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SOLSTICE VIII:

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Ann Arbor, MI
1997

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TABLE OF CONTENT

SOLSTICE:
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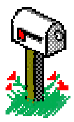
SOLSTICE, VOLUME VIII, NUMBER 1; SUMMER, 1997.

Why Whales Don't Freeze or Kidney-Shaped Airports: Spatial Analysis and Spatial Design.

John D. Nystuen
University of Michigan



Direct e-mail to the author: click here or send to nystuen@umich.edu

Paper Presented at
the Association of American Geographers Annual Meeting
Fort Worth, Texas
April 2, 1997
Reprinted (and lightly edited) in Solstice, by invitation.

KEYWORDS: boundary flows, spatial analysis, spatial design.

Abstract
Whales are warm bodies in a cold sea. Heat flow is a function of temperature gradient and, given long exposure and the large temperature difference between the interior of the whale's body and its watery environment (even with very good insulation), it seems as though whales should freeze. The arrangement of the blood vessels near the surface of the whale's skin creates a counter-current action that prevents this outcome. Kidneys contain similar counter-current processes that perm it concentration and transfer of waste products from blood vessels to urine tract. The shape of the kidney is an important feature in this process. An airport is a transfer point between travel domains in which two unlike carriers, motor vehicles and airplanes, must interact to exchange people and luggage. The exchange is facilitated by kidney-shaped airports. These unlike phenomena share some fundamental spatial properties, which when acknowledged, provide understanding and opportunity for design. Do airports have to be kidney-shaped? Certainly they do not, but it helps if they are. Spatial analysis addresses the spatial/temporal context in which things happen, an approach that has proven to be very useful for understanding spatial processes and for contributing to the design of effective spatial systems. Geographers have learned much through spatial analysis but have been little concerned with spatial design. Planners and architects focus on spatial design but often without addressing underlying spatial properties. The advent of GIS refocuses attention on fundamental spatial properties; geographers can play a pivotal role in this now interdisciplinary endeavor.

Introduction

My interest in boundaries and boundary processes led me to consider how the shape of boundaries facilitates or hinders exchange across boundaries (Nystuen, 1967). Today, I will share with you, in this oddly titled talk, some examples of very unlike boundary processes that are influenced by passive shapes, indeed, are made possible by the pattern of the flow channels near or in the boundary. In recent years geographers have shied away from analogies about spatial systems drawn from other disciplines particularly condemning biological analogies or metaphors as a means for understanding geographical systems. I think that stricture stifles imagination and limits opportunity for discovery. I have learned much from such comparisons. Also not to be discounted is the pleasure found in making connections between unlike phenomena. Let me describe the connection between whales, kidneys, and kidney-shaped airports.

Why Whales Don't Freeze

Whales are warm bodies in a cold sea. They are mammals with an internal body temperature close to that of human beings yet they spend much of their time in oceans that are at near freezing temperatures. Whales commonly maintain a temperature gradient close to 35 degrees Celsius (63 degrees Fahrenheit) in a distance of a meter or less from their warm interior to their cold watery environment. Heat flows down a temperature gradient and, even with thick blubber as insulation, over time a disastrous heat loss might be expected. Whales are not likely to be able to eat fast enough to generate a balance for the heat loss; for one thing, the food itself must be warmed up after being eaten. Heat exchange for three dimensional bodies is proportional to the surface area of contact. Even though this area is minimized by the rounded shape of the whale, it is still vast. The total calorie exchange would appear to be vast. At first consideration then, it seems that whales should freeze to death.

They avoid this fate by the arrangement of the blood vessels near the surface of their skins. These vessels are shaped like hairpins pointed directly outward with the sharp turn next to the surface of the skin. Consider the temperature of the blood just at the turn near the skin surface (Figure 1). It is cool due to the proximity of the cold sea. As the blood returns to the interior of the whale it is warmed by heat flow from its warmer surroundings. Part of those surroundings is the set of blood vessels carrying blood on the outward leg of the hairpin route. The out-bound blood loses heat to the cooler in-bound blood, which in turn is warmed. By the time the outbound blood reaches the hairpin turn it is as cold as the sea itself. By the time the in-bound blood reaches the interior of the whale, it is as warm as the interior. There is very little temperature gradient between the whale's surface and the sea, ergo, there is very little heat transfer, for a temperature gradient is needed to transfer heat.

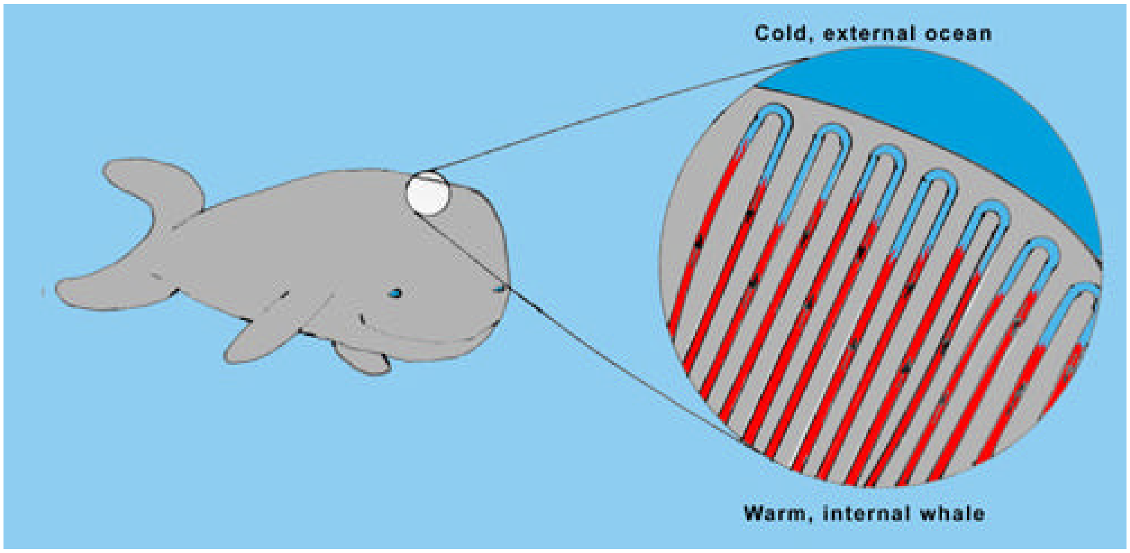


Figure 1. The whale's counter-current boundary system.

The counter-current arrangement maintains a large heat gradient without the need for a heat pump such as is found in a refrigerator. Energy is required to move the blood. The countercurrent system will not work without motion in the blood stream. Of course, if the whale's heart stops beating, heat loss to its environment is the least of its problems. The passive counter-current shape is found in several natural and man-made mechanisms. The blue heron standing in icy water keeps the heat from draining out of his body through his feet, in part, by standing on one foot, but also by the counter-current design of blood vessels in its other leg. The foot that is in the water is cold but heron's body remains warm. Engineers are familiar with this design and use it to maintain high temperatures inside boilers without having the boiler sides very hot and without much heat loss to the atmosphere surrounding the boiler. The design is particularly useful for nuclear reactors for they get very hot inside. The design requires that the coolant keep moving.
In the abstract, the high energy gradient is possible because of the shape of the semi-permeable transportation routes near the boundary of the two media. In this case, these routes are permeable to heat flow. No heat pump is required to move heat from the cold media to the hot as in a refrigerator. The only energy required is that needed to drive the fluid through the transportation channels.

The Kidney
Another biological example of the counter-current pattern is found in the kidney. Here the problem is to concentrate sodium ions and other salts in the urine by transferring these ions from the blood stream to the urine tract while maintaining the proper water-salt balance in the body: also by expelling or conserving water as the need may be. This transfer is accomplished in the kidney. The function of certain details of the anatomy (read morphology in geographer's parlance) has only been established in recent decades. One mystery was the purpose of the *Loops of Henle*. These are long hairpin-shaped loops in the urine ducts within the kidney pointing from the outside or cortex of the kidney toward the medulla or concave inner core of the kidney (Figure 2). The blood vessels of the

kidney loop into the medulla in the same fashion -- by making long hairpin turns. Sodium ions and other ions move through the semi-permeable wall of the blood vessels into the intercellular zone near the urine ducts and thence into the urine ducts by osmotic pressure. Ions move down the density gradient. The counter-current process operates along the Loops of Henle such that high concentrations of salts are possible at the turn of the loops. This is because blood approaching this area builds up high ion concentrations but looses the concentration via the counter-current action on the out-bound leg of the blood vessel. The site of active transport of sodium ions is along the length of the ascending limb of the Henle's loop (Mercer and Wasserman). In this fashion high concentrations of uric acid and salts are possible in the urine of land animals. A passive energy gradient is maintained by the shape or arrangement of these loops and the system satisfies one requirement our bodies must meet in order to stay out of the salty sea from whence we came.

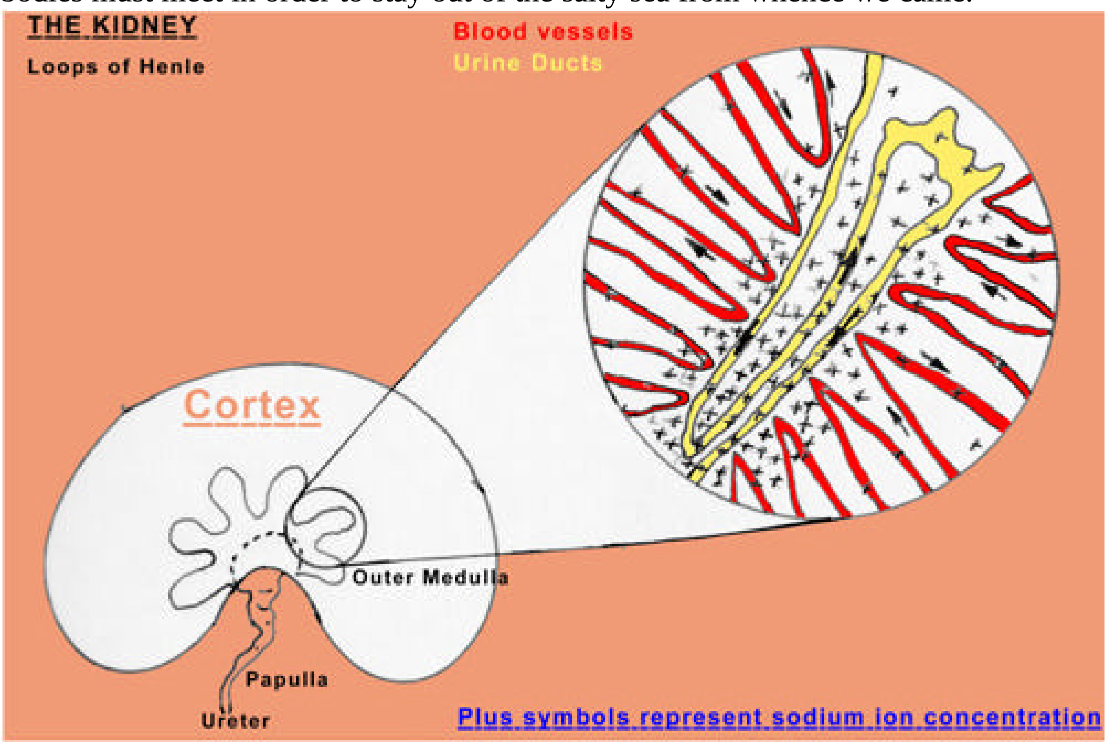


Figure 2. Simplified schematic of the kidney.

The operation of the kidney is very intricate and more complicated than I indicate here. Suffice to note that the arrangement of the transportation channels permits a transfer of an element from one medium to another. The kidney example is the reverse of the whale example. In the case of the whale, the purpose of the shape is to prevent heat transfer between two media. In the case of the kidney the purpose is to sustain a transfer at high concentrations.

Because the walls of the transfer channels are semi-permeable, ions can be exchanged whenever channels are in close proximity. This explains the kidney shape. Transfers occur along Henle's loops. Salt concentrations fall in all direct ions from this zone. The counter-current action in the blood vessels ceases by the fanning out or spreading of the blood vessels in the cortex of the kidney. The urine ducts loop back to the outer medulla thereby lowering the ionic pressure and then return to the concentrated zone increasing the ion pressure and exiting from the kidney into the ureter at the concave inner surface of the kidney. The length of the Henle's loops determines the maximum concentration that can be achieved. Desert animals have long loops. Blood travels at near constant speed through the vessels. The speed of water flow in the urine ducts is a variable and regulates the degree of uric acid concentration. The kidney is a marvelous organ and, as I said before, much more complicated than I describe here. However, we can learn a lesson from its shape.

Kidney-Shaped Airports

The kidney has an efficient shape for its purpose -- to transfer elements from one medium to another. The shape is an interesting form at various geographic sales. We are often concerned with the transfer of elements from one travel domain to another. For example, from airplanes to automobiles at airport terminals. At an airport the stream of airplanes and the stream of surface vehicles are best kept separate. Normally the transportation routes (spatial domains) of the two types of vehicles do not cross for, if they do, extra effort and expense must be used for traffic control or for building structures such as bridges or tunnels to eliminate grade crossings. Each type of vehicle has its own movement characteristics. Most airplanes are much larger than cars and must have considerable head and shoulder room to safely maneuver when on the ground. They land at high speed on linear runways and then slow down and taxi to the terminals. Motor vehicles approach the terminal in a similar fashion, reducing velocities from open highway speed to maneuver into position at the terminal but they are not as large a space user as taxiing aircraft. Both aircraft and motor vehicles are concentrated around the terminal building. The elements of exchange are, of course, people, luggage and cargo. Many huge airports have radial walkways leading to the departure gates from the center of the terminal building. People are concentrated at the terminals and fan out to board and leave by plane, When arriving by air, they leave the terminal by motor vehicle on a concave transport route at the inner surface of the terminal building. Basically, transportation carriers with different spatial travel domain are required to interact with some sort of preservation of the elements exchanged; that is, what comes in must also leave otherwise people and things will pile up in the terminal. An efficient design is to have the domain of the carrier with the larger space needs wrapped around the domain of the carrier with fewer space needs. The whole thing is kidney-shaped.

Many medium and large airports are, in fact, this shape. O'Hare Airport in Chicago is a perfect example (Figure 3. Chicago's O'Hare). Most likely if you consider the metropolitan airport nearest your home you will discover it is some version of this basic shape. Airport terminals can be classified into three types by shape or layout: *linear, kidney-shaped,* and *compound.* Terminals for small airports are usually linear in form. They reflect the need for only a single linear runway for the airplanes. For medium-sized airports, with more than one runway involved (each oriented in different direction) there is some advantage in placing terminals near the intersection of the runways. This defines a concave space for the approach road and the beginnings of the kidney shape. For very large international terminals, traffic is sufficiently great to justify intermediate transportation domains linking motor vehicles and aircraft. The problem with the large terminals is that the walking link becomes inconveniently long. People who frequently use O'Hare Airport or the Miami Airport probably understand this problem. Other examples of kidney-shaped airports are La Guardia and Newark in the New York Region; San Francisco's International Airport; and, Tokyo's Narita International Airport. Underground light or heavy rail connectors or full circle terminals such as Kennedy Airport in New York in which surface transportation paths cross aircraft paths via bridges for aircraft or tunnels for surface vehicles may be utilized. These large terminals may take a variety of forms but they are no longer planar: that is, paths on a two dimensional surface where unlike paths do not cross (Arlinghaus and Nystuen). The Seattle-Tacoma Airport is an example of a kidney shaped airport with outliers connected by underground light rail vehicles. One common pattern of a non-planar system is comb-like with a straight main stem and shorter perpendicular arms where the departure gates are located. The new Denver and the new Atlanta airport are examples of compound designs as is the Dallas-Fort Worth Airport. This arrangement comes with the added expense and inconvenience of an intermediary transportation mode between the highway vehicles and the aircraft. If that mode is a heavy rail, such as a short subway, it works best if its track is linear, hence the comb or marina-like pattern. Such airports require huge land area and are often found far from the metropolitan core.

Figure 3. Chicago, O’Hare International Airport.

Travel effort always involves three types of costs: *acceleration, uncertainty,* and *queuing.* Acceleration is associated with areas and energy and defines the spatial parameters of the moving vehicles and their travel domain. Uncertainty is overcome by proper dissemination of information about departure gates and times. For informational purposes it is best to have a high concentration of people in the center of the terminal. Everyone must find where his/her departure gate is located in the terminal, or, when deplaning, where to pick up the luggage and locate a limousine or other surface transportation contact. The terminal is the space where this sorting occurs. Unfortunately the cost of addressing the first two types of travel efforts: *acceleration* and *uncertainty* are substitutable by the third cost of *queuing*. Capacity of structures, number of runways, departure gates, luggage carousels, storage, announcements, open ticket counters can all be smaller, fewer, and have less capacity by making the passengers, surface vehicles and aircraft wait in lines. Because the aircraft and surface vehicles have such different passenger capacities, and because of favored times of day for departures, holding areas, waiting rooms and long lines are an inevitable part of the travel effort to move from one travel domain to another.

Spatial Analysis and Spatial Design

The terminal building is the permeable membrane or interface that facilitates the exchange between surface vehicles and aircraft. Do airport have to be kidney-shaped? Certainly not, but it helps if they are because the shape is an optimum pattern for accommodating flows near and through the boundary of two media with different spatial parameters.

Understanding spatial systems through such analysis informs one about possibilities for spatial design. When teaching GIS courses I find that applying spatial analysis to design problems carries one beyond technique and often provides a sense of surprise and satisfaction. I delight in finding connections between unlike things where the connections are the consequence of abstract spatial properties.

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SOLSTICE, VOLUME VIII, NUMBER 1; SUMMER, 1997.

TO THE MEMORY OF CLYDE TOMBAUGH, 1906-1997.

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Clyde discovered the planet Pluto in 1930 at the age of 24. He also established by means of his thorough exploration of the firmament that it is extremely unlikely that any other solar planets exist.

New Mexico State University had gathered in one building all of the Research Professors from various departments. These included Art Kruse, Mathematician, and Walter Lwowski, Chemist together with astronomers Mr. and Mrs. Herbert Reta Beebe and spouses, they constituted Clyde's lunch group. Clyde presided in a very democratic way over this highly scholarly group who all became comedians during lunch. The laughter was almost non-stop with everyone making puns whenever possible, the ringleader being Clyde himself. I was privileged to join this group when Walter brought me to lunch one day as his guest. For the next decade we lunched together every weekday. The louder the groans, the more a pun was enjoyed and appreciated. I enjoyed these lunches so much that I stayed at New Mexico State University in order to have lunch with the group each day.

Now I get to the point. We had many discussions about the possibility of extra-terrestrial life. Clyde always expressed total certainty that among the billions of stars in galaxies, super galaxies, and clusters, there must be many stars that have planets. He further frequently expressed his conviction that among all these planets that he was sure existed, there must be very many that could support life of one kind or another. He was also of the most confirmed opinion that some intelligent was included amongst these.

Clyde founded the astronomy and the geology departments at NMSU. He was most knowledgeable about geography. He was a great and humble man who thoroughly deserved all of the acclaim he received.

One day I was complaining to the "lunch bunch" that I had received twenty e-mail letters, six inches of mail in my university mail box, two letters among them being mathematical papers to referee for publication. Clyde blustered and proclaimed loudly, "do you think you get a lot of mail? I get so much mail that it's downright astronomical!" Everyone laughed heartily. This was one of the few times when Clyde made a wonderful play on words and did not realize it.

I composed a poem for his 89th birthday and here it is. What a great guy and we all miss him.

To our good friend Clyde Tombaugh
HAPPY BIRTHDAY TO YOU!!!!!!!!!!!!!!
(22 stanzas of 2 lines each, which rhyme but do not always scan)

On the Fourth of February 1906
A little bundle was sent who would do some great tricks

If it had been 1907
I'd say the bundle was sent from heaven

Clyde arrived into the Tombaugh family
But could not yet speak, so he did not deliver a homily

Nobody could know then that world-renowned he would become
And that to no evil temptation he would succumb

He likes to eat his bread with butter
He set the whole wide world a-flutter

When in 1930 the planet Pluto he discovered
This remarkable phenomenon was thus uncovered

By an almost infinite amount of hard work
From its arduous nature he did never shirk

Now we have the privilege and pleasure of lunching
With him, and hear his hilarious puns while munching

He often likes to eat baked fish
Which shows he has good taste in a dish

His mind is witty and so quick
He likes to spread his butter thick

He doesn't like to waste a thing
Uneaten bread homeward he will bring

He likes his coffee with some cream
When he makes a great pun he will beam

A great football analysis he can make
Showing up the coach's stupid mistake

He makes good jokes about a crow
And this list seems to grow and grow

He loves to make an outrageous pun
And give us all a lot of fun

When bad enough they make us groan
And that's the theme of this here poem

He always likes to grind his lens
To perfection with no amends

He built his own big telescope
And doesn't sit around and mope

His Patsy is his perfect wife
And with her he's enjoying life

When he was a lad of 88
We came here to celebrate

Now that he is 89
We're all glad we can say "he is a friend of mine"

So here's a great big toast to Clyde
From whom Pluto could not hide!!!!!!!!

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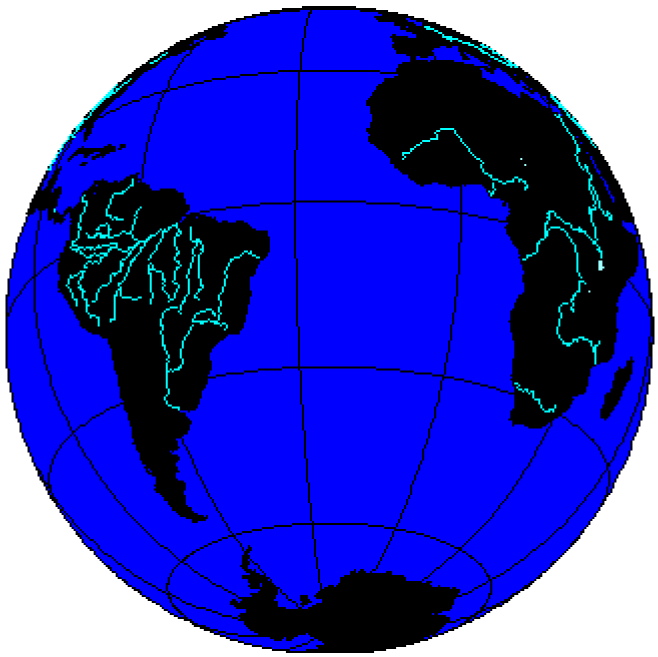

Earth: with 23.5 degrees south latitude as the central parallel.

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DECEMBER, 1997

Related Solstice link:
http://www-personal.umich.edu/~sarhaus/image/sols191.html article about SunSweep

SOLSTICE, VOLUME VIII, NUMBER 2; WINTER, 1997.

THE PHOTOGRAPHIC RECORD.
SUNSWEEP: A VISIT ON THE SUMMER SOLSTICE

John D. Nystuen
University of Michigan
Mail to author
nystuen@umich.edu

A recent visit to Campobello Island in Canada, off the coast of the state of Maine, offered an opportunity to view the eastern element of sculptor David Barr's Sunsweep: an arch (both physical and virtual) that celebrated the U.S./Canadian border with physical endpieces on Campobello and Point Roberts WA and a physical keystone in Lake of the Woods, MN. The actual stone elements are linked virtually in the mind along the border as the sun sweeps from east to west--all are aligned to astronomical events and access to all requires a border crossing. Colleagues and I had worked with Barr in a number of ways and that work was written about in an earlier number of Solstice (1991, Number 1; a direct link to that article). Indeed, as we noted,

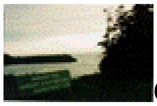
> "Sunlight and shadow, day and night, solstice and equinox, lunar and solar eclipse--all are astronomical events that transform the surface of the earth into an event focused on the contrast between light and dark. The diurnal dynamics of the sweeping edge of the darkness are a foundation critical to the well-being of life on earth. Artistic expressions are numerous, ranging from Amish quilt patterns (``sunlight and shadow") to Indonesian shadow puppets. From a spatial standpoint, the mantle of night serves as a continuum linking disparate elements of the earth's surface; it is a whole composed of unseen parts."

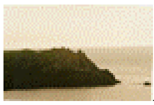
From that earlier scholarly vantage point, it was with great enthusiasm that I went with friends and family to view the sculpture on the Summer Solstice (4:40 a.m.) sunrise on June 21, 1996. The photographic record below is a continuing tribute to the events surrounding this international sculpture.

Information about SunSweep may be obtained at the Information Office at the Park Entrance.

On the web, the smaller images are linked to larger images. Each large image is inserted in the hard copy in a sequence of pages corresponding to the sequence of small images below.

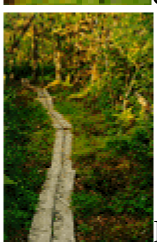

SunSweep, Campobello International Park

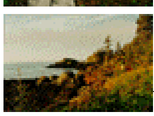

Guidepost


A view from a distance of Ragged Point and SunSweep


A longer view of Ragged Point and SunSweep


On the SunSweep Trail; 1 km path from parking area to sculpture.


Farther along the trail


View from Ragged Point

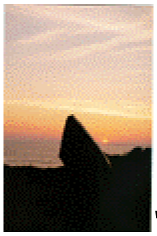

View eastward from Campobello Island


Flags of the Campobello International Park


Bridge from U.S. Mainland to Campobello Island (Canadian).


FDR's cottage on the island


Arch is made of etched Canadian granite


"Sunrise at Campobello"


John D. Nystuen at the arch.


Rhonda Ryznar, Rich Rovner, Leslie Nystuen: members of the solstice party.


SUNSWEEP TRAIL
SUNSWEEP SCULPTURE 0.6 MI.
RACCOON BEACH 1.9 MI.


ROOSEVELT COTTAGE

Related *Solstice* links:
http://www-personal.umich.edu/~sarhaus/image/sols196.html Jacobs, US 12 article
http://www-personal.umich.edu/~sarhaus/image/sols295.html Arlinghaus, Spatial Planning article

BUFFERS AND DUALITY

Sandra L. Arlinghaus, Frederick L. Goodman, Daniel Jacobs
The University of Michigan

e-mail to authors:
Arlinghaus
Goodman
Jacobs

"To see a world in a grain of sand
And a heaven in a wildflower;
To hold infinity in the palm of your hand,
And eternity in an hour."
William Blake, *Auguries of Innocence*.

Common sense tells us that rivers, rails, coastlines, and abstractly equivalent lines across the geographic landscape serve not only as barriers to flows of people, goods, and services, but also as transmitters of these flows. The manner in which they serve as such has captured the imagination of geographers for many years. Nystuen (1967) sees the margin of an advancing forest adjacent to a lake as either accelerating or retreating in growth depending on the manner in which trees propagate seed (by wind or by squirrel). In a different environmental context, but an abstractly similar argument, Nystuen also sees the oyster as a boundary dweller in the fragile margin of Chesapeake Bay, anchored in the sandy shores of the land while deriving food from the fluctuating wavy water boundary that washes over the shore. Abler, Adams, and Gould (1971), in their classic textbook on elementary spatial analysis, reflect on barriers and carriers as do various more recent texts.

Duality

The basic idea, however, of geographic lines having a dual role may well be as old as the human race; what child has not noticed that the bridge used to cross the creek can also be used as a dock from which to launch paper boats downstream? Enduring ideas remain fertile because their simple, elegant character permit many interpretations.

Duality is a concept that is useful when looking at the whole of an entity. A purely dual situation is one that exhibits perfect symmetry. The non-Euclidean world of projective geometry exhibits complete duality of statement: "two points determine a line" and "two lines determine a point" are equally valid projective statements (Coxeter, 1955). In the Euclidean world they are not, of course, equally valid statements. Parallel Euclidean lines do not meet in a point. This sort of pure symmetry is possible only in abstract worlds:

"barriers are carriers" and "carriers are barriers" can become equivalent only in abstract geographic space.

Buffers

One way to mitigate the barrier/carrier dichotomy associated with real-world geographic lines is to expand the dimension of the geographic line. Mark Jefferson's provocative early twentieth century maps illustrate this idea. Jefferson's introduction of a 10 mile buffer behind each railroad line in Europe (Figure 1) causes one to grasp simultaneously where there are, and where there are not, both rails and civilization, (Jefferson, 1928). Spreading the line offered extra insight into process: the role of the railroad in settlement patterns. Jefferson's map employs a jump in dimension to offer extra insight: from the one dimensional cartographic line representing the railroad to the two dimensional rail buffer swath. Jefferson's jump is in Euclidean dimension; indeed, the underlying mathematics on which the additional insight is based is discrete in its logical form. There are gaps between Euclidean dimensions.

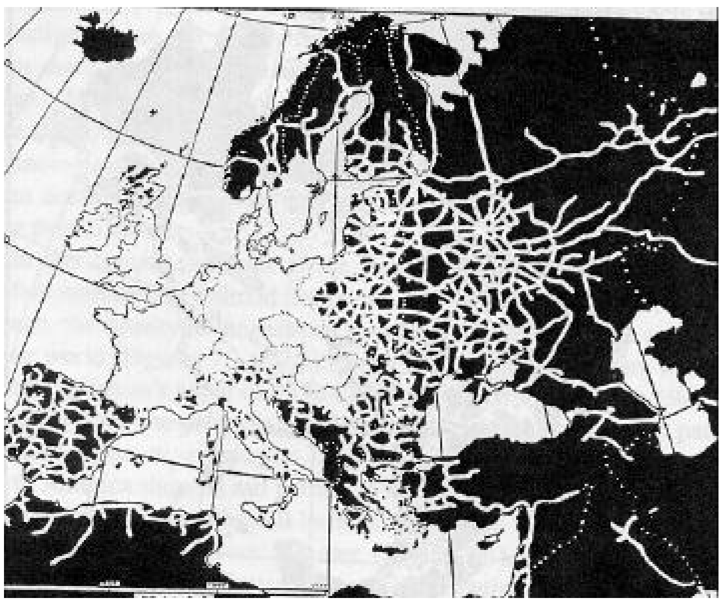


Figure 1. Mark Jefferson's map of Europe, *The Civilizing Rails* (1928) (reference below), provokes a strong visual image of the role of the railroad in the settlement of this region. Buffers tracing railroad routes are 10 miles wide. Cited here along general guidelines communicated by Jefferson family.

A different strategy to analyze the duality of barrier and carrier was employed by Arlinghaus and Nystuen (1990) using fractional dimensions (fractals) based on continuous mathematics (Mandelbrot, 1983). Often, condominium complexes are built to take advantage of some interesting natural view; nonetheless, residents also generally wish easy access to and from their homes. In this case, an ideal planning situation might seek to maximize public interest (in view and access) and minimize environmental damage. The fractal approach offers cuts of the land with a view of the water out the front with a road in the back. It minimizes coastal damage by maximizing space-filling characteristics of the cuts. A local Michigan condominium developer pursued actual development of this project and found that the costs of dredging were prohibitive. Self-similar space-filling curves were used to generate a shape that spoke to one abstract mini-max principle; at the applied level however other issues precluded actual project realization.

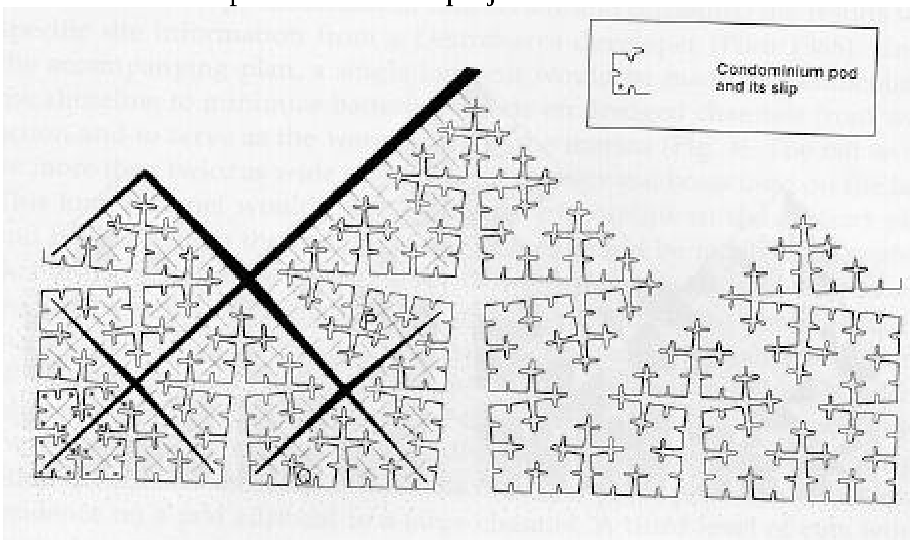


Figure 2. Space-filling marina based on fractional dimensions for dual land/water access; base map used to generate map that appeared in Arlinghaus and Nystuen, Geographical Review article cited in references.

In the map of Figure 2, the boundary is allowed to fill space (gain higher fractional dimension) until a condition of optimal exchange across, and flow along, the housing/marina complex boundaries is achieved. Dimensional alterations can create various degrees of resolution of abstract dual situations, and they can do so from a fundamental viewpoint that is either discrete or continuous. Such resolutions are of course particularly useful when they mesh with real-world economic and other considerations. Failure to find such a fit does not however mean that such an approach should be abandoned. The planning effort driven only by the bottom line is just as ineffective as the planning effort driven only by abstract concepts.

The U.S. Route 12 Buffer and Virtual Classroom

The man-made carrier of the railway line, vital in opening up new territories, suggests capturing disparate human characteristics in various buffers and using these buffers to tap perhaps unforeseen resources. The railroad can represent far more than a cartographic line on a map. Goodman and Jacobs, in a current education project, are creating a community of education travelers, in both actual and virtual space, within the set of schools, museums, universities, and other educational institutions along the U.S. 12 buffer (from Detroit to Aberdeen, Washington; Figure 3).

The Route 12 Project was created as a means through which diverse elements of local and national communities can come together. It is an educational network, both electronic and physical, that is unfolding in the counties along Route 12. Teachers and students, alike, use the network to share ideas, lessons, research, local historical information, and a host of other educational resources. The child from the inner city of Detroit becomes "adjacent" to colleagues on farms in rural Idaho. Indeed, one exchange has seen students from Detroit sharing first hand, their view of information about the development of the U.S. auto industry with students from Bowman, North Dakota. The North Dakotans in return offer to the Detroiters a view of critical dependence of a town, not on the automobile, but rather on the railroad. Extension of contact in space, coupled with expansion of a line to a buffer, mitigate self-centeredness; apparently of particular importance in geographic education in a country of physical extent as vast as is ours. As with Nystuen’s oysters in Chesapeake Bay, the child "barometers," physically fixed in positional locale along the US-12 corridor, become movable in virtual space. This movement frees the imagination to participate in diverse educational activities not previously easily available and such freedom serves also to defeat geographic isolationism so common when the child’s world is only a tiny part of the globe. The virtual classroom, developed along the computer networks in this geographic corridor, offers an exciting basis for developing cross-cultural understanding.

The initial development of this classroom rests, however, on traditional field methods in which both Goodman and Jacobs go to the participants and expend substantial effort assessing what sorts of resources might be available at different locations and convincing individuals of the merits of participation based on the resource assessment. To date, Jacobs has made three trips across the entire corridor. He has also made partial trips, hauling a classroom of 6th grade students from Detroit Open School across U.S.12 to the western edge of Michigan. Indeed, as James Edwards, principal of Walker Elementary school (in Canton, Michigan) put his vision of the Route 12 Project: it is "a program that could not only supplement a child’s regular education, but also give him or her a stronger sense of community and belonging. This feeling of community is invaluable for the students’ holistic educational process. Broad local support is imperative if we expect our children to assume responsibility for and leadership in their community." It is to this broader sense of community that the Route 12 project speaks.

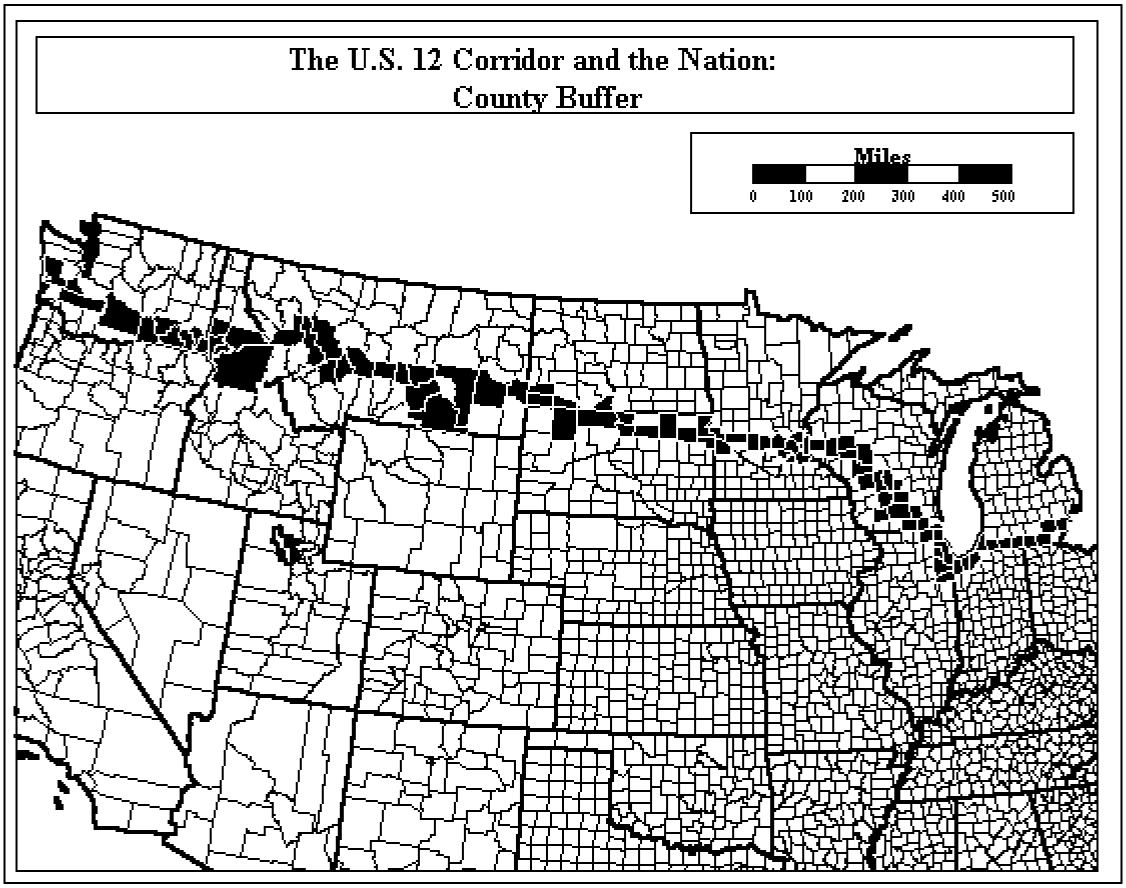


Figure 3. The U.S. 12 County buffer. Counties adjacent to U.S. 12 are shown in black, with white boundaries. Mapping done in Atlas GIS, v. 3.03. Information being mapped from U.S. Bureau of Census.

Not only does the Route 12 Project fit within the pragmatic view of the school principal's broad assessment of student education, but also it fits within the broader scholarly realm of previous geographical and mathematical analyses. The Euclidean extension of the U.S. 12 route, in the style of Jefferson, to a zone of buffers based on county boundaries permitted the capture of a set of schools and the creation of a virtual U.S. 12 classroom. Visual implementation of positional data was executed in the Euclidean world of GIS; the technology matched the dimension and faithfully portrayed data associated with this Euclidean buffer.

When Jacobs made three trips covering the buffer, with children from various schools within the buffer, his effort reflected that of Arlinghaus and Nystuen in filling in between the integral dimensions. The difference is that while his travels fill a gap in the real world, the electronic world of the GIS is not routinely based on a mathematics that fits fractional dimensional analysis. Thus, unlike the work of Arlinghaus and Nystuen in which the mathematics did fit the environment, it is left to the future to fill in this piece in the abstract setting of the Route 12 Project. The correspondence between scholaraly ideas is, at this stage, asymmetric.

Asymmetry

Often when one thinks of interweaving the abstract and the applied, the abstract is discarded if it does not meet the test of application. There is asymmetry in considering the merits these two different approaches have to offer. Indeed, the practical approach of an overlay, exhibited by county buffer superimposed on Route 12, could offer to municipal authorities across a broad spectrum of geographic scales, from the city, to the county, to the state (for example), of convincing evidence on the merits of overlay legislation. From a practical and applied standpoint, one must, at some level, confine laws to geographically defined and confined regions. Often, however, natural features, educational concerns, and other far-flung notions transcend political boundaries. The geographic literature, newspapers, and other sources are filled with example. One quite standard one involves watersheds (Figure 4).

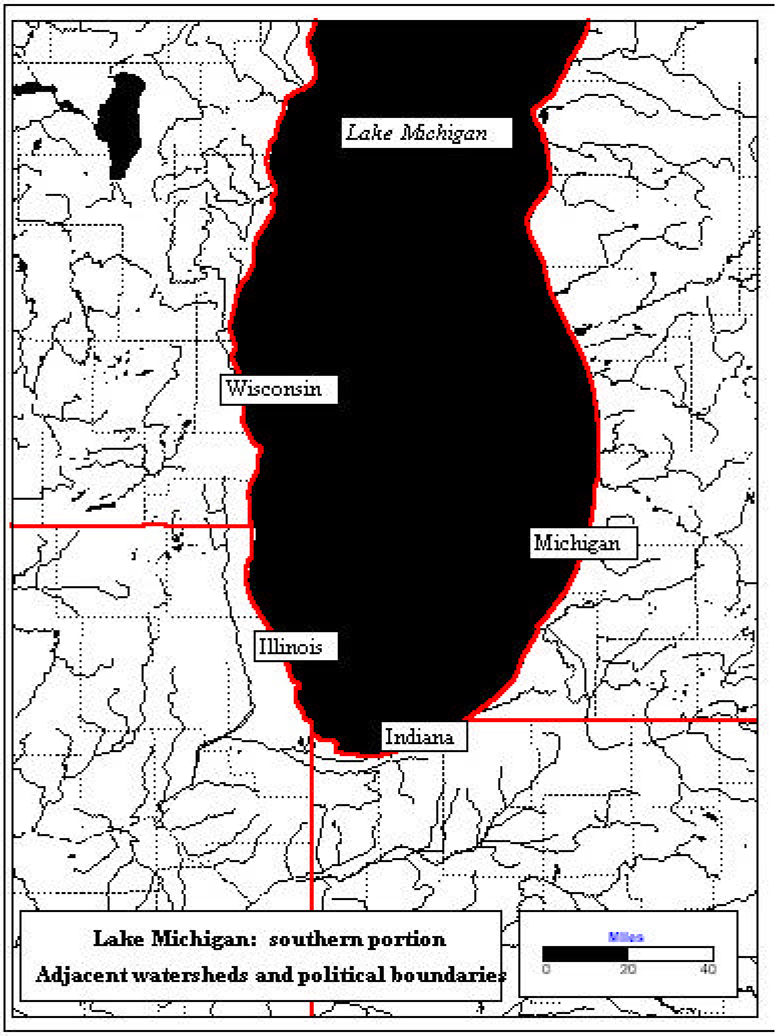


Figure 4. Natural watercourses overlain with political boundaries at the county and state levels. Base map from Atlas GIS, v. 3.0.3 with hydrological layers superimposed from the Digital Chart of the World.

Developers and municipal authorities often care how new development will affect an adjacent neighbor. But, what does "adjacent" mean? All too often, it simply means "shares a man-made boundary." This meaning illustrates that it is the man-made boundaries that dominate: the Route 12 classroom suggests that even when man-made boundaries help to define geographic extent, it is possible for concerns other than the political to become dominant. Thus, in the watershed example, if "adjacent" instead means "shares a watercourse with" then the watershed, rather than the political entity, has become the fundamental planning unit. A brief glance at almost any map that shows both drainage networks and political boundaries illustrates that they have little in common (Figure 4). The fit is bad. Here, perhaps, the abstract idea of using the drainage basin as a fundamental unit should take the lead and laws of units more local than a drainage basin made to fit within the basin…a case in which the abstract guides the applied.

Applied Geography of the U.S. 12 Project

The Route 12 Project approach also has precedent, in the applied realm, in other parts of the world. One traditional way to stretch a child's view or imagination is to do so physically, through travel or through direct contact with others his or her age across a spectrum of geographically distant points and cultures. Hence the presence of field trips, pen-pals, and other time-tested strategies are common in the pre-collegiate curriculum. The presence of electronic networks offers yet other imaginative ways to achieve similar ends; when these are coupled with electronic mapping capability they not only stretch viewpoint, but increase geographic awareness and knowledge, as well.

When GIS is introduced, the spatial connections that are being forged in the virtual classroom of U.S. 12, become evident visually. As did Jefferson's maps, the map of the U.S. 12 county buffer (Figure 3) presents a clear image of geographic position in relation to a network. Jacobs introduced census data into the U.S. 12 Buffer to illustrate locations of linguistic groupings along the U.S. 12 network. Students thus use maps to find not only their position along the U.S. 12 classroom, but also their position based on heritage in the broader linguistic family tree of mankind (Figure 5 exhibits one map from a set of about 100 different ones that Jacobs has generated).

The maps are employed not merely to show the power of electronic mapping, but also to form images in fertile young minds that would certainly not easily have been available in pre-GIS mapping days. Maps that are tailored to the project at hand, that are inexpensive, and that can readily be given to each child, offer great promise in overcoming educational inadequacies so evident in the pre-collegiate geographical curriculum.

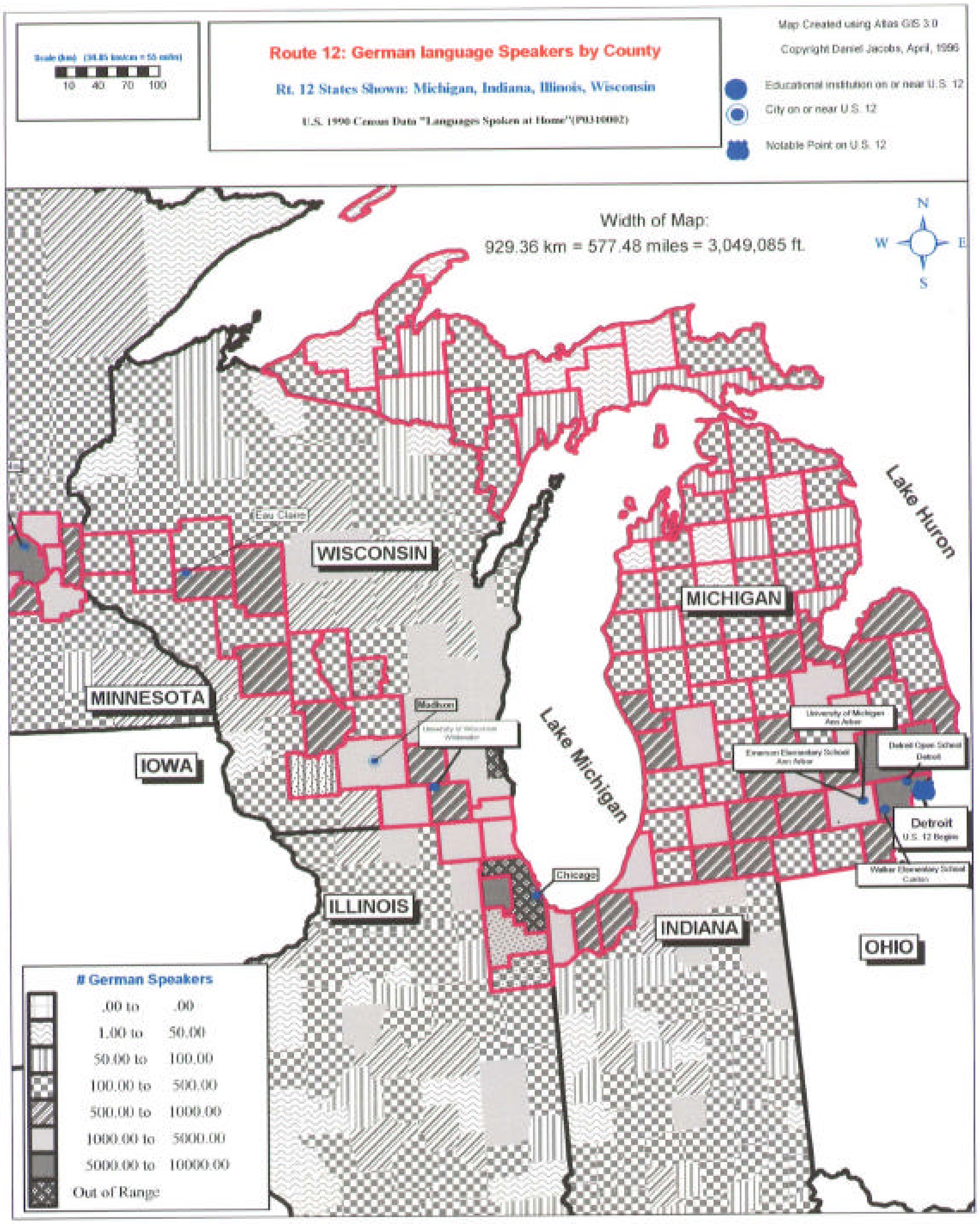


Figure 5. Jacobs' map of German speakers in the eastern portion of Route 12 county (and state) buffers. The U.S. Census measures 24 distinct language categories under the heading of "Languages Spoken at Home." Basemap: Atlas GIS, v.3.0.3; data: U.S. Bureau of Census.

As are roads, rails, and rivers, natural languages are also both barriers and transmitters. Jacobs and Goodman capitalize on this observation to communicate disparate concepts within a single virtual classroom. In so doing they weave together the regional "dialects" of the urban/rural as well as of urban/suburban, rich/poor, and various permutations of these and other socio/demographic indicators, into an educational fabric far richer than the sum of its dichotomous parts.

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Link to related Solstice article:
http://www-personal.umich.edu/~sarhaus/image/sols193.html, Sum-graph article, Arlinghaus, Arlinghaus, and Harary.

A GRAPH THEORETIC VIEW OF THE JOIN-COUNT STATISTIC

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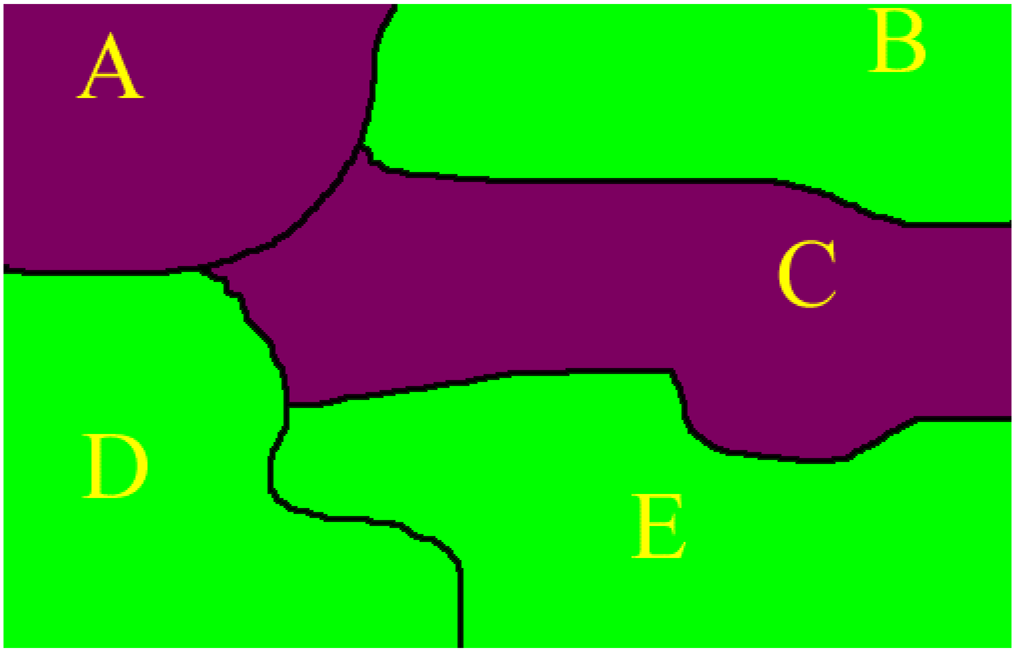
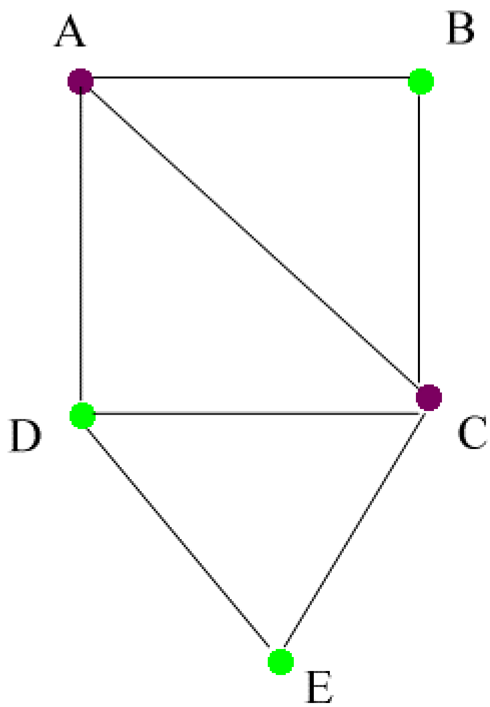
Spatial autocorrelation measures, to some extent, the influence of neighboring regions on each other. Given a thematic map, with regions colored by some variable, two regions are defined to be adjacent (neighbors) if they have a common boundary that includes a line segment (touching at a point, only, does not constitute adjacency). With positive spatial autocorrelation, similar values of the variable are clustered in space. With negative spatial autocorrelation, dissimilar values of the variable are clustered in space. No spatial autocorrelation indicates a random pattern of clustering in space.

How to set bounds for "positive", "negative", and "no" spatial autocorrelation is a problem with an infinite number of solutions. One way, the join-count statistic, is through analogy with simple biological patterns of "pure" and "hybrid" inheritance patterns. Often the biological model is explained using eye-color. Instead, suppose that one mapped variable is "urban". Suppose there are two possible values for this variable…urban, and non-urban (called rural). Represent one state as U and the other as R. Then there are four possible adjacency patterns for any pair of adjacent parcels: UU, UR, RU, and RR. At random, each of these occurs 25% of the time. Thus, pairs of parcels of dissimilar character would be expected 50% of the time. When UR+RU<50%, it follows that values for UU and RR are higher than expected; a condition of positive spatial autocorrelation. When the values are about as expected, the pattern is random. When UR+RU50%, spatial autocorrelation is negative; dissimilar pairs of parcels dominate (Vasiliev, in CRC Practical Handbook of Spatial Statistics).

In the map of a hypothetical region below, there are 5 states. The ones of largely urban character are colored purple; rural ones are colored green. The name of each state (A, B, C, D, or E) is inserted as a label. We offer a method of looking a clustering that uses graph theoretic ideas.



Any spatial object composed of areas and linkages between areas can be represented as a graph: nodes and edges linking nodes. When the areas are colored, the corresponding nodes can also be colored to represent the map coloring. The map above can therefore be represented as a graph with colored nodes as below. Two nodes have an edge linking them if and only if the nodes represent adjacent areas on the map. Thus, A is adjacent to B, C, and D in the map, but not to E; in the graph there are edges linking A to each of B, C, and D, but not to E.



Enumeration of linkage patterns of colored nodes is tracked quite simply using an adjacency matrix. The nodes are lined up in any order along the top and the left-hand side (for example) of a matrix. A value of 0 in the AC position indicates that there is no link between nodes A and C; that these nodes do not represent adjacent areas on the map. A value of 1 in the AC position would indicate that there is a link between A and C; that these nodes do represent adjacent areas on the map. Thus, one might choose to merely arrange the labels for the areas in alphabetical order. The colors behind the node labels represent the node colors. The colors behind the numerals indicate what sort of adjacency pair that numeral represents: a light purple background indicates a urban/urban pairing; a light green background a rural/rural pairing; and, a white background a rural/urban or a urban/rural pairing. In that case, the following adjacency matrix emerges:

	A	B	C	D	E
A	0	1	1	1	0
B	1	0	1	0	0
C	1	1	0	1	1
D	1	0	1	0	1
E	0	0	1	1	0

However, we do have the freedom to choose other orderings for the labels without altering any of the results. This particular ordering, based on alphabetical order of place names, does not lend any additional insight. It is useful to choose an ordering that does so. If instead, one orders the place names into two groupings, rural and urban, then the resulting matrix is partitioned into sets of 0s and 1s in which the size of the "pure" and "hybrid" adjacency patterns can be read directly from the matrix. Clustering rows and columns in the matrix reflects corresponding clustering in the map, as below. Both matrices are symmetric about the main diagonal and both matrices have 0s all along the main diagonal; in addition, the rural and urban blocks of submatrices are clustered together along the main diagonal in the matrix below. In the matrix above, they are not. Spatial autocorrelation with adjacency matrices is useful in displaying spatial autocorrelation in the associated map from which the adjacency matrix was derived. Order of labels can be critical.

	A	C	B	D	E
A	0	1	1	1	0
C	1	0	1	1	1
B	1	1	0	0	0
D	1	1	0	0	1
E	0	1	0	1	0

From the matrix below, it is easy to read off that of the 14 cells in which there is an edge (of the 14 pairs of adjacent regions)
UU=2
UR=5
RU=5
RR=2
so that RU+UR14/2
and autocorrelation is negative; dissimilar regions are clustered.

Directions for further research are suggested by the cleanly-colored adjacency matrix sorted into blocks that mesh with the basic problem structure:

- if more categories are introduced, can these be handled also using the graph-theoretic mechanism? With two categories, U and R, there are four adjacency pairings. With three categories, there would be 27.

- powering of the adjacency matrix will count the number of second-order adjacencies...to include second-nearest regions. A visual mechanism such as that above might produce interesting visual results.
- what other graphical ordering systems will offer extra insight into spatial problems (see sum-graph reference above, use the direct link).

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Related Solstice link:
http://www-personal.umich.edu/~sarhaus/image/sols296.html

Differences in Feature Representation in Digital Map Databases

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National Research Council

December 15-17, 1997
Natcher Conference Center
National Institute of Health
Bethesda, MD

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Abstract
Map databases are integral to many ITS (Intelligent Transportation Systems) applications in navigation, traffic forecasting, and route planning. With the increasing deployment of ITS technology demands for accurate and complete digital map databases of the nation's road network are surging. The development and maintenance of high quality digital map databases is expensive and time-consuming. Database sharing will be a sensible approach whenever possible in order to reduce cost. In the US map databases are being produced by a variety of public agencies and private vendors. Quality and levels of accuracy vary depending on data sources and production procedures. Verifying the quality and accuracy of map databases for purposes of navigation is a pragmatic and important concern. The Society of Automotive Engineers (SAE) has developed a Truth-in-Labeling Standard (SAE document J1663), the goal of which is to provide a consistent method for describing and comparing map databases. While the standard requires that database vendors provide a standardized label that lists basic database characteristics such as lineage, coverage, accuracy, content and scope of a database, there are currently no guidelines for feature representation (such as the layout of road intersections) in digital databases. Comparison of two different map databases reveals significant representational differences due to differences in precision of source material, data model and intended uses.

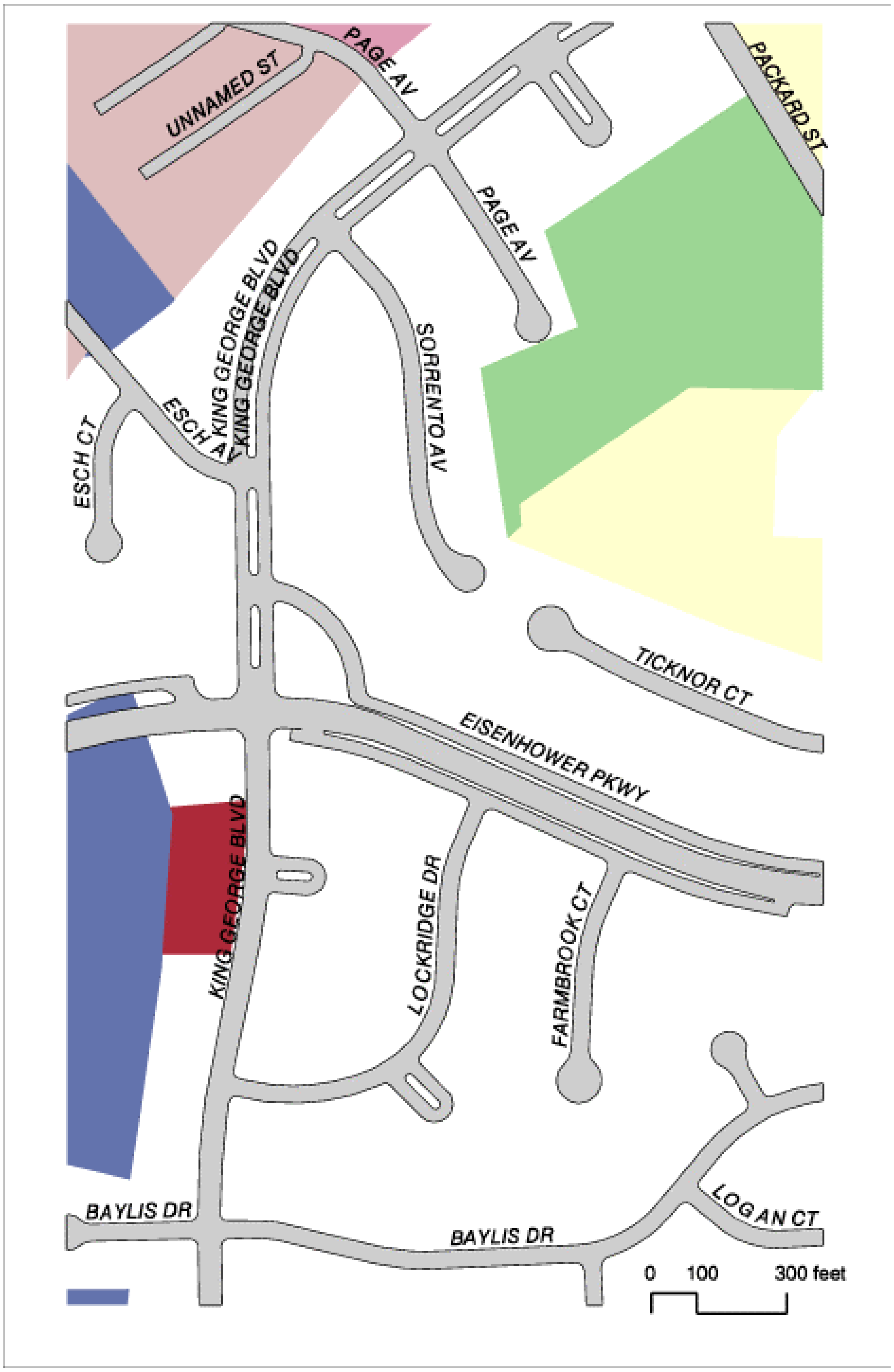
Problem
Current standards for data exchange are insufficient for unambiguous and successful transfer of information between digital map databases, in part because of semantic differences in feature representation. Real world entities are complex. Which faces of this

complexity are captured in the feature representation depend upon broader contexts and circumstances than can be reported in the metadata statements about the database. The examples presented here illustrate the dimensions of this problem.

Keypoints

Various reasons for the different representation of features in digital map databases exist. Four main reasons/sources of representational differences are distinguished. They are illustrated and discussed below.

1. Differences in Feature representation due to different interests. Agencies and companies focus on different types of geographic features. Municipal governments often take an area-oriented perspective, representing parcels and streets as polygons. Vendors of digital navigation maps use a network view with street addresses, street names and driver instructions.



UNNAMED ST
PAGE AV
PACKARD ST
PAGE AV
KING GEORGE BLVD
KING GEORGE BLVD
SORRENTO AV
ESCH AV
ESCH CT
TICKNOR CT
EISENHOWER PKWY
KING GEORGE BLVD
LOCKRIDGE DR
FARMBROOK CT
LOGAN CT
BAYLIS DR
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0
100
300 feet

Figure 1a

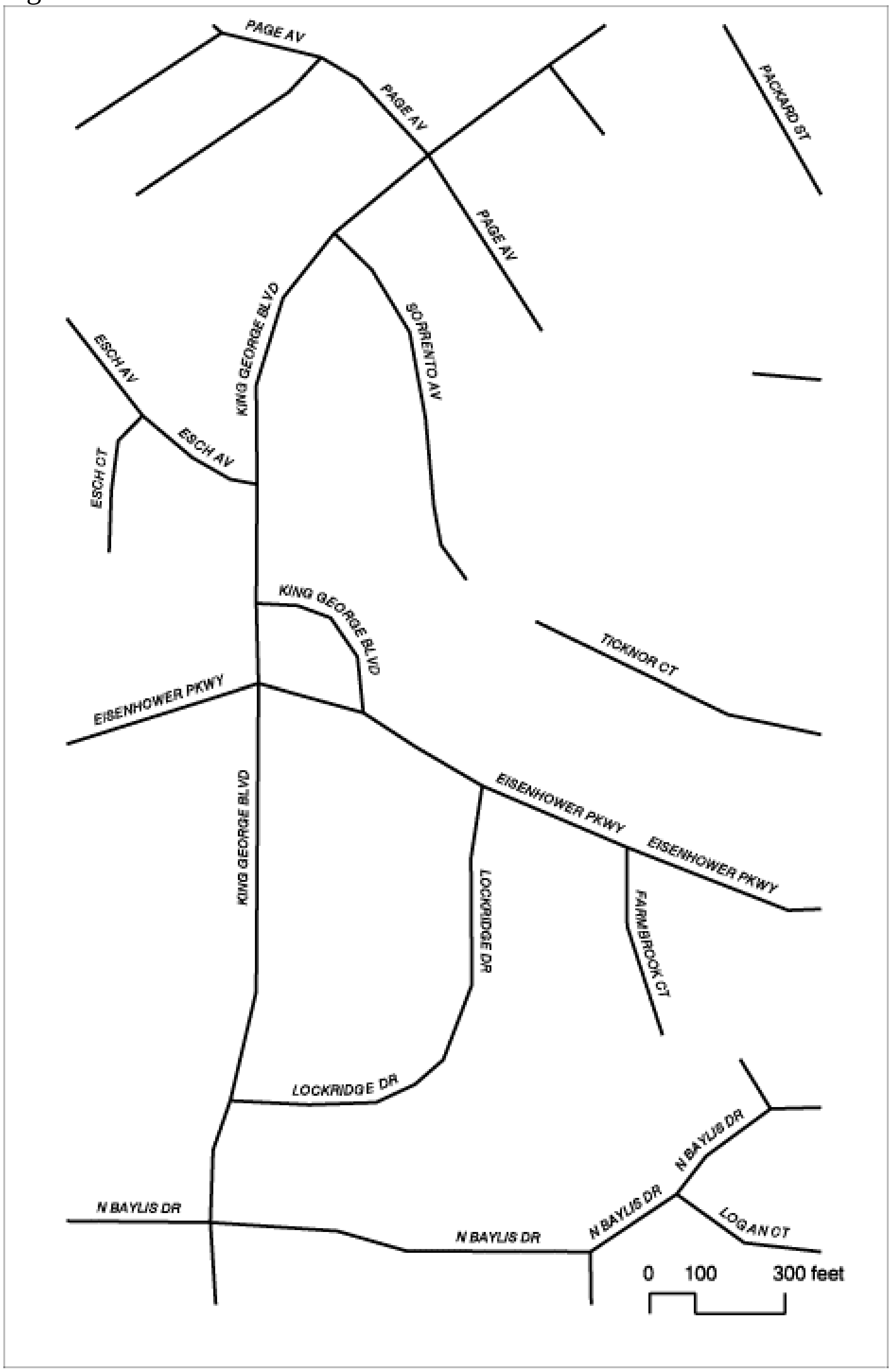


Figure 1b

2. Differences in feature representation due to underlying data model. There are many public and private sources for digital map data. Agencies and companies develop their own data models that may be proprietary. "Stone School Rd" crossing the Interstate shows that one database uses a planar model (black arclines), whereas the other employs a non-planar model (blue arclines, no nodes).

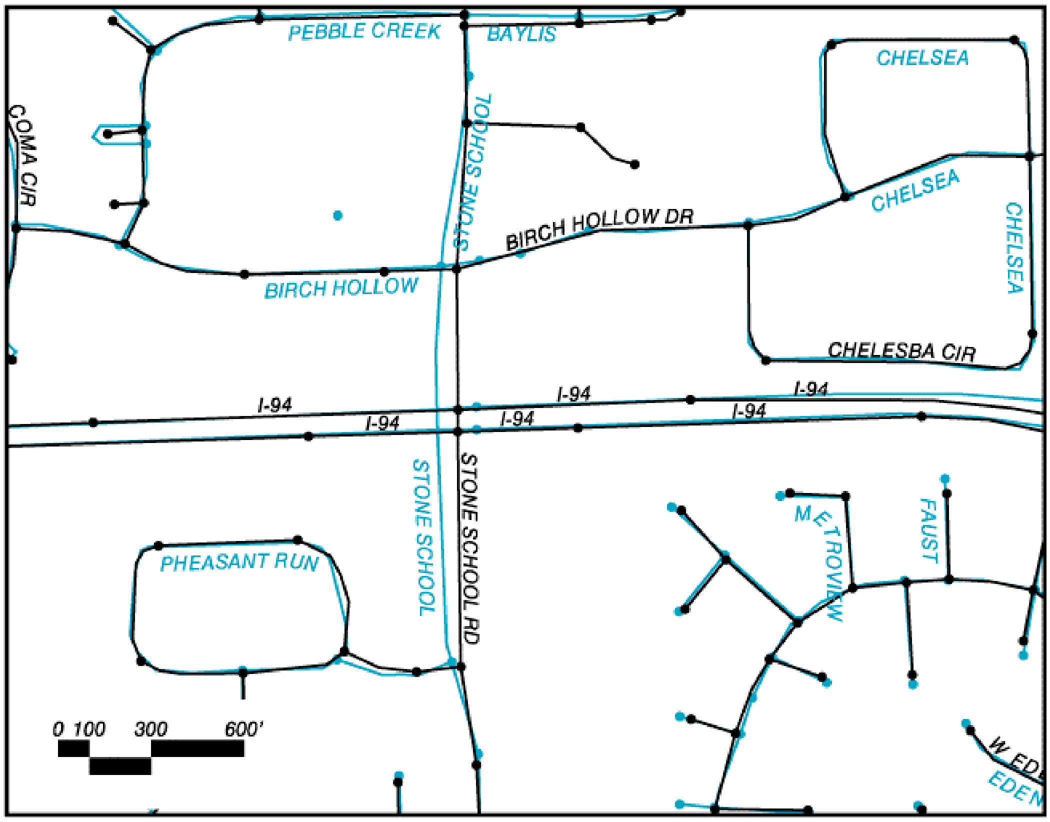
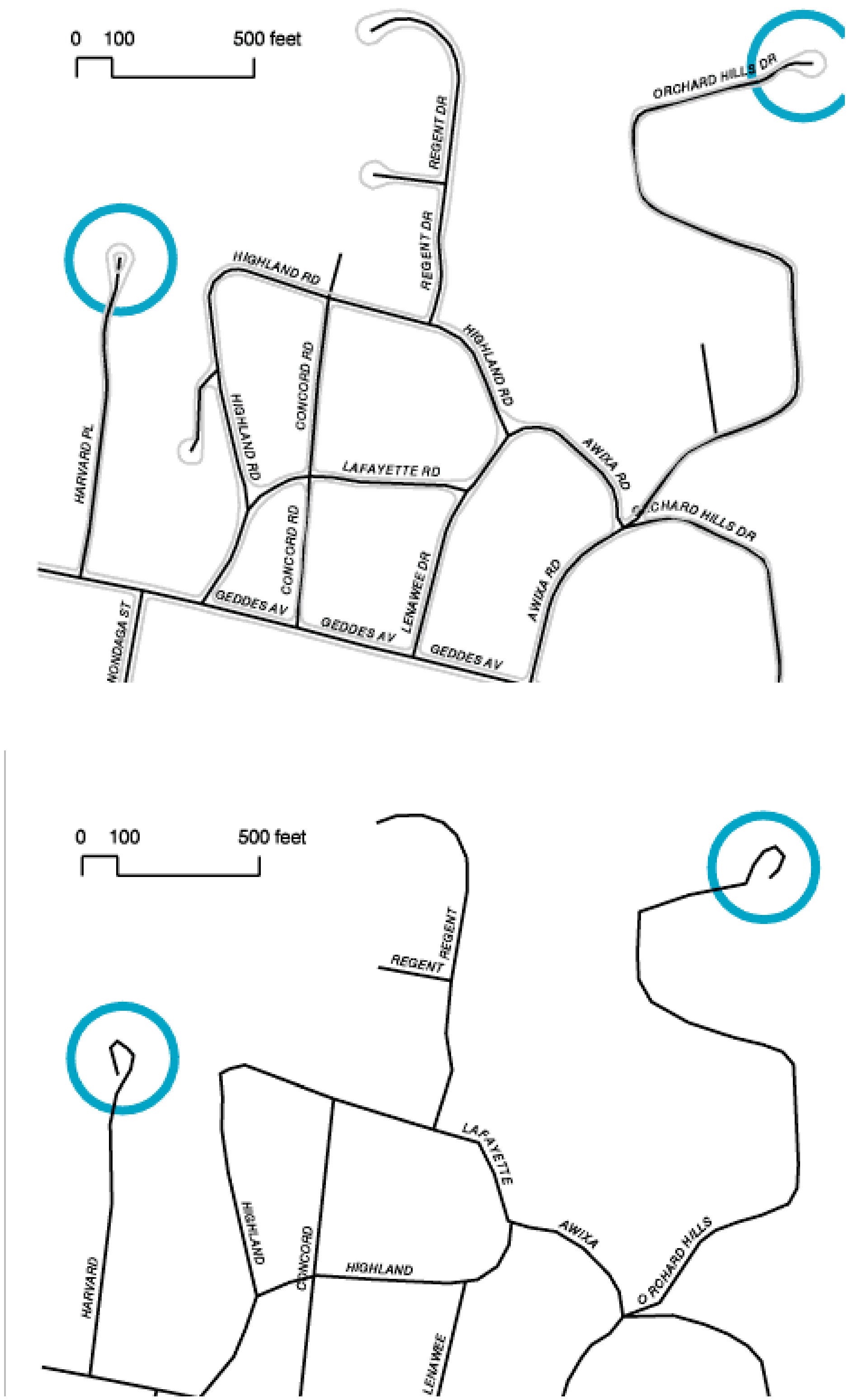


Figure 2

3. Differences in feature representation due to individual preferences. Operators who digitize maps may develop individual ways to represent features such as road intersections or dead end streets.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ORCHARD HILLS DR
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HIGHLAND RD
CONCORD RD
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HARVARD PL
LAFAYETTE RD
AWIXA RD
AWIXA RD
LENAWEE DR
GEDDES AV
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0
100
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AWIXA
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CONCORD
HARVARD
LENAWEE

Figure3a

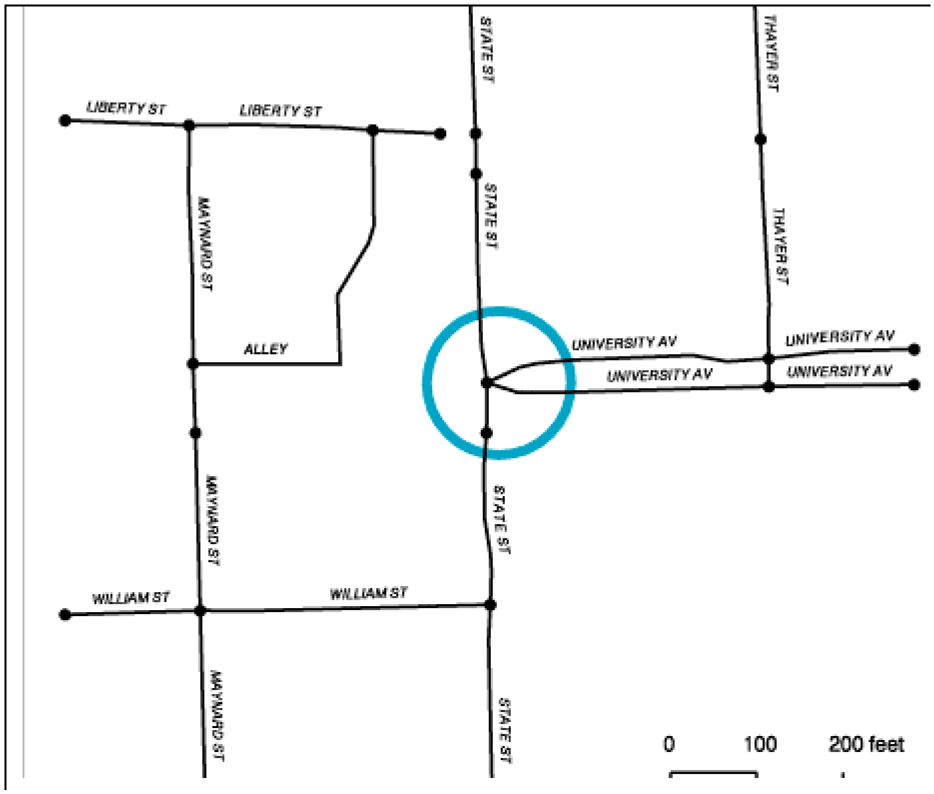
STATE ST
THAYER ST
LIBERTY ST
LIBERTY ST
STATE ST
MAYNARD ST
THAYER ST
UNIVERSITY AV
UNIVERSITY AV
ALLEY
UNIVERSITY AV
UNIVERSITY AV
MAYNARD ST
STATE ST
WILLIAM ST
WILLIAM ST
MAYNARD ST
STATE ST
0
100
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Figure3b

Figure3c

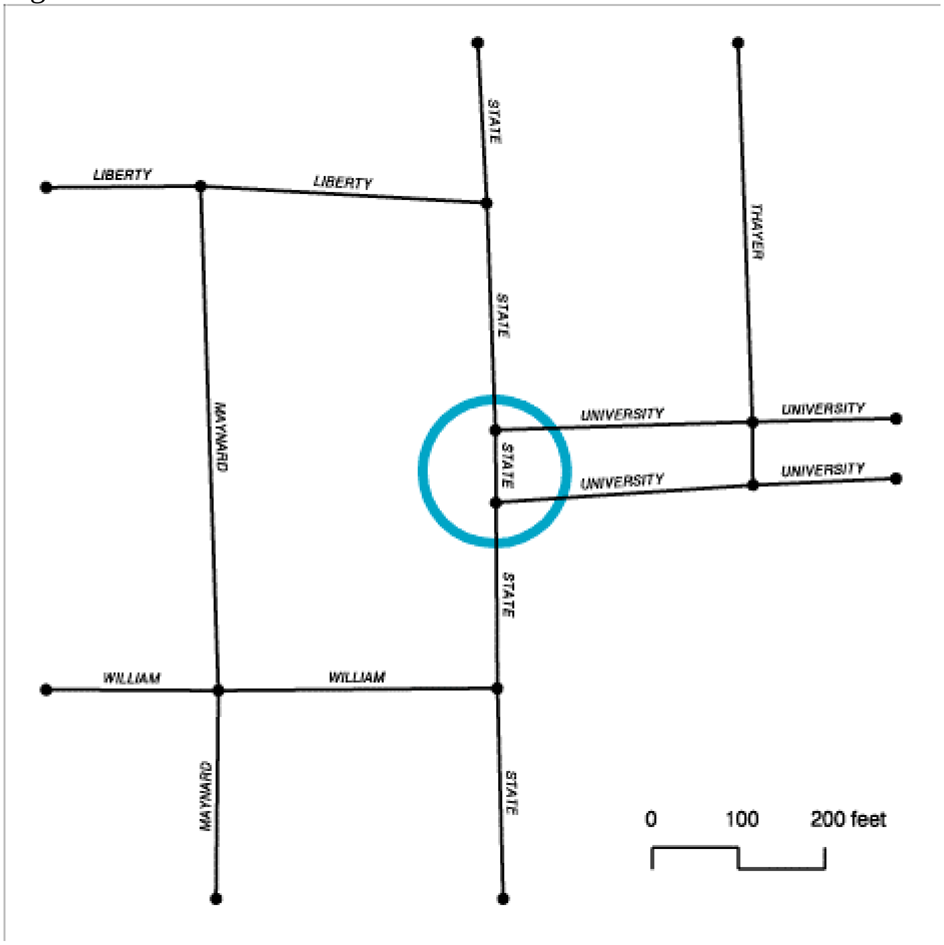

Figure3d

4. Difference in feature representation due to map scale and resolution. The larger the scale and finer the resolution of the original map, the more detail can be expected in features such as intersections.

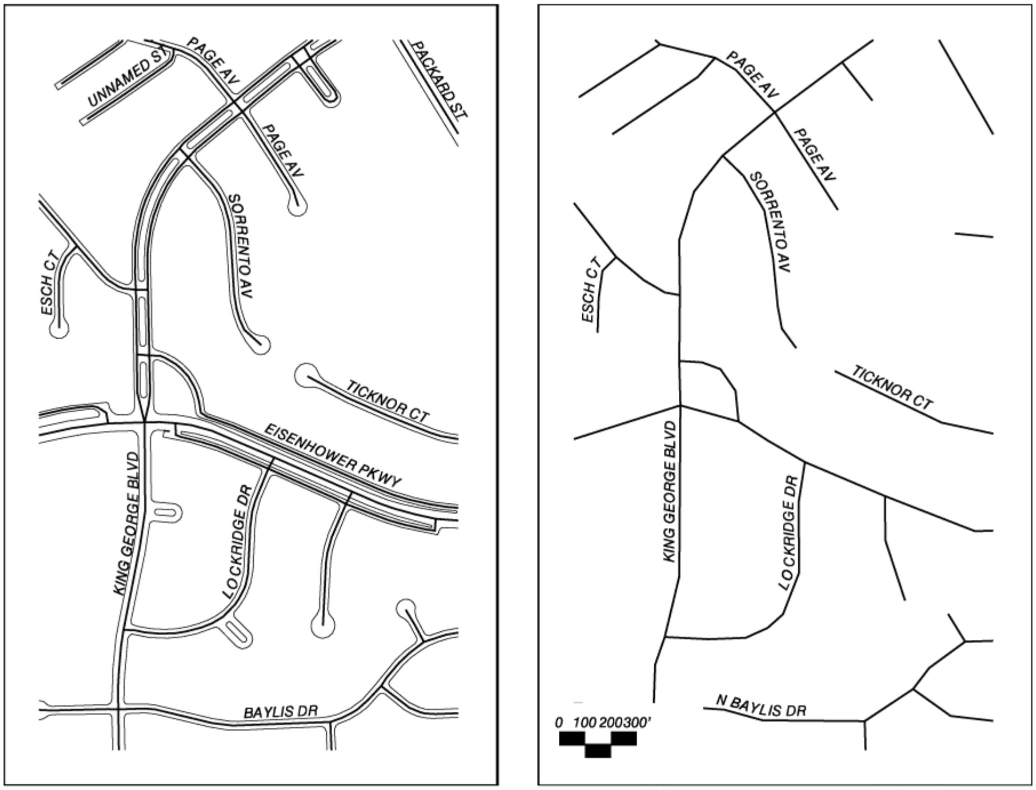

Figure 4

Discussion

One means to address standardization of feature representation is to provide detailed descriptions of the data set through metadata. While this is attempted in the new Truth-in-Labeling standard, it does not address feature representation. Metadata requirements are new. The Truth-in-labeling approach for standards applies to new datasets. Metadata for older dataset are hard to reconstruct; time depth and therefore change data simply may not be available. While standards provide a good start - the descriptive requirements may not be of sufficient detail for meaningful data sharing. Subtle data modeling differences create not so subtle differences in feature representations. Transportation data models may be planar or non-planar. An overpass of one road over another road in a planar model is generally represented by a node with four incident arcs. The node at the intersection has an associated attribute describing turn restrictions in order to convey the correct driver instructions (i.e. for route guidance). In a non-planar model of the same feature - no node exist since the arcs are unconnected in the 3-dimensional space. Thus, linking non-planar and planar databases is problematic.

Conclusion

The consequences of different feature representation are manifold. In terms of data exchange, data sharing and integration different feature representation leads to

- Lack of comparability (pattern matching)

- Lack of compatibility (data base/model anomalies)

Furthermore results from data analyses performed on different databases are likely to display different results. Differences in feature representation become an issue with increasing interest and need to exchange data. Generally there are two approaches to overcome the problem. 1. Descriptive and detailed metadata provision that includes information on feature representation is used to emphasize the different treatment of the features. 2. Standardization or formulation of conventions for feature representation which consider semantic differences.

Acknowledgments
This research was made possible by a grant from Federal Highway Administration (DOT). We would like to further acknowledge the generous provision of digital map databases and orthophotographs by the City of Ann Arbor, MI; ETAK Corp., Southeastern Michigan Council of Governments (SEMCOG), and NavTech Inc.

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Summary description of pattern; Comparison of map pattern; Theoretical model; Point to point order distances; Locus to point order distances; Summary description of pattern; Comparison of map pattern; Theoretical order distances; Analysis of the pattern of urban places in Iowa; Almost periodic disturbance model; Lattice parameters; Disturbance variables; Scale variables; Comparison of M(2) and Iowa; Evaluation; Tables.

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Abstract; Introduction; Definition of geographic center; Geographic center of a curved surface; Geographic center of Wisconsin; Geographic center of the conterminous U.S.; Geographic center of the U.S.; Summary and recommendations; Appendix A: Calculation of Wisconsin's geographic center; Appendix B: Calculation of the geographical center of the conterminous U.S.; References.

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General problem; Definition of the two-circle problem; Analytic strategy; Derivation of B% and AB% as a function of r(B) and d(AB).

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Los Angeles, 1994; Policy implications; References; Tables and complicated figures.

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Frank E. Barmore: Where Are We? Comments on the Concept of Center of Population.

Introduction; Preliminary remarks; Census Bureau center of population formulae; Census Bureau center of population description; Agreement between description and formulae; Proposed definition of the center of population; Summary; Appendix A; Appendix B; References.

Sandra L. Arlinghaus and John D. Nystuen: The Pelt of the Earth: An Essay on Reactive Diffusion.

Pattern formation: global views; Pattern formation: local views; References cited; Literature of apparent related interest.

Volume III, No. 1, Summer, 1992.

Harry L. Stern: Computing Areas of Regions with Discretely Defined Boundaries.

Introduction; General formulation; The plane; The sphere; Numerical examples and remarks; Appendix--Fortran program.

Sandra L. Arlinghaus, John D. Nystuen, Michael J. Woldenberg: The Quadratic World of Kinematic Waves.

Volume II, No. 2, Winter, 1991.

Reprint of Saunders Mac Lane: Proof, Truth, and Confusion, The Nora and Edward Ryerson Lecture at The University of Chicago in 1982.

The fit of ideas; Truth and proof; Ideas and theorems; Sets and functions; Confusion via surveys; Cost-benefit and regression; Projection, extrapolation, and risk; Fuzzy sets and fuzzy thoughts; Compromise is confusing.

Robert F. Austin: Digital Maps and Data Bases: Aesthetics versus accuracy.

Introduction; Basic issues; Map production; Digital maps; Computerized data bases; User community.

Volume II, No. 1, Summer, 1991.

Sandra L. Arlinghaus, David Barr, John D. Nystuen: The Spatial Shadow: Light and Dark -- Whole and Part.

This account of some of the projects of sculptor David Barr attempts to place them in a formal systematic, spatial setting based on the postulates of the science of space of William Kingdon Clifford (reprinted in Solstice, Vol. I, No. 1.).

Sandra L. Arlinghaus: Construction Zone--The Logistic Curve.

Educational feature--Lectures on Spatial Theory.

Volume I, No. 2, Winter, 1990.

John D. Nystuen: A City of Strangers: Spatial Aspects of Alienation in the Detroit Metropolitan Region.

This paper examines the urban shift from "people space" to "machine space" (see R. Horvath, Geographical Review, April, 1974) in the Detroit metropolitan regions of 1974. As with Clifford's Postulates, reprinted in the last issue of Solstice, note the timely quality of many of the observations.

Sandra Lach Arlinghaus: Scale and Dimension: Their Logical Harmony.

Linkage between scale and dimension is made using the Fallacy of Division and the Fallacy of Composition in a fractal setting.

Sandra Lach Arlinghaus: Parallels Between Parallels.

The earth's sun introduces a symmetry in the perception of its trajectory in the sky that naturally partitions the earth's surface into zones of affine and hyperbolic geometry. The affine zones, with single geometric parallels, are located north and south of the geographic parallels. The hyperbolic zone, with multiple geometric parallels, is located between the geographic tropical parallels. Evidence of this geometric partition is suggested in the geographic environment--in the design of houses and of gameboards.

Sandra L. Arlinghaus, William C. Arlinghaus, and John D. Nystuen: The Hedetniemi Matrix Sum: A Real-world Application.

In a recent paper, we presented an algorithm for finding the shortest distance between any two nodes in a network of n nodes when given only distances between adjacent nodes (Arlinghaus, Arlinghaus, Nystuen, Geographical Analysis, 1990). In that previous research, we applied the algorithm to the generalized road network graph surrounding San Francisco Bay. Here, we examine consequent changes in matrix entries when the underlying adjacency pattern of the road network was altered by the 1989 earthquake that closed the San Francisco--Oakland Bay Bridge.

Sandra Lach Arlinghaus: Fractal Geometry of Infinite Pixel Sequences: "Super-definition" Resolution?

Comparison of space-filling qualities of square and hexagonal pixels.

Sandra Lach Arlinghaus: Construction Zone--Feigenbaum's number; a triangular coordinatiztion of the Euclidean plane; A three-axis coordinatization of the plane.

Volume I, No. 1, Summer, 1990.

Reprint of William Kingdon Clifford: Postulates of the Science of Space.

This reprint of a portion of Clifford's lectures to the Royal Institution in the 1870s suggests many geographic topics of concern in the last half of the twentieth century. Look for connections to boundary issues, to scale problems, to self-similarity and fractals, and to non-Euclidean geometries (from those based on denial of Euclid's parallel postulate to those based on a sort of mechanical `polishing'). What else did, or might, this classic essay foreshadow?

Sandra Lach Arlinghaus: Beyond the Fractal.

The fractal notion of self-similarity is useful for characterizing change in scale; the reason fractals are effective in the geometry of central place theory is because that geometry is hierarchical in nature. Thus, a natural place to look for other connections of this sort is to other geographical concepts that are also hierarchical. Within this fractal context, this article examines the case of spatial diffusion.

When the idea of diffusion is extended to see "adopters" of an innovation as "attractors" of new adopters, a Julia set is introduced as a possible axis against which to measure one class of geographic phenomena. Beyond the fractal context, fractal concepts, such as "compression" and "space-filling" are considered in a broader graph-theoretic setting.

William C. Arlinghaus: Groups, Graphs, and God.

Sandra L. Arlinghaus: Theorem Museum--Desargues's Two Triangle Theorem from projective geometry.

Construction Zone--centrally symmetric hexagons.

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Electronic copy of Solstice, as well as of selected other monographs, is available on the web page of the Institute of Mathematical Geography (current electronic address available in various search engines).

1. Arlinghaus and Nystuen. *Mathematical Geography and Global Art: The Mathematics of David Barr's Four Corners Project*. 1985. 78 pp.
2. Arlinghaus. *Down the Mail Tubes: The Pressured Postal Era, 1853-1984*. 1985. 79 pp.
3. Arlinghaus. *Essays on Mathematical Geography*. 1986 167 pp.
4. Austin. *A Historical Gazetteer of South East Asia*. 1986. 118 pp.
5. Arlinghaus. *Essays on Mathematical Geography, II*. 1987. 101pp.
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18. Gordon. *The Cause of Location of Roads in Maryland: A Study in Cartographic Logic*. 1995. 109pp.
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Philbrick, Allen K. *This Human World*. Reprint.
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Nystuen, John D. et al. *Michigan Inter-University Community of Mathematical Geographers*. Complete Papers. Reprint.
Griffith, Daniel A. Discussion Paper #1. *Spatial Regression Analysis on the PC*. 84pp.