A Fractal Approach to Land Use Planning

by Aron Faegre

> *We should care about fractals…because lots of things that seem impossible to comprehend become more understandable if we identify the basic pattern and watch what it produces through repetition.* –Jane Jacobs

Land use planning as practiced in the United States today is fundamentally based on Euclidian geometry. By this I mean that specific areas of land are zoned with certain properties such as "residential," "industrial," "commercial," or "agricultural." Each of these areas is bounded by lines and intended to function principally for the purpose that the zoning name reflects.

This system stems from the historic cultural problem that occurred in the early 1900's when industry was king and became a major threat to the quality of life for other land uses. This Euclidian land use zoning approach assumes that a fundamental type of use should be established throughout a reasonably large area, and that each of these areas should to some extent be isolated from other, different uses. In other words, it assumes that *each use is to some degree incompatible with the others*.

Similarly, today's zoning ordinances assume that within each zone there are certain outright permitted uses that are fundamentally consistent with the intent of the zone. However, because these general use categories are hard to define and some diversity of uses is considered healthy, a variety of other uses are often allowed through a "conditional use" process. For example, in an agricultural zone some non-agricultural commerical uses may be allowed, if only in the form of a home occupation. However, a home occupation could only be established through a public hearing and review process. Uses that differ from that of the basic zone intent require the applicant to "prove" why it would be acceptable.

One must gain the concurrence of neighbors, local transportation engineers, police and fire departments, and so forth.

With the science of fractals, there is a new method available to organize, map, and establish uses within zones. What are fractals? Jane Jacobs, cited above, provides a simple description and example:

> [Fractals are] complicated-looking patterns that are actually made up of the same motif repeated on different scales.... For instance, a muscle is a twisted bundle of fibers. Dissect out any of those fiber bundles, and you find that it, too, is a twisted bundle of fibers. And so on.... That's a real-life fractal. Mathematicians make computer-generated fractals, fascinating in the complexity and seeming variety, yet each fractal is made of repetitions." [p.22, *The Nature of Economics*, Jane Jacobs].

By the use of fractal geometry in land use planning, a much richer interpenetration of uses can easily be described and established. Rather than thinking of all industrial uses as being incompatible with all residential uses, a pattern can be established which considers both the size and category of uses within the same framework. For example, a small industrial use (such as a home occupation) might be viewed as an outright allowable use within a larger residential zone. Likewise a small residential use (such as a caretaker) might be viewed as an outright allowable use in an industrial zone. Current zoning ordinances in some cases allow for this much diversity. However, that kind of minor interpenetration is usually considered a threat to the whole zoning system. There is always an underlying fear that if even one real "industrial use" is allowed into a "residential" neighborhood, then the agency will have to allow all the others to come as well.

The real problem, however, is that the normal approach to land use zoning tends to create sterile environments. It creates suburban tract house areas that stretch for miles on end, while also creating expansive industrial areas with their own integrity and isolation. Every morning thousands of cars take the local

population from the residential areas and move them to the industrial areas. Like waves of migration the life and spirit of a culture migrates between home and work. Once people are away from home, the residential areas become dead and the industrial areas come to life. Once nightfall comes the commercial areas are devoid of life, with everyone back at home in the residential areas. This difficulty of resolving how to interpenetrate different uses or forms into a workable whole is a common problem for all planning methods that rely on a Euclidian framework of geometry.

Architecture as example

Since I am primarily an architect, let me try to illustrate the above by an example from my field. A building is often thought of as a self-contained, single object. To create it, architects have developed a straightforward, linear approach. First, a "program" is made for the building. Then the "program" is turned into a "schematic design," which is eventually turned into a "construction drawing" to be used to contract with a builder.

During the "programming" stage an attempt is made to name all the specific uses and required places needed within the building. A verbal description is made of each use or place, with a list of its square footage, spacial relationship to other uses or places, and equipment or utilities needed for the item. This is a method of creating a whole by inventing pieces that are then assembled and massaged together.

This approach posits that the building can be created through a study of the essential elements needed for the building. As with physics, the ingredient atomic particles are identified, and then assembled into molecules. This is a directed process where one stage of design is intended to morph into the next,

each following logically from the former. Often, this results in an actual building of spaces that are little more than a diagram of the original program. One can look at the program document, and the final building, and find a one-to-one correspondence between them. This system has worked well for much of the past 75 years.

The concept of fractals, however, presents alternatives to this linear programming process of the past. Fractals are nothing more than *self-similar constructions*. When any piece or part of a fractal is examined in detail, it is found to also contain the image of *all* of its parts. This is quite different from the concept that each program element is unique and different from any other.

A fractal program for a building could attempt to find the "kernel" concept that is trying to be achieved. The program would then show how, by taking this kernel idea and elaborating on it or expanding on it, a building comes into being, meets the needs of the owner, is healthy for its occupants and visitors, and creates "life" for all. In this sense, the program might be thought of as a "seed" from which the building design develops.

Another approach to using fractals in programming is to expand the building design to include more than a determination of the physical spaces and their configuration. For example, suppose we wish to design a museum building in a remote site. Let's say the museum is to contain exhibits about the local area, which is a nature wonderland – one the last pristine saltwater estuaries remaining on the west coast. But there are only limited funds for the building, and the estuary also functions as a research resource. We could start by trying to define what the exhibits will be. We could believe that if we don't know what the exhibits will be, then we are unable to fully define the program – and thus are unable to design the building form. However, the uniqueness of the place also

being a research facility means that new science is constantly being created – so the subject for the exhibits keeps changing.

By using a broader, fractal view of the program, we can say that the program should include anything that will help the building project come to life and be the success that is desired. Thus, for this rural museum, we may decide to build two bunk houses and a dining hall on a nearby property to house university student volunteers who will be solicited to come live in this beautiful natural setting, to study the unique marsh, and then design and build the exhibits. We may find that in this rural location, where only limited funds are available, the best hope for success of the museum lies in creating some rustic housing for these volunteers. Or again, by using fractal principles, we might conclude that the single most important element in this program for the exhibit hall is to build a bunkhouse two miles down the road! We'll still need an exhibit hall of some size to put the exhibits into. But in this hypothetical fractal program for the exhibit hall space, the first and most important piece is to build the piece that attracts the people who will create, build, and man the exhibits. By this means we truly create a dynamic, evolving exhibit hall filled with excitement about the saltwater estuary that was the subject in the first place.

A nod to economics

The current system of land use zoning is designed around an underlying, if unacknowledged, approach of meeting an "average" of needs. It is a form of "dumbing down" the uses of the landscape. Not everyone, however, wants average conditions. In fact, it is probably safe to say that *nobody* wants average conditions. In the arena of economics, this problem of using "average conditions" as the basis for rules about "future conditions" is well discussed in Nassim Taleb's book "The Black Swan." He predicted the 2008-9 economic crash

from the simple fact that the entire financial market system was using Gaussian "average" probabilities to create an estimated $500 trillion derivative market (Taleb was at one time a stock market derivative trader). He points out that "living," complex systems like the stock market are ultimately governed by the exceptions to the rule, not by the average conditions. He points out that at the stock market's peak, half of the entire gains of the past 20 years came from 10 days of the stock market—that is, from *one-thousandth* of the time period.

Taleb points out that using averages from the past will never account for massive changed conditions that invariably will occur in a dynamic "living" system. Rather than "Gaussian" curves for data, he shows that "Mandelbrotian" curves using "scaled" curves for data provides more accurate approximations of reality. This implies that the system is fractal, as fractals are patterns of information that are self-similar at different scales, unlike the Gaussian curves.

Taleb's answer with respect to the stock market is that one must pay attention to the present more than the past, and recognize that what we don't know is more important that what we do know. Now let's see how all of this plays out in the arena of land-use planning.

Land use planning in Oregon

Our modern American concept of "land use zoning," which divides land uses into the general categories of residential, commercial, and industrial, and creates setback and height limits, was initiated in New York City in 1916. That led to the State of New York creating "The Standard State Zoning Enabling Act," which established a method by which any local jurisdiction could regulate the placement of buildings to maintain the health and habitability of a city. Some courts found this kind of regulation to be a violation of the Fourteenth

Amendment (under the due process of law principal[1]). Following a series of appeals, the zoning ordinance of the City of Euclid, Ohio was finally heard by the Supreme Court, and in 1926 was found to be Constitutional. By the late 1920's such zoning codes were adopted by many cities across the nation and they were called "Euclidian" zoning regulations – a term that is oddly prescient of the fundamental problem with regulation for today's land use needs.

Zoning regulations have become more and more complex during subsequent years, however the basic underlying concept used for land use zoning has not changed in any substantial way. New major classes of zones have been added – agricultural, forest, open space, airport – and many new minor classes of zones have been added – duplex, multi-family, light industrial, heavy industrial, general commercial, neighborhood commercial. Similarly, building setback and height formulas have been made complex with potential differences based on rewards for certain types of uses. Finally, concepts of "design review" have been added to attempt to regulate the aesthetics of the building design, finishes, and form. Zoning ordinances are now typically thick documents – Portland's is 1,478 pages and growing – that attempt to regulate in detail what can happen on virtually every parcel and square foot of land within a jurisdiction.

Oregon for the past 50 years has been recognized as a leader in the creation of innovative use of land use regulation. The origins of this recognition start with the creation of the "Exclusive Farm Use" zone in 1963, the Beach Protection Bill in 1967, Senate Bill 10 in 1969 that required all cities and counties to adopt comprehensive land use plans, and Senate Bill 100 in 1973 that established the Land Conservation and Development Commission. Most of these were accomplished by Governor Tom McCall, who served from 1967-75, and they set

[1] Using the principal "*nor shall any State deprive any person of life, liberty, or property, without due process of law*" (underline added).

in place a strong land use system to protect the resource lands that surround urban areas.

Up until that time zoning had been primarily considered as a health and welfare standard to promote livability in a city, not protect the health of the natural resources. With Senate Bills 10 and100 this issue of livability was expanded to the agricultural, forest, and natural resource lands surrounding the city. The key innovative measures in that legislation were: 1) the creation of "urban growth boundaries" and 2) the creation of a process of "periodic review." The urban growth boundary established hard, fixed lines around urban areas, beyond which resource zones had to be protected. The periodic review created a kind of living process whereby the zoning boundaries and rules were required to undergo change as the population and needs of local areas changed.

What I am proposing here is a fundamentally new approach to land use zoning, based on recent discoveries and methods from the sciences of biology and geophysics. These new sciences of "life" and "land" point to two fundamental flaws in land use zoning rules as currently practiced: 1) that only one land use designation should be applied to each plot of land; and 2) that the zone boundary must be mapped as a fixed geometric line.

Those are both "linear" land use zoning concepts; they exist because at the time of original formulation of zoning laws there were no better tools or methods. Because this linear approach tends to result in stale, monoculture environments, more recent years zoning codes commonly add "mixed use" zones, "overlay" zones, and exceptions upon exceptions in an effort to create more livable and healthy environments that allow for a complex interrelationship between humans, plants, animals, and the landscape.

Today we recognize that man's activities can have a devastating effect on the earth's natural systems. We are attempting to regulate our land uses toward the goal of protecting natural systems at all scales, from maintaining the water quality of small nearby streams to promoting activities that reduce our human impact on the global climate. As a culture we are striving to find "sustainable" and "green" methods to reverse what are currently negative trends. Unfortunately, by using our existing linear land use zoning system – one that by its fundamental approach starts by grossly simplifying uses and boundaries – we will by necessity always end up with a system that cannot work in confluence with natural systems. We are attempting to swim to safety, but picking a direction that is always against the tide of nature. There is an easier way to get there.

With the advent of computers, the sciences of ecology and population dynamics have developed innovative ways of understanding, describing, and promoting the creation of healthy, complex relationships between populations and environments. It has been found that there are often simple "feedback loops" that, though appearing small, have large influence on the overall health of a natural system. These methods were developed to study and protect endangered populations of natural species of native salmon, spotted owls, and butterflies. But there is no reason those same tools cannot be used in our land use zoning ordinances to promote healthy populations of the species Homo sapiens. The mapping of natural resources in a specific land use are, and the design of the human and natural trails that connect them can be, designed using computer models that include sensitive feedback loops and population dynamics considerations at their initial formulation.

Likewise, the geophysical sciences have determined elegant and simple mathematical tools for understanding and describing the forms of natural objects. In 1967 Benoit Mandelbrot published his famous paper "How long is the

Coast of Britain?" and then went on to invent a brand new kind of geometry (geo=earth, metry= measure). He called this newly defined system "fractal geometry" and showed how it can very easily map natural systems in ways that Euclidian geometry tries but fails to do. Again, there is no reason our land use zoning regulations cannot use this fractal geometry invented just 40 years ago, in lieu of the Euclidean geometry invented 2000 years ago. Applying this new geometry to land use would outright allow that all categories of uses can occur in all zones; what would differ is the scale of the activities allowed in each. Likewise, the trails and connectors between uses can be initiated on a natural fractal geometry "growth form" basis, rather than as sets of linear Euclidian single-use "highways."

Some applications

At a recent (January 2009) Ecological Farming Association Conference at the Asilimar Conference Center in Monterey a workshop session titled "Kitchen Artists" included Jim Denevan, founder and star chef of "Outstanding in the Field," a nationwide program of artful dinners, each carefully set up for the perfect combination of seating and setting in farm fields, vineyards, and orchards. With Denevan the art of eating has been turned into an experience of the farm and landscape that has created the food.

This brings to mind the Oregon land use case of the blueberry farm outside of Salem that set up a small building that sold blueberry pancakes. It became very popular because people loved coming to the farm that grows the blueberries, to get pancakes made from those berries. However, for the old guard, which had a Euclidian view of land use, this became a major threat to the future or Oregon's land use law that protects farms. So they filed law suits and forced the pancake sales to end. A farm, they claimed, is only a place to grow food, not to eat it.

Their real fear, of course, was that soon there would be a restaurant on every farm and, eventually, a massive loss of farm land and farms – the "slippery slope" argument. Aside from the fact that there is a higher probability that an asteroid will destroy all the farms, would it really be so bad if there were quite a few farms that had restaurants serving their land's bounty? That is old fearful thinking at work, and this narrow-minded approach of denying all new forms or combinations of use almost guarantees that the farms will die. It prevents innovation, change, and experience. There are easier ways to deal with the real issues underlying the objections – such as just making sure that the farm land is preserved and parking lots are limited in size. It would be a simple matter to limit the number of seats in the restaurant. Instead, we have thrown the baby out with the bath water.

What process would allow for zoning lines to change and morph through time, in response to living needs and experiences? One possibility would be to allow a kind of iterative land use process based on a modern evolutionary dynamics approach used in biology [*Evolutionary Dynamics*, Martin Nowak, 2006]. Under such a model we would create a set of rules to allow a slow change to land uses based on local decision-making.

An example of such an evolutionary land use process might be as follows:

1. Any property in one land use zone ("A") that touches a different land use zone ("B") on one property line may change its land use zone "A" to land use zone "B".

The process can be given positive and/ or negative feedback rules to further enliven the process:

2. To slow down the speed of land use changes, there can be a requirement that any change from "A" to "B" requires an application followed by a 4-year waiting period.
3. If there were a goal of creating more "B" zones then a rule might require only a 1-year waiting period to change from "A" to "B."
4. To speed up the potential of land use changes the rule could be that a property be within only 100 feet of another zone to be able to adopt that new one, thus allowing leap-frogging of one zone into another.
5. If it were desired that the changing land use only occur along a street, and not hop to other streets, then the rule would be that the "touching" property line would have to be a shared side or front property line (allowing it to go "next door" and "cross the street."
6. Finally, a property zone change could require the signed approval of some or all of the adjoining property owners, which would establish a social process for the changes.

The initial creation of land use zone lines would be by elected public officials as it is today (they could start just as they are today). The rules would be set by elected public officials just as they are today – a new set of zoning regulations called the "evolutionary rules." But what is really new is that the local citizens under the new rules can "evolve" their property when they are near another and, through individual self-control, change to what they see as an advantage to themselves. It also allows neighbors to team up with each other to "evolve" their properties in multiple iterative moves as a group, with benefits to all of them.

These rules could relate to big things or little things – specific zones, changes in density within the same uses, height limits, the need for public infrastructure improvement requirements, the need for "green" construction requirements, or any other aspect of land use. By creating a system that can evolve through local decisions, it allows the citizens to take more responsibility for what occurs in

their neighborhood. It allows for changes that are not pre-mediated by public officials. It allows for changes that have a life of their own, and therefore can be something new and innovative. Most importantly, it changes the process to one where overall goals and process is set by government, but individuals become equally important in having choice about where their local properties can develop and evolve.

Innocent until proven guilty: an alternative to exceptions

Planners nowadays work to create more diversity through creating special exceptions to the rules, or special conditions that are permitted contingent on other conditions. For example, certain rules might be added to the zoning laws that specifically allow some forms of housing to be placed in a downtown that is otherwise intended to be only a "commercial" use zone. In that case, housing might be added to promoted "bringing life back to the city." Likewise some "home-based" businesses might be promoted in residential zones to reduce highway traffic problems and respond to family needs for working at home. In Oregon, these kinds of exceptions to the zoning ordinances are being promoted.

Fractal geometry provides a system of math and science that can establish these kinds of mixes of uses through a positive process that encourages and innately allows the diversity, rather than through a negative "exceptions" process that does not allow the use unless it can be proven acceptable. It is the difference between being "innocent until proven guilty" and being "guilty until proven innocent." That is, the use of fractal geometry would turn the zoning process into an affirming process rather than a denying process.

There is a sense in which we already require the interpenetration of "agricultural" with the other zones; we just don't recognize it as such. Every urban center has a

system of parks within it. Within this context of a park within an urban area, we then historically find that each large commercial building surrounding the park has within it a courtyard garden of its own. In current practice this interpenetration of gardens with commerce is created through zoning ordinances that require "landscaping" or “courtyards” or “plazas” as a kind of agricultural zoning into the base zone. Landscape requirements in zoning ordinances have gotten quite extensive. It has gotten down to requirements for specific numbers of trees and square feet of shrubs per square foot of parking lots.

In fact, every park and every tree in an urban area can be considered a small piece of agricultural zone within the city limits. The size of these "agricultural zones" varies from hundreds of feet on a side for a large public park down to a 3-foot by 3-foot tree planting well in a sidewalk. We're all familiar with these kinds of requirements and few people questions the need for this interpenetration of agriculture into our urban areas. The reason we like the interpenetration of "green" into our urban, commercial, industrial, and residential high density areas, is that we know it improves our “quality of life.”

However, isn't the inverse just as needed? Shouldn't every agricultural zone include pockets of commercial, pockets of industrial, and pockets of high-density residential? Shouldn't a farm owner be encouraged to have a small home business that serves his community with special skills he or she can share with others?

I recently worked for 10 months with a 24 year-old young man who owned land in Oregon in an "exclusive farm use" zone. One of his special skills is that he is a world amateur champion skateboarder. He applied for a conditional use permit to teach skateboarding to young kids living in his rural community. He had set up skateboard ramps in two of his barns and wanted to be able to teach skateboarding to neighboring kids. He was turned down out of fear that this

would set a precedent that ultimately could destroy the entire exclusive farm use zone. Since the skateboarding was not related to an agricultural use, it was considered a threat to the whole system. Suppose that, instead, his skateboarding were thought of in the same way we think of a tree being planted within an urban center. His skateboarding proposal was simply a little spark of life being offered to the kids in the community. Is there some reason that rural kids should have to drive 15 miles to a city in order to learn this popular sport?

Under the science and math of fractals, a level of diversity can be established that allows for a certain amount of interpenetration of uses but no more. In other words, a home occupation skateboard park in a barn might be established as a size that is outright allowed in the zone without creating a threat. Rather it enlivens the zone and gives it spirit. A significantly larger size use (such as the size of an urban park) might be allowed in an agricultural zone on intervals of say two miles -- so that it is predefined as something that cannot take over the whole zone. Even a blueberry pancake restaurant, which under current zoning would be a threat to the whole zone, might be considered beneficial to the agricultural zone if a use of that intensity were only allowed say every five miles within the zone.

The point is that there are ways of allowing diversity and life into our agricultural zones without initiating their destruction. But it requires a new way of looking at zoning that considers the size and intensity of the use as being just as important as the use itself. Thus, just as every urban household cannot be denied its little vegetable or flower garden, so every agricultural property should be allowed its small home occupation that adds life and spirit to our rural lands.

The use of fractal geometry to lay out zoning maps would allow for a framework that acknowledges that all places of human environment should include a mixture of agricultural, industrial, commercial, and residential uses. Rather than

starting from a negative position, that each type of use should be isolated from the other, a positive starting point would establish that *all use types should be incorporated into all zones* -- but to varying extents. Thus, for example, in a residential zone, some form of home occupation (as a commercial or industrial use) would always be an outright allowable use. There could be varying limitations on amount of deliveries, amount of client visits, and size of space devoted to the use, but it would start from a position that home occupations are desirable and positive uses. Home occupations would be allowed unless proven to be objectionable. Innocent until proven guilty.

Our zoning ordinances are getting thicker and thicker every month and year. We are adding more and more exceptions, special requirements, overlay zones, public review, and debate. We are trying to create built environments that are dynamic and healthy places to live in. But we are using a zoning language and zoning tools from a bygone era. We are using tools from an era when industrialism and capitalism had run rampant through the country and were destroying our natural environment and expanding out of control.

We now live in a world that has shrunk as a result of rapid commercial airplane service between cities and countries. We live in a world with an Internet communications system that links all parts of the world at the speed of light, and with new knowledge about how the universe was formed and what elementary particles it is constructed of. Using fractals we can better understand how patterns of land use create livability. For example, consider the following fractal analysis of interpenetrability between urban and agricultural/ resource land.

- From the Space Shuttle take out a telescope and look down at the city of Portland, Oregon

- Focus on the city as a whole with its defined Urban Growth Boundary surrounding it
- Notice that there is a dense downtown core of urban development, yet there are large tracts like Forest Park that are all green: at this scale it is a mixture of urban and natural
- Now zoom in with a higher-power telescope to the downtown core that is mostly gridded and built up
- But inside of that you find a waterfront park of green grass, trees, and flowing water, wild nature inside the city
- And then you zoom in yet closer and find within that park a commercial food vendor selling tacos, a propane burner charring the meat and onions to be joined with beans and wrapped for lunches
- And when you zoom in yet closer you find a flowerpot hanging from the fabric-covered metal roof structure, the nasturtiums in full bloom
- And now you see that the flower is bringing about a smile on the face of a person waiting in line for lunch, in the beautiful city of Portland, Oregon.

I've tried to present examples of how the tools from biology and geophysics can be integrated into land use ordinances and maps to create healthier environments for both humans and the natural environment. I firmly believe that Oregon can continue to be an innovator and leader by adopting these next-generation tools to promote sustainability and "green" living.

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