.3 the levels of the parts are shaded differently.

The configuration of squares in this example ( fig. 5.1) is taken from figure 4.4. By means of the connections, squares are placed in dependence relations among themselves. This example shows how, in a dependency hierarchy, the same physical entity ( square) can appear on different levels. Because we are looking at a configuration of parts, not a diagram, the connections are parts of the configuration as well. The connection parts, by themseleves, do not constitute a configuration of another level. They belong, like the squares, to a single configuration.

Please note that in the same configuration the supply can move two ways. If it is a water supply system the water is distributed from a central point to the various branches. If it is a waste collecting system, the flow goes from the branches towards the center. But the dominance situation remains the same. The center always dominates the branches. Branches can sift freely, but when centers shift, branches must adapt.

7.5.3 A third family of relations, *relations of gravity*, are those where one configuration 'carries' or 'supports' another. When, for instance, a lintel is placed on columns, the lintel must be displaced if the configuration of columns is to transform, but the lintel can be displaced without disturbing the configuration of columns. Thus, if one agent controls the columns and another the lintel, the column agent dominates.

6.6 Of these three families only the third is fully determined by physical constraints. As already pointed out earlier, in most cases morphological constraints ( e.g. enclosure) may suggest, but do not always force, dominance. Usually there are, in addition, agreements among the agents in control of the parts, having to do with the purpose and function of the artifact we are designing. Or simply having to do with preferences shared by the agents.

Very often we are so familiar with the dependency hierarchy at hand that we find the relation of dominance quite natural. Yet this may be the result of habit and convention and not of natural laws. It is because we are familiar with the forms we make - know how things transform and are manipulated by various actors - that they strike us as self-evident.

## 8. CONTROL DISTRIBUTION

8.1 As noted when discussing figure 1 we can determine a dominance situation by observing the transformations of a configuration without knowing exactly who controls what. In the hierarchy of figure 3, we defined the configuration of squares (Cb2) as a single control unit of a level lower than the configuration of pegs (Cb1). But it is easy to see a large number of control units in Cb2. Indeed, every square could be one, so could every group of squares in a single enclosure. It follows that we can think of many separate agents controlling one or more parts, instead of a single agent controlling all squares. Thus, different patterns of control distribution are easily possible relative to Cb2.

In the same example, the configuration of pegs (Cb1) does not so easily suggest a distribution of control. Its parts must act together to form the enclosures, leaving less freedom for independent moves.

In other words, the configuration of fig. 3 is most naturally understood as a single configuration of pegs, enclosing many configurations of squares. This difference between the higher and the lower level in terms of control distribution is typical for dependency hierarchies. We imagine them quite naturally as a single agent in control of the higher level confronting a number of lower level agents all in the same vertical relation with it. Think of the street with many houses along it, the table with many chairs around it, the wall with many windows in it. Indeed, the tree branch with many leaves growing from it.

8.2 When we return to the squares (Cb2) in figure 3, we see how an agent could control any number of squares distributed over any number of enclosures. Yet, so suggestive is the form, that we feel that control over squares in more than one enclosure is almost like playing the same role twice. The dominance relation between squares and their enclosure is evident and powerful, while the relation among squares, short of sharing the same enclosure, is not evident in figure 3.

The same can be said of the example of figure 5.3. One agent could control different squares of the same shade, but the relation we recognize is the one of dominance, not the interaction between parts of the same level.

The very nature of the hierarchical structure is to isolate entities on the same level and to establish vertical relations. For that reason, the distribution of control over the lower level configuration is more free and variable.

8.3 We can also imagine a single agent in control of a higher level configuration and, at the same time, having control over some of the lower level parts. But it is clear that this agent must play two different roles. Being a higher level power makes it dominate a number of lower level agents and being a lower level agent at the same time may cause a conflict of interest. A same agent may exercise control on different levels, but that does not make the parts it control into a single

configuration. The form makes the same individual act as two different agents.

8.4 Thus, we can see, in the figures 4 and 6, a great variety of possible control distributions over the same form. But this variety does not diminish the autonomy of the physical situation and the relational agreements we attach to it. To change the dependency hierarchy, those in control must get together and decide to change the relational conditions they have agreed upon sofar.

## 9. TERRITORIAL HIERARCHIES.

9.1 Control over a Physical configuration means that we can transform the configuration. Transformations must take place somewhere and, unless we also have control over a space to work in, we may not be able to move. Yet, control over physical parts is not the same as control over space. In complex physical organisations we can distinguish a separate hierarchy based on the control of space. This *territorial hierarchy* has its own autonomy which, like the physical hierarchies discussed so far, is based on agreement among parties.

9.2 We define here control of space as the ability to determine what goes into the space. A territory T is a space under control of a party P. Each territory has boundaries and P controls T when P can decide what may cross the boundary to enter T.

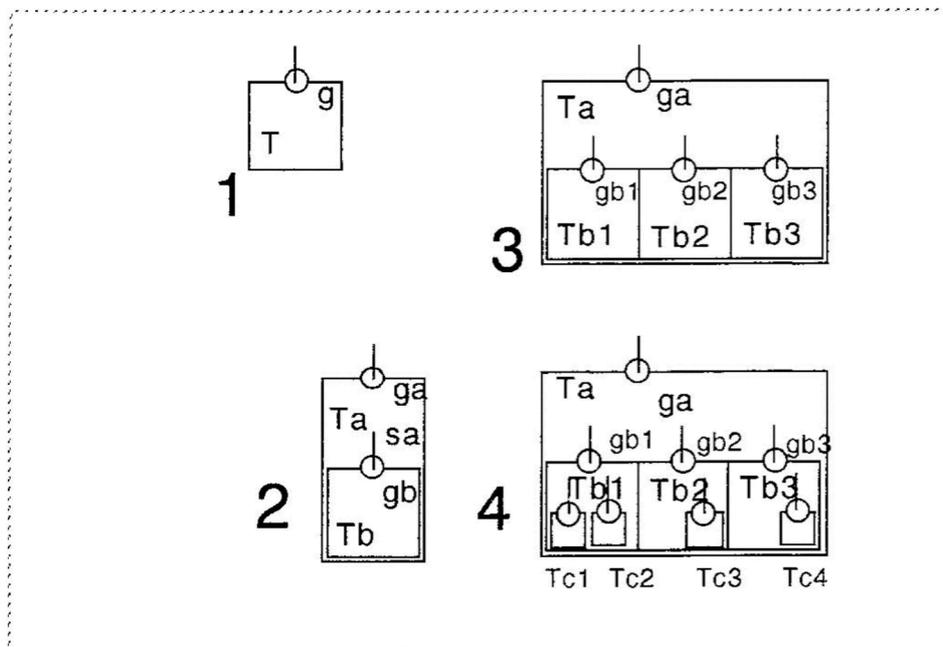


fig.6

9.3 Suppose a single territory T is entered through a gate g. ( figure 6.1) Outside that gate we must expect another space 's' under control of another party. ( If there is no other party to be kept out g is meaningless and there is no T.)

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This means that s must have guarded boundaries too and hence its own gate. (fig. 6.2) If ga in fig 6.2 is the only gate through which gb can be reached, we find that whoever controls ga must dominate whoever controls gb, because Tb can only admit what enters Ta first. It follows that ga is access not only to sa but also to Tb. It is therefore correct to say that there is a largere territory Ta which encompasses all space accessed through ga. In other words, Tb is included in Ta.

This relationship is easily understood when we read for Ta the state of Massachusetts, and for Tb the city of Boston.

9.4 Because the total space of Ta encompasses both Tb and sa, we can say that, in Ta, sa is the public space while Tb is the private space of Ta.

There are many cities in Massachusetts. We can think of a situation, more common than our example so far, where several Tb are included in one Ta. (fig.6.3) When we control any included territory Tb, we can freely step out in the public space sa of Ta. But we can close off our territory from whatever comes from sa.

Hence the boundary relation is asymmetric. Agent PTa may not close our door gb2 and imprison us. Thus, all inhabitants of a Tb have free access to sa, they are also inhabitants of Ta, and sa is the space they share: their public space.

These definitions of public and private space are in accord with the normal usage of the terms. (We must not speak of public and private territory, but of public and private space, because we are talking about spaces that are parts of a territory, and sa is not a territory by itself but only the public part of a territory.)

9.5 Consider a deeper territorial structure, where each Tb in turn contains one or more territories Tc, The inhabitants from Tc, stepping outside their gate, will enter a common, public space sb. This time, a territory Tb is the sum of sb and all included territories Tc, and sb is public space to all those so included.

However, to a visitor from territory Tb2, who goes out into sa and approaches the gate of Tb1, Tb1 as a whole is private space she can not enter freely. Once admitted she will find herself in sb which, to those coming from Tc, was public space.

We see that the concepts of public and private space are relative and depend on which way we move. going outward, moving into ever more encompassing territories, we move always into public space. Returning and going inward in ever deeper territories, we move always into private space.

Understanding te hierarchical structure of territory frees architects and urban designers from confusion, often encountered, about 'private'. 'semi-private'. 'semi-public' and 'public' spaces. Any space we may find ourselves in can be seen as public or private depending on which other space we see it related to.

## 10 TERRITORIAL INTERPRETATION OF CONFIGURATIONS

10.1 Territorial boundaries are determined by control, and although it is convenient to mark them with walls, fences, or corner posts, this need not be the case. Territorial boundaries are often invisible, although clearly defined, like those between nations. When we observe bathers on a beach or campers on a campground, we see likewise territorial divisions without readily visible boundaries. The wall and the gate, on the other hand, may not mark a territorial boundary at all: for a house in its surrounding garden, the doorway is not a territorial gate: the boundary is between garden and street. There is no one-on-one relation between physical form and territorial organisation.

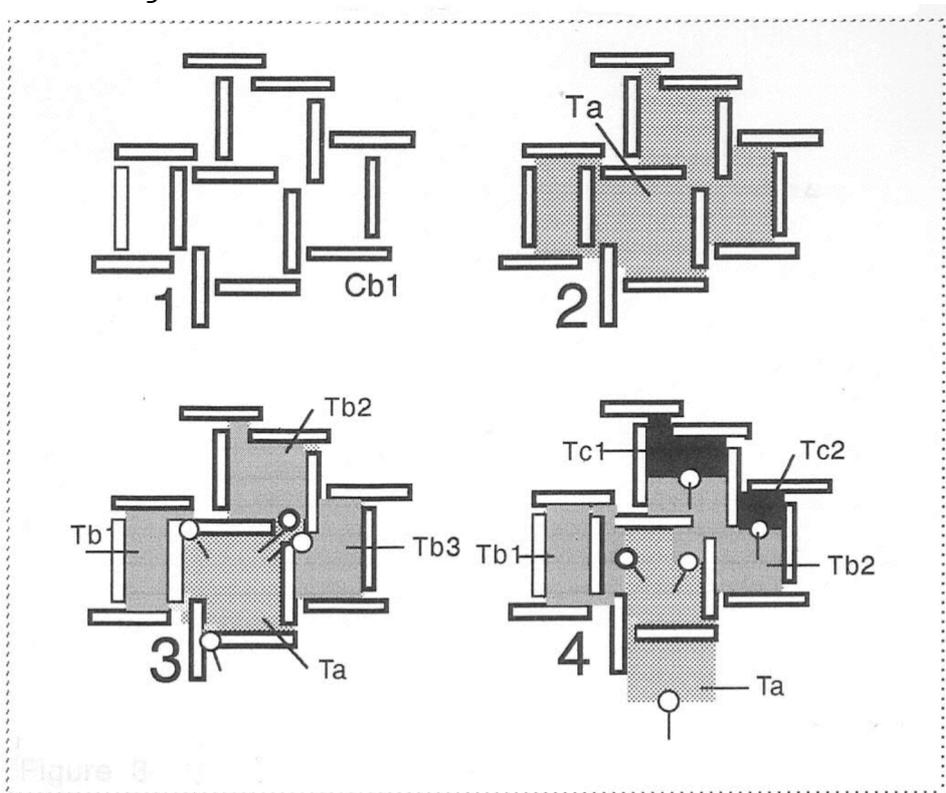


fig.7

10.2 Any given configuration of physical parts can be interpreted territorially in different ways. Figure 7.1 shows the higher level configuration Cb1 of the earlier example of figure 4.4. If we read in this picture a constellation of walls, we may first see it as one territory bounded by the outer walls of the configuration. (fig.7.2)

in figure 7.3, Ta is still bounded by Cb1. We see inside Ta a hierachy of three included territories Tb, the boundaries of which still follow closely the wall configuration. To read a territorial hierachy in this figure, gates have been placed and it is assumed the boundaries, indicated by Cb1, are otherwise closed.

In figure 8.4 the territorial organisation departs from

the spatial organisation suggested by Cb1. First, Ta has expanded outwards and its gate now is located away from Cb1. Second, we find that Tb2 and Tb3 have merged into one territory Tb2. Third, we find that the boundaries between the public space of Ta and included territories Tb no longer follow the walls locating gates gb1 and gb2 free in physical space. Fourth, we find new territories included in Tb2, making a deeper hierarchy. Their boundaries and gates are placed within the spaces formed by Cb1.

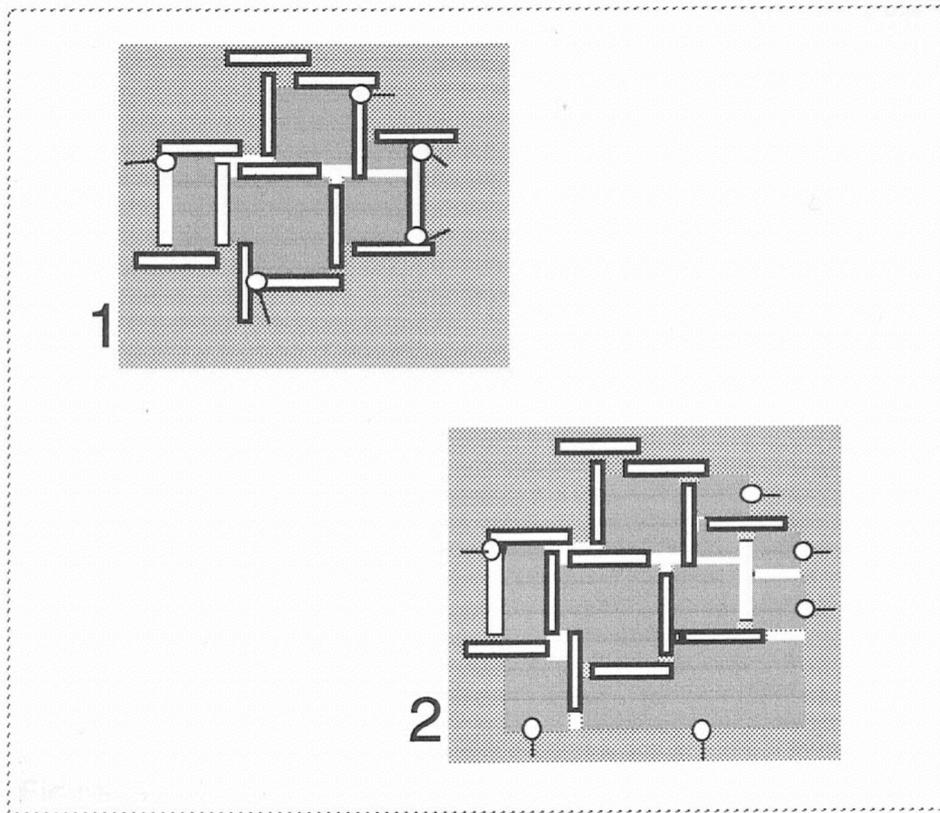


fig.8

10.3 Another variation of territorial interpretation of Cb1 assumes that it is fully occupied by territories of the same depth, all with their gates at the periphery of Cb1. (fig.8.1) This implies a larger territory containing Cb1. This situation isw analogous to an urban block surrounded by public streets.

The final interpretation of Cb1 follows the same organisation but here the outer boundaries of the territories are found well outside of Cb1. (fig.8.2) We can think of frontyards and five toterritorial gates are no longer within Cb1.

10.4 In addition to this exercise with a form of enclosure we can look again at C3 of figure 5.2 repeated in figure 9.1. This time in relation with territorial control. C3, obviously, can be under control of one party and therefore be inside a single territory Ta. The 'gate' of Ta is here indicated by the crossing of the boundary by the supply lines. (fig.9.2)

The territorial hierarchy of figure 9.3 follows exactly the dependents levels of the supply configuration C3.

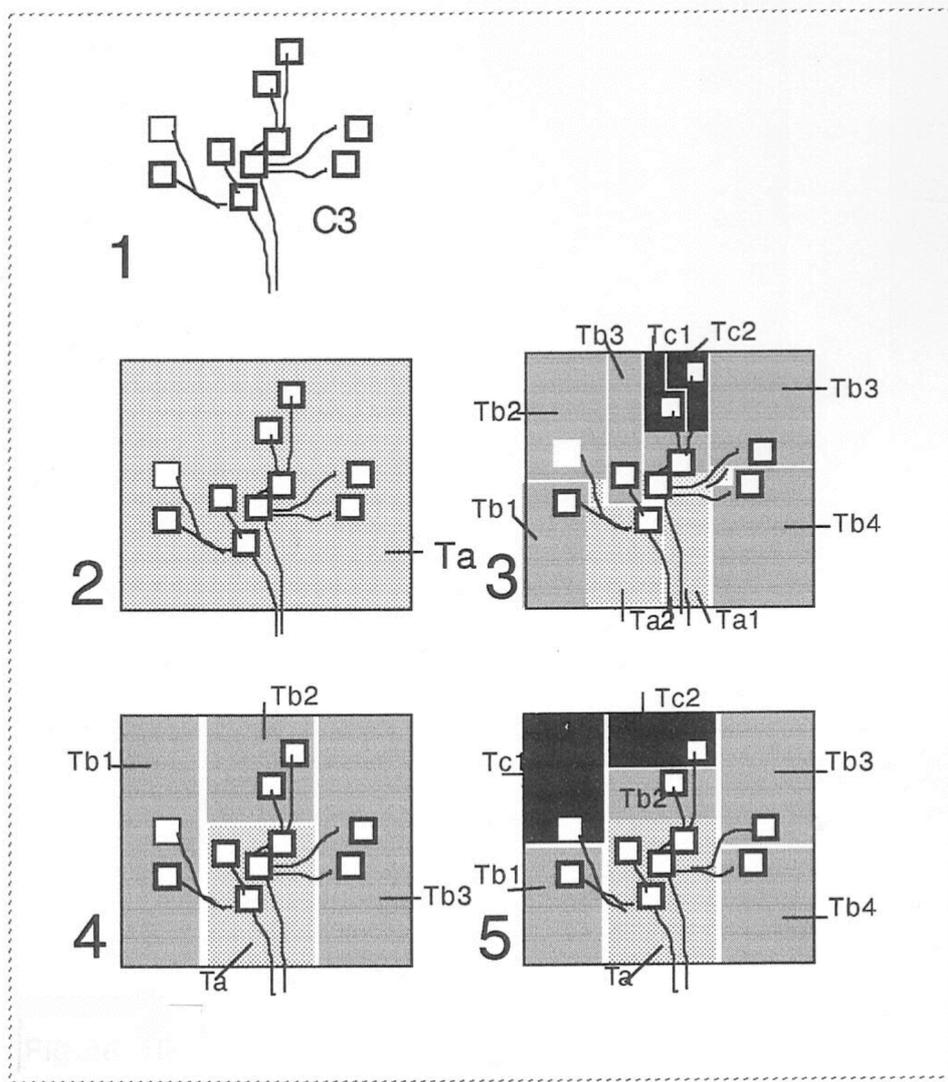


fig.9

In figure 9.4 we find several levels of the dependency hierarchy of C3 within the public space of a single territory (Ta) while in Tb1, Tb2 and Tb3 each time two control entities (squares) of the same level of the dependency hierarchy of C3 inhabit the same territory.

Figure 9.5 completes these variations of the ways in which a dependency hierarchy can be located territorially. The gates of the territories are where the supplylines of C3 cross boundaries. This gate location produces a territorial hierarchy of three levels, with Tc1 included in Tb1 and Tc2 included in Tb2. The squares of C3 are placed in the territorial hierarchy in such a way that there is no correspondence between the levels of the two hierarchies. For instance, the two squares in Tb2 and Tc2 are on the same level in the dependency hierarchies, but the territory in which one is located is included in the territory in which the other is located.

10.5 Figures 11 go back to Cb2 of figure 4.4. When we interpret the squares as buildings brought together in common

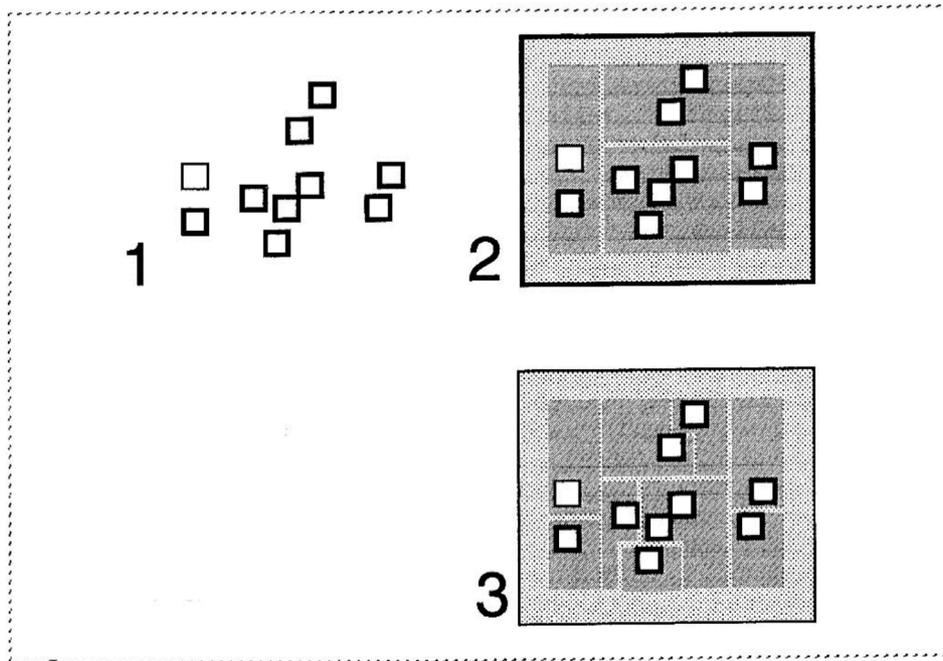


fig.10

lots surrounded by a public street network, we get something like figure 10.2. In figure 10.3 all territories in the 'block' are still directly related to the outer public space. There is no difference of territorial depth compared with figure 10.2, but there are more territories; most squares being located in their own.

## 11. RELATIONS BETWEEN TERRITORIAL CONTROL AND DEPENDENCY CONTROL

11.1 We have discusse the relation between two kinds of control hierachies (the physical configurations revealing dependency relations among their arts, and the territorial organisation revealing relations of inclusion). So far we have done so only in terms of location of the one relative to the other.

But each combination of a territorial situation with a physical configuration can be interpreted in different ways as a control situation. If, for instance, a party controls a territory and in that territory we find two physical control units, (e.g.the two squares in Tbl in figure 9.4) different control distributions may occur. We may have one agent controlling both the territory and the two squares, but we may well have one agent controlling the territory and another controlling the squares. This simple example may show how complex control situations may easily result in any given combination of a configuration and a territorial organisation.

11.2 In many artifacts we have more than one dependency hierarchy. In figure 11 we see again squares on different levels of the dependency hierarchy in the supply form we examined

earlier. But now, all the squares together are also part of a lower level in relation to the configuration of pegs in which they are located. When we imagine, added to that combination, a territorial organisation where gates for the supply form may be located differently from the gates for other uses of the territories that are found in it, we see a whole which only begins to suggest the complex control situations we may find in a single house.

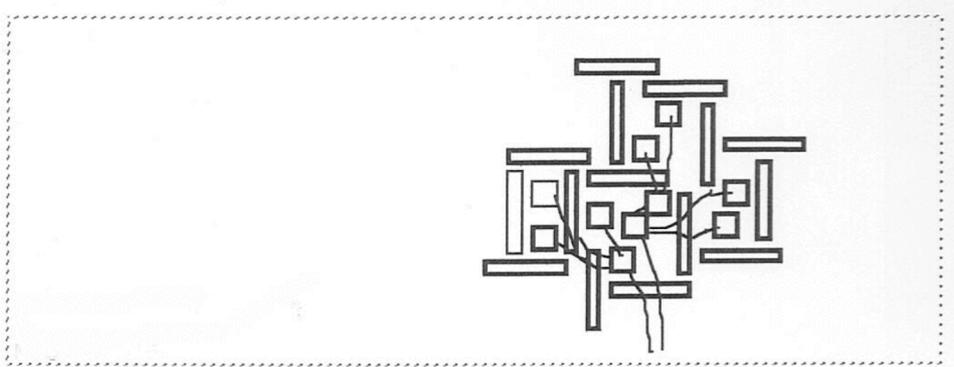


fig.11

## FINAL COMMENTS

Knowledge of hierarchical properties of environmental forms and other complex artifacts is of value to the designer.

Control hierarchies help us understand how the artifact predetermines the relation between those who act upon it and how, in turn, the way agents relate to one another shapes the artefact.

The hierachies we see in our artifacts are the result of explicit or tacit agreements among those who act upon them. Conventions about ways of seeing the world, about our relations towards things and among agents determine, to a large extent, the artifacts we make and the ways in which they transform over time by the acts of agents.

This paper seeks to formalize the general principles according to which complex artifacts 'behave' when subject to agent's control. Apart from a few examples, it does not describe particular cases observable in real life, but aims at making such description possible. By means of control hierarchies presented here, we can begin to examine the ways artifacts shape the behavior of designers, the relations among designers, and the way those relations shape artifacts. Understanding the hierarchical structure of our artifacts and the control distributions exercised upon them will help us to organize ourselves when making complex artifacts, how to work in teams and delegate responsibilities and, above all, how to understand the capacity of the artifact to transform and remain useful over time.

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