Reading the Digital City

A Selective, Annotated Bibliography of Urban Design and GIS

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Abstract

This document examines the literature relevant to the preparation and use of urban models from the perspective of Geography and Geographic Information Systems (GIS). It offers an annotated bibliography of a a broad spectrum of academic and popular literature. This guide should serve as a primer to staff at DND wishing to be familiar with the state of practice in the broad fields of Geographic Information Science and Urban Geography.

Résumé

Ce document présente une revue de la littérature pertinente à la préparation et l'utilisation de modèles urbains dans la perspective de la géographie et des systèmes d'information géographique (SIG). Il offre une bibliographie annoté couvrant un large spectre de littérature académique et populaire. Ce guide devrait être utile en tant que point de départ pour le personnel du MDN souhaitant se familiariser avec le niveau de pratique actuel en sciences de l'information géographique et en géographie urbaine.

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Executive summary

Reading the Digital City

Robin M. Harrap; DRDC CORA CR 2008-003; Defence R&D Canada – CORA; January 2009.

Background: The earliest occurrences of urban warfare might be as ancient as War itself. In the last decades the topic has gained a lot of attention in military circles, probably because of the recent events in Iraq, Bosnia, Somalia, Chechnya and other conflicts involving military operations in densely populated areas. As a consequence, defence scientists (DS) are now routinely asked to develop models and simulations that represent operations in urban environments. Some DS's will find the need, consequently, to expand their toolbox by familiarizing themselves with some concepts of urban geography and geographic information systems (GIS). In the OR tradition of thinking out of the box, we felt the need to obtain a perspective from outside the defence realm. The multi-disciplinary experience of Mr. Rob Harrap, Professor at the Department of Geology at Queen's University, offered us that perspective.

Principal results : This document has been created with a scientific readership in mind. It achieves two principal goals: first, to put urban geography and GIS in the context of their practice in academia and second, to provide a commented reading list that can be used as a "primer" on these topics. The range of works listed goes beyond the traditional boundaries of geography and GIS though. This is intentional, as we wanted to give an overview of a modern geographer's toolbox, which also covers knowledge in mathematics and computer science, for example. The ensemble thus represents a wide corpus of references that should help defence analysts widen their horizons.

Significance of results: While the ensemble of works listed by Mr. Harrap is of undisputed interest, the most immediately useful items will probably be found in the sections on *Urban GIS* (p.32) and *Geographic Information Systems* (p.34). The review of works on *Artificial Intelligence* (p.21) will be of interest to scientists involved in geosimulation and multi-agent simulation in general. Operational research analysts will also be interested in the one work listed under *Decision Support Systems* (p.20).

Future work: While *Reading the Digital City* provides a unique set of references on urban geography issues, it does so from outside the military domain. To complement that perspective it would be valuable to find an expert with enough experience in military GIS to develop a similar document with a narrower scope and more depth. Together, the two documents would offer a solid and balanced reference for defence scientists.

Sommaire

Reading the Digital City

Robin M. Harrap ; DRDC CORA CR 2008-003 ; R & D pour la défense Canada – CARO ; janvier 2009.

Contexte : Le rôle des villes dans le déroulement des guerres est probablement aussi ancien que la guerre elle-même. Au cours des dernières décénies le sujet de la guerre urbaine a reçu une attention accrue, probablement à cause des événements en Irak, Bosnie, Somalie, Tchétchénie et autres conflits comprenant des opérations militaires en régions densément peuplées. Conséquemment, les scientifiques de la défense (SD) ont souvent la tâche de développer des modèles et simulations pour représenter les opérations en milieux urbains. Certains SDs éprouveront par conséquent le besoin d'étendre leur gamme d'outils en se familiarisant avec certains concepts de géographie urbaine et les systèmes d'information géographique (SIG). Afin de promouvoir une pensée hors de la boîte, nous avons cherché à obtenir une perspective extérieure au monde de la défense. L'expérience multi-disciplinaire de M. Rob Harrap, Professeur au Département de géologie de l'Université Queen's, nous offrait une telle perspective.

Résultats principaux : Ce document a été écrit pour un auditoire scientifique. Il atteint deux buts particuliers : premièrement de placer la géographie urbaine et les SIGs dans le contexte de la pratique académique et deuxièmement de fournir une liste de lecture commentée qui puisse être utilisée comme point de départ dans l'étude de ces disciplines. L'étendue des travaux cités va cependant au-delà des limites traditionnelles de la géographie et des SIGs. Ceci est intentionnel puisque nous voulions donner un aperçu de la gamme d'outils du géographe moderne. Or, la géographie d'aujourd'hui touche tout autant aux mathématiques qu'à l'informatique, ce qui élargit passablement le champ des connaissances à couvrir. L'ensemble des travaux présentés ici constitue donc un corpus large qui devrait aider le lecteur à élargir ses horizons.

Portée des résultats : Bien que l'ensemble des références présentés par M. Harrap soit d'un intérêt certain, les items les plus immédiatement utiles se retrouveront probablement dans les sections *Urban GIS* (p.32) et *Geographic Information Systems* (p.34). La revue des travaux sur l'intelligence artificielle (*Artificial Intelligence*, p.21) sera particulièrement intéressante pour les scientifiques impliqués en géosimulation et en simulation multi-agents. Les analystes en recherche opérationnelle seront aussi intéressés par l'ouvrage listé dans *Decision Support Systems* (p.20).

Recherches futures : *Reading the Digital City* fournit une collection unique de références sur la géographie urbaine en adoptant une perspective extérieure au domaine mililtaire. Afin

de complémenter cette vision il serait utile de trouver un expert possédant suffisamment d'expérience avec les SIGs militaires qui puisse développer un document similaire qui soit à la fois plus approfondi mais ratissant moins large. Ensemble, les deux documents constitueraient une référence solide et équilibrée pour les scientifiques de la défense.

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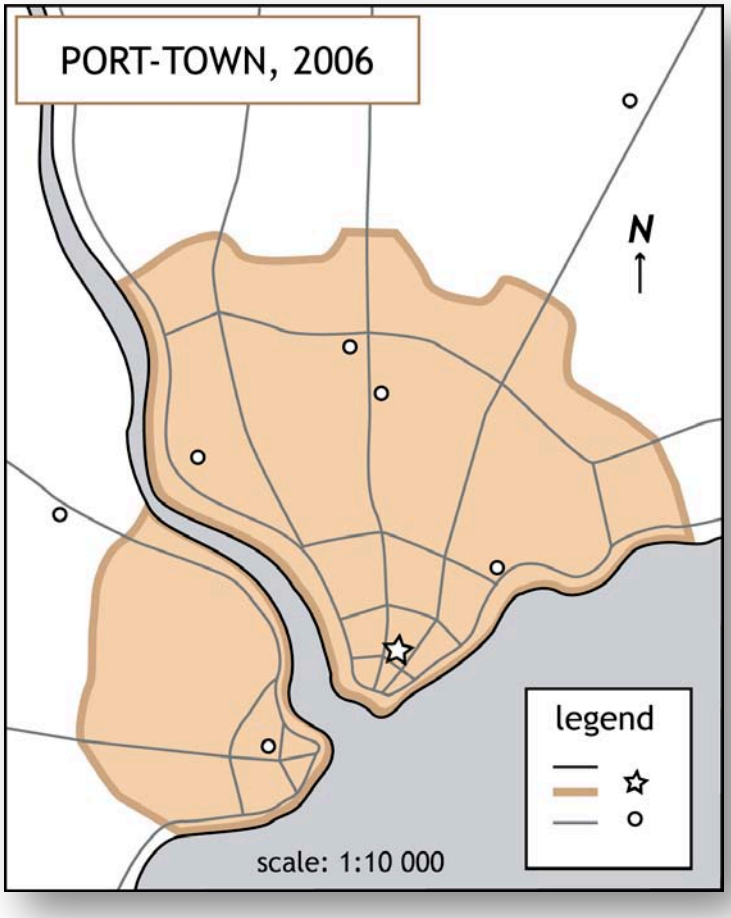

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A Thought

When asked (by Alan Kay, no slouch himself) how in one PhD thesis he managed to invent interactive computer graphics, lay the foundation for object-oriented programming, invent Computer Aided Design, develop the foundations of constraint programming methods, and prototype novel human computer interfaces, Ivan Sutherland replied "I didn't know it was hard."

Becoming well-read in the key works in a field is a double edged sword: afterwards we know much about what has, is, and could be done, but we also know what is hard. The key is to then not shy away from the hard problems and big visions, not to pursue the easy answers on small problems that will matter little in a few years, not to have the confidence to go for it!

It has been my experience that a compromise road is to read not *within* a field but *across* fields; in many cases the hard problems of one field have already been solved by another field. As we drown in too much information, most shrink to reading within a narrow field; I encourage you instead to read widely, when possible, and deeply, when necessary. This is not to say that you should not read deeply; it is a certainty that it will be necessary. It is simply to say that, without intent, you will likely never read widely.

Table of Contents

Reading the Digital City

Studying urban GIS and visualization – the application of computer cartography and computer graphics principles and tools to urban design and analysis problems – is made complex by the extremely wide range of contributing disciplines, and the diverse nature of the historic and modern literature on the topic. This report is an attempt to provide annotated references to a large number of text sources and to thus provide a 'way in' to the literature.

I've chosen to concentrate on texts rather than the scientific 'paper' literature as texts are both more accessible (the vast majority of the books referenced are available at any online bookstore or by order through a storefront bookstore) and also less introspective. Scientific papers, while containing the latest results, are often presented in such a terse form that they are difficult to follow.

The selection of books is personal and idiosyncratic. I've made an attempt to include many classic works but have also thrown in works that are especially useful in a pragmatic sense and others that just made me consider the field in a new way.

Overview

The text literature on urban areas includes separate literatures from architecture, urban planning, urban design, geographic information systems, computer science, and game design. Each contributes unique perspectives and concrete methods useful to anyone interested in digital representations of urban space.

It is a consequence of the nature of modern academic training that people have compartmentalized skills. The result is that in many cases a problem's solution is well known in one area but discussed as a new and exciting research problem to be solved in another. This is equally true of theoretic subjects – mathematical analysis approaches – as it is of pragmatic approaches that work well-enough in the field. An especially strong case exists in game design – the pragmatics of game design and programming has delivered solutions that sell for tens of dollars that outperform visualization tools that sell for tens of thousands, and in fact the popularity of games has virtually obliterated the computer workstation market as mainstream graphics cards increased in performance.

As a result, my metrics for inclusion in the bibliography are that a work must either:

- Contribute to the theoretic understanding of a method, problem, or field,
- Contribute to learning new problem solving methods or tools, or
- Contribute pragmatic methods with a proven record (even if a theoretic basis is lacking)

I've broken the books down by discipline in a crude fashion. However, even with that subdivision and the annotations the list is somewhat daunting; remember, I've had decades to gather these books and go through them. As an aid to the perplexed I've thus included a set of themed reading lists, each providing about 5 works that are good places to start.

Scope

The specific scope of this collection is any work that contributes towards an understanding of the design, construction, or analysis of urban areas. In a spatial sense, some works treat entire urban areas as items and look at phenomena at a global scale, while others consider the inside of a building in detail and treat the outside street, neighborhood, and city as context. The spatial scale is thus vast. The temporal scale is similarly large.

I've broken down a crude scale hierarchy for space and time, and each work is placed within that context as part of the annotations; in some cases this was very difficult as the work was either abstract or else so diverse that the answer was of limited value. Use the scale notes with caution.

As for the conceptual scope, while I realize that in the long run the real goal is to analyze and thus understand spatial behavior in urban areas, much of the knowledge of what spatial areas are must arise from an understanding of their design and construction. Especially if the cross-cultural barriers to spatial understanding are considered, a deep understanding of details such as ornamentation of buildings, patterns of habitation of buildings and the evolving use of the space between them, and the form and evolution of neighborhoods is essential. As pointed out in a previous report, if we are to understand urban areas, the difficulty lies as much in the semantics of those spaces that arise from cultural specificity as it lies in methods for acquiring spatial data and storing it. The terrain matters, but the human terrain matters more.

This of course widens the scope somewhat on what we can and should consider worthwhile, and the provided references reflect this view.

The "History" Versus "Accepted" Versus "Cutting Edge" Distinction

One thing that will be readily apparent when looking at the references that comprise the bulk of this report is that I do not discriminate against, in fact openly suggest seeking out, historical materials.

First, a document that seeks to define the "leading edge" will be out of date immediately. This is to some sense inevitable with a bibliography, but if I were to focus on the newest publications the effect would be greater than if I focus instead on the key works.

Second, key works are in some sense only recognizable after the fact. Scientists are no better than anyone else at predicting what will be the 'big thing' in a decade, and reference works to some extent can only be recognized as milestones by the influences they exert on future work and the imagination of those who read them.

Finally, in my judgment writers have become less skilled at abstract forecasting and evaluation: where once a writer would predict a general approach of merit, more writers nowadays appear to focus on the widgets and gadgets of the future. Perhaps this is a personal bias, but I care less for the next flavor of cell phone or iPod than I do for the next general approach to handling information, or better yet the one after that.

As a result the references provided are from a broad range of times; while reading Vennevar Bush's prediction of mechanical reference networks may seem quaint, we should also remember that he laid out the architecture for the World Wide Web almost 50 years in advance, and with far more vision towards human-centered tools than was realized in the Web, even as it stands today.

Of course, the truly key works are those that, like Bush's writings, lead to inventions or co-evolved with them. As Alan Kay said, "the best way to predict the future is to invent it."

Foundation Concepts

There are a number of concepts that are foundational to this report, and which are so embedded in the comments on books that I believe some level of introduction of their meaning and use is essential. This is not an exhaustive treatment by any means.

GIS and Cartography

GIS, or Geographic Information Systems, are software tools that are meant to support the collection, display, analysis, and sharing of spatial data. In other words, a GIS supports making maps or drawings of spatial situations – towns, streets, countries – and annotating them. The real power of a GIS tool is that if the annotations are consistent and complete, say for example a building being annotated with who has lived there for some number of years, then sophisticated analysis is possible. There are obviously issues of data quality, confidence, analytical methods, and so on, but in principle building spatial datasets allows sophisticated spatial analysis.

One truism of GIS is that it is painful to build spatial data but easy to share it; as a result careful documentation and consistent annotation are crucial, and the Internet is a broad platform for dissemination of such data. Data repositories now provide widespread access to spatial data either within the web browser (e.g. Google Maps) or within a specialized application (e.g. Google Earth or ArcGIS).

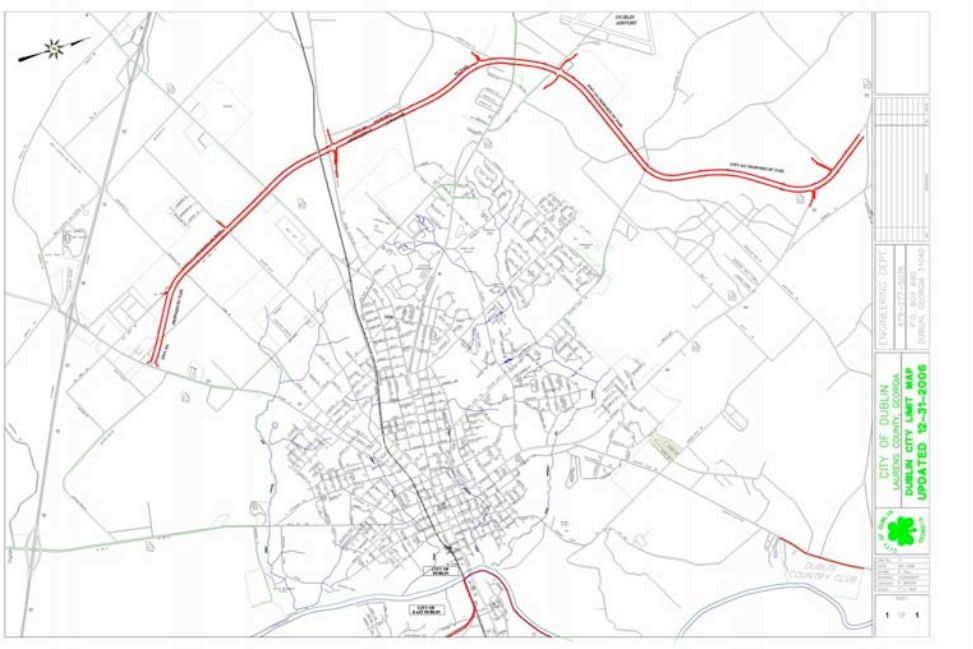
Cartography is somewhat distinct from GIS, in that the ultimate goal of cartography is the production of effective maps that clearly communicate; this is subsumed in GIS into the larger problem of the data, and sharing that data, and analyzing any available data. The flip side of this is that GIS tools were originally designed primarily as support for cartographic tasks, and analysis in the form in which cartographers were familiar with working. In other words, GIS tools for the most part excel at two-dimensional representations and two-dimensional analysis of map areas. Obviously for an urban area this is something of an issue.

The treatment of three dimensional situations with spatial analysis and so on is currently spread between the field of visualization (of the shapes), 3d GIS (attempts to build 3d versions of the 2d GIS methods) and computer graphics and mathematical theory. As of yet there is no satisfactory tool for integrated GIS in 3d; in other words, the ideal urban GIS does not exist and may not exist for some time.

GIS Data Collection – Urban Case

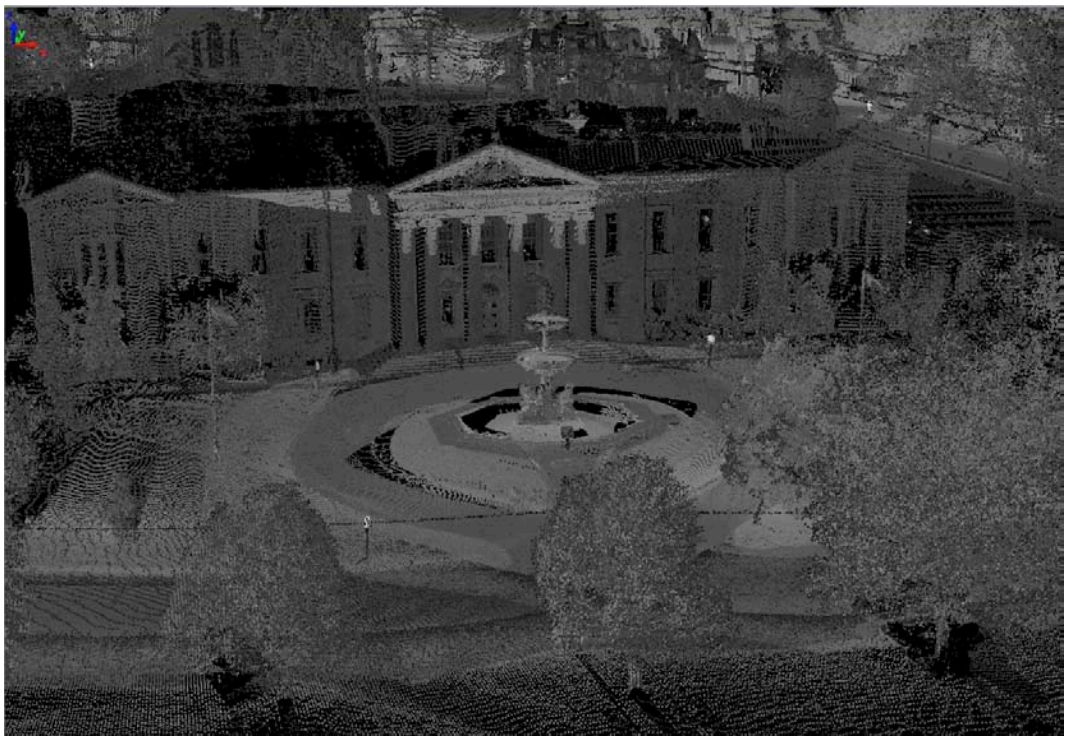
In the case of urban GIS in two dimensions, or urban visualization in three dimensions, the starting point is the acquisition of data. A number of methods exist for acquiring the needed information:

- Surveying: acquiring urban areas through traditional surveying practice. Labor intensive and very expensive, but accurate.
- Infrastructure Maps: acquiring urban data from existing, usually CAD, representations of streets, sewers, building shapes, and so on. In principle an effective approach but the original data may be only available in paper form, and may be distributed between many organizations. Maps may be out of date or deliberately false.
- GPS Surveying: acquiring urban data using Global Positioning System receivers and annotation devices. Labor intensive and limited by geometry of buildings. Passive systems (e.g. tracking vehicles to get roadways) may be useful.
- Photogrammetry and Remote Sensing: using remote sensing or airborne photography to construct maps, usually in combination with some level of GPS ground surveying for calibration.
- Vernacular photography: using available photographs (e.g. from the Web) or field photographs to reconstruct geometries. This is a new approach but shows much promise for passive generation of data (e.g. the field vehicle gets data while doing other tasks)
- LiDAR scanning: using a Laser Ranging device to acquire very accurate urban models, often accurate at the centimeter level. Expensive but has the potential to provide change detection at a decimeter scale.



CAD and the City: An example of a CAD drawing of a midsize town, in this case Dublin, Georgia. (source http://www.dublin.org)

Most urban GIS projects will include more than one data source, and managing the heterogeneous and often contradictory data sources is a prime problem for geographic field staff.

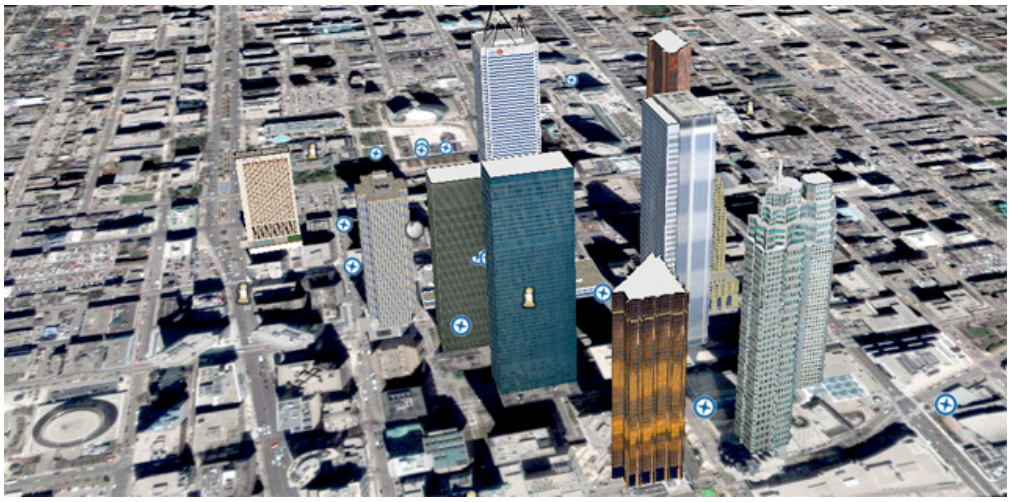


The future of urban data collection? LiDAR imagery of the Kingston courthouse, collected with the Terrapoint TITAN mobile scanner at driving speed.

Visualization

The visualization approach, discussed briefly above, is to treat urban areas as three dimensional rather than the traditional two dimensional approach of historic GIS. Acquired 3d field data is viewed as some combination of geometric objects and imagery. To date the emphasis within visualization tools has been on model construction and photorealism, reflecting the market for these tools in industrial design and cinematography. More recently, and with the urban visualization market growing, an increased emphasis on ease of use and analysis has come about.

A more recent trend has been to build visualization tools for the 'masses,' the prime example of this being Google Earth and Google Sketchup. These are not photorealistic tools by any means, but their reach is very wide and their user base exceeds all other visualization tools combined. Note that Sketchup is based directly on the ideas of Ivan Sutherland expressed in his tool SketchPad; it is rather sad that between 1963 and the early 2000's these ideas had seen little use other than in hard-to-use CAD tools. We teach students to model buildings in Sketchup in a few minutes, whereas 3d Studio Max or other high end visualization tools have a learning curve measured in months. Of course, Sketchup is limited. The question is, though, whether the limitations really affect the intended use.



Toronto seen in Google Earth: Buildings constructed from a few polygons in SketchUp and faced with textures look surprisingly good.

Research Domains in the Digital City

The major domains of research relevant to the "Digital City" idea are varied at at first examination may seem unrelated. I provide a brief idea of each major domain and why it is relevant here. A full discussion of each domain would comprise a technical report on each and so I've opted for brevity; consult the reference lists for more information on any of these.

Computer Science and Computer Graphics

Computer science research pushes the limits on how formal languages can be used to model phenomena. For many computer scientists, urban simulation problems are familiar enough to be targets for research; for many of the funding agencies, urban problems are pressing enough to justify targeted research initiatives. Computer graphics research, more recently, has taken on an urban focus because of the realization that video games and urban visualization tools like Google Earth require highly optimized graphics and furthermore offer good potential for commercialization of new methods.

Within computer science and computer graphics, recent highlights include work on procedural modeling of buildings and cities, new methods to use high-performance graphics cards as model co-processors, and work on efficient representation of very large, complex scenes such as cities.

Urban Design and Urban Planning

Urban planning and urban design work is at the intersection between the politics, engineering, and aesthetic of blocks, neighborhoods, and cities. It is always situated in an economic and, increasingly, sustainability framework. As a result, the literature is diverse and the influences great. The specific design literature I focus on is that which addresses the interface between people, architecture, and urban areas

at the block to superblock level; this is a small subset of the entire field and downplays political issues in favor of pragmatics.

In terms of urban analysis, the advantage of this focus is that the flip side of urban design – how to fill a space with buildings and streets and so on – is urban analysis – how people use space, what might be around the next corner, and so on. This is, as yet, an underdeveloped area; most urban planners use methods that GIS and computer science practitioners would consider primitive. This of course means that there is great opportunity for new tools, and the work of urban generative modelers in computer science is a great example of a need being filled.

Architecture

Architecture can be divided into two rough camps: architecture of buildings as aesthetic statements ("Great Architecture") and the architecture of useable buildings for everyday use ("Pragmatic Architecture"). I have a very low opinion of the first type: it is more about the ego of the architect and current fashion than it is about harmony and usability, or at least that seems to be the trend. While the creations of Frank Gehry may look startling, they are for the most part neither sustainable nor human-centered.

Vernacular architecture and pragmatic design covers the vast majority of buildings, thankfully, and as with urban planning the flip side of these is the foundations for analysis of urban and building spaces based on an understanding of conventions and forms. While CAD tools and Visualization tools are well suited for supporting architectural design and engineering, there is to date a general lack of easy to use tools for visualizing building interiors and moreover analyzing them. Again, an opportunity for someone, as yet realized. My intuition is that some combination of urban game and training system will realize this niche in the very near future. From the point of view of urban warfare this is a central need.

Design

Design in and of itself is about effective techniques for individuals or groups to be both creative and efficient. Creativity support in and of itself is non-trivial since we for the most part don't really understand what creativity really is. Certainly the pragmatics that come from architectural and industrial design practice give us some sense of what some rules might be.

Thinking about design divorced partially from specific instances is an example of abstraction or generalization, and it is my view that many of the key design principles derived from GIS and urban design will turn out to have importance in framing urban analysis questions; as an example, my view that cultural issues permeate understanding space is simply a restatement of the design goal of making sure that a design serves the target audience.

Design research of interest focuses on how groups make decisions, how tools can effectively support the group and their interaction with a larger community, and how design ideas can be used in automated design support tools.

GIS

GIS tools provide a foundation for spatial model building, analysis, and communication. GIS arose from cartography, as noted elsewhere herein, and this has limited its applicability to at least detailed, fundamentally three-dimensional, urban questions. The poor support for time in GIS is also a challenge since for the most part we are interested not only in the three-dimensional configurations of urban areas but how these change over time.

Key areas in GIS research that are addressing these issues include the application of automata to the study of growth, the application of reasoning systems and discrete event systems to the creation of agent-based simulations, and the refinement of knowledge representation strategies for spatial data to support both formal and informal systems of concepts. In terms of detailed urban areas, the field has been upset somewhat by the arrival of extremely simple and popular visualization tools like Google Earth; as of yet these lack any real analytical capacity but the rate of change of these is very high.

Urban Infrastructure and Data Collection

The renewal of urban infrastructure in North America represents expenditures on the billions of dollars a month scale; any methods that can save even a tiny portion of this will be welcomed by the civil engineering community and city engineers. Yet this is a community that is only slowly moving from simplistic CAD models towards GIS and visualization tools.

Urban data collection using remote sensing, surveying, GPS, and LiDAR are a huge target for research in optimal workflows, improved automation, and improved dissemination of results. Whereas most cities currently have tens-of-meter accurate models of their infrastructure, in the near future they expect to have centimeter accurate one-time models and some are moving towards change detection using multiple centimeter accurate models. LiDAR and truck-mounted photogrammetry are driving this surge in data collection, and research is widespread on all aspects of these problems, but one of the main driving forces in urban data collection is actually…

Gaming

Digital games have gone from simplistic to ultra-realistic in ten years. Their target audience is so large and affluent that the largest single driving force in the price of computer hardware today is the gaming market. As noted, game algorithms are a major focus in computer science.

As an academic field, and to an extent as a publishing target, gaming is relatively new. Many of the works published are academic criticisms of the field from a philosophical or sociological perspective, but design-centered works are starting to appear and, like my focus here on urban design in the large, are diverse and inclusive.

Gaming blurs into training and simulation, and offers a pragmatic testing ground for new ideas. My intuition is that GIS will, in the long run, be a branch of gaming at

least in economic terms. Already one of the main markets for high resolution urban models from GIS is the game developer community.

The Bibliography

I've included a lot of works that I find inspiring; some are rather tangential to the urban design problem, but they influenced how I approach this and all topics and so they are included. I've tried to stick with works that I feel are useful; only a few negative reviews are included. However, a book being absent from the list does not correspond to my not feeling it is useful, I may not have seen it, so feel free to contact me with suggestions (see below).

I've grouped the works in crude categories for ease of access, and included reading list suggestions afterwards. I've also categorized, roughly, the spatial and temporal scale according to the crude framework that follows.

Spatial Scale Framework

The spatial scale of the works here in ranges from the very large to the very small; from countries to small items within rooms. Other works are aspatial – they describe concepts that are not inherently rooted in one scale, or make a consistent effort to situate themselves across scales.

The dominant scales I will examine are:

- Abstract: space is mentioned, but it doesn't particularly matter what the length scale is.
- Aspatial: works with no specific scale, either by intent or by nature.
- Global: works that address issues at the largest scales. Countries and large regions are the components within such works.
- Regional: works that address issues at the scale of hundreds of kilometers. Only the largest cities cover significant portions of such spatial extents. Most towns and cities can be represented as point-features therein.
- Metropolitan / pan-Urban: works that address issues at the scale of tens of kilometers. Large cities encompass entire regions at this scale. Groups of smaller cities comprise districts.
- Urban: works that address issues at the scale of kilometers. The largest features represented are districts within large cities, or towns and villages in their entirety. Major streets are represented as lines, smaller streets are generalized or absent.
- Super-block: works that address issues at the scale of hundreds of meters to kilometers. The largest features are major transportation corridors, barriers, and district edges; all streets are represented in some form, but alleys and paths may not be. This is the scale of traditional detailed city street maps. Notably, very large buildings are represented directly at this level.
- Block: works that address issues at the scales of tens to hundreds of meters. Plans of individual streets, engineering drawings of subdivisions and large buildings, detailed streetscapes and the like are at this level of

representation. At and below this scale the investigation is fundamentally three dimensional.

- Building or Lot: discussions at the scale of a mid-sized building to all of the structures on an average parcel; certainly the scope is less than 30x30m and detail includes architectural style
- House or Internal: work at the scale of an individual small building or house; CAD or 3d Modeling representations predominate, and models include architectural styling, significant detail to visual realism, and inclusion of utilities. Some models may have functional representations of openings such as doors and windows.
- Detail: modeling of architectural details, street furniture, plants, and room contents at the .1 to 5m scale. Emphasis is on components for use in higher level models. Functional and physical-simulation representations are common at this scale.
- Microscale: works that address items directly, but retain some connection to the larger spatial context. Design documents about controls in a room, or placement of microsensors, are typical examples. As embedded sensors become more common in the near future work on this scale will expand.

The books and papers reviewed below are placed in this context. Note that GIS predominates at the upper scales (global to block), CAD at middle to small scales (Super-block to microscale) and modeling tools such as 3d Visualization software are predominately used at the block to detail scale.

Temporal Scale Framework

Traditional GIS and CAD tools represent time poorly if at all. Although the representation of time has been covered in great detail in the robotics, AI, and plan/simulation literature, the use of time is at best primitive in GIS because the historical focus of these tools was on capture and use of data from cartographic products, which already have implicate time.

In GIS a distinction is made between time as represented in the data – the time of the events captured, or the temporal scope of the datasets – and time as needed to accurately annotate the dataset themselves – the operator time of the creation, use, and archiving of the datasets as datasets. This is discussed in detail in Peuquet (2002).

If there is any single fatal weakness of traditional GIS approaches for representing and simulating urban areas at any spatial scale it is the weakness of temporal representations. This is generally recognized in the scientific literature and yet the inherent weaknesses have not been substantially addressed despite more than three decades of discussion.

The temporal scales inherent in the work discussed in the bibliography, vis a vis dataset time, are:

- Atemporal: there is no time, at least at human scales of observation, inherent in the data. Positions of continents at human scales are an example.

- Abstract: Time is mentioned, but it doesn't particularly matter what the time scale is.
- Centuries: phenomena represented remain essentially unchanged over more than a century. Slowly evolving river courses, dynamic topography, and the like fall into this category.
- Decades: phenomena and objects are unchanged over tens to perhaps a hundred years. At the large scale, some buildings fall into this category, though at the smaller scale changes are likely occurring.
- Years: phenomena and objects change over a few years; this corresponds to the normal electoral cycle in democracies, the typical planning cycle of cities, and the gradual evolution of buildings under occasional renovation.
- Sub-year: phenomena and objects change over a few weeks to months.
- Daily to weekly: phenomena and objects change on a daily basis; a high level view of a warehouse or of outcomes in a classroom might be represented at this scale.
- Chronological: phenomena and objects can be realistically expected to change over minutes to hours; the use of human scale timing is needed. Human activity occurs at this scale: traffic, pedestrian movement, transactions in stores, and so on are all expected to be significant over a few minutes.
- Narrative Time: human stories are almost-chronological, but sometimes skim across time to suit the pacing of story. Much human understanding is story based. As a result, some time scales are best explained as 'variable from chronological to larger, to suit the telling of events as a story.'
- Physical time: time has no inherent granularity, but is a continuum over which phenomena are modeled. Physical laws such as ballistics occur at this scale. This scale is significant because time is no longer viewed as snapshots but instead as an index. GIS and CAD tools are generally incapable of this level of representation, but physics-based modelers are only useable at this level.

Atemporal and physical time are fundamentally different views than the other, snapshot-based, representations. Most of the papers discussed here are at the chronological to year timescale.

In terms of operator time, the crucial temporal issue is scope: will a dataset become invalid over time? What is that range of time? Is it related to other datasets or phenomena? A detailed look at this is beyond the scope of this review as it has been essentially not studied in the urban literature.

Suggesting Additions To The List

As shown by the 'version' number on the title, it is my intention that this document will evolve as I read more. Given the flood of available things to read and limited time to find, let alone read it, I encourage you to send me a note when you come across a gem even marginally relevant to the overall topic of this report. In fact, send me anything you think is of high quality even if it isn't particularly relevant!

I'll include suggested materials in future versions and will acknowledge the source if you wish. Send an email to Harrap@geol.queensu.ca or a note to me at:

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Math and Statistics

Introductory:

Burt, J.E., Barber, G.M. 1996 Elementary Statistics for Geographers, 2ed. Guilford Press, 640pp.

A solid introduction to statistics and spatial statistics focused on the needs of geographers and geoscientists. [abstract space and time]

Huff, P. 1954 How to Lie with Statistics. Norton and Co.

The classic reference to the deliberate and accidental lies that statistics can generate. Very short and readable, and a good companion to Monmonier's follow-up, How to Lie with Maps. [aspatial, atemporal]

Poundstone, W. 1992 The Prisoner's Dilemma: John von Neumann, Game Theory, and the Puzzle of the Bomb. Anchor Books. ISBN 0 385 41580 X.

A very readable and strangely haunting book about the origin and social history of game theory, the formal mathematical analysis of games used in simulation studies. Game theory is central to the idea of payback and risk analysis, and this book, although not overly mathematical, gives a good, intuitive grounding in the subject. [aspatial, historical]

Singh, S. 1999 The Code Book: The Science of Secrecy from Ancient Egypt to Quantum Cryptography. Random House, New York, 410pp.

As with Schneier's book, is this a book you want to read, or a book you need to read? Actually, to me it is a fascinating study of how math and, later, computers have been used in politics and war. However, it also covers enough about encryption and decryption to give you a background when you need passwords and encryption! [aspatial, historical]

Intermediate to Advanced:

Biermann, A.W. 1997 Great Ideas In Computer Science. MIT Press. 0-262-52223-3.

Biermann provides a solid overview of introductory computer science, in a readable and thorough style, making this a good self-study guide. Starts at square one and gets as far as basic AI techniques. [aspatial, atemporal]

Simon, H.A. 1969 The Sciences of the Artificial. MIT Press, Cambridge, Mass. 123pp.

This book is a thousand pages of insight crammed into just over a hundred pages of text, and it reads wonderfully. But you'll read it about once a year for several years, learning more every time. Simon, one of the founders of AI, was a management scientist, computer scientist, economist, and the list goes on. Full of profound insights, some of which we can only recognize because they've come true since he said them (note the date...). [abstract but with concrete references: aspatial, narrative time?]

Teorey, T.J. 1994 Database Modelling and Design: The Fundamental Principles. Morgan-Kaufman ISBN 1-55860-294-7

A practical, well referenced introduction to database systems modelling and design. Not for the amateur, but a good place for an amateur to start on the road to being an expert, or at least the experts so inform such amateurs as myself. [aspatial, atemporal]

Computers and Computer Science

Introductory:

Hernandez, M.J. 2003 Database Design for Mere Mortals, 2ed. Addison-Wesley, 611pp.

A very good introduction to database design; since relational and object-relational databases are the foundations of most spatial information systems, understanding how databases work is a core skill for urban analysis. [aspatial, atemporal]

Morville, P. 2006 Ambient Findability. O'Reilly, 190pp.

A fabulous introduction to search and organization on the Web. Morville covers everything in exactly the right detail to provide an introduction without bogging down in the details. Should be required reading for anyone organizing resources for others to use. [aspatial, chronologic to narrative time]

Nisan, N., Schocken, S. 2005 The Elements of Computing Systems: Building a Modern Computer From First Principles. MIT Press, 326pp.

Treats understanding of computers in a constructive fashion – more of a tutorial than a text, leads students through steps in building the major subsystems of a modern computer, from hardware to software. Excellent and challenging to anyone from novice to master. [aspatial, atemporal]

Raymond, E. 1991 The New Hacker's Dictionary. MIT Press. 0-262-68069-6.

Many of the terms used in computer science and GIS have origins in the hacker culture of the 1960's and 1970's. Although by no means essential to everyday work, this dictionary is a good reference for the technical meaning of terms such as interrupt, crash, and cracker. [aspatial, historical]

Rolland, F.D. 1998 The Essence of Databases. Prentice-Hall, London, 226pp.

A very useful, to-the-point guide to databases, SQL, and design. This is, in short, the stuff you should know backwards if you are in the geomatics community, and the starting point for developers and computer science types! I've used this book for teaching for years and it serves well. [aspatial, atemporal]

Schneier, B. 2000 Secrets and Lies: Digital Security in a Networked World. John Wiley and Sons, Indianapolis, Ind. 414pp.

Unfortunately, you need to read this. Fortunately, it is a great book. Enough said. [aspatial, historical]

Stokes, J. 2007 Inside the Machine: An Illustrated Introduction to Microprocessors and Computer Architecture. No Starch Press, 292pp.

A fascinating introduction to the low-level design and operation of CPU's, with an emphasis on the history of the Intel 4004-8086 series (which are inside most modern desktop and laptop computers). Probably more than anyone needs to know to do GIS or urban analysis, but you never know! [microscale, physical time]

Tannenbaum, A. 2002 Metadata Solutions: Using Metamodels, Repositories, XML, and Enterprise Portals to Generate Information on Demand. Addison-Wesley, 490pp.

More than you ever wanted to know about metadata, but that's probably good, because metatadata is central to building information resources, GIS and otherwise, especially if finding those resources in large collections is important [aspatial, physical to years time]

Taylor, D.A. 1998 Object Technology, A Manager's Guide 2ed. Addison-Wesley, 203pp.

A compact, well written guide to what object oriented software, databases, and design are about. Not technical at all, yet still gets the crucial points across. [aspatial, atemporal]

Watson, R.T. 2005 Data Management: Databases and Organizations 4ed. Wiley, 603pp.

A reasonably gentle introduction to database issues and organizational issues in implementing information technology. A good follow-on to Rolland's book. [aspatial, chronologic to years time]

White, R., Downs, T. 2006 How Computers Work, 8ed. Que Books, 452pp.

A solid, highly visual introduction to how hardware and software works, biased towards Windows machines. Excellent coverage of everything from chips to printers to application programming. Very easy to read, and suitable for novices. [microscale, physical time]

Intermediate to Advanced:

Cormen, T.H., Leiserson, C.E., Rivest, R.L., Stein, C. 2001 Introduction to Algorithms 2ed. MIT Press, Cambridge, Mass. 1180 p.

If you want to design and implement efficient code you need to have a good reference on algorithms - and this is a good start! Less intimidating than Knuth, and complete with code in Java in this edition. Not exciting reading, but not meant to be, either! [aspatial, atemporal]

Date, C.J. 1975 An Introduction to Database Systems. Addison-Wesley.

The classic, though rather computer-science-heavy introduction to database systems. There are many other books on databases available, but Date defined many of the terms and concepts of modern database theory in this book, and so it remains essential to serious database hackers. A recent, up-to-date edition is available. [aspatial, atemporal]

Duda, R.O, Hart, P.E., Stork, D.G. 2005 Pattern Classification 2ed. John Wiley and Sons, New York. 653pp.

Is it AI? Is it not? Well, I'm putting it here! A bible of pattern recognition/classification methods, with abundant methods relevant to data mining, geomatics, and AI. Intimidating, but a great reference. The math isn't so bad if you approach the book from a problem-oriented tack. [aspatial, atemporal]

Gershenfeld, N. 1999 The Nature of Mathematical Modeling. Cambridge University Press, 344pp.

A solid, scary book about math and modeling, with a bias towards physical and chemical systems. Assumes you are a grad student at MIT.... or at least that interested in math. [aspatial, physical time]

Guting, R.H., Schneider, M. 2005 Moving Objects Databases. Morgan Kaufmann, 388pp.

A computer science and logic take on handling point features that move in time. Somewhat distinct from GIS in that time is at the root of their approach, and as a result spatio-temporal analysis is a given rather than a nightmare. [abstract space and time]

Knuth, D.E. 1973 (edition) The Art of Computer Programming, Volume 1: Fundamental Algorithms. Addison-Wesley Publishing Company, Reading, Mass. 634pp.

There are much newer editions of this, I'm sure. Anyway, this is the classic programmers reference. People refer to it simply as 'Knuth.' The subsequent volumes dissect such problems as searching, sorting, and so on in more detail, but start here. Though you'll need to know a lot of computer science to even read the densely packed pages. [aspatial, atemporal]

Mitchell, M. 1996 An Introduction to Genetic Algorithms. MIT Press, Cambridge, Mass., 208pp.

Genetic algorithms are optimization methods based roughly on the algorithm of life - reproduction and mutation to produce offspring, weeded by selection for opimality. Mitchell introduces the methods of genetic algorithms elegantly in this slim, accessible book. [aspatial, atemporal]

O'Sullivan, D., Igoe, T. 2004 Physical Computing: Sensing and Controlling the Physical World with Computers. Thomson Course Technology, 464pp.

A good introduction to sensor networks and sensing devices at the level of electronics. As sensor-net integration becomes more pervasive these kind of sensors will become a core part of near-real-time GIS analysis. [abstract space, physical time]

Computer Graphics

de Berg, M., van Kreveld, M., Overmars, M., Schwarzkopf, O. 2000 Computational Geometry - Algorithms and Applications 2ed. Springer, Berlin, 367pp.

A comprehensive review of the mathematics and computer-science of geometric forms, with some attention to the relevance of these approaches to GIS. Useful as a pathway to understanding how topological GIS works, for example. [aspatial, atemporal]

Foley, J.D., Van Dam, A., Feiner, S.K., Hughes, J.F. 1990 Computer Graphics: Principles and Practice, 2ed. Addison-Weslet Publishing. ISBN 0-201-12110-7.

A classic, encyclopediac reference on theoretical and practical issues in photorealistic computer graphics. The book is very clearly written, and explains all of the fundamental concepts and methods that GIS systems exploit. The overall aim of this book is more towards realistic scene building rather than interactive graphics, but the overall coverage is so good that the book remains a very good reference. [aspatial, atemporal]

Hansen, C.D., Johnson, C.R. (eds) 2005 The Visualization Handbook. Elsevier, 962pp.

An exhaustive collection of papers on visualization and graphics from the computer science perspective. Some good overview papers, but much of it is devoted to studies of particular toolsets rather than methods or approaches.[microscale to global, physical time]

Lamb, T., and Bourriau, J. 1995 Colour: Art and Science. Cambridge University Press. 0 521 49645 4.

A solid introduction to the perception, description, and application of colour. [aspatial, atemporal]

Rosenblum, L. et al. 1994 Scientific Visualization: Advances and Challenges. Academic Press.0-12-227742-2.

A collection of papers concerning visualization of scientific data. The sections on next-generation tools and on global data visualization are good. The overall level of this book is quite advanced, but for specific problems it can be quite useful. [microscale to global, physical time]

Russ, J.C. 1995 The Image Processing Handbook. CRC Press. ISBN 0-8493-2516-1

A complete and rather overwhelming introduction to image processing, and a very useful resource for remote sensing specialists and lay-users alike. Profusely illustrated, and so profusely expensive. [aspatial, atemporal]

Project Management

Brooks, F.P. Jr. 1975 The Mythical Man Month: Essays in Software Engineering. Addison-Wesley. 0-201-00650-2.

Brooks was the system architect of the first large operating system, OS 360 at IBM. This book is about the sociology of software design - how teams interact, how information passes or does not pass between coworkers, and how to get projects done on time. One of the most important books of modern computer science, because it demonstrates clearly that we have known for twenty years how to solve the problems that dominate all modern software projects, but lack the will or wisdom to apply the cure. [aspatial, chronologic or narrative time to years]

DeMarco, T., Lister,T. 1999 Peopleware - Productive Projects and Teams, 2ed. Dorset House, New York, N.Y. 245pp.

Read this book before trying to organize a team to day anything. Sure, they focus on software. It doesn't matter. A great book, and a great companion to Brooks' The Mythical Man Month. [aspatial, chronologic or narrative time]

Graham, P. 2004 Hackers and Painters: Big Ideas from the Computer Age. O'Reilly, Cambridge, Mass. 258pp.

Essays from a LISP hacker and successful Web-entrepreneur. About all kinds of things. But pay special attention to the ones on why different programming languages are different! Shouldn't be rocket science, but strangely most programmers learn exactly one language well in their career. If the only tool you have is a hammer.... [aspatial, atemporal plus history]

Spolsky, J. 2002 Joel on Software. Apress, 362pp.

A great collection of pragmatic and brutally honest discussions about project management, programming, and computer science. [aspatial, atemporal]

Taylor, A.G. 2004 The Organization of Information 2ed. Libraries Unlimited, Westport, Conn. 417pp.

Everything you thought you'd never need to know about organizing things, and a very solid overview of the process of building and maintaining indices and metadata. No, it ain't inspiring, but it's bloody useful. [aspatial, atemporal]

Decision Support Systems

Turban, E., Aronson, J.E. 2000 Decision Support Systems and Intelligent Systems 6ed. Prentice-Hall, Upper Saddle River, N.J. 867pp.

This is the classic reference on decision support. It is massive, detailed, broad, full of case studies, and authoritative. Useful but not a quick read! Note from the title that it contains a lot on artificial intelligence, so this might be considered a cross-over book to that discipline too. [detail to global, physical to years]

Programming-Specific

Friedman, D.P,., Felleisen, M. 1987 The Little LISPer. MIT Press, Cambridge, Mass., 180pp.

A very odd but good book. The whole point is to teach you to think in LISP. There is no text, just columns of questions and answers. If you have the discipline to use the book, is is a marvelous approach to learning to think in a different way. If you want pragmatic help with programming in LISP, use Paul Graham's book instead. Better, read both. [aspatial, atemporal]

Graham, P. 1996 ANSI Common LISP. Prentice Hall, Upper Saddle River, N.J. 432pp.

LISP is a paradigmatic language - one of the central languages you should consider at least being familiar with. Not as pragmatically useful as Python or Visual Basic, but far more powerful. And as Eric Raymond said, even if you don't use it often, it will forever make you a better programmer. Oh, the book is a very good introduction, too! [aspatial, atemporal]

Kernighan, B.W., Ritchie, D.M. 1988 The C Programming Language, 2nd ed. Prentice Hall, Englewood Cliffs, N.J. 272pp.

Not meaning to go on a rant here, but you should learn at least enough C to get a grasp of pointers as a programming metaphor. C is absolutely 'the' language for writing operating systems and low-level code. It will teach you precision and rigor. Or you will crash your computer! This is a classic book, partially because it is so short, and also because it is so complete despite being so short! [aspatial, atemporal]

Lutz, M., Ascher, D. 2003 Learning Python 2ed. O'Reilly, Cambridge, Mass., 591pp.

Python is a wonderful compromise language - cross-platform, open source, powerful, easy to integrate with other tools, readable, and accessible. Python is one of the available scripting languages in ArcGIS, which alone makes it a useful tool in geomatics. This is a good first book on Python; from here you can go on to using Web resources or to many other good Python manuals available in print. And by the way, don't even think about comparing Python to VBA or Visual Basic - I'll scream and curse at you if you do. [aspatial, atemporal]

Artificial Intelligence

Allen, J. 1989 Natural Language Understanding, 2ed. Benjamin Cummings, 654pp.

Blending linguistics with artificial intelligence with cognitive science, this has for years been the classic reference on how human language and computers can almost co-exist. [aspatial, chronologic time]

Cawsey, A. 1998 The Essence of Artificial Intelligence. Prentice-Hall, London, 190pp.

A great first book on AI. Not detailed, but just enough to decide if you want to know more. Not a history, either - see Crevier or Kurzweil for that. Just the facts, ma'am. [aspatial, atemporal]

Clancey, W.J. 1997 Situated Cognition: On Human Knowledge and Computer Representations. Cambridge University Press, Cambridge, U.K. 406pp.

An evaluation of the degree to which knowledge is embedded in situations, rather than being separate from the world. Technical but pragmatic. Clancey was one of the first expert system programmers and is thoroughly aware of why general purpose systems fail. [detail, physical time]

Crevier, D. 1993 AI: The Tumultuous History of the Search for Artificial Intelligence. Basic Books. ISBN 0-465-00104-1

AI is at the core of recent advances in GIS - we now have huge (terabyte) datasets, but it is virtually impossible to find anything in them. Cooperative tools with limited programmatic reasoning are one approach. Crevier covers the history of AI without providing much of a technical basis, making this a good historical but not technical introduction. See Kurzweil for a more technical (and much longer) introduction, and Luger& Stubblefield for a 'how-to' approach. [aspatial, atemporal plus historical]

French, R.M. 1995 The Subtlety of Sameness: A theory and computer model of analogy-making. MIT Press. 0-262-06180-5.

A PhD thesis rewritten as a book. Fascinating attempt to use a hybrid statistical-emergent programming paradigm to study analogical processes in a micro-domain, that of the dinner tabletop. French provides an excellent example of how emergent systems can solve complex problems without suffering the combinatorial explosion or brittleness problems of traditional expert systems. The introduction and conclusion chapters are reasonably general introductions to analogy in AI, and the core of the book is a detailed examination of the hybrid architecture of Tabletop. [detail, physical to chronologic time]

Giarratano, J.C., Riley, G.D. 2005 Expert Systems Principles and Programming, 4th ed. Thomson Course Technology, 842pp.

A very solid and pragmatic introduction to expert systems from the people who brought you CLIPS, a standard and freely available expert system shell. Not a general introduction to AI, not a programming guide, something in between. By the way, I really hate the idea of calling a publishing company 'Thomson Course Technology.' Give me a break. What are we going to call books in the future - static carbon-based software? [aspatial, physical or narrative time]

Hoftstadter, D.R. 1979 Godel, Escher, Bach: An Eternal Golden Braid. Random House, New York, N.Y. 777pp.

Cognition, logic, music, art, humor, cryptography, mythology, and a lot more all woven together into a study of strangeness in thought and music and art. Fabulous, a very difficult read, but wonderful mind training. Hofstadter is a brilliant writer, and there are so many layers herein that I really wonder if I've actually read it, or just seen one level, or... [abstract, but inherently about detail scale and chronologic or narrative time]

Kurzweil, R. 1990 The Age of Intelligent Machines. MIT Press, ISBN 0-262-61079-5.

A classic and very detailed historical and technical introduction to artificial intelligence. Enough history to put things in context, and enough technical content to provide a basic understanding of the major issues in knowledge representation, machine learning and so on. Excellent contributions from many of the leading researchers in AI. [aspatial, chronologic time]

McCorduck, P. 2004 Machines Who Think, 25th Anniversary Edition A.K. Peters, 565pp.

A thorough and interesting technical history of artificial intelligence. Despite being technical, it is quite accessible, and makes a good introduction to the broad themes in A.I. [aspatial, atemporal plus decades of history]

Minsky, M. 1985 The Society of Mind. Simon and Shuster, 339pp.

A collection of 270 one page essays on how the mind might work. Simply brilliant. Even if you disagree with Minsky's thesis, this is a great book just to explore ideas. Minsky has a marvelous eye for everyday things that are actually very curious. [aspatial, atemporal]

Openshaw, S., and Openshaw, C. 1997 Artificial Intelligence in Geography. John Wiley and Sons, New York, N.Y. 329pp.

This is the only accessible book about geospatial AI that I know of. It is quirky, occasionally obtuse, broad, narrow, and frustrating. The coverage of some subjects is detailed, yet that of others is sloppy at best. I'd recommend it only to those who really need to have covered all of the possible sources, which isn't much of a recommendation, is it? [metropolitan to global, years to decades]

Stefik. M. 1995 Introduction to Knowledge Systems. Morgan Kauffman, ISBN 1 55860 166 X

An exhaustive, clear, and essential guide to representing knowledge in any form, and in particular, to representing knowledge using computer systems. The coverage of symbol systems, representation, and semantics are the best I've read, and the well-reasoned examples illustrate the technical material very well. Knowledge Systems are to GIS' what GIS is to CAD - the next evolutionary step, and the challenge of building a meaningful geoscience information system, as opposed to a confused one, is well aided by books such as this one. [microscale to building scale, physical to narrative time]

Cognitive Science And Philosophy

Brockman, J. and Matson, K. (eds.) 1995 How Things Are: A Science Tool-Kit for the Mind. Morrow. ISBN 0-688-13356-8.

The best guide I've seen to what science is and isn't, and the philosphical implications of different scientific viewpoints. The chapters are written by distinguished scientists who, in writing about an aspect of what they do, and the philosphical implications they feel are central to their results. [varies widely]

Berger, J. 1972 Ways of Seeing. Penguin, 166pp.

A brilliant series of lectures, illustrated of course, on what art is. Fabulous, somewhat controversial, and decidedly non-academic. Provides a useful side-course on understanding cultures. [aspatial, narrative time and centuries of history]

Carter, R. 1998 Mapping the Mind. Pheonix Press, 372pp.

A great overview of the brain, of mental function, and perception. Focuses on the localization of function in the brain, but a fun read nontheless! [aspatial, atemporal]

Gaarder, J. 1991 Sophie's World - An Adventure in Philosophy. Pheonix House, London, U.K. 405pp.

A novel about a girl learning about philosophy, or is it a book about philosophy with a girl as the focus, or is it... Never mind. A very nice, gentle introduction to philosophy. [aspatial, narrative]

Gelernter, D. 1994 The Muse in the Machine: Computerizing the Poetry of Human Thought. Free Press 0-02-911602-3

Gelernter at his finest. He starts out arguing for and about what humans can think that computers can't, and ends up with complete, novel, startling theory of discovery, inspiration, and reasoning based on emotional memory. The problem is, he makes a fairly convincing argument that thinking won't show up on computers any time soon. [aspatial, atemporal]

Gigerenzer, G., Todd, P.M. 1999 Simple Heuristics That Make Us Smart. Oxford University Press, 416pp.

A collection of papers that introduces the concept of simple rules-of-thumb used in everyday decision making. Gigerenzer makes the point that most of our decision processes are simple, fast and frugal. [detail to aspatial, chronologic time]

Glymour, C. 1992 Thinking Things Through: An Introduction To Philosophical Ideas and Achievements. 382pp.

A fabulous, gentle, and thoughtful introduction to reasoning, philosophy, and logic. If you are only ever going to read one book on any of these topics, this should be it. [aspatial, centuries time]

Hawkins, J. 2004 On Intelligence. Times Books, New York, N.Y. 261pp.

This is a reexamination of low- to high-level processes in the brain to try to come up with a new model of memory and cognition. It is by an outsider - a technoguru with a life long interest in neuroscience - and though the results are obviously provocative, the jacket blurbs from famous cognitive scientists certainly support the general conclusions. You can be the judge. [aspatial, atemporal]

Hofstadter, D.R. 1997 Le Ton beau de Marot: In Praise of the Music of Language. Basic Books, New York, 632pp.

How do you study what translation really is? You send a poem to hundreds of people to be translated from an historic french dialect to.... whatever! Hofstadter pulls this together into a fascinating book about the nature of translation, of language, and ultimately, knowledge. [aspatial, atemporal]

Johnson-Laird, P. 1993 The Computer and the Mind. Fontana Press. ISBN 0 00 686299 3.

A readable introduction to cognitive science, as opposed to AI, although the lines blur at times. Not the best coverage of the subject, but probably the most compact and useful for the layperson. Complements MacEachren's How Maps Work well. [aspatial, chronologic time]

Klein, G. 1998 Sources of Power: How People Make Decisions. MIT Press. ISBN 0-262-11227-2.

Klein and co. spent about 20 years studying decision-making behaviour in firefighters, military commanders, and crisis management teams, and the results of their work are profound. People do not make decisions in crisis or data - limited situations using rational processes, but instead use an intuitive sense built up by experience. In so doing, they dramatically outperform those that do try to be 'rational'. Klein examines the individual, the team, and the process of learning and gives us an idea of why people outperform expectations so often (and, incidentally, why it is almost impossible to program a computer to do most tasks). [aspatial, chronologic time]

Lakoff, G., 1987 Women, Fire, and Dangerous Things - What Categories Reveal About the Mind. University of Chicago Press, Chicago, Ill., 614pp.

A ground-breaking study in cognitive semantics. How does everyday language reveal how our minds work? Categories are central to GIS and Geology, and understanding how poeple use them is essential. The follow-up book to this - Metaphors We Live By - with Lakoff and Johnson is essential reading too. [aspatial, chronologic time]

Lakoff, G., Johnson, M. 1983 Metaphors We Live By. University of Chicago Press, Chicago, Ill. 256pp.

A detailed examination of metaphors used in everyday speech and what they tell us about mental processes. Many of these metaphors are spatial, some are temporal, and we all use them here and there! Reissued 2003. [building to neighborhood scale, chronologic time]

Laurel, B. 1993 Computers as Theatre. Addison-Wesley, Reading, Mass. 227pp.

A classic, highly influential attempt to see computers as medium rather than background technology. Superb, interesting, and highly relevant to the fusion of the 'tool' approach with the 'human' approach to design. [detail scale, chronologic or narrative time]

National Research Council (US) 2005 Learning to Think Spatially. National Academies Press, 313pp.

What exactly is spatial reasoning, how do humans learn it, and how can we teach it? As a side effect of discussing the cognitive issues in map use and understanding this report does a fairly good job of providing an overview of GIS and other spatial technologies. [detailed to global scale, atemporal]

Norman, D.A. 1993 Things that make us smart: defending human attributes in the age of the machine. Addison-Wesley. ISBN 0-201-58129-9.

This book could equally be in any other catagory here. Probably the most important book on this book list. Norman is one of the parents of the Cognitive revolution in psychology, and a very clear writer on how information and structure in the real world interacts with the mind to produce confusion and chaos. What a tool is, and what data is, requires an understanding of what humans are and are not, and what limitations they have. A glorious book. [detail scale, chronologic to years time]

Reason, J. 1990 Human Error. Cambridge University Press, 302pp.

Exactly why do people mistakes make? If you want to reduce human error, this is a great study of errors and occurrence. [aspatial, atemporal]

Sterelny, K. 2002 Thought in a Hostile World: The Evolution of Human Cognition. Blackwell Publishing, 262pp.

A hard read, but ultimately rewarding. Sterelny addresses what intelligence may have evolved for! Much of the argument is rather academic, but the ultimate conclusions are far reaching and I find strangely uplifting. [detail to block scale, chronological time]

Suchman, L.A. 1987 Plans and Situated Actions: The Problem of Human-Machine Communication. Cambridge University Press, Cambridge, U.K. 203pp.

This book is really really good and really really hard to read - the style is brutal, but the content is brilliant. Suchman brings anthropological methods to the study of people using computers, with interesting results. A pioneering work. [Detail to building scale, chronological time]

Thagard, P. 1992 Conceptual Revolutions. Princeton University Press, 285pp.

Can we study science as our subject matter? Certainly. Can we study scientific change itself? Thagard examines diagrammatic methods of representing scientific change – concept change – using graph theory, software, and a historians eye to detail. Fascinating, and a treatment that is overdue for scientific data in and of itself. [aspatial, decades to centuries]

Thagard, P. 1996 Mind: Introduction to Cognitive Science. MIT Press, 213pp.

A succinct and clearly written introduction to cognitive science; provides a good grounding for understanding general cognition, and a launching point for more detailed works. [aspatial, atemporal]

Systems Thinking, Anthropology, ... and other inspiration

Ahl, V., & Allen, T.F.H. 1996. Heirarchy Theory: A Vision, Vocabulary and Epistemology. Columbia University Press. ISBN 0-231-08481-1

A wonderful, to-the-point look at heirarchical systems, their role in science, and their behaviour. To me, this rates with Kuhn's Structure of Scientific Revolutions for laying very general and overarching rules for how human understanding in science works. [aspatial, atemporal]

Casti, L. 1997 Would-be Worlds: How Simulation is Changing the Frontiers of Science. Wiley.0-471-12308-0

A basic overview of the use of simulations to understand the world. The coverage ranges from numerical simulations of weather to video-games as interactive explorations of system dynamics. A good philosophical overview of simulations from the leading authority on the subject. [detail to global, physical time]

Diamond, J. 1997 Guns, Germs and Steel: The Fates of Human Societies. W.W. Norton & Co., 480pp.

A fabulous examination of why certain cultures conquered the world in the last 500 years: the story turns out to be profoundly spatial, and speaks to the relationship between geography, ecology, and culture. [all spatial and temporal timescales.]

Florida, R. 2002 The Rise of the Creative Class. Basic Books, 434pp.

How do cities become culturally and economically great? What is the cultural fabric that results in this? A great book from a free-thinking scholar willing to say unpalatable things and stand by them. [urban to metropolitan scale in a global context, years timescale]

Gelernter, D. 1991 Mirror Worlds, or The Day Software Puts the Universe in a Shoebox... How it will happen and what it will mean. Oxford University Press, 237pp.

An examination of what networked knowledge and distributed sensors could mean for the future. Note the date – this work significantly predates the World Wide Web yet predicts many issues that we now (in 2008) see as pressing problems: privacy, security, authority of knowledge, and so on. [Virtual space; chronological to years timescale]

Holland, J.H. 1975/1992 Adaptation in Natural and Artificial Systems. MIT Press, Cambridge, Mass., 211pp.

A classic study of complexity, algorithms, evolution, and genetic processes. Not particularly accessible, but groundbreaking and with ideas aplenty! [aspatial and atemporal]

Mandelbrot, B.B. 1983 The Fractal Geometry of Nature. Freeman, 468pp.

What is the geometry of spatial features in nature like? Mathematics, art, and philosophy collide in this text which created a sensation in the 1980's and led to widespread investigation of generative methods for landscapes. [abstract space, but philosophically global to detail to microscale, atemporal]

Prusinkiewicz, P., Lindenmayer, A. 1990 The Algorithmic Beauty of Plants. Springer, 228pp.

A classic investigation of the scaling, geometric, and generative systems of plants. The underlying L-system complements the fractal concept of Mandelbrot, and has been widely adapted for use in generative urban modeling. [detail to building scale, chronological to decades time].

Resnick, M. 1994 Turtles, Termites, and Traffic Jams: Explorations in Massively Parallel Microworlds. MIT Press. ISBN 0 262 18162 2.

An account of the use of simulation to understand complex systems - systems where the individual rules of behaviour are simple, but the sheer number of interactions result in very complex behaviour. Although not as technical as other books on complex and chaotic systems, this one is very clear and moreover uses clear examples from everyday life. [detail to building level, physical to years timescale]

Design

Alexander, C. 1964 Notes on the Synthesis of Form. Harvard University Press. ISBN 0 674 62751 2.

Alexander, an architect and philospher at Berkeley, has written a series of books about how value arises in structure and form, and how design can exploit this knowledge. Alexander is an advocate of sociological design, whether the object to be designed is a building or a program, and in this he stands against the normal over scientific, over mathematical treatment of design that permeates the North American academic scene. A difficult read, but rewarding in the end. [microscale to detail, atemporal]

Brand, S. 1990 The Media Lab: Inventing the Future at MIT. Viking.

The Media Lab at MIT is a think-tank and graduate school orientied towards examining the implications of computer media for all forms of human expression, including art, music, writing, theatre, and film. Although the implications of this work for GIS and geoscience decision support systems are not immediately obvious, the overall aim of the Lab is the same as the aim of GIS/dds: to maximize the potential for humans to interact with data and with each other. A very interesting book by a very influential thinker. [microscale to detail, chronologic to decades time]

Carroll, J.M. 2000 Making Use - Scenario-based design of human-computer interactions. MIT Press, Cambridge, Mass., 368pp.

Carroll introduces an approach to designing software for real users in this academic but readable book. Yes, I'm implying that many academic books aren't readable. Anyway, scenarios are user-

centred design stories or vignettes, and I've used them many times to good effect. [aspatial; chronologic/narrative time]

Elam, K. 2001 Geometry of Design. Princeton Architectural Press, 107pp.

A concise introduction to proportion and geometry in design, with an emphasis on 2d layout issues. Beautifully illustrated, with overlays and artwork throughout. [abstract space, atemporal]

Holtzman, S.R. 1994 Digital Mantras: The Languages of Abstract and Virtual Worlds. MIT Press, 320pp.

A broad philosophical fusion of space, time, language, metaphor, and history. Ranges from artificial intelligence and the use of space to art to music. [abstract to building scale, atemporal to chronologic]

Kepes, G. (ed.) 1965 Education of Vision. George Braziller, 233pp.

A design book intended to educate the perception of space, art, and design of the reader. A series of papers, some more useful than others; some concern the use of visual metaphor in science, for example. [aspatial, atemporal]

Krug, S. 2000 Don't Make Me Think: A Common Sense Approach to Web Usability. Que Books, 195pp.

It's about Web design, but not really. It's about understanding your users when doing any design. A classic book. And perhaps not surprisingly, well designed. [abstract space and time only]

Lidwell, W., Holden, K., Butler, J. 2003 Universal Principles of Design. Rockport Press, 215pp.

A collection of design patterns, loosely modeled on Alexander's 'Pattern Language,' but focussing on general principles of design, and especially graphic design. A great browsing book. [aspatial, atemporal]

Mitchell, W.J., McCullough, M. 1995 Digital Design Media. Wiley, 494pp.

A challenging, fascinating, superb introduction to all aspects of software and support tools that influence design tasks such as industrial, architectural, and urban design projects. Fascinating, though now a bit dated; I really hope this gets updated at some point. [aspatial, atemporal]

Moggridge, B. 2007 Designing Interactions. MIT Press, 766pp.

A retrospective and collection of interviews with many of the key designers of the last 50 years. Uneven in interest level but fascinating to see how designers work and think. [aspatial, historical time]

Norman, D.A. 1988 The Design of Everyday Things, Doubleday, 257pp.

An absolute classic work on how artefacts can be analyzed, designed, built in the context of human understanding, decision making, error making. [detail to building scale, chronologic or narrative time]

Schedroff, N. 2001 Experience Design. New Riders Press, Indianapolis, Ind. 304pp.

A great book on integrated data, knowledge, information, wisdom, but not necessarily in that order! Interesting graphic design, information design, and knowledge design ideas in an unconventional form. Eminently browsable. [aspatial, chronologic time]

Schriver, K.A. 1996 Dynamics in Document Design.Wiley. ISBN 0471-30636-3.

So where is all of the data in an organization? A lot is in maps and databases, but a lot more is in documents. In an academic organization, one of the central fixtures and focusses of the place is the library. Shriver provides an excellent guide to critically evaluating exactly what we mean by a document, how users percieve them, and how to improve their usability and impact. A very important subject normally ignored completely by information architects. [aspatial, atemporal]

Schwartz, P. 1991 The Art of the Long View. Addison Wesley 0 201 48917 1.

This is perhaps the most strange and oblique book on this list. Schwartz, who runs a think tank called the Global Business Network, worked in economic forcasting for Shell for many years, and this book is a summary of the highly successful Shell approach. Interesting because the 'Long View' approach has a lot to say about how to put together a group to do long term brainstorming style work. If you want to understand why Schwartz's method works, read Klein's Sources of Power. [aspatial, chronological to principally decade time scales]

Sterling, B. 2005 Shaping Things. MIT Press, 215pp.

An odd little book. Sterling attempts to lay out the transitions from craft based to machine based to information based manufacture, design, and life. It doesn't completely work, but he has the guts to take a stab at where we may be, where we NEED to be, in 50 years. [microscale to detail scale primarily, years to decades timescale]

Wurman, R.S. 1996 Information Architects. Graphis. 3 85709 458 3.

A critical examination of how various design firms apply graphics and information design to the problem of communicating concepts and data despite the ever increasing avalanche of data available. Although this book is in many ways more a 'inspiration' than a directly applicable guide, some of the examples are directly relevant to GIS and decision support for exploration. [aspatial, atemporal]

Fiction

Stephenson, N. 1992 Snow Crash. Bantam Books, New York, 470pp.

How do you mock cyberpunk literature while elevating it to new heights? How do you describe a GIS-enabled future VR-Internet in such a prophetic way that the Vice-president of the US quotes you regularly (not that Gore gave him credit, but...)? You write a book that starts out being satire and rapidly becomes the most thoughtful work on virtuality written to date. [aspatial inherently, essentially about virtuality; virtuality at detail to superblock-representation scale, chronological time]

Stephenson, N. 1995 The Diamond Age, or, A Young Lady's Illustrated Primer. Bantam Books, New York, 455pp.

A science fiction book with a study of the nature of cultural diversity and another on the nature of educational technology hidden within. Not an easy read, but a superb book from the leading thinker on the nature of virtuality. I based an entire research project on this book - taking a few of the ideas and seeing what could be done with them - and there are many more remaining to be explored - but if you do, give Stephenson his due credit in your references. [global to microscale, chronological time to decades]

Architecture

Allen, E. 1995 How Buildings Work: The Natural Order of Architecture, 2ed. Oxford University Press, 245 pp.

A broad introduction to the design, science, and history behind architecture. Useful at a high-school level but ultimately so general it is of little real use. [Building scale, atemporal]

Alexander, C., Ishikawa, S., Silverstein, M.1977 A Pattern Language: Towns, Buildings, Construction Oxford University Press, New York, 1177pp.

What makes buildings comfortable? What keeps people sane? What is architecture, anyway? Is there a language of design? Sane design for people, and yes, the language is here. A quirky book, phenomenal, readable in many ways, a very early and elaborate hypertext, an inspiration to create useable knowledge. [global to detail scale, physical time to the scope of civilizations]

Arnheim, R. 1977 The Dynamics of Architectural Form. 289pp.

A broad introduction to the ideas of architectural mass and form. Originally a series of lectures, transcribed, edited and illustrated into a nice small book. [detail to building to block scale, chronological time]

Brand, S. 1994 How Buildings Learn: What Happens After They're Built. Viking, 243pp.

Takes Alexander's general philosophy of architecture and applies it to how buildings become better buildings over their 'lifetime.' A very interesting premise and an interesting series of case studies. [Detail to block scale, daily to decade time scale]

Ching, F.D.K., Jarzombek, M.M., Prakash, V. 2007 A Global History of Architecture. Wiley, 800pp.

A profusely illustrated reference on the global to detailed, ancient history to modern and future state of architecture and small-scale urban design. [detail to block scale, chronological to centuries timescale]

Ching, F.D.K. 1996 Architecture: Form, Space, and Order 2ed. Wiley, 400pp.

An architectural design elements book, profusely illustrated with informal diagrams. A mix of principles for educating the design sense (mass and form, connectivity, and the like) and architectural components. Broadly similar to Universal Principles of Design. [detail to building to neighborhood scale, though dominantly building; atemporal]

Ching, F.D.K. 1997 A Visual Dictionary of Architecture. Van Nostrand Reinhold, 319pp.

A guide to architectural elements, principles, and supporting science, primarily of interest as a back-up to a traditional architecture guidebook. Western-centric. [Micro to detail to building scale; atemporal]

Cole, E. ed. 2000 The Grammar of Architecture. Bullfinch, 352pp.

A book of architectural fragments, historical to modern, organized as a source of inspiration for design. A great reference if you are designing a building, or understanding historical buildings, or... [micro to building scale, atemporal except in historical sense]

Frederick, M. 2006 101 Things I learned in Architectural School. MIT Press, 202pp.

A beautiful, zen-minded flipbook that captures the essence of design thinking for architecture. Simply illustrated, multilayered. A great book. [Detail to building scale, some temporal discussions]

Giedion, S. 1949 Space, Time, and Architecture: The Growth of a New Tradition. Harvard University Press, 665pp.

This is a classic, early study of architecture and urban areas, ranging from history to pragmatic cases to academic theorizing. Highly influential in launching the academic study of historic architecture. [detail to blocks, years to centuries]

Mitchell, W.J. 1990 The Logic of Architecture: Design, Computation, and Cognition. MIT Press, 292pp.

A very challenging but to me foundational book on thinking about the representation of space. It took me months of attempts to get through this because Mitchell's point of view is so different from traditional GIS or computer representation. Classic to say the least. [detail to building scale, atemporal]

Norberg-Schulz 1965 Intentions in Architecture. MIT Press, ~300pp.

A classic philosophical study of the foundations of architectural style and thinking. Highly influential but somewhat abstract vis a vis day to day practice or a working understanding of actual cities or buildings. [building to block, years to centuries]

Rossi, A. 1982 The Architecture of the City. MIT Press, 202pp.

A review, from a Eurocentric perspective, of the co-evolution of buildings and urban areas through time. Really written for other architects, but the illustrations are very useful for thinking about spatial form and evolution. [building to neighborhood, years to centuries]

Schoenauer, N. 2000 6,000 Years of Housing (revised and expanded). Norton, 502pp.

The nature of the private house from stone age to present; explicitly cross-cultural and so a vital resource for understanding street and building patterns at a global scale. [building to superblock scale; scope is centuries but individual discussions at chronological scale as well]

Szalapaj, P. 2002 CAD Principles for Architectural Design. Architectural Press, 242pp.

A guidebook to using CAD tools to build architectural models, at a novice-to-intermediate level. Clearly illustrates some foundation concepts and tools, and uses examples from real buildings to show relevance. [detail to building scale, atemporal]

Urban Design and Urban Planning

Alexander, C., Neis, H., Anninou, A., King, I. 1987 A New Theory of Urban Design. Oxford University Press, 251pp.

The theory and philosophy behind A Pattern Language. Not as accessible, often dogmatic, and primarily of academic interest. If you find Pattern Language superb, this is worth looking at; otherwise it is not essential.[aspatial, atemporal, or at least abstract view]

Alexander, C. 1979 The Timeless Way of Building. Oxford University Pres, 552pp.

Like A New Theory of Urban Design this is primarily a work of urban philosophy. Unlike that work this verges on religion; it has an eastern religion feel to me. I find it more interesting than A New Theory of Urban Design primarily because it does lay down a rigorous aesthetic of a new approach to design. This work predates and presages Alexander's later work on urban philosophy. [aspatial, atemporal]

Duany, A., Plater-Zyberk, E., Speck, J. 2004 Suburban Nation: The Rise of Sprawl and the Decline of the American Dream. North Point Press, 294pp.

A review of the current state of suburban design in America, with an emphasis on social process and the new urbanism approach to building healthy cities. [block to metropolitan area, years to centuries]

Ford, L.R. 2000 The Spaces Between Buildings. John Hopkins Press, 225pp.

Takes a geographic perspective on the spaces between buildings: sidewalks, alleys, and parking lots. Examines their architectural impact, distribution, and significance across cultures and times. [detail to block scale, years to centuries].

Gareau, J. 1991 Edge City: Life on the New Frontier. Anchor Books, 548 pp.

Traces the evolution of metropolitan areas from towns to suburbs to mall-culture to exurbs. A broad view of the evolution of cities, in a narrative fashion, highly engaging. [neighborhood to metropolitan areas, years to centuries time]

Gindroz, R. and Urban Design Associates 2003 The Urban Design Handbook: Techniques and Working Methods. Norton, 208pp.

A casebook in effective participatory urban planning methods. Pragmatic and focused. [block to neighborhood, years]

Habraken, N.J. 1998 The Structure of the Ordinary: Form and Control in the Built Environment. MIT Press, 359pp.

An anthropologic study of the relationship between use and space. Multilayered representations of space use from the building to urban scale with reference to both idealized and historic space configurations. [detail to neighborhood scale, chronologic to historic timescale]

Hillier, B. 1996 Space is the Machine: a configurational theory of architecture. Cambridge University Press, 463pp.

A view on the mass of buildings, the spaces between them, and how we use urban space. A very difficult read but influential and interesting in its focus on the whole space, not just the buildings themselves. [detail to block scale; chronological to years timescale]

Jellicoe, G. and Jellicoe, S. 2005 The Landscape of Man: Shaping the Environment from Prehistory to Present Day, 3ed. Thames and Hudson, 408pp.

A broad, photograph-based study of urban space; for the most part historical sites are the emphasis. Very useful for the broad range of cultures covered. [Building to Urban scale, covers centuries of history but not particularly a study of building change]

Komninos, N. 2002 Intelligent Cities. Spon, 301pp.

What makes some cities innovative, and some not? Why do cities come and go in a global competitive 'marketplace?' This somewhat Eurocentric study examines these issues; as such it is not about the physical infrastructure of the city, it is about the social and political place as it affects innovation and economics. [metropolitan to global; years to decades]

Lang, J. 2005 Urban Design: A Typology of Procedures and Products. Architectural Press, 421pp.

A solid, well illustrated and effective overview of urban design methods as the title suggests. Includes topical case studies illustrating methods in practice. Very useful but not an 'original.' [building to neighborhood scale, chronologic time to decades]

Lynch, K. 1960 The Image of the City. MIT Press, 194pp.

Lynch dissects how people move through downtown areas. In doing so, he destroys many of the sacred notions of town planning, who destroy character and human pathways to appease the automobile. And he essentially invents the discipline of modern urban planning in the process. Fabulous. [Building to Superblock scale; chronological time to decades though primarily an experiential focus]

Lynch, K. 1981 Good City Form. MIT Press, 514pp.

A somewhat abstract, almost dogmatic look at the design of cities; compared to his other work a little on the long-winded side. Very solid scholarship as always but, like Alexander, ideological first and objective second.

Lynch, K., Hack, G. 1982 Site Planning, 3ed. MIT Press, 499pp

An examination of how urban sites are planned; exhaustive, authoritative, and still worth looking at! Less theoretical than 'Good City Form' and more evolved than 'The Image of the City.' [Detail to neighborhood, but dominantly block scale; years to decades]

Lynch, K. 1972 What Time is This Place. MIT Press, 277pp.

An examination of time in urban spaces: past, present, future. Time as seen via preservation of historic buildings, development time, and experiential time of the occupants of space. [Building to block level, chronological to centuries time scale]

Marshall, S. 2005 Streets & Patterns. Taylor and Francis, 318pp.

A broad ranging book on the evolution and implications of street patterns, especially for transportation and urban flow. Excellent foundation in network representation; at times this is a rather academic book but elsewhere highly pragmatic. [building to metropolitan scale, chronologic to decades timescale]

Mitchell, W.J. 1995 City of Bits: Space, Place, and the Infobahn. MIT Press, 225pp.

The relationship between real and virtual paces is increasingly tenuous, especially in the context of work and play. Mitchell, in this early work, examines the nature of real and virtual social spaces. [building to urban to virtual, chronologic or narrative time]

Moughton, C. 1998 Urban Design: Street and Square, 3ed. Architectural Press, 300pp.

A solid, somewhat eurocentric, look at the design of dense urban cores. Critical, loaded with case studies, and well referenced to say the least. If it has any flaw, it is that it ignores suburbs almost completely. [Building to block to neighborhood, years to decades]

Moughton, C., Cuesta, R., Sarris, C., Signoretta, P. 1999 Urban Design: Method and Techniques, 2ed. Architectural Press, 212pp.

A pragmatic guide to urban design techiques, quite U.K.-centric, in the form of case studies and discussions. [detail to block scale, chronologic to decades]

Rowe, C., Koetter, F. 1978 Collage City. MIT Press, 186pp.

A review of the composition of large urban areas; their composite nature, cultural mosaic, and evolution. A classic in urban planning and design. [neighborhood to metropolitan area, decades to centuries]

Shane, D.G. 2005 Recombinant Urbanism: Conceptual Modeling in Architecture, Urban Design, and City Theory. Wiley, 344pp.

A difficult, somewhat academic book that attempts to establish why city districts happen, what generates internal boundaries, and what the global culture of cities is heading towards. Uses metaphors from complex systems theory to mixed effect. [blocks to metropolitan areas, years to decades]

Schumacher, E.F. 1973/1999 Small is Beautiful: Economics as if People Mattered, 25th Anniversary Edition. Hartley and Marks, 286pp.

An openly ideological look at how we live; one of the foundation works of the environmental movement and still relevant. [Block to metropolitan, days to decades]

Urban GIS

Batty, M. 2006 Cities and Complexity: Understanding Cities with Cellular Automata, Agent-Based Models, and Fractals. MIT Press, 565pp.

A retrospective on a lifetime of using and in fact extending GIS to model cities at the large scale. A mix of math, stats, GIS, and urban design. A difficult read, but if you want to understand large scale phenomena in cities, a great book. [blocks to metropolitan areas, atemporal or at least abstract time]

Bishop, I., Lange, E. (eds.) 2002 Visualization in Landscape and Environmental Planning: Technology and Applications. Taylor and Francis, 296pp.

A collection of papers addressing the use of visualization and 3d GIS in examining problems at the scale of small regions; like all collections of papers the coverage is spotty but the papers that are here are quite good. [detail to superblock level, chronological time predominates]

Braile, R.K., Klosterman, R.E. eds. 2001 Planning Support Systems: Integrating Geographic Information Systems, Models, and Visualization Tools. ESRI Press, 443pp.

An introduction to using GIS to support planning and development of urban areas. [superblock to metropolitan, chronological to decades]

Bosselmann, P. 1998 Representation of Places: Reality and Realism in City Design. University of California Press, 228pp.

Examines the relationship between the design intent in urban areas and the choice of representation through a series of case studies. Academic interest primarily. [building to urban scale, years to decades]

Dodge, M., Kitchin, R. 2001 Mapping Cyberspace. Routledge, London, U.K. 260pp.

Treating the Internet and the Web as a place, and mapping it, leads to many new insights about geography, information, and place. Cybergeography begins here. A great book if you can loosen your mind from what is to what could be and what overlies what is and... so on. [Fundamentally aspatial and atemporal philosophical work]

Forrester, J. 1969/2002 Urban Dynamics. (reprinted by Pegasus Communications, 2002, 299pp).

An early and highly influential attempt to model the growth of cities, resource use, and hence the future of humanity. Dated but of immense historical impact. [urban to global scale, months to centuries]

Greene, R.P., Pick, J.B. 2006 Exploring the Urban Community, a GIS Approach. Prentice Hall, 495pp.

A pedestrian introduction to urban scale issues as addressed by GIS. Covers the bases and thorough, but uninspired. [superblock to metropolitan scale; chronological to years timescale]

Higuchi, T. 1975/1983 The Visual And Spatial Structure of Landscapes. MIT Press reprint 1988, 218pp.

An experimental investigation of what the perception of spatial features on the landscape means for representation in GIS, visualization tools, and media in general. A somewhat challenging read, and primarily historical, but the rules of thumb on perception and design are brilliant. [detail to regional, some temporal discussions]

Huxhold, W.E, Fowler, E.M., Parr, B. 2004 ArcGIS and the Digital City. ESRI Press, 305pp.

A focused tutorial for ArcGIS concentrating on city data and city problems. Light on theory, but does effectively teach land use skills for ArcGIS Desktop. ARCGIS SPECIFIC. [Neighborhood to metropolitan, atemporal]

Longley, P.A., Batty, M. eds, 2003 Advanced Spatial Analysis: The CASA Book of GIS. ESRI Press, Redlands, Ca. 463pp.

Normally I don't recommend collections of papers; normally I especially wouldn't recommend one that includes only authors from one school. This one is just too good and too interesting. A wide range of urban GIS issues are covered thoughtfully in this collection. Note that many of the papers are available for free download on the CASA website. [Building to Regional Scale, some temporal content]

Maantay, J., and Ziegler, J. 2006 GIS For the Urban Environment. ESRI Press, 596pp.

A broad textbook on GIS for urban analysis at the broad level – from neighborhood to region. Includes extensive case studies and profusely illustrated, and assumes no real background in GIS. [Urban to Metropolitan scale, atemporal]

McHarg, I.L. 1992 Design with Nature. Wiley, 197pp.

The 25th anniversary re-edition of a classic on environmental design. If only to consider eco-friendly alternatives when taking on development projects, this is a classic for browsing or reading. Many of the methods now used in urban GIS were originally developed by McHarg, using overlays and pencils. [detail to superblock, years to decades]

Pamuk, A. 2006 Mapping Global Cities: GIS Methods in Urban Analysis. ESRI Press, 182pp.

A broad, introductory methods book on mapping and urban analysis, with a bias towards the ArcGIS approach. Starts with a broad overview of basics, and so suitable as a first book on GIS for novices. Somewhat biased towards statistical analysis of spatial patterns. [superblock to metropolitan, years to decades]

Smith, B.L. 2006 3ds Max 8 Architectural Visualization. APress, 554pp.

A comprehensive guide to using 3ds Max 8 to build urban and building models: assumes no knowledge of visualization or software to start. Good piece of work though to my view not enough background on what the software is doing – a bit of a recipe book at times.[abstract space and time]

Infrastructure Studies

Hayes, B. 2005 Infrastructure: A Field Guide to the Industrial Landscape. Norton, 536pp.

An interesting premise, a 'wildlife field guide' to understanding features you see in the urban environment on a day to day basis. If you've ever wondered what those boxes on telephone poles are, and so on, this is a great guide, and for the huge size and abundant photos, it is quite affordable. [detail to urban scale, chronological to decades time]

Sendich, E. 2006 Planning and Urban Design Standards. Wiley, 720pp.

This is a fantastic resource for western urban planning, design, architecture, and related infrastructure systems. It is correspondingly expensive, but in my view worth every penny. A cross between a dictionary and an encyclopedia and a training manual. [microscale to urban scale, atemporal]

Geographic Information Systems

Introductory Texts:

Berry, J.K. 1995 Spatial Reasoning for Effective GIS. GIS World Books, 208pp.

A series of essays from GIS World magazine about foundation concepts in spatial analysis and GIS. A lot are presented in a relaxed style that is nevertheless challenging in terms of developing a deep understanding of statistical concepts and analytical assumptions. Excellent work.[abstract space and time]

Borrough, P.A. and McDonnell, R.A. 1998 Principles of Geographical Information Systems. Oxford University Press, ISBN 0-19-823365-5

A very solid introduction to GIS and some aspects of spatial statistics. Unfortunately not as compact as the original Borrough book, but what has been added makes this one a really useful addition to a library. Key features are a solid treatment of error analysis, fuzzy set approaches to GIS, and a detailed overview of interpolation techniques. [abstract space and time]

Bossler, J.D. ed. 2002 Manual of Geospatial Science and Technology. Taylor and Francis, 623pp.

A broad collection of survey papers on GIS, GPS, and Remote Sensing. Useful if you need targeted short material (at the level of an Encyclopedia). Unfortunately, quite expensive. [aspatial, atemporal]

Chang, K.-t. 2006 Introduction to Geographic Information Systems, 3ed. McGraw Hill. 432pp.

A good, somewhat technical introduction to GIS and spatial analysis. Specifically uses ArcGIS in exercises, making it a good fit if that is your software toolset anyway. Not quite as broad as Lo and Yeung, so unless you want the ArcGIS specificity I'd go with that book instead. [abstract space and time]

Chrisman, N. 2006 Charting the Unknown: How Computer Mapping at Harvard Became GIS. ESRI Press, 218pp.

A personal memory of GIS from one of the founders, with an emphasis on events at Harvard, where many of the core methods were developed. Primarily historical interest. [aspatial, historical time]

DeMers, M.N. 2002 GIS Modeling in Raster. Wiley, 203pp.

A solid introduction to raster modeling using Tomlin's Map Algebra. Clearly written and to the point. Map Algebra is a foundation of spatial analysis in GIS. [abstract space, atemporal]

Lo, C.P., Yeung, A.K.W. 2002 Concepts and Techniques of Geographic Information Systems. Prentice-Hall, 492pp.

A good, well illustrated, general introduction to GIS. Unlike Chang, not tied to a specific software toolset. A second edition is planned for late 2006. [abstract space and time]

Longley, P.A., Goodchild, M.F., Maguire, D.J., Rhind, D.W. 2005 Geographical Information Systems: Principles, Techniques, Management, and Applications (abridged). Wiley, 358pp.

A great collection of papers attempting to provide an educational overview of every major area in GIS. In the abridged edition, many of the papers are on the attached DVD (the full edition is very expensive). A good resource, though many of the papers are not particularly engaging. [abstract space and time]

O'Sullivan, D., Unwin, D.J. 2003 Geographic Information Analysis. John Wiley & Sons.

Authoritative, well written, reasonably complete yet not overwhelming, and affordable. Buy a copy and keep it handy. I don't find statistical techniques interesting for their own sake, but this book makes them accessible and relatively painless! [abstract space and time]

Schuurman, N. 2003 GIS - A Short Introduction. Blackwell, Malden, Mass. 169pp.

A very nice introduction to GIS that, unlike most accounts, does not discount the human side. Schuurman outlines the complex relationship between human geography, GIS, and real users. Technically limited by its length, but regardless a nice place to start thinking about GIS and its use in the real world. [aspatial, atemporal]

Advanced or Focused Texts:

Arctur, D., Zeiler, M. 2002 Designing Geodatabases: Case Studies in GIS Data Modeling. ESRI Press, 393pp.

A case-based introduction to building Geodatabases, ESRI's advanced object-oriented data storage and analysis model. ARCGIS SPECIFIC. [aspatial, atemporal]

Bailey, T.C., Gatrell, A.C. 1995 Interactive Spatial Data Analysis. Prentice Hall, 413pp.

A good, though somewhat dated, introduction to the statistical side of spatial data analysis; includes custom course software on disk. [aspatial, atemporal]

Bimber, O., Raskar, R. 2004 Spatial Augmented Reality: Merging Real and Virtual Worlds. A.K. Peters, 369pp.

An attempt to summarize the wide ranging field of augmented and virtual reality, with an emphasis on human scale features. Excellent foundations on computer graphics and physical setups, but less coverage on applications and futures. [detailed to block scale, chronologic time]

Christakos, G., Bogaert, P., Serre, M. 2001 Temporal GIS: Advanced Functions for Field-based Applications. Springer, 217pp.

A good but technical view on temporal models in GIS. Includes libraries and tools for spatiotemporal analysis on disk. Math heavy at times.[abstract space and time]

de Smith, M.J., Goodchild, M.F., Longley, P.A. 2007 Geospatial Analysis: A Comprehensive Guide to Principles, Techniques, and Software Tools, 2ed. Troubador Press, 491pp.

A reference work more than a text; detailed coverage of spatial analysis methods, tools and limitations, albeit from a dominantly GIS perspective. The computer science aspects of this text are weak, but as a single reference on spatial analysis it is unmatched. [abstract space and time]

Earle, S., Gibson, R., Walsh, J. 2005 Mapping Hacks: Tips and Tools for Electronic Cartography. O'Reilly, 525pp.

A new approach to GIS: the open source community is busy reinventing GIS and GPS tools to suit their need for free and modifiable software. Lots of useful pragmatic methods for GIS included, even if you aren't interested in home-brewed software. [aspatial, atemporal]

El-Sheimy, N., Valeo, C., Habib, A. 2005 Digital Terrain Modeling: Acquisition, Manipulation, and Applications. Artech House, 257pp.

A succinct technical coverage of the issues in representing terrain in GIS and Remote Sensing. Very useful for users with complex terrain geometries or needing to process raw data into terrain TIN or GRID files. [block to urban scale, atemporal]

Golledge, R.G., Stimson, R.J. 1997 Spatial Behavior: A Geographic Perspective. Guilford Press, 620pp.

A rich sourcebook on spatial analysis methods useable at the scale of urban modeling of individuals and neighborhoods. Very useful as a resource; a bit daunting as a book to just 'read.' Extensively referenced. [detail to urban scale, physical to years timescale]

Gould, P., White, R. 1990 Mental Maps, 2nd ed. Routledge, 172pp.

A cognitive GIS book; like MacEachern's "How Maps Work" attempts to explain people's understanding, use, and communication of space. [building to neighborhood scale, chronologic time]

Gunther, O. 1998 Environmental Information Systems. Springer-Verlag. ISBN 3-540-60926.

A very interesting but very odd book. Gunther sets out to lay a framework for systems that manage environmental data, and really doesn't pull it off. The interesting thing is that the book is still quite useful. There is too little GIS for this to be a GIS book, and the rest covers subjects as diverse as object oriented database systems and modeling, metadata management systems, and the semantics of environmental data. All of the sections are clear, informative, and useful, but somehow they just don't seem to add up to a book with this title! [aspatial, atemporal]

Kennedy, M. 1998 The Global Positioning System and GIS, 2ed. Taylor and Francis, 345pp.

An introduction to GPS and its integration with GIS. Useful if you really need to know the details of how GPS works, but don't want the engineering and mathematical minutae. [global to detail scale relevance, physical to chronological time]

Laurini, Robert, and Thompson, Derek. 1992 Fundamentals of Spatial Information Systems. Academic Press, 680pp., ISBN 0-12-438380-7.

Everything you never wanted to know about the internal workings of GIS, including both advanced raster techniques and vector techniques. This is not a book about USING GIS, as much as a book about how the GIS works. A good book for finding out what is going on behind the scenes. [aspatial, atemporal]

MacEachren, A.M. 1995 How Maps Work: Representation, Visualization, and Design. Guilford Press. ISBN 0-89862-589-0

This book is as much about how we see maps as it is about how maps are physically made, whether by computer or hand. While it won't directly teach you about GIS data structures and such, it will make your maps much clearer. Unique and very challenging due to the breadth of issues covered, from neural aspects of perception to map symbolization to GIS. [abstract, often narrative time]

Maune, D.F. 2001 Digital Elevation Model Technologies and Applications: The DEM Users Manual. Published by the American Society for Photogrammetry and Remote Sensing, Bethesda, Maryland.

An excellent collection of technical articles on how 3d elevation models can be captured; includes excellent coverage on LiDAR techniques, though somewhat dated. A new edition is apparently available (2008) but I've not seen it [neighborhood to regional scale, atemporal]

Ott, T., Swiaczy, F. 2001 Time-Integrative Geographic Information Systems: Management and Analysis of Spatio-Temporal Data. Springer, 234pp.

A solid, non-mathematical introduction to spatiotemporal GIS, with an emphasis on representation of time, spatiotemporal queries, and applications. Assumes no particular knowledge of advanced GIS. [abstract space and time]

Openshaw, S., Abrahart, R.J. eds 2000 Geocomputation. Taylor and Francis, New York, 413pp.

A fabulous collection of papers intended to move GIS beyond data storage and into a fully integrated realm of simulation. Of course, people had been trying to do that since the first GIS tools, with varying degrees of success, but this is a good collection nontheless. Perhaps changing the name from GIS to Geocomputation helps. [abstract space and time]

Peng, Z.-R., Tsou, M.-H. 2003 Internet GIS - Distributed Geographic Information Services for the Internet and Wireless Networks. John Wiley and Sons, Hoboken, N.J. 679pp.

If you want to know about Internet GIS and want to read about it, rather than mine the Web for examples, this is the book to read. Better yet, read this one and look at Web examples at the same time! My only complaint would be that the book doesn't cover open source tools as thoroughly as I'd like... [aspatial and atemporal]

Peuquet, D.J. 2002 Representations of Space and Time. Guilford Press, New York, N.Y. 379pp.

A very interesting, alternative look at GIS thinking, tools, and results. Should be required reading for all graduate students in geomatics/GIS, regardless of whether they live at the technical end of the spectrum or the social end. Despite the often academic detail, this is stuff you should know, think about, debate with your colleagues, and help grow into an integrated discipline. [wide range of spatial and temporal scale; explicitly about issues with time in GIS and the broad issues]

Peuquet, D.J., Marble, D.F.1990 Introductory readings in Geographic Information Systems. Taylor and Francis. ISBN 0-85066-856-5

A collection of wide ranging references on GIS, divided into background, practical applications, and more theoretical design and evaluation sections. The practical applications section is somewhat dated, but the other sections are still classics in the fundamentals of GIS. The book is similar to a textbook in scope, but in self-contained paper form. [individual papers cover wide range of spatial scales; atemporal]

Rigaux, P., Scholl, M., Voisard, A. 2000 Spatial Databases with Application to GIS. Morgan Kaufmann, 410pp.

A technical introduction bridging GIS to database theory. Well written, which makes up for how technical much of the material is. [aspatial, atemporal]

Tomlinson, R. 2003 Thinking about GIS: Geographic Information System Planning for Managers. ESRI Press, Redlands, CA. 283pp.

A low-level, project-management-focus book on GIS from the Canadian consultant who pioneered it. Broad and useful at approaches for ensuring a project is on scope and on-design. [aspatial, atemporal]

Wilson, J.P., Fotheringham, A.S. (eds) 2008 the Handbook of Geographic Information Science. Blackwell Publishing, 634pp.

A solid attempt at a high-level handbook on the science behind geographic information systems. Together with Worboys and de Smith, provides a solid foundation for a high level reading of GIScience.

Worboys, M., Duckham, M. 2004 GIS: A Computing Perspective. CRC Press, Boca Raton, Fla., 426pp.

A solid technical introduction to how GIS tools work at a computing level. Reading this book I didn't feel like I was learning a side issue - how I might write a GIS - but instead how GIS really works. Does that make sense? Not sure. It's a great book, but not an easy read, because the authors don't avoid the hard parts! [aspatial, atemporal]

Zeiler, M. 2000 Modeling Our World: The ESRI Guide to Geodatabase Design. ESRI Press, 199pp.

A definitive guide to the data models found in ArcGIS, their strengths, and their limitations (to some degree). Not a trivial read – you need to read each page and figure and then think through what his examples mean to you; this is definitely worth the effort if you are an ArcGIS user.

Graphic Design, Cartography and Maps

Monmonier, M. 1991 How To Lie With Maps. University of Chicago Press, Chicago, Ill. ISBN 0-226-53415-4

A very readable guide to intellectual self defense in map interpretation and analysis. Not specifically a GIS book, but a key guide to understanding how maps may be used to mislead. [urban to global scale, historical]

MacEachren, A.M. 1994 Some Truth with Maps: A Primer on Symbolization and Design. Association of American Geographers. ISBN 0-89291-214-6 [order from AAG, 1710 16th St. Washington, D.C.20009-3198]

A classic, small, readable introduction to making presentable and accurate maps using GIS. Much of the material is adapted from traditional cartography, but in a way that highlights how GIS tools fit in. This is a 'how-to', not a theory book (see instead MacEachren's How Maps Work) nor a case study book (see instead Tufte's Envirioning Information). [aspatial, atemporal]

Tufte, E.R. 1990 Envisioning Information. Graphics Press (available from P.O. Box 430, Cheshire, Connecticut, 06410).

This book is an absolute classic, and perhaps the most cited book in graphic design and cartography of the last decade. Using hundreds of examples from past centuries, Tufte covers all aspects of making clear and informative graphics and maps. [wide range of spatial and temporal scales in examples]

Tufte, E.R. 1983 The Visual Display of Quantitative Information. Graphics Press (as above).

Tufte's first book is not strictly about spatial graphics, but it is a classic in illustrating techniques for making graphs and charts clear and informative. [aspatial, atemporal]

Tufte, E.R. 1996 Visual Explanations. Graphics Press (as above).

An attempt to look at what defines understandability in information graphics. A source of inspiration for thematic diagrams more than a directly applicable book on cartography or map design, the book is beautifully laid out and written. [Case studies cover a wide range of spatial and temporal scales but principles are intended to be general]

Tufte, E.R. 2003 Beautiful Evidence. Graphics Press, 213pp.

A broad examination of the use of graphics to demonstrate or convince; a follow-on from Visual Explanations. As usual, beautifully illustrated; this one is less compelling to me because it wanders between themes a fair amount. [case studies at a wide range of spatial and temporal scales]

White, T. 2006 Animation: From Pencils to Pixels. Focal Press, 500pp.

A solid introduction to the theory, practice, and evolution of animation, including coverage of pre-computer and computer approaches. Animation informs the future of spatio-temporal visualization tools, and effective design is behind everything, so… [aspatial, physical to narrative time plus history]

Remote Sensing

Donnay, J.-P., Barnley, M.J., Longley, P.A. eds. 2001 Remote Sensing and Urban Analysis. Taylor and Francis, 268pp.

A collection of papers covering a range of topics related to remote sensing of urban areas. Useful because of the topical nature, but definitely not an introductory book on R.S. [neighborhood to metropolitan scale, atemporal]

Game Thinking and Game Design Books

Baillie-de Byl, P. 2004 Programming Believable Characters for Computer Games. Charles River Media, 464pp.

Many urban simulations have beautiful detailed building and terrain models, yet contain agents that behave in such simplistic ways that any modeling of behavior is limited if not just impossible. Realistic agent behavior – whether for a game or for spatial analysis – is nontrivial, amounting to significant AI plus significant social science-based calibration. This book attempts to lay a foundation for programming such behavior. [detail scale, physical to chronological time]

Bjork, S., Holopainen, J. 2005 Patterns in Game Design. Charles River Media, 423pp.

A first attempt at applying Pattern Languages (see Alexander…) to the problem of designing interactive media in general and games in particular. If nothing else looking through the Patterns gives a broad look at what elements are in the architecture of a game. [aspatial, atemporal]

Eberly, D.H. 2007 3d Game Engine Design: A Practical Approach to Real-Time Computer Graphics. Morgan Kaufmann, 1018pp.

A solid introduction to building an efficient 3d graphics engine for gaming. As the title says, ultimately a pragmatic introduction to computer graphics. [abstract space, physical to chronological time]

Gauthier, J.-M. 2003 Building Interactive Worlds in 3d: Virtual Sets and Pre-Visualization for Games, Film and the Web. Focal Press, 422pp.

A good introduction to the design of virtual environments; a mix of hands-on how to and background principles. Verges on a tutorial at times. Does not provide a broad conceptual overview, just skills and tools. [detail to superblock scale, chronologic time]

Huizinga, J. 1950 Homo Ludens: A Study of the Play Element in Culture. Beacon Books, 220pp.

Why are games so important to people, what social role do they play, and how do games inform us about how we should design other experiences? Primarily an academic study, this work legitimized the study of games in and of themselves. [aspatial, historical]

Koster, Raph 2005 A Theory of Fun For Video Games. Paraglyph Books, 244pp.

A broad reaching attempt to define what makes games fun; narrative, interface form, intent, difficulty, and the like are examined in due course. A somewhat challenging book, and peripheral to urban design, but certainly an influence on ease-of-use approaches and any work that is about learning rather than building and designing. Shouldn't design be fun?[aspatial, atemporal]

Millington, I. 2006 Artificial Intelligence for Games. Morgan Kauffman, 856pp.

A broad introduction to artificial intelligence issues for gameplay; consequently, a good introduction to artificial intelligence issues for GIS and spatial reasoning! [aspatial, physical to chronological time]

Salen, K., Zimmerman, E. 2004 Rules of Play: Game Design Fundamentals, MIT Press, 670pp.

A fabulous introduction to game thinking, game design, and in fact interactive digital design in general. See also the related 'Game Design Reader.' [abstract spatial scales, physical to chronological time scale]

Salen, K., Zimmerman, E. (eds.) 2006 The Game Design Reader: A Rules of Play Anthology. MIT Press, 924pp.

A great collection of historic and recent papers related to game design, computer science, and human-computer interaction.

Papers

Covering even a fraction of the papers published on the topics discussed would be impossible, so I've instead chosen to highlight a few that I thought were particularly useful; most are papers I've used in teaching and have some confidence are both worth reading and furthermore worth tracking down in the first place.

I've broken these up into only two groups: collections of papers ("readers" in essence) and individual papers.

Collections

Carmona, M., Tiesdell, S. (eds) 2007 Urban Design Reader. Architectural Press, 375pp.

A broad collection of typically quite short papers, ranging from philosophy to pragmatics, with perhaps a bit more of an emphasis on theory than on practicalities. [Building to Metropolitan scale, chronological to centuries time scale]

Larice, M., Macdonald, E. (eds) 2007 The Urban Design Reader. Routledge, 541pp.

A large, broad collection of readings with perhaps a more ideological focus than Carmona and Tiesdell; similarly somewhat academic rather than 'hands-on.' [Building to Metropolitan scale, chronological to centuries time scale]

Individual Papers

Allen, J.F. 1984 Towards a General Theory of Action and Time. Artificial Intelligence, 23, 123-154.

The 'must-read' paper on time and computing. Provides the foundation on which theories of time in GIS are build. [abstract space and time]

Anderson, J.R. Hardy, E.E., Roach, J.T., Witmer, R.E. A Land Use and Land Cover Classification System For Use With Remote Sensor Data. USGS Professional Paper 964, 41pp.

A classic examination of division of land into cover and use classes based on medium resolution (LandSat) remote sensing data. [block to metropolitan scale, atemporal]

Bainbridge, W.S. 2007 The Scientific Research Potential of Virtual World. Science, 317, July 27, 472-476.

A good introduction to the types of social research that can be carried out in game and virtual worlds, and a discussion of the ethical issues in doing such research. Highlights the size and diversity of the population using these games as of 2007. [abstract space, chronologic to narrative time].

Barrett, C.L, Eubank, S.G., Smith, J.P. 2005 If Smallpox Strikes Portland. Scientific American, March, 53-61.

Explores the use of spatial models to examine threats of disease to urban areas. An interesting and readable case study. [urban to metropolitan scale, chronologic to years]

Barsalou, L.W. 2003 Abstraction in perceptual symbol systems. Phil. Trans. R. Soc. Lond. B, 358, 1177-1187.

How do people reason about things they perceive? How are categories formed on-the-fly. What is a concept? Not a light paper, but this type of reasoning is at the core of how people interpret scenes. [detailed space, chronologic time]

Brown, B., Perry, M. 2002 Of Maps and Guidebooks: Designing Geographical Technologies. ACM DIS2002 Conference Proceedings, available online.

A pragmatic look at how geographic location can be used in computer systems; explores the notion of place and space as design metaphors. [detail to urban scale, chronologic time]

Bruderlin, B., Heyer, M., Pfutzner, S. 2007 Interviews3d: A Platform for Interactive Handling of Massive Data Sets. IEEE Comp. Graph. Applic., Nov./Dec., 48-59.

A new approach to dealing with gigabyte to terabyte datasets, with a specific emphasis on urban models. Interesting viewpoint; many ideas gleaned from the game industry. [detail to metropolitan level, physical to chronologic time]

Bush, V. 1945 As We May Think. The Atlantic Monthly, July. Online at http://www.theatlantic.com/doc/194507/bush

A classic paper that bridges human use of information, information technology, social aspects of information sharing, and more, written in 1945. An absolute must-read. [aspatial, chronologic time to centuries]

Buxton, W. 2003 Performance by Design: The Role of Design in Software Product Development. Proceedings of the Second International Conference on Usage-Centered Design, Portsmouth, NH, 26-29 Oct, 2003, 1-15. http://www.foruse.com/2003/

A rant about design and software; entertaining and educational because it is both true and sad that most software design is so badly done. Unfortunately, the same general principles can be applied to many urban projects.

Chandrasekaran, B., Josephson, J.R., Benjamins, V.R. 1999 What Are Ontologies, and Why Do We Need Them? IEEE Intelligent Systems, Jan./Feb., 20-26.

The title pretty much says it all. Superb paper. [aspatial, atemporal]

Cutumisu, M., Szafron, D., Schaeffer, J,. McNaughton, M., Roy, T., Onuczko, C., Carbonaro, M. 2006 Generating Ambient Behaviors in Computer Role-Playing Games. IEEE Intelligent Systems, Sept/Oct., 19-27.

A great overview of how rich interaction with conversational agents can be achieved; extends traditional games with rich narrative scripting. Points the way towards urban simulations with rich interaction with 'townsfolk.' [building to block scale, chronologic and narrative time]

De Oliveira, J.C.,Yu, S.J., Georganas, N.D. 2004 Synchronized World Embedding in Virtual Environments. IEEE Comp. Graph. Applic., July-Aug., 73-83.

Examines the merging of multiple world fragments into large coherent virtual worlds. Useful in the context of organizational data sharing for urban model development. [abstract space and time]

Feiner, S.K. 2002 Augmented Reality: A New Way of Seeing. Scientific American, April, 48-55.

A good introduction to the major issues with augmented reality interfaces, with examples of current projects. [detail to urban scale, chronologic time]

Gehorsam, R. 2003 The Coming Revolution in Massively Multiuser Persistent Worlds. IEEE Computer, April, 93-95.

What can we learn from online games about how people will and could use computers? A bit dated but still interesting. [abstract space, chronologic time]

Genesereth, M.R. 1994 Software Agents. Communications of the ACM, July, 48-147.

A great though somewhat dated introduction to agents for simulation. Not to be confused with agents in virtual worlds, these agents do things on a network – they extend our reach to network resources, for example. [aspatial, chronologic time]

Gershon, N. 1998 Visualization o an Imperfect World. IEEE Comp. Graph. Applic., July-Aug., 43-45.

How do we deal with the fact that data used in visualizations is incomplete and contains errors? [abstract space and time]

Goodchild, M.F. 2003 Geographic Information Science and Systems for Environmental Management. Annual Review of Environment and Resources, 28, 493-519.

A useful single-paper introduction to GIS and GIScience from the leading pundit. Broadly in the context of environmental science which is appropriate for urban thinking. [urban to country scale, atemporal]

Haines, E. 2006 An Introductory Tour of Interactive Rendering. IEEE Comp. Graph. Applic., Jan.-Feb., 76-87.

A very solid introduction to why computer graphics knowledge is relevant! Explains the issues with high-speed graphics and hardware quite clearly [abstract space, physical time]

Harrap, R.M. 2008 An Overview of LiDAR for Urban Applications. Queen's University GIS Laboratory Memo, 9pp.

A basic introduction to what LiDAR is and what it can be used for. Available on request.

Kay, A., Goldberg, A. 1977 Personal Dynamic Media. IEEE Computer, 10, 31-41.

The birth of modern computing in a single paper – the team that integrated interface hardware and software, early ideas about object-oriented programming, and a deep understanding of how users use tools into the Windows-Icon-Menu-Pointer interface we now use almost exclusively. The title is a reference to the ideas of Marshall McLuhan about the co-evolution of forms of media and expression. [micro to detail scale; physical time to chronologic time]

Lechner, Tom, Ben A. Watson, Seth Tisue, Uri Wilensky & Martin Felsen, 2004, "Procedural Modeling of Land Use in Cities." Technical Report NWU-CS-04-38 (Evanston, IL). Online at: http://ccl.northwestern.edu/cities/papers/cities.tr.pdf

A fascinating study of metropolitan-level urban modeling using simulation tools and the SimCity game engine.

Leubke, D., Humphreys, G. 2006 How GPUs Work. IEEE Computer, February, 96-100.

A solid introdution to how GPUs, the graphics co-processors that drive CAD and GIS visualization, work. Very useful if you need to buy a new one or just want to understand why some tasks are hard and some not when implemented in software and hardware. [microscale, physical time to chronological time]

Louwsma, J., Zlatanova, S., van Lammeren, R., van Oosterom, P. 2006 Specifying and Implementing Constraints in GIS – with Examples from a Geo-Virtual Reality System. GeoInformatica, 10, 531-550.

A quite technical paper on how a spatial information system can incorporate rules on placement of features in space. Constraints are a necessary and poorly understood component of procedural models, and a vital part of data quality analysis in GIS. [abstract space, atemporal]

MacEachern, A., Gahegan, M., Pike, W., Brewer, I., Cai, G., Hardisty, F. 2004 Geovisualization for Knowledge Construction and Decision Support. IEEE Comp. Graphics Applic., Jan/Feb, 13-17.

What is geovisualization and what is it form? In brief form attempts to capture the cognitive issues and showcase some techniques for visualization spatiotemporal data. [detail to global scale, chronologic time to decades]

Mackaness, W.A. 2006 Automated Cartography in a Bush of Ghosts. Cart. GIS, 33, 245-266.

Where is automation 'at' for spatial data handling at the urban to metropolitan scale? An interesting examination of the limits of machine processing of spatial data framed in cognitive terms. [detail to metropolitan scale, atemporal]

Manocha, D. 2005 General-purpose Computations Using Graphics Processors. IEEE Computer, August, 85-88.

A great overview of a new field – using graphics cards as auxilury processors for scientific programming. [microscale, physical time]

Mayall, K., Hall, G.B. 2005 Landscape grammar 1: spatial grammar theoryand landscape planning. Environment and Planning B: Planning and Design, 32, 895-920.

A fabulous paper outlining attempts to build neighborhoods with spatial simulation and GIS; the underlying methodology is much better described here than in many procedural modeling papers. [detail to block level, chronologic to decades time]

Mayall, K., Hall, G.B. 2007 Landscape grammar 2: implementation. Environment and Planning B: Planning and Design, 34, 28-49.

The implementation and testing of the methods described in Mayall and Hall 2005. Again, a good paper; this one is a little long-winded at times but the results are very interesting. [detail to block level, chronologic to decades time]

Meyer, B. 2006 Testable, Reusable Units of Cognition. IEEE Computer, 20-24.

Makes the case that systems should structure information into segments that support learning. Useful for thinking about building systems that educate users over time. [aspatial, atemporal]

Miller, G.A. 1956 The Magic Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information. Psychological Review, 63, 81-97. (available for download online)

The paper that essentially laid the groundwork on the relationship between human problem solving and human memory limits. A difficult read but ultimately a hugely important design principle. [aspatial, atemporal]

Muller, P., Wonka, P., Haegler, S., Ulmer, A., Van Gool, L. 2006 Procedural Modeling of Buildings, ACM Transations on Graphics, 25, 3, 613-23. Also available online, with additional resources at:
http://www.vision.ee.ethz.ch/~pmueller/wiki/CityEngine/Documents

Following from Parish's work on cities, an attempt to use procedural modeling at the scale of buildings. Fascinating from a computer science perspective, but the use of actual urban design criteria is still quite limited. Purely a generative approach, no real analysis included.

Naaman, M. 2006 Eyes on the World. IEEE Computer, October, 108-11.

An interesting case study (from Yahoo) on how metadata provides a foundation for bringing together different types of spatial information. [urban to metropolitan scale, chronologic to years]

Parish, Y.I.H., Muller, P. 2001 Procedural Modeling of Cities. Proceedings of the 28th Annual Conference on Computer Graphics and Interactive Techniques, ACM, 301-308. Available online widely. Also a workshop at ACM Siggraph 2001. http://www.vision.ee.ethz.ch/~pmueller/wiki/CityEngine/Documents

A first attempt to model the large scale structure of cities using L-systems; procedural models allow the generation of many iterations of cities from relatively few rules. A great foundation paper. [Urban to metropolitan scale, abstract time but meant to represent years to decades]

Rettig, M. 1994 Prototyping for Tiny Fingers. Communications of the ACM, 37, 21-27.

A fabulous paper on designing prototypes of systems; if you are trying to understand cities, not essential, but if you are trying to build tools to help users do something with city data, essential. [detail scale, chronologic time]

Rickel, J., Marsella, S., Gratch, J., Hill, R., Traum, D., Swartout, W. 2002 Toward a New Generation of Virtual Humans for Interactive Experiences. IEEE Intelligent Systems, July/August, 32-38.

If we are building virtual environments for simulation, where do the inhabitants come from? Specifically focused on inhabitants for military mission rehearsals. [Detail to block level, chronologic time]

Rottensteiner, F. 2003 Automatic Generation of High-Quality Building Models from Lidar Data. IEEE Comp. Graph. Applic., Nov./Dec., 42-50. [detail to block level, atemporal]

Shneiderman, B. 2007 Creativity Support Tools: Accelerating Discovery and Innovation. Communications of the ACM, 50, 20-32.

An excellent overview of current work supporting design, from programming interfaces to environments, from widgets to music. [aspatial, chronologic time]

Simon, H.A. 1973 The Structure of Ill Structured Problems. Artificial Intelligence 4, 181-201.

Why are some problems easy to handle and some not? Will some problems always be intractable? A classic, thought-provoking paper from the master. [aspatial, atemporal]

Star, S.L, Griesemer, J.R. 1989 Institutional Ecology, "Translations" and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907-1939. Social Studies of Science, 19, 387-420.

A challenging but ultimately vital study of how different communities share information through negotiation of understanding via 'boundary objects.' Highly influential and in my mind a vital part of thinking about how others will use our tools and data. [detail to building scale, chronologic to decades time]

Sui, D.Z. 1998 GIS-based urban modeling: practices, problems, and prospects. Int. J. Geographical Information Science, 12, 651-71.

An excellent review of the state of GIS-based urban modeling, with a good bibliography and summaries of major research areas. [broad coverage of space and time]

Sutherland, I. 1963 Sketchpad: a man-machine graphical communication system. Proceedings of the AFIPS Spring Joint Computer Conference, Detroit, Michigan, May 21-23, 329-346.

A classic project that saw the origins of object-oriented programming, CAD, graphical interfaces, and the like, all in one PhD project. Both the original thesis and this summary are essential reading since many of the core ideas are still poorly implemented in modern systems. [microscale to abstract, atemporal]

Vinge, V. 2004 Synthetic Serendipity (FICTION). IEEE Spectrum, July, 35-44.

Vinge attempts, and largely succeeds, to paint a picture of the future where online information mining, ubiquitous online access, augmented reality, and cheap fabrication combine to utterly change our relationship to design. Essential reading for the discussion of sensor webs alone! [microscale to global, chronologic time]

Zyda, M. 2005 From Visual Simulation to Virtual Reality To Games. IEEE Computer, September, 25-32.

What do games tell us about understanding space? How can they be used to educate and/or train? With a military/urban focus, this is a good overview of work at the ISI at the University of California. [detail to block scale, chronologic time]

Academic Journals

While the academic literature can be, well, academic, some journals do carry pragmatic articles, and some are simply worth reading because some of the academic ideas therein are useful. I've grouped the relevant journals into two groups: pragmatic versus academic. They are listed in rough order of relevance to urban projects.

Pragmatic:

IEEE Computer Graphics and Applications

IEEE Computer

Communications of the ACM

Architectural Design

Computer Graphics World

Scientific American

Academic:

Computers, Environment, and Urban Systems

Environment and Planning B: Planning and Design

IEEE Intelligent Systems

Landscape and Urban Planning

Cartography and Geographic Information Science

International Journal of Geographic Information Science

Transactions in GIS

Websites

Environmental Science Research Institute Inc. (ESRI): http://www.esri.com

The people that make ArcGIS and related tools…

Community Viz: http://www.communityviz.com

Originally a branch of a non-profit organization, dedicated to building urban design tools (which run on top of ArcGIS), now a stand-alone organization. Useful tools for planning at the building to neighborhood scale.

University College, London Center for Advanced Spatial Analysis (CASA): http://www.casa.ucl.ac.uk/

The CASA group publishes extensively on urban design, urban GIS, and spatial analysis.

Peter Wonka at Arizona State University: http://www.public.asu.edu/~pwonka/Publications/publications.htm

Wonka is at the forefront of recent work in procedural modeling of urban areas.

AutoDesk: http://www.autodesk.com

The people that make AutoCAD and 3d Studio Max

Urban Sim: http://www.urbansim.org/

An American research project on urban simulation at the urban to metropolitan level; code and documentation available online.

Procedural Modeling Group (Pascal Muller and co-workers): http://www.vision.ee.ethz.ch/~pmueller/wiki/CityEngine/Documents

A group that has pioneered generative modeling of urban domains from city to building façade scale.

Information Sciences Institute, University of Southern California: http://www.isi.edu/

A think tank that does a lot of work on urban models for military applications.

Photosynth Project, Microsoft Live Labs: http://labs.live.com/photosynth/

A fascinating attempt to build urban models from tourist photographs. Not as highly detailed as, say, Lidar models, but perhaps more useful. Requires Internet Explorer web browser, and installs software to your computer, but worth it!

The Reading Lists

The material provided above may seen a bit daunting not to mention overly broad. As a 'way in' to reading select bits of this literature I provide a series of directed reading lists, each with about 10 items, as starting points for exploration. Note that, in keeping with my overall philosophy that historical materials are important in understanding a discipline, a number of the references are primarily of historical significance.

A "What is GIS" List

1. GIS Overview – Lo and Yeung 2002 Concepts and Techniques of Geographic Information Systems
2. Spatial Thinking – Berry 1995 Spatial Reasoning for Effective GIS

3. Databases – Rolland The Essence of Databases (or any other simple introduction)
4. Social GIS – Schuurman 2003 GIS – A Short Introduction
5. Cartography and Design – MacEachern 1994 Some Truth with Maps: A Primer on Symbolization and Design

A "What is Urban Theory" List

1. Understanding Urban Areas - Lynch 1960 Image of the City
2. Design Philosophy - Alexander 1979 The Timeless Way of Building
3. Design Patterns – Alexander et al 1977 A Pattern Language: Towns, Buildings, Construction
4. Urban Academic Theory – Shane 2005 Recombinant Urbanism: Conceptual Modeling in Architecture
5. Configurations and Space – Habraken 1998 The Structure of the Ordinary: Form and Control in the Build Environment

A "Urban Architecture" List

1. Architectural Design Concepts – Frederick 2006 101 Things I Learned in Architecture School
2. Design Grammars and Math - Mitchell 1991 The Logic of Architecture
3. Styles of Urban Areas – Schoenauer 2000 6,000 Years of Housing
4. Urban Artefacts – Norman 1988 The Design of Everyday Things
5. Urban / Building Change – Brand 1994 How Buildings Learn: What Happens After They're Built
6. Game World Influences – Gauthier 2003 Building Interactive Worlds in 3d

A "Urban GIS Quick" List

1. Spatial Perception - Higuchi 1975 The Visual and Spatial Structure of Landscapes
2. Spatial Representation – Bosselmann 1998 Representation of Places: Reality and Realism in City Design.
3. Urban GIS Modeling – Longley and Batty 2003 Advanced Spatial Analysis
4. Planning Methods – McHarg 1992 Design With Nature
5. ArcGIS and Cities – Maantay and Ziegler 2006 GIS for the Urban Environment
6. Urban Models and GIS – Sui 1998 GIS-based Urban Modeling (paper)

A "Technical Background on GIS" List

1. Spatial statistics and reasoning: Burt and Barber 1996 Elementary Statistics for Geographers
2. Algorithms and Theory – Worboys and Duckham 2004 GIS: A Computing Perspective
3. Details on Methods – Wilson and Fotheringham 2008 The Handbook of Geographic Information Science
4. Spatial Analysis Methods – de Smith et al 2007 Geospatial Analysis
5. Computing and GIS - Mitchell and McCullough 1995 Digital Design Media
6. Computers – Nisan and Schocken 2005 The Elements of Computing Systems

7. Programming – Taylor 1998 Object Technology, a Manager's Guide
8. Time and Space – Peuquet 2002 Representations of Space and Time

A "Data Collection for Infrastructure" List

1. Urban Infrastructure – Hayes 2005 Infrastructure: A Field Guide to the Industrial Landscape
2. Project Management – Brooks 1975 The Mythical Man Month: Essays in Software Engineering.
3. GPS – Kennedy 1998 The Global Positioning System and GIS

A "Broader Thinking" List

1. Systems thinking: Simon 1969 The Sciences of the Artificial
2. Futures - Stephenson 1995 The Diamond Age (fiction)
3. Vision and Art – Berger 1972 Ways of Seeing
4. Design Languages - Alexander 1964 Notes on the Synthesis of Form
5. Sensors and Futures – Gelernter 1991 Mirror Worlds.
6. Map Thinking - MacEachern 1995 How Maps Work: Representation, Visualization and Design
7. Internet and Search – Morville 2006 Ambient Findability.
8. Alternative Representations – Tufte 1990 Envisioning Information

The Glossary

The literature listed is jargon-filled. I've chosen a few core terms to define here because they tend to come up a fair amount, or at least are useful in framing thinking about parts of the literature listed above. A full glossary of GIS is available separately (about 20 pages, not practical to include here).

The 11 Core Terms

1 – GIS: Geographic Information Systems, or Geographic Information Science: The systems, and supporting theory, of how to handle spatial information, from collection to analysis to communication.

2 – Urban Planning: Procedures for either planning the use of urban areas or for developing new policies for urban development, such as zoning laws. Urban planning is a deeply politicized process in most parts of the world.

3 – Interval Algebra: Allen's division of time into qualitative intervals, and construction of a logic on top of that. What is before what? Or during?

4 – Map Algebra: Tomlin's realization that many spatial analysis operations can be treated as addition, subtraction, and other algebraic operations on overlaying grids of values. Raster map algebra is the foundation of spatial analysis in GIS.

5 – Visualization: Representation of 2.5d or 3d features with a software system where the emphasis is on understanding or insight through visual 'recognition' rather than formal analysis. In most visualization systems, the user can navigate within the volume of information to get different perspectives.

6 – 2.5d Versus 3d: In 2.5d data (common in GIS) any one feature set can not overturn. This makes representing true 3d shapes (like a building façade) difficult at best. In true 3d systems, this is not a limitation. The distinction arises since hardware to handle 2.5d data was historically much more affordable.

7 – Lynch Analysis: The realization, by Kevin Lynch, that people think of urban areas as nodes and paths, barriers and landmarks, and districts. Different cultures may have a different mental model of the same area.

8 – Vector Data: Spatial data with features represented as points, lines, polygons, surfaces, or volumes with associated tables of notes (typically one record in a table per spatial feature). Vector data is well suited to representing discontinuous features such as streets, but poorly suited to continuous phenomena such as temperature.

9 – Raster Data: Spatial data with phenomena represented as one or more values (usually numeric) in a grid cell or volume cell, and usually with the array of cells being regular (cells have equal x,y dimensions…).

10 – Generative Modeling: Using procedures (rules in software) to build features, either in a tightly constrained way (e.g. a new building face that minimizes renovation costs) or a loosely constrained way (e.g. a family of a thousand possible development build-outs for a city).

11 – User-centered Design: The notion that design should be for and about the end users of a product. In urban design, there are two possible end users – the planner is the end user of a new tool, but the community is the end user of a new design for an area.

Conclusions

The reading lists provided above attempt to focus the process of diving into the urban design and GIS literature. The rather exhaustive reference list provides a wider view. The emphasis here, of course, is on learning-by-reading; this should ideally be supplemented by learning-by-doing through short courses and projects.

The technology used in urban design and visualization is changing daily, but the core ideas are not, and in fact many were established in the 1960's and have advanced little (other than photorealism, perhaps) since then. The core ideas of understanding how people use space and then supporting design of, or analysis of, spaces is universal.

One issue that is poorly covered in these readings at a surface level, but which I feel very strongly about, is the degree to which urban design in general, and an individual's understanding of an urban space in particular, is situated in their knowledge and world view. Different cultures use the same space differently; there are human universals, but there are also cultural commonalities and then individual differences.

We are at the junction between a time when urban space was a physical space plus a space of ideas for development of new bricks and mortar, and a time when many if not most urban spaces may be virtual, either unrealized design alternatives generated by designer and design tool, or virtual worlds in games and simulations that will increasingly drive education, training, and planning. As I write this, in early 2008, video game technology has already surpassed analytical 3d visualization tools in terms of ease-of-use, physical realism, and even the direct modeling of physics for in-game effect. When urban designers and analysts take these tools and apply them to their more formal tasks (as researchers like Nick Hedley at SFU are now doing) the results will be very interesting.

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I've of course been influenced by the things I've read in these fields. However, a number of individuals have directly influenced this work through discussions, feedback, and through resources they've provided over the years:

Directly:

Cosma Shalizi – his book list, online, is a joy to peruse. Kind of scary, actually. See them at: http://www.cscs.umich.edu/~crshalizi/notabene/ (at least for now…)

Fred Cameron – provided context, discussions, feedback, and funds!

Nick Chrisman – provided history of GIS – he was one of the originals, and explained the context of some early decisions.

Nick Hedley – his work on augmented reality shows where we should be going. His enthusiasm is contagious.

Students – many students have given me ideas, inspiration, and cause for perspiration over the years. In particular, the students in GISC 304, '3d Visualization of Natural Systems,' have openly debated many of the works herein.

Indirectly:

Stewart Brandt – his book review site, at the Global Business Network, is an excellent resource. In particular, his reviews told me about…

Christopher Alexander – his work led me back to thinking about urban design and the future of cities, 30 years after I'd stopped doodling alternative city designs in notebooks in grade school. His view on human-centered design has also been an inspiration.

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This document examines the literature relevant to the preparation and use of urban models from the perspective of Geography and Geographic Information Systems (GIS). It offers an annotated bibliography of a a broad spectrum of academic and popular literature. This guide should serve as a primer to staff at DND wishing to be familiar with the state of practice in the broad fields of Geographic Information Science and Urban Geography.

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