Wegzeit - the Geometry of Relative Distance

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Preamble

Translator's note: This is a lightly edited automatic translation of my diploma thesis in architecture, originally submitted and defended at TU Wien in June 2002 under the advisorship of Dr. Bob Martens. In order to remain faithful to the source, I have not corrected the various shortcomings of the text.

— Dietmar Offenhuber, June 2024

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Wegzeit - the Geometry of Relative Distance

Abstract

This thesis investigates how non-linear space - i.e., space structured by relative units - can be used in architecture using virtual environments. The method is based on the concept of *relative space* used in human geography and analytical cartography. Using Los Angeles as an example, the result is a dynamic view of the city and its states of motion, a view that differs significantly from the usual architectural representations. Six prototypical models for representing relative spaces were developed for this thesis. Each emphasizes different properties of the underlying relative space. The proposed models are implemented as dynamic virtual environments that change their shape and extent depending on the local size of the thematic parameter under consideration and the selected reference point.

Introduction

We usually consider space to be structured by invariable, absolute units; a meter represents a constant length, no matter where it is measured. However, in our daily lives, we often use relative units of distance, measuring space in terms of time or transportation costs. These units vary depending on the location. For our perception, behavior, and spatial decisions, such relative units are often more important than the absolute distances. Constructing space based on relative sizes can produce geometrical constructs that are ambiguous and contradictory; they often cannot be represented in Euclidean geometry. Visualize these relative spaces requires models that are based on their individual properties.

Travel time distance is a crucial factor influencing the shape and use of our cities. This thesis examines Los Angeles, a city where automobile traffic and travel times are central, through the lens of non-linear spatial concepts.

The relevance of non-linear spaces has previously been explored in fields such as geography, physics, psychology, and sociology. This view is based on a radical concept of space that leads away from the “true” shape of the object. Space becomes malleable, ambiguous, and changeable.

Architectural representations of space are often insufficient particularly when planning for mobility. They cannot account for aspects such as velocity of movement, perception, and imagination that significantly influence our spatial behavior.

In this thesis, six models of representation were developed to visualize different properties of relative space. While temporal change is usually depicted through animation, this work uniquely expresses it as a spatial relation.

Initially, my interest was to examine the influence of cognitive maps on the spatial structure of the city. However, during on-site observations, I noticed the prominent role of travel time distances. Every interviewee could easily estimate how long it would take to travel to a specific location, but very few could approximate the actual distance in miles. The city’s vast urban area appears in the inhabitants’ minds more in terms of temporal than spatial distances. Consequently, I decided to examine the city’s representation using time units instead of spatial units.

Concepts of space

The term “space” is used in everyday language in various contexts. For example, a distinction is made between:

- Space as the perceptible world, the totality of places: this is both the physically measurable outer world and the inner world of perception.
- Space as empty nothingness, as the counterpart to matter: Space remains when all objects are removed.
- Space as an abstract system of order: geometric space. Space is an explanatory model, a way of structuring information.
- Space as the totality of possibilities: Space is not only what exists, but also what can be. One speaks, for example, of the scope or room one has to make decisions.

Essentially, however, there are two aspects of spatiality that determine our daily lives. On the one hand, the space of perception, which we directly experience physically, and on the other, space as an abstract idea, as a mental construct.

Both aspects are mutually dependent to a certain extent and are always present simultaneously. They are, however, based on opposing concepts of space that are mutually exclusive.

Space of sensation

The space of sensation is limited: it only extends directly to our fingertips and encompasses the range of our tactile sense. It is the space we can grasp solely through our extremities and feel through muscle sensation. Remote senses such as hearing and sight are only indirectly connected to the physical sense of space.

The space of sensation is an interior space. It cannot be shared with others and can only be occupied by oneself. It has a clear center: one’s own body (Franck 1997). The immediate importance of spatial events increases with their proximity to this center, right up to events in our body that are of existential importance to us (Franck 1997; Poincaré 1914). The structure of space is, therefore, not homogeneous.

The arms are the coordinates for the spatial determination of events and objects. This spatial understanding is common to most living beings. In his article “The Relativity of Space,” Henri Poincaré cites the fundamental function of defense against attackers and dangers:

> “When a frog’s head has been cut off and a drop of acid is placed at some point on its skin, it tries to rub off the acid with the nearest foot. If that foot is cut off, it removes it with the other foot. Here we have, clearly, that double parry I spoke of just now, making it possible to oppose an evil by a second remedy if the first fails. It is this multiplicity of parries, and the resulting coordination, that is space” (Poincaré 1914).

Space of imagination

The abstract space of the imagination is a way of overcoming the limited space of perception. The latter is centered on one’s own body, and the points in it are determined in their relevance by their proximity to this center.

However, people can move in space and use their knowledge and memory to place themselves in an advantageous position in relation to a spatial event. This makes every accessible place in space potentially equally important, and the space of the imagination becomes homogeneous. People think themselves out of space, as it were, and view it from the outside. Space is an abstract system of order and, as such, is universal. Every object can be determined through position, size, and orientation. Therefore, the space of the imagination is a necessary extension of the immediate, physically perceived space of perception, which makes spatial behavior and decisions possible in the first place.

In this sense, all types of information media are extensions of one’s body. As Marshall McLuhan describes, they expand the space of the imagination (McLuhan 1964, 54).

Geometry can be seen as a formal science of the abstract space of the imagination (Münch 1999). It represents a way of systematically organizing space. Subsequently, however, geometry detaches itself from its function of representing reality, as can be seen in the family of non-Euclidean geometries.

Absolute vs. relative space

The absolute space postulated by Isaac Newton could be seen as a pure form of the abstract space of the imagination thought through to its logical conclusion. It is the perfect empty space that, like a container, holds the world’s objects. Space itself exists as a kind of non-object, independent of all objects, and is itself imperceptible. It has no physical properties, only geometric ones (Münch 1999). It is infinite, eternal, and unchangeable. Its structure is homogeneous; all points are equivalent, and none are preferred. This differs from relative space, which is centered on a variable point and in which it can never be decided whether an object is at rest or in uniform motion: “Absolute space, in its own nature, without relation to anything external, remains always similar and immovable. Relative space is some movable dimension or measure of the absolute spaces, which our senses determine by its position to bodies, and which is commonly taken for immovable space” (Newton 1968). Newton’s concept of space presupposes the existence of something that is not empirically accessible; thus, it is metaphysical. On the other hand, Newton places empirical observation at the center of his scientific theory: “We are to admit no more causes of natural things than such as are both true and sufficient to explain their appearances” (Newton 1968).

Not least because of this contradiction, Newton’s concept of space was often criticized in the following centuries. In the previously cited article “The Relativity of Space,” Henri Poincaré summarizes the arguments against Newton’s concept of space: It is meaningless to speak of absolute space. To determine a position, reference can only be made to other objects, not to space itself, which is not perceptible. It is, therefore, also impossible to decide whether an object is at rest or in motion.

But not only position in space can only be determined relative to a reference point. Nor can we speak about absolute volumes and distances. If the universe were to grow a hundredfold overnight while remaining geometrically similar to itself, there would be no way for the observer to notice this transformation. All measuring devices, as well as our perceptual apparatus, would change in the same way and would not be able to register the change.

However, Poincaré goes further in his argument: even form and proportion cannot be absolutely determined; space is, therefore, amorphous. A complex and irregular distortion that affects the entire space and results in the transformed forms no longer being self-similar would also apply to our sensorium to the same extent. In this case, too, there would be no way of noticing the distortion (Poincaré 1914).

Modern physics teaches us that there is no absolute, preferred reference system. Nevertheless, when we talk about the absolute reference system in everyday life, we usually mean the choric space, i.e. the reference system of the earth’s surface. This is done in the knowledge that we are employing an imprecise term that is nevertheless sufficiently precise for its specific use, e.g. in the engineering sciences, to be understood and used.

Spatial reference systems

Any spatial operation starts with the question of the reference system. In all the aspects of space mentioned so far, we can distinguish between two types of reference systems:

- *Egocentric reference systems* use one’s own point of view as a reference point. Space is polarized and ordered by this center. Directions are related to the center.
- *Exocentric reference systems* use a reference point outside our own body. They are not influenced by the movement or position of the observer.

In the egocentric reference system, directions are indicated by terms such as front/back and left/right. It is used in conversation to put oneself in someone else’s position and to describe paths.

Exocentric reference systems are essential for structuring and orientation in the shared environment. The most common exocentric reference system is that of the four compass directions. In “The Image of the City”, Kevin Lynch describes several other exocentric reference systems used in different cultures. For example, the Siberian Chukchee use a three-dimensional system of 22 directions, which are determined by the position of the celestial bodies at different times of the day and night (Lynch 1960).

However, universal reference systems do not always have to be symmetrical. Micronesian navigators used a precise but asymmetrical system. It refers to star constellations and the positions of islands and differentiates between 28 and 30 directions. Lynch also mentions types of exocentric reference systems that are not universal systems of order but are centered on a specific location. Merchants in a foreign city, for example, memorize the location and direction of the train station, to which they return directly after completing their business. On small islands, inhabitants may use the terms “inland” or “seaward” for all spatial references. The villages are lined up along the beach, and so in this one-dimensional system, for example, “the next but one village” is sufficient for directions.

Another special case of exocentric reference systems that are not universal is orientation along an existing or imaginary network of paths. Mythological paths in the territory of the Australian Arunta connect sacred places with each other; these paths must not be left (Lynch 1960).

Architectural design in relative space

Planners and architects usually work in an exocentric frame of reference, as the objective form of the planning object must be determined as precisely as possible. Nevertheless, there are examples of design methods that start from the individual’s point of view.

Some of them stem from the domain of film architecture. Unlike buildings, which can be seen from all sides, and stage architecture, film architecture has only one relevant point of reference: the camera lens. This eliminates the need to plan three-dimensional objects that can be seen from several sides. Instead, illusionistic design techniques such as accelerated perspective and perspective anamorphosis become relevant again and are further developed.

In the classic Schüfftan effect, invented by Fritz Lang’s set designer Eugen Schüfftan and used for the first time in the film *Metropolis*, several sets of different sizes are combined from several directions simultaneously into a single image using a system of half-mirrors; actors act in sets made of miniature models.

Another challenge for the film architect is the temporal structuring of the spatial experience. Events and objects are no longer distributed in space but in time. Instead of the topos sequence, the chronosequence comes to the fore.

The rethinking forced by the medium of film, from the absolute reference system of the planner to the subjective point of view of the viewer, is currently also increasingly influencing classical architecture. Wherever planning is done for the static viewer’s experience, film production techniques are used.

- Jon Jerde, the architect who became famous for his plans for shopping malls and theme parks, uses storyboards in his planning. He takes into account the subjective point of view and the temporal sequence of the visitor’s experience.
- Norman Klein, author, looks at the casinos of Las Vegas 20 years after Venturi and coins the term “scripted spaces” - “a street or interior in which the spectator imagines himself as the main character in an imaginary story.” Spaces that are constructed according to a script and that tell stories through the sequence of the route, the framing of the image in the user’s field of vision, and the events that are placed within it (Klein 1997).

- Architect Phillip Thiel works with so-called “Experience Scripts”: a comprehensive system of spatial notation that aims to capture behavior, perception, and even emotional involvement. He links these to the anatomy and materiality of space. This method, which he calls “Environtecture,” turns the architect into a director who uses scores to plan the user’s experience (Thiel 1997).

Relative space

The previous chapter discussed planning approaches focusing on the user's sensory experience. Architectural design, however, is almost exclusively carried out in an exocentric system of reference. Many parameters that define the subjective space remain unconsidered.

What architecture has largely lacked are spatial models that build on the subjective experience of space and consider its sometimes inhomogeneous structure. It may be useful here to glance at related fields that, like architecture, are primarily concerned with spatial structures - geography and cartography.

From their inception, both disciplines were confronted with the challenge of truthfully representing the curvature and unevenness of the earth's surface on a flat plane. The shortest distance in space is not the same as the shortest distance on Earth's curved surface. The orthogonal projection does not represent inclined surfaces and slopes in their true size. For any spatial representation, it is necessary to be clear about which properties of space are to be reproduced - but this inevitably has the consequence that other properties of space are not conveyed correctly. Multiple models are therefore needed to capture all aspects of reality.

The following chapter explains the concept of relative space as it is used in human geography.

Relative location

The relative location is a position descriptor that refers to other spatial features without the use of a universal ordering system.

> Here is an example:
> Linz is located on the Danube, 180 km from Vienna and 100 km from Salzburg.
> Or: Vienna is located between Budapest and Linz.

When determining the relative location of a place, it is not only the position relative to neighboring places that is important. It is also important how these places are connected, for example by roads. The relative location is therefore less determined by its topographic position than by its topological place in a network.

Two cities separated by a state border without a border crossing will not appear in the same route description, even though they are topographically close. The location of a room in an apartment will never be given in relation to the rooms in the apartment next door, even if they are the closest.

If we consider a set of places connected by a system of paths, we notice that some places are better integrated into the path network than others. Relative places have different connectivity.

Graph theory

Graph theory, a branch of topology, is useful for describing relative locations on a network of paths. In this case, a graph is used to represent a set of places and the connecting paths.

In the terminology of graph theory, the locations are referred to as nodes or vertices, the paths as edges. Each edge is bounded by two nodes. In turn, two nodes can only be connected by one edge. A path is a path made up of several edges between any two nodes in the network. The topological distance between two nodes is defined by the number of edges in the shortest connecting path between the two nodes.

For each location in the network, the distance to the furthest node in the network can be specified. The central node in the network is therefore the one whose topological distance to other nodes is as small as possible. This topological distance is also referred to as the radius of the graph. As can easily be seen, the centrality of a node can change as soon as an edge is added or removed somewhere in the network (Diestel 2000).

In the past two decades, graph theory has been increasingly used to deal with architectural and urbanistic issues. Under the term *space syntax*, Bill Hillier has developed models for qualitatively examining architecture on the basis of its topological properties, see (Hillier 1999).

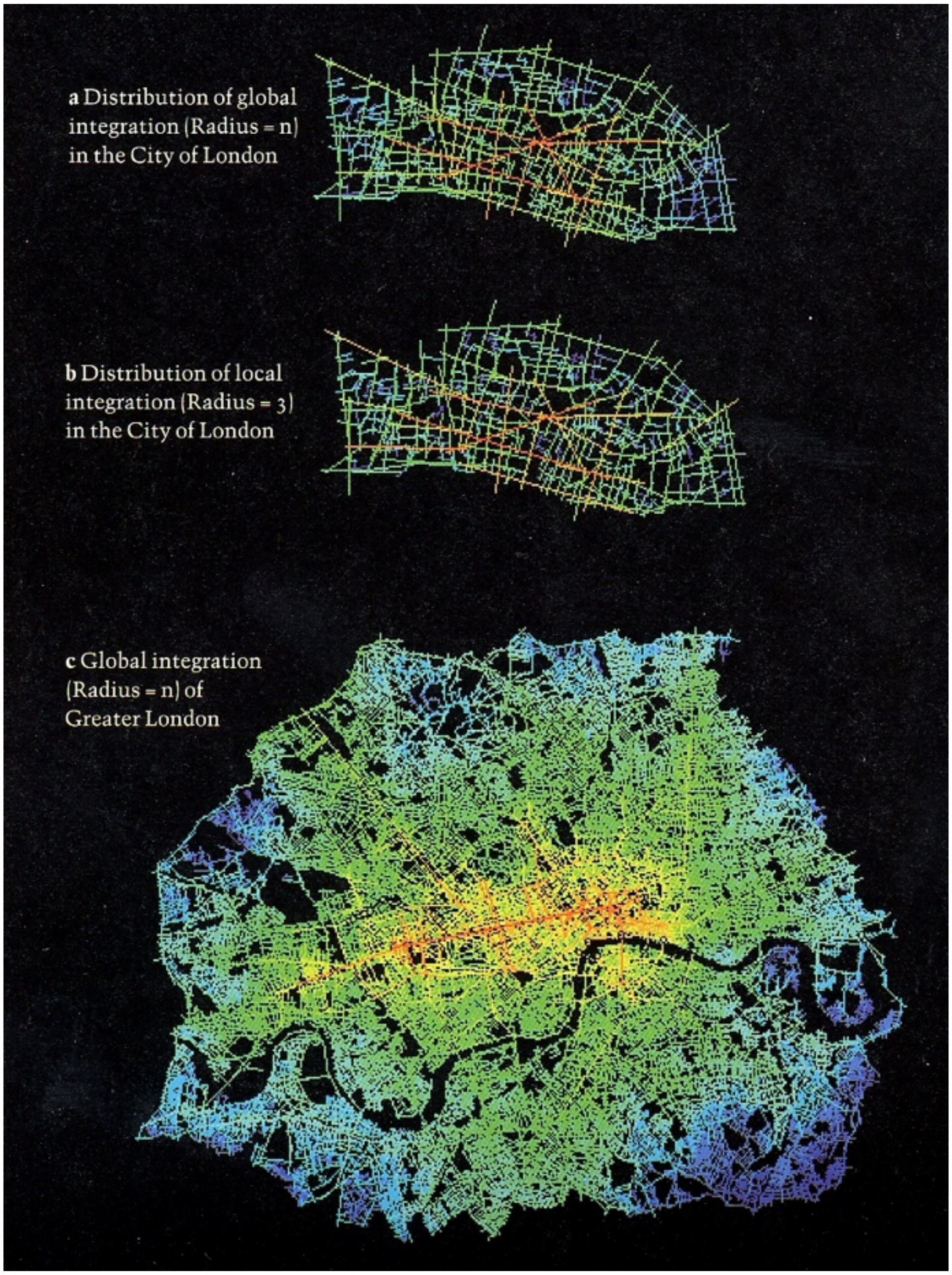


Figure 1: Illustration of connectivity in London's street system - from (Hillier 1999, 215)

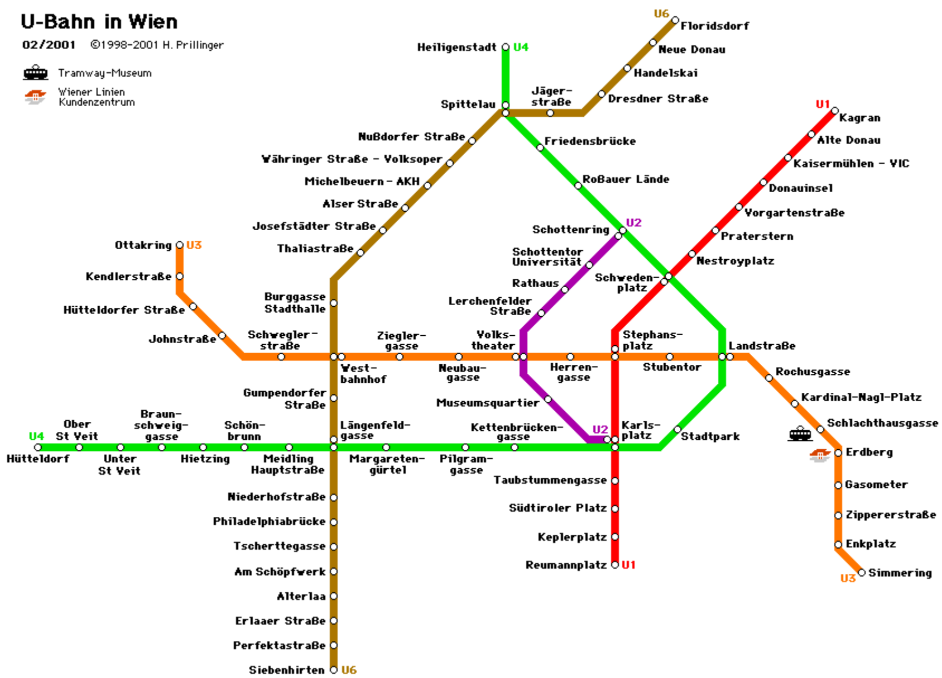


Figure 2: Subway in Vienna Online source: http://mailbox.univie.ac.at/~prillih3/metro/m/largemap .htm Accessed:10.12.2001

Relative distance

The concept of the shortest distance between two locations, which can be clearly established in geometric space, is much less clear in everyday life. The geometrically shortest path is rarely the most convenient, the fastest, or the easiest. As with the concept of relative location, the context in which spatial distance is measured is critical.

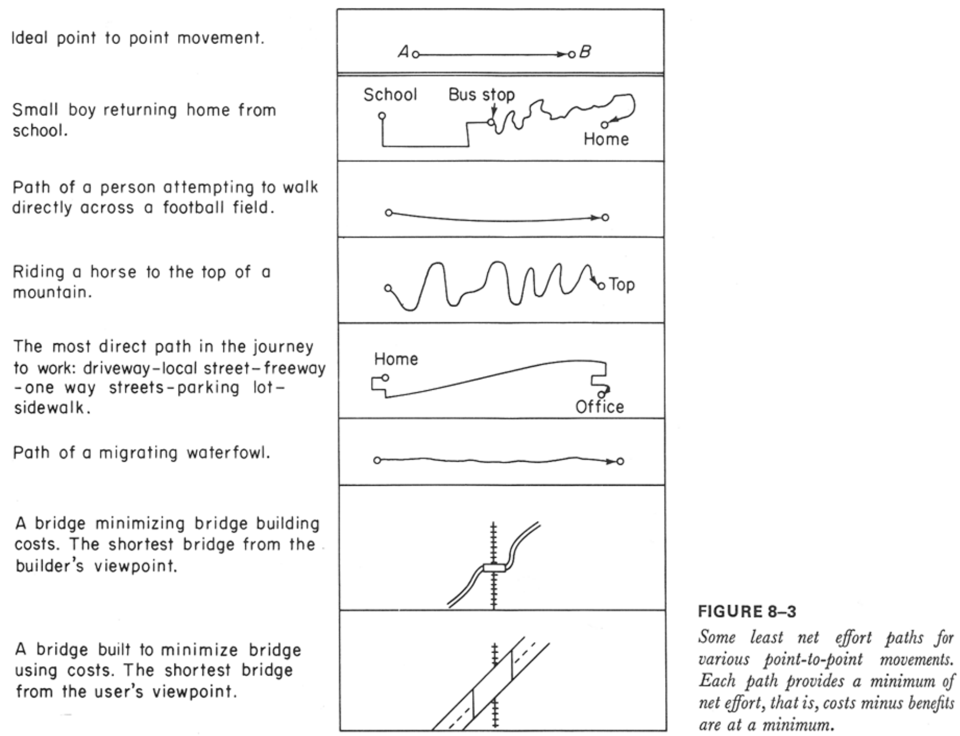


Figure 3: Different examples of least effort paths, (Abler, Adams, and Gould 1971, 218)

Distance measurement is based on comparison with a defined unit of distance, the scale. It is assumed that this unit of distance is the same everywhere and at all times in space, i.e. that the scale is absolute.

Relative distances, on the other hand, as used in the following, are based on parameters whose magnitude varies in space.

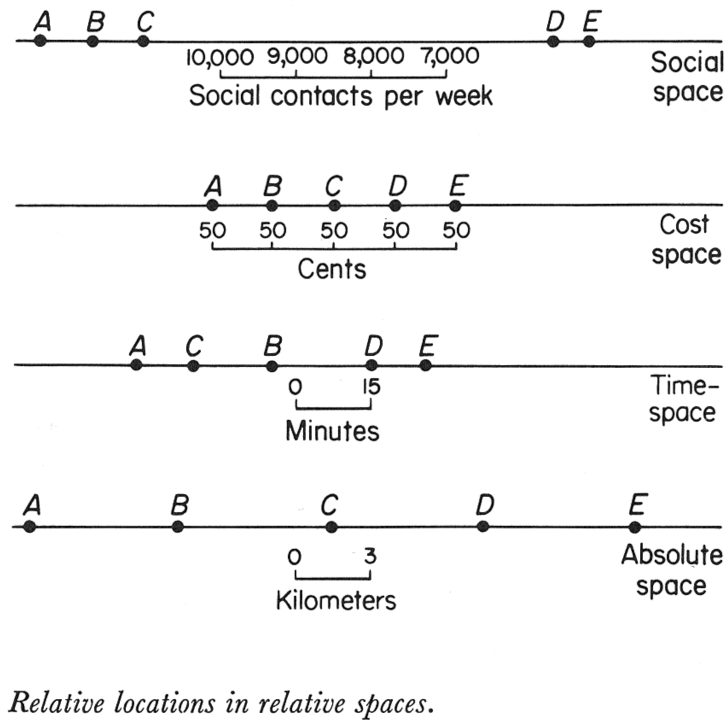


Figure 4: Relative locations in relative spaces. according to (Abler, Adams, and Gould 1971, 76)

The diagram above shows different types of relative distance between five locations. The selected parameter determines the distance and thus the structure of the respective space.

Relative distances can also be expressed in absolute units such as meters or kilometers. The distance between two cities in the road network can either be expressed in absolute terms as the crow flies or in relative terms, expressed in road kilometers. For a wheelchair user, distances in the city or within a building will be different, as the routes are not the same as a pedestrian would use.

Relative space

Spaces that are defined by relative distances are subsequently referred to as relative spaces.

The representation of relative spaces appears distorted compared to the usual representations with absolute distances. However, relative spaces are well suited to visualize the spaces in which people live and make decisions. Anyone involved in the transportation of goods is more concerned with transportation costs and times than absolute distances. One moves in the space of costs and time rather than in absolute space.

In relative space, many properties of absolute space, such as the relative position of places, are retained.

However, the representation of relative spaces is usually not entirely straightforward. Relative distances, especially travel time distances, are usually not symmetrical. The time it takes to travel from point A to point B can differ significantly from the time from point B to point A. The distance depends on the direction, so the shortest distance between two points can no longer be conclusively determined in Euclidean geometry.

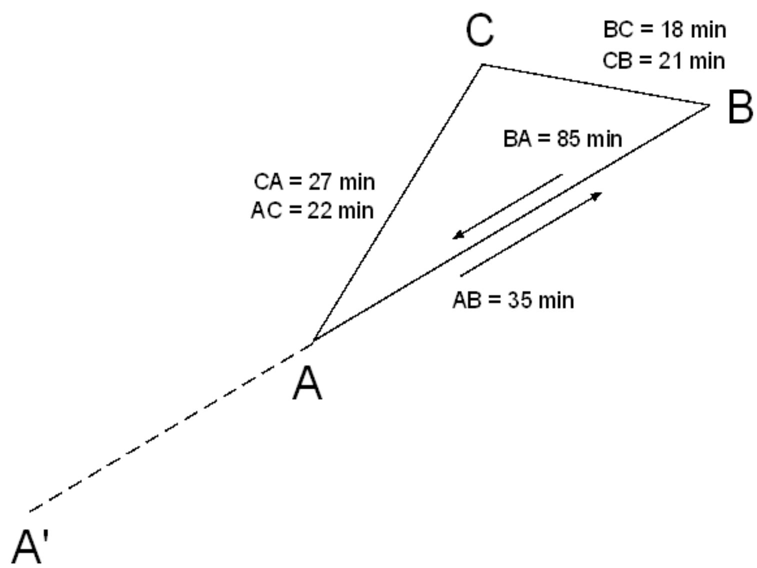


Figure 5: Temporal distances often cannot be expressed geometrically. An example of an impossible triangle

However, the challenges of representing relative distances go further. If we consider three points in space with known time distances to each other, it is sometimes not possible to connect them geometrically to form a triangle. If, as in the diagram above, the distance BA is greater than AC and CB taken together, the triangle inequality no longer applies and a triangle can no longer be formed between the points.

Such a configuration can be expressed most simply in a matrix. Complex network systems can thus be conveniently analyzed using graph theory without having to consider the geometric arrangement:

Table 1: Asymmetric time distances in matrix form (Abler, Adams, and Gould 1971, 80).

	A	B	C
A	–	7	3
B		–	1
C			–

- *Centered relative space*s Parameters such as travel time, cost distance or interaction can only be specified relative to a single common reference point. In the corresponding relative space, the distance to this reference point is assigned to any point in space. In this case, we speak of a *centered relative space*. The position of a point in the relative space is defined by its relationship to a common center. When a different center is selected, the shape of the relative space also changes.

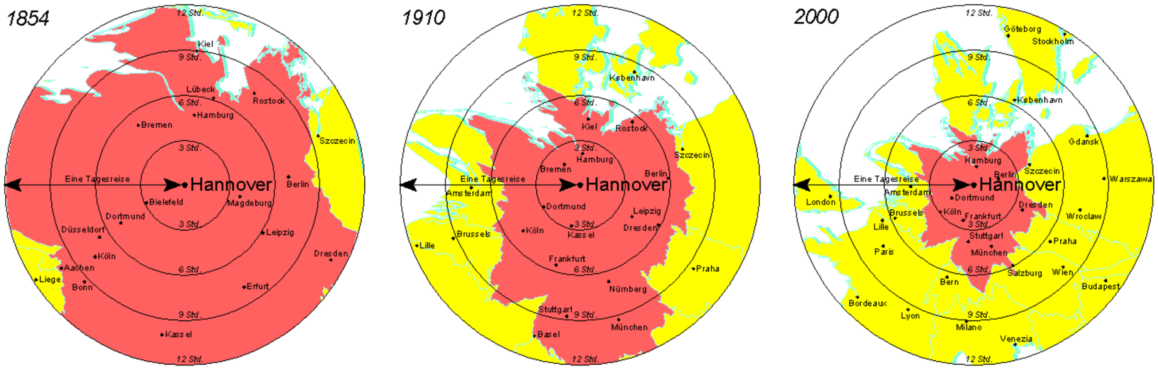


Figure 6: An example of a centered relative space - Klaus Spiekermann, Michael Wegener “Radius Reisezeit”, installation at EXPO 2000 Hanover

- *Non-centered relative spaces* are not related to a common center. The locations are defined by their relative positional relationships to each other. The position of a point in the relative space is determined by its relationship to all other points in the space. Area-related parameters such as population density, economic resources etc. can be represented well in non-centered relative spaces.

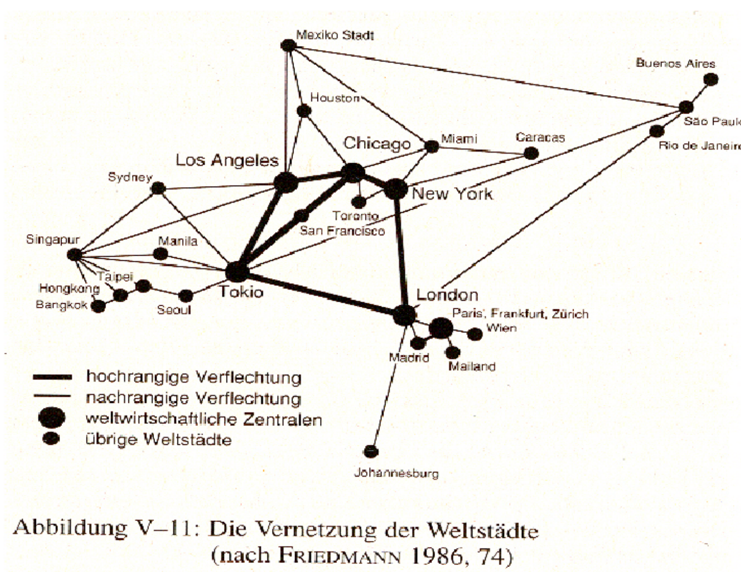


Figure 7: Example of a non-centered relative space - after (Reichart 1999, 110)

Relative space effects

Considering geographic space in this way, one can identify phenomena or events that either expand or shrink relative space. Abler et al. speak of space-adjusting techniques.

Examples of space-shrinking forces

- The increasing speed of transportation and communication.
- Infrastructure: more direct routes, bridges over rivers

- Faster, more powerful means of communication
- World languages
- At the level of the individual: money, education
- ...

Examples of space-expanding forces

This includes all types of obstacles that offer resistance to shrinking forces:

- Space contraction due to air traffic is offset by waiting times at check-in counters and the accessibility of airports as space-expanding forces.
- Topographical obstacles such as rivers and mountains
- Political obstacles such as national borders
- regularly or suddenly occurring situations such as traffic jams,
- Legal obstacles such as speed limits or stop signs
- Language boundaries

Examples of ambivalent forces

Some forces can both shrink and expand space, either simultaneously, at time intervals or abruptly and unpredictably:

- Traffic rules, priority rules
- Traffic lights

Each routing favors areas and at the same time marginalizes other things that separate and connect at the same time: they are filters that only allow a certain type of interaction, e.g. sea coasts.

Any activity, idea or circumstance that makes it easier or more difficult for people to overcome distances has a space-expanding or shrinking effect. Some of the factors mentioned apply differently to each individual inhabitant, some are not constant locally and over time or are random. However, many of them are so regular and universal that they significantly influence and structure the shape of the environment.

Imploded position

The interaction of expanding and shrinking forces leads to effects that Peter Haggett has described as spatial implosion (Haggett 2001). Transport routes and information infrastructure between large cities are generally better developed than those between smaller towns. In a traditional representation of a city network, for example, this fact is difficult to depict. However, if the distance between towns is expressed in relative units such as transport costs, travel time or road kilometers, it can be seen that the large centers are closer together in the representation. Less well connected places, on the other hand, appear to be pushed to the edge, even if they are topographically more central.

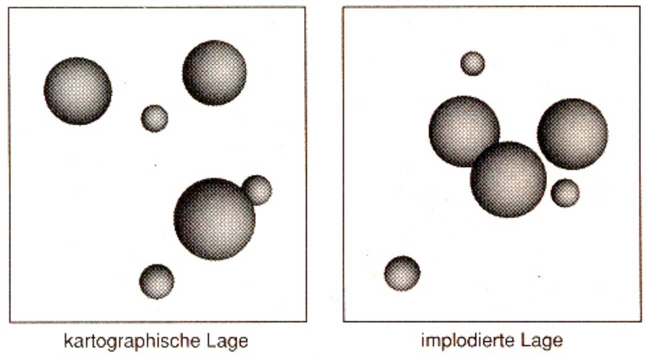


Abbildung V–8: Die Implosion eines Städtenetzes
(nach HAGGETT 1983, 426)

Figure 8: Geographical and imploded location, according to (Haggett 2001, 248).

Active and passive spaces

While places with good transport connections benefit from their relative location in the road network, the opposite is the case for peripheral places. In this context, a distinction is made between active spaces and passive spaces.

The assumption of space-time convergence is therefore only superficial consideration correct. With the introduction of new modes of transportation, the structure of active and passive spaces changes.

Places that were previously in a preferred location become peripheral passive spaces and vice versa (Reichart 1999, 107f).

The city as a relative space

Relative spaces arise on different levels. In the material reality of the city, movement is probably the most important space-defining factor - “Cities are movement economies” (Hillier 1999). The second aspect dealt with examines space as a conceptual image that arises through perception and experience. The third example deals with communication and interaction in space. All three levels of relative spaces are mutually dependent and cannot be considered separately in the urban context.

The relative space of travel time - the city as an economy of movement

Every form of movement produces spatial patterns, which in turn influence and restrict subsequent patterns of movement. The built space is created by movement.

> „Wo sind wir, wenn wir reisen? wo liegt dies ‚Land der Geschwindigkeit‘, das nie genau mit dem zusammenfällt, das wir durchqueren?“ (Virilio 1978, p19)[1]

Movement processes are multi-layered. Movement takes place at different speeds, people move actively or are moved passively as passengers. Their journeys are singular events or are repeated in a daily rhythm. The tour takes place in familiar or unfamiliar territory, is experienced as a conscious process or merely as a necessary evil to overcome spatial distance.

The types of movement are primarily determined by the different means of transport, which have different degrees of freedom. Movement can either unfold freely in space or is restricted to the linear paths of a network. The journey can either begin and end at any point or only at defined nodes within the network. Depending on the degree of freedom, movement patterns can be represented with surface, line or point elements.

[1]Translation by the author: “Where are we when we travel? Where is this ‘land of speed’ that never exactly coincides with the one we are crossing?”

Table 2: Types of movement, From (Waldo R. Tobler 1999)

Domain	Boundary	Examples
Go anywhere	Leave anywhere	Walking, rowboat, helicopter
Go anywhere	Leave at nodes	Ship, airplane, seal under ice
On network	Leave anywhere	Automobile on street
On network	Leave at nodes	Railroad, freeway, subway

- *Direction of movement* - In cities, there are places that have a preferred direction of movement and places that do not. The state of movement in space can be represented by a vector field of different velocity vectors.
- *Spatial hierarchies of transportation routes*- Transportation routes are organized into a hierarchy. Places in the city are grouped by how well they are connected to the road network. The best locations are at intersections of major traffic routes. Other areas are less connected. To get from one area to another, it's often necessary to take a longer route.
- *Hierarchies of velocity* - Movement processes are organized spatially according to their velocity. They are usually separated from each other, with each area assigned a certain speed of movement. A specific place is designed to be perceived at a particular speed. Deviations are sometimes experienced as unusual and frustrating. However, the speed hierarchy is not always seamless. For example, we often have to deal with distances that are both too long for a walk and too short for a car journey. These transport gaps are, for example, between 0.5 and 5 km, 5 and 25 km/h, or 5 and 15 minutes.
- *Scale and speed* - The assigned speed is always directly related to the spatial scale of the respective location. This can be observed, for example, in large parking lots in front of shopping centers. When looking for a parking spot, people generally move at a speed of approx. 10 km/h, i.e. faster than a person walking. This speed is comfortable for the size of the parking lot, one can stay oriented and have enough time to make the necessary decisions. For the pedestrian looking for his car after shopping, the same parking lot suddenly appears uncomfortably large and confusing. The scale of the surroundings determines the preferred way of getting around, the speed and the choice of means of transport. Small-scale historic city centers favor pedestrians and hinder drivers. Sprawling cities that were planned for car traffic from the outset frustrate pedestrians. However, speed is not only regulated by spatial and legal measures and structures, but also by social influences and expectations. Anyone walking too slowly in an affluent residential area or lingering unnecessarily long in one place quickly raises suspicion.
- *Travel time as distance* - For centuries, travel time was the only practical way to measure long distances. In a large geographic context, we think in absolute distances because of our daily use of maps, signposts, etc. However, in a small geographic context, such as a city, we still think in terms of temporal distances. This has practical advantages when planning our daily routines. For example, when traveling in rural areas, we usually have a relatively clear idea of the absolute distances to the next important places. Signposts and road signs inform us at regular intervals. Here we are in the relative space of kilometers. Places separated by hilly and winding terrain may seem farther apart than they really are, nevertheless, absolute distances still play a greater role here than temporal distances. Signposts on hiking trails, on the other hand, are usually marked with time distances. However, when we travel in urban areas, we rarely see signposts to places within the city that indicate absolute distances.

> Moreover, these signs often do not indicate the shortest route, but rather the most memorable, the one with the greatest traffic capacity, or the fastest. In familiar space, we tend to think in time distances. When we compare our idea of the distance between two places with the physical reality, such as a city map, we often find that we have misjudged the distances.

Relative spaces of imagination

In contrast to the previously mentioned parameters, which are all measurable in the physical environment and valid for all involved parties equally, there are also a series of subjective parameters by which the city can be structured. Our behavior in space is always influenced by the perception and conception of spatial reality. To understand the structure of a city and its activity patterns, we must also consider the conceptual space of its residents and users. This is less about how far apart two places actually are, but rather how far they are perceived to be by the people involved, see (Abler, Adams, and Gould 1971, 75).

Here, we will primarily focus on the mental representation of space as it is generated by sensory perception and memory.

The space of perception is the space that is consciously or unconsciously perceived and assessed. The previous section already highlighted the role of speed in perception and thus in the representation of the environment. In addition to the subjective sense of time, experience and memory also play a significant role. The already familiar return journey to a previously unknown place generally seems shorter than the outbound journey. This selective subjective perception leads to the concept of conceptual space.

Concepts are always dependent on personal evaluations and individual motivations, which in turn depend on education, age, social status, and group affiliation.

Playing children or beggars constantly explore the possibilities of their surroundings and how they can use them for their benefit. Their spatial behavior fundamentally differs from that of an office worker on their daily commute.

Representations of the mental space are known as mental maps. They were introduced as a method for analyzing cities by the urban planner Kevin Lynch.

Mental maps: Kevin Lynch's urban analyses

An older but still foundational study on the relationship between perception, behavior, and the built environment is Kevin Lynch's 1960 work "The Image of the City." Kevin Lynch, an architect and urban planner at MIT, was interested in the visual quality of the American city. To this end, he examined the mental image that residents form of their city (Lynch 1960, 12).

Lynch was concerned with statements about the visual quality of architecture and urbanism beyond design and aesthetics - qualities such as memorability, legibility and imaginability were at the forefront of his investigations. According to his hypothesis, a city is perceived as pleasant when one can form a clear mental image of its structure and consequently navigate it easily.

Lynch conducted extensive interviews with residents in three prototypical American cities. Boston, MA was chosen as an example of a European-style city with a historic core, high density and distinct image. Los Angeles as a newer American city with a different scale and without a long history. Finally, Jersey City, NJ was chosen as an example of a rather anonymous city with a very weak image.

In the interviews, residents were asked to describe their route from home to work as accurately as possible, paying particular attention to prominent environmental elements and their emotional attachment to them. In addition to these verbal interviews, participants were asked to draw sketches of their surroundings, including all significant elements they could remember. The results of these empirical surveys were compared with observations made by trained observers.

From the collected observations in interviews and drawings, Lynch synthesized a visual vocabulary of the mental image. This consists of five main elements which, according to Lynch, are particularly important for the construction of a mental image: he described them as paths, edges, areas, nodes and landmarks.

- **Paths** “Paths are the channels along which the observer customarily, occasionally, or potentially moves. They may be streets, walkways, transit lines, canals, railroads.” (Lynch 1960, 41). These are the predominant elements for the majority of respondents. The design elements of the city are organized by paths and stored in memory as a linear sequence. The appearance of the paths gives the inhabitants an indication of their significance as main or secondary roads. The most important characteristic is their continuity, as well as an idea of which areas they come from and where they lead to (Lynch 1960, 49)
- **Edges** “Edges are the linear elements not used or considered as paths by the observer. They are the boundaries between two phases, linear breaks in continuity: shores, railroad cuts, edges of development, walls. They are lateral references rather than coordinate axes.” (Lynch 1960, 41). Examples of edges are barriers such as coastlines and railroad lines. They are continuous and clearly visible. However, they do not have to be impenetrable; they are often connecting seams rather than separating barriers.
- **Districts** “Districts are the medium-to-Iarge sections of the city, conceived of as having two-dimensional extent, which the observer mentally enters”inside of” […] Always identifiable from the inside, they are also used for exterior reference if visible from the outside.” (Lynch 1960, 41). This refers to areas with a characteristic identity that are easily recognized by observers.
- **Nodes** “the strategic spots in a city into which an observer can enter, and which are the intensive foci to and from which he is traveling.” (Lynch 1960, 41).
- **Landmarks** are visual reference points that the observer cannot “enter”, i.e. they are external features such as buildings, signs, or hills. Lynch distinguishes between distant landmarks, which are visible from different points in the city, and local landmarks, which are small and only visible from close up. Radial references are distant landmarks from whose viewing angle the observer can deduce his position, see (Lynch 1960, 49). Land-marks do not always have to be particularly large and free-standing structures such as towers etc. Lynch mentions an inconspicuous old wooden building in Los Angeles that was frequently mentioned in the interviews. The two-storey building recedes slightly behind the other buildings in its building line and thus stands out from the surrounding, more modern and taller buildings (Lynch 1960, 81).

Lynch’s investigation seeks a direct connection between the commonalities of individual imaginaries and specific elements of the built environment. His elements are at once clearly identifiable parts of the material environment, the vocabulary of the imaginary, and the cartographic symbols for its representation. “These elements are simply the raw material of the environmental image at the city scale." (Lynch 1960, 83).

His sketches are a good illustration of the nature of relative spatial representations. They have a strong topological correspondence to reality, but appear distorted. The representation is subject to subjective, individual differences - directions are distorted, proportions are not correct. However, the order and continuity of the elements were usually correct.

The sketch maps of the people surveyed by Lynch showed a relatively high degree of agreement with each other. However, as Lynch himself admits, his studies mainly surveyed members of the middle class. Later studies, on the other hand, show large differences based on the social status and group affiliation of the respondents.

Lynch saw his research as the basis for a new method of urban planning that focused on the experience of the urban resident.

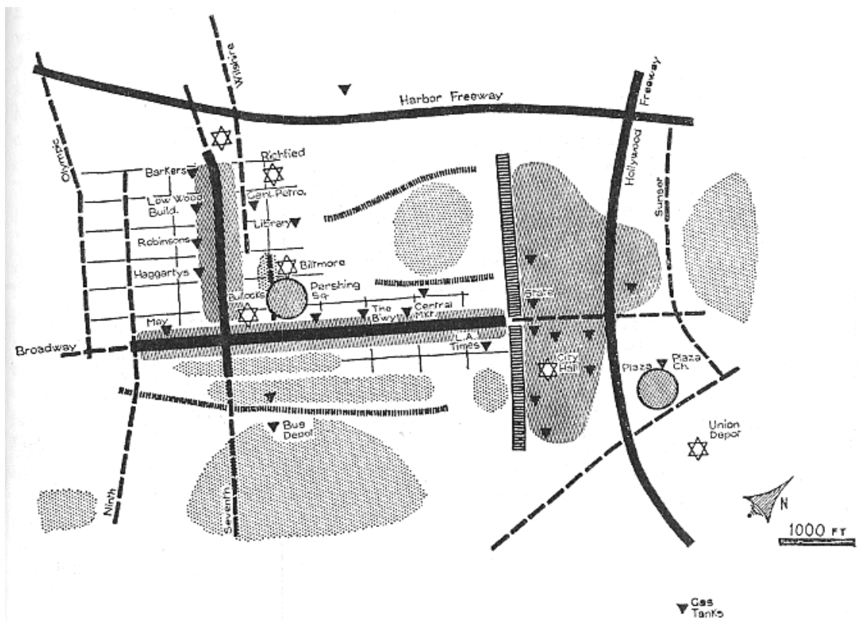


Figure 9: Structure of downtown Los Angeles, depicted through Lynch's elements.

Since Kevin Lynch's work, numerous urban studies have been conducted using mental maps, and the limitations of the method have become apparent. The first problem with mental maps created by subjects is their interpretation.

In order to obtain more data, studies have asked respondents to produce both drawings and textual descriptions of the area under study. This revealed significant differences and contradictions between drawings and textual descriptions by the same person. In the context of a study in Frankfurt, the subjects drew the city in an idyllic, idealizing way, while the same people often adopted a contrasting, critical attitude towards the city in the textual description (Ploch 1995, 28).

Not mentioned is the undeniable influence of images from the media or tourism on the image. In Lynch's work, continuity and topological similarity to reality are mentioned as criteria for an intact image of the environment. In some of the interviews, however, influences can already be seen that break up and fragment this continuity of the mental image: "as in Boston, these drivers seemed to have difficulty in locating the freeway, in tying it to the rest of the city structure. There was a common experience of a momentary loss of orientation when coming off a freeway ramp"(Lynch 1960, 42).

Relative space of communication

The third example finally departs from a geometric concept of space. The city is understood as a system of signs. Lynch's elements represent attempts to understand urban space not primarily in terms of its three-dimensional form but as a semiotic system. However, he usually describes the city from the perspective of the pedestrian. Although spatial relationships appear subjectively distorted, the basic structure of the space remains intact. In "Learning from Las Vegas", Robert Venturi and Denise Scott Brown express the notion of space as a system of signs in a much more radical form.

Fundamental to Venturi's work was the observation that a driver traveling at 50 miles per hour perceives the urban environment differently than a pedestrian: the spatial-geometric structure recedes into the background, the driver perceives the surrounding space primarily as a system of signs. "symbol in space before form" (Venturi, Brown, and Izenour 1972).

The "Strip" in Las Vegas, a commercial landscape completely geared to the perspective and needs of the driver, served as a suitable location for investigating this understanding of space. The underlying problem of an architectural language for motorized individuals is the change in the observer's attention, which is oriented strictly looking ahead:

> "A driver 30 years ago could maintain a sense of orientation in space. At the simple crossroad a little sign with an arrow confirmed what was obvious. One knew where one was. When the crossroads becomes a cloverleaf, one must turn right to turn left [...]. But the driver has no time to ponder paradoxical subtleties within a dangerous, sinuous maze. He or she relies on signs for guidance - enormous signs in vast spaces at high speeds." (Venturi, Brown, and Izenour 1972, 9).

The conclusions that Venturi et al. draw from this observation represent a break with the principles of modernism. Architecture becomes the medium of explicit information. The façade of the typical casino on the strip detaches itself from the building and at the same time becomes its most important part - a larger-than-life billboard. The three-dimensional shape of the building and its architectural form lose their significance, as they can hardly be noticed by the moving observer.

Textual and symbolic information in the form of concise signs and opulent corporate signs become the most important organizing elements of the urban landscape of the strips. At a cursory glance, this landscape appears completely disorganized, but in fact it is a superimposition of different information systems that work on different scales. Contrary to the seemingly poor "memorability" of the landscape, one can find one's way around it.

According to the authors, the conciseness of textual references is adapted to the receptiveness of the traveling observer. In the logo, boundaries between word and symbol are blurred (see e.g. the Mac Donald's "M" etc...). The casino signs contain information for several zones of distance and speed. While the upper part, visible from afar, offers no specific information and is designed as a heraldic element for long-distance effect, the font becomes smaller and smaller towards the bottom and its content becomes more and more specific.

The following diagram shows all the written words that drivers can read from the *Strip*:

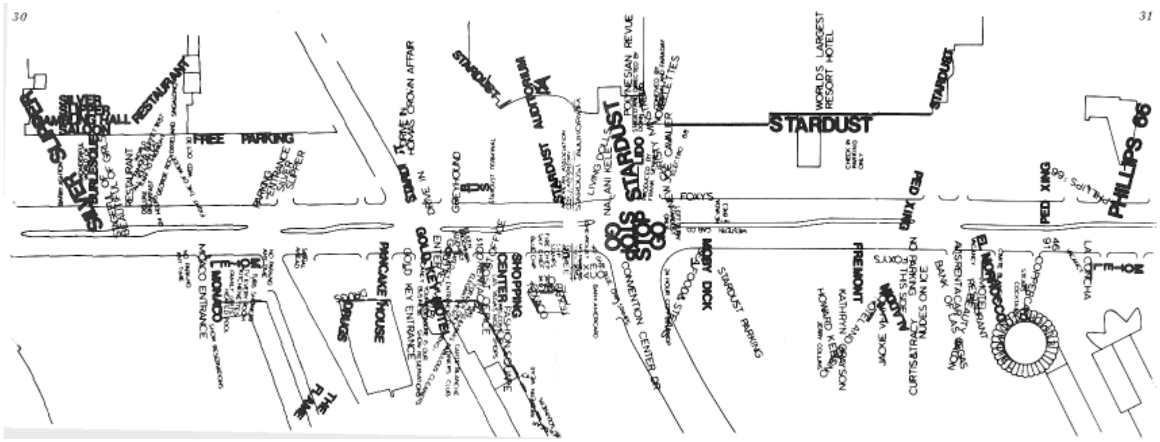


Figure 10: Illustration of the Las Vegas Strip with all textual information that can be read from the driver's perspective (Venturi, Brown, and Izenour 1972, 30).

As Venturi and Scott-Brown emphasize, the scale of the sign in relation to the building is determined by the size of the space and the speed of the observer. On the small scale of the medieval street, hardly any signage is necessary to draw attention to a product on offer, for example. The product is visible and speaks for itself. In the wider shopping street, the pedestrian is no longer forced to walk past the shop windows displaying the products; signage is necessary to draw attention to individual stores. At the scale of the strip, the relationship between building and signage is finally reversed - in response to the high speed of the observer and the spaciousness of the surroundings, the sign becomes more important than the building:

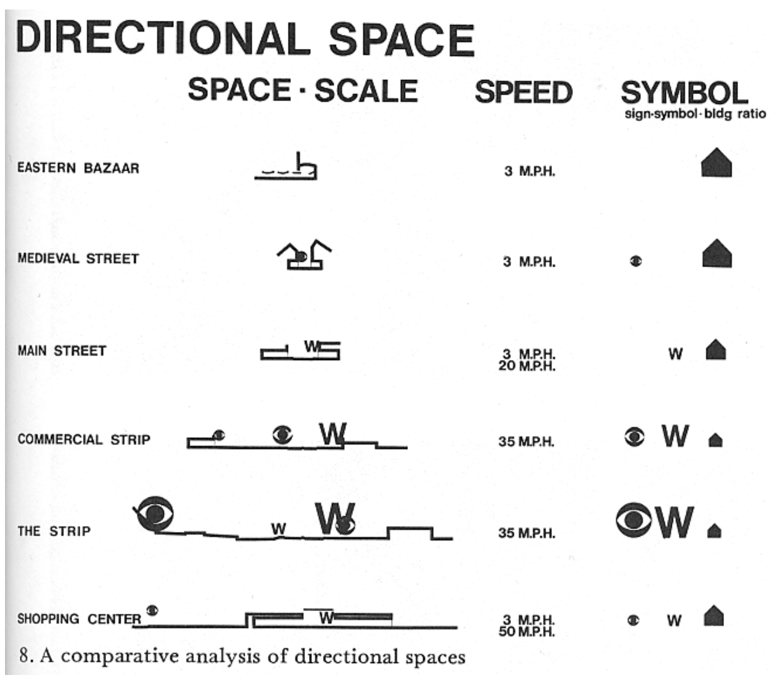


Figure 11: See (Venturi, Brown, and Izenour 1972, 11).

It is obvious that traditional representations of architecture are no longer sufficient for the representation of these phenomena. How can the effectiveness of a casino sign be conveyed in a 1:100 floor plan and elevation? Venturi and Scott-Brown are aware that this requires new methods of representation that take this new understanding of space into account:

> "how do you distort these to draw out a meaning for the designer? [...] How do you represent the strip as perceived by Mr. A. rather than as a piece of geome-try?"
> (Venturi, Brown, and Izenour 1972, 76)

Context Los Angeles

I chose the city of Los Angeles as the location for this study. For several reasons, it is particularly well suited as an case study for the principle of relative space:

- The city is largely laid out as a uniform grid over the area. Against the background of this abstract structure, relative spatial effects resulting from the use of the city become more visible.
- The hierarchy of speeds is more important than a distinctly spatial one. The topographical location of a place is less important than its temporal accessibility.
- Behind the ostensible lack of spatial differentiation, a complex structure of spatial, cultural and infrastructural values is emerges from everyday practice.

Driving in Los Angeles

> "Ask an Angeleno the distance from one locale to another and most likely you'll receive your response in minutes rather than in miles. Traversing the local landscape truly conflates time with space. in the ultimate transit culture, attempting to minimize travel time becomes significant if not an obsession." – from the curatorial statement of the LA Freewaves Festival, Nov. 2000

In the minds of the residents, distances are primarily present as travel time distances. Several local radio stations are exclusively devoted to reporting the current traffic situation. Many online services offer dynamic maps of the region with real-time traffic information showing the speed of automobile traffic on all major roads and freeways.

Figure 12: LA 6 color speedmap Online source: http://traffic.tann.net/maps/lar6traffic.jsp Accessed: 20.4.2002

Reyner Banham describes Los Angeles as a “transportation palimpsest”, a surface of constant, multi-layered movement, subject to ongoing changes and overlapping with new traffic flows (Banham 1971, 75). A palimpsest is usually an ancient manuscript on papyrus or parchment that has been repeatedly overwritten. Because the old contents were not completely erased, they remain partially legible. In a figurative sense, it also refers to a place whose history can still be read from traces.

In Los Angeles, processes and flows of movement appear to be organized with greater complexity than in cities of comparable size. Rather than converging on a central business district, traffic is evenly distributed among a large number of regional centers.

The dominance of automobile traffic as a formative influence is also reflected in statistics. Two-thirds of the city’s developed land is devoted to vehicles in some form, whether as roads, freeways, or parking lots. The city has the highest traffic density of any U.S. city: 125,860 miles are traveled per square mile of city area per day by motor vehicle.[2] 85.64% in 2000 of the working population uses a private automobile for their commute. These 4,115,248 people take an average of 26.5 minutes (1.11 people/car) to get to work[3] and ultimately spend an average of 82 hours in traffic jams every year[4] - LA is leading all other US cities also in this respect.

However, the stereotype of the disproportionate freeway density compared to other US metropolitan areas is debated:

> “However, Los Angeles has less freeway space per capita than most urban areas –

[2]See http://www.publicpurpose.com/hwy-2000density.htm accessed 16.8.2002
[3]See http://www.losangelesalmanac.com/topics/Transport/tr19.htm accessed 16.8.2002
[4]See http://abcnews.go.com/sections/us/DailyNews/ontheroad1_991119.html accessed 16.8.2002

> ranking 44th out of the largest 57 urbanized areas in 1996, according to Federal Highway Administration data. [...] The plain fact is that Los Angeles, with an urbanized area density of 5,800 residents per square mile, has a freeway system that is at least one-third too small to accommodate travel demand," writes traffic consultant Wendell Cox.[5]

Lev Manovich wrote the following about Los Angeles in a report from the Siggraph conference in 1995:

> „The city offers a precise model for the virtual world. There is no center, no hint of any kind of centralized organization, no traces of the hierarchy essential to traditional cities. One drives to particular locations defined strictly by their street addresses rather than by spatial landmarks. A trendy restaurant or club can be found in the middle of nowhere, among the miles of completely unremarkable buildings. The whole city feels like a set of particular points suspended in a vacuum, similar to a bookmark file of Web pages. You are immediately charged on arrival to any worthwhile location, again as on the Web (mandatory valet parking)" (Manovich 1995).

The quote echoes another often noted perception of Los Angeles: the apparent indeterminacy and confusion of the urban environment and its elements. The city seems almost abstract due to its vastness, density, and regularity. Branches of large petrol stations, fast food, and supermarket chains are found in almost identical form countless times in the urban landscape, blurring local identities and recognizability. This impression can already be found in the interviews conducted by Lynch in the 1960s.

> "It's as if you were going somewhere for a long time, and when you got there you discovered there was nothing there, after all." (Lynch 1960, 41)

Much of this urban indeterminacy has its origins in radical urban changes, such as those brought about by the construction of the freeway network or large-scale urban renewal programs of the 1950s and 1960s.

> "In Los Angeles there is an impression that the fluidity of the environment and the absence of physical elements which anchor to the past are exciting and disturbing. Many descriptions of the scene by established residents, young or old, were accompanied by the ghosts of what used to be there. Changes, such as those wrought by the freeway system, have left scars on the mental image" (Lynch 1960, 45).

The erased and imagined city

Imaginary space and material reality seem to be more strongly interwoven and intermingled in Los Angeles than elsewhere.

> "In February 1990, at a public lecture series on art in Los Angeles, three out of five leading urban planners agreed that they hoped L.A. would someday look like the film Blade Runner" (Klein 1997, 94)

Thanks in no small part to the local film industry, which has featured Los Angeles in countless self-referential productions, a comprehensive imaginary geography of the city has emerged. This geography shares elements and place names with reality. This relative space, enriched by

[5] See http://www.demographia.com/db-ladn-traffic.htm accessed 16.8.2002

historical places that no longer exist and imaginary places that never existed in the form described, is present in the consciousness of most residents and visitors to the city. It also has a considerable influence on the development of the real environment.

The historian and writer Norman Klein describes this as urban erasure. Political decision-makers use local myths to argue for and enforce radical urban development measures. Urban erasure targets areas with a particularly strong cultural and historical identity, followed by their mythologization by the local film industry. As an example, the Victorian residential neighborhood Bunker Hill and the historic Chinatown in the area of today's Union Station both occupy a central place in crime stories and film noir of the 1930s and 1940s. Both of these areas have fallen victim to radical urban renewal and have almost completely disappeared from urban geography today (Klein 1997).

The shooting locations of the film *LA Confidential*, which takes place in Los Angeles in the 40s, encompasses all aspects of the imaginary Los Angeles:

Table: Locations of the movie *LA Confidential* (in order of their appearance in the movie).

```
Hancock park
Beverly Hills
Manns Chinese Theatre, Hollywood Blvd
Parking Lot, Hollywood Blvd.
1184 Gretna green, Brentwood (R. Neutra Haus)
1736 Nottingham, Los Feliz
9781 South Duquesne, South Central LA
1st & Olive street - (Echo Park, im Film Bunker Hill )
Cementary, South Central
Orange Grove, Anaheim
Wilshire Blvd
5261 Cheramoya Avenue, Hollywood
Griffith Park
San Bernadino
9608 Vendome, Silverlake
Ventura Freeway, Cahuenga Pass
2345 Halboro
```

Today, Los Angeles is a place where many different ethnic and cultural groups live together. Each population group has a different perception of the city.

Table 3: Largest ethnic groups in Los Angeles, Census 2000, change from 1990[6]

Ethnicity	Percentage of the population	Change
Hispanic or Latino	44.56%	(+28.31%)
White, not Hispanic or Latino	31.09%	(-18.57%)
Asian	11.95%	(+22.48%)
Black or African American	9.78%	(-6.00%)
Some Other Race	23.53%	(+22.47%)

[6] See http://www.losangelesalmanac.com/topics/Population/po13.htm

Brief history of Los Angeles

Greater Los Angeles consists of five counties: Los Angeles, Orange, Ventura, San Bernardino, and Riverside, along with several independent municipalities. The municipality of Los Angeles has a disjointed border, with enclaves like Beverly Hills, Culver City, and West Hollywood surrounded by the urban area of the city.

The current structure of Los Angeles has been, and continues to be, influenced by three main factors:

1. The influence of modern transportation including light rail and the automobile.
2. A vision of the city as an rural/urban garden city, contrasting with large cities such as Chicago, Boston, and New York, which were considered too dense and unsanitary.
3. Fear of natural disasters, such as earthquakes and landslides, leading to a lighter and flatter design.

Since its founding in 1781, the development of Los Angeles has always been closely linked to the advancement of new transportation systems. Until around 1870, Los Angeles remained a relatively insignificant small town with an agricultural focus and a population of around 6,000. In 1876, the city was connected to the transcontinental railroad line, which has just been completed, connecting San Francisco and the East Coast. This new connection to the interior of the continent led to the first major wave of immigration. The new inhabitants were mainly settlers from the Midwest, attracted by the warm climate and rich agricultural resources. Between 1870 and 1900, around 20 new towns were founded in the area around the small town of Los Angeles. An extensive network of individual villages and towns—Pasadena, Santa Monica, Anaheim, Santa Ana, Pomona, Riverside, and Redlands—developed in Los Angeles County. All of these were primarily agricultural communities. In 1890, the population of the city was 50,000 inhabitants. (Wachs 1997, 107).

The strongest growth period coincided with the emergence of modern inner-city transit systems in larger cities. Developed East Coast centers like Boston, Philadelphia, and New York already had dense urban cores at the pedestrian scale. In contrast, Los Angeles lacked an enclosed, developed city center. This allowed new areas to be designed for the higher capacity and speed of emerging transportation. The rapidly developed streetcar network became essential infrastructure and was instrumental in developing new land. Building contractors and speculators, main shareholders of railway companies, continually extended new lines into undeveloped areas. Cheap plots of land along these lines became valuable building land with favorable infrastructure. The street car, driving urban development, led to rapid city growth at an early stage. Suburbanization began before the city center was fully developed, preventing it from attaining the same importance as city centers in cities of comparable size. Reyner Banham commented in 1973: „a note on downtown … because that is all downtown Los Angeles deserves“ (Banham 1971, 212).

From 1910 to 1920, Los Angeles boasted the largest inner-city streetcar system in the country, and by 1923, the Pacific Electric Company's network spanned 1,164 rail miles. During this period, the Los Angeles Planning Commission, comprised of developers and bankers, focused on subdividing building land and dedicating areas for transportation infrastructure (Wachs 1997, 180).

In 1918, 6,000 building permits were issued in Los Angeles. By 1923, during the last peak before the Great Depression in 1929, the number had skyrocketed to 62,548. In 1925, 600,000 plots of land were up for sale, which could have accommodated a population of 7 million. However, this population size was not reached until 50 years later (Dear 1996, 92).

In summary, unlike in comparable cities, suburbanization in Los Angeles was not a post-war phenomenon. Instead, Los Angeles experienced strong growth and decentralized development from early on, with suburbs developing simultaneously with the city core. By the 1920s, the current size of greater LA was already defined in terms of transportation and parcel subdivisions (Wachs 1997, 119).

Following the railroad system, the private automobile had a lasting influence on the shape of the city, spreading through Los Angeles at an impressive rate. As early as 1929, 777,000 automobiles were registered in the city, which corresponded to one car for every three inhabitants. With this figure, Los Angeles far surpassed all other cities in the country at the time. Urban expansion, once restricted to rural corridors along railroad lines, now faces no barriers to seamless development (Wachs 1997, 113).

Increasing density and growing automobile traffic soon pushed the shared railroad and car tracks to their capacity limits. Built with private funds for land speculation, these lines struggled to operate profitably and comprehensively. Consequently, the city administration refused to take them over (Wachs 1997).

The gradual decline of the streetcar system began due to the overwhelming competition from automobiles, culminating in the Pacific Electric Railway Co.'s takeover by a consortium of General Motors, Firestone, Mack Truck, and Chevron. This shift led to the transformation of rail transportation into a bus system. In 1937, Los Angeles began expanding its freeway system, a process that is still ongoing. The first completed freeway was the Arroyo Freeway, connecting Downtown Los Angeles to Pasadena (Dear 1996, 94).

The urban planning model of an "Stadtland USA" (urban countryside USA) in the sense of Holzner (Holzner 1996, 257) seems to apply to Los Angeles in a special way. Its Central Business District no longer plays a dominant role. Commuter flows run in many different ways between different parts of the city. Typical edge cities, or outer-city centers, like Century City, Studio City, and Burbank are not a recent phenomenon. They developed in parallel with the growth of the region from the very beginning. Some emerged from old independent municipalities that were eventually absorbed by the urban area.

Los Angeles was long considered the epitome of a low-density, sprawling city. However, with a rapidly increasing population and planning measures against sprawl under terms like *smart growth*, its average residential density has risen sharply. According to a recent study, Los Angeles is now the most densely populated city in the United States, with a land consumption of 0.11 acres per capita.[7]

Navigating the city

As a foreigner from Europe in Los Angeles, one quickly realizes that usual methods of orientation in the city don't work. Driving through the city, there's a recurring sense of *déjà vu*; Using visual landmarks to navigate proves ineffective. However, with a city map like the *Thomas Guide*, finding a specific address becomes as systematic task, compareable to looking up a number in a telephone book.

[7] See http://www.sprawlcity.org/ Accessed: November 10, 2001

Navigation along traffic routes

The addressing method allows precise estimation of routes and distances. The regular grid of streets with its long boulevards – Hollywood, Sunset, Beverly, Wilshire, Olympic running east-west; Fairfax, La Brea, Western, Vermont running north-south – enables basic orientation. Key landmarks include topographical elements such as the characteristic hill profiles (Hollywood Hills, Silverlake, Griffith Park) and the Pacific Ocean to the west. Prominent urban landmarks are the skyscrapers of Downtown in the east and of Beverly Hills/Santa Monica in the west, connected by the Wilshire Corridor, which is also lined with skyscrapers. The areas in between (San Fernando Valley, LA) are flat and spacious, allowing orientation at the large-scale even for those unfamiliar with the area. However, orientation becomes more difficult on a smaller scale, as street intersections are visually challenging to identify and find again due to their almost identical branches of gas stations and fast food restaurants.

> ’Below this grand scale, however, structure and identity seemed to be quite difficult. There were no medium-sized districts, and paths were confused. People spoke of being lost when off habitual routes, of depending heavily on street signs” (Lynch 1960, 41)

However, knowing the sequence of the most important avenues and boulevards in the four cardinal directions and the viewing direction, it is easy to determine the respective position. Problems can only arise due to road interruptions. Many roads end abruptly at a topographical obstacle, only to reappear many miles further on.

As will later become clear in Section 6.9, following complicated directions from memory in an unfamiliar area is not a major problem for most inhabitants. It can be assumed that people orient themselves not following a memorized image of the surroundings in Lynch’s sense, but by an abstract coordinate system defined by a few reference points, the mesh size of the grid, and the sequence of the most important streets. Interestingly, city maps of Los Angeles typically do not include building footprints or building lines, except in areas such as downtown.

City maps like the “Thomas Guide” are indispensable for navigating unfamiliar street names and addresses in Los Angeles, often carried in every vehicle. Every resident can readily name the page of the roughly 400-page guide that lists their home address. Lev Manovich’s quote introduces a new way of navigation through car GPS systems, which allow users to navigate without topographical context, akin to using a web browser. In this system, places become singular points in an undefined space. Users enter the desired destination address, and the route is announced via voice output, making local knowledge and orientation unnecessary. This system functions like a city browser, managing places like bookmarks and guiding the driver to the desired address.

Using buildings for orientation

In historical European cities, orientation usually depends on buildings, requiring a very good knowledge of the area for precise directions. In Vienna, the radial system aids in approximate localization. However, giving exact directions from memory to someone unfamiliar with the city also demands a high level of familiarity. In such cases, most will point out a few easily recognizable buildings visible from a distance to help a stranger find their way.

Relative space concepts in other disciplines

The following chapter takes a look at related disciplines that investigate relative spaces and their non-linear representation methods. In geography and cartography, various solution approaches and mapping models exist for relative, especially temporal parameters. Many of these models have been taken up again in information visualization and used to represent abstract data sets. The examination of relative spaces also takes place in the field of art, whether in the observation of non-material phenomena of reality such as speed and movement or in the formulation of alternatives to the objective-absolute description of space.

This chapter examines related disciplines that investigate relative spaces and their methods of representation for non-linear phenomena. In geography and cartography, various approaches and mapping models have been proposed for relative, especially temporal parameters, and many of these models have been adopted in the field of information visualization to represent abstract data sets. The examination of relative spaces also takes place in the arts, whether in observing non-material aspects of reality or as critiques of supposedly objective treatments of space.

Geography and cartography

Models of relative space have been researched in geography since the 1950s. The description of complex social and economic relationships made it necessary to find clear forms of representation for these phenomena. As a rule, this is done through thematic maps – maps for the representation of various types of information which, although not directly topographical in nature, are nevertheless assigned to a specific location.

Below are the absolute-spatial and corresponding relative-spatial forms of representation for thematic parameters:

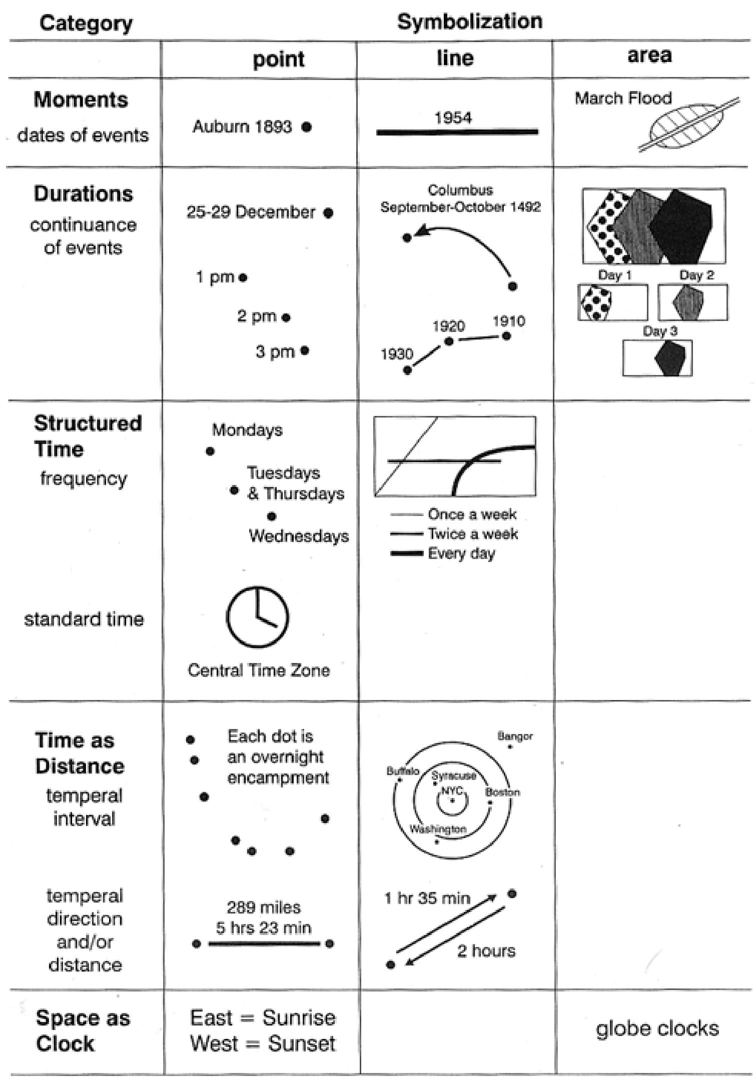


Figure 13: Cartographic symbols for the representation of temporal parameters (Vasiliev 1996)

Choropleths

Choropleth maps are divided into sub-areas filled with different colors or textures (an area symbol). Each color or texture corresponds to a specific characteristic of the parameter under consideration. The entire value range of the parameter is classified into discrete intervals, which are usually assigned a color gradient from dark to light.

The data structure typically predetermines the subdivision of an area into sub-areas. For example, census data use census districts as the smallest spatial unit, resulting in rather imprecise spatial allocation of the examined parameters.

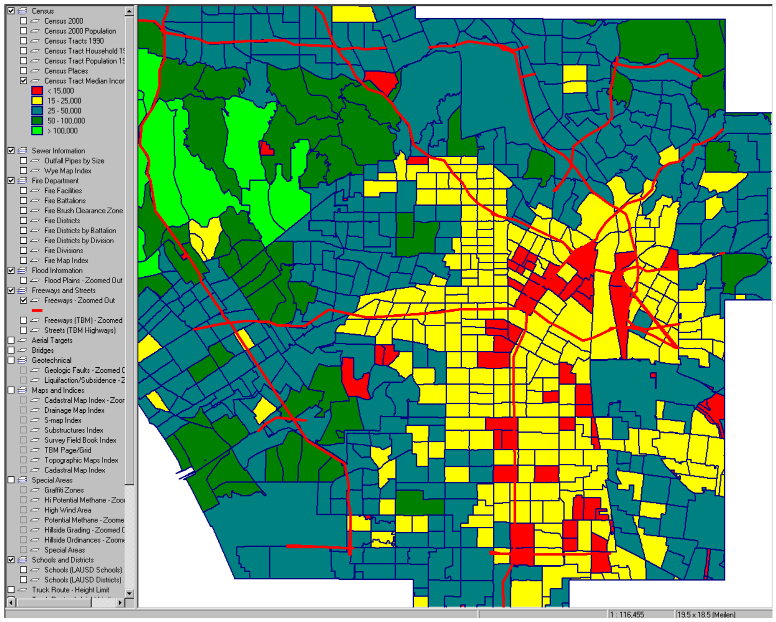


Figure 14: Choropleth map of median income in Los Angeles per Census Tract. Online source: http://navigatela.lacity.org Accessed:4/14/2002

Isolines

Isolines are a suitable display tool for values continuously distributed in space. Unlike choropleths, the sub-regions are not predefined but are represented by contiguous lines connecting points with the same parameter values. The value range of the parameter to be displayed is again classified into discrete intervals. Accordingly, contour lines on topographic maps are isolines that enclose areas of the same elevation. Isolines can express continuous phenomena such as temperature and other properties.

Isochrones

Travel time distances can be represented as isochrones, which are lines of equal temporal accessibility centered around a common origin. This centralization limits their usability in traditional maps. Additionally, isochrones vary significantly throughout the day, suggesting potential for future interactive maps that use network analysis to quickly calculate isochrones from any point.

On a smooth horizontal surface, isochrones would appear as concentric circles with equal spacing. However, obstacles or obstructions distort these shapes; difficult-to-reach points make isochrones converge, while areas allowing high speeds result in wider isochrone distances.

Isochrone maps can be challenging for observers to interpret. Depending on the mode of transportation, representations might include islands or holes, depicting scenarios where distant areas are closer in time than nearby ones. Multiple route options further obscure which specific route the time distance refers to.

A schematic representation of different forms of isochrones:

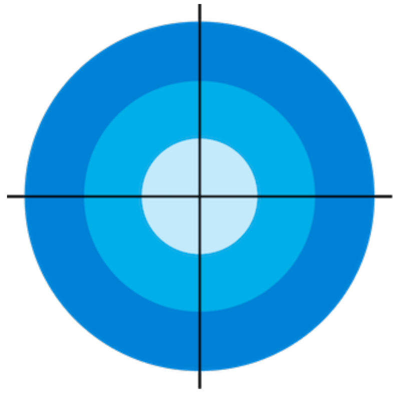


Figure 15: Isochrones on a uniform horizontal surface

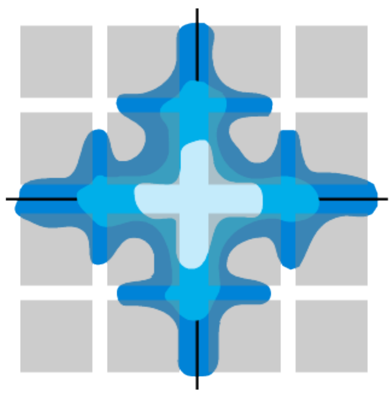


Figure 16: Isochrones in an urban grid

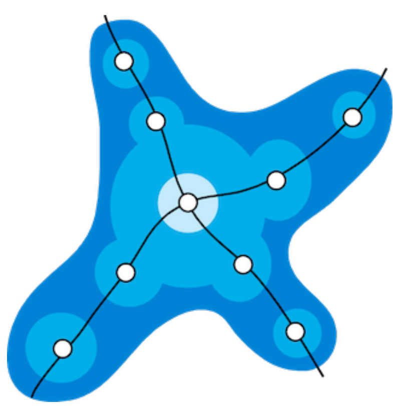


Figure 17: Isochrones in a subway network

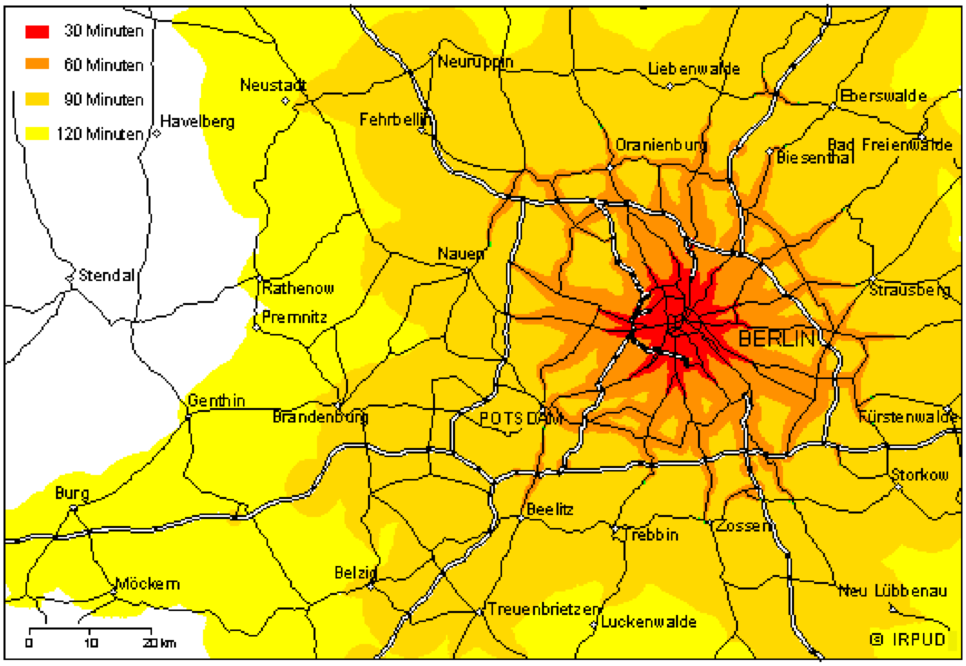


Figure 18: Travel time isochrones in the road network (close range) © 1999 Carsten Schürmann, IRPUD

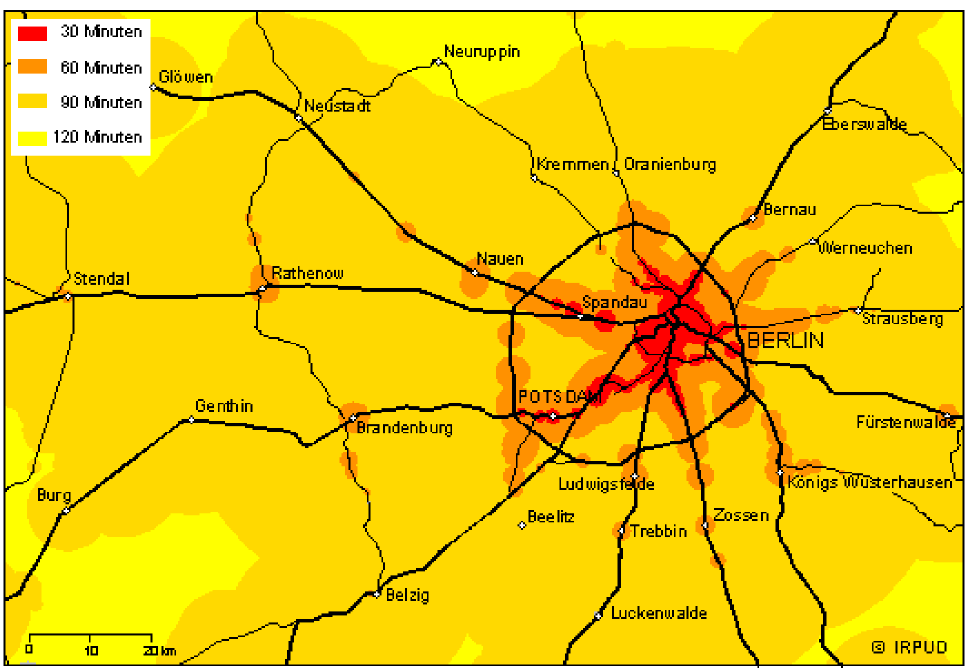


Figure 19: Travel time isochrones in the railroad network (close range), © 1999 Carsten Schürmann, IRPUD

Isotachs

Isochrone maps are limited by their common origin centering, a drawback avoided with isotachs. Isotachs are isolines that enclose locations of the same velocity. By determining the local velocity for each point, the representation is no longer centered.

A series of isochrone maps with different points of origin can be used to approximate the spatial velocity distribution. Additionally, isochrone maps with any origin can be derived from an isotach map.

Isotach maps are commonly used in meteorology to represent wind speeds. They often complement isochrone maps in transportation applications.

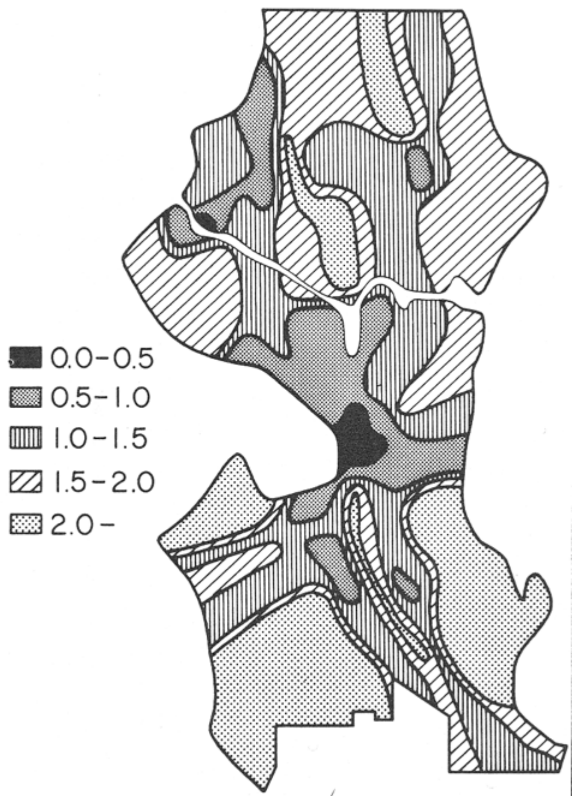


Figure 20: Seattle isotach map - Traffic Engineering Division, City of Seattle, and William Bunge (Abler, Adams, and Gould 1971)

Cartograms

Cartograms or cartographic anamorphoses are geographical maps that have been intentionally distorted to represent non-geographical information (Kocmoud 1997, 4). Cartograms, like choropleth or isoline representations, can express thematic parameters. However, cartograms differ by expressing the value of a parameter directly as spatial extent or distance. The parameter is now understood as a measure of space itself, rather than as a local variable quantity in absolute space. In distortion cartograms, spatial distance influence is equalized, as each point has the same density value and equal areas represent the same parameter value.

This method offers several advantages. It provides a clear, intuitive understanding of the parameter's size distribution, assuming the real spatial shape of the area is known. Unlike choropleth maps, which are often not immediately legible and rely heavily on the legend for value classification, this approach can enhance clarity.

Cartograms are distinguished as either contiguous or non-contiguous. In the case of non-contiguous cartograms, the units of observation are rendered as distinct elements individually resized according to the parameter to be displayed. They have a more abstract-diagrammatic character and are easier to produce by hand. As an example, Dorling's circle cartograms represent the spatial elements as circle symbols of variable size (Dorling 1994).

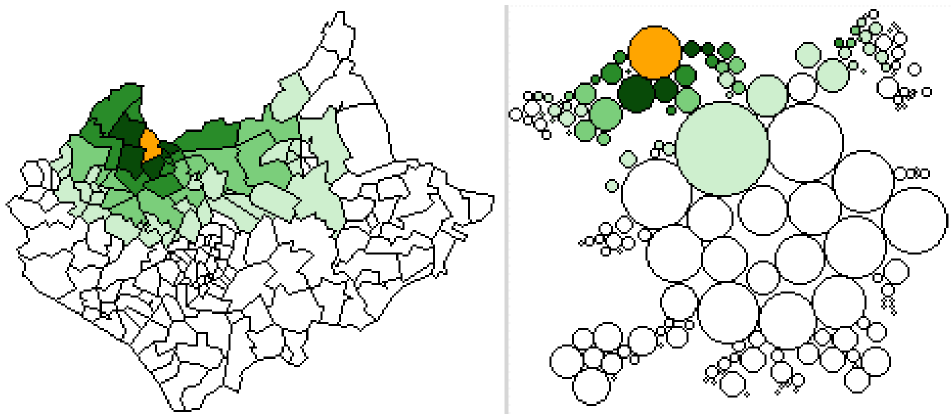


Figure 21: Choropleth map and non-contiguous cartogram. Online source: http://www.mimas.ac.uk/argus/ICA/J.Dykes/3.3.html Accessed:12/10/2001

In contiguous cartograms, the continuity of the space is maintained, appearing as if drawn on an infinitely stretchable blanket. The local density of the parameter under consideration acts as a stretching force. Various algorithms exist for generating coherent cartographic representations (Kocmoud 1997, 22).

- In the rubber map algorithm (W. R. Tobler 1973) and the rubber sheet distortion algorithm (Dougenik, Chrisman, and Niemeyer 1985), the thematic parameter is first considered as a point distribution. The map is then distorted iteratively until all points are equidistant.
- Dorling's Cellular Automaton method is based on Conway's Game of Life algorithm (Dorling 1994).
- In the DEMP (Density Equalizing Map Projections) algorithm, individual sub-regions are scaled radially in relation to their center of gravity, deforming adjacent regions. This algorithm is applied iteratively for each sub-region. (Merrill, Selvin, and Mohr 1992).
- Kocmoud's constraint-based approach uses various shape constraints to retain the familiar shape of spatial units like federal states or census districts, ensuring the map remains comprehensible to the viewer (Kocmoud 1997).

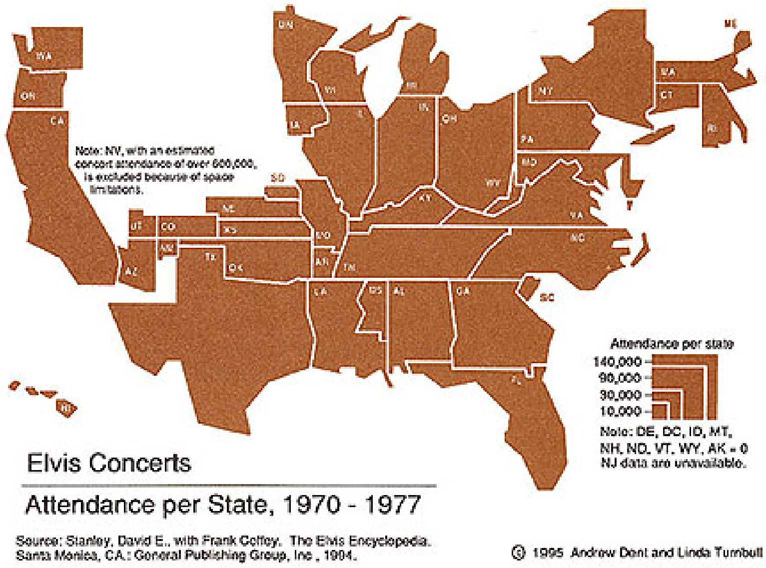


Figure 22: Elvis concert attendance by state, Andrew Dent and Linda Turnbull, source: http://www.owu.edu/~jbkrygie/krygier_html/geog_353/geog_353_lo/geog_353_lo03.html

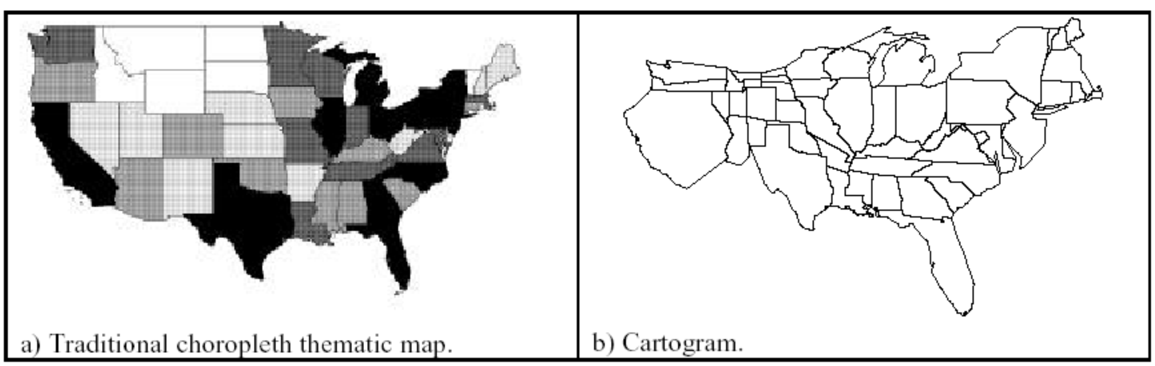


Figure 23: Population size: Choropleth map vs. cartogram (Kocmoud 1997)

Transforming isochrone maps

Using time units as the scale for isochrone maps results in concentric circles of equal distance. Transforming these into relative space alters the complex shapes of the isochrones into concentric circles, thereby deforming the space. However, obtaining a relative space representation is not always possible, as isochrones can form holes or islands, leading to ambiguities. Consequently, the space appears folded, and the geographical shape is lost or appears inverted.

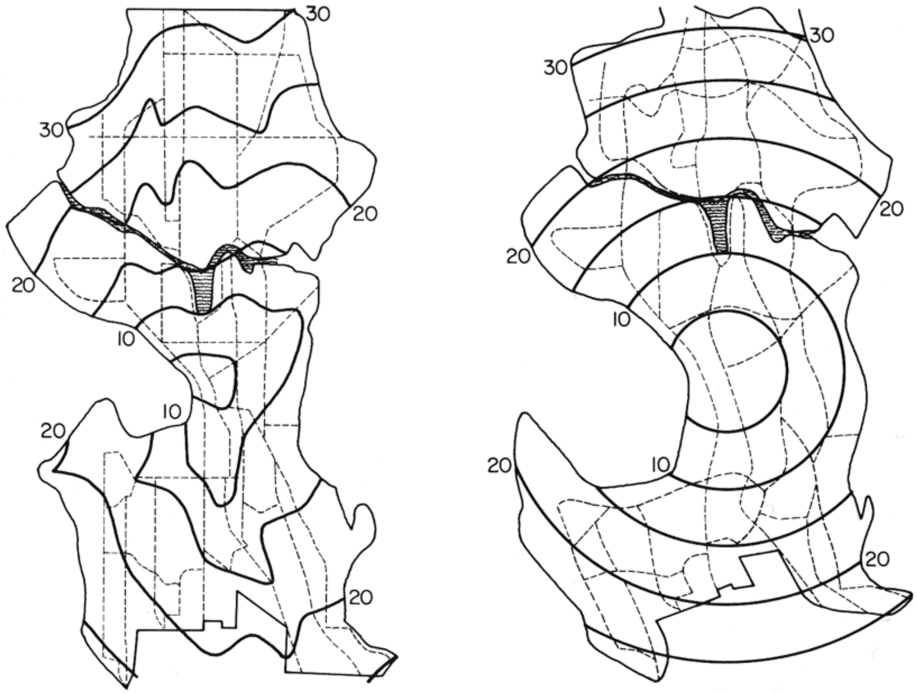


Figure 24: Seattle isochrone starting from the Central Business District in topographic space and in time-related relative space - traffic engineering division, city of seattle, and william bunge (Abler, Adams, and Gould 1971, 79).

Taxicab geometry

A special form of non-Euclidean geometry, known as taxicab or Manhattan geometry, plays an important role in representing time distances. this geometry is particularly helpful when mapping or calculating time distances or actual path lengths in built-up areas.

In taxicab geometry, only directions parallel to the orthogonally aligned spatial axes are permitted. Each direction or path is expressed in an orthogonal grid with a defined mesh size, which approaches zero in its continuous form. The distances correspond to the actual path a vehicle must travel in a completely regular street grid of the same mesh size to reach any point in the city.

Taxicab geometry allows more than a single shortest distance between two points, making it distinct from Euclidean geometry. In this way, two-cornered, closed figures with only two corner points are possible, explicitly excluded in Euclidean geometry.

A circle would look like this in taxicab geometry:

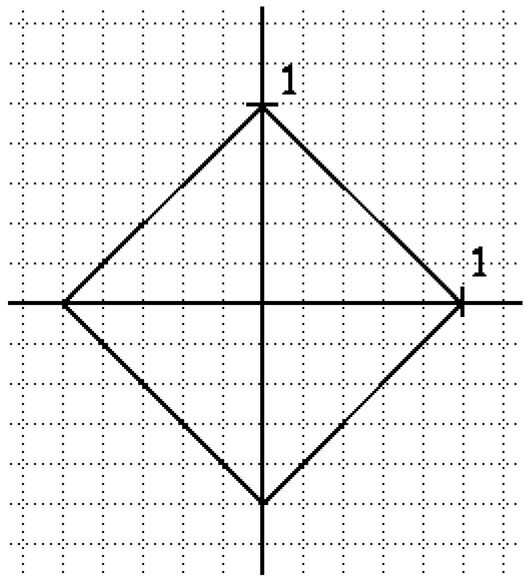


Figure 25: a circle in taxicab geometry

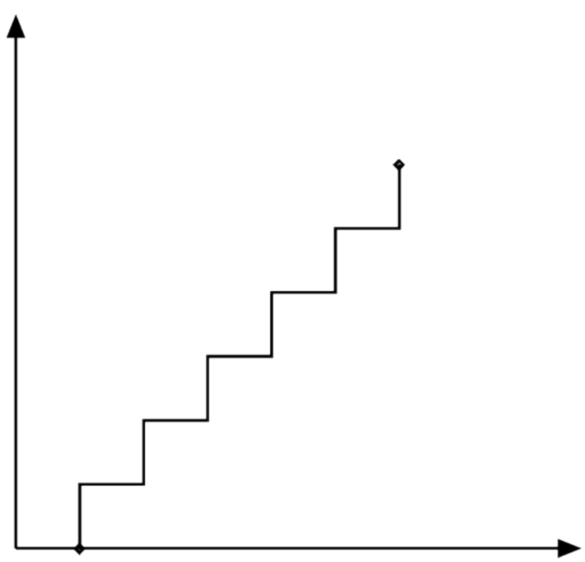


Figure 26: A diagonal in taxicab geometry

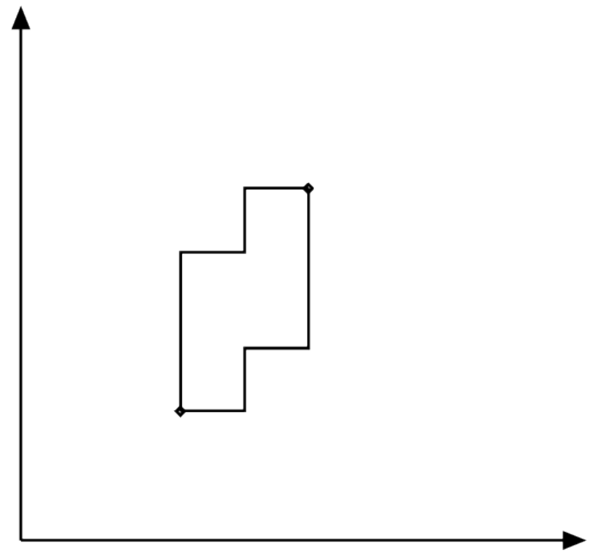


Figure 27: A “twoangle” taxicab geometry

In isochrone maps of cities with orthogonal street grids, the forms of taxicab geometry often reappear (Gardner 1997).

Information visualization

In recent years, models of non-linear space have been increasingly developed in information visualization. These models focus on visually processing and structuring complex, multidimensional data sets, where the information itself becomes a spatial parameter. Similarity regarding the parameter is expressed through spatial proximity of the elements. Non-linear display models aim to present complex data sets as a whole while simultaneously highlighting specific areas.

Hyperbolic space

Hyperbolic space, a type of non-Euclidean geometry, is well suited for representing extremely complex and extended networks. In two-dimensional hyperbolic geometry, this can be visualized as being inscribed on a hyperbolic saddle surface, described mathematically by the relationship $x^2 - y^2 = r^2$, also known as a pseudo-sphere. This surface has an infinite area, and a triangle in hyperbolic space has angles summing to less than 180°, with its shortest paths being concave. Additionally, through any given point, an infinite number of parallels to a straight line can be drawn.

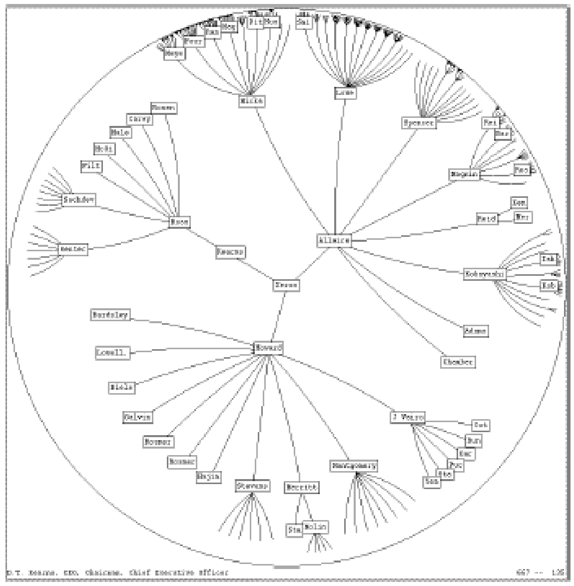


Figure 28: Representation of a tree structure in the hyperbolic plane (Lamping, Rao, and Pirolli 1995).

This two-dimensional hyperbolic space can be projected into the Euclidean plane using the Poincaré projection, resulting in a disk-shaped hyperbolic surface. The bounding circle represents the infinite extension of the hyperbolic space. Straight lines of constant length in hyperbolic space appear as circular arcs on the Poincaré disc, becoming shorter as they move further from the center. A point moving away from the center at a constant speed appears to slow down in the projection as it nears the bounding circle but can never reach it, as the circle corresponds to an infinite distance from the center.

In this model, space is distorted uniquely, allowing unlimited amounts of data to be displayed in their entirety at once. The size of the representation in the center remains large enough to examine details of the data structure. By moving the data structure in hyperbolic space, the focused area can be changed. Despite its complexity, this spatial model is surprisingly accessible and creates an impression reminiscent of looking through a fisheye lens (Lamping and Rao 1994).

Non-Linear magnification

The basic principle here is the simultaneous display of a strongly magnified focus point alongside the context of the entire data structure (also known as the focus + context technique). Non-linear magnification and distortion viewing summarize techniques that magnify individual details without removing the examined area from context or obscuring parts of the whole. Additionally, the use of multiple focal points and lines extends the hyperbolic space model (Keahey and Robertson 1996; Kilian 2000).

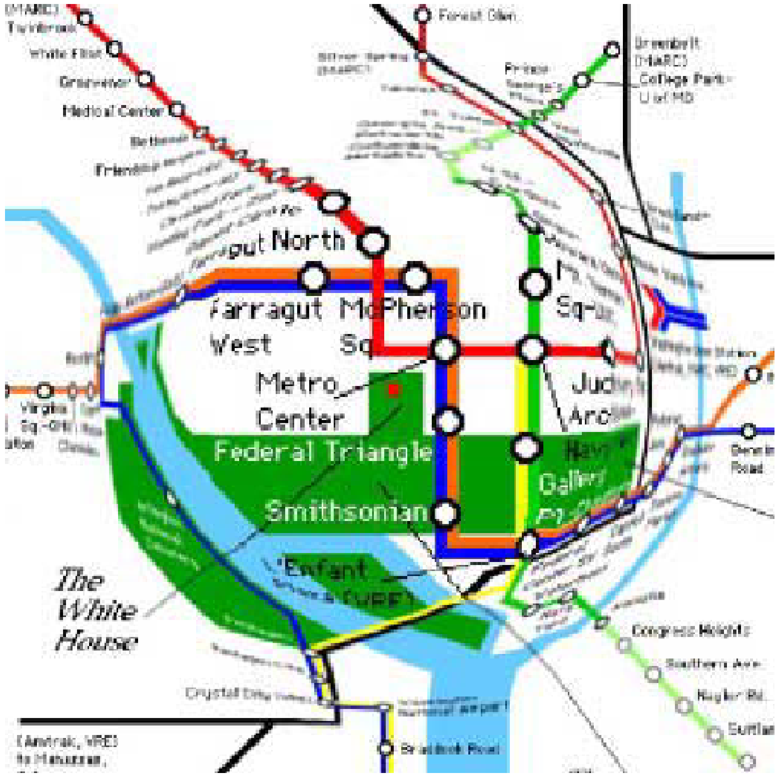


Figure 29: Example of non-linear magnification in (Keahey 1998)

3D - Distortion Viewing

Although most of these techniques are limited to two-dimensional space, the extension into the third dimension can be useful in several ways. To make the highlighted area readable through spatial distortion, local enlargement is interpreted as a distortion of the plan towards the camera, and as perspective proximity. Shading techniques are then used to depict a light/shadow gradient on the distorted surface, making the spatial distortion perceptible.

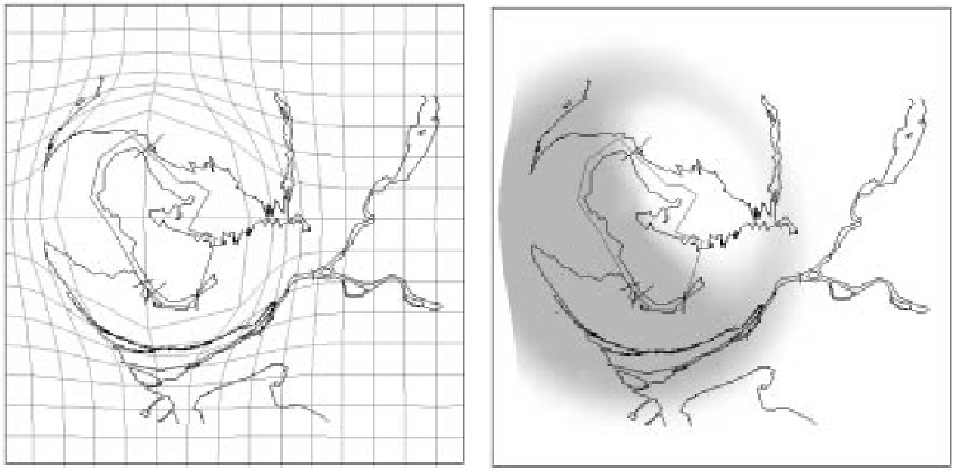
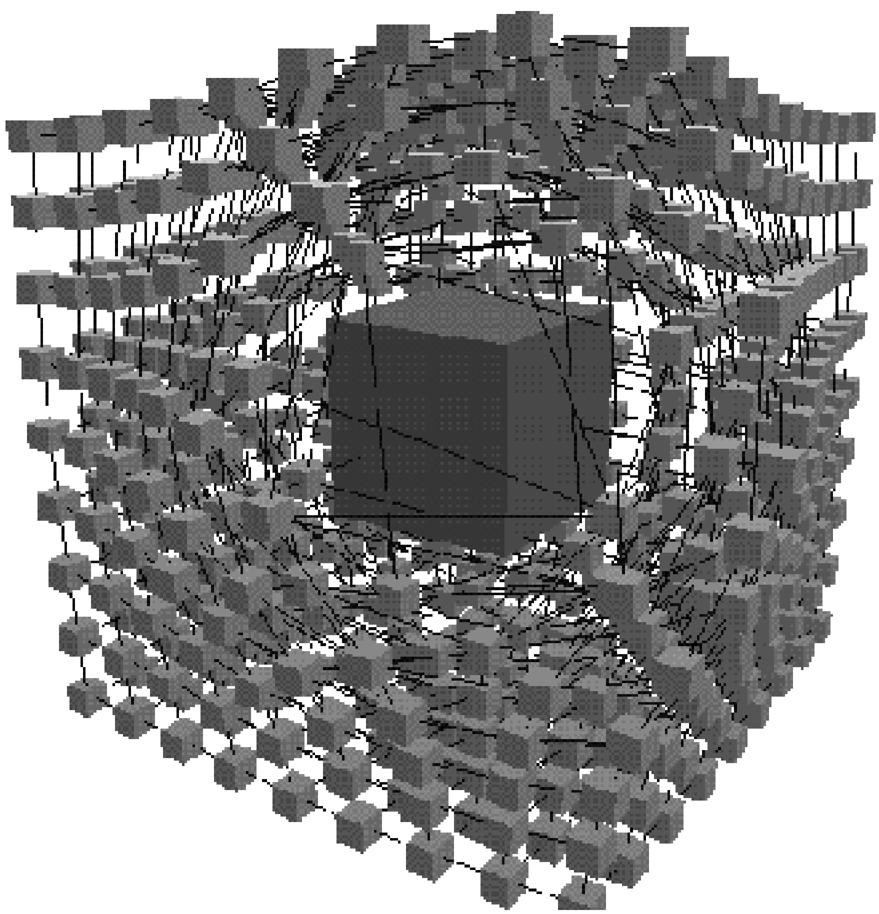


Figure 30: Non-Linear Magnification - suggestion of distortion by superimposed grid and shading of the surface (Carpendale, Cowperthwaite, and Fracchia 1995)

Carpendale et al. attempted to transfer and generalize the methods of two-dimensional distortion viewing to three-dimensional space. In addition to avoiding spatial overlaps, particular attention was paid to the visual access of the focused elements in order to avoid a viewed spatial element being obscured by other elements(Carpendale, Cowperthwaite, and Fracchia 1995).



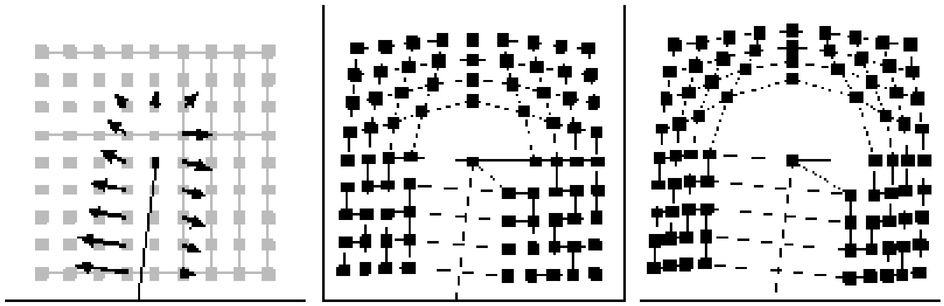


Figure 31: Visual access in 3d-distortion viewing.

Art

The perception and appropriation of space are central themes in contemporary art, a domain inherently tied to the subjective vantage point. The following three examples systematically examine subjective spaces and their geometry.

Situationism

The term psychogeography was chosen by the situationists to describe the imaginative and perceptual spaces of our everyday environment. It is not the environment itself, but the effects of the environment on people's behavior and feelings that are to be examined and depicted.

Derivé is a method for subjective, psychogeographic mapping of the urban environment. A group of 1-4 people suspend all their usual social ties and activities for a certain period of time (usually several days) and devote themselves to exploring their immediate surroundings.

The aim is not to see the urban environment through the filter of the daily rhythm of work and leisure, but to be guided and directed by existing signs and places without having a clear goal in mind.

It was important that this was not a matter of randomly "letting oneself drift", but rather a conscious process of mapping:

> "The sudden change of ambiance in a street within the space of a few metres; the evident division of a city into zones of distinct psychic atmospheres; the path of least resistance which is automatically followed in aimless strolls (and which has no relation to the physical contour of the ground); the appealing or repelling character of certain places" (Debord 1955).

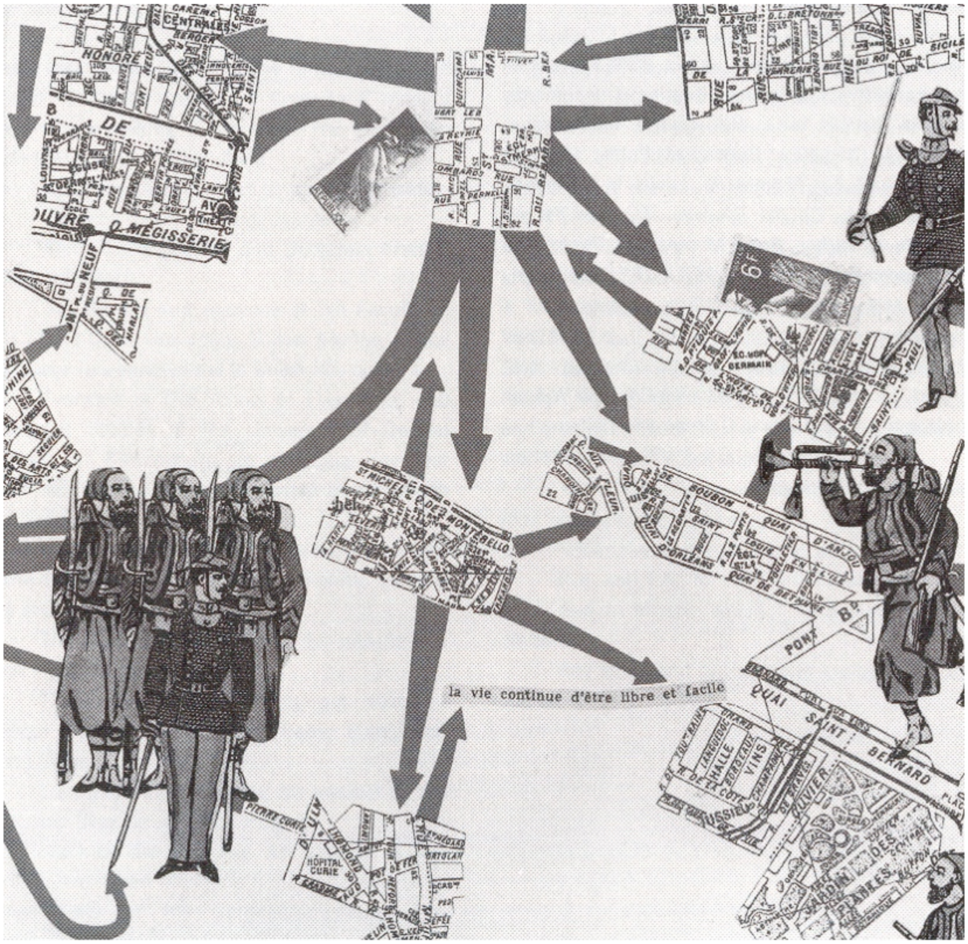


Figure 32: Life continues to be free and easy, 1959– Guy Debord (Sadler 1999)

Richard Long

British visual artist Richard Long's "walking projects" explore familiar regions through personal, subjective experiences. Unlike the Situationists, who reassemble geographical space based on subjective criteria, Long's method involves walking for several days, forming a basis for his cartographic activity by maintaining the familiar image.

The imaginary, abstract geometry of the map becomes a leitmotif traced in the real environment. He arbitrarily draws circles and straight lines on the map, making the delineated space the subject of his wanderings.

The only evidence of the performance "a seven day circle of ground - seven days walking within an imaginary circle 5 ½ miles wide, Dartmoor, England 1984" is a circular diagram with place names. The path of the walker is not marked. Most place names are the artist's own, while some indicate dates; seven locations on the diagram are labeled "Midday." The designation "tent" marks the center of the imaginary circle. It is unclear whether the "map" represents an actual geographic area. There are no points of reference to geographically fix the area explored by Long. Instead, it is a relative spatial representation, a cognitive map that more readily reveals the chronological sequence of his journey rather than his actual route. The abstract circle could be seen as an ironic commentary on the supposedly objective nature of maps, which attempt to geometrically organize subjective experiences and arbitrary decisions (Corner 1999, 234).

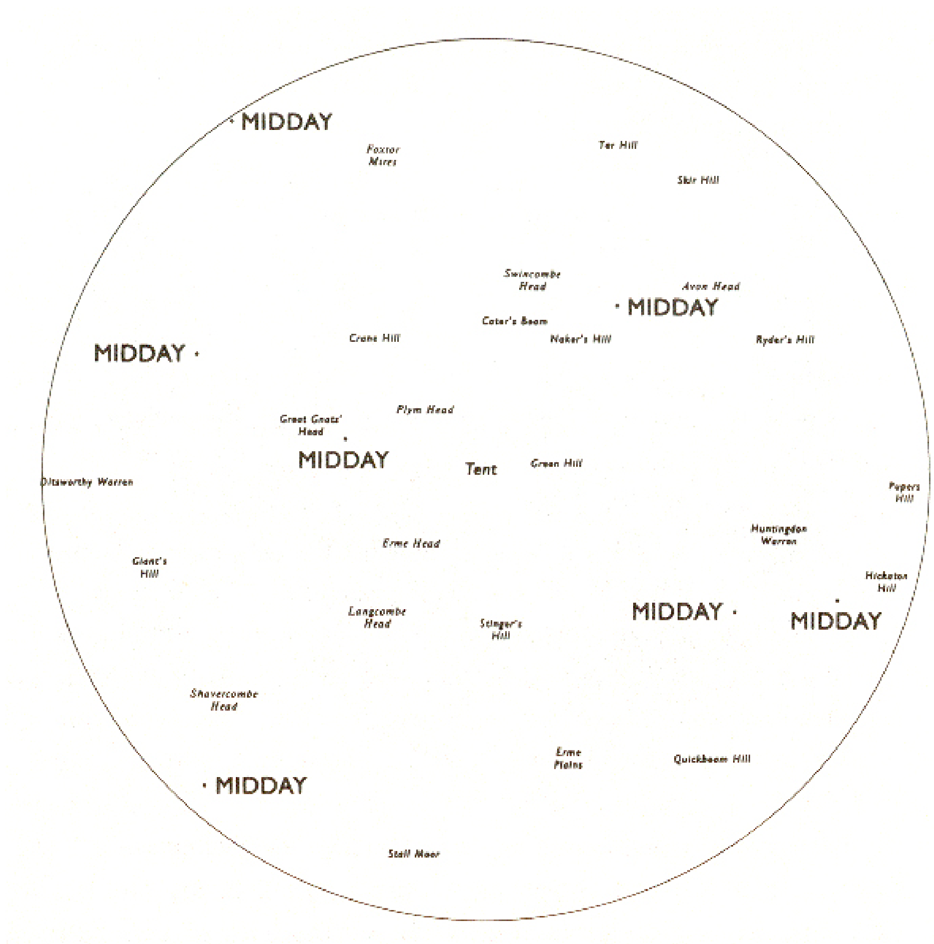


Figure 33: A seven day circle of ground... – Richard Long (Corner 1999, 234)

Masaki Fujihata

The works of the Japanese artist and scientist explores various aspects of perception, speed, and space.

In 1991, Fujihata hiked to the peak of Mt. Fujijama with a group of students, each equipped with a GPS receiver that constantly recorded their geographical coordinates and walking speed. Although the GPS data provided exact positions on the plain, there was no data on their altitude. To overcome this, Fujihata reconstructed the elevation of the paths using the walking speed—slower speeds indicated steeper terrain. This method allowed him to create several three-dimensional profile curves of the mountain from the individual paths, leading to a reconstructed model, as shown in the figure below. The “explosion” of geometry in the left-hand illustration resulted from the group spending more time on the mountain peak, which the speed function interpreted as increased steepness.

Figure 34: Impressing Velocity, Masaki Fujihata 1992 source: https://web.archive.org/web/20030211235638/https://www.c3.hu/~masaki/proposal/ accessed 6.9.2001

Fujihata explores themes of speed and perception also in his video installations. A video camera mounted on a model train transmits the image of the speeding train. By analyzing this image, the speed of individual picture elements is measured and used to deform the image plane. Fujihata explains that he aims to counteract the adaptation of visual perception to speed, making it possible to experience speed anew.

Proposed models of representation

In the following section of the thesis, the previously described methods of visualizing relative space are applied to analyzing the city. Various options are available for visualizing thematic parameters:

Diagrams, maps, or plans provide static representations on paper, using cartographic symbolism or cartograms to depict thematic parameters. However, representing time-variable parameters on paper is difficult. This problem can be addressed using computer animation, which allows explicit visualization of temporal-spatial parameters. However, it can convey the dynamic nature of relative spaces only to a limited extent. With appropriate modeling and coding, virtual environments allow direct visualization of parameter changes on the shape of the relative space.

The advantages of using virtual environments (VEs) are quickly summarized: They enable dynamic display models that react to viewer behavior, allowing users to change parameters and explore resulting changes interactively. However, existing cartogram algorithms are often computationally intensive and therefore not suitable for interactive VEs. The challenge lies in finding an adequate model that is simple enough to be calculated and displayed in real time by common computer systems.

General goals and criteria

Designing dynamic virtual environments (VEs) require planning of model behavior, interaction modalities, and the interface. Instead of using statically modeled geometry, the representation is determined by a set of mathematical rules.

An important criterion for visualization models is the recognizability of the represented shape, which involves retaining topology, preserving shape features, and maintaining spatial orientation. It is crucial to prevent the geometry from overlapping itself and ensure that neighboring areas in real space connect appropriately in relative space without overlaps. Additionally, straight paths should not loop or fold in relative space. This is managed by limiting the degrees of freedom in shape changes and implementing specific restrictions and obstacles that preserve the recognizable shape without significantly distorting the result. These restrictions, commonly known as constraints in real-time computer graphics, play a vital role in achieving this balance.

Other criteria include:

- **Communicating model behavior through interaction** allows observers to recognize the influence of subjective parameters. Interaction with the system enables the observer to grasp its form-determining principles and their influencing factors.
- **Combining internal and external views:** Exocentric and egocentric reference systems complement each other and lead to easier access to the respective model. The entire system can be viewed from the outside, and several subjective cameras also offer an internal view.
- **Simplifying navigation:** A well-known issue in virtual reality is the complex navigation, which complicates orientation and interaction within the environment. To address this, standard navigation models like walk, fly, or examine were not used. Instead, a simplified, restricted navigation model was developed to help users avoid getting lost while still conveying the space's nature vividly. Users can move freely along defined paths and steer the subjective camera to other paths by clicking on them.

Shape defining forces

The shape of the geometry is determined by the interplay of simulated forces between specific nodal points. Their strength depends on the relative distances to be displayed.

In an early version, I used a spring model for this deformation. Each distance was assigned a spring force, whereby the rest length of the spring equation was used as the target distance. In the spring equation Fk = k(l-z0), the resting length z0 was used for the target distance.

The disadvantage of this approach was that the interaction of the spring forces in the system caused oscillations that could build up and corrupt the representation.

For this reason, I decided to use a different method for calculating relative distances in the model. The distance is not changed all at once, but in small steps over time, controlled by a damping factor. This allows for a balanced representation by aggregating different forces through a gradual change without instability of the spring-mass system. Different damping factors also allow the shape-changing influences of different constraints to be weighted differently.

Design considerations

I avoided the VR-typical representation of urban space, where buildings are modeled with simplified geometry; instead, the recorded video material served as a reference to the material reality of the city. The use of image strips of the streetscapes allowed me to capture visual perception rather than objective reality.

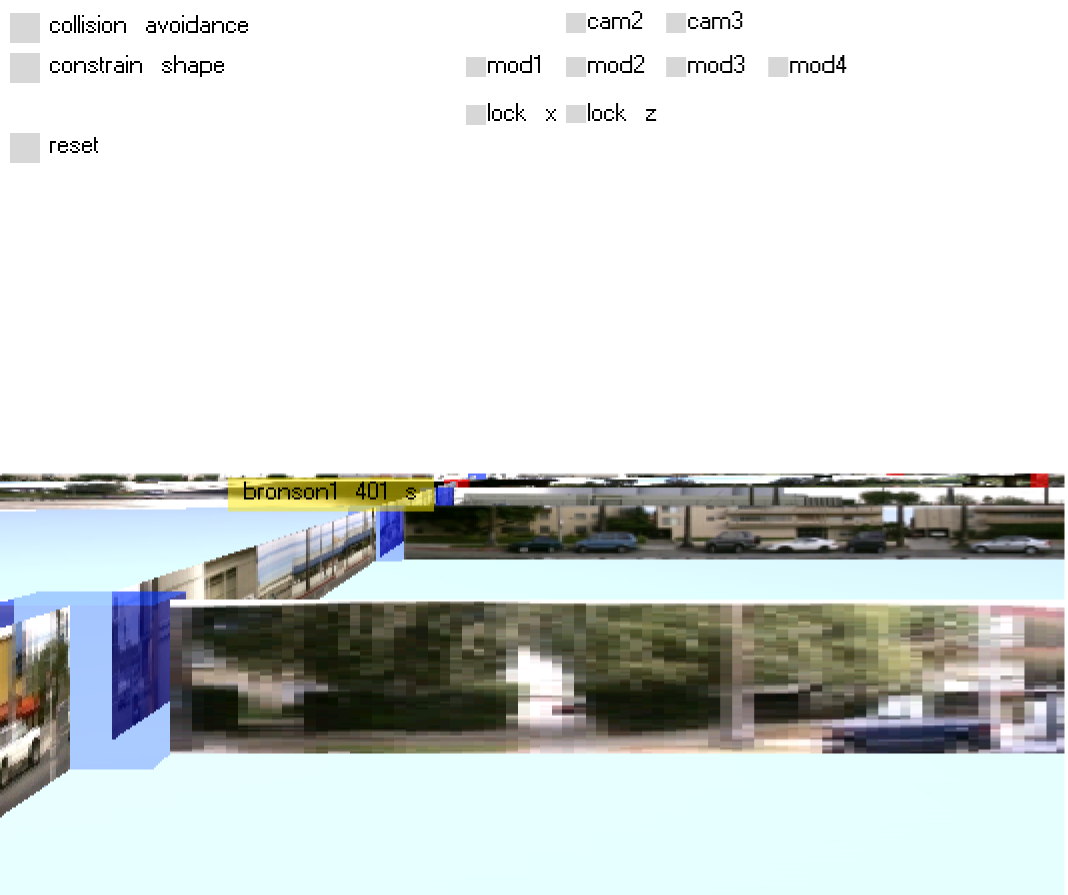


Figure 35: Screenshot of one of the created environments

Software

I developed the virtual environments using the Virtools dev environment, an authoring system for games and interactive 3D applications. Virtools dev uses its own visual programming system. Its scripts used function similarly to symbolic flow diagrams according to the boxes and wires paradigm. Graphical programming is object-oriented; one or more scripts can be assigned to each element, which are processed in parallel and can exchange information with each other.

A simple Virtools script is shown here for illustration. It is a constraint that sets the Y-coordinates of the node objects to zero. The node elements are grouped together.

Virtools scripts are essentially comprised of the following components: - *Building Blocks* are smaller program modules that perform specialized tasks and are connected to each other via signal paths. The example below shows the “Group Iterator” and “Set Position” building blocks. Building blocks have the inputs on the left and the outputs for processing the script on the right. Data input and data output channels are arranged at the top. - *Parameter Operators* perform simple arithmetic operations, but unlike Building Blocks, they are not integrated into the signal flow of the script; they are activated when needed by the Building Blocks to which they are connected. - Parts of a script can be grouped together in so-called *behaviors* with their own signal and data inputs/outputs, which can then be used like building blocks in the script.

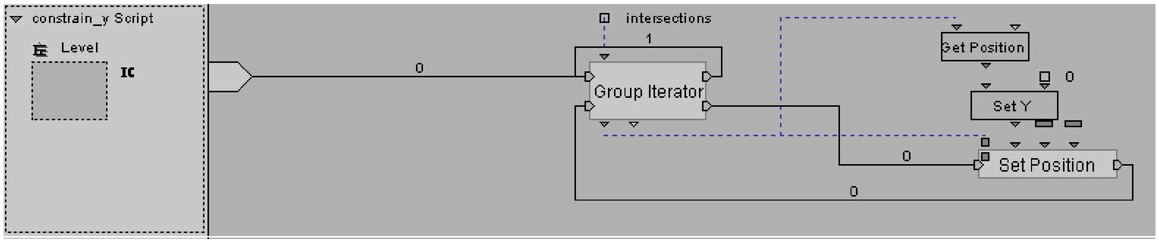


Figure 36: an example of a Virtools script

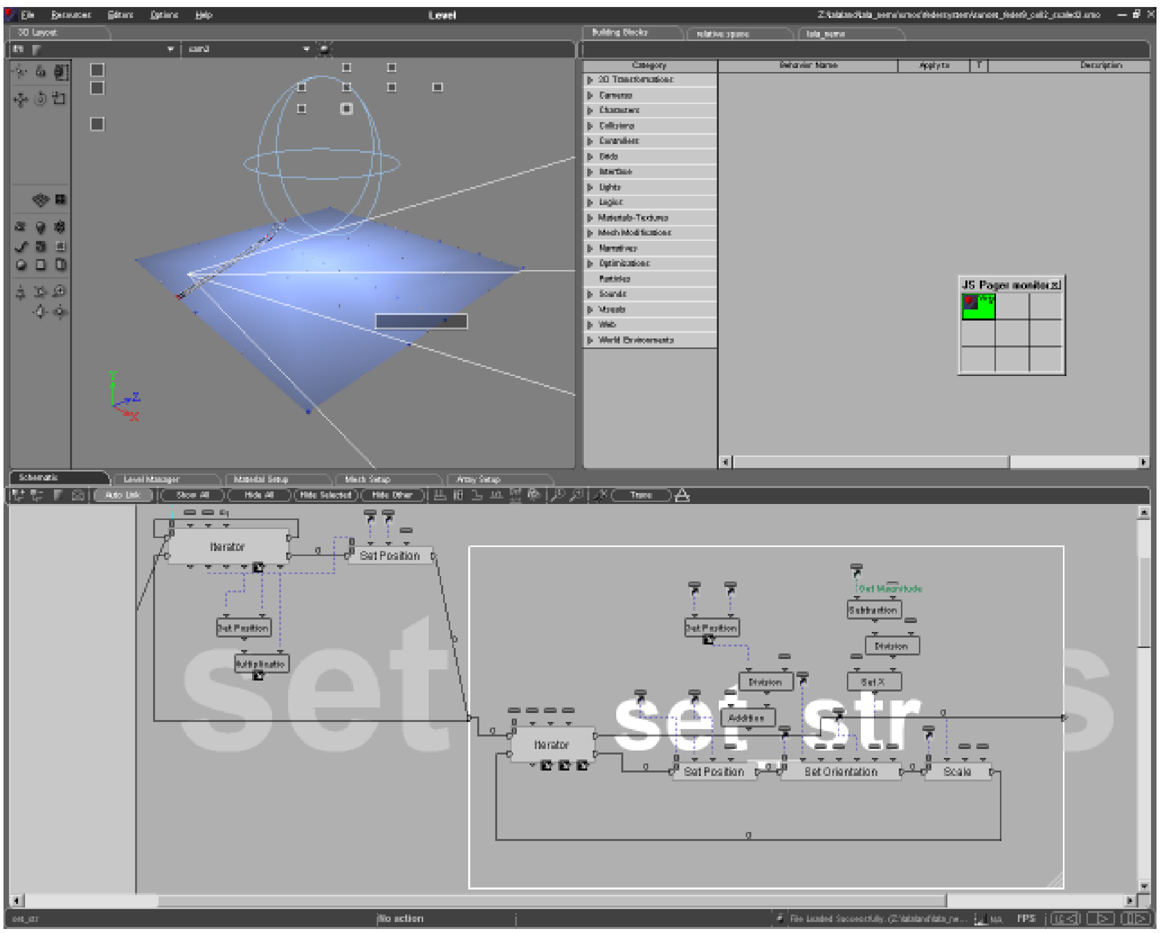


Figure 37: The Virtools dev environment

Videotraces

Figure 38: Video trace from the car window driving on Pasadena Fwy

The study of relative temporal distances in an urban environment requires temporal data from large areas. One problem is the availability of suitable data sources. The area to be studied is usually too large for accurate and complete measurements, and publicly available data sources such as traffic counts are too limited and imprecise. In addition, city maps with building footprints and information on their use are not readily available for Los Angeles.

Therefore, we used systematic video recording of movements in the city, which provides both a visual representation of the study area and information about the time traveled.

The essential characteristic of video is the representation of spatial events in constant time intervals. Time is divided into discrete units called frames. An analog film strip therefore can serve as a measuring tape to measure space in units of time. To simulate this filmic quality in the medium of digital video, we have used various methods to combine individual frames into continuous image montages.

Data sources and methods

Video recordings of driving in various neighborhoods in Los Angeles were taken between September and December 2000.

The video camera with a wide-angle lens was mounted in the side windows of a car using a special mounting bracket. In order to obtain the most detailed individual images possible, recording used progressive fields, i.e. in the full frame resolution of 720x576 D1-PAL at 25 frames per second.

Alignment of image segments

Each frame of the digitized video sequence was cropped to a narrow, 20-pixel-wide vertical strip and then placed side by side in After Effects.

As the camera moves, the perspective in each frame changes, so the frames do not fit together seamlessly in the composite.

For best results, the image strips should be as narrow as possible to minimize the influence of the central perspective. The vanishing points of the individual images become a vanishing line in the composite. However, since the temporal resolution of the video format is limited to 25 full frames per second, a minimum width of the strips is necessary to obtain a continuous image of the recorded objects, such as buildings.

Another problem was vertical jitter, which made the montage difficult to read. This was solved with the following alternative method of image assembly.

Image alignment with vertical adjustment

For vertical alignment, the image mosaicing program Panorama Factory was used, which allows stitching panoramic images from a series of individual images.[8]

This method requires a certain amount of overlap between the cropped frames, for which the 20-pixel cropping was sufficient at the given driving speed. Some manual adjustment was required. Panoramic stitching helped to compensate for the perspective distortion at the edge of each video frame, as well as the vertical jitter of the camera while driving.

Alternative approach for creating large-scale composites

Removing the requirement for a fixed horizontal overlap of the frames resulted in a more natural image after stitching. However, this alternative method no longer allowed for the representation of temporal distance. The resulting montages were then further spatially normalized with the help of a city map and used as textures in the virtual environments.

The image parallax created an interesting effect in the montages - objects in the foreground appear horizontally compressed, while distant objects appear horizontally stretched. The distant objects move much slower than the near objects. In the following display models, these montages are horizontally distorted depending on the speed. Depending on the scaling, only a certain distance from the camera appears in the correct proportion. As Paul Virilio observed:

> "Aber es gibt auch ein Phänomen von NÄHE, das hier ins Auge gefaßt werden muß. Die Geschwindigkeit, mit der die Objekte über den Bildschirm des Guckfensters wandern, hängt auch vom Grad ihrer Nähe ab: je weiter das Flugzeug sich vom Erdboden entfernt, umso langsamer zieht die überflogene Landschaft vorbei; die Welt wird statisch." (Virilio 1978)[9]

Figure 39: Time-based montage - the distance between the vertical markers corresponds to one second.

Figure 40: Vertical alignment - the image becomes more natural, but loses temporal accuracy.

[8] See http://www.panoramafactory.com

[9] Translation by the author: "But there is also a phenomenon of NEARNESS that must be considered here. The speed at which the objects move across the screen of the window also depends on their proximity: the further the airplane is from the ground, the slower the overflown landscape passes by; the world becomes static."

Video documentation of the model (added 2015)

https://youtu.be/YsbKSZpa0Kc

2D road network

The video notation developed so far makes it possible to display individual travel times on a time scale. The next step is the representation for an entire area. Travel times are linear parameters, so it makes sense to represent the study area as a network. Road intersections can be represented by nodes, and the road segments between them can be used to express variable travel time distances.

I selected several ½ x ½ mile square areas based on the following criteria:

- The entire speed hierarchy of traffic areas should be present in the area: Freeways, freeway on-ramps, arterials, secondary highways, residential streets, alleys, parking lots, pedestrian areas, etc ...
- The area should also have a heterogeneous, mixed-use structure.
- The area's road network should be easy to represent as a linear network, i.e. it should consist of mostly straight paths.

The following example shows a part of East Hollywood bordered by the streets Sunset Blvd, Western Ave, Franklin Ave and Bronson Ave. The 101 Hollywood Freeway runs through the area, with an off-ramp on Sunset Blvd. and on- and off-ramps on the transverse Hollywood Blvd. The area north of Hollywood Blvd. is predominantly residential, the area around Hollywood Blvd. is dominated by small-scale commercial uses, and Sunset Blvd. is dominated by large-scale commercial uses in the form of shopping centers and hardware stores.

Figure 41: Aerial view of the selected area

Figure 42: Street names and parcels

Data sources

The model is based on data collected in the field. This includes video sequences from both sides of the road on most of the passable routes, the measurement of traffic light phases at a given time of day using a stopwatch, and the recording of posted speed limits. The actual travel time for each segment was determined from the video sequences. Maps were obtained online from the Los Angeles City Council GIS server.[10] An aerial photograph from Microsoft Terraserver served as additional visual reference.[11]

Figure 43: Video trace, North side Hollywood Blvd.

Model of calculation

The area is represented by a spatial network of nodes and edges of defined length. While the topology of the network remains invariant, the distances between nodes are variable. This means that the network can take on different spatial shapes without affecting local adjacencies.

The change in shape is not abrupt, but gradual. This has several advantages:

- The transition between different points in time can be observed.
- The spatial consistency of the path network is more likely to be maintained with a gradual change than with an abrupt one.

[10] See http://navigatela.lacity.org
[11] See http://terraserver.microsoft.com/default.asp

- The delay helps the algorithm to reconcile the different damping forces, which otherwise would not always be geometrically solvable.

Each edge in the network can initially be assigned a target distance. By iteratively moving the nodes closer together or further apart, their current distance is brought closer to the assigned target distance.

This process is continued until the current edge lengths in the network match the target distances. A temporal damping factor determines the speed at which the shape change occurs. This prevents strong deformations, which can occur due to abrupt changes in distance.

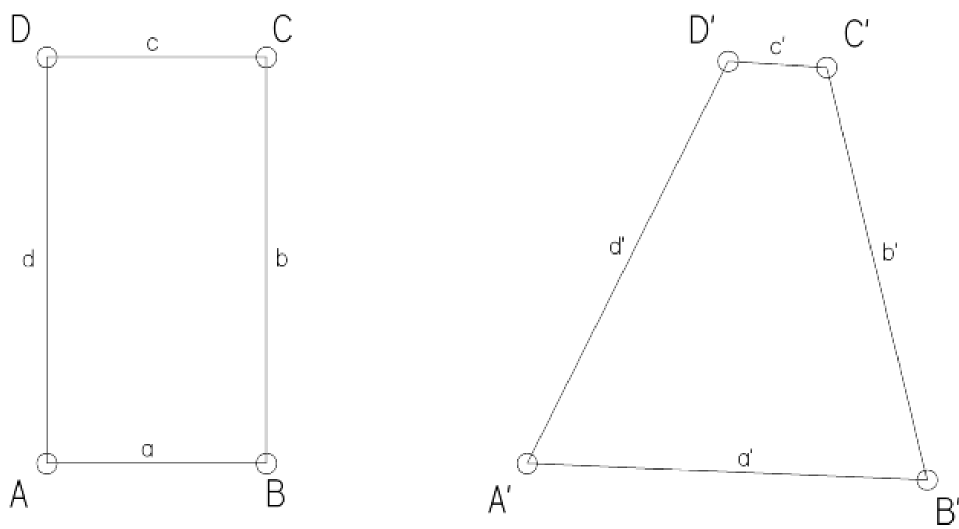


Figure 44: Left: Network with absolute distances a to d. Right: network with relative distances a' to d'

Calculation of the travel time distance

Two types of time distances are used in this example:

- The actual travel time

- The shortest possible travel time distance in both directions based on speed limits and traffic light phases.

Based on the consideration that movement on a route section can only take place during a green phase of the next traffic light, a value for an average travel time can be calculated from the route length, the speed limit and the traffic light phase of the next traffic light in the respective direction. The ratio of red to green phase including yellow phase influences the possible average speed. For example, if the ratio of traffic light phases is 0.5, the average speed is halved because only half the time is available for movement.

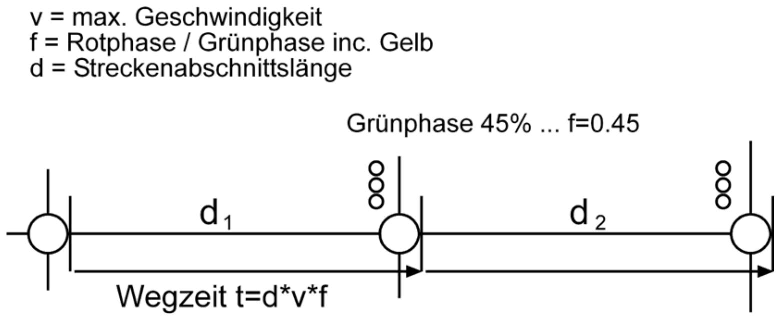


Figure 45: Calculating time distance

Implementation

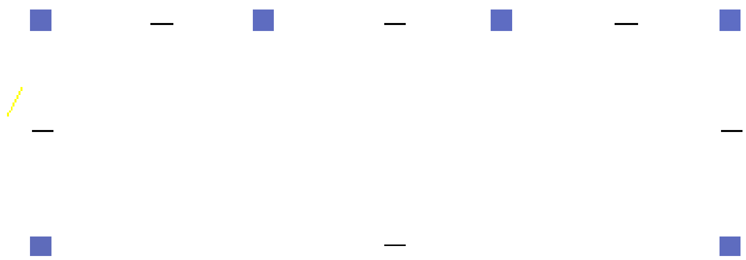


Figure 46: Starting point - node and edge objects

Preparation of the geometry: A list of node and edge objects describes the network. The edge list contains different sets of time distances, the nodes have initial positions.

Update positions of the node objects: The edge table is iterated and the time distances are read out. The two node objects are moved by a fraction of the desired target distance determined by the damping factor.

Inactive nodes: Path segments for which no data is available can be inserted as inactive nodes. They divide an edge in a constant ratio and thus follow the deformation of the route network. The inactive nodes are color-coded; in this example, they were used to represent the 101 freeway.

Navigation: In this model, the direction of movement was neglected when displaying time distances. The different travel time distances for both directions were divided into two different data sets. The model can now be mapped either for the direction of movement east or north or for the direction of movement west or south. The influence of actual traffic volume on minimal distances was not taken into account.

Constraints: In order to maintain the readability of the display, a number of constraints have been implemented that have as little effect as possible on the size of the relative distances displayed.

- **Shape Constraint:** This constraint prevents self-intersection of the network. It adds a gentle stretching to the entire network, causing it to unfold. This can lead to slight inaccuracies in the representation of the target distances. To prevent this, the shape constraint is dynamically adjusted as needed.

- **Collision Avoidance:** Invisible collision objects can be inserted into the spaces between routes to prevent the network from self-intersecting.

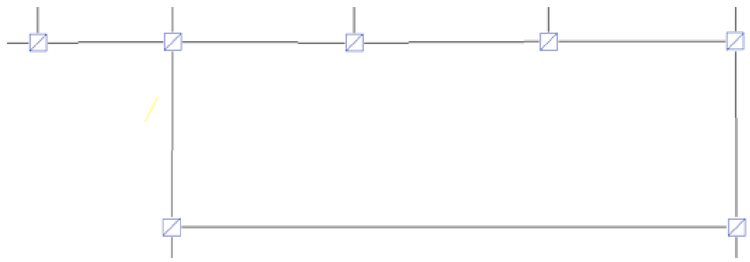


Figure 47: Undeformed starting point

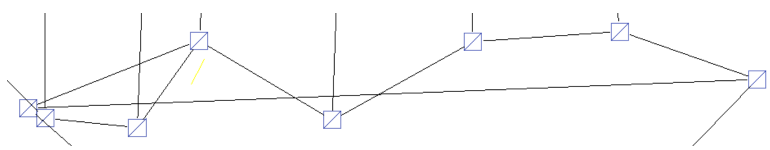


Figure 48: Without collision avoidance

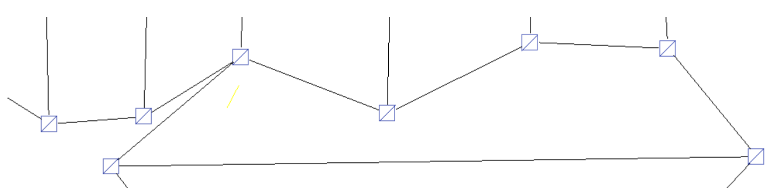


Figure 49: With collision avoidance

- **Y-lock**: The vertical coordinate of all nodes is fixed, so the network unfolds in the horizontal plane. (Note: in the American left-handed system used, the y-axis points upwards)
- **X-lock**: fixes nodes that have an X-coordinate of 0 to this value.
- **Z-lock**: fixes nodes that have an Z-coordinate of 0 to this value.

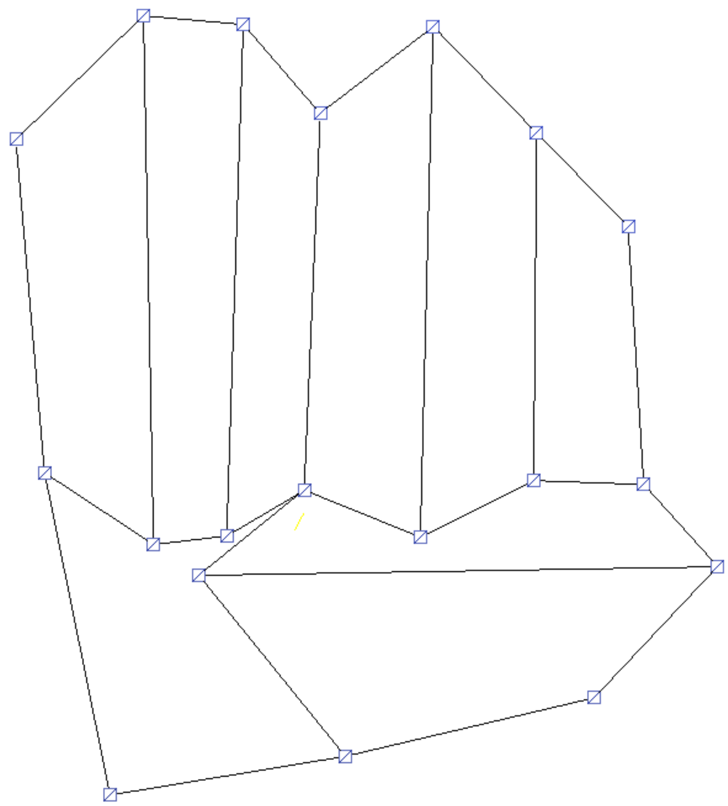


Figure 50: Without locks

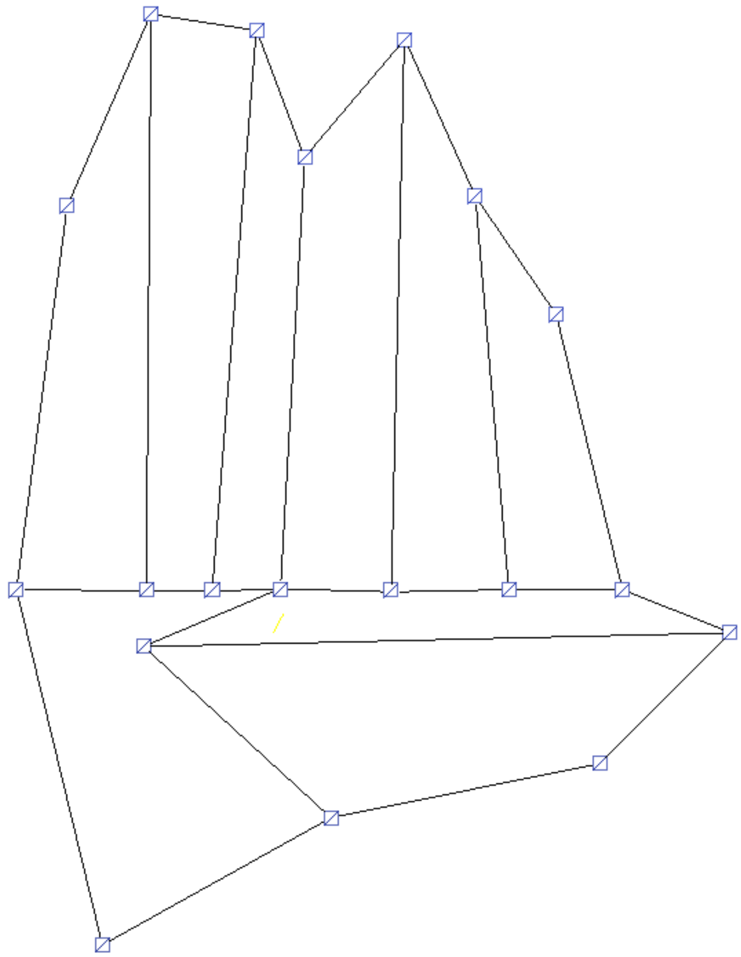


Figure 51: Z-lock

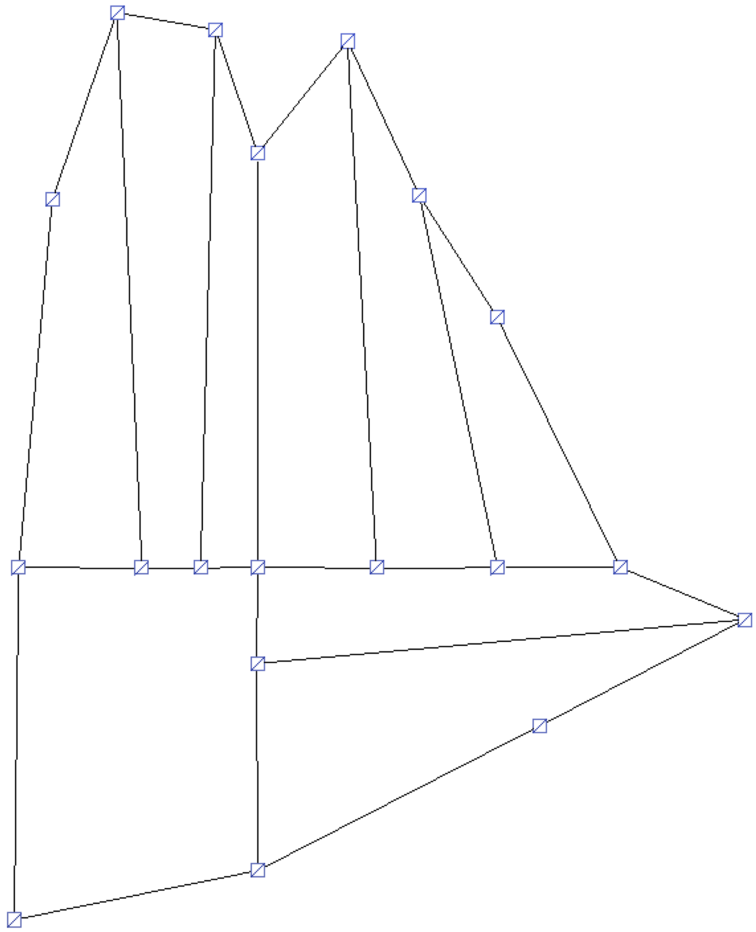


Figure 52: ZX-lock

Screenshots of the 2D model

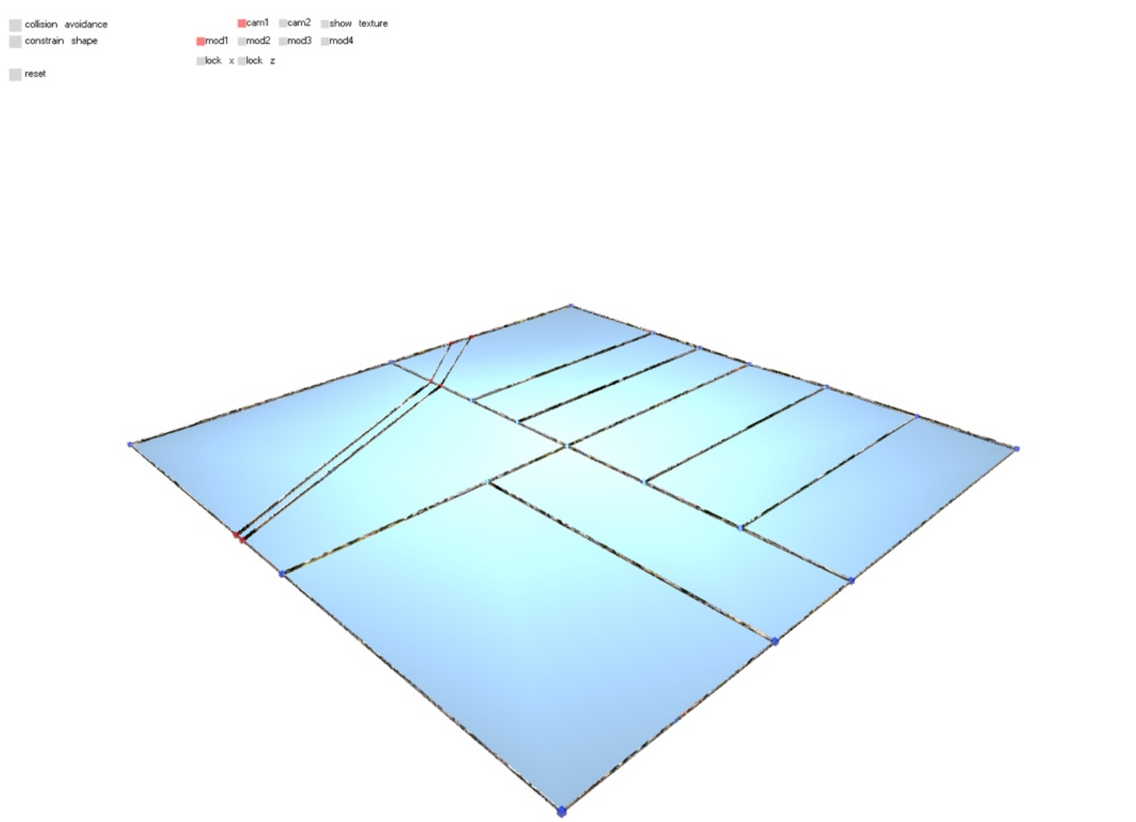


Figure 53: Undistorted network

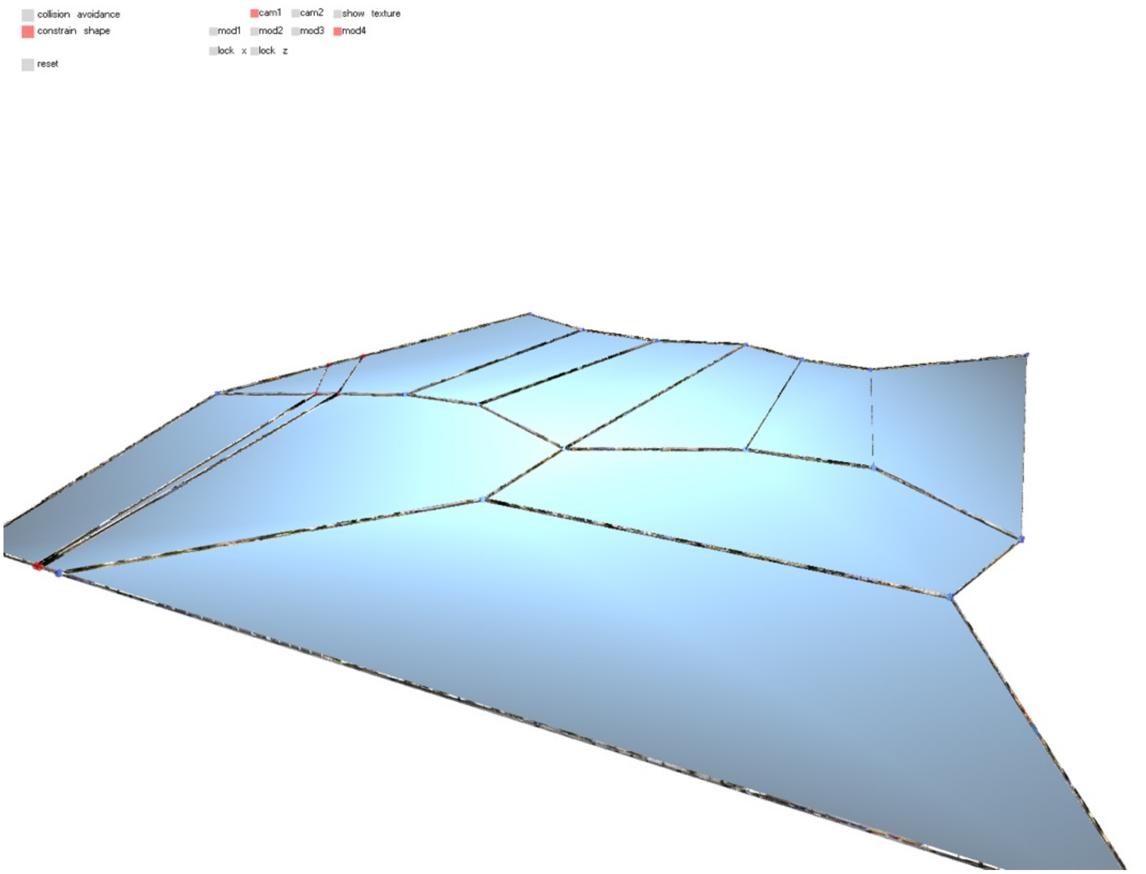


Figure 54: Recorded time distances

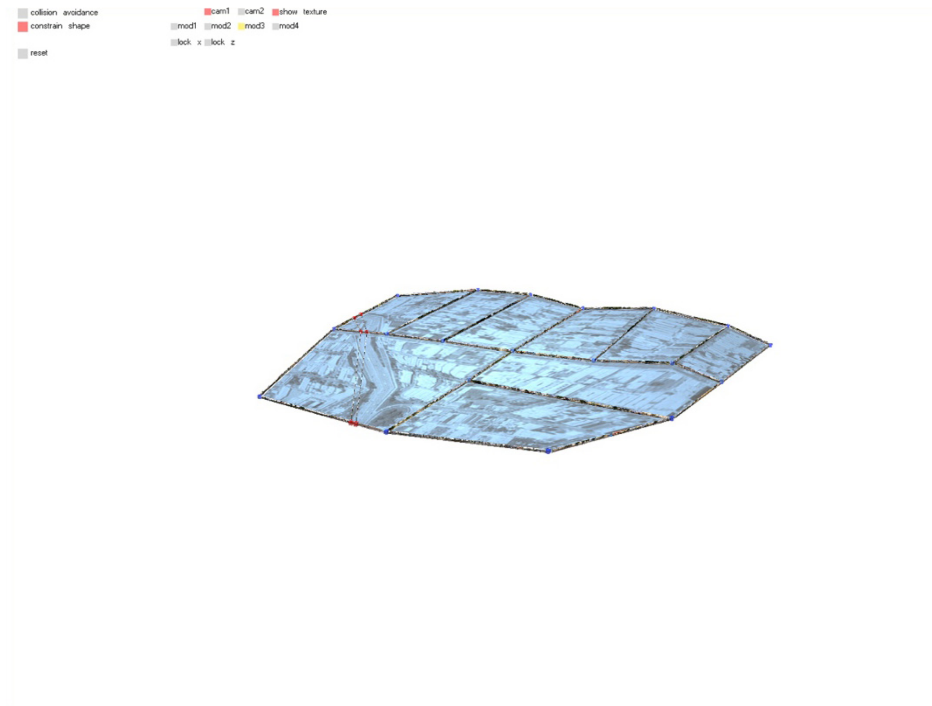


Figure 55: Minimal time distances based on speed limits and traffic light phases

Figure 56: Interior view contrained to a path

Figure 57: Interior view contrained to a path in relative space

Video documentation of the model (added 2015)

https://youtu.be/YsbKSZpa0Kc

3D path network

The next step is the three-dimensional formulation of the linear path network.

Depending on the distribution of the target distances, conditions may occur that cannot be represented in the two-dimensional model. The forces driving the time distances resolve to a mean state, but the target distances are not always accurate.

The additional degree of freedom of the third dimension makes such contradictory situations solvable, but also expands the range of possible shapes of the network to infinity. It is therefore necessary to invest further thought in the adequate formulation of the constraints.

The three-dimensional model was implemented using the Glendale freeway interchange between the 2 and 134 freeways. The interchange involves a complex spatial structure where travel times vary widely throughout the day.

Data sources

Video tracks were recorded in each directional lane, access ramp, and overpass, with the camera facing left from the driver's position. The video traces allowed the determination of specific travel times for each route based on the video time codes.[12]

Figure 58: Aerial view of the freeway interchange. Online source: http://terraserver.microsoft.com Accessed:12/10/2001

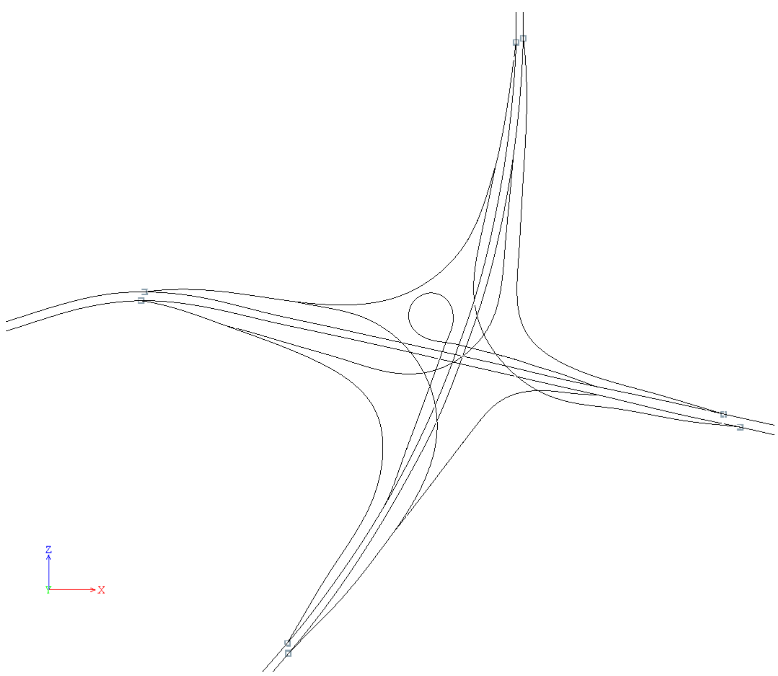


Figure 59: Extracted geometry

[12]The basic geometry was taken from the Thomas digital city atlas (http://www.thomasmap.com/digital_cd-roms.htm) and further modeled using an aerial photograph from the Microsoft Terraserver online archive.

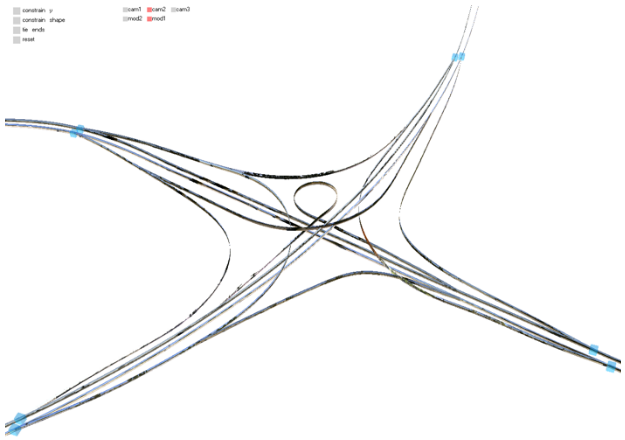


Figure 60: Screenshot of the finished model

Implementation

The complexity of the three-dimensional model required additional constraints:

- **Tie Ends:** This constraint keeps the directional lanes parallel and close together, keeping the two intersections at a constant distance.
- **Target Shape:** Stores the original position of all nodes and applies a force to return them to that position as much as possible within the available degrees of freedom.
- **Y Constraint:** Fixes the nodes at their original vertical height, making the system quasi-two-dimensional.

These individual constraints are coordinated to shape the model effectively and can be combined for better results.

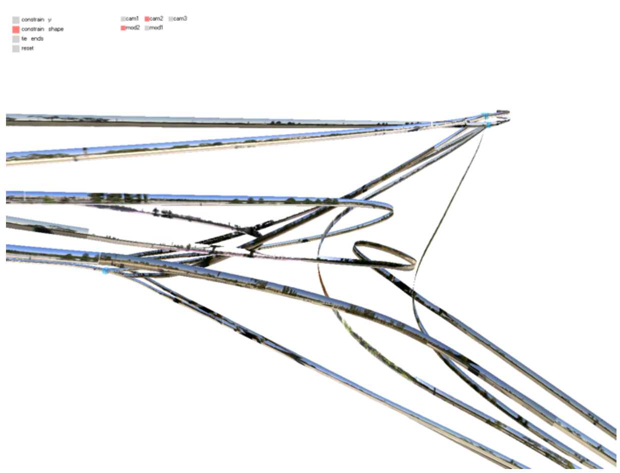


Figure 61: Goalshape constraint

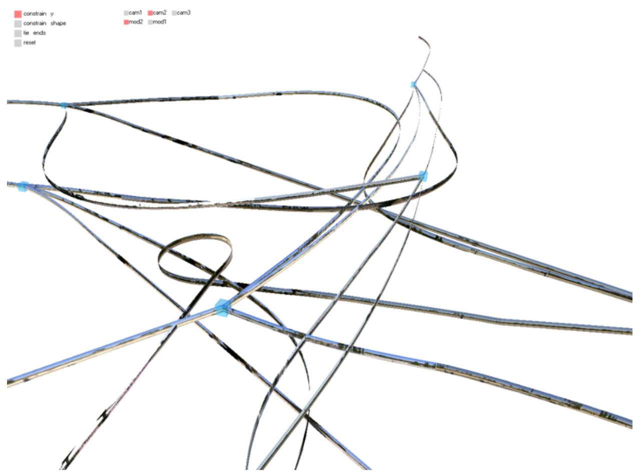


Figure 62: Y constraint

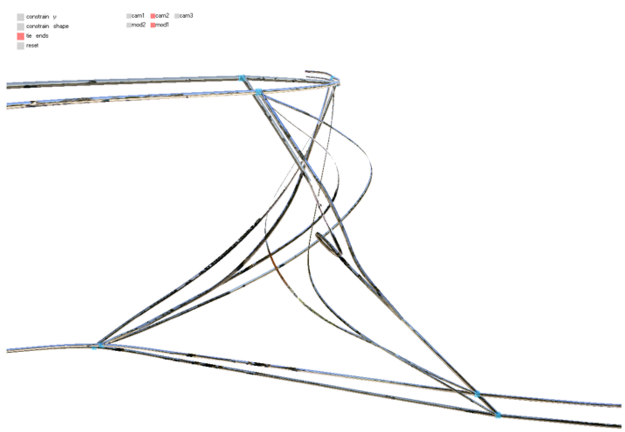


Figure 63: Tie Ends constraint

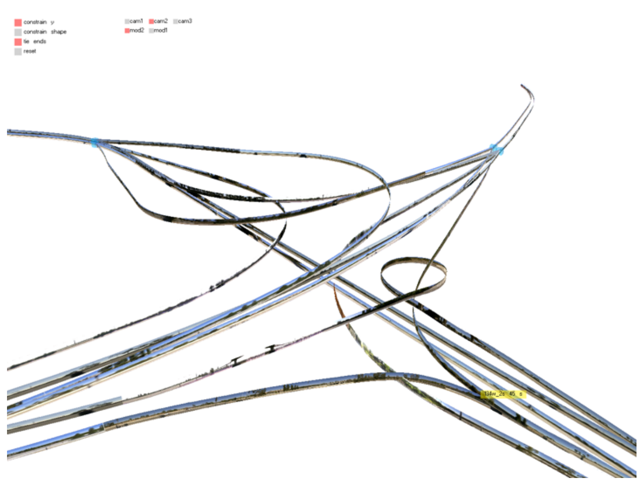


Figure 64: Tie Ends + Y constraint

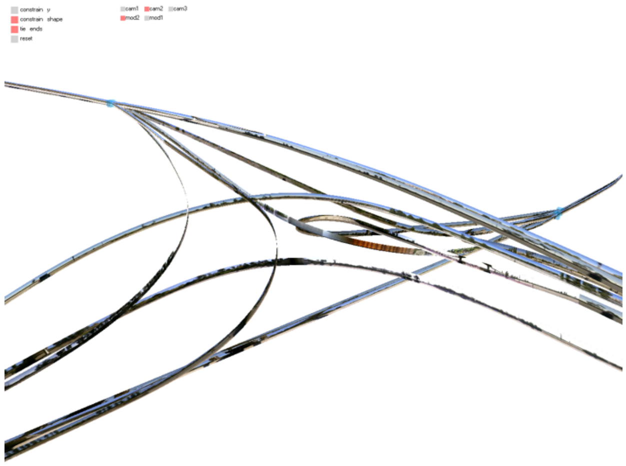


Figure 65: Tie Ends + Constrain Shape

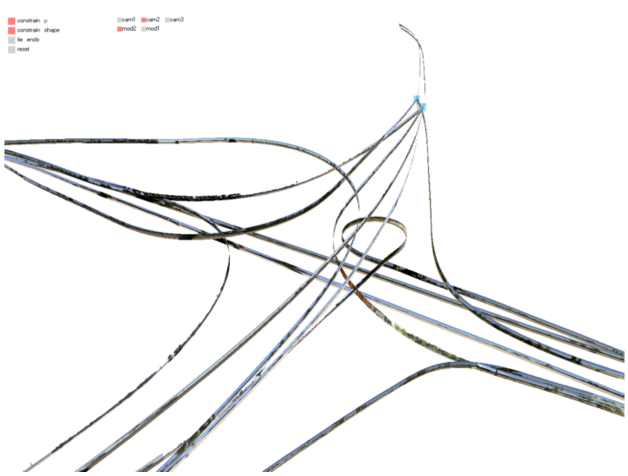


Figure 66: Constrain Shape + Y-Constraint

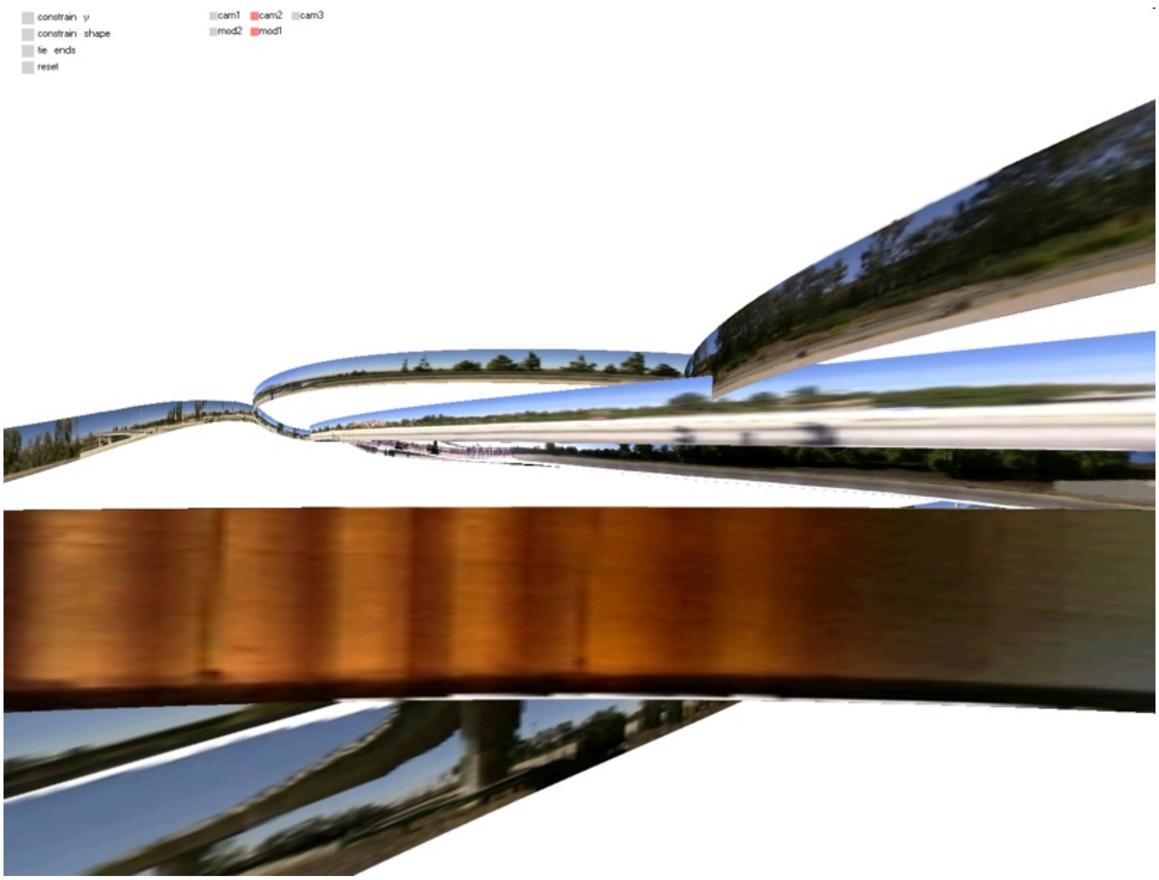


Figure 67: Subjective camera parallel to video trace

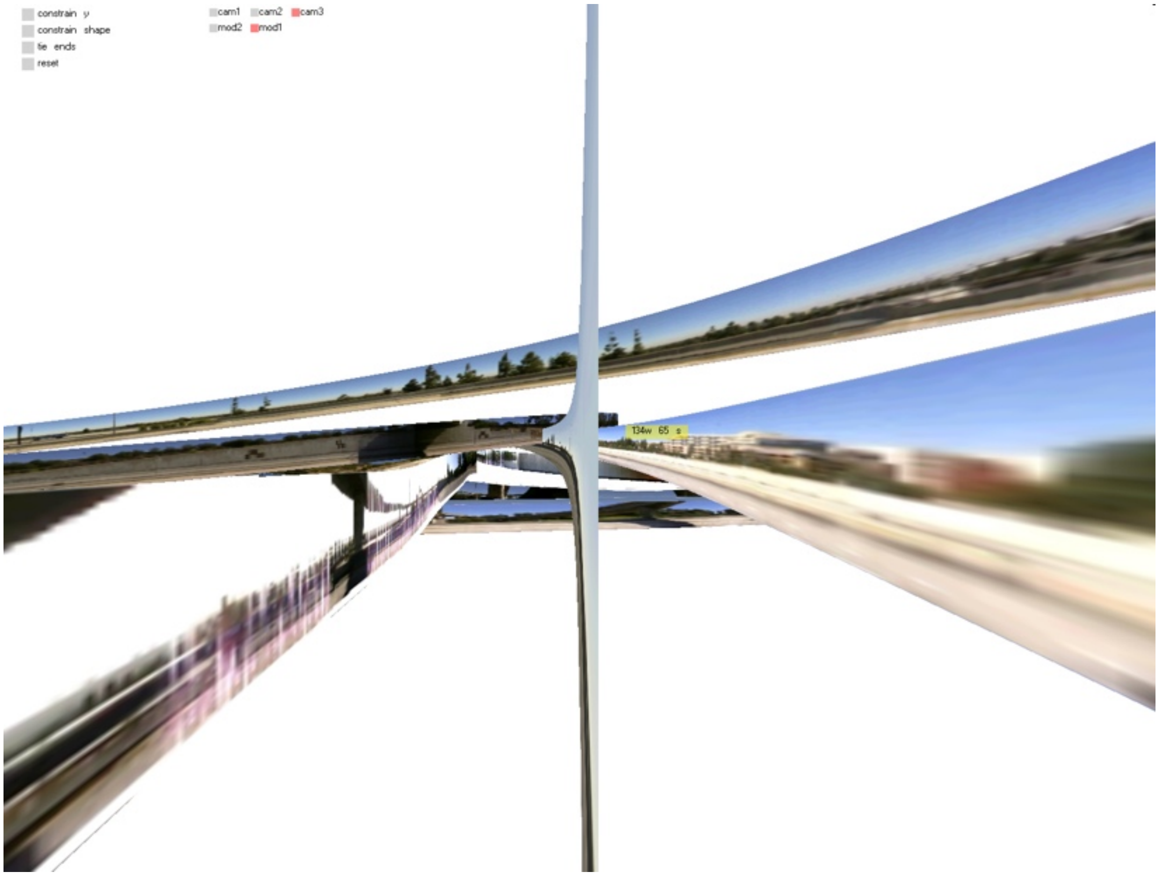


Figure 68: Subjective camera in direction to video trace

In conclusion, the two-dimensional implementation is sufficient in most cases for representing urban traffic and road networks. Problems can arise with complex, curved routes and dense road networks, where a three-dimensional view becomes useful. The three-dimensional representation provides greater expressiveness due to the additional degrees of freedom. However, it is still necessary to implement constraints to maintain comprehensibility.

Wegzeit - the Geometry of Relative Distance

Abstract

This thesis investigates how non-linear space - i.e., space structured by relative units - can be used in architecture using virtual environments. The method is based on the concept of relative space used in human geography and analytical cartography. Using Los Angeles as an example, the result is a dynamic view of the city and its states of motion, a view that differs significantly from the usual architectural representations. Six prototypical models for representing relative spaces were developed for this thesis. Each emphasizes different properties of the underlying relative space. The proposed models are implemented as dynamic virtual environments that change their shape and extent depending on the local size of the thematic parameter under consideration and the selected reference point.

Introduction

We usually consider space to be structured by invariable, absolute units; a meter represents a constant length, no matter where it is measured. However, in our daily lives, we often use relative units of distance, measuring space in terms of time or transportation costs. These units vary depending on the location. For our perception, behavior, and spatial decisions, such relative units are often more important than the absolute distances. Constructing space based on relative sizes can produce geometrical constructs that are ambiguous and contradictory; they often cannot be represented in Euclidean geometry. Visualize these relative spaces requires models that are based on their individual properties.

Travel time distance is a crucial factor influencing the shape and use of our cities. This thesis examines Los Angeles, a city where automobile traffic and travel times are central, through the lens of non-linear spatial concepts.

The relevance of non-linear spaces has previously been explored in fields such as geography, physics, psychology, and sociology. This view is based on a radical concept of space that leads away from the “true” shape of the object. Space becomes malleable, ambiguous, and changeable.

Architectural representations of space are often insufficient particularly when planning for mobility. They cannot account for aspects such as velocity of movement, perception, and imagination that significantly influence our spatial behavior.

In this thesis, six models of representation were developed to visualize different properties of relative space. While temporal change is usually depicted through animation, this work uniquely expresses it as a spatial relation.

Initially, my interest was to examine the influence of cognitive maps on the spatial structure of the city. However, during on-site observations, I noticed the prominent role of travel time distances. Every interviewee could easily estimate how long it would take to travel to a specific location, but very few could approximate the actual distance in miles. The city’s vast urban area appears in the inhabitants’ minds more in terms of temporal than spatial distances. Consequently, I decided to examine the city’s representation using time units instead of spatial units.

Concepts of space

The term “space” is used in everyday language in various contexts. For example, a distinction is made between:

Space as the perceptible world, the totality of places: this is both the physically measurable outer world and the inner world of perception.

Space as empty nothingness, as the counterpart to matter: Space remains when all objects are removed.

Space as an abstract system of order: geometric space. Space is an explanatory model, a way of structuring information.

Space as the totality of possibilities: Space is not only what exists, but also what can be. One speaks, for example, of the scope or room one has to make decisions.

Essentially, however, there are two aspects of spatiality that determine our daily lives. On the one hand, the space of perception, which we directly experience physically, and on the other, space as an abstract idea, as a mental construct.

Both aspects are mutually dependent to a certain extent and are always present simultaneously. They are, however, based on opposing concepts of space that are mutually exclusive.

Space of sensation

The space of sensation is limited: it only extends directly to our fingertips and encompasses the range of our tactile sense. It is the space we can grasp solely through our extremities and feel through muscle sensation. Remote senses such as hearing and sight are only indirectly connected to the physical sense of space.

The space of sensation is an interior space. It cannot be shared with others and can only be occupied by oneself. It has a clear center: one’s own body (Franck 1997). The immediate importance of spatial events increases with their proximity to this center, right up to events in our body that are of existential importance to us (Franck 1997; Poincaré 1914). The structure of space is, therefore, not homogeneous.

The arms are the coordinates for the spatial determination of events and objects. This spatial understanding is common to most living beings. In his article “The Relativity of Space,” Henri Poincaré cites the fundamental function of defense against attackers and dangers:

“When a frog’s head has been cut off and a drop of acid is placed at some point on its skin, it tries to rub off the acid with the nearest foot. If that foot is cut off, it removes it with the other foot. Here we have, clearly, that double parry I spoke of just now, making it possible to oppose an evil by a second remedy if the first fails. It is this multiplicity of parries, and the resulting coordination, that is space” (Poincaré 1914).

Space of imagination

The abstract space of the imagination is a way of overcoming the limited space of perception. The latter is centered on one’s own body, and the points in it are determined in their relevance by their proximity to this center.

However, people can move in space and use their knowledge and memory to place themselves in an advantageous position in relation to a spatial event. This makes every accessible place in space potentially equally important, and the space of the imagination becomes homogeneous. People think themselves out of space, as it were, and view it from the outside. Space is an abstract system of order and, as such, is universal. Every object can be determined through position, size, and orientation. Therefore, the space of the imagination is a necessary extension of the immediate, physically perceived space of perception, which makes spatial behavior and decisions possible in the first place.

In this sense, all types of information media are extensions of one's body. As Marshall McLuhan describes, they expand the space of the imagination (McLuhan 1964, 54).

Geometry can be seen as a formal science of the abstract space of the imagination (Münch 1999). It represents a way of systematically organizing space. Subsequently, however, geometry detaches itself from its function of representing reality, as can be seen in the family of non-Euclidean geometries.

Absolute vs. relative space

The absolute space postulated by Isaac Newton could be seen as a pure form of the abstract space of the imagination thought through to its logical conclusion. It is the perfect empty space that, like a container, holds the world's objects. Space itself exists as a kind of non-object, independent of all objects, and is itself imperceptible. It has no physical properties, only geometric ones (Münch 1999). It is infinite, eternal, and unchangeable. Its structure is homogeneous; all points are equivalent, and none are preferred. This differs from relative space, which is centered on a variable point and in which it can never be decided whether an object is at rest or in uniform motion: "Absolute space, in its own nature, without relation to anything external, remains always similar and immovable. Relative space is some movable dimension or measure of the absolute spaces, which our senses determine by its position to bodies, and which is commonly taken for immovable space" (Newton 1968). Newton's concept of space presupposes the existence of something that is not empirically accessible; thus, it is metaphysical. On the other hand, Newton places empirical observation at the center of his scientific theory: "We are to admit no more causes of natural things than such as are both true and sufficient to explain their appearances" (Newton 1968).

Not least because of this contradiction, Newton's concept of space was often criticized in the following centuries. In the previously cited article "The Relativity of Space," Henri Poincaré summarizes the arguments against Newton's concept of space: It is meaningless to speak of absolute space. To determine a position, reference can only be made to other objects, not to space itself, which is not perceptible. It is, therefore, also impossible to decide whether an object is at rest or in motion.

But not only position in space can only be determined relative to a reference point. Nor can we speak about absolute volumes and distances. If the universe were to grow a hundredfold overnight while remaining geometrically similar to itself, there would be no way for the observer to notice this transformation. All measuring devices, as well as our perceptual apparatus, would change in the same way and would not be able to register the change.

However, Poincaré goes further in his argument: even form and proportion cannot be absolutely determined; space is, therefore, amorphous. A complex and irregular distortion that affects the entire space and results in the transformed forms no longer being self-similar would also apply to our sensorium to the same extent. In this case, too, there would be no way of noticing the distortion (Poincaré 1914).

Modern physics teaches us that there is no absolute, preferred reference system. Nevertheless, when we talk about the absolute reference system in everyday life, we usually mean the choric space, i.e. the reference system of the earth's surface. This is done in the knowledge that we are employing an imprecise term that is nevertheless sufficiently precise for its specific use, e.g. in the engineering sciences, to be understood and used.

Spatial reference systems

Any spatial operation starts with the question of the reference system. In all the aspects of space mentioned so far, we can distinguish between two types of reference systems:

Egocentric reference systems use one's own point of view as a reference point. Space is polarized and ordered by this center. Directions are related to the center.

Exocentric reference systems use a reference point outside our own body. They are not influenced by the movement or position of the observer.

In the egocentric reference system, directions are indicated by terms such as front/back and left/right. It is used in conversation to put oneself in someone else's position and to describe paths.

Exocentric reference systems are essential for structuring and orientation in the shared environment. The most common exocentric reference system is that of the four compass directions. In "The Image of the City", Kevin Lynch describes several other exocentric reference systems used in different cultures. For example, the Siberian Chukchee use a three-dimensional system of 22 directions, which are determined by the position of the celestial bodies at different times of the day and night (Lynch 1960).

However, universal reference systems do not always have to be symmetrical. Micronesian navigators used a precise but asymmetrical system. It refers to star constellations and the positions of islands and differentiates between 28 and 30 directions. Lynch also mentions types of exocentric reference systems that are not universal systems of order but are centered on a specific location. Merchants in a foreign city, for example, memorize the location and direction of the train station, to which they return directly after completing their business. On small islands, inhabitants may use the terms "inland" or "seaward" for all spatial references. The villages are lined up along the beach, and so in this one-dimensional system, for example, "the next but one village" is sufficient for directions.

Another special case of exocentric reference systems that are not universal is orientation along an existing or imaginary network of paths. Mythological paths in the territory of the Australian Arunta connect sacred places with each other; these paths must not be left (Lynch 1960).

Architectural design in relative space

Planners and architects usually work in an exocentric frame of reference, as the objective form of the planning object must be determined as precisely as possible. Nevertheless, there are examples of design methods that start from the individual's point of view.

Some of them stem from the domain of film architecture. Unlike buildings, which can be seen from all sides, and stage architecture, film architecture has only one relevant point of reference: the camera lens. This eliminates the need to plan three-dimensional objects that can be seen from several sides. Instead, illusionistic design techniques such as accelerated perspective and perspective anamorphosis become relevant again and are further developed.

In the classic Schüfftan effect, invented by Fritz Lang's set designer Eugen Schüfftan and used for the first time in the film Metropolis, several sets of different sizes are combined from several directions simultaneously into a single image using a system of half-mirrors; actors act in sets made of miniature models.

Another challenge for the film architect is the temporal structuring of the spatial experience. Events and objects are no longer distributed in space but in time. Instead of the topos sequence, the chronosequence comes to the fore.

The rethinking forced by the medium of film, from the absolute reference system of the planner to the subjective point of view of the viewer, is currently also increasingly influencing classical architecture. Wherever planning is done for the static viewer's experience, film production techniques are used.

Jon Jerde, the architect who became famous for his plans for shopping malls and theme parks, uses storyboards in his planning. He takes into account the subjective point of view and the temporal sequence of the visitor's experience.

Norman Klein, author, looks at the casinos of Las Vegas 20 years after Venturi and coins the term "scripted spaces" - "a street or interior in which the spectator imagines himself as the main character in an imaginary story." Spaces that are constructed according to a script and that tell stories through the sequence of the route, the framing of the image in the user's field of vision, and the events that are placed within it (Klein 1997).

Architect Phillip Thiel works with so-called "Experience Scripts": a comprehensive system of spatial notation that aims to capture behavior, perception, and even emotional involvement. He links these to the anatomy and materiality of space. This method, which he calls "Environtecture," turns the architect into a director who uses scores to plan the user's experience (Thiel 1997).

Relative space

The previous chapter discussed planning approaches focusing on the user's sensory experience. Architectural design, however, is almost exclusively carried out in an exocentric system of reference. Many parameters that define the subjective space remain unconsidered.

What architecture has largely lacked are spatial models that build on the subjective experience of space and consider its sometimes inhomogeneous structure. It may be useful here to glance at related fields that, like architecture, are primarily concerned with spatial structures - geography and cartography.

From their inception, both disciplines were confronted with the challenge of truthfully representing the curvature and unevenness of the earth's surface on a flat plane. The shortest distance in space is not the same as the shortest distance on Earth's curved surface. The orthogonal projection does not represent inclined surfaces and slopes in their true size. For any spatial representation, it is necessary to be clear about which properties of space are to be reproduced - but this inevitably has the consequence that other properties of space are not conveyed correctly. Multiple models are therefore needed to capture all aspects of reality.

The following chapter explains the concept of relative space as it is used in human geography.

Relative location

The relative location is a position descriptor that refers to other spatial features without the use of a universal ordering system.

Here is an example:Linz is located on the Danube, 180 km from Vienna and 100 km from Salzburg.Or: Vienna is located between Budapest and Linz.

When determining the relative location of a place, it is not only the position relative to neighboring places that is important. It is also important how these places are connected, for example by roads. The relative location is therefore less determined by its topographic position than by its topological place in a network.

Two cities separated by a state border without a border crossing will not appear in the same route description, even though they are topographically close. The location of a room in an apartment will never be given in relation to the rooms in the apartment next door, even if they are the closest.

If we consider a set of places connected by a system of paths, we notice that some places are better integrated into the path network than others. Relative places have different connectivity.

Graph theory

Graph theory, a branch of topology, is useful for describing relative locations on a network of paths. In this case, a graph is used to represent a set of places and the connecting paths.

In the terminology of graph theory, the locations are referred to as nodes or vertices, the paths as edges. Each edge is bounded by two nodes. In turn, two nodes can only be connected by one edge. A path is a path made up of several edges between any two nodes in the network. The topological distance between two nodes is defined by the number of edges in the shortest connecting path between the two nodes.

For each location in the network, the distance to the furthest node in the network can be specified. The central node in the network is therefore the one whose topological distance to other nodes is as small as possible. This topological distance is also referred to as the radius of the graph. As can easily be seen, the centrality of a node can change as soon as an edge is added or removed somewhere in the network (Diestel 2000).

In the past two decades, graph theory has been increasingly used to deal with architectural and urbanistic issues. Under the term space syntax, Bill Hillier has developed models for qualitatively examining architecture on the basis of its topological properties, see (Hillier 1999).

Illustration of connectivity in London's street system - from (Hillier 1999, 215)

Subway in Vienna Online source: http://mailbox.univie.ac.at/~prillih3/metro/m/largemap.htm Accessed:10.12.2001

Relative distance

The concept of the shortest distance between two locations, which can be clearly established in geometric space, is much less clear in everyday life. The geometrically shortest path is rarely the most convenient, the fastest, or the easiest. As with the concept of relative location, the context in which spatial distance is measured is critical.

Different examples of least effort paths, (Abler, Adams, and Gould 1971, 218)

Distance measurement is based on comparison with a defined unit of distance, the scale. It is assumed that this unit of distance is the same everywhere and at all times in space, i.e. that the scale is absolute.

Relative distances, on the other hand, as used in the following, are based on parameters whose magnitude varies in space.

Relative locations in relative spaces. according to (Abler, Adams, and Gould 1971, 76)

The diagram above shows different types of relative distance between five locations. The selected parameter determines the distance and thus the structure of the respective space.

Relative distances can also be expressed in absolute units such as meters or kilometers. The distance between two cities in the road network can either be expressed in absolute terms as the crow flies or in relative terms, expressed in road kilometers. For a wheelchair user, distances in the city or within a building will be different, as the routes are not the same as a pedestrian would use.

Relative space

Spaces that are defined by relative distances are subsequently referred to as relative spaces.

The representation of relative spaces appears distorted compared to the usual representations with absolute distances. However, relative spaces are well suited to visualize the spaces in which people live and make decisions. Anyone involved in the transportation of goods is more concerned with transportation costs and times than absolute distances. One moves in the space of costs and time rather than in absolute space.

In relative space, many properties of absolute space, such as the relative position of places, are retained.

However, the representation of relative spaces is usually not entirely straightforward. Relative distances, especially travel time distances, are usually not symmetrical. The time it takes to travel from point A to point B can differ significantly from the time from point B to point A. The distance depends on the direction, so the shortest distance between two points can no longer be conclusively determined in Euclidean geometry.

Temporal distances often cannot be expressed geometrically. An example of an impossible triangle

However, the challenges of representing relative distances go further. If we consider three points in space with known time distances to each other, it is sometimes not possible to connect them geometrically to form a triangle. If, as in the diagram above, the distance BA is greater than AC and CB taken together, the triangle inequality no longer applies and a triangle can no longer be formed between the points.

Such a configuration can be expressed most simply in a matrix. Complex network systems can thus be conveniently analyzed using graph theory without having to consider the geometric arrangement:

A

B

C

A

–

7

3

B

–

1

C

–

Asymmetric time distances in matrix form (Abler, Adams, and Gould 1971, 80).

Centered relative spaces Parameters such as travel time, cost distance or interaction can only be specified relative to a single common reference point. In the corresponding relative space, the distance to this reference point is assigned to any point in space. In this case, we speak of a centered relative space. The position of a point in the relative space is defined by its relationship to a common center. When a different center is selected, the shape of the relative space also changes.

An example of a centered relative space - Klaus Spiekermann, Michael Wegener “Radius Reisezeit”, installation at EXPO 2000 Hanover

Non-centered relative spaces are not related to a common center. The locations are defined by their relative positional relationships to each other. The position of a point in the relative space is determined by its relationship to all other points in the space. Area-related parameters such as population density, economic resources etc. can be represented well in non-centered relative spaces.

Example of a non-centered relative space - after (Reichart 1999, 110)

Relative space effects

Considering geographic space in this way, one can identify phenomena or events that either expand or shrink relative space. Abler et al. speak of space-adjusting techniques.

Examples of space-shrinking forces

The increasing speed of transportation and communication.

Infrastructure: more direct routes, bridges over rivers

Faster, more powerful means of communication

World languages

At the level of the individual: money, education

...

Examples of space-expanding forces

This includes all types of obstacles that offer resistance to shrinking forces:

Space contraction due to air traffic is offset by waiting times at check-in counters and the accessibility of airports as space-expanding forces.

Topographical obstacles such as rivers and mountains

Political obstacles such as national borders

regularly or suddenly occurring situations such as traffic jams,

Legal obstacles such as speed limits or stop signs

Language boundaries

Examples of ambivalent forces

Some forces can both shrink and expand space, either simultaneously, at time intervals or abruptly and unpredictably:

Traffic rules, priority rules

Traffic lights

Each routing favors areas and at the same time marginalizes other things that separate and connect at the same time: they are filters that only allow a certain type of interaction, e.g. sea coasts.

Any activity, idea or circumstance that makes it easier or more difficult for people to overcome distances has a space-expanding or shrinking effect. Some of the factors mentioned apply differently to each individual inhabitant, some are not constant locally and over time or are random. However, many of them are so regular and universal that they significantly influence and structure the shape of the environment.

Imploded position

The interaction of expanding and shrinking forces leads to effects that Peter Haggett has described as spatial implosion (Haggett 2001). Transport routes and information infrastructure between large cities are generally better developed than those between smaller towns. In a traditional representation of a city network, for example, this fact is difficult to depict. However, if the distance between towns is expressed in relative units such as transport costs, travel time or road kilometers, it can be seen that the large centers are closer together in the representation. Less well connected places, on the other hand, appear to be pushed to the edge, even if they are topographically more central.

Geographical and imploded location, according to (Haggett 2001, 248).

Active and passive spaces

While places with good transport connections benefit from their relative location in the road network, the opposite is the case for peripheral places. In this context, a distinction is made between active spaces and passive spaces.

The assumption of space-time convergence is therefore only superficial consideration correct. With the introduction of new modes of transportation, the structure of active and passive spaces changes.

Places that were previously in a preferred location become peripheral passive spaces and vice versa (Reichart 1999, 107f).

The city as a relative space

Relative spaces arise on different levels. In the material reality of the city, movement is probably the most important space-defining factor - “Cities are movement economies” (Hillier 1999). The second aspect dealt with examines space as a conceptual image that arises through perception and experience. The third example deals with communication and interaction in space. All three levels of relative spaces are mutually dependent and cannot be considered separately in the urban context.

The relative space of travel time - the city as an economy of movement

Every form of movement produces spatial patterns, which in turn influence and restrict subsequent patterns of movement. The built space is created by movement.

„Wo sind wir, wenn wir reisen? wo liegt dies ‚Land der Geschwindigkeit', das nie genau mit dem zusammenfällt, das wir durchqueren?“ (Virilio 1978, p19)

Movement processes are multi-layered. Movement takes place at different speeds, people move actively or are moved passively as passengers. Their journeys are singular events or are repeated in a daily rhythm. The tour takes place in familiar or unfamiliar territory, is experienced as a conscious process or merely as a necessary evil to overcome spatial distance.

The types of movement are primarily determined by the different means of transport, which have different degrees of freedom. Movement can either unfold freely in space or is restricted to the linear paths of a network. The journey can either begin and end at any point or only at defined nodes within the network. Depending on the degree of freedom, movement patterns can be represented with surface, line or point elements.

Domain

Boundary

Examples

Go anywhere

Leave anywhere

Walking, rowboat, helicopter

Go anywhere

Leave at nodes

Ship, airplane, seal under ice

On network

Leave anywhere

Automobile on street

On network

Leave at nodes

Railroad, freeway, subway

Types of movement, From (Waldo R. Tobler 1999)

Direction of movement - In cities, there are places that have a preferred direction of movement and places that do not. The state of movement in space can be represented by a vector field of different velocity vectors.

Spatial hierarchies of transportation routes- Transportation routes are organized into a hierarchy. Places in the city are grouped by how well they are connected to the road network. The best locations are at intersections of major traffic routes. Other areas are less connected. To get from one area to another, it’s often necessary to take a longer route.

Hierarchies of velocity - Movement processes are organized spatially according to their velocity. They are usually separated from each other, with each area assigned a certain speed of movement. A specific place is designed to be perceived at a particular speed. Deviations are sometimes experienced as unusual and frustrating. However, the speed hierarchy is not always seamless. For example, we often have to deal with distances that are both too long for a walk and too short for a car journey. These transport gaps are, for example, between 0.5 and 5 km, 5 and 25 km/h, or 5 and 15 minutes.

Scale and speed - The assigned speed is always directly related to the spatial scale of the respective location. This can be observed, for example, in large parking lots in front of shopping centers. When looking for a parking spot, people generally move at a speed of approx. 10 km/h, i.e. faster than a person walking. This speed is comfortable for the size of the parking lot, one can stay oriented and have enough time to make the necessary decisions. For the pedestrian looking for his car after shopping, the same parking lot suddenly appears uncomfortably large and confusing. The scale of the surroundings determines the preferred way of getting around, the speed and the choice of means of transport. Small-scale historic city centers favor pedestrians and hinder drivers. Sprawling cities that were planned for car traffic from the outset frustrate pedestrians. However, speed is not only regulated by spatial and legal measures and structures, but also by social influences and expectations. Anyone walking too slowly in an affluent residential area or lingering unnecessarily long in one place quickly raises suspicion.

Travel time as distance - For centuries, travel time was the only practical way to measure long distances. In a large geographic context, we think in absolute distances because of our daily use of maps, signposts, etc. However, in a small geographic context, such as a city, we still think in terms of temporal distances. This has practical advantages when planning our daily routines. For example, when traveling in rural areas, we usually have a relatively clear idea of the absolute distances to the next important places. Signposts and road signs inform us at regular intervals. Here we are in the relative space of kilometers. Places separated by hilly and winding terrain may seem farther apart than they really are, nevertheless, absolute distances still play a greater role here than temporal distances. Signposts on hiking trails, on the other hand, are usually marked with time distances. However, when we travel in urban areas, we rarely see signposts to places within the city that indicate absolute distances. Moreover, these signs often do not indicate the shortest route, but rather the most memorable, the one with the greatest traffic capacity, or the fastest. In familiar space, we tend to think in time distances. When we compare our idea of the distance between two places with the physical reality, such as a city map, we often find that we have misjudged the distances.

Relative spaces of imagination

In contrast to the previously mentioned parameters, which are all measurable in the physical environment and valid for all involved parties equally, there are also a series of subjective parameters by which the city can be structured. Our behavior in space is always influenced by the perception and conception of spatial reality. To understand the structure of a city and its activity patterns, we must also consider the conceptual space of its residents and users. This is less about how far apart two places actually are, but rather how far they are perceived to be by the people involved, see (Abler, Adams, and Gould 1971, 75).

Here, we will primarily focus on the mental representation of space as it is generated by sensory perception and memory.

The space of perception is the space that is consciously or unconsciously perceived and assessed. The previous section already highlighted the role of speed in perception and thus in the representation of the environment. In addition to the subjective sense of time, experience and memory also play a significant role. The already familiar return journey to a previously unknown place generally seems shorter than the outbound journey. This selective subjective perception leads to the concept of conceptual space.

Concepts are always dependent on personal evaluations and individual motivations, which in turn depend on education, age, social status, and group affiliation.

Playing children or beggars constantly explore the possibilities of their surroundings and how they can use them for their benefit. Their spatial behavior fundamentally differs from that of an office worker on their daily commute.

Representations of the mental space are known as mental maps. They were introduced as a method for analyzing cities by the urban planner Kevin Lynch.

Mental maps: Kevin Lynch's urban analyses

An older but still foundational study on the relationship between perception, behavior, and the built environment is Kevin Lynch's 1960 work "The Image of the City." Kevin Lynch, an architect and urban planner at MIT, was interested in the visual quality of the American city. To this end, he examined the mental image that residents form of their city (Lynch 1960, 12).

Lynch was concerned with statements about the visual quality of architecture and urbanism beyond design and aesthetics - qualities such as memorability, legibility and imaginability were at the forefront of his investigations. According to his hypothesis, a city is perceived as pleasant when one can form a clear mental image of its structure and consequently navigate it easily.

Lynch conducted extensive interviews with residents in three prototypical American cities. Boston, MA was chosen as an example of a European-style city with a historic core, high density and distinct image. Los Angeles as a newer American city with a different scale and without a long history. Finally, Jersey City, NJ was chosen as an example of a rather anonymous city with a very weak image.

In the interviews, residents were asked to describe their route from home to work as accurately as possible, paying particular attention to prominent environmental elements and their emotional attachment to them. In addition to these verbal interviews, participants were asked to draw sketches of their surroundings, including all significant elements they could remember. The results of these empirical surveys were compared with observations made by trained observers.

From the collected observations in interviews and drawings, Lynch synthesized a visual vocabulary of the mental image. This consists of five main elements which, according to Lynch, are particularly important for the construction of a mental image: he described them as paths, edges, areas, nodes and landmarks.

Paths “Paths are the channels along which the observer customarily, occasionally, or potentially moves. They may be streets, walkways, transit lines, canals, railroads.” (Lynch 1960, 41). These are the predominant elements for the majority of respondents. The design elements of the city are organized by paths and stored in memory as a linear sequence. The appearance of the paths gives the inhabitants an indication of their significance as main or secondary roads. The most important characteristic is their continuity, as well as an idea of which areas they come from and where they lead to (Lynch 1960, 49)

Edges “Edges are the linear elements not used or considered as paths by the observer. They are the boundaries between two phases, linear breaks in continuity: shores, railroad cuts, edges of development, walls. They are lateral references rather than coordinate axes.” (Lynch 1960, 41). Examples of edges are barriers such as coastlines and railroad lines. They are continuous and clearly visible. However, they do not have to be impenetrable; they are often connecting seams rather than separating barriers.

Districts “Districts are the medium-to-Iarge sections of the city, conceived of as having two-dimensional extent, which the observer mentally enters”inside of” [...] Always identifiable from the inside, they are also used for exterior reference if visible from the outside.” (Lynch 1960, 41). This refers to areas with a characteristic identity that are easily recognized by observers.

Nodes “the strategic spots in a city into which an observer can enter, and which are the intensive foci to and from which he is traveling.” (Lynch 1960, 41).

Landmarks are visual reference points that the observer cannot “enter”, i.e. they are external features such as buildings, signs, or hills. Lynch distinguishes between distant landmarks, which are visible from different points in the city, and local landmarks, which are small and only visible from close up. Radial references are distant landmarks from whose viewing angle the observer can deduce his position, see (Lynch 1960, 49). Land-marks do not always have to be particularly large and free-standing structures such as towers etc. Lynch mentions an inconspicuous old wooden building in Los Angeles that was frequently mentioned in the interviews. The two-storey building recedes slightly behind the other buildings in its building line and thus stands out from the surrounding, more modern and taller buildings (Lynch 1960, 81).

Lynch’s investigation seeks a direct connection between the commonalities of individual imaginaries and specific elements of the built environment. His elements are at once clearly identifiable parts of the material environment, the vocabulary of the imaginary, and the cartographic symbols for its representation. “These elements are simply the raw material of the environmental image at the city scale.” (Lynch 1960, 83).

His sketches are a good illustration of the nature of relative spatial representations. They have a strong topological correspondence to reality, but appear distorted. The representation is subject to subjective, individual differences - directions are distorted, proportions are not correct. However, the order and continuity of the elements were usually correct.

The sketch maps of the people surveyed by Lynch showed a relatively high degree of agreement with each other. However, as Lynch himself admits, his studies mainly surveyed members of the middle class. Later studies, on the other hand, show large differences based on the social status and group affiliation of the respondents.

Lynch saw his research as the basis for a new method of urban planning that focused on the experience of the urban resident.

Structure of downtown Los Angeles, depicted through Lynch's elements.

Since Kevin Lynch's work, numerous urban studies have been conducted using mental maps, and the limitations of the method have become apparent. The first problem with mental maps created by subjects is their interpretation.

In order to obtain more data, studies have asked respondents to produce both drawings and textual descriptions of the area under study. This revealed significant differences and contradictions between drawings and textual descriptions by the same person. In the context of a study in Frankfurt, the subjects drew the city in an idyllic, idealizing way, while the same people often adopted a contrasting, critical attitude towards the city in the textual description (Ploch 1995, 28).

Not mentioned is the undeniable influence of images from the media or tourism on the image. In Lynch's work, continuity and topological similarity to reality are mentioned as criteria for an intact image of the environment. In some of the interviews, however, influences can already be seen that break up and fragment this continuity of the mental image: “as in Boston, these drivers seemed to have difficulty in locating the freeway, in tying it to the rest of the city structure. There was a common experience of a momentary loss of orientation when coming off a freeway ramp”(Lynch 1960, 42).

Relative space of communication

The third example finally departs from a geometric concept of space. The city is understood as a system of signs. Lynch's elements represent attempts to understand urban space not primarily in terms of its three-dimensional form but as a semiotic system. However, he usually describes the city from the perspective of the pedestrian. Although spatial relationships appear subjectively distorted, the basic structure of the space remains intact. In “Learning from Las Vegas”, Robert Venturi and Denise Scott Brown express the notion of space as a system of signs in a much more radical form.

Fundamental to Venturi's work was the observation that a driver traveling at 50 miles per hour perceives the urban environment differently than a pedestrian: the spatial-geometric structure recedes into the background, the driver perceives the surrounding space primarily as a system of signs. “symbol in space before form” (Venturi, Brown, and Izenour 1972).

The “Strip” in Las Vegas, a commercial landscape completely geared to the perspective and needs of the driver, served as a suitable location for investigating this understanding of space. The underlying problem of an architectural language for motorized individuals is the change in the observer's attention, which is oriented strictly looking ahead:

“A driver 30 years ago could maintain a sense of orientation in space. At the simple crossroad a little sign with an arrow confirmed what was obvious. One knew where one was. When the crossroads becomes a cloverleaf, one must turn right to turn left [...]. But the driver has no time to ponder paradoxical subtleties within a dangerous, sinuous maze. He or she relies on signs for guidance - enormous signs in vast spaces at high speeds.” (Venturi, Brown, and Izenour 1972, 9).

The conclusions that Venturi et al. draw from this observation represent a break with the principles of modernism. Architecture becomes the medium of explicit information. The façade of the typical casino on the strip detaches itself from the building and at the same time becomes its most important part - a larger-than-life billboard. The three-dimensional shape of the building and its architectural form lose their significance, as they can hardly be noticed by the moving observer.

Textual and symbolic information in the form of concise signs and opulent corporate signs become the most important organizing elements of the urban landscape of the strips. At a cursory glance, this landscape appears completely disorganized, but in fact it is a superimposition of different information systems that work on different scales. Contrary to the seemingly poor “memorability” of the landscape, one can find one’s way around it.

According to the authors, the conciseness of textual references is adapted to the receptiveness of the traveling observer. In the logo, boundaries between word and symbol are blurred (see e.g. the Mac Donald’s “M” etc...). The casino signs contain information for several zones of distance and speed. While the upper part, visible from afar, offers no specific information and is designed as a heraldic element for long-distance effect, the font becomes smaller and smaller towards the bottom and its content becomes more and more specific.

The following diagram shows all the written words that drivers can read from the Strip:

Illustration of the Las Vegas Strip with all textual information that can be read from the driver’s perspective (Venturi, Brown, and Izenour 1972, 30).

As Venturi and Scott-Brown emphasize, the scale of the sign in relation to the building is determined by the size of the space and the speed of the observer. On the small scale of the medieval street, hardly any signage is necessary to draw attention to a product on offer, for example. The product is visible and speaks for itself. In the wider shopping street, the pedestrian is no longer forced to walk past the shop windows displaying the products; signage is necessary to draw attention to individual stores. At the scale of the strip, the relationship between building and signage is finally reversed - in response to the high speed of the observer and the spaciousness of the surroundings, the sign becomes more important than the building:

See (Venturi, Brown, and Izenour 1972, 11).

It is obvious that traditional representations of architecture are no longer sufficient for the representation of these phenomena. How can the effectiveness of a casino sign be conveyed in a 1:100 floor plan and elevation? Venturi and Scott-Brown are aware that this requires new methods of representation that take this new understanding of space into account:

“how do you distort these to draw out a meaning for the designer? [...] How do you represent the strip as perceived by Mr. A. rather than as a piece of geome-try?” (Venturi, Brown, and Izenour 1972, 76)

Context Los Angeles

I chose the city of Los Angeles as the location for this study. For several reasons, it is particularly well suited as an case study for the principle of relative space:

The city is largely laid out as a uniform grid over the area. Against the background of this abstract structure, relative spatial effects resulting from the use of the city become more visible.

The hierarchy of speeds is more important than a distinctly spatial one. The topographical location of a place is less important than its temporal accessibility.

Behind the ostensible lack of spatial differentiation, a complex structure of spatial, cultural and infrastructural values is emerges from everyday practice.

Driving in Los Angeles

"Ask an Angeleno the distance from one locale to another and most likely you'll receive your response in minutes rather than in miles. Traversing the local landscape truly conflates time with space. in the ultimate transit culture, attempting to minimize travel time becomes significant if not an obsession." – from the curatorial statement of the LA Freewaves Festival, Nov. 2000

In the minds of the residents, distances are primarily present as travel time distances. Several local radio stations are exclusively devoted to reporting the current traffic situation. Many online services offer dynamic maps of the region with real-time traffic information showing the speed of automobile traffic on all major roads and freeways.

LA 6 color speedmap Online source: http://traffic.tann.net/maps/lar6traffic.jsp Accessed: 20.4.2002

Reyner Banham describes Los Angeles as a "transportation palimpsest", a surface of constant, multi-layered movement, subject to ongoing changes and overlapping with new traffic flows (Banham 1971, 75). A palimpsest is usually an ancient manuscript on papyrus or parchment that has been repeatedly overwritten. Because the old contents were not completely erased, they remain partially legible. In a figurative sense, it also refers to a place whose history can still be read from traces.

In Los Angeles, processes and flows of movement appear to be organized with greater complexity than in cities of comparable size. Rather than converging on a central business district, traffic is evenly distributed among a large number of regional centers.

The dominance of automobile traffic as a formative influence is also reflected in statistics. Two-thirds of the city's developed land is devoted to vehicles in some form, whether as roads, freeways, or parking lots. The city has the highest traffic density of any U.S. city: 125,860 miles are traveled per square mile of city area per day by motor vehicle. 85.64% in 2000 of the working population uses a private automobile for their commute. These 4,115,248 people take an average of 26.5 minutes (1.11 people/car) to get to work and ultimately spend an average of 82 hours in traffic jams every year - LA is leading all other US cities also in this respect.

However, the stereotype of the disproportionate freeway density compared to other US metropolitan areas is debated:

"However, Los Angeles has less freeway space per capita than most urban areas – ranking 44th out of the largest 57 urbanized areas in 1996, according to Federal Highway Administration data. [...] The plain fact is that Los Angeles, with an urbanized area density of 5,800 residents per square mile, has a freeway system that is at least one-third too small to accommodate travel demand,“ writes traffic consultant Wendell Cox.

Lev Manovich wrote the following about Los Angeles in a report from the Siggraph conference in 1995:

„The city offers a precise model for the virtual world. There is no center, no hint of any kind of centralized organization, no traces of the hierarchy essential to traditional cities. One drives to particular locations defined strictly by their street addresses rather than by spatial landmarks. A trendy restaurant or club can be found in the middle of nowhere, among the miles of completely unremarkable buildings. The whole city feels like a set of particular points suspended in a vacuum, similar to a bookmark file of Web pages. You are immediately charged on arrival to any worthwhile location, again as on the Web (mandatory valet parking)“ (Manovich 1995).

The quote echoes another often noted perception of Los Angeles: the apparent indeterminacy and confusion of the urban environment and its elements. The city seems almost abstract due to its vastness, density, and regularity. Branches of large petrol stations, fast food, and supermarket chains are found in almost identical form countless times in the urban landscape, blurring local identities and recognizability. This impression can already be found in the interviews conducted by Lynch in the 1960s.

“It’s as if you were going somewhere for a long time, and when you got there you discovered there was nothing there, after all.” (Lynch 1960, 41)

Much of this urban indeterminacy has its origins in radical urban changes, such as those brought about by the construction of the freeway network or large-scale urban renewal programs of the 1950s and 1960s.

“In Los Angeles there is an impression that the fluidity of the environment and the absence of physical elements which anchor to the past are exciting and disturbing. Many descriptions of the scene by established residents, young or old, were accompanied by the ghosts of what used to be there. Changes, such as those wrought by the freeway system, have left scars on the mental image” (Lynch 1960, 45).

The erased and imagined city

Imaginary space and material reality seem to be more strongly interwoven and intermingled in Los Angeles than elsewhere.

“In February 1990, at a public lecture series on art in Los Angeles, three out of five leading urban planners agreed that they hoped L.A. would someday look like the film Blade Runner” (Klein 1997, 94)

Thanks in no small part to the local film industry, which has featured Los Angeles in countless self-referential productions, a comprehensive imaginary geography of the city has emerged. This geography shares elements and place names with reality. This relative space, enriched by historical places that no longer exist and imaginary places that never existed in the form described, is present in the consciousness of most residents and visitors to the city. It also has a considerable influence on the development of the real environment.

The historian and writer Norman Klein describes this as urban erasure. Political decision-makers use local myths to argue for and enforce radical urban development measures. Urban erasure targets areas with a particularly strong cultural and historical identity, followed by their mythologization by the local film industry. As an example, the Victorian residential neighborhood Bunker Hill and the historic Chinatown in the area of today's Union Station both occupy a central place in crime stories and film noir of the 1930s and 1940s. Both of these areas have fallen victim to radical urban renewal and have almost completely disappeared from urban geography today (Klein 1997).

The shooting locations of the film LA Confidential, which takes place in Los Angeles in the 40s, encompasses all aspects of the imaginary Los Angeles:

Table: Locations of the movie LA Confidential (in order of their appearance in the movie).

Hancock park Beverly Hills Manns Chinese Theatre, Hollywood Blvd Parking Lot, Hollywood Blvd. 1184 Gretna green, Brentwood (R. Neutra Haus) 1736 Nottingham, Los Feliz 9781 South Duquesne, South Central LA 1st & Olive street – (Echo Park, im Film Bunker Hill) Cementary, South Central Orange Grove, Anaheim Wilshire Blvd 5261 Cheramoya Avenue, Hollywood Griffith Park San Bernadino 9608 Vendome, Silverlake Ventura Freeway, Cahuenga Pass 2345 Halboro

Today, Los Angeles is a place where many different ethnic and cultural groups live together. Each population group has a different perception of the city.

Ethnicity	Percentage of the population	Change
Hispanic or Latino	44.56%	(+28.31%)
White, not Hispanic or Latino	31.09%	(-18.57%)
Asian	11.95%	(+22.48%)
Black or African American	9.78%	(-6.00%)
Some Other Race	23.53%	(+22.47%)

Largest ethnic groups in Los Angeles, Census 2000, change from 1990

Brief history of Los Angeles

Greater Los Angeles consists of five counties: Los Angeles, Orange, Ventura, San Bernardino, and Riverside, along with several independent municipalities. The municipality of Los Angeles has a disjointed border, with enclaves like Beverly Hills, Culver City, and West Hollywood surrounded by the urban area of the city.

The current structure of Los Angeles has been, and continues to be, influenced by three main factors:

The influence of modern transportation including light rail and the automobile.

A vision of the city as an rural/urban garden city, contrasting with large cities such as Chicago, Boston, and New York, which were considered too dense and unsanitary.

Fear of natural disasters, such as earthquakes and landslides, leading to a lighter and flatter design.

Since its founding in 1781, the development of Los Angeles has always been closely linked to the advancement of new transportation systems. Until around 1870, Los Angeles remained a relatively insignificant small town with an agricultural focus and a population of around 6,000. In 1876, the city was connected to the transcontinental railroad line, which has just been completed, connecting San Francisco and the East Coast. This new connection to the interior of the continent led to the first major wave of immigration. The new inhabitants were mainly settlers from the Midwest, attracted by the warm climate and rich agricultural resources. Between 1870 and 1900, around 20 new towns were founded in the area around the small town of Los Angeles. An extensive network of individual villages and towns—Pasadena, Santa Monica, Anaheim, Santa Ana, Pomona, Riverside, and Redlands—developed in Los Angeles County. All of these were primarily agricultural communities. In 1890, the population of the city was 50,000 inhabitants. (Wachs 1997, 107).

The strongest growth period coincided with the emergence of modern inner-city transit systems in larger cities. Developed East Coast centers like Boston, Philadelphia, and New York already had dense urban cores at the pedestrian scale. In contrast, Los Angeles lacked an enclosed, developed city center. This allowed new areas to be designed for the higher capacity and speed of emerging transportation. The rapidly developed streetcar network became essential infrastructure and was instrumental in developing new land. Building contractors and speculators, main shareholders of railway companies, continually extended new lines into undeveloped areas. Cheap plots of land along these lines became valuable building land with favorable infrastructure. The street car, driving urban development, led to rapid city growth at an early stage. Suburbanization began before the city center was fully developed, preventing it from attaining the same importance as city centers in cities of comparable size. Reyner Banham commented in 1973: „a note on downtown ... because that is all downtown Los Angeles deserves“ (Banham 1971, 212).

From 1910 to 1920, Los Angeles boasted the largest inner-city streetcar system in the country, and by 1923, the Pacific Electric Company’s network spanned 1,164 rail miles. During this period, the Los Angeles Planning Commission, comprised of developers and bankers, focused on subdividing building land and dedicating areas for transportation infrastructure.

In 1918, 6,000 building permits were issued in Los Angeles. By 1923, during the last peak before the Great Depression in 1929, the number had skyrocketed to 62,548. In 1925, 600,000 plots of land were up for sale, which could have accommodated a population of 7 million. However, this population size was not reached until 50 years later (Dear 1996, 92).

In summary, unlike in comparable cities, suburbanization in Los Angeles was not a post-war phenomenon. Instead, Los Angeles experienced strong growth and decentralized development from early on, with suburbs developing simultaneously with the city core. By the 1920s, the current size of greater LA was already defined in terms of transportation and parcel subdivisions (Wachs 1997, 119).

Following the railroad system, the private automobile had a lasting influence on the shape of the city, spreading through Los Angeles at an impressive rate. As early as 1929, 777,000 automobiles were registered in the city, which corresponded to one car for every three inhabitants. With this figure, Los Angeles far surpassed all other cities in the country at the time. Urban expansion, once restricted to rural corridors along railroad lines, now faces no barriers to seamless development (Wachs 1997).

Increasing density and growing automobile traffic soon pushed the shared railroad and car tracks to their capacity limits. Built with private funds for land speculation, these lines struggled to operate profitably and comprehensively. Consequently, the city administration refused to take them over (Wachs 1997).

The gradual decline of the streetcar system began due to the overwhelming competition from automobiles, culminating in the Pacific Electric Railway Co.'s takeover by a consortium of General Motors, Firestone, Mack Truck, and Chevron. This shift led to the transformation of rail transportation into a bus system. In 1937, Los Angeles began expanding its freeway system, a process that is still ongoing. The first completed freeway was the Arroyo Freeway, connecting Downtown Los Angeles to Pasadena (Wachs 1997).

The urban planning model of an "Stadtland USA" (urban countryside USA) in the sense of Holzner (Holzner 1996, 257) seems to apply to Los Angeles in a special way. Its Central Business District no longer plays a dominant role. Commuter flows run in many different ways between different parts of the city. Typical edge cities, or outer-city centers, like Century City, Studio City, and Burbank are not a recent phenomenon. They developed in parallel with the growth of the region from the very beginning. Some emerged from old independent municipalities that were eventually absorbed by the urban area.

Los Angeles was long considered the epitome of a low-density, sprawling city. However, with a rapidly increasing population and planning measures against sprawl under terms like smart growth, its average residential density has risen sharply. According to a recent study, Los Angeles is now the most densely populated city in the United States, with a land consumption of 0.11 acres per capita.

Navigating the city

As a foreigner from Europe in Los Angeles, one quickly realizes that usual methods of orientation in the city don't work. Driving through the city, there's a recurring sense of déjà vu; Using visual landmarks to navigate proves ineffective. However, with a city map like the Thomas Guide, finding a specific address becomes as systematic task, compareable to looking up a number in a telephone book.

Navigation along traffic routes

The addressing method allows precise estimation of routes and distances. The regular grid of streets with its long boulevards – Hollywood, Sunset, Beverly, Wilshire, Olympic running east-west; Fairfax, La Brea, Western, Vermont running north-south – enables basic orientation. Key landmarks include topographical elements such as the characteristic hill profiles (Hollywood Hills, Silverlake, Griffith Park) and the Pacific Ocean to the west. Prominent urban landmarks are the skyscrapers of

Downtown in the east and of Beverly Hills/Santa Monica in the west, connected by the Wilshire Corridor, which is also lined with skyscrapers. The areas in between (San Fernando Valley, LA) are flat and spacious, allowing orientation at the large-scale even for those unfamiliar with the area. However, orientation becomes more difficult on a smaller scale, as street intersections are visually challenging to identify and find again due to their almost identical branches of gas stations and fast food restaurants.

'Below this grand scale, however, structure and identity seemed to be quite difficult. There were no medium-sized districts, and paths were confused. People spoke of being lost when off habitual routes, of depending heavily on street signs" (Lynch 1960, 41)

However, knowing the sequence of the most important avenues and boulevards in the four cardinal directions and the viewing direction, it is easy to determine the respective position. Problems can only arise due to road interruptions. Many roads end abruptly at a topographical obstacle, only to reappear many miles further on.

As will later become clear in Section 6.9, following complicated directions from memory in an unfamiliar area is not a major problem for most inhabitants. It can be assumed that people orient themselves not following a memorized image of the surroundings in Lynch's sense, but by an abstract coordinate system defined by a few reference points, the mesh size of the grid, and the sequence of the most important streets. Interestingly, city maps of Los Angeles typically do not include building footprints or building lines, except in areas such as downtown.

City maps like the "Thomas Guide" are indispensable for navigating unfamiliar street names and addresses in Los Angeles, often carried in every vehicle. Every resident can readily name the page of the roughly 400-page guide that lists their home address. Lev Manovich's quote introduces a new way of navigation through car GPS systems, which allow users to navigate without topographical context, akin to using a web browser. In this system, places become singular points in an undefined space. Users enter the desired destination address, and the route is announced via voice output, making local knowledge and orientation unnecessary. This system functions like a city browser, managing places like bookmarks and guiding the driver to the desired address.

Using buildings for orientation

In historical European cities, orientation usually depends on buildings, requiring a very good knowledge of the area for precise directions. In Vienna, the radial system aids in approximate localization. However, giving exact directions from memory to someone unfamiliar with the city also demands a high level of familiarity. In such cases, most will point out a few easily recognizable buildings visible from a distance to help a stranger find their way.

Relative space concepts in other disciplines

The following chapter takes a look at related disciplines that investigate relative spaces and their non-linear representation methods. In geography and cartography, various solution approaches and mapping models exist for relative, especially temporal parameters. Many of these models have been taken up again in information visualization and used to represent abstract data sets. The examination of relative spaces also takes place in the field of art, whether in the observation of non-material phenomena of reality such as speed and movement or in the formulation of alternatives to the objective-absolute description of space.

This chapter examines related disciplines that investigate relative spaces and their methods of representation for non-linear phenomena. In geography and cartography, various approaches and mapping models have been proposed for relative, especially temporal parameters, and many of these models have been adopted in the field of information visualization to represent abstract data sets. The examination of relative spaces also takes place in the arts, whether in observing non-material aspects of reality or as critiques of supposedly objective treatments of space.

Geography and cartography

Models of relative space have been researched in geography since the 1950s. The description of complex social and economic relationships made it necessary to find clear forms of representation for these phenomena. As a rule, this is done through thematic maps – maps for the representation of various types of information which, although not directly topographical in nature, are nevertheless assigned to a specific location.

Below are the absolute-spatial and corresponding relative-spatial forms of representation for thematic parameters:

Cartographic symbols for the representation of temporal parameters (Vasiliev 1996)

Choropleths

Choropleth maps are divided into sub-areas filled with different colors or textures (an area symbol). Each color or texture corresponds to a specific characteristic of the parameter under consideration. The entire value range of the parameter is classified into discrete intervals, which are usually assigned a color gradient from dark to light.

The data structure typically predetermines the subdivision of an area into sub-areas. For example, census data use census districts as the smallest spatial unit, resulting in rather imprecise spatial allocation of the examined parameters.

Choropleth map of median income in Los Angeles per Census Tract. Online source: http://navigatela.lacity.org Accessed:4/14/2002

Isolines

Isolines are a suitable display tool for values continuously distributed in space. Unlike choropleths, the sub-regions are not predefined but are represented by contiguous lines connecting points with the same parameter values. The value range of the parameter to be displayed is again classified into discrete intervals. Accordingly, contour lines on topographic maps are isolines that enclose areas of the same elevation. Isolines can express continuous phenomena such as temperature and other properties.

Isochrones

Travel time distances can be represented as isochrones, which are lines of equal temporal accessibility centered around a common origin. This centralization limits their usability in traditional maps. Additionally, isochrones vary significantly throughout the day, suggesting potential for future interactive maps that use network analysis to quickly calculate isochrones from any point.

On a smooth horizontal surface, isochrones would appear as concentric circles with equal spacing. However, obstacles or obstructions distort these shapes; difficult-to-reach points make isochrones converge, while areas allowing high speeds result in wider isochrone distances.

Isochrone maps can be challenging for observers to interpret. Depending on the mode of transportation, representations might include islands or holes, depicting scenarios where distant areas are closer in time than nearby ones. Multiple route options further obscure which specific route the time distance refers to.

A schematic representation of different forms of isochrones:

Isochrones on a uniform horizontal surface

Isochrones in an urban grid

Isochrones in a subway network

Travel time isochrones in the road network (close range) © 1999 Carsten Schürmann, IRPUD

Travel time isochrones in the railroad network (close range), © 1999 Carsten Schürmann, IRPUD

Isotachs

Isochrone maps are limited by their common origin centering, a drawback avoided with isotachs. Isotachs are isolines that enclose locations of the same velocity. By determining the local velocity for each point, the representation is no longer centered.

A series of isochrone maps with different points of origin can be used to approximate the spatial velocity distribution. Additionally, isochrone maps with any origin can be derived from an isotach map.

Isotach maps are commonly used in meteorology to represent wind speeds. They often complement isochrone maps in transportation applications.

Seattle isotach map - Traffic Engineering Division, City of Seattle, and William Bunge (Abler, Adams, and Gould 1971)

Cartograms

Cartograms or cartographic anamorphoses are geographical maps that have been intentionally distorted to represent non-geographical information (Kocmoud 1997, 4). Cartograms, like choropleth or isoline representations, can express thematic parameters. However, cartograms differ by expressing the value of a parameter directly as spatial extent or distance. The parameter is now understood as a measure of space itself, rather than as a local variable quantity in absolute space. In distortion cartograms, spatial distance influence is equalized, as each point has the same density value and equal areas represent the same parameter value.

This method offers several advantages. It provides a clear, intuitive understanding of the parameter's size distribution, assuming the real spatial shape of the area is known. Unlike choropleth maps, which are often not immediately legible and rely heavily on the legend for value classification, this approach can enhance clarity.

Cartograms are distinguished as either contiguous or non-contiguous. In the case of non-contiguous cartograms, the units of observation are rendered as distinct elements individually resized according to the parameter to be displayed. They have a more abstract-diagrammatic character and are easier to produce by hand. As an example, Dorling's circle cartograms represent the spatial elements as circle symbols of variable size (Dorling 1994).

Choropleth map and non-contiguous cartogram. Online source: http://www.mimas.ac.uk/argus/ICA/J.Dykes/3.3.html Accessed:12/10/2001

In contiguous cartograms, the continuity of the space is maintained, appearing as if drawn on an infinitely stretchable blanket. The local density of the parameter under consideration acts as a stretching force. Various algorithms exist for generating coherent cartographic representations (Kocmoud 1997, 22).

In the rubber map algorithm (W. R. Tobler 1973) and the rubber sheet distortion algorithm (Dougenik, Chrisman, and Niemeyer 1985), the thematic parameter is first considered as a point distribution. The map is then distorted iteratively until all points are equidistant.

Dorling's Cellular Automaton method is based on Conway's Game of Life algorithm (Dorling 1994).

In the DEMP (Density Equalizing Map Projections) algorithm, individual sub-regions are scaled radially in relation to their center of gravity, deforming adjacent regions. This algorithm is applied iteratively for each sub-region. (Merrill, Selvin, and Mohr 1992).

Kocmoud's constraint-based approach uses various shape constraints to retain the familiar shape of spatial units like federal states or census districts, ensuring the map remains comprehensible to the viewer (Kocmoud 1997).

Elvis concert attendance by state, Andrew Dent and Linda Turnbull, source: http://www.owu.edu/~jbkrygie/krygier_html/geog_353/geog_353_lo/geog_353_lo03.html

Population size: Choropleth map vs. cartogram (Kocmoud 1997)

Transforming isochrone maps

Using time units as the scale for isochrone maps results in concentric circles of equal distance. Transforming these into relative space alters the complex shapes of the isochrones into concentric circles, thereby deforming the space. However, obtaining a relative space representation is not always possible, as isochrones can form holes or islands, leading to ambiguities. Consequently, the space appears folded, and the geographical shape is lost or appears inverted.

Seattle isochrone starting from the Central Business District in topographic space and in time-related relative space - traffic engineering division, city of seattle, and william bunge (Abler, Adams, and Gould 1971, 79).

Taxicab geometry

A special form of non-Euclidean geometry, known as taxicab or Manhattan geometry, plays an important role in representing time distances. this geometry is particularly helpful when mapping or calculating time distances or actual path lengths in built-up areas.

In taxicab geometry, only directions parallel to the orthogonally aligned spatial axes are permitted. Each direction or path is expressed in an orthogonal grid with a defined mesh size, which approaches zero in its continuous form. The distances correspond to the actual path a vehicle must travel in a completely regular street grid of the same mesh size to reach any point in the city.

Taxicab geometry allows more than a single shortest distance between two points, making it distinct from Euclidean geometry. In this way, two-cornered, closed figures with only two corner points are possible, explicitly excluded in Euclidean geometry.

A circle would look like this in taxicab geometry:

a circle in taxicab geometry

A diagonal in taxicab geometry

A “twoangle” taxicab geometry

In isochrone maps of cities with orthogonal street grids, the forms of taxicab geometry often reappear (Gardner 1997).

Information visualization

In recent years, models of non-linear space have been increasingly developed in information visualization. These models focus on visually processing and structuring complex, multidimensional data sets, where the information itself becomes a spatial parameter. Similarity regarding the parameter is expressed through spatial proximity of the elements. Non-linear display models aim to present complex data sets as a whole while simultaneously highlighting specific areas.

Hyperbolic space

Hyperbolic space, a type of non-Euclidean geometry, is well suited for representing extremely complex and extended networks. In two-dimensional hyperbolic geometry, this can be visualized as being inscribed on a hyperbolic saddle surface, described mathematically by the relationship $x^2 - y^2 = r^2$, also known as a pseudo-sphere. This surface has an infinite area, and a triangle in hyperbolic space has angles summing to less than 180°, with its shortest paths being concave. Additionally, through any given point, an infinite number of parallels to a straight line can be drawn.

Representation of a tree structure in the hyperbolic plane (Lamping, Rao, and Pirolli 1995).

This two-dimensional hyperbolic space can be projected into the Euclidean plane using the Poincaré projection, resulting in a disk-shaped hyperbolic surface. The bounding circle represents the infinite extension of the hyperbolic space. Straight lines of constant length in hyperbolic space appear as circular arcs on the Poincaré disc, becoming shorter as they move further from the center. A point moving away from the center at a constant speed appears to slow down in the projection as it nears the bounding circle but can never reach it, as the circle corresponds to an infinite distance from the center.

In this model, space is distorted uniquely, allowing unlimited amounts of data to be displayed in their entirety at once. The size of the representation in the center remains large enough to examine details of the data structure. By moving the data structure in hyperbolic space, the focused area can be changed. Despite its complexity, this spatial model is surprisingly accessible and creates an impression reminiscent of looking through a fisheye lens (Lamping and Rao 1994).

Non-Linear magnification

The basic principle here is the simultaneous display of a strongly magnified focus point alongside the context of the entire data structure (also known as the focus + context technique). Non-linear magnification and distortion viewing summarize techniques that magnify individual details without removing the examined area from context or obscuring parts of the whole. Additionally, the use of multiple focal points and lines extends the hyperbolic space model (Keahey and Robertson 1996; Kilian 2000).

Example of non-linear magnification in (Keahey 1998)

3D - Distortion Viewing

Although most of these techniques are limited to two-dimensional space, the extension into the third dimension can be useful in several ways. To make the highlighted area readable through spatial distortion, local enlargement is interpreted as a distortion of the plan towards the camera, and as perspective proximity. Shading techniques are then used to depict a light/shadow gradient on the distorted surface, making the spatial distortion perceptible.

Non-Linear Magnification - suggestion of distortion by superimposed grid and shading of the surface (Carpendale, Cowperthwaite, and Fracchia 1995)

Carpendale et al. attempted to transfer and generalize the methods of two-dimensional distortion viewing to three-dimensional space. In addition to avoiding spatial overlaps, particular attention was paid to the visual access of the focused elements in order to avoid a viewed spatial element being obscured by other elements(Carpendale, Cowperthwaite, and Fracchia 1995).

Visual access in 3d-distortion viewing.

Art

The perception and appropriation of space are central themes in contemporary art, a domain inherently tied to the subjective vantage point. The following three examples systematically examine subjective spaces and their geometry.

Situationism

The term psychogeography was chosen by the situationists to describe the imaginative and perceptual spaces of our everyday environment. It is not the environment itself, but the effects of the environment on people's behavior and feelings that are to be examined and depicted.

Derivé is a method for subjective, psychogeographic mapping of the urban environment. A group of 1-4 people suspend all their usual social ties and activities for a certain period of time (usually several days) and devote themselves to exploring their immediate surroundings.

The aim is not to see the urban environment through the filter of the daily rhythm of work and leisure, but to be guided and directed by existing signs and places without having a clear goal in mind.

It was important that this was not a matter of randomly "letting oneself drift", but rather a conscious process of mapping:

"The sudden change of ambiance in a street within the space of a few metres; the evident division of a city into zones of distinct psychic atmospheres; the path of least resistance which is automatically followed in aimless strolls (and which has no relation to the physical contour of the ground); the appealing or repelling character of certain places" (Debord 1955).

Life continues to be free and easy, 1959– Guy Debord (Sadler 1999)

Richard Long

British visual artist Richard Long's "walking projects" explore familiar regions through personal, subjective experiences. Unlike the Situationists, who reassemble geographical space based on subjective criteria, Long's method involves walking for several days, forming a basis for his cartographic activity by maintaining the familiar image.

The imaginary, abstract geometry of the map becomes a leitmotif traced in the real environment. He arbitrarily draws circles and straight lines on the map, making the delineated space the subject of his wanderings.

The only evidence of the performance "a seven day circle of ground - seven days walking within an imaginary circle 5 ½ miles wide, Dartmoor, England 1984" is a circular diagram with place names. The path of the walker is not marked. Most place names are the artist's own, while some indicate dates; seven locations on the diagram are labeled "Midday." The designation "tent" marks the center of the imaginary circle. It is unclear whether the "map" represents an actual geographic area. There are no points of reference to geographically fix the area explored by Long. Instead, it is a relative spatial representation, a cognitive map that more readily reveals the chronological sequence of his journey rather than his actual route. The abstract circle could be seen as an ironic commentary on the supposedly objective nature of maps, which attempt to geometrically organize subjective experiences and arbitrary decisions (Corner 1999, 234).

A seven day circle of ground… – Richard Long (Corner 1999, 234)

Masaki Fujihata

The works of the Japanese artist and scientist explores various aspects of perception, speed, and space.

In 1991, Fujihata hiked to the peak of Mt. Fujijama with a group of students, each equipped with a GPS receiver that constantly recorded their geographical coordinates and walking speed. Although the GPS data provided exact positions on the plain, there was no data on their altitude. To overcome this, Fujihata reconstructed the elevation of the paths using the walking speed—slower speeds indicated steeper terrain. This method allowed him to create several three-dimensional profile curves of the mountain from the individual paths, leading to a reconstructed model, as shown in the figure below. The "explosion" of geometry in the left-hand illustration resulted from the group spending more time on the mountain peak, which the speed function interpreted as increased steepness.

Impressing Velocity, Masaki Fujihata 1992 source: https://web.archive.org/web/20030211235638/https://www.c3.hu/~masaki/proposal/ accessed 6.9.2001

Fujihata explores themes of speed and perception also in his video installations. A video camera mounted on a model train transmits the image of the speeding train. By analyzing this image, the speed of individual picture elements is measured and used to deform the image plane. Fujihata explains that he aims to counteract the adaptation of visual perception to speed, making it possible to experience speed anew.

Proposed models of representation

In the following section of the thesis, the previously described methods of visualizing relative space are applied to analyzing the city. Various options are available for visualizing thematic parameters:

Diagrams, maps, or plans provide static representations on paper, using cartographic symbolism or cartograms to depict thematic parameters. However, representing time-variable parameters on paper is difficult. This problem can be addressed using computer animation, which allows explicit visualization of temporal-spatial parameters. However, it can convey the dynamic nature of relative spaces only to a limited extent. With appropriate modeling and coding, virtual environments allow direct visualization of parameter changes on the shape of the relative space.

The advantages of using virtual environments (VEs) are quickly summarized: They enable dynamic display models that react to viewer behavior, allowing users to change parameters and explore resulting changes interactively. However, existing cartogram algorithms are often computationally intensive and therefore not suitable for interactive VEs. The challenge lies in finding an adequate model that is simple enough to be calculated and displayed in real time by common computer systems.

General goals and criteria

Designing dynamic virtual environments (VEs) require planning of model behavior, interaction modalities, and the interface. Instead of using statically modeled geometry, the representation is determined by a set of mathematical rules.

An important criterion for visualization models is the recognizability of the represented shape, which involves retaining topology, preserving shape features, and maintaining spatial orientation. It is crucial to prevent the geometry from overlapping itself and ensure that neighboring areas in real space connect appropriately in relative space without overlaps. Additionally, straight paths should not loop or fold in relative space. This is managed by limiting the degrees of freedom in shape changes and implementing specific restrictions and obstacles that preserve the recognizable shape without significantly distorting the result. These restrictions, commonly known as constraints in real-time computer graphics, play a vital role in achieving this balance.

Other criteria include:

Communicating model behavior through interaction allows observers to recognize the influence of subjective parameters. Interaction with the system enables the observer to grasp its form-determining principles and their influencing factors.

Combining internal and external views: Exocentric and egocentric reference systems complement each other and lead to easier access to the respective model. The entire system can be viewed from the outside, and several subjective cameras also offer an internal view.

Simplifying navigation: A well-known issue in virtual reality is the complex navigation, which complicates orientation and interaction within the environment. To address this, standard navigation models like walk, fly, or examine were not used. Instead, a simplified, restricted navigation model was developed to help users avoid getting lost while still conveying the space’s nature vividly. Users can move freely along defined paths and steer the subjective camera to other paths by clicking on them.

Shape defining forces

The shape of the geometry is determined by the interplay of simulated forces between specific nodal points. Their strength depends on the relative distances to be displayed.

In an early version, I used a spring model for this deformation. Each distance was assigned a spring force, whereby the rest length of the spring equation was used as the target distance. In the spring equation Fk = k(l-z0), the resting length z0 was used for the target distance.

The disadvantage of this approach was that the interaction of the spring forces in the system caused oscillations that could build up and corrupt the representation.

For this reason, I decided to use a different method for calculating relative distances in the model. The distance is not changed all at once, but in small steps over time, controlled by a damping factor. This allows for a balanced representation by aggregating different forces through a gradual change without instability of the spring-mass system. Different damping factors also allow the shape-changing influences of different constraints to be weighted differently.

Design considerations

I avoided the VR-typical representation of urban space, where buildings are modeled with simplified geometry; instead, the recorded video material served as a reference to the material reality of the city. The use of image strips of the streetscapes allowed me to capture visual perception rather than objective reality.

Screenshot of one of the created environments

Software

I developed the virtual environments using the Virtools dev environment, an authoring system for games and interactive 3D applications. Virtools dev uses its own visual programming system. Its scripts used function similarly to symbolic flow diagrams according to the boxes and wires paradigm. Graphical programming is object-oriented; one or more scripts can be assigned to each element, which are processed in parallel and can exchange information with each other.

A simple Virtools script is shown here for illustration. It is a constraint that sets the Y-coordinates of the node objects to zero. The node elements are grouped together.

Virtools scripts are essentially comprised of the following components: - Building Blocks are smaller program modules that perform specialized tasks and are connected to each other via signal paths. The example below shows the “Group Iterator” and “Set Position” building blocks. Building blocks have the inputs on the left and the outputs for processing the script on the right. Data input and data output channels are arranged at the top. - Parameter Operators perform simple arithmetic operations, but unlike Building Blocks, they are not integrated into the signal flow of the script; they are activated when needed by the Building Blocks to which they are connected. - Parts of a script can be grouped together in so-called behaviors with their own signal and data inputs/outputs, which can then be used like building blocks in the script.

an example of a Virtools script

The Virtools dev environment

Videotraces

Video trace from the car window driving on Pasadena Fwy

The study of relative temporal distances in an urban environment requires temporal data from large areas. One problem is the availability of suitable data sources. The area to be studied is usually too large for accurate and complete measurements, and publicly available data sources such as traffic counts are too limited and imprecise. In addition, city maps with building footprints and information on their use are not readily available for Los Angeles.

Therefore, we used systematic video recording of movements in the city, which provides both a visual representation of the study area and information about the time traveled.

The essential characteristic of video is the representation of spatial events in constant time intervals. Time is divided into discrete units called frames. An analog film strip therefore can serve as a measuring tape to measure space in units of time. To simulate this filmic quality in the medium of digital video, we have used various methods to combine individual frames into continuous image montages.

Data sources and methods

Video recordings of driving in various neighborhoods in Los Angeles were taken between September and December 2000.

The video camera with a wide-angle lens was mounted in the side windows of a car using a special mounting bracket. In order to obtain the most detailed individual images possible, recording used progressive fields, i.e. in the full frame resolution of 720x576 D1-PAL at 25 frames per second.

Alignment of image segments

Each frame of the digitized video sequence was cropped to a narrow, 20-pixel-wide vertical strip and then placed side by side in After Effects.

As the camera moves, the perspective in each frame changes, so the frames do not fit together seamlessly in the composite.

For best results, the image strips should be as narrow as possible to minimize the influence of the central perspective. The vanishing points of the individual images become a vanishing line in the composite. However, since the temporal resolution of the video format is limited to 25 full frames per second, a minimum width of the strips is necessary to obtain a continuous image of the recorded objects, such as buildings.

Another problem was vertical jitter, which made the montage difficult to read. This was solved with the following alternative method of image assembly.

Image alignment with vertical adjustment

For vertical alignment, the image mosaicing program Panorama Factory was used, which allows stitching panoramic images from a series of individual images.

This method requires a certain amount of overlap between the cropped frames, for which the 20-pixel cropping was sufficient at the given driving speed. Some manual adjustment was required. Panoramic stitching helped to compensate for the perspective distortion at the edge of each video frame, as well as the vertical jitter of the camera while driving.

Alternative approach for creating large-scale composites

Removing the requirement for a fixed horizontal overlap of the frames resulted in a more natural image after stitching. However, this alternative method no longer allowed for the representation of temporal distance. The resulting montages were then further spatially normalized with the help of a city map and used as textures in the virtual environments.

The image parallax created an interesting effect in the montages - objects in the foreground appear horizontally compressed, while distant objects appear horizontally stretched. The distant objects move much slower than the near objects. In the following display models, these montages are horizontally distorted depending on the speed. Depending on the scaling, only a certain distance from the camera appears in the correct proportion. As Paul Virilio observed:

"Aber es gibt auch ein Phänomen von NÄHE, das hier ins Auge gefaßt werden muß. Die Geschwindigkeit, mit der die Objekte über den Bildschirm des Guckfensters wandern, hängt auch vom Grad ihrer Nähe ab: je weiter das Flugzeug sich vom Erdboden entfernt, umso langsamer zieht die überflogene Landschaft vorbei; die Welt wird statisch." (Virilio 1978)

Time-based montage - the distance between the vertical markers corresponds to one second.

Video documentation of the model (added 2015)

https://youtu.be/YsbKSZpa0Kc

Hill model

Previous models did not consider the asymmetry of temporal distances; they could only be represented in one direction at a time. This model introduces a new metaphor to represent this asymmetry, encoding directional time differences in the slope of the terrain. When the speed of movement is slower in one direction than in the opposite direction, the visualization renders the path as sloping upward, alluding to the metaphor of climbing a hill where the downward path is faster. This model makes it possible to simultaneously express the ratio of outward and return travel times.

The urban structure is again described as a network in which two travel times are assigned to each route, allowing the travel time difference to be determined for each edge. In a two-dimensional view of the geometric area, the absolute distances are maintained in the ground plan projection, while the travel time difference is plotted vertically.

Applying this principle to the entire network reveals certain limitations. The multitude of possible paths connecting two nodes leads to ambiguities that result in multiple height values being assigned to a node. In addition, path loops with different travel times depending on the direction of rotation further complicate the model.

Interface and implementation

The user selects the start and destination nodes in the route network display. Using real-time travel times, the model then calculates the shortest route between these nodes.

The model uses data from the Automated Traffic Surveillance and Control (ATSAC) system[13] to calculate travel time differences. This central traffic control system determines traffic load and influences traffic signal timing (interval, phase distribution, and time offset) using monitoring

[13] See https://web.archive.org/web/20020208143109/http://trafficinfo.lacity.org/html/atsac_1.html

cameras installed at 150 intersections in the Los Angeles area. Real-time traffic information, including average speeds in both directions on major road sections, is available online From where it was automatically transcribed.

Figure 69: ATSAC system screenshot (LA City traffic info) [14]

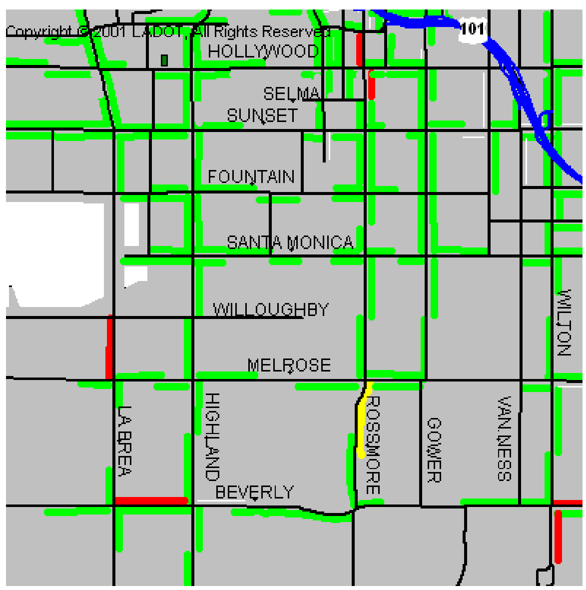


Figure 70: Online output Image of the ATSAC system (LA City traffic info) [15]

An area in downtown LA was chosen for this model. However, the speed information is not very accurate as it only distinguishes between three speed ranges - 0-10 mph, 10-20 mph, and 20+ mph, and not all intersections are included.

[14] See https://web.archive.org/web/20020208143109/http://trafficinfo.lacity.org/html/atsac_1.html
[15] See https://web.archive.org/web/20020208143109/http://trafficinfo.lacity.org/html/atsac_1.html

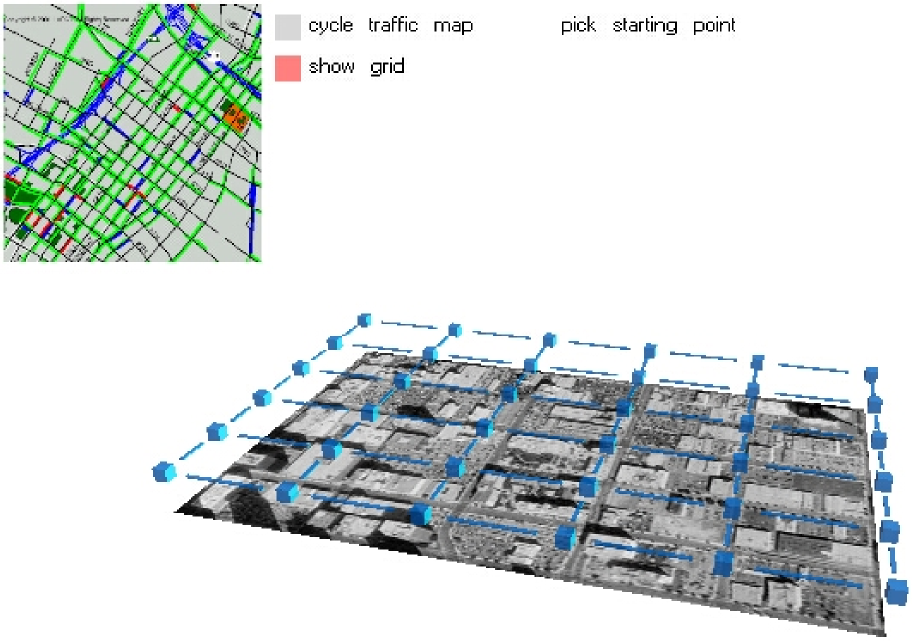


Figure 71: Undeformed network

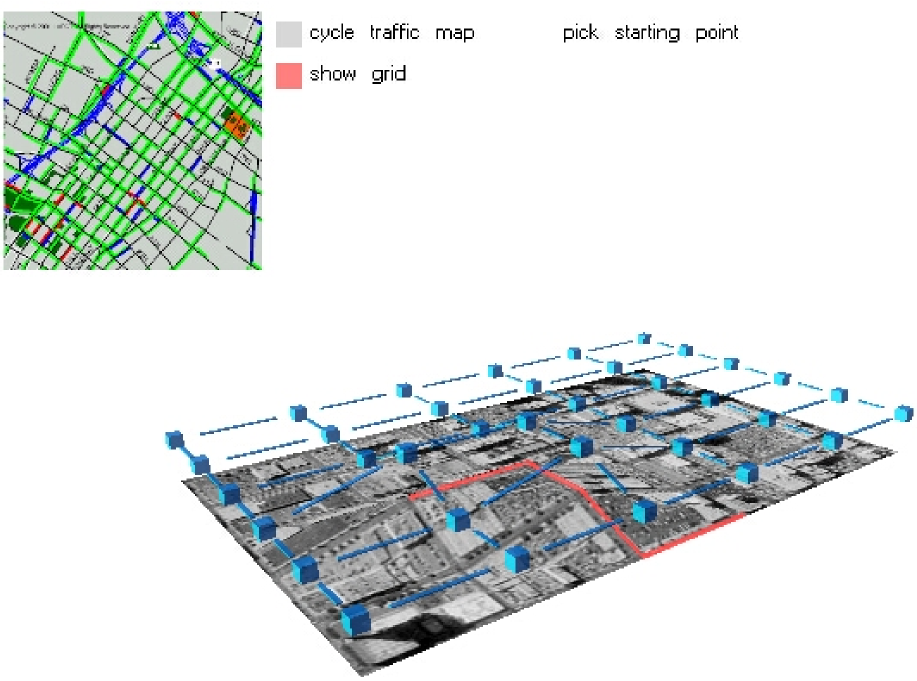


Figure 72: Selecting a route ...

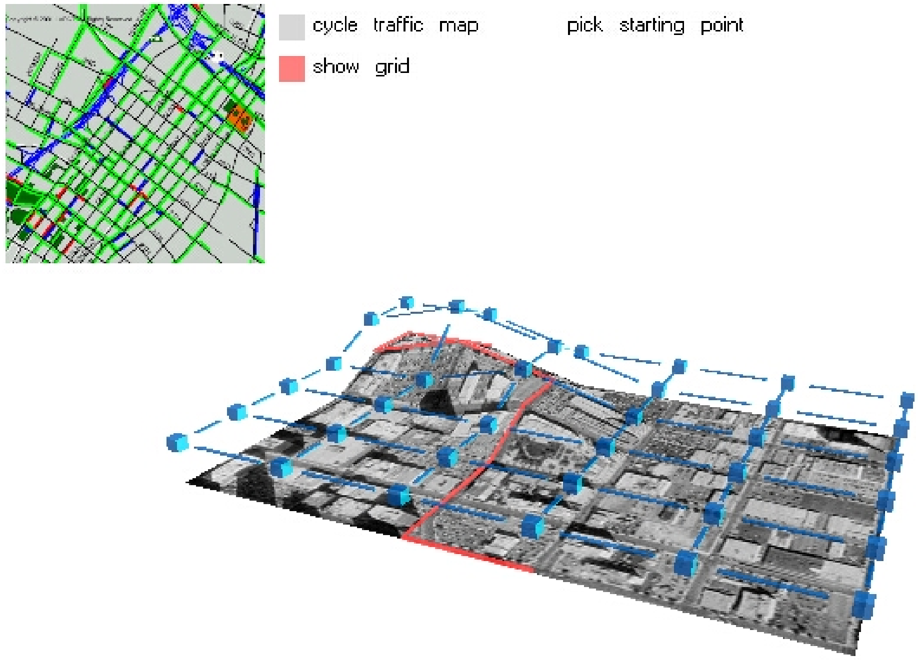


Figure 73: ... and showing travel time difference along that route

Sherman Oaks - Travel time differences caused by traffic light phases

This example uses field measurements of traffic light phases and speed limits. The plan geometry is taken from the city's online GIS service,[16] and the aerial imagery is provided by Microsoft Terraserver.

The travel time model takes into account the direction of travel, which is primarily influenced by the nearest traffic light. As a result, two different traffic lights can significantly affect the travel time for the same route segment, depending on the direction of travel.

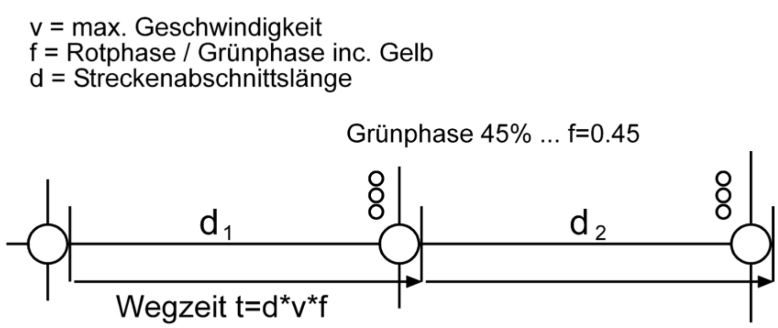


Figure 74: Calculation of the travel time

This means that travel times for the same route in different directions vary at the two intersections solely due to differing traffic light phases.

[16] See http://navigatela.lacity.org

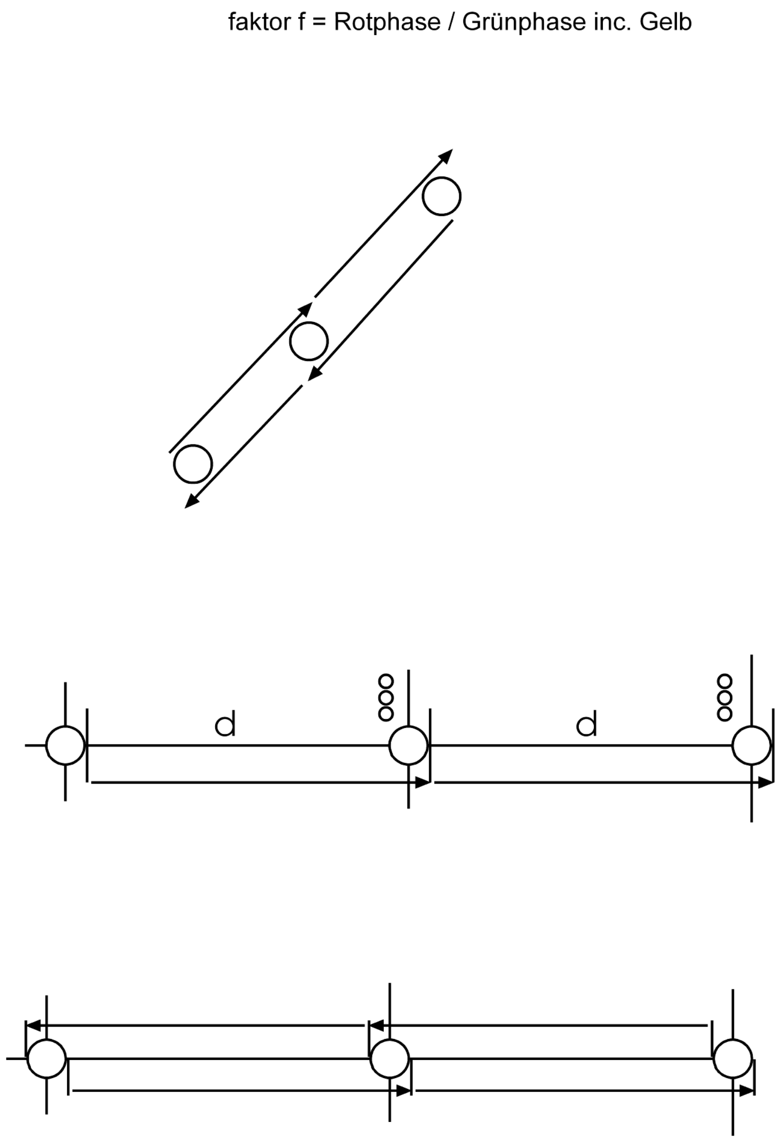


Figure 75: Asymmetry due to traffic light phases

The coordination of traffic phases, though not considered here, would offset this effect to some extent. Additionally, the actual traffic volume, which influences waiting times for actions like left turns, could not be determined in this context.

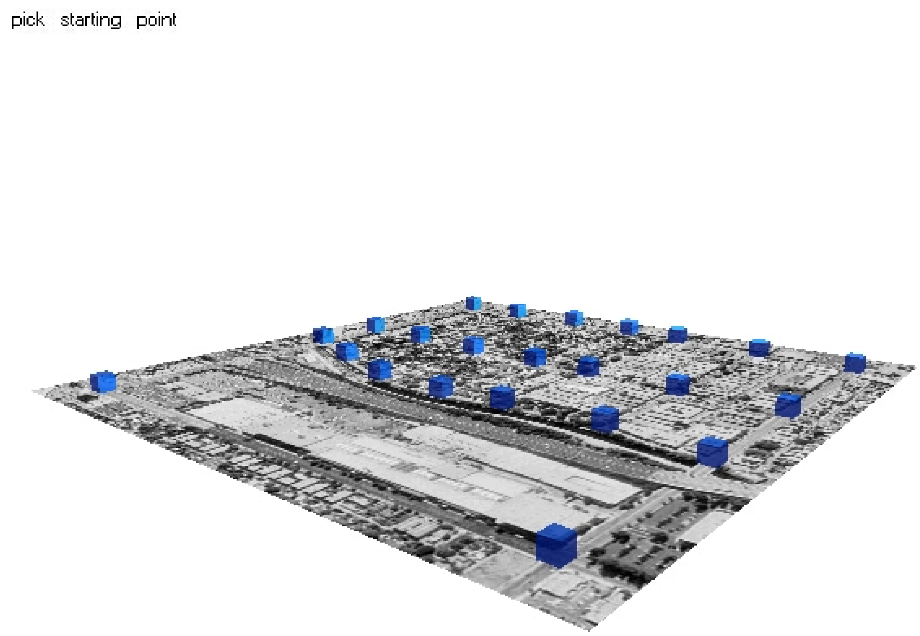


Figure 76: Sherman Oaks undistorted model

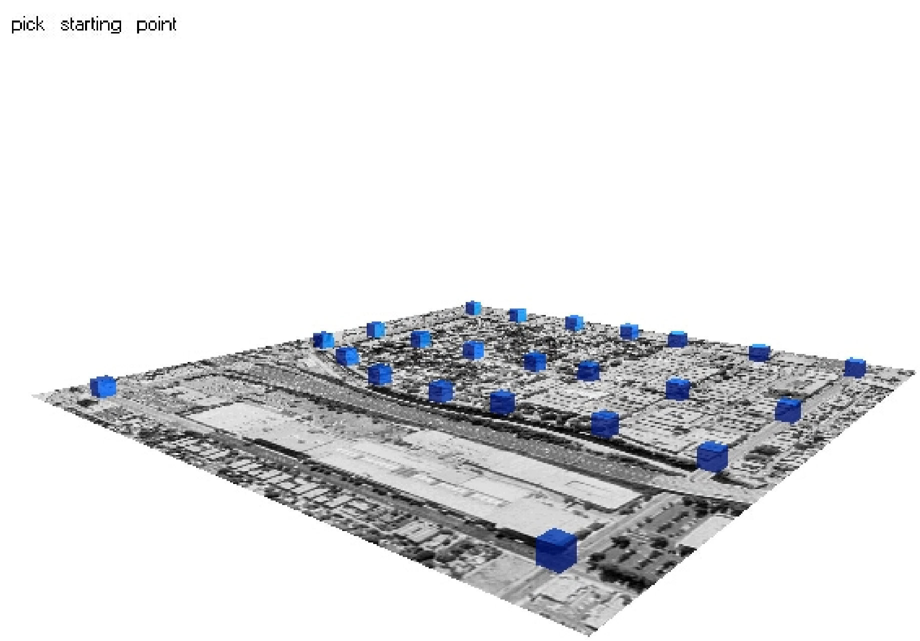


Figure 77: Travel time asymmetry due to traffic light phases.

The capabilities of the model become apparent when dealing with larger areas. For example, commuter traffic can be clearly visualized throughout the day. Areas that attract traffic can be easily visualized as hills. However, this requires complete data on traffic speeds on the road network in both directions. Coupling with real-time data, e.g. from the ATSAC system, could be an interesting application for the model.

Video documentation of the model (added 2015)

https://youtu.be/YsbKSZpa0Kc

Area cell model

In the previous models, the urban area was considered as a linear network of paths. The next model is intended to represent area-related parameters such as population density.

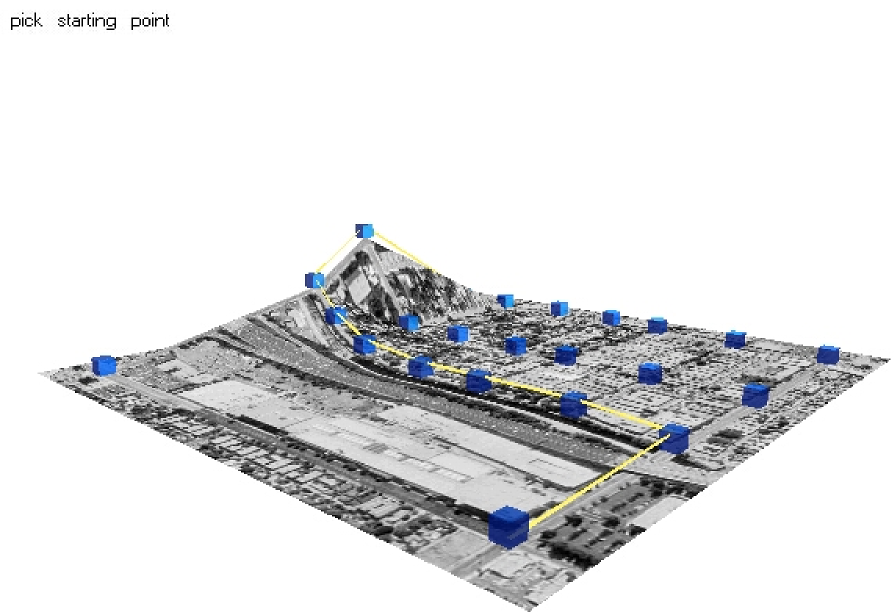


Figure 78: Area Cell Model

Implementation

The area is divided into discrete sub-areas called cells, which can vary in size and be assigned thematic parameters. To avoid self-overlapping geometry and prevent a stretched cell from encroaching on a neighboring cell, repulsive forces are implemented. These forces ensure each cell maintains a defined distance from its neighbors. The target distance to each of the eight neighboring cells is determined by the scaling of both the cell and its neighbors.

Table 4: Determining the distance to the neighboring cells

Orthogonal distance	Diagonal distance
D= f(S1 - S2) f between 0.5 and 1	S= fs*qr(2)*(S1 - S2) f between 0.5 and 1

A factor of f=0.5 results in a distance where neighboring cells would touch. A larger value allows the cells to be moved a little further apart.

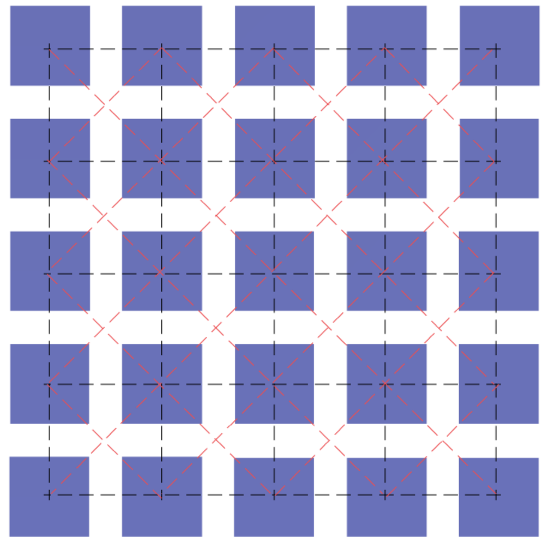


Figure 79: Undeformed grid

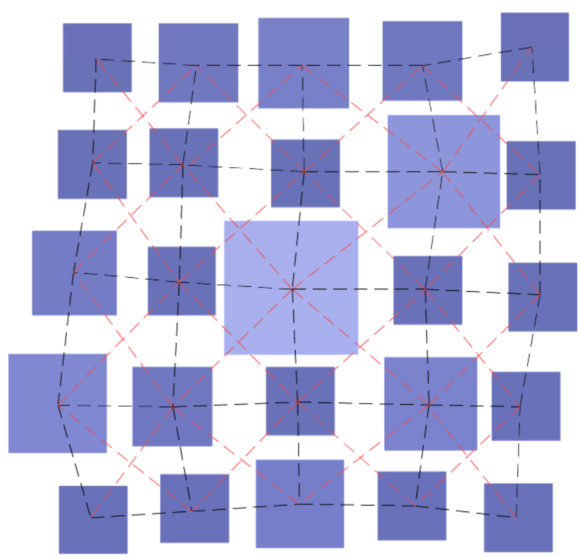


Figure 80: Deformed grid with repulsion

Representing information density

The following example examines urban space through locally available information density. The subjective sense of spatial size and distance can be influenced by the amount of information in the environment. A figure from "Learning from Las Vegas" was used to illustrate this approach. In this diagram, Venturi et al. recorded every legible word from a driver's perspective on the Las Vegas Strip, including traffic signs, casino signs, and announcement boards.

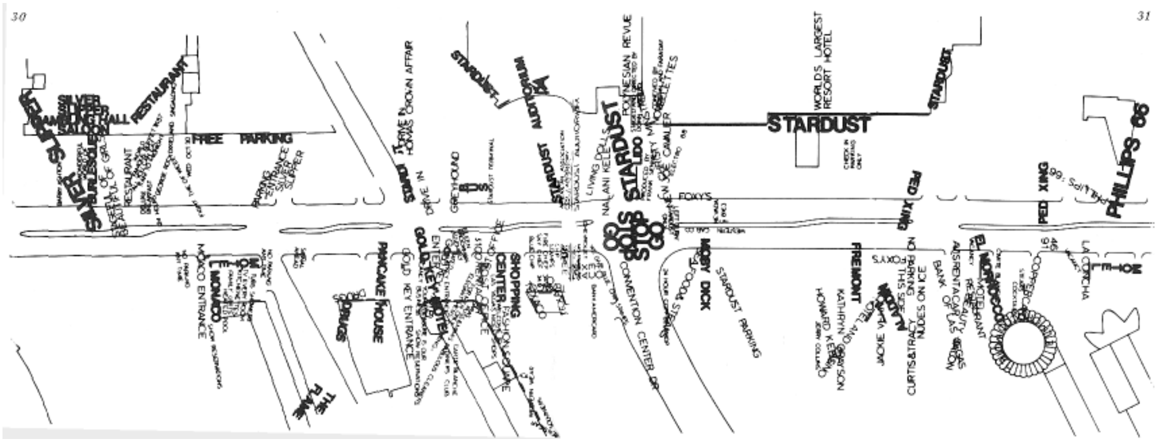


Figure 81: Every Legible word from the Driver's perspective (Venturi, Brown, and Izenour 1972)

For the relative spatial representation in the surface model, a regular grid was superimposed on the diagram and each piece of textual information was assigned to a grid field. Each cell was scaled according to the number of words and letters in its assigned field.

The implementation again allows navigation through both external and internal perspective. In the inside view, the user can move the camera to a cell by clicking on it. The information assigned to each area can also be changed interactively or new information can be added to the VE.

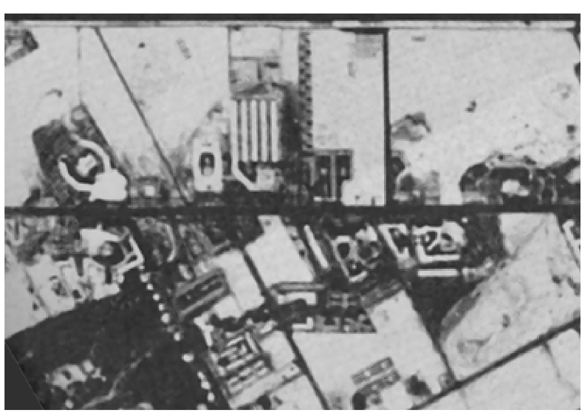


Figure 82: Historic areal image (Venturi, Brown, and Izenour 1972)

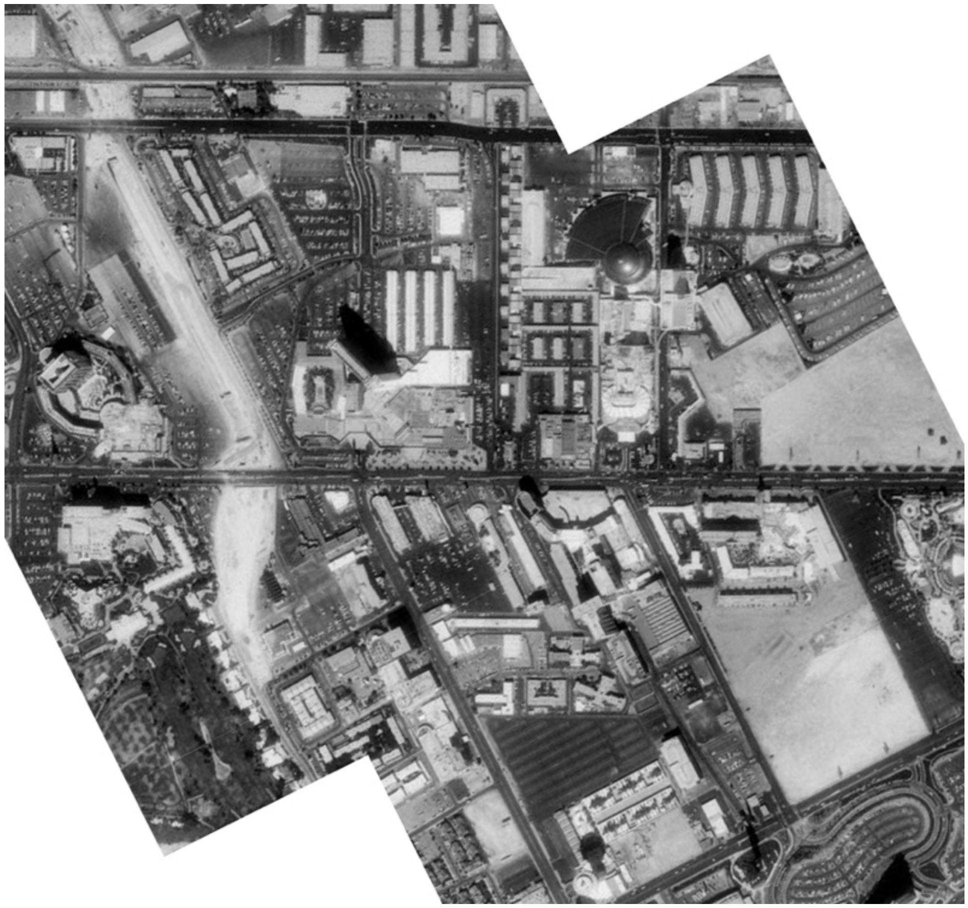


Figure 83: The same area in its present form (fall 2001) Online source: http://terraserver.microsoft.com Accessed:9/15/2001

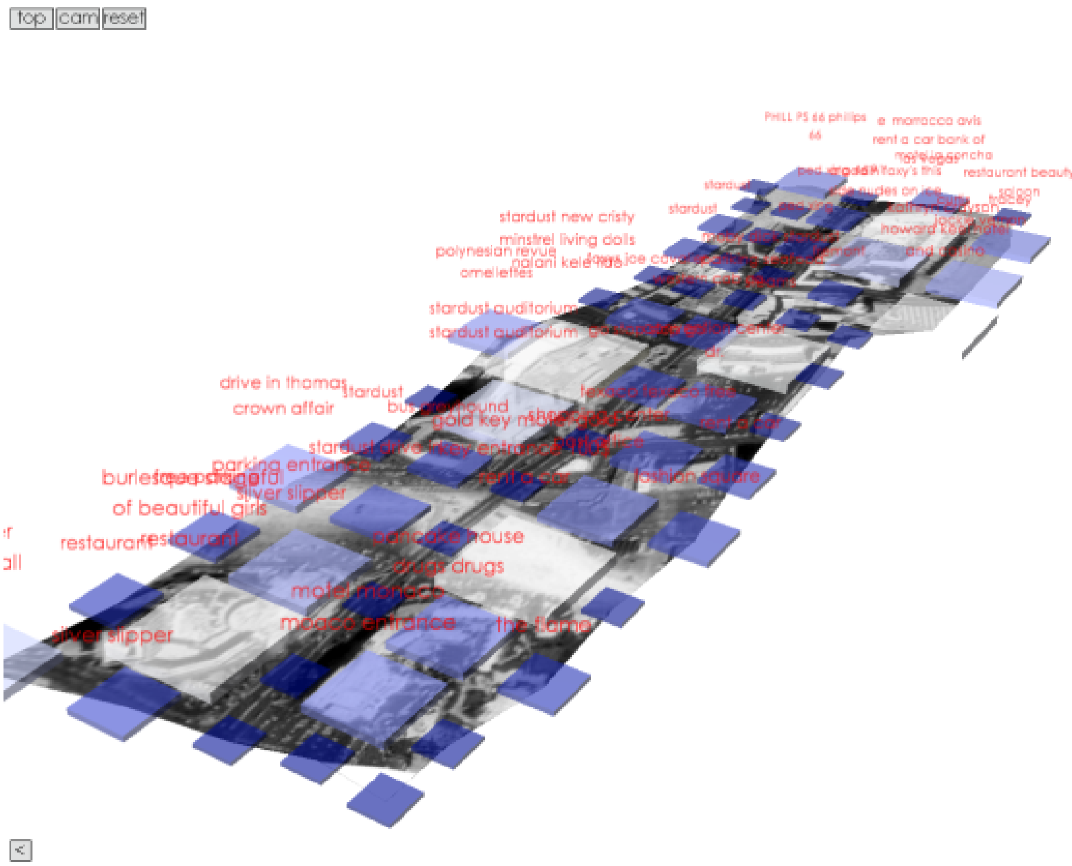


Figure 84: Representation with superimposed cells - their color saturation corresponds to the scaling factor

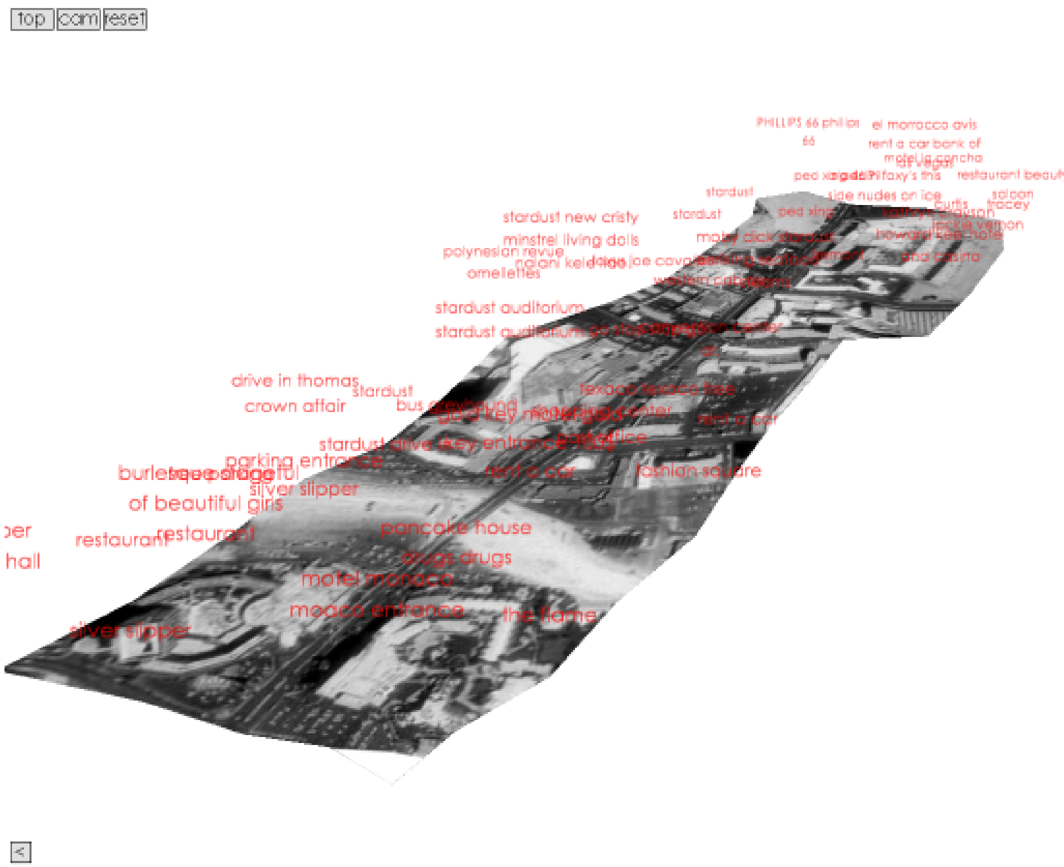


Figure 85: Representation with cells hidden

This example is limited to two dimensions, but the extension to three dimensions should be relatively easy due to the smaller number of degrees of freedom compared to the model described in section 6.3. At the time of the study, the author did not have a three-dimensional data set available.

Video documentation of the model (added 2015)

https://youtu.be/YsbKSZpa0Kc

v/t (velocity / time) model

This visualization model focuses on the spatial distribution of movement speeds in urban areas, effectively serving as a spatial version of the time-velocity diagram: v(t) = s/t. In this model, travel time and direction are plotted on the horizontal plane, while the associated speed is plotted on the vertical plane. Zones with the same speed appear at the same vertical height.

The idea behind this representation is that urban environments are often divided into distinct speed zones, creating a spatial “decoupling” for motorized city users. Areas with different speeds lead to varied levels of perception, making them experience these zones separately from the rest of the environment.

Data Sources

This model uses previously recorded data from the Sunset Blvd. / Western Av. area to illustrate principles rather than conduct a systematic empirical investigation. Based on available data on land use, speed limits, and zoning, existing areas were categorized by typical speeds:

- Roads and highways were assigned applicable speed limits.
- Parking lots were assigned a speed of 5 mph.
- Residential areas and sidewalks were assigned a speed of 2 mph.

Calculation

The relationship between speed and travel time is a reciprocal transformation of the distance/time diagram.

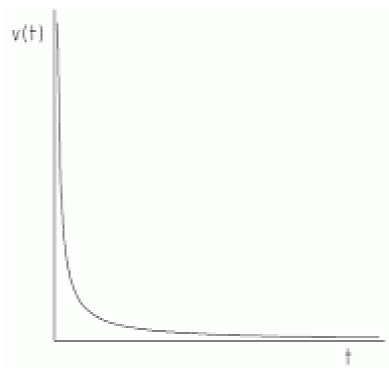


Figure 86: Relationship between speed and travel time

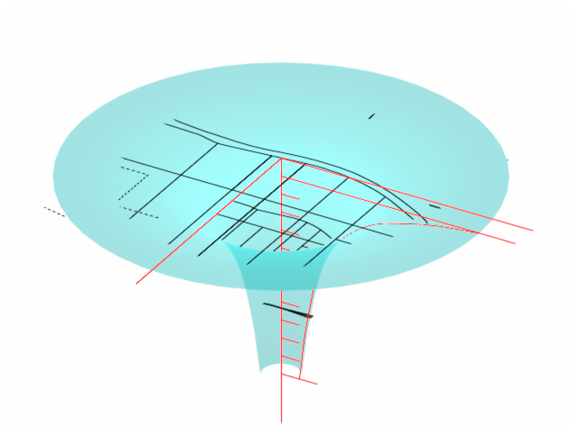


Figure 87: The surface of constant time distance, represented by v(t), which points downwards in this case.

Spatializing the diagram to include motion direction results in an inverted funnel shape, representing a constant spatial distance at different speeds. At a speed of 0, its opening radius is infinite. This model maintains a clear representation of real space but, unlike previous continuous models, it introduces discontinuity.

Implementation

The representation is centered, so the travel time distances of each speed range are accurate relative to a common origin. To accommodate this, the user can move the origin within the implementation. In addition, the speed ranges can be adjusted vertically, allowing the user to interactively assign different speeds.

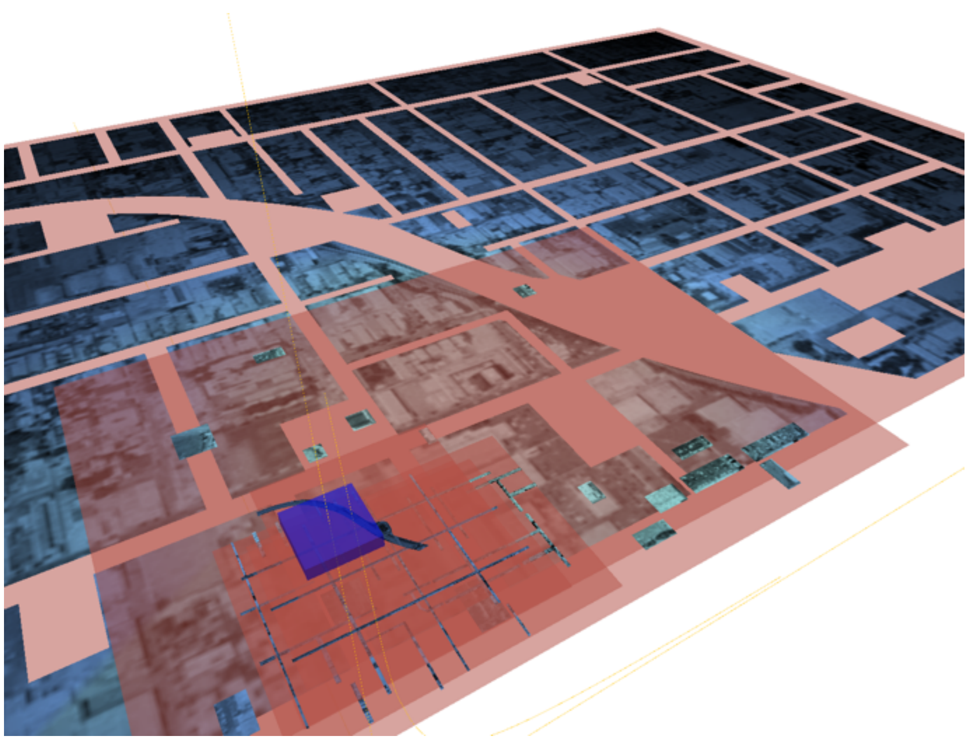


Figure 88: View of the model

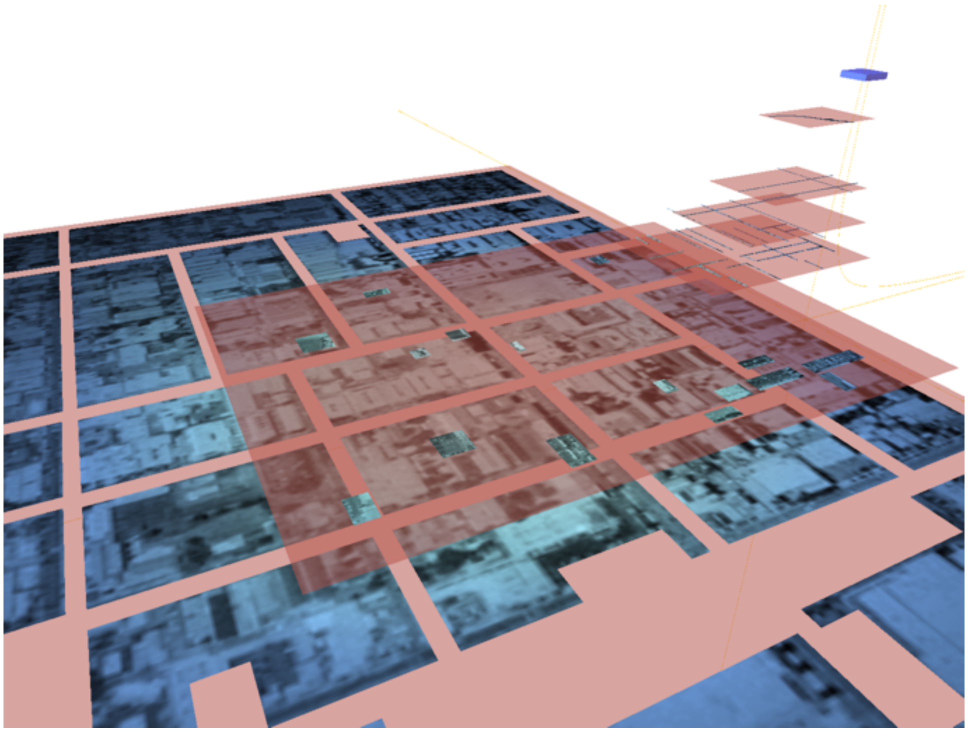


Figure 89: Interactive manipulation of the origin

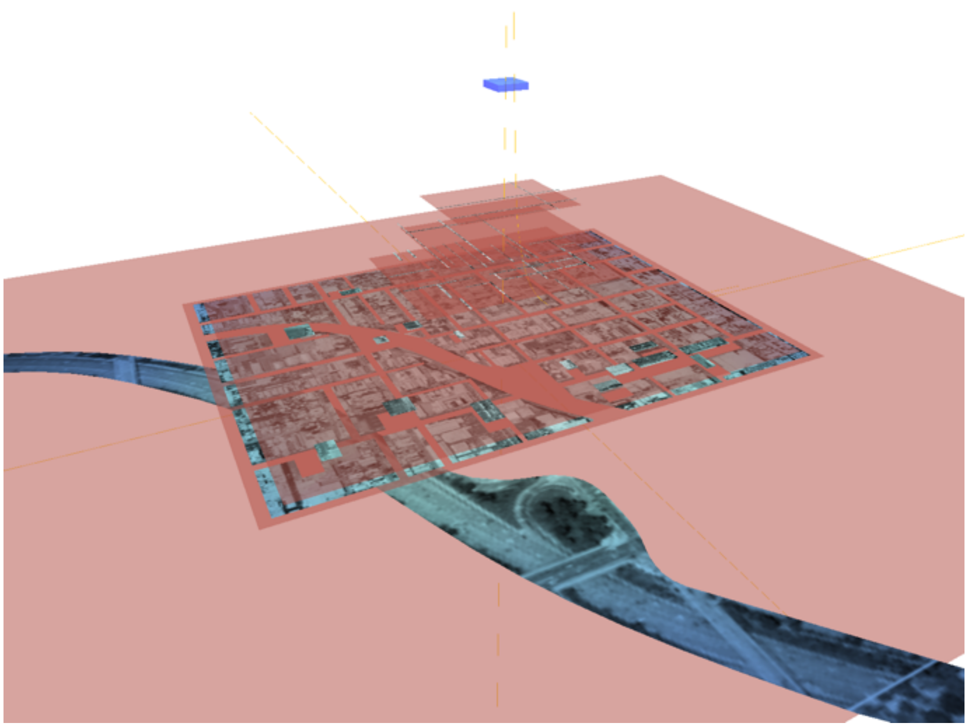


Figure 90: A traffic jam on the freeway

The model shows a snapshot of urban travel speeds. If data sets of speed ranges over the course of the day were available, they could be used for animations. A disadvantage in the implementation is the need to predefine the speed ranges. For future work, it might be interesting to have a continuous display instead of the separation into individual areas.

Narrative space

This final part of the thesis returns to the importance of relative concepts of space in everyday life by examining the construction of space through verbal description. This representation is not based on a mathematical model, which makes this approach different from all previous ones. Rather, it is an experiment to determine whether relative space can be communicated verbally and whether the structure of the city can be reconstructed from these descriptions.

Data sources

The starting point for the presentation are directions obtained by telephone. Respondents were selected from the Los Angeles business directory and asked to describe the route to their office, store, etc. by telephone. The destination of a route description is also the starting point for the next route description. In this way, after about 30 phone calls, a connected virtual path through the city was created that crossed itself several times. Based on these intersections and the repeated reference to common landmarks or main traffic routes, it was possible to reconstruct the real space from the route descriptions. For example, if an intersection was mentioned in several descriptions, the intersecting routes could be connected at this point.

Most of the interviewees were spontaneously willing to provide information and generally provided very well structured and accurate information. In general, it is noticeable that the directions received become more detailed the closer they get to the destination. However, many calls were answered by automated information systems with voice servers. These were equipped with a variety of directions that could be interactively accessed by the caller via key assignments.

Implementation

The telephone directions were recorded on minidisc and transcribed. With this information I tried to reconstruct a coherent map of the described urban areas. No prior knowledge of the places described in real space was added; all spatial information was taken from the conversations. The text of the transcription was arranged like paths on a map. Cardinal points such as east/west and directional descriptions such as left/right determine the course of the texts. The following text fragment illustrates the process:

“you take the beverly boulevard, ok, going to east. go straight beverly, you pass vermont, go straight beverly, then left at north hoover and at hoover is the temple hospital” See also in the Appendix: the full transcription of the recorded conversations.

The resulting map contains all the directions, but makes it difficult to follow the individual conversations. For this reason, it was implemented as a dynamic environment in the Macromedia Flash software environment: by “touching” the texts with the mouse, related descriptions are highlighted in color. This makes it possible to follow the course of a single conversation.

Each conversation begins with a closed text box containing the greeting. The destination of the directions is marked with a red circle. To make it easier to follow the text at junctions, red help arrows have been used at difficult points.

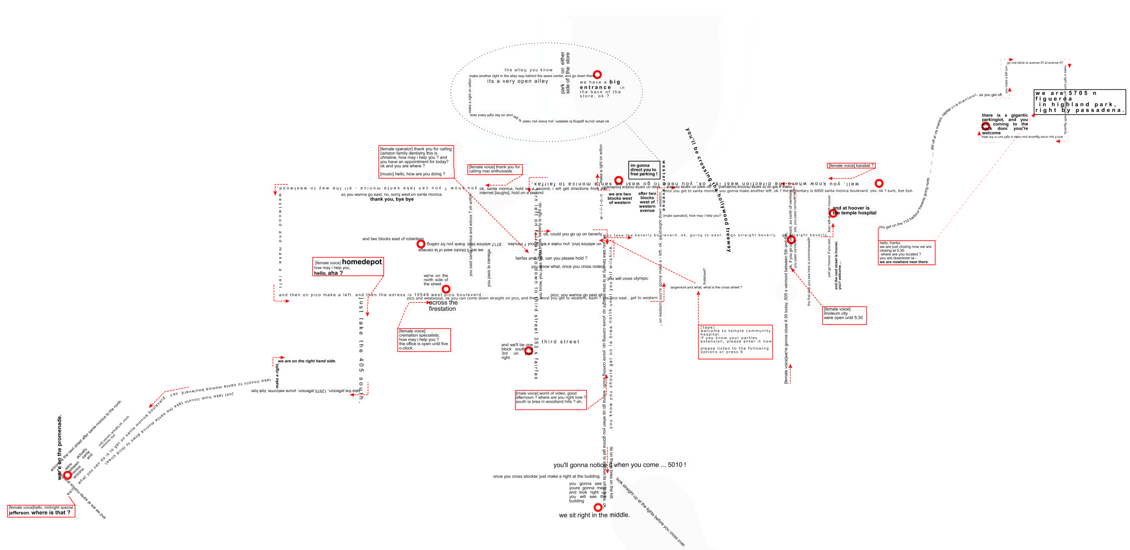


Figure 91: Assembled map

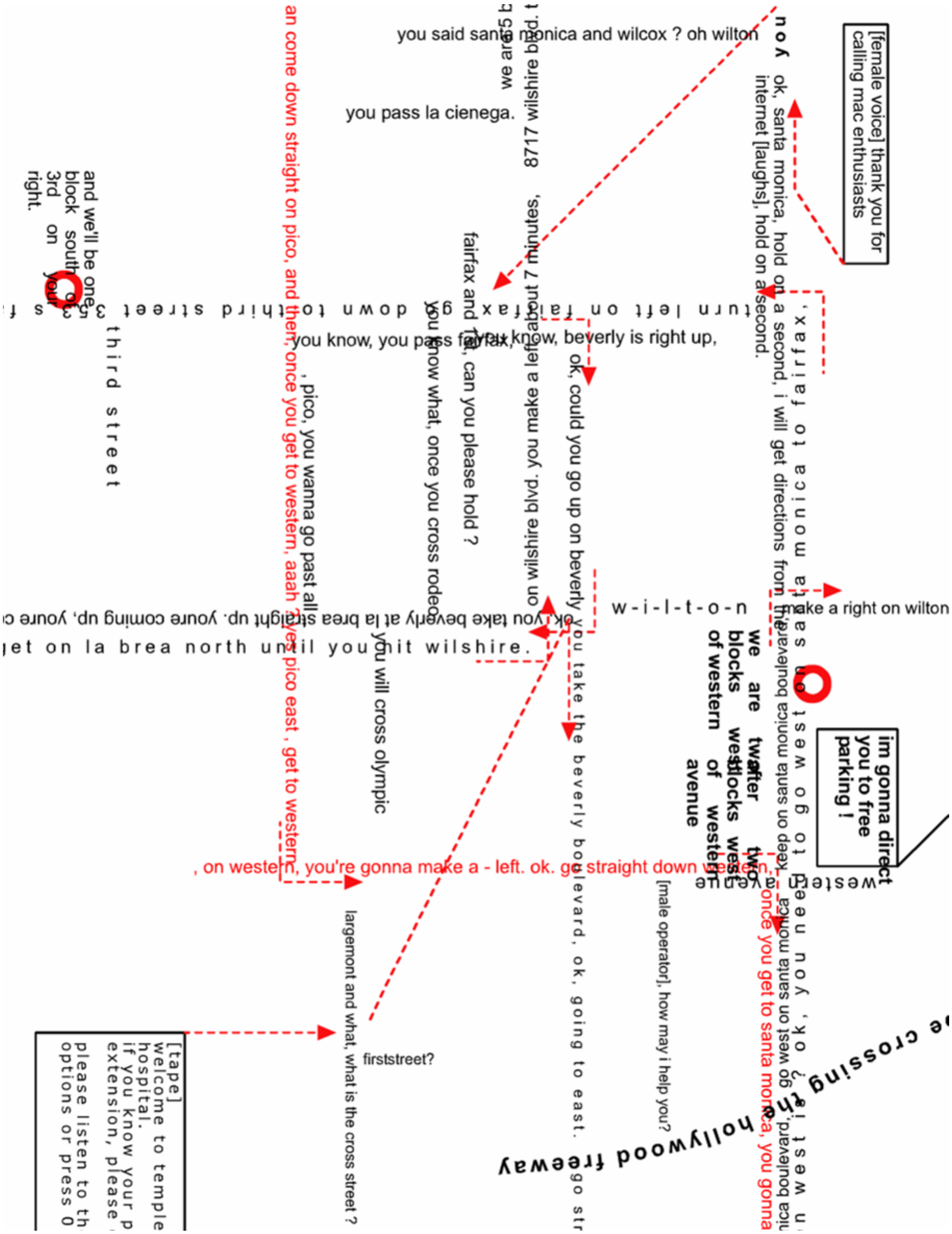


Figure 92: Excerpt from the dynamic map, a coherent description is highlighted in red

Conclusions and outlook

Architecture and planning are increasingly called upon to consider a multitude of social, psychological, economic, environmental and logistical aspects. Each aspect involves a different perspective on space. What the discipline lacks is a system to represent these different relative spaces with their unique characteristics. We need models that can dynamically visualize perceptual content, motion states, or speed hierarchies.

The title "Wegzeit - the geometry of relative distance" implies a geometrical approach to visualize spaces based on relative distances. However, especially when it comes to temporal distances, this expectation can never be fully met. Only a small subset of the properties of relative spaces can be captured, while other properties are necessarily neglected.

The use of interactive virtual environments (VEs) extends traditional methods of visualization. To this end, I have also reviewed historical methods for visualizing relative space. However, many of them are not suitable for dynamic VEs because they prioritize a correct, static representation, which leads to performance problems. In contrast, the models proposed in this thesis can be computed in real time, allowing an interactive visualization of the dynamic nature of relative space.

Formulating these models involved a design process that required many decisions. The traditional notion fo design, giving shape to objects, is replaced by modeling their behavior. A complex set of rules is essential to satisfy representation requirements: relative distances should be accurate, and the shape of space should remain recognizable, avoiding mathematically correct but perceptually inadequate representations (e.g., self-intersecting geometry). Interface design is equally important; the risk of disorientation in dynamic relative spaces is high, requiring a model that allows for quick and deliberate navigation. Legibility is a significant challenge; observers must be familiar with the absolute space shape to understand relative parameters.

Constructing and mapping relative spaces require extensive and accurate data sets. The data used in this work only partially met this requirement, primarily serving to illustrate developed models. Nonetheless, the models call attention to important considerations for collecting suitable data sets.

Relative spatial models have diverse applications in architecture:

1. **Temporal Accessibility and Path Lengths:** These concepts, discussed in urban contexts, can also apply to individual buildings. The arrangement and dimensioning of elevators in high-rise buildings, for example, can be analyzed for travel times and lengths using relative space models.

2. **Multisensory Planning:** Space is perceived not just visually but also through hearing and touch. Acoustic and tactile perception spaces can be examined with relative space models.

3. **Subjective Experience in Exhibition Architecture:** Content and information should be arranged in the visitor's relative spaces of time and attention rather than in the absolute space of a plan layout.

4. **Planning for Special User Groups:** Models can investigate environments for people with walking difficulties, examining path lengths from ramp and lift arrangements, and designing spaces for the blind.

The investigation of social spaces is perhaps the most intriguing possibility. Although this work focuses on movement processes, many other structures organizing space can be explored. Psychological studies on anxiety spaces, for example, show that relative spaces can illuminate the emotional dimension of architecture. Group-specific characteristics of architecture can be better addressed with relative spaces.

If architecture is understood in the broadest sense as the spatial organization of objects, information and events, it becomes necessary to include a variety of spatial concepts in the planning process.

Acknowledgements

I want to thank everyone who supported me in this thesis project, especially:

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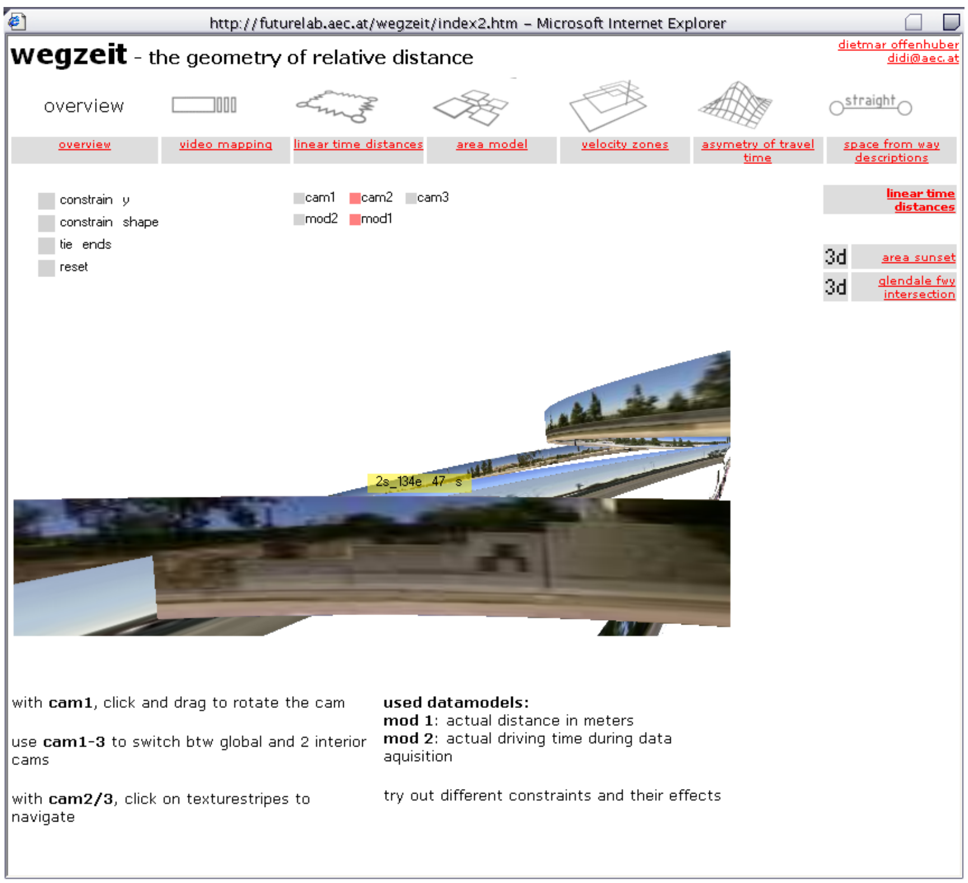
Martin, Karl, Elisabeth and my family.

Appendix

Screenshot der Website http://futurelab.aec.at/wegzeit (no longer active)



Selection of video traces of the investigated areas

Freeway intersection Glendale

Figure 93: 2 N

Figure 94: 2 N-134 E

Figure 95: 2 N-134 W

Figure 96: 2 S

Figure 97: 2 S-134 E

Figure 98: 2 S-134 W

Figure 99: 134 E

Figure 100: 134 E-2 N

Figure 101: 134 E-2 S

Figure 102: 134 W

Figure 103: 134 W-2 N

Figure 104: 134 W-2 S

Sunset Blvd. / Western Ave.

Figure 105: Bronson W

Figure 106: Carlton N

Figure 107: Franklin N

Figure 108: Fwy 101 N

Figure 109: Fwy 101 S

Figure 110: Garfield W

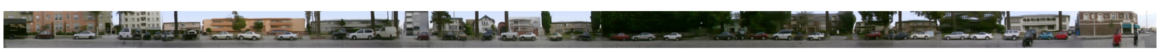


Figure 111: Grammercy E

Figure 112: Hollywood N

Figure 113: Milton E

Figure 114: Sunset S

Figure 115: Taft E

Figure 116: Van Ness W

Figure 117: Western E

Figure 118: Parkinglot Sunset

Recorded traffic light phases

date	time	street 1	green...4	pct...5	street 2	green...7	pct...8	cyle length
sunset / general	NA	NA	NA	NA	NA	NA	NA	NA
21.10.2000	16:30	wilcox	NA	NA	willoughby	NA	NA	90.0
21.10.2000	16:30	wilcox	30.0	0.3	fountain	53.0	0.6	90.0
21.10.2000	16:30	wilcox	70.0	0.7	de longpre	28.0	0.3	105.0
21.10.2000	16:30	wilcox	20.0	0.2	sunset	63.0	0.7	90.0
21.10.2000	17:00	sunset	53.0	0.6	cahuenga	30.0	0.3	90.0
21.10.2000	17:00	sunset	67.0	0.7	el centro	16.0	0.2	90.0
21.10.2000	17:00	sunset	60.0	0.7	goroon st	23.0	0.3	90.0
22.10.2000	12:00	sunset	35.0	0.6	bronson	25.0	0.4	60.0
22.10.2000	12:00	sunset	55.0	0.6	wilton	30.0	0.3	90.0
22.10.2000	12:00	sunset	60.0	0.7	st. andrews	25.0	0.3	90.0
22.10.2000	11:50	sunset	45.0	0.5	western	50.0	0.6	90.0
22.10.2000	13:00	franklin	38.0	0.6	garfield	15.0	0.2	60.0
22.10.2000	13:00	franklin	38.0	0.6	wilton	15.0	0.2	60.0
22.10.2000	13:00	franklin	33.0	0.6	bronson	20.0	0.3	60.0
22.10.2000	13:00	franklin	33.0	0.6	western	20.0	0.3	60.0
22.10.2000	17:00	melrose	37.0	0.4	la brea	46.0	0.5	90.0
22.10.2000	17:00	pico	38.0	0.4	la brea	41.0	0.5	90.0
22.10.2000	22:31	sunset	41.0	0.7	orante	12.0	0.2	60.0
22.10.2000	22:34	sunset	31.0	0.5	highland	22.0	0.4	60.0
22.10.2000	22:45	sunset	31.0	0.5	wilcox	22.0	0.4	60.0
22.10.2000	22:46	sunset	31.0	0.5	cahuenga	22.0	0.4	60.0
22.10.2000	22:52	sunset	28.0	0.5	gower	25.0	0.4	60.0
22.10.2000	22:57	sunset	43.0	0.7	gordon	10.0	0.2	60.0
22.10.2000	22:58	sunset	30.0	0.5	bronson	23.0	0.4	60.0
22.10.2000	23:03	sunset	30.0	0.5	wilton	23.0	0.4	60.0
22.10.2000	23:05	sunset	43.0	0.7	st. andrews	10.0	0.2	60.0
23.10.2000	14:21	sunset	50.0	0.6	western	40.0	0.4	90.0
23.10.2000	14:26	sunset	62.0	0.7	st. andrews	28.0	0.3	90.0
23.10.2000	14:30	sunset	60.0	0.7	wilton	30.0	0.3	90.0
23.10.2000	14:33	hollywood	45.0	0.6	western	30.0	0.4	90.0
23.10.2000	14:20	western	46.0	0.8	beverly	14.0	0.2	67.0
23.10.2000	15:20	western	10.0	0.1	elmwood	110.0	0.9	127.0
23.10.2000	14:17	western	30.0	0.5	beverly	30.0	0.5	67.0
23.10.2000	14:14	western	25.0	0.2	maplewood	95.0	0.8	127.0
23.10.2000	14:08	western	50.0	0.8	lemon grove	10.0	0.2	67.0
23.10.2000	14:06	western	33.0	0.6	melrose	27.0	0.4	67.0
23.10.2000	14:06	western	35.0	0.6	romaine	25.0	0.4	67.0
23.10.2000	13:57	western	50.0	0.8	lexington	10.0	0.2	67.0
23.10.2000	13:56	western	35.0	0.5	st. monica	40.0	0.5	82.0
23.10.2000	13:54	western	27.0	0.4	fountain	33.0	0.6	67.0
23.10.2000	13:44	western	50.0	0.6	sunset	40.0	0.4	97.0
27.10.2000	11:35	sunset	60.0	0.7	wilton	30.0	0.3	97.0
27.10.2000	11:33	western	50.0	0.6	sunset	40.0	0.4	97.0
27.10.2000	11:17	sunset	45.0	0.8	serrano	15.0	0.2	67.0
27.10.2000	11:12	sunset	45.0	0.6	hobart	30.0	0.4	82.0
27.10.2000	11:09	sunset	45.0	0.8	kingsley	15.0	0.2	67.0
27.10.2000	11:06	sunset	32.0	0.5	normandie	28.0	0.5	67.0
27.10.2000	11:02	sunset	30.0	0.5	alexandria	30.0	0.5	67.0
27.10.2000	11:00	sunset	33.5	0.6	normandie	26.5	0.4	67.0
27.10.2000	10:57	sunset	35.0	0.8	kingsey	10.0	0.2	52.0
27.10.2000	10:48	sunset	32.5	0.5	hobart	27.5	0.5	67.0
30.10.2000	14:51	poinsetta	26.9	NA	sunset	64.0	NA	97.9

30.10.2000	14:58	sunset	27.0	NA	la brea	62.0	NA	96.0
30.10.2000	14:58	highland	28.6	NA	sunset	61.0	NA	96.6
sherman oaks	00:00	NA	NA	NA	NA	NA	NA	NA
17.11.2000	12:27	riverdrive	34.1	0.6	hazeltine	25.9	0.4	67.0
17.11.2000	12:31	hazeltine	36.2	0.8	milbank	11.4	0.2	54.6
17.11.2000	12:31	fashion square	21.2	0.4	hazeltine	39.2	0.6	67.3
17.11.2000	12:38	moorpark	78.0	0.8	hazeltine	21.8	0.2	106.7
17.11.2000	12:59	woodman	40.4	0.6	moorpark	29.6	0.4	77.0
17.11.2000	13:02	milbank	15.2	0.2	woodman	54.2	0.7	76.5
17.11.2000	12:59	stern	11.5	0.1	moorpark	107.9	0.9	126.3
17.11.2000	13:04	fwy e	44.5	0.6	woodman	25.2	0.4	76.7
17.11.2000	13:07	woodman	19.3	0.3	fwy w	50.3	0.7	76.6
30.10.2000	14:46	woodman	26.1	0.4	riverdrive	45.6	0.6	78.8

Transcripts of recorded way descriptions

track 1

welcome to bank of america

[female voice server]to find your nearest location please enter the area code and phonenumber you are calling from or enter your 5 digit zip code, then press #.

our nearest location is - the hollywood main banking center at 6300 sunset boulevard in hollywood, california. there is an ATM at this location.

to repeat this information press star, to continue press 1

to hear the next nearest banking center press 2

the largemont village banking center at 100 n largmont blv. los angeles california.

to repeat this information press 1

[...] this location is near the intersection of 1st street.

track 08

[tape]welcome to temple community hospital, if you know your parties extension, please enter it now.

please listen to the following options or press 0

[male operator], how may i help you

largemont and what, what is the cross street ?

firststreet?

you take the beverly boulevard, ok, going to east.

go straight beverly, you pass vermont, go straight beverly, then left at north hoover and at hoover is the temple hospital

yes, you pass vermont, ok ? just go hoover if you see, the first stop you see here is commonwealth and the next street is hoover.

you'r welcome ...

track 09

wrong number

track 11

[female voice]hello, franks

we are just closing now, we are closing at 5:30. where are you located ? you are downtown la we are nowhere near there.we are 5705 n figueroa in highland park, right by passadena. you get on the 110 harbour freeway going north get off at via marisol, capital v-i-a m-a-r-i-s-o-l, as you get off, you make a left turn, go one block to avenue 57. at avenue 57 make a right turn, go two blocks to north figueroa, and if you cross figueroa you make a right turn in the alley, there is a gigantic parkinglot, and you are coming to the back door. your're welcome

track 12

[female voice][unverständliche begrüßung] homedepot, how may i help you, hello, aha ? just take the 405 south, take the jefferson, make a right, we are on the right hand side. 12975 jefferson. youre welcome, byé bye.

track 13

[female voice]hello, midnight special.

jefferson, where is that ? well, what you can do is to get on santa monica boulevard. take lincoln to santa monica boulevard. ok? and we are at santa monica and third, were actually between santa monica and arizona. arizona is the next street after santa monica to the north. just take from lincoln take the santa monica down to third street. wer'e on the promenade.

[we're open] until eleven, actually. ok, youre welcome, bye.

track 14

[female voice]we're gonna close 4:30 today .505 s vermont between 5th and 6th.

track 15

[female voice]linoleum city

were open until 5:30

ok, if you go up vermont, so north of vermont, make a left on to santa monica boulevard, go west on santa monica, you'll be crossing the hollywood freeway, we are two blocks west of western avenue, im gonna direct you to free parking, keep on santa monica boulevard, make a right on wilton, w-i-l-t-o-n, after two blocks west of western avenue,so when you're getting to western, you know you need to get over on the right hand lane, make a right on wilton, make another right in the alley way behind the sears [] center, its a very open alley and go down there, park on either side of the store, the alley, you know, we have a big entrance in the back of the store, ok ?

ywb

track 16

[female voice]thank you for calling mac enthusiats,

ok, santa monica, hold on a second, i will get directions from the internet [laughs], hold on a second. you said santa monica and wilcox ? oh wilton, you know ? you can take santa monica - all the way to westwood, and make a left. and then on pico make a left. and then the adress is 10549 west pico boulevard. we're on the north side of the street. across the firestation

so you wanna go east, no, sorry, west on santa monica.

tw,b

track 17

[female voice]cremation specialists, how may i help you ?

the office is open until five o.clock. pico and westwood, ok you can come down straight on pico, and then, once you get to western, aaah, yes pico east. get to western, on western, you're gonna make a - left. ok. go straight down western, once you get to santa monica, you gonna make another left. ok ? the cementary is 6000 santa monica boulevard. yes. ok ? sure, bye bye.

track 18

[female voice]karabel ?

well, you know where the direction west is ? ok, you need to go west on santa monica to fairfax, turn left on fairfax, go down to third street and we'll be one block south of 3rd on your right. 353 s fairfax

track 20

answering machine roberts refinishing

track 21

[female operator] thank you for calling carlston family dentistry, this is christine, how may i help you ? and you have an appointment for today? ok and you are where ?

fairfax and 1st, can you please hold ? [music] hello, how are you doing ?

ok, could you go up on beverly, you know, beverly is right up, ok, you take beverly at la brea straight up. youre coming up, youre coming south. (la brea verläuft über einen hügel south of beverly) you know what, once you cross rodeo, you will cross olympic, pico you wanna go past all , wanna go up when you gonna get to stocker,its on la brea, ok, its on the la brea on the hill. you'll gonna notice it when you come ... 5010 look straight up at the lights before you cross over, you gonna see , youre gonna meet and look right up you will see the building. we sit right in the middle. once you cross stocker, just make a right at the building.

track 25

[male voice recording] thank you for calling the south west museum. if you know your parties extension, you may dial it at any time during this recording.

for direction and hours press one.

the south west museum is located at 234 museum drive in highland park. exit avenue 43 from the passadena 110 freeway and follow the museum sign. museum hours are 10 am to 5 pm tues-sun. adm is 5 $ for adults.3$ for senior citizens ...

track 26

[male voice recording] thank you for bel air camera. if you know your parties extension, you may press it at any time. for store hours and adress press 5 [...]

hi. we.re located at 10925 kenros av. , corner of geli and kenros of in westwood village our hours are ... [...]

track 29

[female tape voice]hello, welcome to sports cheley, for store hours please press one. for location and adress, press 2 ... we are located one block south of the 210 freeway at 920 foothill blv. 1/2 block east of the angels crest highway exit. our ski-pro shop is at 950 foothill blvd and our rental shop is at 975 foothill blvd.

track 30

[male voice]world of video, good afternoon ? where are you right now ? south la brea in woodland hills ? ah, baldwin hills. you know you should get on la brea north until you hit wilshire. on wilshire blvd. you make a left. about 7 minutes, you know, you pass fairfax, you pass la cienega. we are 5 blocks west of la cienega and two blocks east of robertson. 8717 wilshire blvd. thank you for calling.

track 31

hello, thank you for calling rite aid

please listen to the following choices.

if you are calling from a doctors office, press 8 now.

if you are calling to refill a prescription and you know your prescription number, press 1

if you would like to speak with someone in the pharmacy, press 3

if you have a general question or need information about the store press 4

please hold while i transfer your call

welcome to the rite aid information line.

you have the ability to find our nearest location, including our new gnc vitamin locations, speak with customer services, or speak with the local pharmacist. please make your selection anytime from the following menue.

for store locations press one

press one for your closest 24 h location

we have located 3 locations in your area

to have directions to these locations faxed to you press 8

to speak with the location at 7900 west sunset blvd. in los angeles at sunset and fairfax by the directors guild, los angeles california, press 1

to speak with the location at 334 south vermont avenue in los angeles at third and vermont by ralph's market, los angeles , california, press 2

to speak with the location at 300 n cannon drive at beverly hills on the corner of cannon and dayton two blocks east of rodeo drive, beverly hills, california, press 3

track 33

thank you for calling the huntington library, art collection and botanical gardens located at 1151 oxford rd, san marino, california 91108 for visitor information please stay on the line.

track 34

the huntington library is located in the city of san marino, just south of passadena. major cross streets are allan avenue and california blvd. to the north, and huntington drive and sierra madre blvd. to the south from califorina blvd. turn south on allan avenue and proceed two blocks to the entrance gate. from huntington drive turn north on sierra madre blvd.and continue to california blvd.. turn left on california and left again at allan avenue. nearby freeways with convenient access to the huntington are the 110 passadena fwy, the 210 foothill fwy and the san berhardino fwy. directions from these freeways follow. from other freeways consult a map connecting routes. from the downtown los angeles area take the 110 fwy north to passadena and continue it until the freeway ends at the arroyo parkway. continue north on royal for several blocks then turn right at california blvd. follow california for approx. 2 miles, going past the caltec campus then turn right at allan avenue, then proceed straight to the entrance gate. from the 210 freeway travelling eastbound into passadena exit at the hill avenue offramp. continue straight alongside the freeway for several blocks then turn right at allan avenue and follow it for approx. 2 miles to the huntington gate.

if you are coming westbound on the 210 there is an allan avenue offramp at the freeway. exit at allan av. turning to your left and proceed south for two miles to the huntington gates. from the san bernardino fwy exit at san gabriel blvd. and proceed north for approx. 3 miles. at california blvd. turn left and continue another mile. turn left again at allan avenue and continue two blocks to the huntington gates. to reach the huntington by bus from los angeles take the 79 op the 379 and stop at huntington drive and san marino av. from passadena, take the 188 and exit at colorado blvd. at allen avenue or the 264 exiting at sierra madre blvd. and huntington dr it is a approx. half mile walk to the huntington gates from any of these bus stops. if you need additional information ...

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Links, further material

Video documentation

https://www.youtube.com/watch?v=YsbKSZpa0Kc

Archive of the project (2005)

http://www.vectorsjournal.org/index.php?page=7&projectId=64

besenbahn, video based on the project

With Sam Auinger and Hannes Strobl https://stadtmusik.org/films/besenbahn/

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