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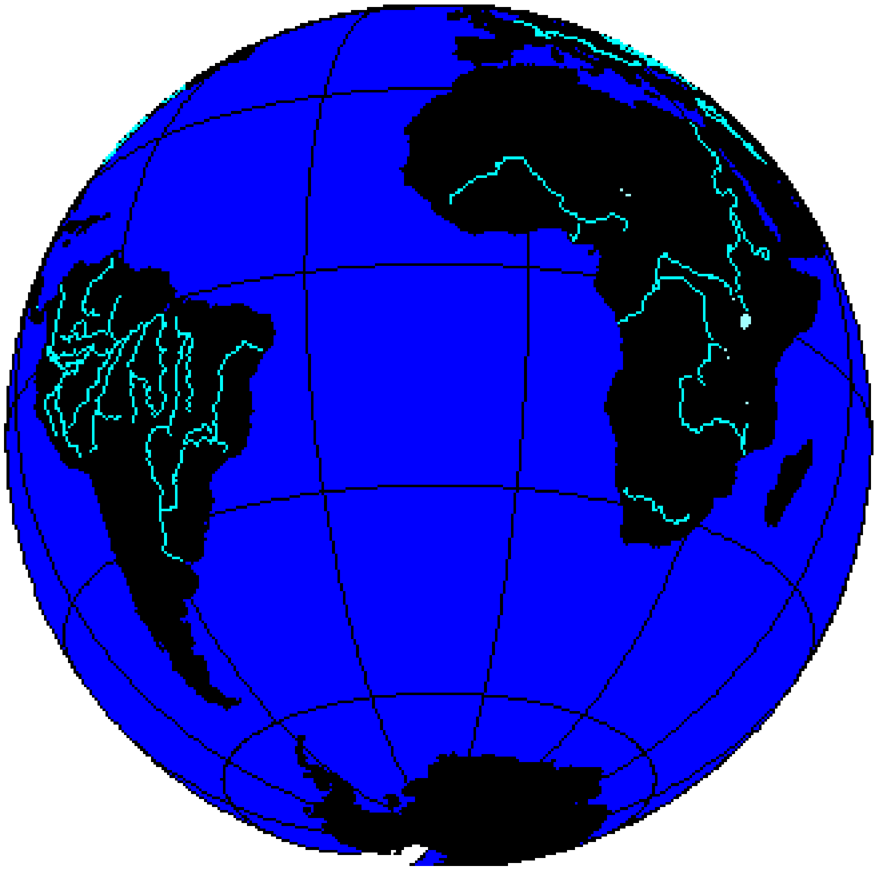

Earth: with 23.5 degrees south latitude as the central parallel.

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MISSION STATEMENT

The purpose of Solstice is to promote interaction between geography and mathematics. Articles in which elements of one discipline are used to shed light on the other are particularly sought. Also welcome are original contributions that are purely geographical or purely mathematical. These may be prefaced (by editor or author) with commentary suggesting directions that might lead toward the desired interactions.
Individuals wishing to submit articles or other material should contact an editor, or send e-mail directly to sarhaus@umich.edu.

SOLSTICE ARCHIVES

Back issues of Solstice are available on the WebSite of the Institute of Mathematical Geography, http://www.imagenet.org and at various sites that can be found by searching under "Solstice" on the World Wide Web. Thanks to Bruce Long (Arizona State University, Department of Mathematics) for taking an early initiative in archiving Solstice using GOPHER.

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To cite the electronic copy, note the exact time of transmission from Ann Arbor, and cite all the transmission matter as facts of publication. Any copy that does not superimpose precisely upon the original as transmitted from Ann Arbor should be presumed to be an altered, bogus copy of *Solstice*. The oriental rug, with errors, serves as the model for creating this weaving of words and graphics.

Lewis and Clark, 200 Years: A Visual Tribute to an Exploration.
The Gates of the Rocky Mountains.

Sandra L. Arlinghaus, Robert J. Haug, and Ann E. Larimore
The University of Michigan

The historical texts of Meriwether Lewis, Captain United States Army, and William Clark, Captain United States Army, offer the mind's eye a stunning visual scene of explorers navigating a walled passage along the Missouri River, through the Rocky Mountains, just upstream from what is now Great Falls, Montana.

Journal Entry: July 19, 1805

Quotation from Lewis [DeVoto, pp. 159-160]:

this morning we set out early and proceeded on very well tho' the water appears to encrease in velocity as we advance. the current has been strong all day and obstructed with some rapids, tho' these are but little broken by rocks and are perfectly safe. the river deep and from 100 to 150 yds. wide. I walked along shore today and killed an Antelope. wh[en]ever we get a view of the lofty summits of the mountains the snow presents itself, altho' we are almost suffocated in this confined valley with heat. this evening we entered much the most remarkable clifts that we have yet seen. these clifts rise from the waters edge on either side perpendicularly to the hight of 1200 feet. every object here wears a dark and gloomy aspect. the towering and projecting rocks in many places seem ready to tumble on us. the river appears to have forced it's way through this immence body of solid rock for the distance of 5 3/4 Miles and where it makes it's exit below has thrown on either side vast collumns of rocks mountains high.

the river appears to have woarn a passage just the width of it's channel or 150 yds. it is deep from side to side nor is there in the 1st 3 Miles of this distance a spot except one of a few yards in extent on which a man could rest the soal of his foot. several fine springs burst out at the waters edge from the interstices of the rocks. it happens fortunately that altho' the current is strong it is not so much so but what it may be overcome with the oars for there is hear no possibility of using either the ord or Setting pole. it was late in the evening before I entered this place and was obliged to continue my rout untill sometime after dark before I found a place sufficiently large to encamp my small party; at length such an one occurred on the lard. side where we found plenty of lightwood and pich pine. this rock is a black grannite below and appears to be of a much lighter colour above and from the fragments I take it to be flint of a yellowish brown and light creem-coloured yellow. from the singular appearance of this place I called it *the gates of the rocky mountains*.

Quotation from Clark [DeVoto, pp. 160-161]:

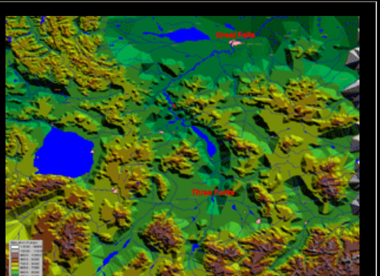
I proceeded on in an Indian Parth river verry Crooked passed over two mountains Saw Several Indians Camps which they have left this Spring. Saw trees Peeled & found poles &c. at 11 oC. I saw a gange of Elk, as we had no provision Concluded to kill Some. Killd. two and dined being obliged[d] to substitute dry buffalow dung in place of wood, this evening passed over a Cream Coloured flint which [has] roled down from the Clifts into the bottoms, the Clifts Contain flint a dark grey Stone & a redish brown intermixed and no one Clift is solid rock, all the rocks of everry description is in Small pi[e]ces, appears to have been broken by Some Convulsion my feet is verry much brused & cut walking over the flint & constantly stuck full [of] Prickley pear thorns, I puled out 17 by the light of the fire to night Musqutors verry troublesom.

Use of the historical and geographical record, coupled with current mapping capability, permits the creation of visual scenes that might have confronted Lewis and Clark at this unique site: The Gates of the Rocky Mountains. We offer these images as a modest tribute to their spectacular exploration. Note the differences that come from using different contour intervals (spacing between successive contours).

Gallery of Images

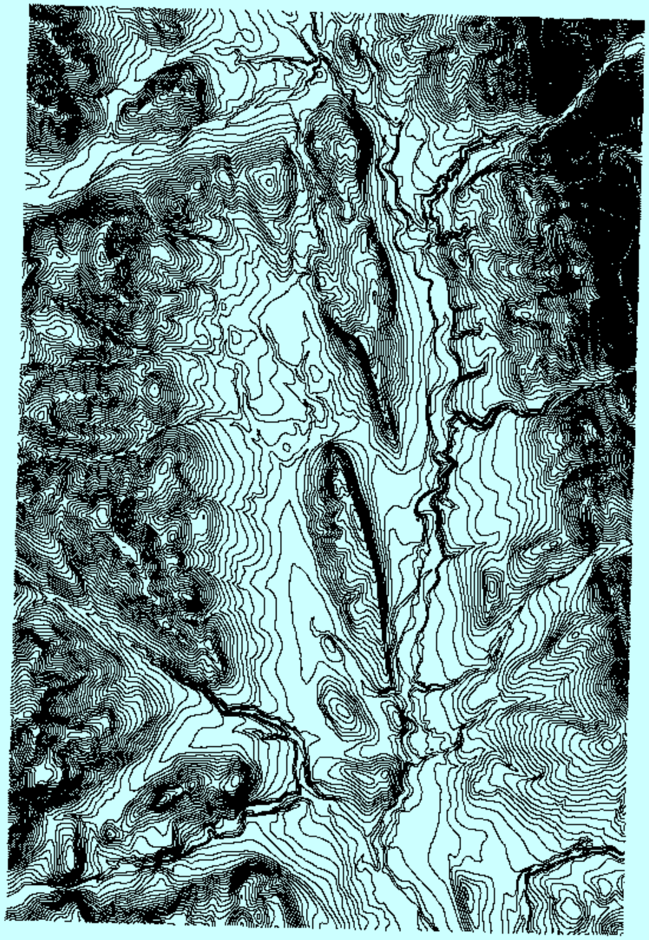
Digital Elevation Models offer one view of the terrain.

Digital Chart of the World. Contour interval of 1000 feet. The Gates of the Rocky Mountains are shown as a red dot.

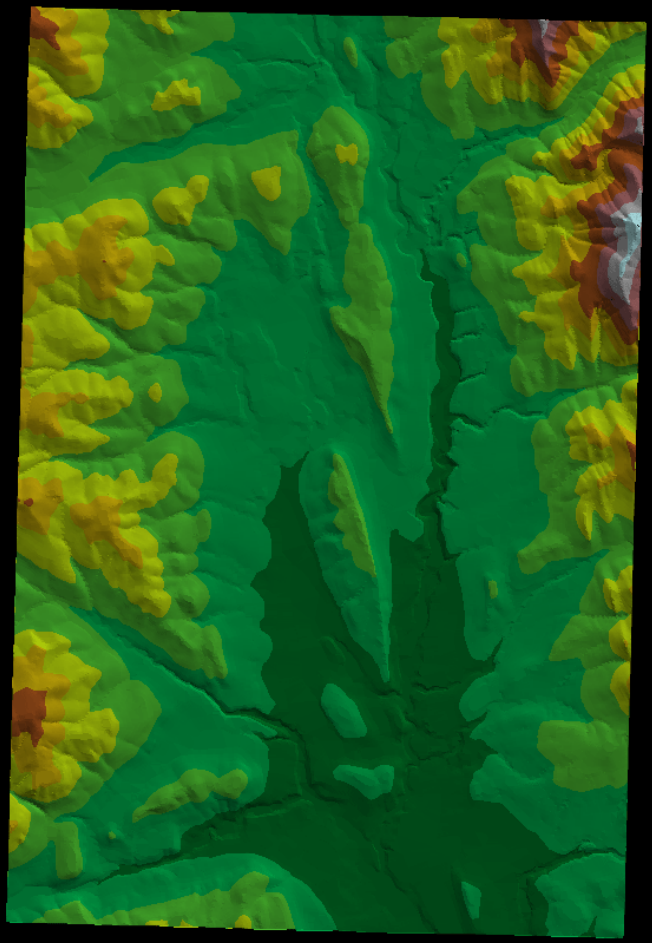


The Digital Chart of the World (from ESRI) offers contours at a 1000 foot contour interval. Creation of a Triangulated Irregular Network from these contours permits visualization of a chunky terrain and offers a general context in which to consider the region. (Click on the small map to see a larger map.)

USGS contours, Digital Elevation Model. Contour interval of 10 feet.

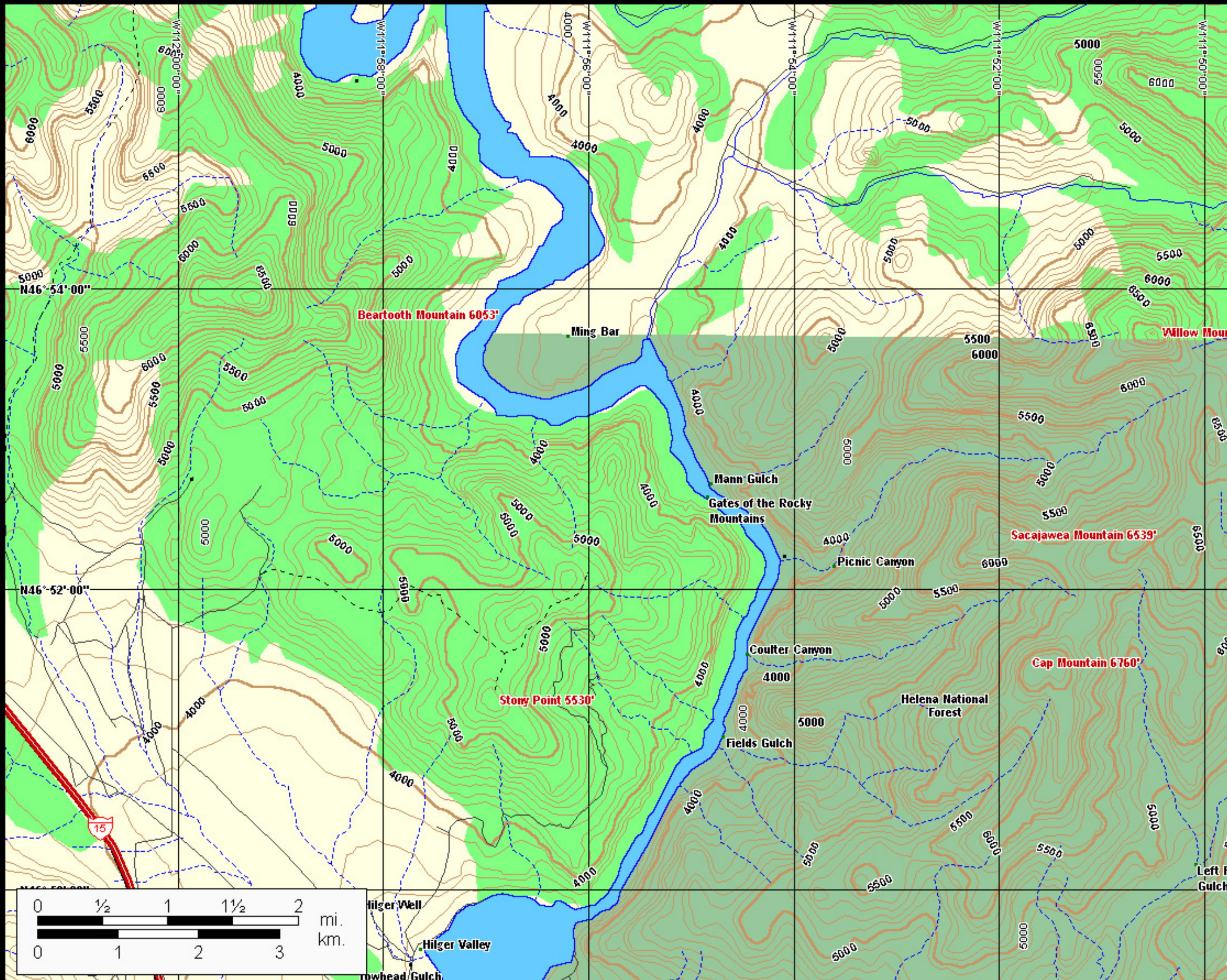


USGS contours show a much more detailed picture than does the Digital Chart of the World.

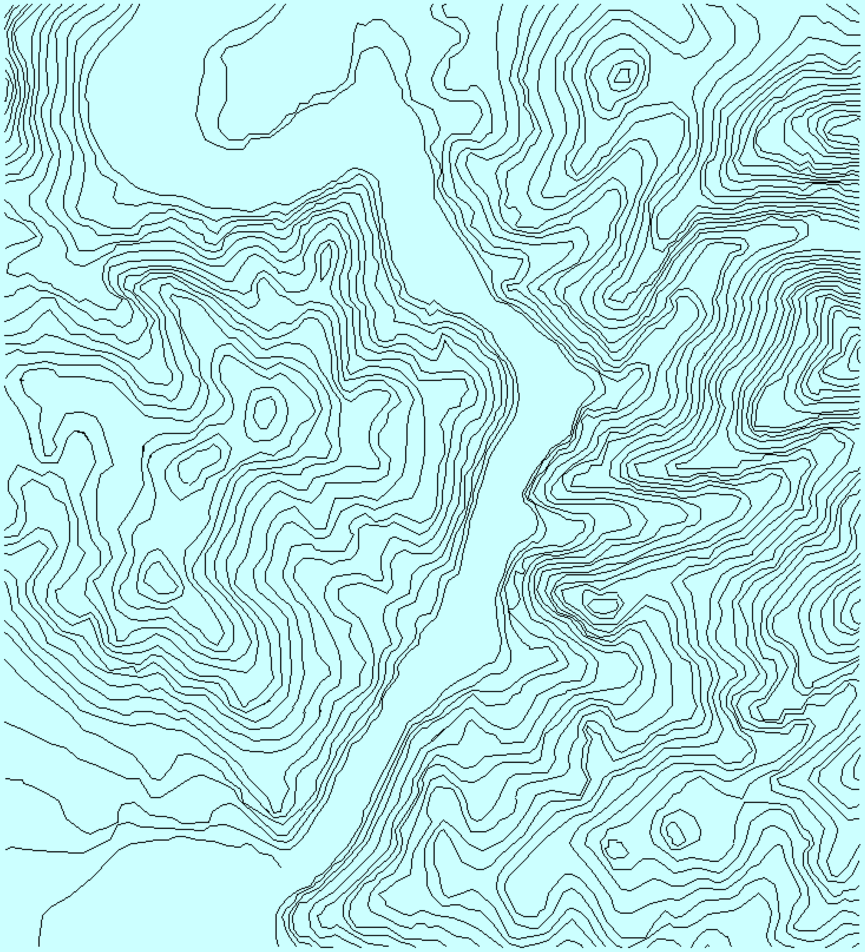


Triangulated Irregular Network created from the USGS DEM.

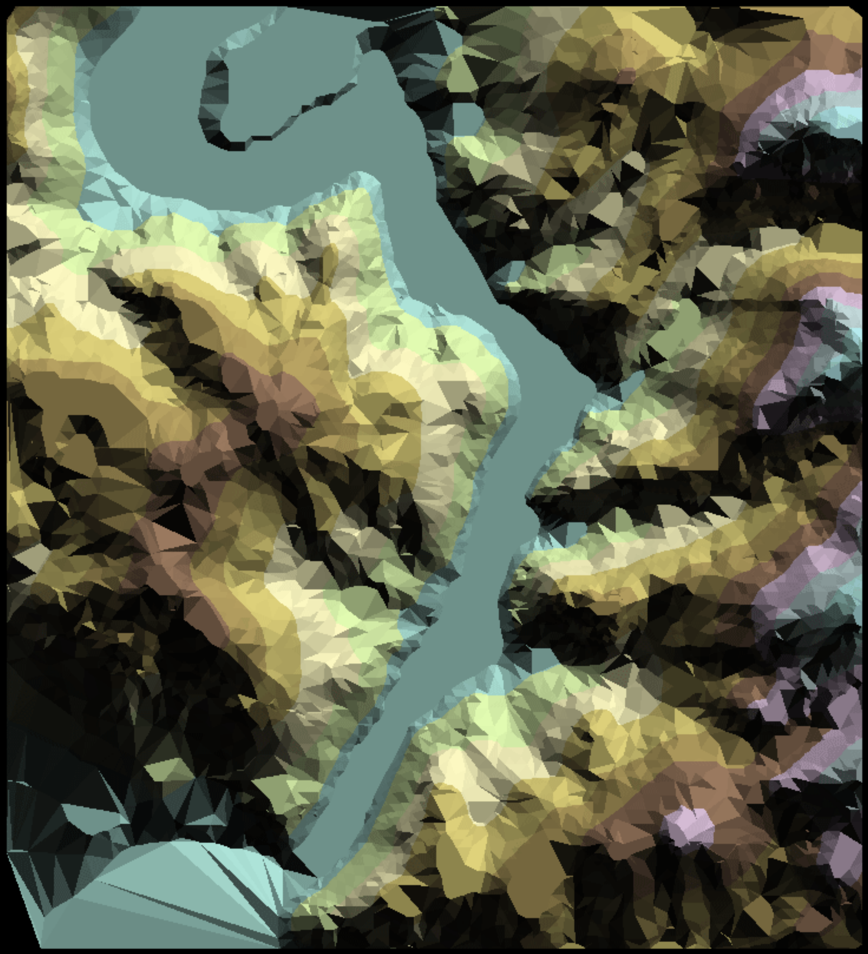
DeLorme Topographic Atlas on CD: contour interval of 100 feet.



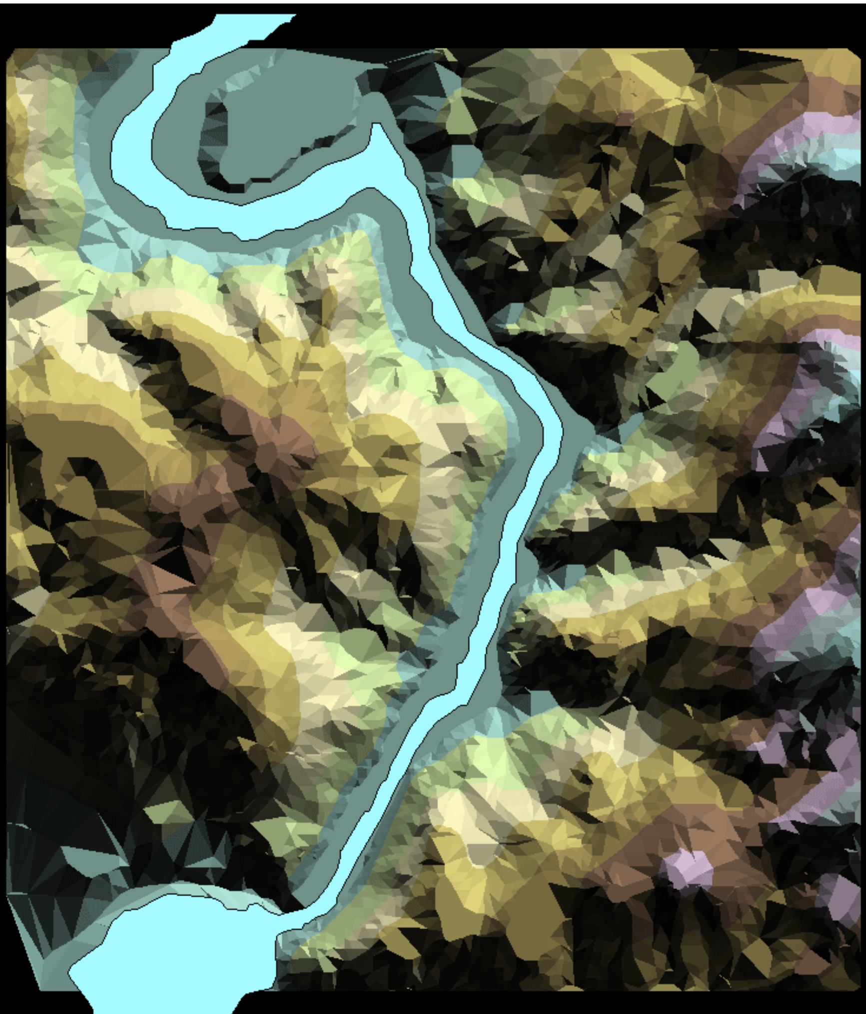
Scroll to the right to see the full display. The Gates of the Rocky Mountains are shown as a red dot.



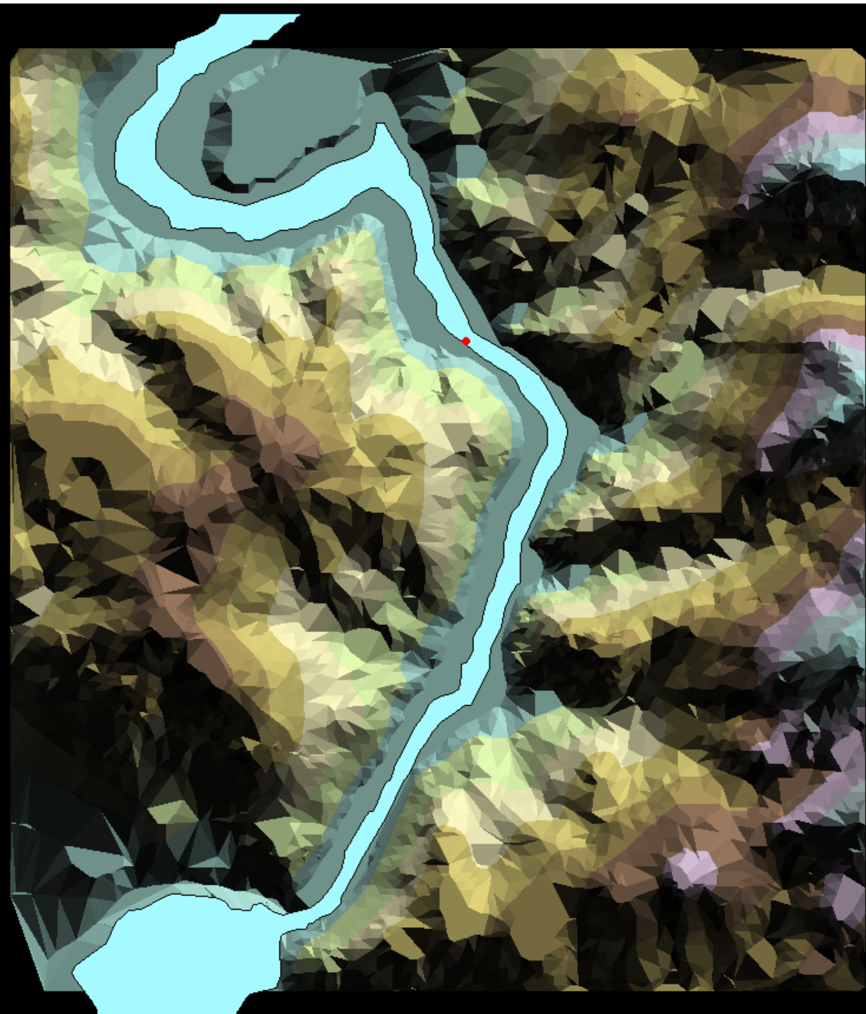
Digitized contours at the 100 foot contour interval level.



Triangulated Irregular Network made from digitized contours.



Missouri River superimposed in light cyan.



The Gates of the Rocky Mountains, red dot.

Each type of base topographic map has merits: the 1000 foot contour interval map is useful, especially when represented as a TIN, as a general context map. When the finest contour interval (10 feet) was used, the general context was not evident. The TIN derived from the contour base shows great detail. The 100 foot contour interval offers a balance between the two. That map, however, was not a digitized map that would work directly in a GIS (ArcView, ESRI). Thus, the contours were digitized from the 100 foot base map, a TIN created from that base, and then the TIN was put into ArcView 3D Analyst extension (ESRI) and saved as VRML 2.0, as a virtual reality of the scene. The much more highly detailed USGS file renders a fine virtual reality scene; however, the size of that file is over 177 MB and it causes many machines to crash. Thus, the more modest file of 3 MB created from the 100 foot contour interval map is included here. Readers should download (free) Cosmo Player from http://ca.com/cosmo/ in order to view the virtual reality files directly in their internet browser.

Click here to see an animation of contours with superimposed TIN; The Gates of the Rocky Mountains are shown as a red dot.

Click here to see the virtual reality scene of "The Gates of the Rocky Mountains" derived from the 100 foot contour interval.

What else might illuminate historical and geographical texts of the future, as an exploration in imaginative interactive communication and education?
One might envision

- creating routes and scenes, defined by the user, in support of text. (See, for example, the outstanding display created at the Department of Geography, University of Missouri in the attached link)
- taking virtual voyages in canoes up the Missouri River as a search (using a search function) of the landscape for animated local sentinels, all while music of the period is playing in the background.
- creating a virtual Mandan village, as a way for present day Americans to view one of the most important trading communities of the period.

Or, one might look ahead to see student or research scouts forging ahead into as yet unimagined connections between marvelous mapping advances and classical texts from the past as history comes alive!

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Digital Chart of the World. Environmental Systems Research Institute, http://www.esri.com/.

Lewis and Clark Across Missouri, http://lewisclark.geog.missouri.edu/index.shtml

USGS, EROS Data Center, http://edc.usgs.gov/geodata/

Dependence of Production of Paddy on the Total Annual Rainfall: A Different Approach*

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Abstract

Some statistical techniques have been employed to discern the dependence of paddy production on total annual rainfall. The study area is West Bengal, a state of India. The study is based upon the computation of Pearson Correlation Coefficient, Entropy, and testing for Poisson distribution.

Key words: West Bengal, Paddy production, Pearson Correlation Coefficient, Entropy, Poisson distribution

Introduction

This brief article aims at finding out a statistical relationship between the paddy production and total rainfall in West Bengal, a state in India. A positive correlation between these two features is well established. Most studies, however, are based on a traditional statistical approach. The present study deviates a bit from the earlier ones. The newness of this study is the application of the concept of entropy as explained by Chaudhuri and Chattopadhyay in *Solstice* (2003). One limitation of the traditional approaches is that they are based on the assumption that the yearly values of the aforesaid features in successive decision periods are serially independent.

This paper develops an approach to incorporating serial correlation (Wilks, 1991) into the decision making process. The underlying idea is to show that in the future both the production of paddy in the aforesaid state as well as probable maximum rainfall can be investigated through the theory of Markov Chain (Wilks, 1995) and that uncertainty in the production of paddy in the coming years can be discerned through the predicted value of maximum probable rainfall.

Experimentation setup

The experimentation set up consists of the following steps:

- Testing for the Markov status through lagged autocorrelations (Wilks, 1995)
- Finding out the interdependence between total yearly rainfall (R) and the production of paddy (P) through the Pearson Correlation Coefficient (Chattopadhyay, 2002)
- Checking for the Poisson distribution in the data series of 'P' considering it as a variable dependent on 'R' (Box and Jenkins, 1976)
- Calculating the entropies in the probability distribution of 'P' with different changes (%) in the value of 'R'.

The study is based on data for the period 1995-2000 made available from *The Statesman*, a leading newspaper of India.

Testing for Markov Status

We have two time series, one for the values of 'R' and the other for the values of 'P'.

For each variable, we consider the null hypothesis:

H0: The data are serially independent

This is to be tested against the alternative hypothesis

H1: The data are serially dependent.

Under the null hypothesis a Chi-square statistic is calculated for each parameter using the formula:

$$X^2= [(\text{Observed value} - \text{Expected value})^2/\text{Expected value}]$$

If the observed value of the statistic is found to exceed the tabular value the null hypothesis is rejected, otherwise accepted .

In our study we have found that

For ‘R’ Chi-square= 10. 319

For ‘P’ Chi-square= 14.319

Both of the values are found to exceed the tabular value (Wilks, 1995) of Chi-square at 1% level of significance, leading us to reject the null hypothesis H0. It can therefore be concluded that on the basis of the body of evidence, we have nothing to believe that either ‘R’ or ‘P’ are serially independent. As the decision is true at 1% level of significance, we have enough reason to infer that in the long run, in 99% cases the data will remain to be serially dependent.

Next to see their Markov status:

Lag-k autocorrelation coefficient (ACC) is computed as

ACC=

(Covariance between k-lagged data pair)/{(sd for first (k-1)data values)(sd for last (k-1)data values)}

…………………………………………………….(1)

where, sd= Standard Deviation.

From the Markovian point of view, Lag-1 ACC, denoted as r1 is the measure of persistence. So if both of the series are found to have significant r1, we can go ahead to test the Markov status defined as

$$rk=(r1)^k \quad ……………………………………………………………..(2)$$

The Lagged ACCs in our study are presented in table-1.

Table-1

Parameter	Lag-1ACC	Lag-2ACC	Lag-3ACC	Lag-4ACC
R	0.4126	0.1703	0.0706	0.0291
P	0.5311	0.2310	0.1501	0.0811

The Lag-1 ACC being of significant value (compared to 1), and the four lagged ACCs being found to obey equation (2), it can be concluded that the series are generated by first-order-two-state Markov Chain (Wilks, 1995). Thus, serial dependendence with a specific pattern is established.

Pearson Correlation Coefficient

The values of 'P' and 'R' have been standardized by using the formula:

Standardized X=[(Actual X-Average of X)/sd of X]……………………………………………(3)

Their scatterplot with a trend line is shown in Fig.01.

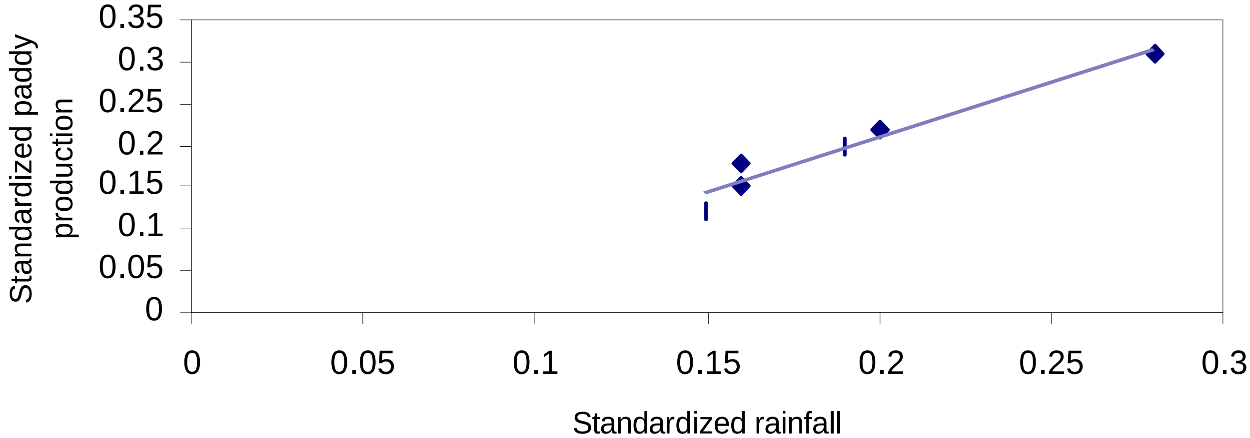
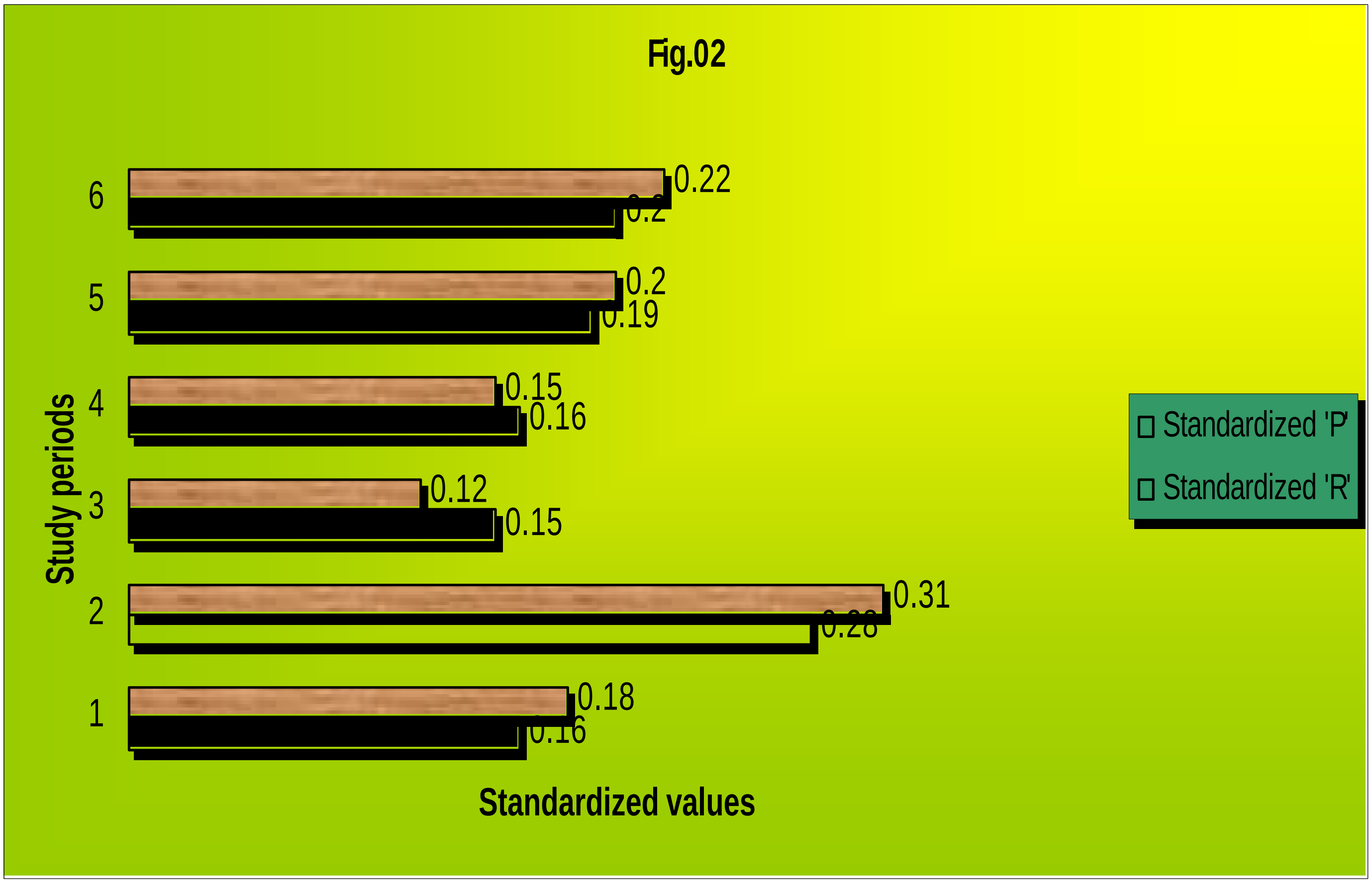


Fig.01-Scatter showing a linear relationship between rainfall and paddy production

The linear trend leads us to calculate a Pearson Correlation Coefficient between 'R' and 'P' which in this case is found to be 0.97, supporting quantitatively the linear relationship. The interrelationship has also been presented in figure-02.



Check for Poisson distribution

We now consider ‘R’ as an independent variable and ‘P’ as the variable dependent on it. Next, consider the null hypothesis:

H0: ‘P’ is not distributed as Poisson.

This is to be tested against,

H1: ‘P’ is distributed as Poisson.

Poisson distribution is presented as

$$f(x)=\exp(-\mu)(\mu^{x})/x! \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Using H0 and (4), a Chi-square statistic is formed and the value at 1% level of significance and with 5 degrees of freedom. The value is found to be, 19.286. Comparing this value with the tabular value, it is found that ‘P’ is Poisson distributed. Thus ‘P’ has randomness with respect to ‘R’.

Entropy calculation

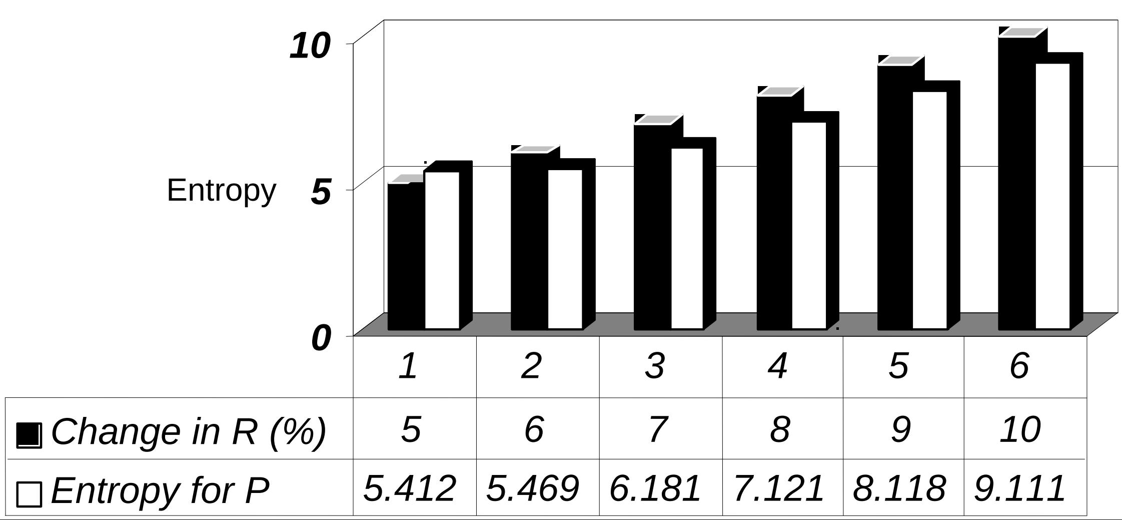
Maximum entropy probability distribution is calculated for ‘P’ with change (%) in ‘R’. Results are presented in table-2.

Table-2

Change (%) in R	Entropy for P
5%	5.412
6%	5.469
7%	6.181
8%	7.121
9%	8.118
10%	9.111

The figure below (Fig. 03) shows that Paddy production is very much vulnerable to change in the value of total rainfall.

Fig.03-Relationship between change in R(%) and entropy for 'P'



Conclusion

It is no surprise that paddy production is dependent on total annual rainfall. The use of an entropy calculation shows the extent to which paddy production is vulnerable to change in the value of total rainfall. The degree to which randomness and uncertainty in production depend on rainfall is characterized by a Markov pattern.

*Acknowledgement:

The author wishes to thank Professor Sandra Arlinghaus for helping in various ways while preparing the manuscript

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Combating the complexity in spatial data:
A neuronal approach

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The author wishes to express his indebtedness and regards to Prof. Sutapa Chaudhuri of Calcutta University, who sowed the seed of flexible computing approach in the author's mind.

Introduction

The datasets acquired from various climatological events are non-linear in nature. The non-linearity arises because climatological systems are superpositions of a set of deterministic, multivariate, and non-linear interactions over an enormous range of spatial scales. In order to understand this system, scientists must observe, summarize, make inference, and ultimately predict its behavior at each scale of variability (1). Thus, some flexible techniques are need. Ordinary statistical approaches are less flexible with respect to non-linearity; their application may not always give appropriate results (2). Statistical inference also requires some pre-processing of the data. When the question of prediction of some climatological data arises, the application of simple time-series analysis cannot give an appropriate forecast because of its limitation in handling a highly non-linear data structure. This observation is true for individual parameters as well as for the event itself. The cases, where grided data are employed, may give huge propagation error, if the traditional numerical methods for them are not mingled with some flexible techniques. The word "flexible" is used to mean that the technique should be able to modify itself in order to minimize the output error as much as possible. Various methods, such as, prepositional logic, probabilistic reasoning, neuronal nets can be tried as flexible techniques. In this article, Neuronal Residual Kriging (NRK) is proposed as a flexible technique to analyze spatial data. NRK can be employed to estimate a non-linear drift and to apply a geo-statistical, predictor (Kriging) to the residuals.

Methodology

The proposed method consists of the following steps:

1. **Data preparation:**

   NRK being a data driven approach, depends highly on quality and quantity of data. That is why the data are prepared by descriptive statistics.

   Attention is given to the data magnitude and variability.

2. **Designing network architecture:**

   A multilayer perception is proposed to be used with proper adjustment of the hidden layers and initial weights.

3. **Training of the data:**

   Method of back propagation is being proposed to be applied with a few essential modifications (if necessary) by some other soft computing techniques. The proposed modifications are:

   (a) Initial weights are selected with the help of genetic algorithm.

   (b) Conjugate gradients are used for the efficient local minimum search or error function.

   (c) Simulated annealing is used in order to escape form local minima.

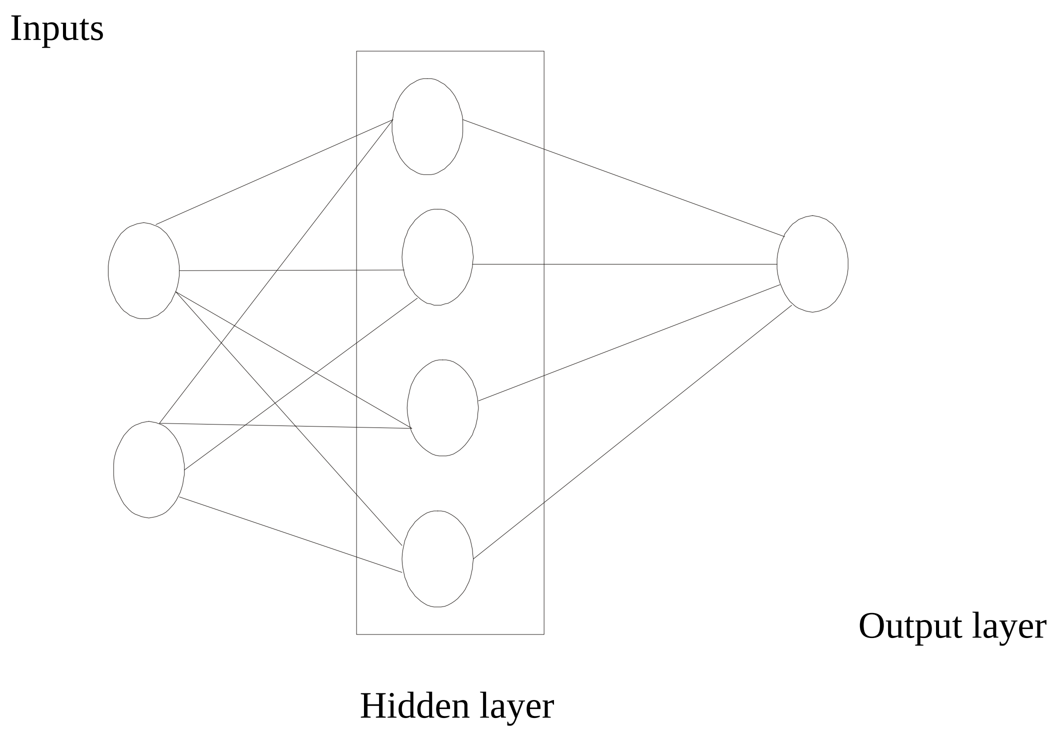
4. **Evaluating performance the network:**

   Different tools can be used for the evaluation, like cross validations accuracy test.

5. **Calculating the final NRK predictions at validation points and comparison**

with the true values are done as final validations.

The basic network architecture for the proposed method can be drawn schematically as:



→flow of information ←error propagation

Advantages of NRK

In NRK, several layers can be employed between input and output layers. Thus, like human neurons, the information can be processed very effectively in those hidden layers, where, through proper choice of activation function, the error in the output layer can be optimized.

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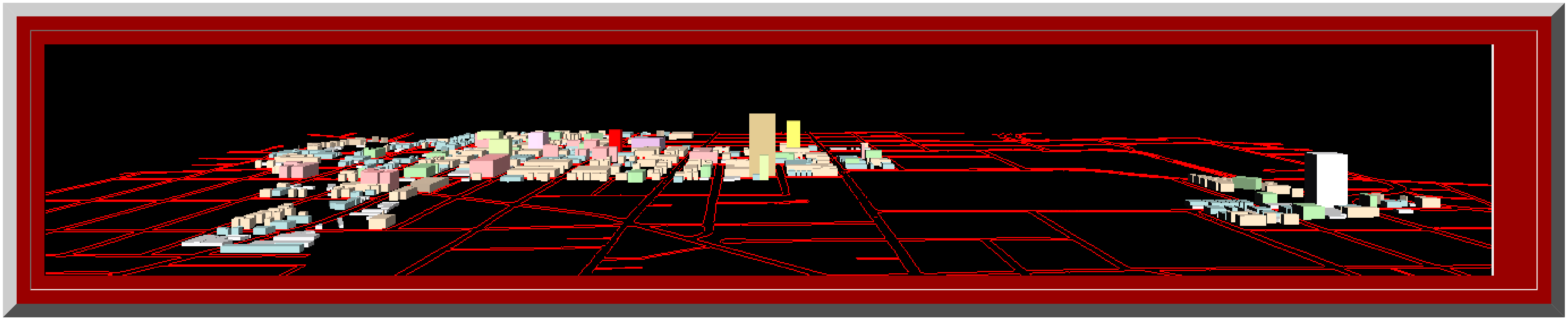

Ann Arbor, Michigan: Virtual Downtown Experiments, Part II

Sandra Lach Arlinghaus

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School of Natural Resources and Environment; Taubman College of Architecture and Urban Planning.
Member and Secretary, Board of Trustees, Community Systems Foundation (International NGO)
Member, Secretary, Vice-Chair, and Chair, City Planning Commission,* City of Ann Arbor (1995-2003);
member, Ordinance Revisions Committee (1995-2003), Master Planning Committee (2002-2003), and Environmental Commission (2001-2003), City of Ann Arbor.

For background information, please view this link to Part I: Ann Arbor, Michigan: Virtual Downtown Experiments

Material in this article is part of a forthcoming book by the author and William C. Arlinghaus entitled ***Spatial Synthesis*** (in press).

Thanks to:

- Merle Johnson of the City of Ann Arbor for permission to use City of Ann Arbor base maps and aerials in this article.
- Karen Hart, Planning Director, and Chandra Hurd, Planning Department, City of Ann Arbor, for files concerning building height in the downtown.
- Matthew Naud, Environmental Services Coordinator and Emergency Services Coordinator, City of Ann Arbor.
- Prof. Peter Beier, Director 3D Laboratory, Media Union, The University of Michigan and his staff members Lars Schumann and Brett Lyons.

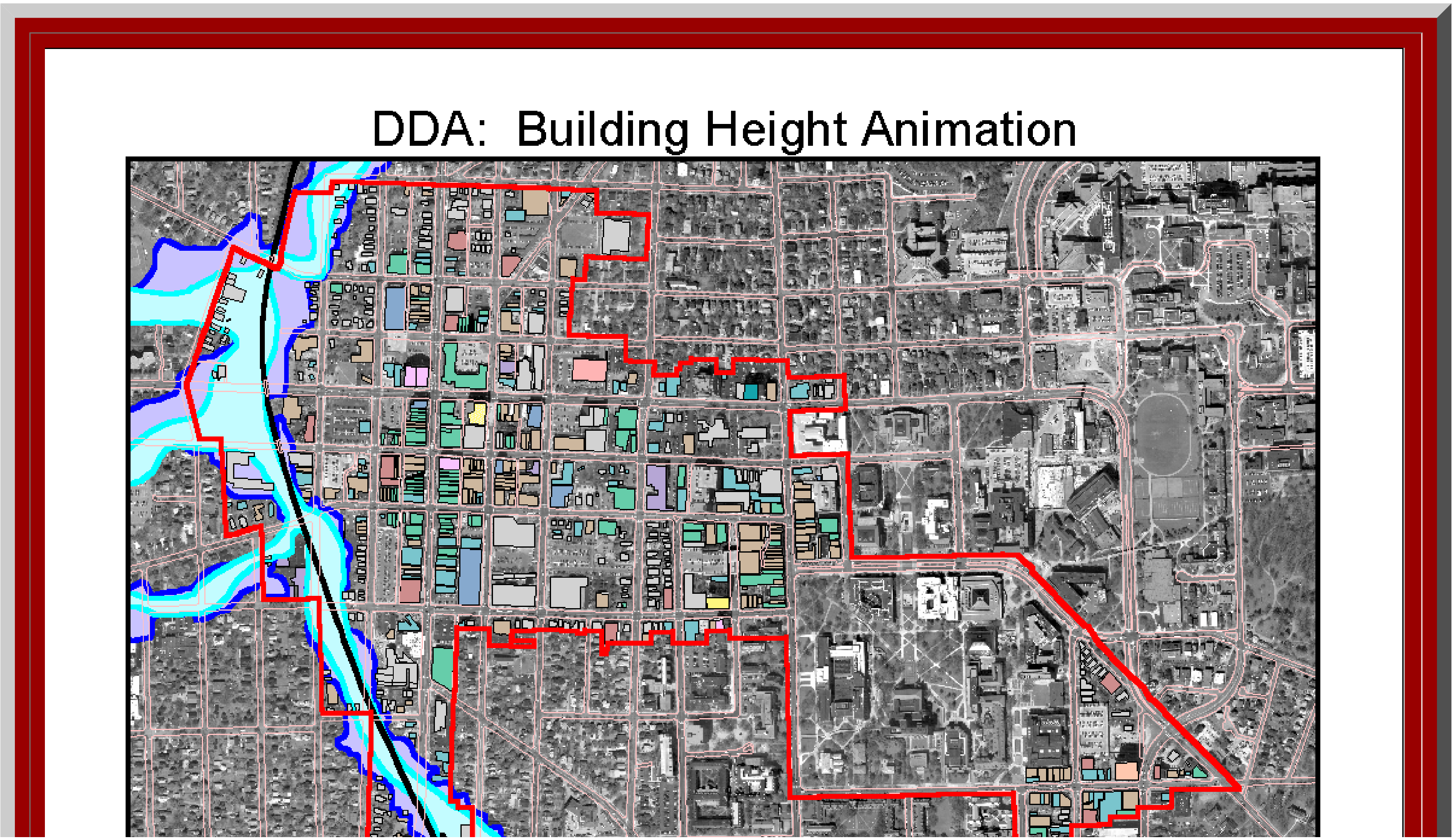
Brief Background

Ann Arbor is a small city (of just over 100,000 population) in southeastern Michigan. It is home to the main campus of The University of Michigan, a state university with over 35,000 students on the Ann Arbor campus. The student population composes about 1/3 of the population of the city. Much of the rest of the population works at the university in some capacity or in research industry, businesses, government, or institutions that locate near the campus. Most cities in the US have shapes that are topologically equivalent to a circle, in terms of paying taxes to the city: land parcels that lie within the city boundaries pays taxes to the city. There are, of course, cities that contain enclaves within their boundaries that are not part of the city itself. In the case of Ann Arbor, however, and other small cities that contain large state universities, the city is more of an annulus (doughnut) in shape. A large hole, containing the university is cut out of the city: lands in this hole do not pay taxes to the city. Hence, a disproportionately large property tax burden is placed on owners of non university parcels within the city (although of course the presence of the university is vital to the well-being of the city in numerous ways). Ann Arbor is a college town.

Thus, there is a need to have mechanisms to create continuing economic development within the city. One way is to increase the stock of housing and space for commercial and other establishments in support of that housing. This path is all the more attractive in light of enduring interests in reducing "sprawl" and in preserving open space in the more rural surrounding lands. In a city with few remaining empty buildable lots, this approach seems to offer few alternatives, the most obvious of which is to increase the density of dwelling units within the city. When density increases are proposed in established residential neighborhoods there is often loud and long public objection from residents of those neighborhoods. There may also be serious environmental considerations, as well. Few residents, however, seem to object to increasing density in the downtown: many who already live in the downtown moved there with an acceptance of taller buildings. Residents of the city who do not live in the downtown often seem not to care about the idea of increasing density in the downtown. What people do seem to care about, however, is what an increase in downtown residential density may mean to the character, appearance, and feeling of the downtown: to its skyline and to the pedestrian experience. To some, an 18 story building is a visual blight on the skyline that provokes negative comment every time it is viewed; yet, others note that they have become accustomed to it and view it as an old, familiar friend. Building height can be a source of substantial dispute.

Inventory of the Vertical City

Prior to considering new tall buildings, it seems appropriate to create an inventory of existing buildings in the downtown area. (In Ann Arbor, the "downtown" generally refers to the "Downtown Development Authority" or DDA: a state-enabled authority that can capture increases in taxable value to pay for improvements within the defined boundaries.) To create this inventory, building footprints were digitized from high quality aerial flown in 2002. Heights were assigned to buildings based on information from the City of Ann Arbor Planning Department (only partially complete). When the building footprints are sorted out according to height it becomes possible to visualize how the taller buildings are arranged with respect to the shorter buildings. Figure 1 shows an animation of this pattern. In that animation the reader has an opportunity to study different layers of downtown space in relation to a plain backdrop and finally to an aerial of the city.



Building footprints enter the animation in order of increasing height in stories: 0, 1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 15, 18, 26

Figure 1. Animation of existing building height in downtown Ann Arbor, Michigan.

The evidence of Figure 1 suggests that buildings of 1, 2, and 3 stories are common in the downtown. Indeed, casual conversations with individuals from around town suggest that no one objects to buildings of any of these heights. One might wonder if that is because they somehow fit a sense of Ann Arbor well or if that is because they are prevalent and people become accustomed to them. In any event, one might imagine an ordinance which allows three stories "by right" on any downtown parcel. The question then becomes, how high elsewhere on prime parcels? For this question one might look to the spacing pattern of existing buildings taller than three stories. Tall buildings adjacent to other tall buildings can create wind tunnels and block wide channels of light. Tall buildings built lot line to lot line may present those as well as other unwelcome effects.

The Floor/Area Ratio as an Urban Planning Tool

The problem of where to locate tall buildings, with sensitivity to existing building types on adjacent and nearby lots, is a difficult one. In Ann Arbor, building height is currently limited by "floor area ratio" (FAR). The FAR is calculated as the ratio of floor area in a building divided by parcel area, times 100. If a given parcel has an FAR of 100 assigned to it, then a building footprint built lot line to lot line may have a height of 1 story. If a parcel has an FAR of 200 assigned to it, then a building footprint built lot line to lot line may have a height of 2 stories. Similarly, an FAR of 300, assigned to a parcel, yields a building of height 3 stories covering the entire parcel. Thus, on a parcel with an FAR of 300, one might, instead, build a building on half of the lot area but of height six stories, or on a third of the lot area but of height 9 stories. On the same parcel, a 30 story building could be built only if its footprint covered one tenth of the land area of the parcel.

The FAR provides a height limit based on the size of foundation needed to support a tall building. It also offers subtle encouragement for preserving some amount of open space and visual variation in the region to which it applies. The drawback is that a tall building may get built with no regard to the broader context of how that new building will fit in with existing buildings on the surrounding parcels. A possible side effect of using FAR (alone) to limit height is that it might encourage parcel amalgamation by large developers, thereby driving out desired local small business owners. [Note: in Ann Arbor, there are also "premiums" designed to encourage residential construction, and other uses viewed as "desirable" in the downtown; these allow an increase in FAR. They will not be covered in this discussion as they introduce no new theoretical issues--just complexity of detail.]

The Floor/Area Ratio, a Closer Look: The Hyperbola as an Urban Planning Tool

In a recent article Claudia Iturriaga and Anna Lubiw consider the problem of labeling maps. Because the current mapping environment is one that allows dynamic positioning of maps (zooming-in and panning), they consider the problem of non overlapping placement of text boxes to be one that is sufficient to solve with text boxes only at the perimeter of the map (with map content in the interior). They note that if the aspect ratio of the label (ratio of height to width) is permitted to vary, with label area held constant, then labels can be fit together in a variety of patterns that will permit a balanced display of map and text boxes. The requirement of constant label area ensures that a certain amount of text content is communicated; shape is permitted to vary. Thus, if the label is viewed as having a fixed lower left corner, then the upper right corner varies along the track of the first quadrant of a rectangular hyperbola with origin at the lower left corner. That is, if width is measured along the x-axis and height is measured along the y-axis, and the area of a label is fixed at K, then the equation describing the label is $xy = K$. This latter equation is precisely the equation of a rectangular hyperbola in the first and third quadrants intersecting the line $y = x$ at (K, K).

It is not a long conceptual leap to imagine the rectangular areas arranged around the perimeter of a rectangular map as being similar to the rectangular areas of building footprints arranged around a rectangular block of a downtown based on a gridded street system. The idea of a rectangle with an elastic aspect ratio tracing out the path of an hyperbola is similar to the idea of Floor Area Ratio (FAR) discussed above. From an abstract viewpoint, the FAR/100, or number of stories, times the parcel area serves as an envelope within which buildings may be built. For example, if a parcel has area 100,000 square feet and an FAR of 300, then 300,000 square feet of floor area may be built on the parcel: as a 3 story building lot line to lot line front, back, and sideways (green building in Figure 2); or, as a 6 story building with each floor having 50,000 square feet on half the parcel (yellow building in Figure 2); or as a 12 story building with each floor having 25,000 square feet on 25% of the parcel area (magenta building in Figure 2). What is constant is the value, K = (FAR/100) *(parcel area). If one graphs this function, with parcel area on the horizontal axis and FAR/100 on the vertical axis, the result is a rectangular hyperbola, xy = 300,000 (Figure 2). Different masses of building in relation to land area result depending on the height one chooses.

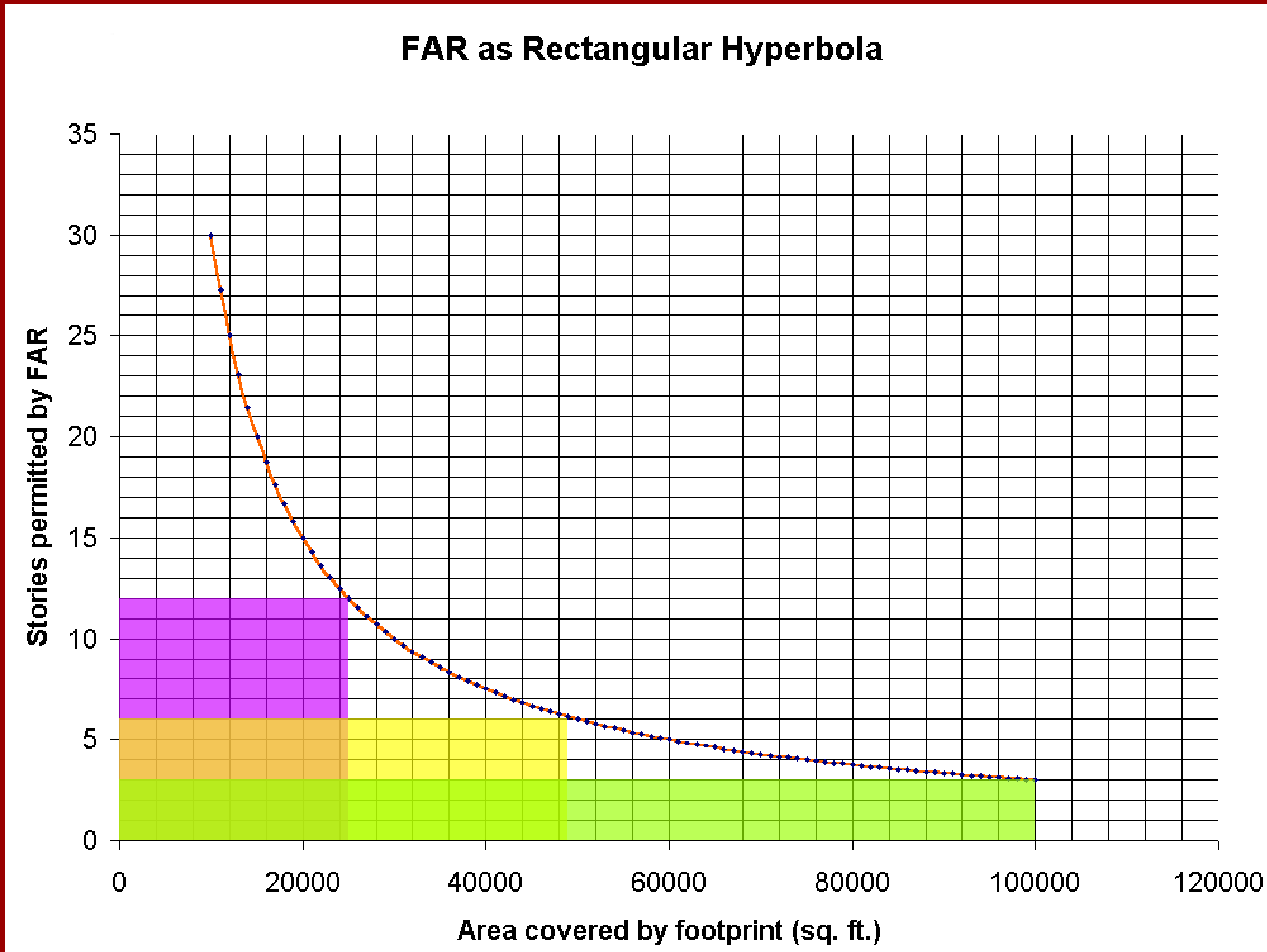


Figure 2. Rectangle with elastic aspect ratio and lower left corner fixed at the origin traces out part of one limb of

a rectangular hyperbola $xy = 300,000$.

When one abstracts away from the grid suggested by Figure 2, and focuses instead on the hyperbola, it is possible to extend the analysis to the more global scene of the entire DDA and to the issue of building mass in relation to land area. Thus, consider that the *x*-axis units are now percent area in the downtown; then, the right-hand limit of the hyperbola is 100% of the land in the DDA. Under these assumptions, what the hyperbola of Figure 2 now says is that 100% of the DDA may be covered with 3 story buildings: that a 3 story building may be constructed, by right, anywhere within the DDA. It also says that 50% of the land area in the DDA may be covered with 6 story buildings, or that one quarter of the land area in the DDA may be covered with 12 story buildings, or that 10 percent of the land in the DDA may be covered with 30 story buildings. The use of the FAR to govern building height may play our at a regional (DDA) level as well as at a local level of the individual parcel. The hyperbola captures the FAR in a systematic manner and it does so at all scales, from local, to regional, to global. It does not reflect planning and geographic elements that the FAR does not capture such as (but not limited to) heights of neighboring buildings and other adjacency considerations, historic preservation issues, shadow or wind tunnel effects and other quality of life issues, or lateral or upper story setback concerns. Issues such as these require the human elements of judgment and common sense. The mathematical implementation can do much, but not all; it is a tool of humans, not a replacement for human thought (although numerous abstract connections remain to be probed: from cartography, to urban planning, to the Zipf rank-size rule and the lectures given by Michael Batty at The University of Michigan and Eastern Michigan University in the spring of 2003).

The principles set forth here, would enable one to consider the total mass of building square footage permitted according to FAR, independent of municipality and local concerns. Subtracting the actual built up area from that would give an estimate of the remaining mass that could be built, by right, according to code. Within that remainder, one might calculate how many more 3 story buildings could be built; how many more 6 story buildings; how many 12 story buildings (or whatever height in whatever units). Such a strategy can completely characterize the mass of building in relation to land area and may suggest a basis for the control of that mass, especially when one decides what future is desired and works back from that to create ordinances and code that will lead to that desired outcome (an approach similar to that take by others, as for example by people at ChicagoMetropolis2020). It offers, however, no guidance as to where tall buildings might be placed in relation to each other or in relation to existing structures, as to which parcels might contain tall buildings, as to wind, light, and sound issues, and as to a host of other qualitative issues. Other approaches might involve a guide to the spacing of buildings (forthcoming), buffers around existing buildings as zones of limited height, or legislated design standards. It is for creative needs such as these, to be superimposed on measures of sheer mass or quantity that can be captured generally as mathematical and geographical propositions, that cities require the service of professional planners and a host of municipal authorities and support personnel.

Beyond the Floor/Area Ratio: Virtual Reality as an Urban Planning Tool.

Virtual reality, the envisioning of alternative three-dimensional scenarios on a computer screen, offers to decision makers the capability to see how the massing of buildings and the general design of the urban landscape might look with various changes. In the case of Ann Arbor, that might mean envisioning the downtown with new tall buildings in a three-dimensional model that can be viewed at the pedestrian level: as a virtual landscape that can be navigated on the computer screen by City Council members as they sit with laptops in Council Chambers or by members of the public as they sit at home or in public libraries using computers with internet connections. Part I of this topic showed virtual reality of the downtown based on

- **VR 1:** parcels were extruded to form chunky buildings that filled entire parcels, lot lines to lot lines, with height assigned by FAR and zoning ordinance (C1A, 200% FAR; C1A/R, 300% FAR; C2A, 400% FAR; C2A/R, 300% FAR; C2B/R, 300% FAR).
- **VR 2:** parcels were extruded to form chunky buildings that filled entire parcels, lot lines to lot lines, with height assigned by records from the Planning Department of the City of Ann Arbor.

Additional work has yielded refinements on these files. Building footprints were digitized from an aerial of the downtown, flown for the City of Ann Arbor in 2002. Many of the footprints had heights from the records of the Planning Department. However, a number (over 300) did not. Buildings with no height were assigned the height based on FAR by zoning type (using information from the City of Ann Arbor Zoning Ordinance) calculated in association with the virtual reality in Part I, above.

The following sequence of interactive maps, made using the ImageMapper 3.3 extension to ArcView, shows the results, using maps and aerials in various combinations:

- **I-Map 1:** Click here for a link to an interactive map showing building footprints and height (on mouse-over) as well as building address and street names (on mouse-over). Parcel boundaries are shown on the underlying aerial and on the green Downtown Development Authority (DDA) area. The Allen Creek floodway (underground) and flood plain are shown, shaded, respectively in blue and turquoise. Click on a building or a street to see associated entries in the underlying database.
- **I-Map 2:** Click here for a link to an interactive aerial showing parcel boundaries, zoning, building height (on mouse-over), and street name. DDA outline, only, is shown in light yellow so the user may zoom in to get a closer view of the aerial within the DDA (up to 800% enlargement--can see cars clearly). The Allen Creek floodway (underground) and flood plain are shown, outlined, respectively in blue and light blue; again, because the shading is removed, the viewer may look at the content of the floodway/floodplain in greater detail than above. Click on a building or a street to see associated entries in the underlying database.
- **I-Map 3:** Click here for a link to an interactive aerial showing zoning boundaries in the downtown, zoning type (on mouse-over), building height (in the "zoneht" record of the database), and street name. Click on a building or a street to see associated entries in the underlying database.

This strategy necessarily produces error. Buildings that do not occupy a full parcel may well be taller than indicated here (as the FAR permits them to be). Others may be lower than what is allowed by FAR because they were not developed to the maximum permitted. Still others may be yet another height because they were part of a Planned Unit Development (PUD). (PUD designation is a custom zoning that permits projects to be built outside the standard zoning currently present for that parcel when there are good reasons to consider such action and when there is substantial public benefit, defined in City Code, for such action.) Finally, some parcels may not be developed for buildings: they may house parking lots or other non-building uses. Obviously, parcels that are empty, parcels housing parking lots, or parcels containing buildings of height less than permitted by FAR are targets for development or re-development. One block often targeted in this manner is the "Brown Block": the block of land bounded by Ashley, Huron, First, and Washington Streets (Figure 2). Vacant lands are easy to select from an aerial; what is not easy to see from an aerial is how new buildings might appear on them in relation to existing buildings. For that visualization, virtual reality is critical to gaining either a pedestrian's eye, or a bird's eye, view.

On November 9, 2003, City Council Member Jean Carlberg (and Mayor ProTempore, Planning Commissioner, and member of the Ordinance Revisions Committee), City Council Member Joan Lowenstein, City of Ann Arbor Planning Director Karen Hart, and former City Attorney (on two occasions) Jerold Lax, visited the GeoWall (with the author and others, a total of 14) at The University of Michigan's 3D Laboratory at the Media Union (Dr. Peter Beier, Director). At that time, they had the opportunity to view the files above at a scale that permitted them to feel as if they were walking among the buildings. Each was given the map displayed in Figure 3 and an earlier version of the commentary following the map. The red building on the map in Figure 3, at the southeast corner of Fifth and Huron Streets, is a location mentioned as a possible site for a new tall building by Ann Arbor Mayor John Hieftje (in personal communication with the author and elsewhere). The commentary following the map enumerates the steps taken to build a virtual structural base of the downtown to use as a model to consider density/height issues in the downtown.

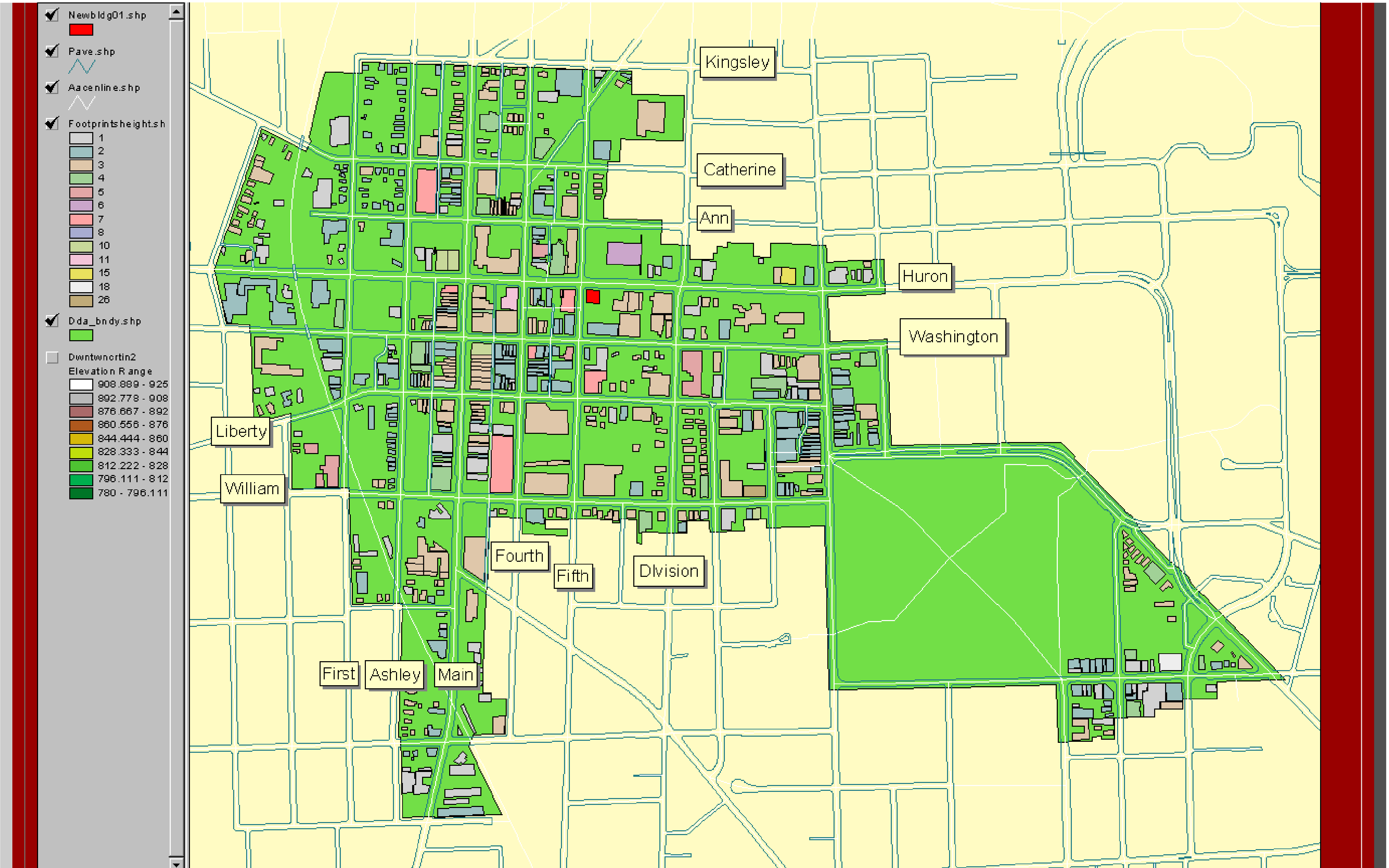


Figure 3. Map handed out to participants in the GeoWall display of November 9, 2003 at the Media Union of The University of Michigan.

Procedure used to date to create a structural building base of downtown (no detail):

- Building footprints were digitized using a city aerial (.tif file). They are represented in the map above as polygons filled with color according to building height (all buildings of the same height have the same color).
- Issues with height:
  - Over 300 polygons had a value of "0" height. For all but 32 of those polygons, the digitized building footprints were assigned values based on the FAR for the zoning category. Because the parcel outline generally exceeded the building footprint in area, this decision likely produces buildings that are shorter than what is permitted (although of course there may be actual buildings that have been constructed at less than what is permitted by right).
  - For the remaining 32 polygons, for which there was no data, a height of 3 stories was inserted (in later files, one was adjusted to 7 stories based on field evidence (Ashley Mews)).
  - Stories were assumed to be 12.5 feet in height.
- Contours, with a contour interval of 5 feet, were used to create a triangulated irregular network as a topographic base level from which to measure building height (rather than from a flat geometric base level).
  - **VR 3**: topographic base level in 3D
  - **VR 4**: topographic base level with buildings extruded from that level. This file may take a long time to load and it may be difficult to navigate because of the extended load time.
- Actual height Virtual Reality: digitized building footprints are superimposed on parcels in the downtown core zones.
  - These VR experiments depict the downtown using actual building heights, where known that are extruded from a topographic base. This base is a Triangulated Irregular Network (TIN) made from a City of Ann Arbor contour map with a contour interval of 5 feet. There are three sets of files for June 21:
    - **VR 5:** sun in the southeast (morning),
    - **VR 6:** in the south (noon),
    - **VR 7:** and in the southwest (afternoon).

    This was done in order to suggest variation in lighting conditions with season and with time of day. The lighting scheme is designed for hill shading and is therefore really only useful for suggesting shadow location as it does not account for light reflected from impervious surface.
  - Later experiments involved inserting building heights for the 300+ parcels of unknown height, as above. Links to
    - **VR 8:** a low sun scene (sun in the southwest) with the new building and
    - **VR 9:** a high sun scene (sun in the southwest) with the new building

    are included here. In these scenes parcels are extruded from topographic base level although it is not shown directly as a TIN in the scenes (in the interests of reducing file load time and map clutter).
- A new building was added in response to comments from Mayor John Hieftje and is shown as a red block in Figure 3 and also in the attached aerial..
- Earlier versions of files were shown to the Ordinance Revisions Committee of City of Ann Arbor Planning Commission.
- Karen Hart and Matthew Naud, both of the City of Ann Arbor, previewed earlier files in the immersion CAVE and on the GeoWall at the 3D Laboratory (Peter Beier, Director) of the Media Union of The University of Michigan.
  - Hart noted the utility of this tool for urban planning and mentioned one local project in particular; she agreed with the author that this tool might be useful in the context of a maximum height ordinance in the downtown;
  - Naud noted the utility of this tool for emergency management, including as a training tool for first responders. He expressed a desire to have building textures and other detail that would aid in building recognition introduced into scenes. Naud also suggested that knowing where hazardous materials were located would be useful to first responders. He followed up by suggesting a connection to others and helping to arrange, and participating in, meetings with them. These meetings have led to some proposals to fund emergency management activities linking various groups of individuals from the public and private sectors
  - Beier noted, on viewing the earliest files in the CAVE, that the buildings appeared to be too tall as one took a walk through the virtual downtown. Later, Lars Schumann (Programmer Analyst II and Lab Manager) and Brett Lyons (Programmer Analyst I), of the 3D Laboratory, Media Union, told the author that the .vrml files used in the CAVE and on the GeoWall have units in meters. Taejung Kwon (Ph.D. student, Taubman College of Architecture and Urban Planning and student in Engineering 477) noted (later yet) that one might calculate a *z*-factor to convert feet (used as the default unit in ArcView in City of Ann Arbor maps) to meters used in .vrml files. Other students in the group, Paul Oppenheim, Adrien Lazzaro, and Aaron Rosenblum agreed with Kwon.

Current activities:

- Research continues on building a "3D Atlas of Ann Arbor" designed to aid decision makers in a variety of contexts from Planning to Emergency Management. It will also serve as a pilot project for a number of more global 3D atlases.
- The author together with Matthew Naud and John D. Nystuen (Professor Emeritus, College of Architecture and Urban Planning, The University of Michigan) are serving as faculty advisors in Professor Peter Beier's Engineering 477 (College of Engineering, The University of Michigan) course on virtual reality, Fall 2003. They are working with the team of four students mentioned above. The students have created a localized study for the "3D Atlas of Ann Arbor" at the intersection of Liberty and Main Streets. It will serve as a pilot study for other detailed 3D urban views.

Comments from the meeting from November 9, 2003 and subsequent follow-up:

- **Council Member Carlberg** noted that she might also wish to know more about where the shadows of new buildings might fall. Lighting changes are difficult to model in VR; however, with aerials that show existing building shadows, it is not hard to imagine where shadows of new buildings might fall. Thus, in the

  linked aerial

  one sees a red square on a parking lot corresponding to the location mentioned as a possible location for a tall building by Mayor Hieftje. The buildings around it cast shadows that extend almost across the street. A new building on the red square, of height greater than adjacent buildings would cast a shadow on both sides of the street. Shadow position is important when considering budgetary allocations from the city's street tree escrow. It is also important in creating a positive pedestrian experience in the downtown.

- **Council Member Lowenstein** commented to the author that the files above were, with navigation aids added, probably enough to be quite useful to City Council. Both she and Planning Director Hart noted their utility in considering issues involving height in the downtown as they relate to a recent city initiative to increase the residential population in the downtown. She also noted that the addition of callouts (notes) that show which buildings might contain hazardous materials, or similar information, might be helpful to firefighters and other emergency first responders. Two-dimensional interactive maps or aerials may well be sufficient for a hazardous materials inventory.

  - An I-Map based on an aerial might offer one approach. On the

    linked map

    the mouse-over callouts shows the building address for three locations. Click on a location to reveal elements of the database associated with each site. In seeing all buildings simultaneously one gets an immediate picture of adjacency patterns: for example, a fire in one building may need immediate containment on the eastern edge to prevent spread to an adjacent building on the east containing volatile material. Careful database construction is critical: the mapping, in this case, is easy in relation to the database construction.

  - A very simple approach might simply employ Adobe Photoshop (version 7.0 was used here) to work with a high quality aerial photograph of the City.

    In the

    attached aerial

    note files and voice files have been added to City Hall, to 219 S. Main, and to the central quadrangle (the "Diag") of The University of Michigan. Thus, emergency workers might have not only the benefit of reading notes attached to buildings that specify the locations of hazardous materials, but also the capability to hear voice transmissions of such locations when already in a tight spot. The drawback to this style of approach is that it requires the user to download the file and open it in Adobe Photoshop (or use some similar strategy to read the notes). If, however, the emergency management team already has Photoshop loaded on laptops, this is not much of a disadvantage. Indeed, it might be viewed as an advantage in file security given that it does not play directly on the Internet.

- **Planning Director Hart**, noted in addition, the importance of modeling upper story setbacks as a next step. She also suggested possible specific locations in the downtown where VR might be particularly helpful, including in the modeling of various aspects of long-standing plans for a renovation of governmental space. As convincing and as helpful as virtual reality can be, it is however, only virtual. When one walks away, it remains only in the mind. Another exciting technological tool that the group saw is the 3D "printer" that creates true 3D objects representing the experienced virtual reality. Hart also noted that she could see numerous uses for this tool. Indeed, sometimes the end desired suggests the process to get there, not only in master planning and other forms of planning, but also in the tools used in planning.

The display below presents the final experiments in this set (given to Ann Arbor City Council in December of 2003) as the first in a series of possible 3D mapping tools to aid in making a variety of difficult decisions: for Ann Arbor as well as more globally. It includes parcels extruded from building footprints, with the sun set in the south at a "low" setting, using an invisible topographic base created from a TIN made from a topographic map with a contour interval of 5 feet. Buildings have been adjusted using a *z*-factor of 0.3048. It also includes street labels that appear as one moves around at a local level as well as navigation aids (click in the lower left corner of Cosmo Player) of assigned camera viewpoints. These, coupled with using the "driving" capability of Cosmo Player, help in getting around the virtual downtown so that one does not get lost in the space of virtual Ann Arbor!

VR 10: this virtual model of downtown Ann Arbor shows views of the downtown

- from the south, along a corridor between Division and State streets
- from the south, looking north along the Main Street corridor
- from the east, looking west along the Huron Street corridor, at pedestrian level.

Use the list of viewpoints in the lower left-hand corner to be taken to these three different camera positions. Also, use the tools in Cosmo Player to structure your own route through the downtown at a bird's eye or human's eye level.

Labels on the streets will appear as one zooms in. Some graphic tasks that are easily accomplished in a GIS are not so easily accomplished in virtual reality. The lettering for these labels was made in a polygon layer of ArcView by tracing default lettering. Automatic labels that are easy to produce in a 2D map do not reproduce in the 3D version. Thus, as with the building footprints, digitizing letters will make them appear. In the process of digitizing letters such as "B" or "D," one might be reminded of converting a multiply connected domain to a simply connected domain and consequently the Jordan Curve Theorem from topology or the Cauchy-Goursat Theorem (or others) from the theory of functions of a complex variable. It is remarkable to see that strong interdisciplinary connections between geography and geometry arise even in the most mundane of mapping tasks.

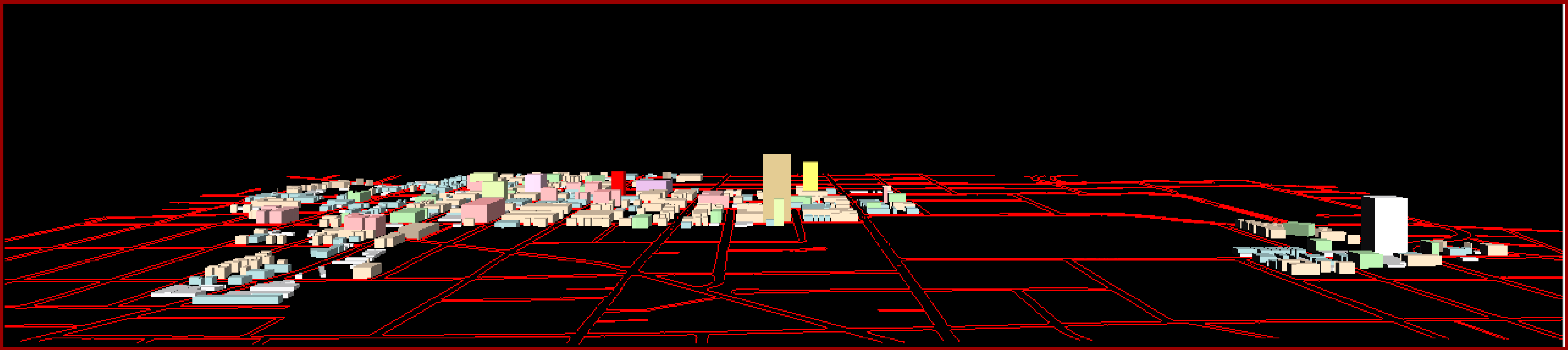
- **VR 11.1, 3 story building added at southeast corner of Huron and Fifth**
- **VR 11.2, 4 story building added at southeast corner of Huron and Fifth**
- **VR 11.3, 5 story building added at southeast corner of Huron and Fifth**
- **VR 11.4, 6 story building added at southeast corner of Huron and Fifth**
- **VR 11.5, 7 story building added at southeast corner of Huron and Fifth**
- **VR 11.6, 8 story building added at southeast corner of Huron and Fifth**
- **VR 11.7, 9 story building added at southeast corner of Huron and Fifth**
- **VR 11.8, 10 story building added at southeast corner of Huron and Fifth**

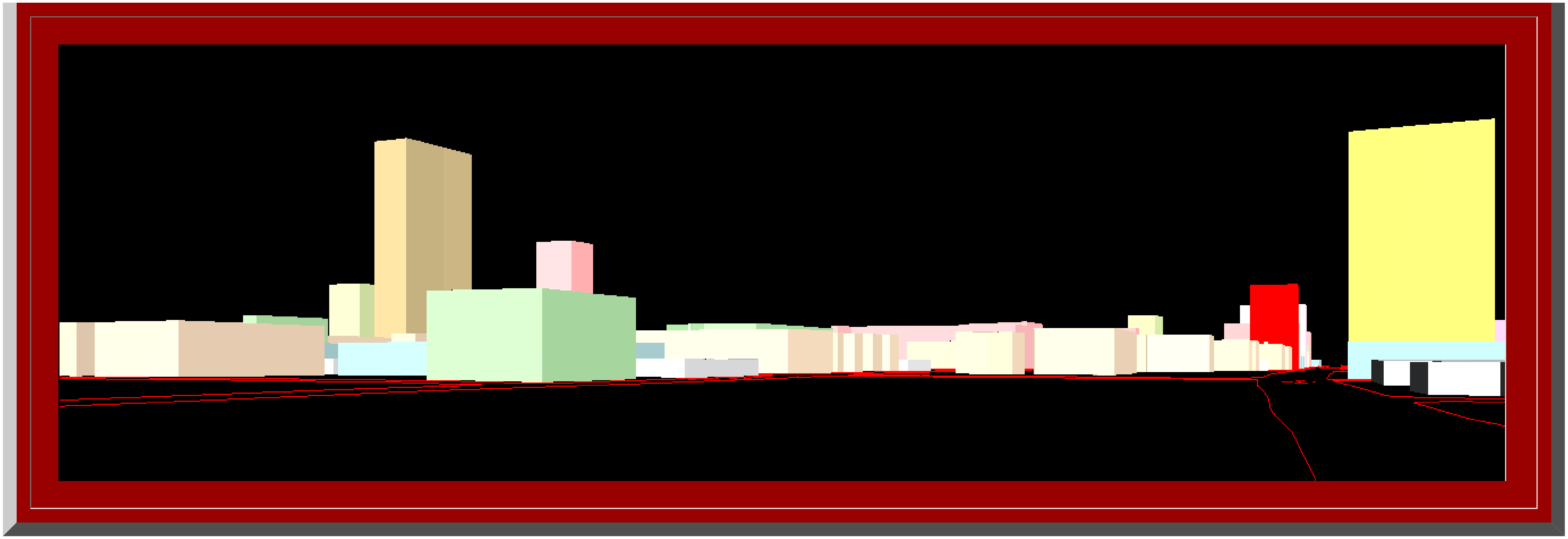
- **VR 11.9, 11 story building added at southeast corner of Huron and Fifth**
- **VR 11.10, 12 story building added at southeast corner of Huron and Fifth**

This set of files shows a sequence of views, all with the same two camera angles--the first is a view of the entire downtown and the second is a view looking west along Huron Street, from a vantage point to the east of State Street. Use the navigation system in the lower left-hand corner to see the views from these preset camera positions; they offer a standard source for comparison as one switches from model to model that the free-roaming form of navigation does not. The red building in each model is a virtual building built on the southeast corner of Huron and Fifth, across from City Hall. It is the empty spot selected by Mayor Hieftje on a number of occasions as one location to consider for building a tall building. The sequence of files shows the virtual building with different numbers of stories: 3, 4, 5, 6, 7, 8, 9, 10, 11, and 12. The general view of the downtown suggests how the new building might or might not fit in the overall skyline view. The local view along Huron Street suggests what the pedestrian experience might be.

Figures 4a and 4b below show animated sequences of screen shots from the virtual reality files. Thus,

- **in Figure 4a, one can watch the bright red building "grow" from 3 to 12 stories, in 1 story increments, in the center of the DDA, across the street from City Hall, at the southeast corner of Huron and Fifth streets. A view such as this one suggest the impact the new building might have on the overall skyline. To get a good general picture, one might wish to have such animations from more than one vantage point and for change involving more than one building. This animation suggests a style of analysis at the global level of the entire downtown.**
- **in Figure 4b, one can watch the same building grow (as in Figure 4a, again in 1 story increments) but from a far more local viewpoint and from a level closer to a pedestrian's eye view. A sequence of such animations might be helpful in understanding the impact of new structures on the pedestrian experience.**





Next steps include:

- Field checking of building heights
- Modeling of upper story set backs

Possible future activities

- Thinning of file size based on scale.
- Produce a number of other files based on various lighting possibilities.
- Introduce cars along the streets, pedestrians on the sidewalks, and so forth.
- Model the weather (colleague John D. Nystuen suggested modeling a snow storm). Nystuen also suggested modeling the underground infrastructure.
- Consider how practical, day to day elements of decision making might be aided.
  - Might VR files serve to replace the model consideration in the PUD zoning?
  - If so, what sort of ordinance revision would be necessary and what legal ramifications might there be in such a consideration or in related ones?

    More generally, what are the legal questions involved in using VR as a planning and emergency management tool; do they differ from those associated with using 2D analysis for such purposes?

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*The author acknowledges productive meetings with and assistance from

- her colleagues on the City of Ann Arbor Planning Commission (Sandra Arlinghaus (Chair), Kevin McDonald (Vice-Chair), Scott Wade (Secretary), Braxton Blake, Jean Carlberg, Kristen Gibbs, Christopher Graham, William Hanson, and Steve Thorp);
- the Ordinance Revisions Committee of that Commission (Hanson, Chair; Carlberg, Arlinghaus, Blake);
- the City of Ann Arbor Planning Department staff (Karen Hart, Planning Director; Wendy Rampson, Coy Vaughn, Donna Johnson, Jeff Kahan, Chandra Hurd, Alexis Marcarello, Christopher Cheng, and Matthew Kowalski);
- Merle Johnson, City of Ann Arbor, Information Technology Services;
- Heather Edwards, Historic District Preservation Coordinator, City of Ann Arbor;
- Matthew Naud, Environmental Coordination Services Director and Emergency Management Director, City of Ann Arbor
- John D. Nystuen, Professor Emeritus, Taubman College of Architecture and Urban Planning, The University of Michigan
- Peter Beier, Professor of Engineering and Director, 3D Laboratory, Media Union, The University of Michigan.

- the Mayor of Ann Arbor, His Honor, John Hieftje

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Software used:

- ArcView GIS, v. 3.2, with Spatial Analyst Extension and 3D Analyst Extension. All from ESRI (Environmental Systems Research Institute, Redlands, CA). http://www.esri.com/
- ImageMapper 3.3, Alta 4, http://www.alta4.com/
- Microsoft Windows XP, http://www.microsoft.com/
- Cosmo Player, http://ca.com/cosmo/
- Adobe PhotoShop and Adobe ImageReady, versions 7.0.

Ann Arbor, Michigan: Virtual Downtown Experiments, Part III

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Link to medium resolution scene of four blocks of Ann Arbor centered on the intersection of Main and Liberty Streets.

Saturday, July 5, 2003.
Front page article by Tracy Davis, "A Pair of Emergency Sirens Added to Ann Arbor System," continued inside, with photos and map.
Excerpt from front page:

> Sandra Arlinghaus already spent time working with computer mapping and geographic information systems at work and in her position as chairwoman of the Ann Arbor Planning Commission, so when she heard the city was trying to figure out where to place new emergency alert sirens, she put her skills to work.
>
> The city's own GIS mappers and emergency directors had sent staff out to gauge how well sirens could be heard in various parts of town.
>
> But Arlinghaus took it a step further: She mapped the locations of Ann Arbor's existing 20 sirens, the approximate areas where they could be heard and how well. The resulting map showed overlaps and gaps that helped city emergency official determine where to place two new ones this week.

Thursday, July 19, 2003.
Opinion Column, "Cheers and Jeers," on the Editorial Page, A8.

> **Cheers**: Sandra Arlinghaus for going beyond her duties as Ann Arbor Planning Commission cha[i]rwoman by mapping on computer the location of Ann Arbor's 20 emergency sirens. Her work showed city official where the sirens could not be heard and helped them establish locations for two new sirens.
