Urban Visualization:
Urban Design and Computer Visualization

Introduction

Historically, the city represents not just a collection of buildings, but also the concrete cosmology of the world. The importance of the city wall was not only for defense, but also as an edge between the civilized and the wild, the known and the unknown. The city, in the form of the heavenly Jerusalem, had been the image of paradise itself, a perfected objects of human art.

The importance of geometry in this historical context is that one can be assured that the form of the city will correspond to meaning. This is the canonical visualization method of city form, from the maps of Rome by Giambattista Nolli [18] to Collage City by Collin Rowe [19] to the Capital Building in Dacca by Louis Kahn to (perhaps more surprisingly, given his futurist rhetoric) Chandigarh by Le Corbusier.

Contemporary urban designers are confronted by cities with overlapping systems of movement and information that has made the reading of geometry insufficient for an understanding of the city. There is an active discussion about the role of the physical setting amid the proliferation of mobility and information.

The authors of this paper have published work that demonstrates the application of urban design principles to problems of urban visualization. In general, the issues for urban visualization focus on two problems, intelligent graphics processing and very large data sets. One of us has published work demonstrating how Lynch's principles from *The Image of the City* can be applied to the problem of applying intelligent algorithms to issues of computer graphics. We have together published work demonstrating how very large and disparate data sets can be visualized and integrated in unique ways.

This paper is intended as a survey of urban design theory positions and their possible applicability to alternative conceptions of urban visualization. We anticipate using this survey as the basis for future work to generate new methods.

We should be clear on several assumptions that we have made while assembling this survey.

First, in this report, we are specifically interested in urban design rather than urban planning. Our working distinction between them is that planning is usually focused on policy issues while urban design is focused on the form of the city. While we will argue later for a method that combines both of these issues, we think it is useful to separate them for analytic purposes.

Second, we do not intend for this to be an historical survey. We are interested in only those theories that specifically address ideas of legibility, which implies an interest in the existing fabric rather than in utopian solutions.

Third, our interest is specifically concerned with the manner in which the insights and schemas of the theorists might be applied as principles for computer visualizations of complex urban environments. This requires an attempt to infer a method within each of the positions.

1 Cognitive Mapping

How do we mentally simplify complex urban environments?

The cognitive mapping approach is based on the perceptual methods by which we structure and store spatial knowledge. E.C. Tolman (1948) introduced the idea of cognitive maps as a description of a general psychological process [24]. This approach is closely identified with Kevin Lynch, one of America's most well known urban planners, who studied the city, concentrating on human perception and navigation. Lynch published *The Image of the City* (1960), centered on the idea of "imagablilty" which studies the perceptual elements of the city and their cognitive prominence.

Lynch's work provides basic techniques for understanding the mental map of the city through recognizing that the landscape has definable elements, which he identifies as paths, edges, districts, nodes, and landmarks [16]. These elements are descriptive of urban spatial organization and are a universal set of methods for navigating a city. He believes that these elements are also directly relate to the form, organization, and function of cities. Lynch studied cities with vastly different spatial organizations such as, Boston, Jersey City, and Los Angeles to test his method of visualizing form at an urban scale. Within his method, any city can be (and is) understood through these five elements.

Lynch's ideas of cognitive mapping are well developed for the reading of both existing urban visualization [26] and for virtual worlds [27]. The five elements identified by Lynch can each be implemented to parse complex urban models into cognitive units (Fig. 1). For example, districts can be identified both by the repetition of blocks or building geometries and by the complementary identification of edges. This approach emphasizes the planametric view; only the landmark element is three dimensional. The strength of this position is the use of predetermined elements that enables preprocessing a large-scale urban model for dynamic, interactive rendering [7].

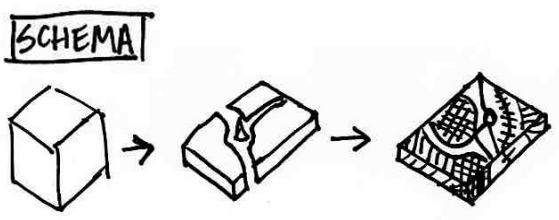

Fig. 1 Diagram of cognitive mapping concepts.

2 Experiential Approach

How do the experiences of movement, uncovering, and texture make a city?

Cities have sometimes been understood as a form of constructed landscape, a view that emphasizes the visual unfolding of the urban environment. This view is often associated with the picturesque both in garden design, and by extension, urban form.

English architect Gordon Cullen exemplifies the experiential approach in his book *Townscape* (1961), a collection of images and essays that express the city through unfolding vision. Most of his examples are small English towns whose growth was incremental and circumstantial.

Cullen conceptualized the city as a complex set of relationships. He argued that many elements go into the making of an environment; buildings, trees, nature, water, traffic, advertisements, etc. are woven together in such a way that drama is released [4]. He did not believe that understanding the city could be achieved through technical or scientific approaches, but it could be achieved through an understanding of vision.

Cullen's experiential approach uses three elements in order to analyze a complex environment or townscape: optics, place, and content. He introduces optics as the concept of serial vision in which movement at a uniformed speed through an environment both embraces an existing view and hints at possible emerging views in a series of "jerks and revelations" [9]. The movement through the urban environment produces a series of frames, each displaying a set of legible elements, which marks the locations of the "jerks and revelations". Place refers to "plastic experience," a journey through pressures and vacuums [4]. Cullen lists a set of qualities of a townscape that create a sense of place, such as, enclosure, gateway, change of level, narrowing, etc [9]. He describes this as "IT," which we also understand as "HERE," and "THERE," relating to the ideas of space. For example, place is recognized when someone is standing on the edge of a cliff or inside a tunnel. Content refers to the surface of place that contains visual organization through style, texture, material, and color. Cullen's introduction of texture is unique; it is not a common topic among other

urban theorists; he relates this to an emotional reaction to the city through aesthetics.

Our interest in Cullen for urban visualization centers on two aspects of his work. One is the interest in serial vision, and the other, connection of vision and place. These show promise of being a useful tool to conceptualize urban space using "fly-throughs" and other animation tools. The other aspect of focus is "content", which we take to mean as texture in an urban visualization. Some work has been done on urban modeling [25], but we believe it may be possible to use texture as more than an afterthought for modeling. This would require the generation of procedural mapping strategies that apply at an urban scale.

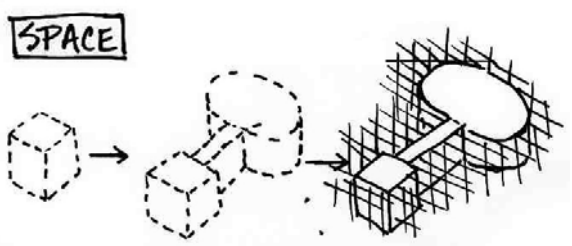

Fig. 2 A diagram of this experiential approach involving the modeling of space (rather than solid) and the generation of surface maps.

3 Rules Approach

How can one principle be iteratively applied to all levels of the city?

Often urban theorists construct a set of rules or principles that are descriptive of the city. The rules can apply to a multitude of elements at various scales.

Architect Christopher Alexander was educated in mathematics and architecture at Cambridge. The combination of disciplines is evident in much of his work. His first book, *Notes on the Synthesis of Form* (1964), explicitly deals with the application of mathematics and computers to design. *A Pattern Language* (1977), while it recants any interest in computers, nevertheless offers a knowledge-based approach to towns, buildings, and construction [1]. *A New Theory of Urban Design* (1987) addresses the question of how we can create built environments that embody the quality of "wholeness" evident in traditional towns and settlements [10]. While it is more than a little hard to give a single definition to what Alexander means by wholeness, he seems to be interested in elements at all scales in the urban environment. His book attempts to recapture the process of how cities develop organically and maintain a quality of wholeness in an organized manner.

Alexander's concepts contribute to urban legibility through his "Seven Rules of Detailed Growth" which apply directly to elements in all levels of the built environment [2]. The rules are

- Piecemeal growth
- Growth of larger wholes
- Vision of growth
- Positive urban space
- Large building restates urban context
- Construction reinforces whole
- "Centers" created at all scales

To test his rules he applied them to an area in San Francisco where he wanted to create wholeness in the built environment.

This recursive approach to analyzing levels of the environment allows people to see the environment not as one whole entity but as sets of relationships. Yet, it is clear that for Alexander these relationships in each level of the environment are seen in all other levels.

Ironically, we will be turning Alexander's ideas back to computers and trying to apply these ideas to urban visualization. The central idea may be the idea of recursion, which is at least implicit in his late writing on urbanism. The idea that rules applied at all scales may form a powerful tool to a method of urban visualization (Fig. 3). It may be that fractal math offers some opportunities, where the operations work at all scales.

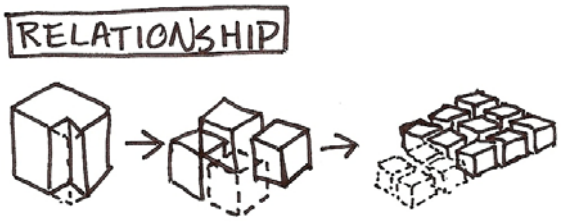

Fig. 3 Diagram of a generative system using recursion.

4 Typological Approach

How do individual buildings or spaces grow into a city?

The typological approach begins with the premise that cities are built from individual pieces of architecture, each of which is established by a building type that includes aspects of space, construction, circulation and grouping. This approach is based on an understanding of type that includes both this idea of building type as well as ideas about typologies of public space.

Aldo Rossi, in *The Architecture of the City,* explains the city as a gigantic man-made object composed of artifacts. Rossi is pointing to the stubborn persistence of the buildings of a city, that have been adapted to new uses but continue as a kind of permanent stage. He states, “Cities are in reality great camps of the living and the dead where many elements remain like signals, symbols, cautions. When the holiday is over, what remains of the architecture is scarred, and the sand consumes the street again [17].”

Rossi conceptualizes the city as an “urban science,” one entity comprised of many parts that create the city as a whole that can only be achieved through years of growth [17]. He introduces the element of time that is unique for urban theorists. He says the city will constantly change and transform through time, but the concept of a particular city will be founded on our memories [4]. He notes particular architectural “facts,” such as monuments that will be the focus of our memory and are essential for giving meaning to the city.

Rossi reads the urban environment through the way buildings, neighborhoods, and districts were formed. He created a typological system based on how structures have common characteristics. First, he categorized the kinds of buildings into types (such as libraries or schools) and then established laws based on their fundamental method of construction. From these laws, he established further laws by which building types are grouped. For example, a single family home can be categorized as a type, and it is understood through a set of laws, applied to individual cases and to groupings

Concepts of typologies in a city are also apparent in *Urban Space* (1979) by Robert Krier, which focuses on a thorough analysis of typologies of urban spaces.

Krier’s view of typologies is a bit different than Rossi’s view. He concentrated on typologies of public space rather building types. Krier believes the physical form of the city is determined by the relationships between the streets and the open spaces, the elevations and sections that enclose them [4] leading to volumetric and 3-D understanding of the city. It is by studying these elements of urban space that a series of typologies may be generated. The typologies originate from three main forms: square, circular, or triangular. Through a diagrammatic process, Krier makes various adjustments to the forms. For example, he says the forms can be independent or work together; they can transform through processes, such as addition, overlapping, and penetrating, etc [15].

Both Rossi and Krier suggest approaches that begin with an instance and then build toward an overall idea of the city. While Rossi’s emphacizes building type and Krier public space, both build recursively from individual instances to the city as a whole (Fig. 4). The recursive nature of both approaches may fit well with ideas of shape grammar [25, 28]. There remains questions concerning how to extend the idea of grammar past the individual building to complex urban form.

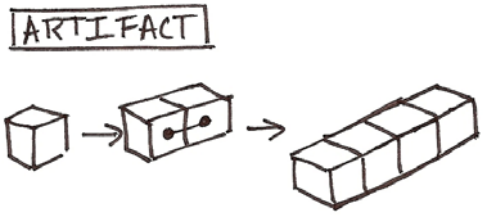

Fig. 4 Diagram of typological system.

5 Space Syntax

How do human occupation and culture connect through space?

Space syntax is a method pioneered by Bill Hillier with Julienne Hanson and the Space Snytax Laboratory at the University College London and in his books, *A Social Logic of Space* (1984) and *Space in the Machine* (1966). This approach attempts to use precise mathematical notation to connect human occupation and space. Hillier’s ideas of spatial patterns focus on measuring movement (pedestrian and automobile) and urban grid

configuration influence. Hillier was also interested in how various societies adopt different spatial forms.
Space syntax utilizes three basic conceptions of space: isovist, meaning the view from any particular point; axial space, referring to a straight line or possible path; and convex space, describing an occupyable void. Interestingly, these concepts map cleanly to the compositional ideas of point, line and space.

Much of the analysis using this method involves using graph theory or a variant as a method of mapping the geometric structure onto a planar dual of human use. This procedure involves beginning with a town map, generating a convex map of spaces, and then axial map of routes through the spaces based on movement and view. The graphs can then be analyzed for both connectivity (the number of adjacent elements) and integration (both local and global).

The space syntax method is often linked to the study of urban morphology, which examines various structures embedded within the city. Hillier's *Space in the Machine* (1996) presents many examples of space syntax used as a method generate morphological views of urban structure for further analysis [11].

This method has been used as a way of conceptualizing large-scale virtual urban environments (Fig. 5) [8]. We believe it is reasonable to believe that it can be extended to other realms of Human Computer Interfaces.

Fig. 5 Diagram of space syntax.

6 City.org

How do non-physical networks interact with city form?

The city has been transformed by the increase of information and digital technology. We need new methods to read the urban environment that recognized the shift in roles of urban geometry and the flow of information.

Robert Venturi , in *Learning from Las Vegas* (1972), studies the Las Vegas strip both for its architecture and for its use of signage as an equivalent to architecture. Venturi noted that the contemporary city was evolving to respond to widespread use of the automobile, and the way people read, understand, and navigate the new city. Based on his interest in iconology as a historical method, he reads Las Vegas as a place filled with symbolism, signs, and information that creates a city that can be described as architecture of communication over space [23]. Space, scale, speed, and symbol were used to analyze the roadside architecture of Las Vegas, and were given equal importance with the more conventional analysis of geometric and planametric form. Venturi et al. noted, in Las Vegas, the important relationship is between the signs, which have dominance over space.

Venturi is one of the first architects to understand that the city is changing into a place full of information. He sees the city as a place that communicates with new media and reminds us that technological advancements (although in his case not yet digital) have recontexturalized our city.

Rem Koolhaas' books, *S, M, L, XL* (1995) and *Mutations* (2001) discuss how communication networks and economic forces affect the physical environment. Rem Koolhaas relates architecture and the city to current social, economic, and cultural issues. His work often reflects global issues and their transformations of the city. [20]. The purpose is to extrapolate possible futures for the city based on current trends. Koolhaas uses new graphic design languages to represent the city; representations of the city involve such mappings as the annual sales volume per square foot for retail space across a region, or the locations of cell phone towers, or a record of the total number of images viewed in one day. The research presents cities not as an architecturally neat system, but as a sometimes chaotic series of shifts, overlaps, and displacements of layers [22].

Stan Allen's book *Points and Lines: Diagrams and Projects for the City* deals most explicitly with the implications of digital technologies and their impact on architecture and the city. While he cites critics who believe that architecture will fade away under the advance of technology, Allen's view is that the physicality of architecture will continue to distinguish it from other media, although it will be transformed. His view of that transformation is based on an idea of field theory that sees architecture not as an isolated object of geometric perfection, but rather as the result of the flow and overlap of forces, many of them extending beyond the physical site of a single building [29].

The implication for urban visualization is that urban visualization will not be only concerned with geometries, but rather with a series of overlapping fields (Fig. 5b). The work by Chang on urban simplification uses building height as an indicator of "monument status" in exactly this sense [7], and in contrast to the simple gestalt properties of the other Lynchian aspects.

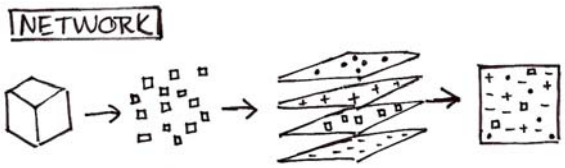

Fig. 5b Diagram of City.org concepts.

7 Urban Visualization

There has been a history of using architectural theories in computer graphics and visualization. From building virtual worlds, creating plausible 3D building models and cities, navigating virtual environments to investigating street patterns and exploring abstract data spaces, computer researchers have utilized various architectural theories to make the visualization believable and pleasing.

Due largely to the disciplinary differences between urban design and computer science, our goal is to find parallels between the steps of building an urban visualization system and urban theories, suggesting how they could be applied to enhance or guide such systems. The specific interpretation and transformation of the abstract qualitative urban theories into tangible running algorithms is still an open area of research. One of the most rewarding aspects of this joint research is the calibration of the needs of each discipline for both broad overview and precise quantification.

Returning to the issues raised in the introduction, it is our belief that urban theories can inform urban visualization both as a method of informing generation and run-time simplification of 3D geometric modeling and in managing information visualization overlay issues for the very large, over-lapping data sets.

7.1 3D Geometric Modeling

Creating believable 3D geometric urban model is essential to an urban visualization system. Work by Rossi and Krier both focus on understanding the relationships between individual pieces of architecture and the city. Depending on the building type, space, construction, circulation, and grouping, each piece of architecture dictates its surrounding typology. Using Rossi and Krier's theories, neighborhoods can be generated with believable buildings of various sizes and shapes.

The buildings generated based on Rossi and Krier's approach need to be bounded by streets and paths, which can be created using Hillier's theory of Space Syntax. By examining axial lines, roads can be created such that an equal balance of connectivity and integration is maintained throughout the city.

Alexander's theory of urban design encompasses elements of an urban environment on all scales. The rules that he created regarding "wholeness" can be recursively applied from a single building, a district, to an entire city. In constructing a 3D model of a city, the recursive nature of Alexander's theory can help add meaning to the urban model on all scales such that a minor change to the creation of the buildings will appear in all levels of the city.

7.2 Run-time Model Simplification

A large urban model containing millions of polygons is still difficult to render in real time with the latest technologies. For interactive visualization of such large urban models, run-time model simplification is essential.

The principal behind model simplification is to reduce the geometric detail on the least important aspects of the model. This principal coincides with Sitte's differentiation between "artistic" models from the economic ones. Using Sitte's theory, the run-time model simplification can more aggressively remove details from the economic models since they are of less importance of the city. The artistic models should contain more geometric detail in most situations as they visually define the general feel of the city.

Lynch's notion of landmarks serves as a similar guideline to Sitte's artistic models. Since the elements of legibility as described by Lynch are based on residents' mental map of an urban environment, these legibility elements are indications of the levels of importance of the architectural pieces within a city. According to Lynch, for as long as these legibility elements are preserved during simplification, individuals' mental map of the city would remain.

While Sitte and Lynch's theories address the geometric importance of urban buildings, Cullen's experiential approach to an urban environment concentrates on the preservation of the textures of buildings. Although simplification of geometry in a visualization system is important, appropriately removing textures can drastically improve the performance of a visualization system. Using Cullen's theory, for as long as the simplification of texture can maintain the sense of "IT, HERE, and THERE," the visualization system can remove the redundant details in the textures.

7.3 Information Visualization Overlay

Informative labeling with either text or icons can help orient the user of an urban visualization system, but too many labels and the screen is cluttered and the underlying model becomes difficult to see. On the other hand, too few labels and it becomes difficult for the user to recognize areas of the city.

Venturi's study of signs and symbols in Las Vegas can serve as a guideline to the appropriate amount of labels used in a visualization system. Buildings with noticeable geometry or texture (symbols) do not require the additional labels; whereas indistinguishable buildings or groups of buildings can be identified through the use of legible labeling.

Although labeling of individual buildings is relevant, it is often more useful to label an entire area within a city. This can be accomplished by either showing the name of the area, or by abstractly representing the area using glyphs similar to that of Koolhaas's graphic design language. Furthermore, as the physical aspects of architecture begin to integrate with digital technologies, these labels of buildings or regions can begin to depict other aspects such as function or use as suggested by Allen.

Notes

[1] Christopher Alexander, Sara Ishikawa, and Murray Silverstein, *A Pattern Language: Towns, Buildings, Construction* (Oxford: Oxford University Press, 1977).

[2] Christopher Alexander and others, *A New Theory of Urban Design* (Oxford: Oxford University Press, 1987).

[3] *American Planning Association APA* (accessed 5 May 2007); available from *http://www.planning.org/25anniversary/influentials.htm*, Internet.

[4] Geoffrey Broadbent, *Emerging Concepts of Urban Space Design* (London: Van Nostrand Reinhold, 1990).

[5] Eamonn Canniffe, *Urban Ethic: Design in the Contemporary City* (United Kingdom: Routledge, 2005).

[6] Remco Chang and others, "Legible Cities: Focus Dependent Multi-resolution Visualization of Urban Relationships," *Proceedings IEEE Visualization 2007 Conference*, (2007).

[7] Remco Chang and others, "Hierarchical Simplification of City Models to Maintain Urban Legibility," *International Conference on Computer Graphics and Interactive Techniques 130, ACM SIGGRAPH 2006 Sketches*, (2006).

[8] Ruth C. Dalton, "Is Spatial Intelligibility Critical to the Design of Largescale Virtual Environments?" *International Journal of Design Computing* 4, (2003).

[9] Gordon Cullen, *The Concise Townscape* (New York: Van Nostrand Reinhold Company, 1975).

[10] Christopher Alexander and others, "A New Theory of Urban Design," review of *A New Theory of Urban Design*, by Besim S. Hakim, *ACSA: Journal of Architectural Education*, 1984, vol. 44(2): 120-123.

[11] Bill Hillier, *Space is the Machine* (Cambridge: Cambridge University Press, 1996).

[12] Bill Hillier and Julienne Hanson, *The Social Logic of Space* (Cambridge: Cambridge University Press, 1984).

[13] Rem Koolhaas and others, *Mutations: Harvard Project on the City* (Barcelona: ACTAR, 2000).

[14] Rem Koolhaas and Bruce Mau, *Small, Medium, Large, Extra-Large* (New York: The Monacelli Press, Inc., 1998).

[15] Robert Krier, *Urban Space* (New York: Rizzoli International Publications, Inc., 1979).

[16] Kevin Lynch, *The Image of the City* (Cambridge: MIT Press, 1960).

[17] Aldo Rossi, *The Architecture of the City* (Cambridge: MIT Press, 1982).

[18] Giambattista Nolli, *Nolli Map*, 1748 (Nuova pianta di Roma data in luce da Giambattista Nolli l'anno MDCCXLVII).

[19] Colin Rowe and Fred Koetter, *Collage City* (Cambridge: MIT Press, 1978).

[20] Li Shiqiao, ed., *Folio 06: Documents of NUS Architecture* (Singapore: Singapore University Press, 2005).

[21] Camillo Sitte, *The Art of Building Cities* (New York: Reinhold Publishing Corporation: 1945).

[22] Rem Koolhaas and others, "Mutations: Harvard Project on the City," review of *Mutations: Harvard Project on the City*, by James Soane, *http://www.ribabookshops.com*, (2007).

[23] Robert Venturi, Denise S. Brown, and Steven Izenour, *Learning form Las Vegas: The Forgotten Symbolism of Architectural Form* (Cambridge: MIT Press, 1977).

[24] Edward C. Tolman, "Cognitive Maps in Rats and Man," *Psychological Review* 55, (1948): 189-208.

[25] Pascal Müller and others, "Image-based Procedural Modeling of Facades," *Proceedings of SIGGRAPH 2007* 26, no. 3 (2007).

[26] Rudolph Darken and John L. Sibert, "Navigating Large Virtual Spaces," *International Journal of Human-Computer Interaction* 8, no. 1 (1996): 49-72.

[27] Rob Ingram and Steve Benford, "The Application of Legibility Techniques to Enhance 3-D Information Visualizations," *The Computer Journal* 39, no. 10 (1996): 819-836.

[28] Bill Mitchell, *The Logic of Architecture* (Cambridge: MIT Press, 1990).

[29] Stan Allen, *Points and Lines: Diagrams and Projects for the City* (New York: Princeton Architectural Press, 1999).

[30] Torsten Blume and Gregor Langenbrink, ed., *DOT.CITY* (Berlin: Jovis, 2004).

[31] William J. Mitchell, *City of Bits* (Cambridge: MIT Press, 1995).

[32] William J. Mitchell, *Placing Words: Symbols, Space, and the City* (Cambridge: MIT Press, 2005).

[33] William J. Mitchell, *The Logic of Architecture: Design, Computation, and Cognition* (Cambridge: MIT Press, 1990).