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Scaling in a suburban street

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Abstract. A fractal environment can accommodate more small objects than expected because fresh small spaces come into play as the size of object diminishes. Could the built environment behave like this? To test this hypothesis the number of cars that could be parked in a street was estimated for different sizes of car. The results indicated that scaling does occur. This is as if space can be manufactured from nothing by designing at an appropriate scale. Countries such as Japan which have a small standard of personal space may in fact be larger than they seem on a map.

Introduction

Could the space in an ordinary suburban street be fractal? It is after all commonly accepted that over a range of scales cities are fractal (Batty and Longley, 1994, chapter 7), some buildings are fractal (Bovill, 1996, pages 1 – 7, 21), and possibly some domestic interiors are as well (Crompton, 2000), so why not an ordinary street? If this is the case, however, then its size will be ambiguous because the size of a fractal is a slippery quantity that depends on the unit of measure. This may be seen in the box-counting method of measuring fractals in which the number of rectangles needed to cover the edges of an image is plotted against their size (Addison, 1997, page 37). As the rectangles get smaller it is found that more are needed to cover a fractal than a simple object. More particularly a shape is said to be scaling if the number of boxes, n, increases as a power function of the length, r, of the box, that is, if $\ln n \propto \ln r$.

Now the process by which a street fills with parked cars is, from a geometrical point of view, rather similar to the box-counting method of measuring fractals. In both cases the edges of the roadway are covered with close-packed rectangles of various sizes. Parking cars is therefore like a natural measure of size and this raises an interesting question that can be settled by experiment: is parking scale dependent? If the answer to this question is yes then perhaps space can be manufactured as if from nothing by adjusting our scale. If we shrink our space expectations to a Japanese rather than American standard we will have more room, obviously, but just how much more exactly? This will depend on the geometry of the environment: it is something to be determined by experiment.

An experiment in parking

To throw some light on this question, Victoria Avenue, Manchester, was surveyed in some detail. It is a tree-lined suburban road bordered with semidetached properties about a hundred years old. Based on an Ordnance Survey map a survey added detail down to the level of gateposts, garden paths, dropped kerbs, speed bumps, trees, posts, and so forth, and interior plans of some of the thirty-two houses were included. With car and turning circle sizes taken from manufacturer's information, the numbers of cars the street could accommodate was found by drawing them on the plan. Figure 1 (see over) shows the survey overlaid with forty-four Rolls Royces. Cars were positioned according to current standards of parking behaviour; this amounted to following three rules.

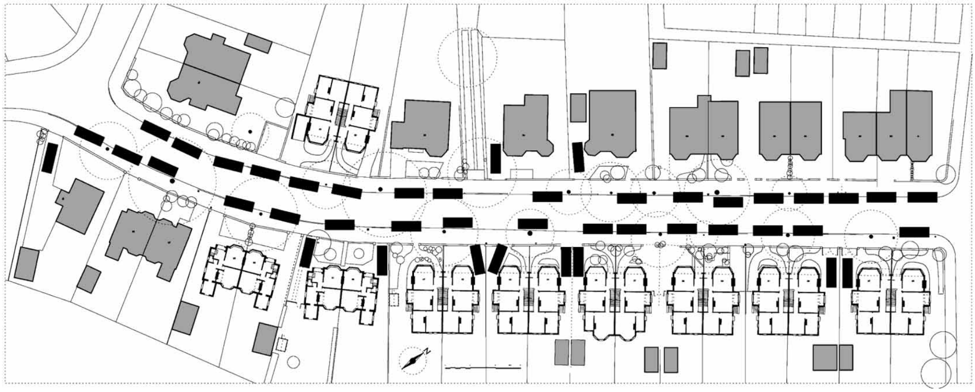

Figure 1. Forty-four Rolls Royces parked in Victoria Avenue

(1) Parking astride the kerb was allowed because Victoria Avenue is not wide enough to allow traffic to pass between large cars parked wholly on the carriageway.
(2) Access to drives and parking spaces in gardens was left unobstructed.
(3) Parking was restricted to areas currently used for parking.

More small cars could have been squeezed in by going deeper into the gardens, but these potential places were not counted. At present, cars are sometimes parked one behind the other in driveways, this two-car depth was taken as a limit. Other than this case where one car is trapped behind another, cars were positioned so that they could drive away unimpeded.

The vehicle types tested were, in descending order of size, removal van, Rolls Royce, Volkswagen Golf, Volkswagen Polo, Austin Mini, DaimlerChrysler Smart car, BMW Isetta, and E.Mobile Arrow buggy. Note that the Mini (1959 – 95) is the old smaller model, the Smart car is a Swiss-made city car, the BMW Isetta (1955 – 62) is better known as the Bubble Car, and the E.Mobile Arrow is a modern electric chariot something like a quad bike. Table 1 shows the results. How accurate are its figures? The number of spaces was estimated in two ways: first as a plausible minimum as shown in figure 2; second, as a maximum by forcing in as many vehicles as possible. The length of the marks on the graph in figure 3 (see over) represents the difference between this maximum and minimum, giving some indication of their accuracy. For the larger vehicles these figures are close, but for the smaller vehicles there is some slack. This comes mostly from putting extra cars down the sides of the houses in spaces that are unavailable to larger models. Interpretation of parking rule (3) is the cause of most of the difference between maximum and minimum. An attempt to pack Smart cars

Table 1. Parking capacity of Victoria Avenue for different-sized vehicles.

	Length (m)	Width (m)	Number of spaces		Area covered (m^2)
			maximum	minimum	
Removal van	8.50	2.52	15	15	321
Rolls Royce	5.83	1.99	46	44	534
Volkswagen Golf	4.15	1.75	80	72	581
Volkswagen Polo	3.72	1.66	97	91	596
Austin Mini	3.07	1.40	134	125	575
DaimlerChrysler Smart car	2.50	1.52	145	133	549
BMW Isetta bubble car	2.29	1.37	200	195	628
E.Mobile Arrow buggy	1.88	0.88	366	318	606

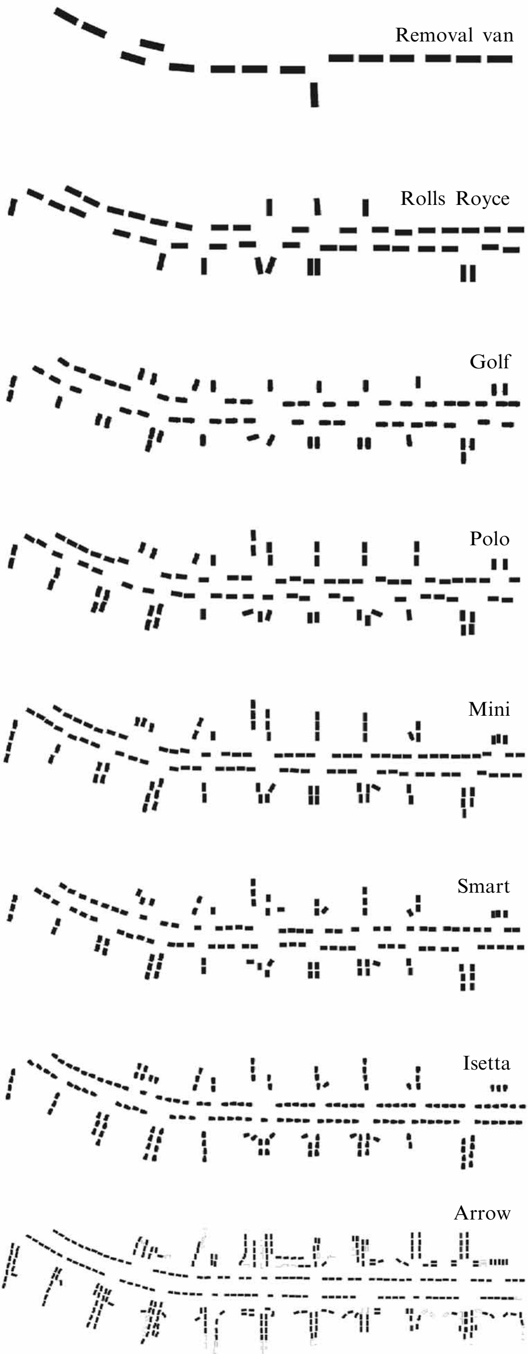

Figure 2. Parking layouts for eight sizes of vehicle in Victoria Avenue.

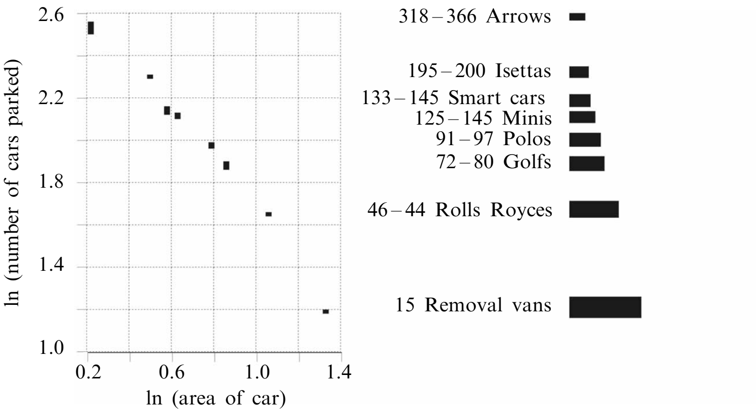

Figure 3. Log – log graph showing number of vehicles versus their area.

by parking perpendicular to the kerb (as is done in France with this abnormally short vehicle) produced an increase from 135 to 145 places. Plainly if very small vehicles, such as the electric buggies, were parked inside houses or in backyards the numbers could be increased very considerably, but the experiment played safe by restricting the test to areas currently used for parking and to normal ways of parking. The minimum column of table 1 gives figures which correspond to normal parking behaviour. However, the relationship between size and numbers parked appears robust even with the differences between maximum and minimum figures in table 1. It shows that the street is completely filled up by fifteen removal vans, so fewer than half the residents could move home at once. Coming down in size, if every household has a Rolls Royce there will still be room for twelve visitors also arriving in Rolls Royces before the road is full. The jump to two and a half Golfs is substantial, but numbers keep increasing as the cars get smaller up to more than twelve Arrow buggies per household.

Figure 2 shows the development of the parking fractal. Resembling an Australian aboriginal dot painting the shape is that of the circulation spaces in Victoria Avenue being gradually filled with tiny cars. It is a sort of tree, but one whose branching points are empty, these being the places where routes meet that must be left open for access. The fractal is scaling; small parts of it resemble the whole, allowing for a change of scale. For example, the pattern of half of the road filled with Golfs looks like the pattern the Rolls Royces make over the whole street. Similarly the pattern of removal vans resembles bits of all the others. Figure 3 shows a graph of ln (number of cars parked) against ln (area of car). The straight line indicates that a power law is at work, with a gradient close to one making this a $1/f$ relationship, a form often observed in nature [see Voss (1989) for other examples]. Salingaros and West (1999) give reasons for the ubiquity of this form, and this result gives experimental support to their arguments.

The straight line enables us to express the parking capacity of the road by a formula. If n is the number of cars of area a parked per 100 m length of Victoria Avenue, then

$$\ln n = -0.93 \ln a + 2.6 .$$

Would other roads have given the same result? Only further experiments can tell for sure, but Victoria Avenue is nothing out of the ordinary. The inner expansion of space it displays is caused by its irregular arrangement of trees, drives, and other obstacles. There is, however, one sort of road where fractal expansion will not apply, one where municipal improvements have marked out parking spaces that privilege normal-size cars. Nature does not favour one size over another and this, I suggest, goes some way to explaining why car parks are such oppressive places. It is not impossible that the imposition of standard parking bays in urban environments may actually reduce parking capacity.

Discussion

The number of small cars is larger than one might expect. To appreciate this, consider that touching end to end 72 Golf cars are as long as 130 Bubble cars, and close packed 72 Golf cars cover the same area as 166 Isetta cars, yet in Victoria Avenue 72 Golf cars can be replaced by 195 Isetta cars. Figure 4 shows part of a standard car park layout filled first with Golf cars and then with Isetta cars. The layout is as tight as possible compatible with their turning circles. Each Golf needs 18.5 m^2 and each Isetta 10.0 m^2. If parking cars was a matter of sharing out area, then one would expect 72 Golfs in Victoria Avenue to be replaced by $(1.85 \times 72 =)133$ Isettas, yet the experiment shows that almost 50% more than this number could be accommodated, and this may be a low estimate. This increase in number of vehicles I will call a *fractal bonus*, and is caused by the street not being an empty space but being partially filled with obstacles such as drives, trees, and walls. The very fabric of the townscape is a fractal whose space expands inwardly the smaller one gets. Nor should this be surprising, if one goes in the opposite direction and the cars get larger then a point is soon reached where very few and then none can be parked. The present upper limit of size beyond which parking is not possible is only a little larger than the size of the large removal vans which regularly foul up traffic in Victoria Avenue. The line on the graph in figure 3 seems to curve downwards at the end, suggesting that no vehicles above 25 m^2 in area will be able to get into the road.

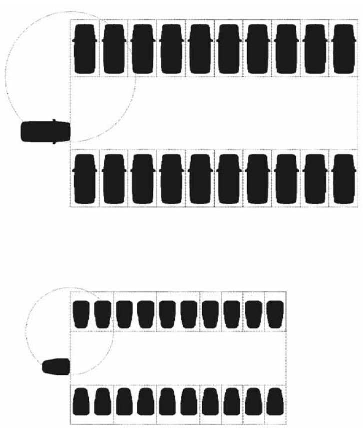

Figure 4. Standard car park layouts for VW Golf cars and Isetta cars compared.

One is reminded of the distribution of animal sizes: large animals are rare, small ones common. Damuth (1981), has a graph showing a log – log straight-line relationship between local population density and body mass of herbivores that is similar to the graph in figure 3. Damuth uses this relationship to show that the amount of energy used by a species is independent of body size, which is to say that no species has an advantage in consuming resources on account of size. I can detect no similar relationship in cars: the connection between metabolic rate and size breaks down because the same body shell is often sold with different engine sizes; cars are not designed to be in such fine balance with their environment as are animals. Nonetheless, if it is accepted that the density of parking places is fractal, another interesting parallel with the natural world may be found in the work of Haskell et al (2002). They showed that, because resource distributions for animals are fractal (that is, scale dependent), different-sized foragers encounter different densities of resources in the same environment. They used this to show that large animals need much larger areas than might be expected. Their predictions emphasise the high potential vulnerability of large carnivores to habitat fragmentation. Those who have ever foraged for a parking space in a large car will understand this problem. How ironic that cars are often named after the same large predatory animals whose problems of finding space they share.

Concluding remarks

Every year cars get slightly bigger than the year before: so much so that cars only thirty years old now seem strangely shrunken. For example, of the typical cars whose sizes were listed in the 1970 edition of *A J Metric Handbook* (Sliwa and Fairweather, 1970, page 55) 40% were less than 4 m long, yet by 2003 only 20% of the 300 car types listed in *What Car Magazine* fell below that figure. Another example: the British Ford Anglia (1959 – 68) was 3.80 m long; today its descendant, Ford's medium-sized family car, the Ford Focus, is 4.37 m long. The expansion of cars over the last thirty years is roughly equivalent to the change from a present-day VW Polo to a VW Golf. The contribution of this creeping growth to congestion will be underestimated if it is supposed that roads are Euclidian. If parking capacity were proportional to the length of a car, one might expect 72 Golfs to be replaced by 80 Polos. But in fact 72 Golfs can be replaced by 91 Polos. The growth in the number of cars on the roads may have masked this more subtle vanishing of communal space. If our environment is fractal, then to increase the size of vehicles is to work against the grain, to magnify our losses. If vehicles get smaller our gains are unexpectedly large. Supposing Victoria Avenue to be a reliable guide, then the ratio of the car-parking capacity of an environment in which the average car is a Golf, and one in which it is a Polo is seven to nine. If the size of a place is a measure of its ability to absorb objects, then countries with a naturally small scale, like Japan rather than America, may be larger than they seem. If the environment is complicated and fragmented the differences may be even more marked.

What does one mean by the size of a space? If a space is fractal, then measuring its capacity involves estimating what can be fitted in at different scales. This means tediously experimenting with different sizes and layouts. How could this process be automated? It is surely not beyond the capacity of programs similar to those that simulate traffic by modelling cars interacting with their neighbours. Perhaps in the future the sizes of fractal places will be measured not with a ruler into equal increments but with cellular automata.

Further research

Could moving traffic also be scaling with respect to car size? A traffic jam presents a close packing of rectangles, but moving traffic in which drivers change lanes to find space is a far more complicated business. This question is now being investigated using cellular automata. A preliminary result using free-flowing traffic along multilane roads did not exhibit scaling, most likely because flow is restrained by headway (the distance to the car in front) rather than vehicle size. Dense stop-and-start traffic has yet to be tested.

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