The knowledge that shapes the city:
The human city beneath the social city

01

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Abstract
In the Atlanta Symposium (Hillier, 2001, 2003a) a theory of the social construction of the city was presented. In this paper it is proposed that underlying the various kinds of social city there is a deeper, more generic human city, which arises from the pervasive intervention of the human cognitive subject in the shaping and working of the city. This intervention is explored at two critical stages in the forming of the city: in the 'vertical' form-creating process by which the accumulation of built forms creates an emergent spatial pattern; and in the 'lateral' form-function process by which the emergent spatial pattern shapes movement and sets off the process by which an aggregate of buildings becomes a living city. The nature of these cognitive interventions is investigated by asking a question: how do human beings 'synchronise' diachronically acquired (and diachronically created) spatial information into a synchronic picture of ambient urban spatial patterns, since it is such synchronic pictures which seem to mediate both interventions? A possible answer is sought by developing the concept of 'description retrieval', originally proposed in 'The Social Logic of Space' as the means by which human beings retrieve abstract information from patterns of relations in the real world. Our ability to retrieve such description happens, it is argued, at more than one level, and can includes the high-level notions of the grid which seems to plays a key role in cognitive intervention in the city. Finally we ask what the ubiquity of the human cognitive subject in the formation of the city implies for how we should see cities as complex systems. It is argued that, as with language, there is a 'objective subject' at the heart of the processes by which cities come into existence, and that this provides us both with the need and the means to mediate between the social physics paradigm of the city, with its focus on the mathematics of the generation of the physical city and phenomenological paradigm with its – too often anti-mathematical - focus on the human experience of the city. Since the intervention of the cognitive subject involves formal ideas and has formal consequences for the structure of the city, we cannot, it is argued, explain either without the other.

Keywords
Complexity, cognitive synchronisation, description retrieval, Space Syntax, urban grid

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The social city and the human city

The idea that the city is in some sense 'socially constructed' is a familiar one, though usually rather imprecise in its formulation. In 'A theory of the city as object' (Hillier, 2001, 2003) some precise mechanisms were suggested as to how this comes about

at two phases of city creation: the aggregation of built forms to shape the emergent street pattern that holds the city together through the dual influence of micro-economic and socio-cultural spatialities; and the shaping of movement by the street pattern to set off the processes by which a collection of buildings becomes a living city. In this paper an additional and more radical hypothesis is put forward: that underlying the various kinds of social city there is a deeper, more generic human city, which arises from the simple fact that all the 'social' interventions that make the city are necessarily made by individual cognitive subjects acting in the light of their understanding of the city. Cities are only socially constructable, it is argued, because they are first constructed by human subjects acting as cognitive agents rather than as social agents, and this is why there is a generic human city under the social city.

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The need for this additional hypothesis arises from three reflections. The first is the *improbable consistency* of the processes that make the city. Cities are created over decades or centuries by vast numbers of agents and agencies acting in hugely variable economic, social, cultural, and technological conditions. Yet the emergent products of these highly varied processes not only have formal invariants, but also occurs within a very narrow part of the overall field of urban spatial possibility (see Hillier, 1996a, Chapter 8, for example). To some extent this can be accounted for by the involvement of spatial laws in the process (Hillier, 2001, 2003) and by the fact that the relation between human activity and space is 'two way generic', in that the relation both ways passes through the relation each has to movement. However, even allowing for these, the consistency of the process across such variable circumstances suggests some other factor is involved, and it will be suggested here that this additional factor is the pervasive role of the human cognitive (rather than social) subject in the creation of the city.

The second is more immediately spatial but it is also an improbability: that of the *improbable linearity* of city spaces at all scales and under virtually all circumstances. The dual process of city creation (Hillier, 2001, 2003) leads of course to different degrees of integration between the public and residential parts of the space, and this is likely to imply greater linearisation in the public than in the residential domain. However, it does not say what part of the spectrum of possible linearity this dual process will occupy. Although it is hard to demonstrate unambiguously, there seems to be in general a highly improbable degree of linearisation in urban spatial forms, whether we are dealing with the micro-structure of alleys and lanes, which are never as labyrinthine experientially as they appear initially in plan due to the fact that their linear structure is invariable less broken up than their convex structure, or with the large scale structure of the 'integration core'. The tendency to conserve

linearity an improbable degree at all scales give to cities a certain *shift to order* which does not seem fully accounted for by the dual process. This shift to order comes, it will be argued, again from the fact that all interventions of social and economic forces in the construction of space are actually mediated by human cognitive subjects.

The third reflection arises from an apparent paradox: that cities are created bottom up but work top down, in that the primary linkage between the form of the city and its functioning, namely the relation between grid configuration and movement, depends on the large scale structure of the grid, not on the properties of individual grid elements. The grid, which is created piece by piece and experienced piece by piece by those using the city, is somehow *synchronised* into at all at once structure in order for the effects on movement to be shaped in the way they are. The question then arises: what is the agent of this *synchronisation*? The answer proposed will be that because all movement results from individual decisions taken by individual subjects, the agent of synchronisation can only be the human cognitive subject. The means by which this synchronisation is achieved is, it will be argued, the model of spatial cognition set out in the first paper, namely one that prioritises the concept of the grid as the limiting form for a space linking a complex of objects.

In this paper, the interventions by cognitive subjects in both of the key processes that make the city are examined, and this will lead us to two conclusions. First, that underlying the socially differentiated cities that we described in (Hillier, 2001, 2003) there is a deeper and more generic human city which is the product of the human cognitive subject rather than of social or economic forces. The second is a proposal for a new epistemology of the city as a complex system, one which aims to mediate the current split between mathematically based social physics theories of the generation of the city and phenomenologically based humanistic theories of the experience of the city. Since it will be shown that both the mathematical form of the city and the relation of this form to its functional regularities and dynamics depends on the ubiquitous intervention of the individual cognitive subject throughout the time and space of the city, it will be argued that the complexity of the city cannot be understood without the involvement of what we might the 'objective' subject of the city, that is not particular individuals but the generalised individual with generic cognitive capabilities acting everywhere through the agencies by which cities are created. It follows that we need a paradigm of the city which is at once mathematical and humanistic.

Vertical and lateral theories

First, we must clarify our problem by embedding it in a view of the city as a complex system. A key issue – perhaps *the* key issue - in the study of complexity is the problem of levels: organised phenomena at one level become elementary the next level up. The question of reduction is how far one level can be accounted for in terms of another, upwards or downwards. In (Cohen and Stewart, 1993) a general framework for relations across levels is outlined. The core argument is that complex phenomena at one level commonly produce lawful (though rarely mathematically describable) emergent simplicities one level up which then have their own emergent dynamic, independent of the complex processes that created them, in the next level of the system. They call such emergent simplicities, in which 'chaos collapses', 'simplexities'. Simplexities of different kinds then interact and modify each other to create 'complicities', or complexes of simplexities, to construct the complexity of the real world.

An implication of this is that we need theories which deal with relations across levels and between parallel processes. We might call the former 'vertical' theories, and the latter 'lateral'. A vertical theory is one which tries to work across levels of emergent phenomena, showing how complex distributed processes produce emergent simplicities which then ignore the complexity of their creation and become independent forces at the emergent level in creating a further level of complexity. A clear example in our field is the emergence of a continuous street network from internally complex processes of aggregating buildings over time, with that emergent pattern then having independent effect on movement and co-presence and thus on the (logically rather than temporarily) next stage of development of aggregates of buildings into a living city. A lateral theory is one which shows how parallel but dynamically independent kinds of process, each with its own emergent simplicities, interact to shape each other. The key example in our field is the interaction of spatial and social processes in space. Each has is own lawfulness – for example, economics has its own laws, and these express themselves in space - but to understand the city we need to understand how these different types of lawfulness interact to produce the 'city as one thing' that we experience and use.

The key question addressed in this paper is that for urban systems to work there needs to be a *mechanism* which accounts for the vertical and lateral connections in the system. It is proposed that the mechanism for both is the human cognitive subject, not simply in the sense of historical individuals located in time and space and acting according to intentions and choices, but in the sense of a generalised individual acting according to laws which, although objective, are intuitively known, and who by virtue of being everywhere in space and time in the formation

and working of the city, everywhere imposes its point of view on the city, and creates the city in the image of its own cognitive capability. This generalised human subject I will call the 'objective subject' of the city. In what follows, the interventions of the objective subject in the key stages of creating cites are explained, and a series of inferences both for how we should understand cities as complex systems is drawn out.

Cognitive synchronisation at two key interfaces

Technically, the need for a theory of the cognitive subject can be seen first in the apparent paradox in the way that cities grow and function that has already been outlined. Cities are constructed bottom-up over long periods through processes involving large numbers of agents, but function top-down in the sense that the critical relation linking the spatial configuration of the city to its function – a lateral relation between kinds of complexity - that is the relation between grid configuration and movement - reflects the emergent structure of the grid, and not simply the local properties of spaces.

In theory, something like this effect could be produced mathematically, since random one-step movement in a graph necessarily leads to a situation in which the number of visits to each node goes to a limit of the connectivity of that node. This is known through a theorem in Markov chain theory, but can be also demonstrated by some simple calculations on the back of an envelope. Given random 1-step movement in a graph, the probability of an individual moving to a neighbouring node is 1/n, where n is the connectivity of the home node. Suppose, for example, a node has 3 connections, then each neighbour has a 1/3 probability of acquiring the individual. Suppose we then assign that probability to each neighbour node, and in the next iteration, divide it amongst the neighbours of those nodes i.e. if there are 4 neighbours (including the original node) then each gets 1/3x1/4. Starting with one individual (or however many we like) per node, and summing the probabilities for each node, the results will go to limits which are directly proportional to the connectivity of each node. A simple example would be a graph in the form of a star with four end nodes and one central node. Each end node acquires 1/4 from the central node from the first iteration, and gives back the whole 1/4 in the second because there is nowhere else to go. The central node acquires 1 from each end node at the first iteration, and gives 1 back to each on the second. So after 4 iterations the total for the end nodes is 2.5 and for the centre 10, after 8 it is 5:20, and so on, and so proportional to the connectivity of each node.

However, two factors suggest this does not account for the results we have. First, human movement is neither random nor one step. Trips are for the most part

pre-planned over a number of steps – say, street segments or alignments. Second, it is not the connectivity of line elements that best reflects the movement flow along lines, but the local integration value, that is, how each line is embedded in its local grid conditions. Both seem to imply that human movement depends on some non-local picture of the grid around the location of each individual at any point in time. What are these non-local pictures like? Whatever form they take, they seem to imply that the diachronically emergent and, more importantly, diachronically *experienced* spatial pattern of the city is somehow *synchronised* in order for its effects on movement to take place. How does this synchronisation take place?

What and where, then, is the *agent of synchronisation*? Since all movement in the city is the result of decisions taken by individual subjects, it seems unavoidable that this critical link in the process is made inside the heads of individuals. The alternative would be to believe that that regularity of the relation between movement and urban grid structure emerges without some kind of cognitive intervention by which the individual subject 'reads' the grid and plans movement in the light of this reading. This is a simple fact, but one with major theoretical consequences. It means that at the crucial interface between the emerging form of the city and its emerging patterns of functioning, that is at the stage where the mechanisms which turn aggregates of building into living cities are set in motion, the cognitive subject intervenes to make the determining link.

Once the intervention of the cognitive subject in the process by which emergent urban grid create the living city is established, it seems hard to avoid the possibility that some similar 'synchronising' mechanism is involved in the (logically if not temporarily) previous stage of the city creating process: the generation of the urban grid itself by the step by step of adding built forms. In 'A theory of the city as object' (Hillier, 2001, 2003) it was shown that the structural and statistical properties of cities could in principle be generated by a relatively localised process. But this process involves a review of the line configuration in the vicinity of a proposed new built form in order to assess relative lengths and allow the process of conserving longer lines to continue. This also amounts to some kind of synchronised picture of what the grid is like in that region of the city, if these judgement are to be made consistently enough for the emergent effects to arise. So once again the key aspect of the grid generating process, and the one that eventually determines the shape of the overall grid, is take by human cognitive subjects in the light of non-local pictures of city.

In key moments, then, in both the vertical and lateral processes of city creation, some quite sophisticated knowledge seems to be brought in through the agency

of individual human subjects, and this knowledge is essentially of the synchronisation of diachronously acquired knowledge of diachronously generated patterns into an 'all-at-once' picture. Morover, this synchronised picture is not simply an image. Everyday behaviour suggests it must operate as a manipulable device for solving cognitive problems such as alternative route evaluation, and also be usable to displace the ego into different locations within it. This suggests that the synchronised picture has important logical and geometric dimensions.

The questions are then: how does this synchronisation take place? And how does it acquire the properties that it seems to have? In what follows we start out from a suggestion in 'The Social Logic of Space' (Hillier and Hanson, 1984): that human beings are able to retrieve abstract descriptions from concrete space-time events, then use these abstractions as templates for further action. The idea at that time was that this obviated the need for the concept pre-given 'rules' underlying human space-time behaviour, since rule like guiding abstractions could be derived from the space-time world itself. The implication was that space-time reality itself could be seen to take priority over pre-given abstractions in creating and reproducing well-ordered spatial systems. In what follows we examine this concept more closely in search of the mechanism of synchronisation, and in doing so bring to light much greater complexity in the idea.

Perception and conception, geometry and logic

We can begin by looking at a recent comment in (Lakoff and Johnson, 1999: 37-8, 574-5) that relational schemes obliterate the time-honoured distinction between the perceptual and the conceptual. He instances the 'container scheme'. If we say that something contains something else, then this implies a structure composed of the notions of inside, outside and the means by which the two are distinguished, say a boundary. When we see containment instantiated, then what we see is at once a perceptual and conceptual scheme. The conceptuality comes from the fact that the scheme is a system of relations. When we see relations in the real world, we are seeing a conceptual as well as a visual scheme.

A related argument was made in 'The Social Logic of Space': that the whole syntax of space could be derived from the relational scheme implied by the concept of an object, since the finiteness of an object in space-time implied a surrounding space which contained it, so that the idea of an object implied a relational scheme between container and contained by way of some kind of boundary. This fundamental scheme could, it was argued in that text, be expressed in an ideography, or concept-writing, and all the basic schemes of spatial relations found in settlement forms could be shown to be a system of transformations by expressing them in this

ideography.(Hillier and Hanson, 1984: Chapter 2).

In fact, the idea of containment seems to imply a good deal more than a simple static relational scheme, especially when considered from the ground level as experiential realities. For example, the very idea of a contained object implies a containing space, and from any point in its vicinity this takes the topological form of *bifurcation* of space at the surface of the object that meets itself on the other side. This poses in its most elementary form the notion of a choice of routes, and so entails a certain commutative logic: whether I go left and right or right and left I arrive at the same place. We can say that the idea of an object at once sets us a problem, and shows us how to solve it.. This suggests that such schemes serve not only as representations but also as 'ideas to think with' in solving problems in complex spaces.

This raises an interesting question. Do we, quite normally, derive conceptual abstractions from relational events in space time, and use them to think with in interacting with the world? If this were the case, then since there do not seem to be non-relational events in our world, it is not clear where this might not apply in some degree. It would imply that in many, if not most, circumstances we retrieve, or attempt to retrieve, something like an abstract relational scheme from concrete complexes of events in space-time, and then use it as a device to think with. This was the foundation of the theory of 'description retrieval' in 'The Social Logic of Space'. This proposed that the extraction of abstract concepts from real space-time relational schemes did not simply apply to elementary schemes, and then to composites of these elementary schemes, but to any-space time relational scheme, however complex, though probably with increasing generality and even inaccuracy as real space-time systems become large and complex.

Description retrieval as synchronisation

Let us then examine how description retrieval happens in simple architectural situations. First, it seems to happen at two levels: at the level of the way in which a complex is put together by relating different elements to each other; and at the level of the whole form or 'gestalt'. We can illustrate this simply through Figure 1 Suppose a person builds a hut with an external space outside the front door (a) and a second person then builds another hut with both the hut and the outside space adjacent to those of the first (b). Suppose then that a third person decides to add a hut. He might add it in a relation to the first two which is quite different to the relation they have with each other (c), and if this continues we arrive at a layout which appears random. Alternatively, he might 'get the idea' i.e. retrieve a description of, the first 'next to' or 'neighbour' relation and duplicate it by placing a third hut adjacent to

either the second or the first (d). If this continues, it will create a recognisable 'pattern' (e) in two senses: first, a pattern in which the local joining rules are consistent (evidently, since we have inserted them into the system), but also in the sense of an emergent global pattern, that is, a 'line of huts', which is *entailed by but not described by* the joining rules by which the system is built. In contrast, in the first case it was not possible to recognise a pattern – that is retrieve a description – at either of the two levels. In the second case we note not only that a description of the global gestalt is retrievable, but also that we have a word in the English language to express it: the 'terrace'.

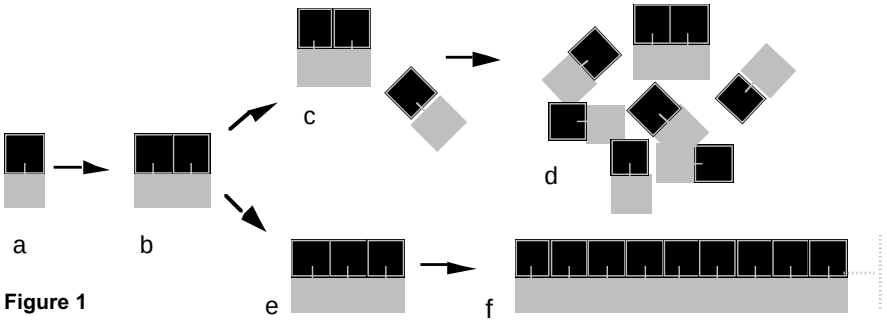

Figure 1

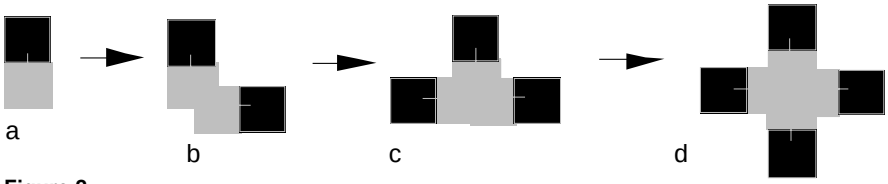

Figure 2

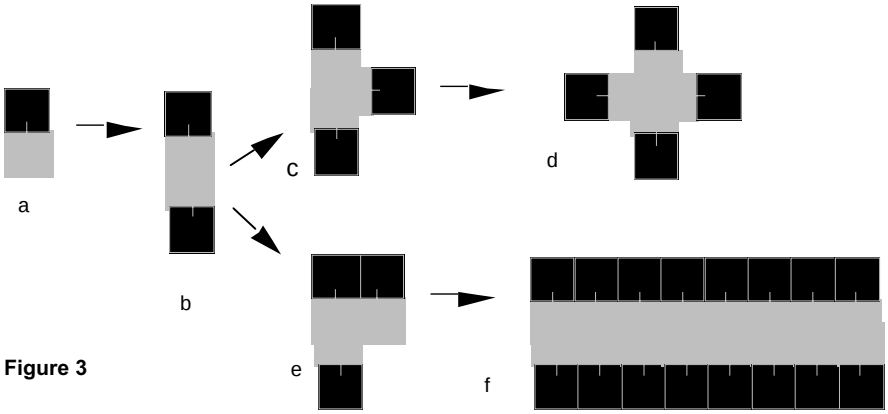

Figure 3

Other similar effects are found if we vary the rules. Suppose then the second person places his hut at 90 degrees to the first (Figure 2). The third can then either randomise, or 'get the idea' and imitate the first relation. If this process continues we find another clear emergent form, in this case a 'courtyard' or 'plaza', though in this case the emergent form 'completes itself' so that for the process to continue a adjustment to the rule must be made, or new start must be made elsewhere. In a third case (Figure 3) the second person places the hut opposite the first hut. This in a sense also 'completes' an overall form since only one other hut can be directly 'opposite' another of the same size. However, one way for the third person to proceed (apart from randomly or arbitrarily) might be to approximate 'oppositeness' as closely as possible by placing the third hut adjacent to the first. This creates a situation where there are two alternative strategies for the fourth person to follow: oppositeness or adjacency, with both rules complementing each other by providing opportunities for the other rule to be followed. If both rules are followed more or less equally then the form that emerges will be another standard type: the 'street'.

Now each of these cases illustrates the well known phenomenon that consistent, rule following local spatial behaviours can lead to clear emergent patterns at the scale of the complex object, and in each case we also saw that the emergent 'gestalt' form was captured by an everyday word. Now it is clear that the process by which the emergent objects are created can be a self-contained description retrieval cycle, since the local rule can be retrieved from the process by 'getting the idea' of the previous actions, and then using this as a template for the next stage of the process. The process does not depend on the prior existence of some rule in our heads. It involves brains, but brains interacting with reality, not simply imposing ideas on reality. In this sense the process is 'reality led'.

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But what about the 'upper level' description retrieval of the emergent form? At this level, the description that is retrieved from the process is clearly neither inserted nor re-inserted into the system, but arises from what happens in the real world independent of the cognitions or actions of the agents of the process. Moreover, at the local level of the joining rule, the abstraction retrieved is at the same scale as the events that make up the process. At the upper level of the whole gestalt, it is at a higher level than the individual events that make the form, and somehow co-ordinates all of these separate actions into a single scheme. It is this higher order co-ordination that we can think of as a kind of *synchronisation*, since over and above the consistency in the local rule which put the system together there is a clear 'all at once' quality to what we represent to ourselves at the level of the whole object. It is to these upper level synchronisations that we seem to assign words, just as there were also words to describe the local joining rules: 'next to', 'opposite', and so on.

Are these upper level objects then description retrievable simple because the joining rules are consistent and therefore synchronisable? That is, are the two levels of description retrieval essentially aspects of the same process? We can explore this by borrowing a very simple yet very powerful mathematical idea from information theory, concerning the foundations of our ideas of randomness and order (Chaitin, 1988). Suppose we have a two sequences of ones and zeros as in Figure 4. The first seems well ordered in the sense that is it made up of repeating sequences of triples of ones followed by triples of zeros. The second does not seem to have any repeating pattern. The sequence of digits in the first case therefore strikes us as in some sense orderly, while those of the second seem random. We can quantify the difference by asking how far we can compress a description of the sequence into fewer bits of information that the sequence itself contains. In general, the more recursive ordering schemes are introduced into the sequence, then the more it is possible to compress its description into periodic sub-sequences, and the more the sequence is non-random. The more a sequence approaches randomness the less it is possible to compress the

111000111000111000111000
110100100010111010110101 1

Figure 4

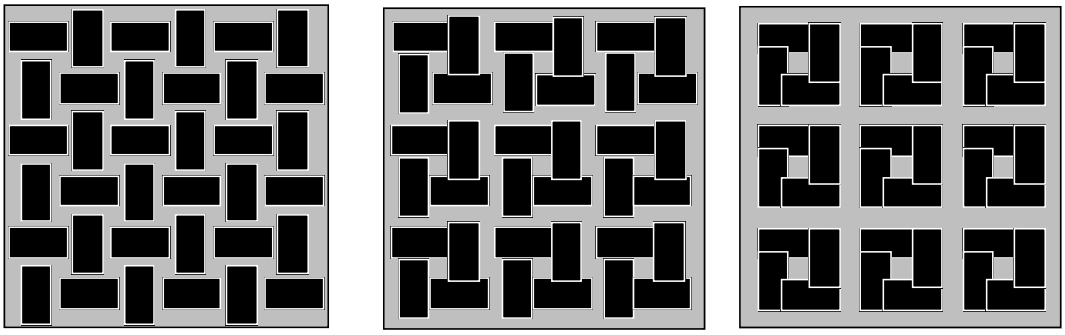
description of it into fewer symbols than the sequence of digits itself, and in the limiting case of the random sequence, the sequence of digits is itself its shortest description.

It is clear that something like this can be applied to the 'low level' description retrieval for the consistent local rules in the emergent forms of Figures 1-3. The more the joining rules can be seen to be recursive, the more the description is compressible into a short form, and intuitively the easier it seems to be to understand. We can see a consistent pattern in the construction rules for the objects, and summarise these into a short description, and this is exactly what we cannot do in the random case in Figure 1. But does this apply to the upper level description? Do the consistent local joining rules in some sense create a *synchonisable* description at the upper emergent level, and is this enough to provide an account of the upper level description?

It is easy to show that this is not in general the case. Figure 5a is a complex space created by recursive local placing rule: place rectangles orthogonally in a discrete T-relation to a rectangle already in the system. How do we see the emergent global pattern? The answer seems to be that we see it as a recursive pattern, but not as a whole gestalt to which we apply can apply a concept or a word. We might say the form is 'labyrinthine' but this is a general descriptor for a whole class of complex spaces – which would accordingly be interesting to study – but not that of a specific pattern type. In terms of the description retrieval model we can say that it is easy to retrieve a description of the consistency of the recursive low level relation, but there is no easily available emergent description of the whole, except as a generalisation of the local relation. We see this as a recursive, but not as a gestalt, form.

Finding the grid

There is, then, it seems, a clear distinction between the two levels of description retrieval: the upper level needs the lower level to construct it, but the description retrieval of the emergent whole is not given simply by summing the local relations. What then accounts for the upper level description and how should we characterise it? The obvious candidate is that in the case of the 'terrace', 'court', 'plaza' or 'street' there was a single global 'organising space' to which all the small objects were related in a the same way which allowed the gestalt to be easily retrieved. This global object was always convex, either a linear convex strip, or a convex shape 'as broad as it is long', both implying that the whole system could be see all at once from any point within it. Should we then say that an upper level 'synchronised' description is retrievable to the extent that there exists a convex global space to which all small objects relate, and which can be seen synchronically from all points within it?



a b c

Figure 5

This would immediately imply that we cannot retrieve upper level descriptions of *any* complex spaces of the general type shown in Figure 5a since by definition there can be no single convex object to which all others relate. Does this then mean that in all cases where the space connecting the objects in non-convex we can only retrieve a low level description of the recursive rules that construct the system? Let us look at a few more cases. In Figure 5b, the blocks have been retreated enough to allow lines of sight to 'just about' pass through and create cross lines, while retaining the irregularity of the building surfaces. Whether we are on the ground moving through the object, or surveying it from above as we are now, we find we begin to use the alignments to build a non-local picture of the space – to thread the beads onto a string perhaps - and the sense that this is simply a locally recursive pattern begins to give way to larger scale spatial synchronisations, and even a concept of the object as a whole.

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What we see here is in fact one of the most pervasive aspects of the improbable linearity of space in human settlements: lines of sight passing through convexly differentiated spaces. Leaving aside the fact that this seems to be something that human beings experience as pleasurable in itself (as in Cullen's acutely observed concept of 'serial vision'), often locating themselves exactly in positions from which the view through a sequence of spaces can be seen, there are powerful configurational reasons why this should be critical. In Figure 5a, which we identify as labyrinthine, it is precisely this property that is lacking, in that in each space we have little visual information beyond that space. In the pure labyrinth, this is taken to the extreme: the space we are in is all we can see. The effect is that all the information we have at any one time is local information. To the extent that lines of sight are opened up between spaces, global as well as local information is available from individual spaces, and, perhaps no less important, this information is configurational in its very nature. Linearisation of relations between spaces thus seems to be critical to the way in which a global picture of space can be built up from points within it, and it is not obvious that this could be done in any other way, certainly as the space becomes

densely filled with objects. *(Footnote: It would be interesting to try to construct a labyrinth which worked as a labyrinth in spite of being able to see sequences of spaces from every point).*

If we then take the process a stage farther as in Figure 5c, where we retreat the objects further so they construct smooth surfaces for convex strips, then the sense of the whole spatial object completely dominates that of a local recursive pattern. In fact, the lack of local differentiation in the space seems to work *against* the idea of recursivity – although the object in 5c is just as easily constructable by a recursive process as 5a, which we agreed was *only* recursive – and at the same time work *for* the idea of a single continuous spatial object. Moreover, for this upper level description we do have a word: the grid, and in fact this is the only word we have to describe the pattern of space in complex spaces with multiple objects.

By looking at the interaction between the behaviours of the material world and human minds, then, we have arrived at the concept of the grid. In my second paper to this Symposium, we will find the grid by another route: as the limiting form of the interaction between the laws of metric and visual integration in complex spaces. It will also be argued that the laws that make this the case are known to or acquired by human beings as invariants of the everyday experience of complex spaces, so that we can expect this concept to play a organising role in the forms of spatial knowing that govern human behaviours in complex spaces. In that paper, the argument will be set up more from the mathematical and cognitive sides. Here we continue to look at this complex of ideas from the experiential side of the cognitive subject.

The keys to the labyrinth

The previous figures suggest that with a little nudging from the cognitive subject the grid can be retrieved as a geometric representation from situations where there is enough linear order linking the local spatial elements. The problem is to define 'enough'. It is clear, for example, that no grid can be retrieved from Figure 5a. We can explore this by generating complex spaces in a rather more lifelike way using less deterministic rules than we have used so far, and introducing variable degrees of randomness into the system. Consider, for example, the 'basic generative process' (Hillier, 2001, 2003) in which we allow dyads of open and closed cells linked by an entrance to accumulate randomly subject to a restriction that each open cell must join to one other and shown in various early pathways in Figure 6. We note two things. First, it is much harder to retrieve a description of the consistent rule, because it is only one of a number of relations between objects that is specified, and others may or may not occur randomly. Secondly, it leads initially not to a clear emergent

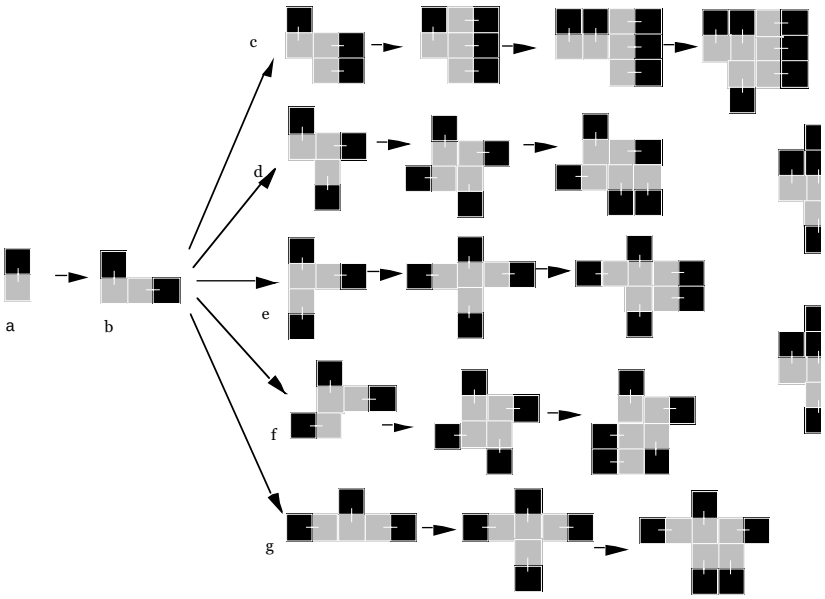

Figure 6

form but to a whole array of possible forms, so uncertainty is created also at the level of the emergent object, and there is no obvious synchronisation of the cells into an overall form.

However, as the process continues, a simple global form does emerge, one for which language does not have a ready term, and which does not seem 'description retrievable' at the global level by the linear criteria we have suggested so far: the irregular ring street or 'beady ring' form (Figure 7). Here both the local rule and the global form are much less geometrically obvious. However, the 'ring street' form, while geometrically unclear is easily discovered topologically, that is as a choice of routes around an object and thus having the commutative logic of the 'container' scheme. This may be aided by the fact that there is not only a central contained object, albeit a composite, but also outer groups of cells which contribute to the definition of the overall form of the internal 'container' space. We may note, incidentally, that when we apply the term 'ring street' to this arrangement, we seem to be adding Euclidean properties to a situation which does not have them in itself. Even so, the whole constructs an elementary commutative diagram in space and so acts as a local ground level *problem solver*. We have perhaps the commutative logic of the elementary building block of the grid without the geometric representation. And in retrieving a description of this we are perhaps doing so through the experiential discovery of the commutative logic rather than a geometric representation.

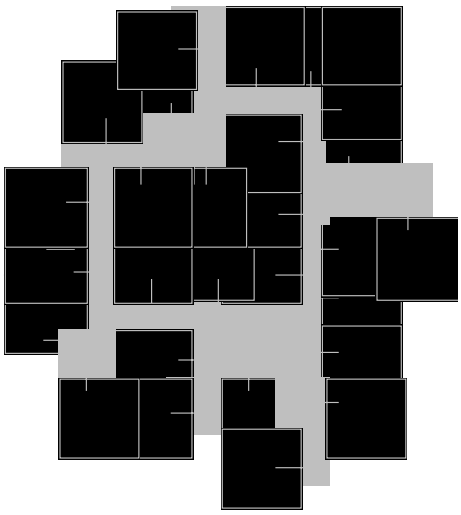

Figure 7

But this 'problem solving' description seems only possible when the system remains small. As the basic generative process continues beyond the simple ring street form (Figure 8), we find it generates the rudimentary topology of the urban grid in the form of a system of islands of built forms linked by a network of intersecting rings of space, but this seems description retrievable neither as a geometric representation or as a commutative diagram of route choices. It creates exactly the kind of de-linearised spatial complex which was shown experimentally by Conroy to be 'unintelligible' to immersive world navigators (Conroy, 2000). It seems to be not graspable as a geometric representation because it lacks the required linearity. However, it does not seem to be retrievable as a commutative diagram of possible choices either, although topologically it is exactly that. Why can we not do this?

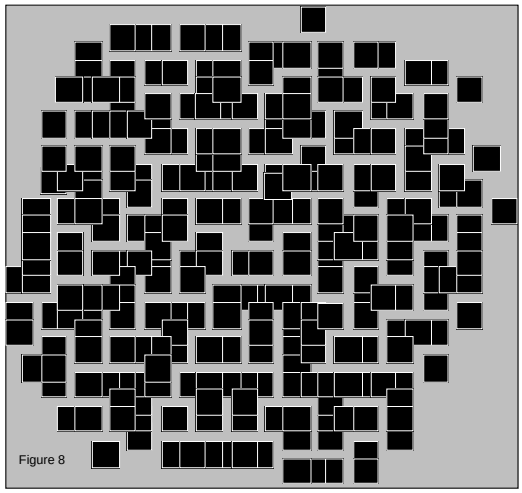

Figure 8

The answer seems again to lie in the lack of linear organisation. We can everywhere see local bifurcations as we encounter objects, but we cannot see how they lead to the same place, or how those places will be related to other possible places. In effect, the lack of linear organisation means we are not longer able to see the space as a system of well-ordered route choices. This implies that the lack of linearity in the visual organisation is responsible both for the lack of conceptual representability and for the lack of the problem solving commutative diagram. We might have thought that the visual was the means to the conceptual and the conceptual the means to the logic of the commutative diagram, but now it seems that things are more compressed: the visual organisation seem to actually *be* both the conceptual organisation and the logical organisation. We can distinguish the two as different ways of looking at the same thing. But we cannot easily avoid the conclusion that in some sense they *are* the same thing. At the very least we have to say that the perceptual is rather more than the means to the conceptual: it is rather in itself the model for the conceptual, so much so that the notion of a complex space as a system of choices seems to depend on the way in which the linear geometry creates a visualisable picture of a commutative diagram covering the whole space.

This abstract but visual – perhaps 'polyvalent' - diagram then seems to be what we are looking for: the means by which a series of experiences of the spatial sequences making up a complex space is synchronised into an 'all-at-once' picture which serves both as a representation and as a problem-solving device. It is this cognitive ability, together with its inherent biases towards linearity, and therefore towards metric and visual integration, that, it can be conjectured, intervenes at the crucial vertical and lateral points of the city creating process. It suggests that Lakoff

and Johnson's elimination of the distinction between the perceptual and the conceptual can be duplicated at a much higher level of complexity, and a third property added: that of the logic of the commutative diagram. The visual structure is not, it seems, just the means to conceptual and logical organisation: it pretty well is both. It is through this that the human cognitive subject is able to act as the agent of synchronisation that is required for cities to become as they are.

Since we showed that both the bottom-up 'vertical' construction of the city as a spatial object and its top-down 'lateral' relation between spatial form and functioning was dependent at every stage on a higher level, 'synchronised' picture of the urban grid, we can argue not only that the intervention of the cognitive human subject is critical to both the form of the city and its functioning, but also that the visual structure of the city pretty well is its intelligible organisation, not just the means to it. The improbable linearisation of urban space in cities comes, we suggest, from this constraint on the ability of human cognitive subjects to read and solve problems in complex spaces with large numbers of objects. The fundamental reason is that only linearisation permits the synchronisation of the overall form into an all-at-once representation, so that it, in turn, can serve as the commutative diagram which is the basis of our ability to understand and navigate the city at the experiential level. The idea of getting to the same place by another route is only cognisable in conditions where a governing geometry allow this to be seen in a perceptual-conceptual image, however imprecise that may be. This, then, we conjecture, is the *agency of synchronisation* by which the city comes to work as a complex system both vertically and laterally.

The objective subject

The proper theoretical conclusion of these explorations is, I believe, that the human cognitive subject is at its heart of the vertical and lateral processes that create the city, not simply in the sense of a series of real historical individuals located at specific points in time and space, but in terms of the invariance of the cognitive apparatus that those historical individual bring to the task of creating the city. We are talking in effect of a generalised individual located at all points in time and space in the city and everywhere imposing its cognitive apparatus on the ambient city. We might call this generalised individual the 'objective subject' of the city creating process, and therefore of the city.

Bringing to light the role of the 'objective subject' in the processes that make cities leads to a natural question: can the 'objective subject' also be found elsewhere in other systems. In fact, the notion of the objective subject originates in reflections of many years ago on the spatial nature of language. In an text which was set aside

from the Social Logic of Space, it was suggested that language was spatial in two senses. The first was that language is permeated by spatial terms such as the English prepositions which form a basis for a good deal of the semantic structure of language, especially through metaphorical extension (for example, 'beyond me' or 'beyond reason', are metaphorical extensions of an elementary spatial model built into the word 'beyond'). In this sense, space was already a powerful, even dominant, presence in language (a point of view which has been amply confirmed by recent work in cognitive neuroscience – for example, Bloom et al., 1999).

However it was also argued that language was spatial *as a whole* in a more fundamental sense. Although languages are clearly the property of communities of speakers and not just individuals, and cannot be understood without the inter-subjective dimension this entails, language is still constructed as though from the point of view of a discrete hypothetical individual located at a particular point in time and space. A key structural feature of language which suggests this is the fact that all languages use universals, that is terms that refer to categories or classes of spatio-temporal events. In fact, most words in language are universals in this sense – for example, the word 'beyond' is a universal no less than the word 'bird', in that both stand for categories or classes of space-time events. This is the paradox of language that gave rise to Plato's epistemology: that all the terms in language through which we are able to refer to the concrete things and events in the space-time world turn out to be conceptual abstractions referring to no particular thing.

Now it is easy to show that categories and classes do not exist in the real world independent of observers. They are constructions created from a particular point of view and are influenced by particular purposes or contexts. One could cite well known instances such as the fact that the English have sixteen terms for rain, but it is simpler to observe that different languages use different categorisations, and so construct different semantic spaces for describing the same general kind of thing. For example, one reason that the English 'the cat sat on the mat' cannot be simply translated in French is that, over and above the facts that cats in French are either male or female, and that French distinguishes the fact of sitting from the act, French breaks up the semantic field of possible floor coverings in a different way to the English, so there is no exact match in French for the range of sizes and textures of floor covering covered in English by the word 'mat'.

In general, we can say that categories and classes are constructed not, of course, from a specific point of view but from a *hypothetical* point in space time, that is from the point of view of something like an abstracted 'objective subject'. In fact, once this spatial point of view is established, we can see that categories are

ways of acquiring apparently – but not really - universal knowledge of space-time in spite of the limitations imposed by being confined at any time to a specific point in space and the limitations such a point of view necessarily imposes. We can clarify this by a thought experiment about ubiquitous beings. If there were a ubiquitous being, then it would not need knowledge of classes since it would experience everything directly. If that ubiquitous being were also concerned with truth, it would eschew all classes since all systems of classes are misrepresentations from a specific point of view, and the being would not have any reason or need to select one misrepresentation at the expense of another. It would seem to follow that it would be hard for human beings to converse with a ubiquitous being. Their languages would be incommensurable.

By reflecting on the ubiquitous being we see that categories arise because human beings are at a single point in space and time, and yet need knowledge of the whole of space and time if their language is to be able to refer to and make sense of the likely range of experience that will be encountered by that spatially located being as it move around in space and time. In that sense we can say that a system of categories works by simplifying, and even to some extent misrepresenting reality in order to have a model through which it can understand that same reality. We will see in my next paper that the 'cognitive' grid works in the same way in relation to urban systems. But in the case of language, we can add a rider: that it is the dependence of language on the point of view of the objective subject that make natural language structurally unsuited to be the language of science, and this is why the development of science had to await the development of a language which refers to the space-time world without the intervention of the objective subject: Euclidean geometry.

A unified paradigm of the city

If, then, it is the case that the city, like language, has an objective subject which plays a critical role both in the 'vertical' form-creating process by which the accumulation of built forms creates an emergent spatial pattern, and in the 'lateral' form-function processes by which the emergent spatial pattern shapes movement and sets off the process by which an aggregate of buildings becomes a living city, then what does this imply for our paradigms of the city? Our field is currently broadly split between the social physics paradigm, which seeks to understand the formation of the physical city as the product of the spatial implications of economic processes, and the humanistic or phenomenological paradigm which seeks to understand the city through our direct experience of it. The social physics view is essentially a mathematical view of the city, while the phenomenological view more or less precludes mathematics. The effect is to create paradigms which are as irreconcilable

methodologically as they are theoretically. The split is made to appear natural by the way we conceptualise our field meta-theoretically as being about the relations between environments simply as material objects and human being as experiencing 'subjects'.

If the argument in this paper corresponds in any sense to what really happens in cities, then it is clear that environmental 'objects' and human 'subjects' are deeply entangled with each other, with the 'subjective' appearing in the 'objective' world as much as the objective world appears in the human subject. Nor is it the case that the object side of the urban system can be dealt with mathematically and the subject side only qualitatively. The fact that the city is shaped by the human cognitive subject does not lessen its mathematical content since, as we will see in my second paper, the cognitive processes by which the subject intervenes reflect mathematical laws. We cannot understand the generation of the material form of the city without understanding the formal aspects of the cognitive subject's role in shaping the city, nor understand the experience of the city without knowledge of the formal shape the city acquires under the influence of cognitive subjects. This will be the central theme of my second paper.

It follows that we cannot progress while the paradigm split remains. Space syntax was originally created to try to find links between the two previously irreconcilable domains of the city, the city of people and the city of things, hence the 'social' logic of space. The project for space syntax research must now be to engage with the problematics of both the mathematical and humanistic paradigms in the hope and expectation that by finding how each is present in the other we will progress towards synthesis. It is the greatest encouragement that, reviewing the papers for this Fourth Symposium, this seems to be what is happening.

References

Bloom, P., Petersen, M., Nadel, L. and Garrett, M. (eds.), 1996, *Language and Space,* MIT Press

Chaitin, G., 1988, *Algorithic Information Theory,* Cambridge, Cambridge University Press

Cohen, J. and Stewart, I., 1994, *The Collapse of Chaos*, Viking Penguin

Conroy, R., 2000, *Spatial Navigation in Immersive Virtual Environments,* Ph.D. thesis, University of London (UCL)

Cullen, G., 1961, *Townscape,* Architectural Press, London

Hillier, B., 1996, *Space is the Machine,* Cambridge, Cambridge University Press

Hillier, B., 2001, 2003, "A theory of the city as object", *Urban Design International*, 2003, Also *Proceedings of the 3rd International Symposium in Space Syntax*, Atlanta, 2001, *http://undertow.arch.gatech.edu/homepages/3sss/*

Hillier, B. and Hanson, J., 1984, *The Social Logic of Space*, Cambridge, Cambridge University Press

Lakoff, G. and Johnson, M., 1999, *Philosophy in the Flesh,* Basic Books (Perseus)