URBAN VISUALIZATION

Urban Design and Computer Visualization

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Abstract. Historically, the city represents not just a collection of buildings, but also the concrete cosmology of the world. The importance of geometry in this context is that one can be assured that one's understanding of the form of the city will correspond to meaning. It is this reading that is the canonical visualization method of the city form. But 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. Our interdisciplinary team of researchers has been studying issues related to urban visualization from the perspectives of urban design and computer visualization. Together, we have published work demonstrating how very large and disparate data sets can be visualized and integrated in unique ways. Building on this existing work that connects the two disciplines, this paper presents a survey of six urban design methodologies that may be useful for visualization. Each approach is described through a brief history, a conceptual overview and a diagrammatic exegesis. The conclusion presents an overview of the complementary natures of the discourses in urban design and computer visualization and a prospectus for application of the identified methodologies to computer urban visualization. We conclude 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.

Keywords. Visualization: urbanism.

1. Introduction

This paper is intended as a survey of urban design theory positions and their possible applicability to alternative conceptions of urban visualization. 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. 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. 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.

2. 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 introduced the idea of cognitive maps as a description of a general psychological process. Kevin Lynch published *The Image of the City*, 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 (Lynch, 1960). 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 related to the form, organization, and function of cities.

Lynch's ideas of cognitive mapping are well developed for the readings of both existing urban visualization (Darken & Sibert, 1996) and for virtual worlds (Ingram & Benford, 1996). 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.

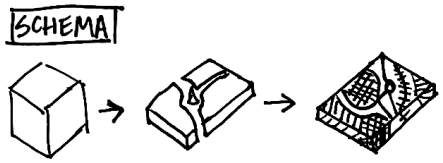

Figure 1. Diagram of cognitive mapping concepts.

3. 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 *The Concise Townscape*, 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's experiential approach uses three elements in order to analyze a complex environment or townscape: optics, place, and content (Cullen, 1975). He introduces optics as the concept of serial vision in which movement at a uniform speed through an environment both embraces an existing view and hints at possible emerging views. Place refers to a journey through pressures and vacuums (Broadbent, 1990) such as, enclosure, gateway, change of level, and narrowing. 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.

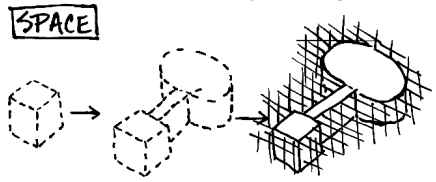

Figure 2. A diagram of this experiential approach involving the modeling of space (rather than solid) and the generation of surface maps.

4. 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 University. This combination of disciplines is evident in much of his work. His first book, *Notes on the Synthesis of Form*, explicitly deals with the application of mathematics and computers to design. *A Pattern Language*, while it recants any interest in computers, nevertheless offers a knowledge-based approach to towns, buildings, and construction (Alexander et al., 1977). *A New Theory of Urban Design* addresses the question of how we can create built environments that embody the quality of "wholeness" evident in traditional towns and settlements (Hakim, 1991). 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 (Alexander et al., 1987). The rules are piecemeal growth, growth of larger wholes, vision of growth, positive urban space, large building restates urban context, construction reinforces whole, and "centers" created at all scales. 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.

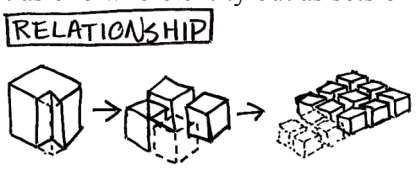

Figure 3. Diagram of a generative system using recursion.

5. 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 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 from 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* by Robert Krier, which focuses on a thorough analysis of typologies of urban spaces. 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 (Broadbent, 1990) leading to a 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 (Krier, 1979).

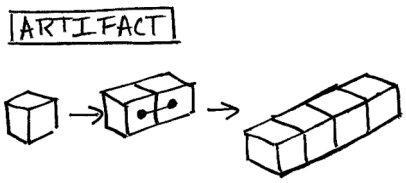

Figure 4. Diagram of the typological system.

6. Space Syntax Approach

How do human occupation and culture connect through space?

Space syntax is a method pioneered by Bill Hillier in his books, *A Social Logic of Space* and *Space in the Machine*. 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.

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 (Hillier, 1984). 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 an 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.

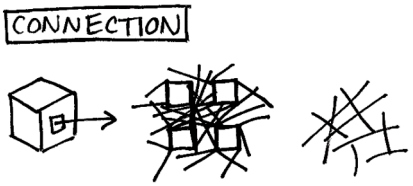

Figure 5. Diagram of space syntax.

7. City.org Approach

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 recognize the shift in roles of urban geometry and the flow of information.

Robert Venturi , in *Learning from Las Vegas*, 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 (Venturi et al., 1972). 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.

Rem Koolhaas' books, *S, M, L, XL* and *Mutations* 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. The purpose is to extrapolate possible futures for the city based on current trends using new graphic design languages to represent the city. The research presents cities not as an architecturally neat system, but as a sometimes chaotic series of shifts, overlaps, and displacements of layers (Soane, 2007).

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 (Allen, 1999).

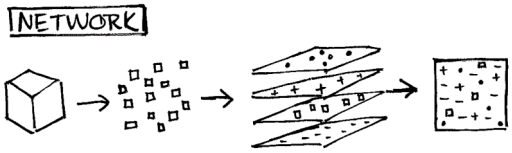

Figure 6. Diagram of City.org concepts.

8. Computer 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.

8.1. 3D GEOMETRIC MODELING

Creating a 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 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.

8.2. 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 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 to 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. The computer application *UrbanVis* developed by Remco Chang utilizes Lynch's urban legibility elements (Fig. 7). The tool simplifies a large number of buildings by using a clustering algorithm based on paths, edges, districts, nodes, and landmarks. This simplification technique offers a new way to understand the urban environment by maintaining a viewers mental map of the city.

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 textures of the 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" (Cullen, 1975), the visualization system can remove the redundant details in the textures.

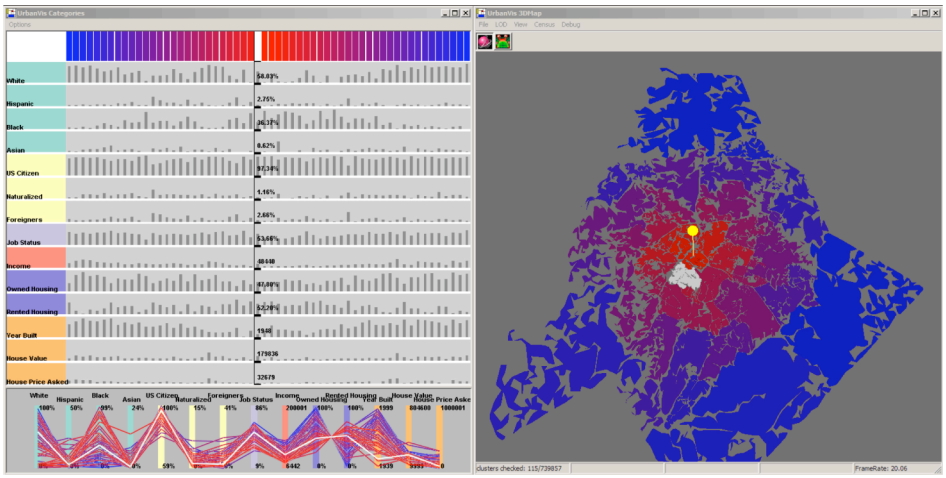

Figure 7. UrbanVis. The left view displays demographic data of the areas around the focus point. The right view shows the clustered building models based on Lynch's elements of urban legibility.

8.3. INFOMRATION VIZUALIZATION OVERLAY

Informative labelling with either text or icons can help orient the user of an urban visualization system, but too many labels on the screen becomes cluttered or the underlying model is 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.

9. Future Work

The Urban Visualization group conducts on-going research on urban legibility focused on the city's spatial structure and its transformation due to technology, telecommunications, and networked infrastructures. This investigation of urban theories is being extended to include the work of Bill Mitchell, Robert Venturi, Christine Boyer, Tarik Fathy, Thomas Sieverts, Stephen Graham, Melvin Webber, and Manuel Castells.

Following from the discovery of new urban models, we are working in collaboration with the Cognitive Science program at UNC Charlotte to analyze urban structures using semantic networks. We are in the process of designing experiments to test new theories with human subjects.

A third initiative aims to produce visualization algorithms based upon urban theories that extend the work begun by Chang. Collaborating with the Charlotte Visualization Center at UNC Charlotte, we are seeking a computer visualization that will implement modern urban theories and visualization techniques. Our goal is to enable a user to gain a sense of urban legibility that will include both the geometric form as well as the flow of information and goods.

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