

Ground truthing space syntax

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I. Different environments, different models

How can we formally model a built environment and capture the fundamental properties relevant to its inhabitants? Space syntax provides a set of rigorously defined techniques for describing spatial configurations like building interiors and urban squares—it appears to be a natural approach to use.^[2] Yet whether you chose to use an axial map, a visibility graph, a segment map, a trial run of agents, or any other such computational method in the space syntax toolkit, the question of ground truthing remains.

You must make a set of decisions about what environmental features to include in your model, to what level of detail you will describe them, how you will consider variable and changing features, and how you will address error and uncertainty. These questions are critical to the cognitive relevance—not to mention the empirical evaluation—of any resulting model, yet they have received less attention than the mechanics of space syntax. A variety of space syntax techniques are now well-defined in algorithmic terms; still, I can find no guidelines for exactly what environmental features to input into those algorithms. What essentials of the multitudinous world should we record and subsequently abstract into the language of space syntax?

Simply put, space syntax analysis begins by dividing open space from closed space. In Central London, the native habitat of space syntax, open space is pavement—that is, roadways, sidewalks, squares—and closed space is buildings. Axes or segments are laid through open space.^[3] Isovists expand through open space.^[4] Agents move through open space.^[5] Consequently, the boundary between open and closed space is key. When modeling the overall structure of a city, particularly one that is dense and built-out, the question of where to draw that boundary isn't vexing. It may even be avoided, by directly creating an axial or segment map from readily-available road-center lines.^[6] Building interiors are also straightforward. Not only are architectural plans usually available, but more importantly, walls and other elements of a building's mass naturally demarcate open space.

Smaller than the far-reaching scale of the city and larger than the enclosing scale of the building is the outdoor landscape. These environments are the surroundings that we move through, the vistas that guide and engage us. At this scale, detail is necessary. Buildings lend some definition to the surrounding space, as do planters, bushes and trees, staircases, ramps, benches, streetlamps, signage, and other pieces of street furniture. Certain landscapes may not be as articulated as others. Consider the differences between a parking lot off an exurban strip and a university campus of quadrangles, lawns, and walkways.

Different professions work at these three scales: architects craft buildings; urban designers and landscape architects shape the outdoor landscape of city squares, shopping centers, and campuses; and urban planners orchestrate cities and regions. Correspondingly, models will include and be defined by different features depending upon the scale they represent. Applying space syntax to building interiors and city structures seems relatively clear. My interest is in the intermediate scale, and my concern is how we draw the line between open space and closed space at that scale of the outdoor landscape.

II. Modeling outdoor landscapes

Two overarching approaches to modeling the world occur to me: visibility and accessibility.^[7] Certainly our experience includes other characteristics, such as auditory, tactile, olfactory, semiotic, and social. The picture becomes even more complex if you also include other people. In the context of space syntax, what matters is the configuration of space—the dividing line between open space and closed space. Visibility and accessibility can each serve as criteria for placing this line. In the archetypal example of London, visibility and accessibility correspond. The buildings and other masses that define closed space block people's movement at the same time as they block people's sight.

My example is a university campus in the United States, where I have found the situation to be much less definite. Paved pathways are clearly accessible, but what about lawns? And with appropriate shoes, a sense of adventure, and a looming appointment, you could walk through a planter, too. A building obviously blocks your vision, but what about a decorative trellis? Depending upon their design, fences can block visibility and they definitely block accessibility. In other words, accessibility and visibility do not necessarily correspond, and details like these aren't necessarily included in maps or plans. Thus the title of this paper. To model an environment like a university campus, you have to take what plans you can find (ideally as CAD files) and then, by surveying on foot and making subjective decisions (ideally in keeping with some sort of systematic guidelines), you must verify and elaborate the details.

III. Visibility as the defining characteristic

Visual perception of our surroundings is certainly fundamental to spatial cognition and behavior. (Yet it is not necessary, as demonstrated by blind and vision-impaired people.) J. J. Gibson, in his ecological theory of perception, proposes that vision allows us to directly perceive our surroundings and their affordances. This emphasis on vision appears in space syntax techniques as well. Axes in an axial map are most easily explained as lines of sight. In that case, an overall axial map represents the topology of the key sightlines in an environment.

Vision is even more so the organizing principle behind the technique known as visibility graph analysis in the space syntax community and viewshed analysis to geographers and landscape architects.^[8] Whichever name is used, the basic ingredient is the isovist, the area visible from a particular point.

If visibility is taken to be the defining characteristic of our interactions with the surrounding environment, then visibility ought to be the criteria we use to place the boundary line that divides open space and closed space. Open space includes spaces that are visible to each other, whereas closed space includes visual barriers. Table 1 lists some environmental features that you may want to record when surveying with visibility in mind. A model that only includes building footprints or road-center lines is too meager to capture all the salient details relevant to visibility in many outdoor landscapes.

Large shrubs and trees can block visibility about as completely as a wall of brick can. Unlike the wall, vegetation may change from season to season. The goals of your model will naturally determine how you address the issue of changing visibility. For instance, if you are using it to evaluate pedestrian flow rates, presumably the model ought to reflect the time of the data collection.^[9]

<p><i>Blocks movement and usually blocks sight:</i></p> <ul style="list-style-type: none"> ▪ building walls (at ground level, which is not necessarily the same as the building footprint) ▪ retaining walls, freestanding walls ▪ fences, gates ▪ sculptures and other art installations ▪ vendor’s carts ▪ tall vegetation (trees, shrubs) ▪ smaller vegetation ▪ street furniture (planters, streetlamps, signposts, benches, picnic tables, staircases, ramps, railings, newspaper racks, bike racks) 	<p><i>Allows for “official” movement (and open to sight):</i></p> <ul style="list-style-type: none"> ▪ walkways, sidewalks ▪ squares, plazas, courtyards <p><i>Allows for “tromp-everywhere” movement (and open to sight):</i></p> <ul style="list-style-type: none"> ▪ lawns ▪ open ground <p><i>Allows for sight, but not movement:</i></p> <ul style="list-style-type: none"> ▪ lakes, streams, and other water features
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Table 1. Some environmental features to consider including in a two-dimensional pedestrian-oriented model of an outdoor landscape’s spatial configuration.

IV. Accessibility as the defining characteristic

With knowledge gleaned from vision and other senses, purposeful movement through an environment is possible. Open space allows for movement and activity. Different varieties of open space afford different amounts of movement. A level, paved walkway is accessible to most everyone, whether they are on foot or in a wheelchair. Stairs reduce accessibility, as does grass, which only some will think to or want to walk across. Again, the question is where to draw the line between open space and closed space.

When modeling an environment, I survey two different sets of accessibility features and create two separate versions. The first, an “official” accessibility model, limits open space to paved areas like walkways. The second, a “tromp-everywhere” accessibility model, expands open space to include other areas through which an able-bodied person might also move. Table 1 lists some relevant features to consider. Note that I am now speaking in terms of environmental features that correspond with open space, whereas I described visibility in terms of identifying closed space. This is a pragmatic decision, although it might reveal a theoretical difference between visibility and accessibility.

As the terms imply, the distinction between “official” and “tromp-everywhere” accessibility is the result of social, not just physical, factors. Many choose not to walk across grass in order to avoid scuffing their shoes, but at the same time they are guided by the implicit social conventions of sticking to the path. Public spaces, private spaces, and “spaces of fear” are just some of the many varieties of other socially defined spaces that human geographers are concerned with. Space syntax research has been guided by an assumption that these social factors arise in large part out of the physical configuration of an environment. Few would want to admit the surveyor’s subjective decisions of what environmental features to include on the map also have an effect. That is another reason to follow consistent guidelines, which clearly separate the options of “official” and “tromp-everywhere” accessibility, when surveying.

As is the case with visibility, accessibility can change based on environmental conditions. My first space syntax model was of a college campus in snowy Minnesota. During the winter, the formerly accessible campus lawns might be underneath a layer of ice or snow. Not that the impediment stopped everyone—over time, intrepid travelers would scrape “cow paths” through the snow. If only pedestrian movement were always so well marked and preserved!

Snow is less of a concern in the environments I am now modeling in Southern California, where car is king. I mention cars because they are another source of variability in an environment.

Late at night, a road may be completely accessible to pedestrians, but come rush hour, no one would think to walk there. Or consider a parking lot that fills up during the day and empties at night.

Speaking of cars and other transportation methods, these guidelines are clearly oriented toward pedestrians. If you were surveying with vehicle accessibility in mind, you would certainly draw a different line between open space and closed space.

V. Assessing models based on human evidence

In this paper I have suggested three different ways to model an outdoor landscape: visibility, “official” accessibility, and “tromp-everywhere” accessibility. Each will produce a quite distinct characterization of the environment in question. Multiply those three approaches by the number of different space syntax techniques available to use with each, and you can be overwhelmed by options.^[10] To create all of those models and run all of those analyses is more akin to a fishing trip than a systematic evaluation. Let’s try the latter. First, we can trim the number of options based on theoretical grounds. Visibility graph analysis is naturally applied to a visibility model; we need not always run such an analysis on either of the accessibility models. If axial maps effectively represent sightlines (which some might say is an improper reduction), that type of analysis is also more appropriate for the visibility model. Segment maps better represent the paths that people can take and the choice points available in an environment, and so they seem more appropriately used with an accessibility model. Of course, we are still left with a number of different models of the environment in question and of analysis methods to use.

Experimental data from people is the criteria we can use to compare and evaluate these different models and analysis techniques. If our goal is to develop a cognitive approach to modeling environments, then the best models and the best analysis techniques will be the ones that most accurately predict human performance on controlled tasks of spatial cognition and human behavior in natural settings, at both the individual and the aggregate scale. The space syntax literature has focused primarily on one variety of human behavior at the aggregate scale: counts of pedestrians walking through particular “gate” points.^[11] The spatial cognition literature is filled with many more relevant and useful experimental methods, although few have been tested against the quantitative models of environments that space syntax techniques provide.

Experimental methods in spatial cognition can reveal individuals’ spatial judgment and memory for an environment, including the systematic distortions that characterize their knowledge of distances, directions, and shapes. And other experimental methods explain how people move through their immediate surroundings (locomotion) and plan their overall travels (wayfinding). All of this research in spatial cognition can help us precisely compare the merits of an “official” accessibility model analyzed as a segment map, a visibility model analyzed as a visibility graph, and so on.

In my current research, I am attempting to unite the careful experimental methodology of spatial memory and judgment with the formal description of environments offered by space syntax. I asked students on that Minnesota college campus (Carleton College) to create a map of the campus and to point from certain well-known locations on campus to other well-known locations (Dara-Abrams, submitted). An axial map analysis of the walking paths on campus—an “official” accessibility model—predicted how well participants performed on the tasks. They were significantly more accurate in their pointing when they were asked to imagine standing at a location with a high global integration value (one of the key space syntax measures used with axial maps), and they were significantly more accurate in placing the more highly integrated buildings in their map. More recently I have been comparing participants’ performance on those types of tasks with all three of the models mentioned in this paper.

Just as each space syntax analysis technique appears to be best used with particular models, particular combinations of model and analysis could conceivably lend themselves better to predicting certain varieties of spatial cognition and behavior than others. For instance, an “official”

accessibility model analyzed as a segment map may be best at predicting people's cognitive maps of a familiar environment—over time they have learned the overall organization of the environment and the possible paths they can take through it—while a visibility model analyzed as a visibility graph may better account for the movements of a tourist wandering in a new environment. Such speculation may make logical sense, but the support of empirical investigation is also needed. I intend my research to help, if only in a small way, toward that end.

VI. Conclusion

Ultimately we would like to understand the interplay between people and their surroundings, an issue central to the theoretical concerns of spatial cognition and the practical concerns of architecture, urban design, landscape architecture, and urban planning. The development of space syntax techniques has shown that a cognitive approach to modeling environments need not recreate the entire world and all its complexity. Focusing only on the spatial configuration of environments—effectively the line between open space and closed space—will produce a useful model. In outdoor settings, this line can be placed according to a variety of options. Here I have discussed visibility as well as an “official” and a “tromp-everywhere” notion of accessibility. To compare the merits of these different models, as well as the space syntax techniques that can be used to analyze them, I suggest that we turn to experimental evidence from spatial cognition. Only together can spatial cognition and space syntax develop a cognitive approach to modeling environments.

Notes

- [1] The National Science Foundation supported the preparation of this paper through the Interactive Digital Multimedia IGERT, grant number DGE-0221713. Thanks go to Helen Couclelis, Daniel Montello, and Mary Hegarty for helpful feedback. As I hope this work will be relevant to a multidisciplinary audience, I include a good number of references in these notes.
- [2] Bafna (2003) provides a concise introduction to space syntax, although his examples are primarily of clearly-defined indoor settings.
- [3] Turner, Penn, and Hillier (2005) give an algorithmic definition of an axial map. Segment maps are demonstrated by Turner (2005) and Iida and Hillier (2005).
- [4] Although not the first to use the term, Benedikt (1979) is the oft-cited paper on isovists.
- [5] See Turner and Penn (2002) for more on agent simulations with space syntax techniques.
- [6] Two uses of road-center lines in the space syntax literature are Dalton, Peponis, and Conroy-Dalton (2003) and Turner (2005).
- [7] Stamps (2005) draws a similar distinction between visibility and accessibility. His experiments demonstrate that people's “impressions of enclosure were more influenced by visual permeability than by locomotive permeability, but the reverse was found for impressions of safety, which were more strongly influenced by locomotive than by visual permeability” (p. 587).
- [8] Turner et al. (2001) introduces visibility graph analysis. See Bishop (2003) as well as Ervin and Steinitz (2003) for brief overviews of viewshed analysis.
- [9] Not only does the visibility of fixed elements in an environment change—the conditions of that environment change too. Here in Santa Barbara, the fog can envelop the coastline and greatly reduce visibility. But these changes do not affect the spatial configuration of an environment; rather, it is the viewing properties of the observer or agent that change. Ervin and Steinitz (2003) discuss the problems posed by atmospheric interference and variable lighting conditions. One solution they consider is using probabilistic analysis to account for the uncertainty and complexity inherent in visibility computations.
- [10] Rather than try to evaluate the different models individually, we could combine all of the models into one, attaching some sort of weight to each element. “Official” accessibility

barriers, like the edge of a paved walkway, could be given less weight than a more solid barrier, like a building wall, say. But modifying the particulars of space syntax—in effect blurring the line between open and closed space—is beyond the scope of this paper, not to mention my expertise.

- [11] The space syntax community has slowly begun to empirically test its models against data from individual human participants. Haq and Zimring (2003) demonstrated such measures to be strong predictors of wayfinding behavior (where people walked) and abilities (how well they performed on assessments of their knowledge) inside large buildings, such as hospitals. And Kim and Penn (2004) found that the integration values, a key space syntax measure, of street maps sketched by people correlate with actual integration values of the streets.

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