Skupin, A. (2007) Where do you want to go today [in attribute space]? In Miller, H. (Ed.) *Societies and Cities in the Age of Instant Access*. Springer. 133-149. [Note: This is a pre-publication version. Please refer to printed book for final version.]

Where do you want to go today [in attribute space]?

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Summary

This paper proposes to conceptualize a geographic trajectory as an attribute-time path (ATP) traversing an *n*-dimensional attribute space. Geographic entities occupying a certain study area are conceptualized as discrete loci in that same *n*-dimensional space. Those entities undergo spatialization and the resulting point locations become vertices as the ATP is projected into lower dimensions to form a spatialized attribute-time path (SATP). Visual exploration of such a path supports novel perspectives on the nature of geographic space, including how it is traversed, transformed, and experienced by those that inhabit it.

Examples based on two different data sets are presented, with population census data providing *n*-dimensional attributes of geographic entities in both cases. The first study illustrates how a transect of Vienna, Austria, reveals patterns of difference/similarity, once it is spatialized. The second set of examples is based on an extremely large neural network model derived from data for all 200,000+ U.S. census block groups. Commuter trajectories captured in New Orleans and San Diego are projected onto the spatialized block groups and the resulting SATPs interpreted.

1. Introduction

As we move across geographic space, aren't we simultaneously moving through a high-dimensional attribute space in which the geographic entities are located that we encounter along the way? Building on this premise, imagine that one has captured several paths that either traverse the same region or are even contained in wholly disjoint geographic regions. If these paths are now passing through areas that exhibit similar attributes, they are coming close to each other in *n*-dimensional space. This fact, as well as such characteristics as *n*-dimensional direction, looping, and so forth may aid our understanding of the paths and of the entities traveling on them, depending on how meaningful the set of measured attributes is.

The human mind can not easily cognize such high-dimensional movement without first implementing means for dimensionality reduction. The key to achieving this is to conceive of a combination of previously separate technologies. The convergence proposed in this paper involves location determination (e.g., through GPS) and spatialization. The latter is here understood as the process of transforming high-dimensional data into a visual form via low-dimensional geometry (Skupin and Buttenfield, 1997), which has in the last few years been implemented for diverse data types from text documents to population census tables (Skupin, 2004, Skupin and Hagelman, 2005).

Attribute-time paths (ATPs) may be encountered in a number of principal circumstances. One would be the case of a geographic object remaining stationary but changing its non-spatial characteristics, thus moving in attribute space. Such a conceptualization of geographic change and its application to area-based census attributes has been described elsewhere (Skupin and Hagelman, 2005). In this paper, a different situation is addressed, where individuals move across geographic space and along the way encounter geographic objects with different characteristics. Moving from one object to the next thus becomes movement through attribute space.

The idea of an ATP derived from the movement of individuals across geographic space constitutes a natural extension of space-time paths (STPs). These have been most prominently associated with the work of Thorsten Hägerstrand (Hägerstrand, 1970, Pred, 1977). The last decade has seen a resurgence of work in the general area of time geography, notably under the influence of improved methods for position measurement and geospatial databases and modeling. These efforts have included the further development of major concepts, such as space-time prisms (Miller, 1991). Early investigations of time geography tended to rely on origin-destination pairs (e.g., places of work and residence), but the capture and analysis of individual space-time paths with high geometric details has now become common place (Kwan, 2002, Mountain and Raper, 2001).

The approach put forward here addresses two issues with existing methods for analysis of space-time paths. One problem is that the existing visualization approaches are too restrictive with regard to geographic space providing x-y coordinates in the display space. This is the case both for 2-D maps of space-time paths and for 3-D space-time cubes, where the third dimension conveys the progression of time. Both approaches are useful for data sets containing paths from a single geographic study area. However, they do not accommodate visualization of paths traversing multiple, disconnected geographic areas, such as different metropolitan areas.

Another issue relates to attempts to categorize geographic objects based on attribute similarity. Particularly prominent have been examples using socio-economic data, such as ESRI’s *Community Tapestry* or similar efforts in Great Britain (Rees et al., 2002, Webber and Longley, 2003). The resulting categories can be mapped onto geographic space and geographic patterns inspected. However, classes are typically treated as discrete *n*-dimensional locales, without much ability to *see* transitory, field-like variation, nor nuanced relationships among categories that in reality exist in *n*-dimensional space.

The approach put forward here addresses both of those concerns. First, by not considering explicit geographic coordinates in the display of space-time paths it becomes possible to compare paths from different geographic areas. Second, major topological structures existing in the *n*-dimensional input space are preserved in the two-dimensional display space. Therefore, one can not only distinguish regions in the *n*-dimensional space, but develop some understanding of their relative location.

2. Integrating spatialization with geospatial data and technology

Central to the notion of spatialized attribute-time paths is the idea that in order to learn more about certain geographic phenomena we may have to [temporarily] ignore traditional geographic coordinates during visualization. Some existing methods, like parallel coordinate plots (PCPs), and scatter plot matrices, follow a similar approach as they transform the geometric representation of geographic objects on the basis of their descriptive attributes. However, those methods tend to also lose some fundamental affordances of traditional geographic geometry, most notably the ability to support observation of complex geographic distributions and relationships in holistic two-dimensional or three-dimensional form. Axes in individual scatter plots correspond to single variables, which makes it difficult to *see* complex high-dimensional relationships, even when larger scatter plot matrices are constructed. In a PCP, multiple axes are placed in parallel, each associated with a particular variable. Through a side-by-side display of these axes and connections made between attribute values for each object, the PCP transforms each geographic object into a line consisting of multiple segments, with strict norms on line geometry (e.g., no looping).

These information visualization methods also tend to be highly interactive, and this interactivity often includes manipulation of geometric and topological relations, far beyond what would be considered permissible when dealing with geographic coordinate space. As a result, users of such methods are dealing with an ever-changing display, where little is fixed and few aspects can be taken for granted.

Compare this to the notion of the base map in traditional cartography, where the relationship is established and fixed between the world coordinate system (e.g., in latitude and longitude) and the projected or display coordinate system. A fixed geographic feature located at a certain latitude and longitude will occupy the same map position today as it did yesterday and as it will tomorrow. The known distance between two fixed positions can likewise be trusted to remain such for some time. Having established geographic location as a relatively fixed aspect of a geographic map, we are then free to utilize the remaining set of visual variables for most mapping tasks. If an object indeed changes its position in the visualization, then this is detected against the back-drop of an otherwise stable base map and thus interpreted as movement of the object across geographic space.

The method proposed here attempts to extend the power of maps in enabling humans to detect complex relationships towards *n*-dimensional attribute space. Instead of using a very limited number of variables, as in scatter plots, or of axes with distinct, predefined meaning, as with PCPs, we propose to create map-like information visualizations (Skupin, 2002b), in which output dimensions are based on transforming a large number of input variables into a low-dimensional output space. Once a geographic object is represented with zero-dimensional, point coordinates in a low-dimensional space, that location remains fixed unless the object's attributes have changed. Thus, a stable base map is created on top of which other features can be displayed. A number of methods could be used to perform dimensionality transformation / spatial layout, including multi-dimensional scaling (MDS), spring layout, and the self-organizing map (SOM). In the experiments presented in this paper SOMs are used due to their scalability to very large data sets.

Meanwhile, space-time paths (STPs) are geographically overlaid with the same geographic objects from which the point spatialization was derived (see Figure 1). Each STP is conceptualized as moving from object to object, forming a topological sequence of geographic objects. When dealing with polygon objects, STP vertices are matched with polygons through point-in-polygon overlay. This is the case for all experiments discussed in this paper. Point or line objects will require certain distance-based transformations before becoming associated with defined STP portions. With geographic objects becoming nodes in a high-dimensional, directed graph (i.e., an ATP) one can finally derive the low-dimensional position of each node from the point spatialization in order to create the SATP (Figure 1).

[Insert Figure 1 approx. here]

One can imagine several principal modes for using SATPs (Figure 2). First, one can construct a point spatialization from geographic objects of a single study area and observe the transformation of an individual STP as it becomes represented in the spatialization. A geographically straight path may thus actually represent a circuitous route that eventually returns to its origin in attribute space (Figure 2a). For an application example, consider spatializing geographic features in a city and then tracing the path of a criminal suspect to see whether the path leads toward places that are measurably similar to the location of crimes for which that person was previously convicted, possibly indicating an impending infraction.

[Insert Figure 2 approx. here]

Second, multiple STPs could be mapped onto a spatialization for an individual study area (Figure 2b). For example, the known paths of multiple suspects may be mapped simultaneously to find out whether any of them have patterns of movement through suspiciously similar locations compared to the locations of previously unsolved crimes.

Third, one could capture STPs within multiple, disjoint sites and spatialize them using a base map containing objects from all sites (Figure 2c). This may prove useful in uncovering broader, generalizable patterns, for example regarding the movement of criminals in multiple cities. Notice in Figure 2c how two geographically completely disjoint STPs turn out to be extremely similar SATPs.

3. Traveling in Attribute Space: Applications and Examples

This section presents a number of examples for SATPs, each intended to convey one particular application mode, as introduced in the previous section. Each example is accompanied by a discussion of the data sources, differences in processing, and other choices made during analysis. In each of these examples the *n*-dimensional source data consist of population census attributes attached to polygon objects.

Two different data sets are used. The first study is based on population data for Vienna, Austria combined with a GPS transect of that city. The remaining examples are all derived from population data for the United States, at the block group level, from which a detailed base map spatialization is derived. Various GPS tracks are transformed into SATPs and presented in different scenarios.

3.1. Single path across a single geographic area

The first example is included here because its scope, source data, and the geographic structures encountered lend themselves well to demonstrating some important features of the SATP concept. It is an example for a single path traversing a single study area (Figure 2a). The source data for constructing the base map consist of 1353 polygons with 158 associated population attributes for the Austrian capital, Vienna, and immediately surrounding areas. These attributes fall into two broad categories:

(1) population attributes (age structure, sex, household size, citizenship, educational attainment, income)

(2) buildings and land use (building purpose, types of heating and bathroom fixtures, land use types, size of places of employment)

A path was captured by GPS while navigating public roads starting in the *Donaustadt* section, which lies at the north-east periphery of the city (Figure 3). After passing through the city center (*Innere Stadt*), the geographic path continues in a south-west direction leading to *Mödling*, outside of Vienna proper. The path crosses 67 different polygon objects.

[Insert Figure 3 approx. here]

[Insert Figure 4 approx. here]

Attributes for the complete set of 1353 polygons are used to train a self-organizing map consisting of 5625 neurons (75x75). Then, instead of visualizing the neural network model itself, the closest matching neuron vector is found for each input vector and two-dimensional coordinates are accordingly derived (see point symbols in Figure 4) by distributing each input object randomly near the best-matching neuron (Skupin, 2002a). Finally, the sequence of 67 geographically traversed polygons is retraced in the spatialization (see node and line symbols in Figure 4).

The trajectory roughly describes a horseshoe shape with the ends located in the lower right and left corners. This shape is traversed twice, from the lower right to the lower left and then proceeding to revert back to the origin. How should this be interpreted? In brief, the SATP indicates the existence of ring-like structures in geographic space that are transected by the geographic path. More detailed analysis of the SATP supports this. The lower right tip of the horseshoe corresponds to the outermost geographic areas in *Donaustadt* and *Mödling*. In other words, arriving in *Mödling* in some sense means returning to *Donaustadt*! Meanwhile, the lower left tip of the horseshoe is geographically located in the center of the city, aptly named *Innere Stadt*. Once there, while continuing to move towards the south-west, in attribute space we are actually beginning the return journey to *Donaustadt* via all the other regions previously traversed.

This mirroring effect can be observed even at finer levels *within* regions, as apparent for the *Leopoldstadt* and *Margareten*. Notice that the outermost polygons in these regions (19 and 47) are neighbors in the spatialization (Figure 4). Geographic movement toward *Leopoldstadt* and away from *Margareten* corresponds to parallel paths, as indicated by the pairing of the previous/next polygons in *Donaustadt* and *Favoriten* (18/48 and 17/49). Within *Leopoldstadt* and *Margareten* one moves towards *Innere Stadt* (polygon sequence 22-23-24-25 in *Leopoldstadt*) or away from it (43-44-45-46 in *Margareten*). Discontinuities in the ring-like structure are also occurring. Notice how *Wieden* is what separates *Margareten* from *Innere Stadt* both in geographic and attribute space, while no such separation exists in geographic space between *Leopoldstadt* and *Innere Stadt*.

In further exploring the specific relationship between STP and SATP the next step would be to look into the distribution of attributes across the spatialization. In the interest of brevity this is not done for the Vienna example, but examples are contained in the following sections.

3.2. Multiple paths across a single geographic area

The previous section described a spatialization based on a relatively small number of geographic objects that cover a limited geographic area. The remaining examples in this paper are all based on a significantly larger data set consisting of all 200,000+ U.S. census block groups and 31 attributes (Table 1).

[Insert Table 1 approx. here]

Like in the previous example, the SOM method is used to create a neural network model, which in this case consists of 250,000 neurons (500x500). Since this model is fairly intricate and constitutes the base map for all further examples, it is useful to first explore the model itself. Visual exploration of a self-organizing map is best begun with a side-by-side view of various component planes. In a SOM, every neuron is associated with an n-dimensional vector of the same dimensionality as the input vector (here: n=31). With a two-dimensional lattice of neurons, one can conceptualize each variable as a field that is sampled at the neuron locations. Component plane visualization depicts each of these fields individually (Figure 5).

[Insert Figure 5 approx. here]

This side-by-side comparison of component planes allows a first glimpse at relationships between variables, for example based on correlated patterns of local maxima and minima. This can include simultaneously elevated values, as in the case of the variables *female households with children* (i.e., single mothers) and *black* population percentage. Negative relationships are also visible, as when the peak of persons *over the age of 64* is matched with a low percentage of *households of married persons with children*. An important advantage of self-organizing maps is that they allow observing local variations, as opposed to remaining at the level of global correlations. For example, while the *age over 64* and *married household with children* variables show plenty of negative correlation, there is a region along the right edge of the SOM, where both have low values, together with a high percentage of persons *age 22 to 29* and *households consisting of single males*.

In the remainder of the paper, this highly detailed self-organizing map is used to create various SATPs. First, the case of multiple paths traversing a single study area is demonstrated. The study area consists of the city of New Orleans, Louisiana. The choice of paths in this example is informed by the argument that differences in income may result in a different experience of geographic space. Much of this may be due to different modes of transportation being available, i.e., private vehicle versus public transport. Accordingly, two paths were captured using GPS. The author's previous residence in the *Mid-City* section of New Orleans served as the origin and the place of employment at the University of New Orleans was the destination for both paths. *Mid-City* is a racially and economically very diverse area, so the assumption of income-driven alternative modes of transport to reach the city's main public university is quite realistic. The first path was captured while traveling on buses of the Regional Transit Authority (RTA), while the second path involved taking a private vehicle on a typical commuting journey using the quickest path (Figure 6a). The sequence of traversed block groups is the basis for showing the two SATPs on the SOM (Figures 7 and 8). Block groups are again numbered in sequence (Figure 8), but a new number is assigned every time a block group boundary is crossed, so that multiple entries into the same block group (i.e., a crisscross path) lead to multiple numbers for that block group, for example (e.g., labels 14, 16, 18 along the public transport path).

[Insert Figure 6 approx. here]

[Insert Figure 7 approx. here]

[Insert Figure 8 approx. here]

Apart from the common start and end point, the two paths mostly cross very different portions of attribute space. Initially, as they make their way out of *Mid-City*, both paths move upwards in the SOM, but then the RTA path moves back towards the origin (notice proximity of vertices 1 and 11) and continues towards the extreme bottom right of the SOM. This is in fact an extreme region, even at the national scale, with the census data indicating 100% of the population being black. As the central business district (CBD) region is entered, the RTA path suddenly bridges a gigantic distance in attribute space, arriving close to the *French Quarter* in both attribute and geographic space. As the RTA path leaves the *French Quarter* and enters the *Faubourg-Marigny*, it temporarily meets up with the path taken by private vehicle, while the latter traverses the *Bayou St. John* area. From there, the two paths diverge again, as the RTA path moves toward a region that is predominantly black and with high percentage of rental property (*New Marigny*) and the private vehicle travels through areas with larger percentage of white population and owner-occupied housing (across from *City Park* and in *Mirabeau Gardens*) (Figure 7).

Overall, the two SATPs traverse distinct *neighborhoods* that are compact in both geographic and attribute space, reflecting the common history of block groups in a neighborhood. Traveling between neighborhoods can involve bridging tremendous gaps in *n*-dimensional space, either directly (e.g., entering the CBD) or via bridge vertices (e.g., node 23).

3.3. Comparing paths within multiple geographic areas

One of the driving motivations behind the development of the SATP concept was the desire to compare space-time paths captured in disjoint geographic areas. This is demonstrated in the final example in this paper. The commuting paths captured in New Orleans are here combined with those captured in San Diego, under the same assumption of having either private or public transport options at one's disposal (Figure 6). Origin of San Diego commuting paths is the author's residence in La Jolla and destination is San Diego State University.

Comparison of paths from different cities may first simply involve observing the degree of diversity of locations along the path according to spatial patterns of links and vertices in the spatialization (Figure 9). In the case of New Orleans, one observes traversal of named neighborhoods as distinct regions, with clear separation along an SATP (see also Figure 8). Compared to this, neighborhoods along San Diego paths appear less well organized and distinct. The private vehicle path shows plenty of crisscrossing between sometimes distant vertices (right portion of Figure 9). Meanwhile, the vast majority of vertices along the public transport path are closely clustered together (left portion of Figure 9), indicating relative uniformity in attribute space, when compared to New Orleans. There are basically only two major breaks from that uniformity. One corresponds to the *Bird Rock* community on the southern edge of La Jolla. The other stems from the path barely entering two block groups along *Mission Bay*.

A major advantage of the SATP approach is that the common base map allows overlays of various paths. When this is done for the public transport paths, one observes that the San Diego and New Orleans paths have fairly little in common (left portion of Figure 9). For the most part, they do not enter the same regions in attribute space. One major exception is seen where the upper portion of the New Orleans path intersects with the lower portion of the San Diego path. In other words, when traveling by public transport from La Jolla to SDSU, the closest parts of the New Orleans public transport path that one will encounter are the *French Quarter* and *Faubourg-Marigny* (see public transport portions in Figures 8 and 9).

In further analyzing the specific causes for relative similarity/dissimilarity one may now want to examine which variables are most related to the observed patterns. There are two principal choices in doing this: (a) exploring the distribution of variables within the finished computational model; or (b) exploring the distribution of original input values across the set of transected objects. The former is shown in Figure 7, where the New Orleans paths are combined with SOM component planes. The other approach is illustrated in Figures 10 and 11, where multivariate point symbols represent a total of 21 variables in four logical groupings. The public transport paths for New Orleans and San Diego are visualized side-by-side, with inset maps showing more detail for the dense cluster of block groups that includes most of the San Diego path and the *French Quarter* / *Faubourg-Marigny* portion of the New Orleans path.

[Insert Figure 10 approx. here]

[Insert Figure 11 approx. here]

One can now observe the attributes of the *Bird Rock* and *Mission Bay* portions of the San Diego public transport path, which set these block groups apart from the rest of the San Diego and New Orleans paths alike, most notably the large proportion of *white population* and *owner-occupied housing*. Finally, the overlap area between the public transport paths in the two cities can be investigated. Here one will find the most striking similarity not in the racial and housing variables, but in the age and household variables. Specifically, the overlap area consists of block groups with a large proportion of persons *between 22 and 39 years* old and a high percentage of *single male households* and, to a lesser extent, *single female households*. Those then are the variables pulling the *French Quarter* / *Faubourg-Marigny* and a portion of the *Mission Valley* towards each other.

4. Conclusions

This paper introduces a conceptualization of geographic travel as a series of discrete geographic objects being encountered in *n*-dimensional attribute space. Path continuity is here solely derived from objects' topological relationships in geographic coordinate space. Alternatively, a geographic path could be conceptualized as simultaneously traversing *n* continuous fields of attributes of varying smoothness, like elevation, temperature, or land cover. This will lead to an SATP with higher geometric detail and more differentiation among paths, similar to the effects previously observed after insertion of temporally interpolated vertices into multi-temporal attribute trajectories of spatially fixed objects (Skupin and Hagelman, 2005).

When dealing with census data, one will frequently find that the street segments on which people travel coincide with area boundaries of census enumeration units. Combined with the peculiarities of a particular data capture technique (here: GPS from within a moving vehicle), this can lead to a somewhat erratic crisscrossing of boundaries, which becomes accordingly represented in the spatialization. To address this, one may want to recognize such razor's edge travel through incorporation of attributes from both of the adjacent objects and map out the SATP accordingly.

One of the ideas informing this research is that people's trajectories through geographic space exist in a complex relationship with their personal histories, attitudes, and perspectives. A number of recent research efforts are founded on this notion, included co-called feminist visualization (Kwan, 2000, Kwan, 2002). This paper asserts that additional insight could be gained through visualization of geographic paths derived from their location in *n*-dimensional attribute space. Defining a spatialization methodology is a necessary first step that this paper focuses on. In the short term, some questions have to be answered regarding the specific technical solutions proposed here. This includes algorithmic choices among spatial layout techniques (here: SOM) and respective parameters (such as the model's granularity). Other questions relate to cognitive plausibility. For example, there may be an inherent conflict between the spatial continuity of an SATP and the apparent crossing of potentially diverse regions in a spatialization. What one observes here is more akin to wormhole jumping or commercial air travel than to the continuity encountered during road-based travel.

The work described here is driven by an aspiration to develop explicit visual manifestations of *n*-dimensional patterns and structures within and among the paths of people though geographic space. Use of the easily measured attributes of geographic space, as captured during a population census or through satellite remote sensing, is a natural first step. However, a long-term goal is to more directly incorporate visual impressions that are experienced by and are influencing people along their path, most notably along roadways (Appleyard et al., 1964). This ultimately connects with the need to develop visualizations supporting better understanding of the relationship that people have with geographic reality, in particular their *sense of place* (Relph, 1976). To that end, impressions based on concrete, ground-level sensory input, including sight and sound, will have to be incorporated as the SATP notion is developed further.

Acknowledgements

The assistance of Josef Benedikt in capturing the GPS track through Vienna, Austria, is gratefully acknowledged. Austrian geographic base data and census data were published by ArcData Österreich and made available through TU Wien, Institut für Soziologie in der Raumplanung und Architektur.

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Variable		Normalized by
1	Population size	Area
2	White population	Population size
3	Black	Population size
4	American Indian / Eskimo	Population size
5	Asian	Population size
6	Hawaiian / Pacific Islander	Population size
7	Other	Population size
8	Multi-race	Population size
9	Hispanic	Population size
10	Males	Population size
11	Females	Population size
12	Age < 5	Population size
13	Age 5-17	Population size
14	Age 18-21	Population size
15	Age 22-29	Population size
16	Age 30-39	Population size
17	Age 40-49	Population size
18	Age 50-64	Population size
19	Age >= 65	Population size
20	Median age	n/a
21	Average household size	n/a
22	Households w 1 male	Households
23	Households w 1 female	Households
24	Households married w/ children	Households
25	Households married w/o children	Households
26	Male head of household w/ children	Households
27	Female head of household w/ children	Households
28	Average family size	n/a
29	Vacant housing units	Housing units
30	Owner-occupied housing unit	Housing units
31	Renter-occupied housing unit	Housing units

Table 1. Variables for 200,000+ U.S. census block groups used as input to SOM training.

Figure 1. Creation of Spatialized Attribute-Time Path (SATP) through combination of GPS and SOM.
Figure 2. Different application modes for the SATP concept.
Figure 3. A drive through Vienna, Austria. Polygon objects numbered in order of traversal.
Figure 4. Transect of Vienna as spatialized attribute-time path.
Figure 5. Some component planes of a self-organizing map trained with all 200,000+ U.S. census blockgroups. Lighter shading indicates higher values.
Figure 6. Routes through two different study areas - geographic overview.
Figure 7. Single site traversed by multiple paths. Example of commuting in New Orleans.
Figure 8. Commuting in New Orleans - overview of traversed neighborhoods in SOM space.
Figure 9. Multiple sites traversed by multiple paths - comparison of commuting in New Orleans and San Diego.
Figure 10. Commuting via Public Transport in New Orleans and San Diego - Race and Housing Variables. Overlap Zone Shown in Detail.
Figure 11. Commuting via Public Transport in New Orleans and San Diego - Age and Household Variables. Overlap Zone Shown in Detail.

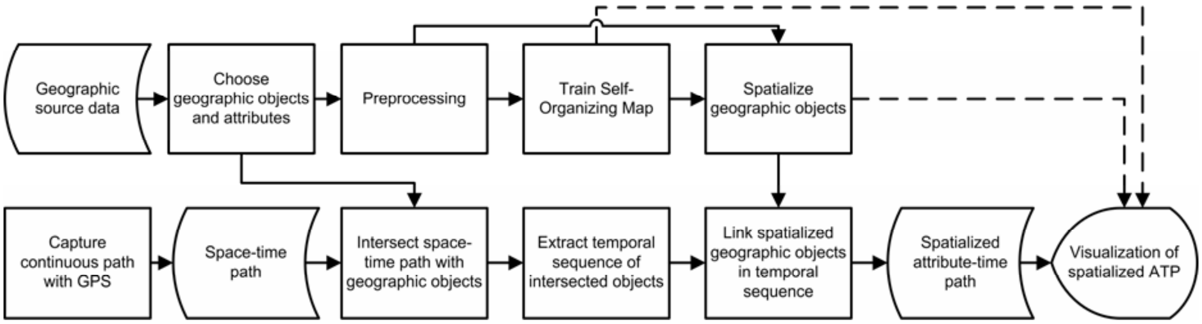


Figure 1. Creation of Spatialized Attribute-Time Path (SATP) through combination of GPS and SOM.

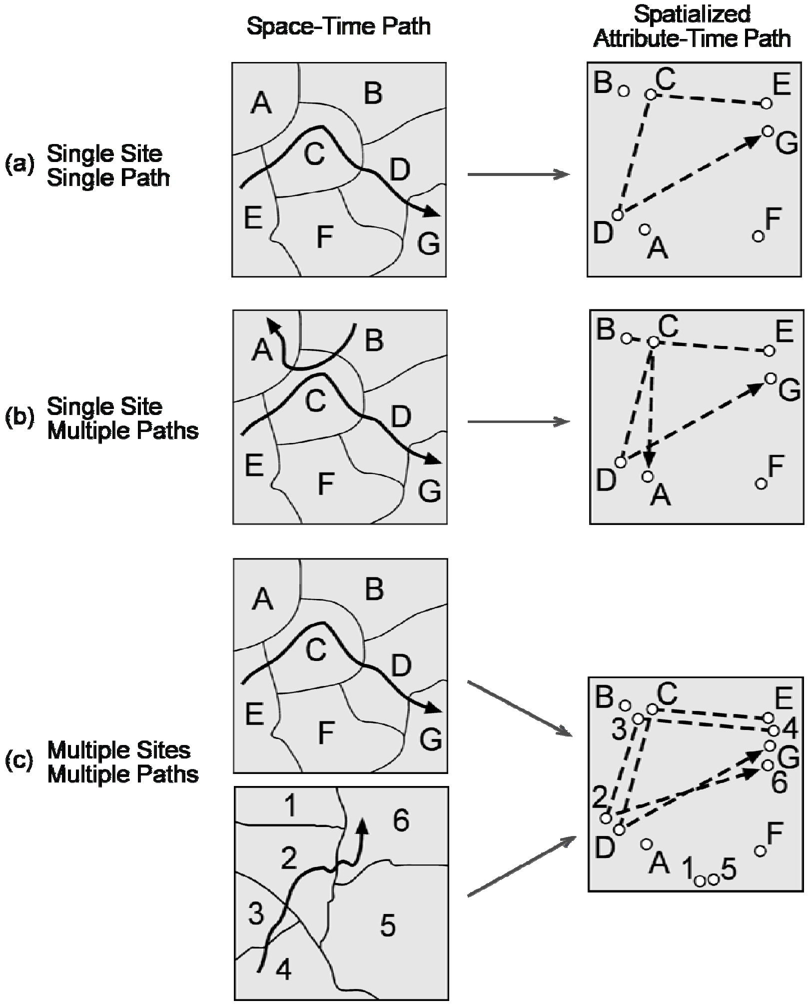


Figure 2. Different application modes for the SATP concept.

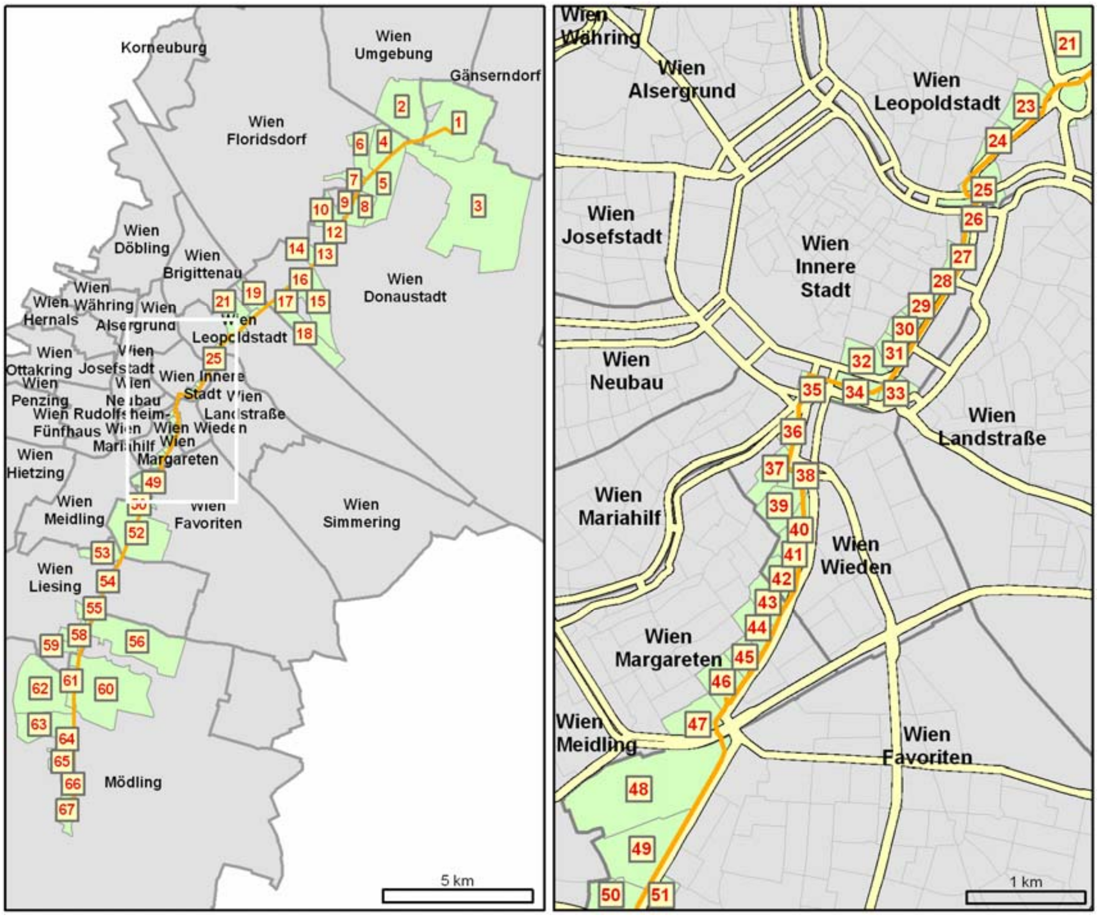


Figure 3. A drive through Vienna, Austria. Polygon objects numbered in order of traversal.

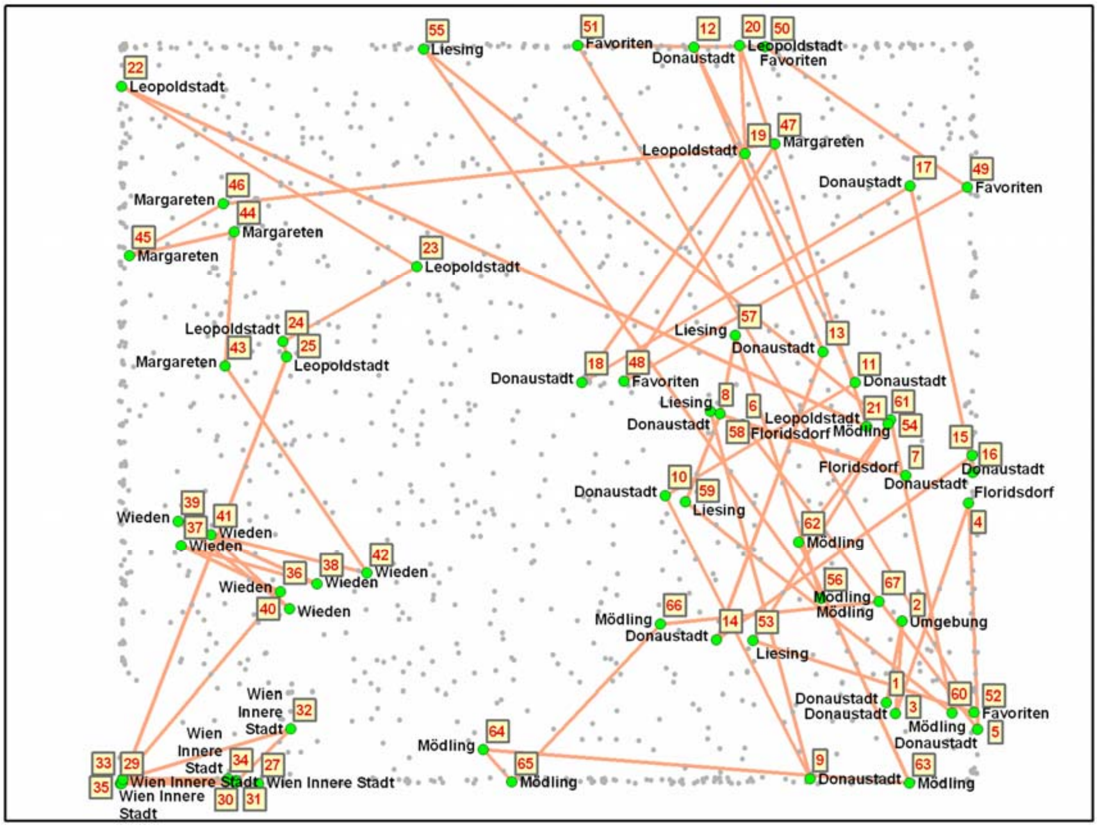


Figure 4. Transect of Vienna as spatialized attribute-time path.

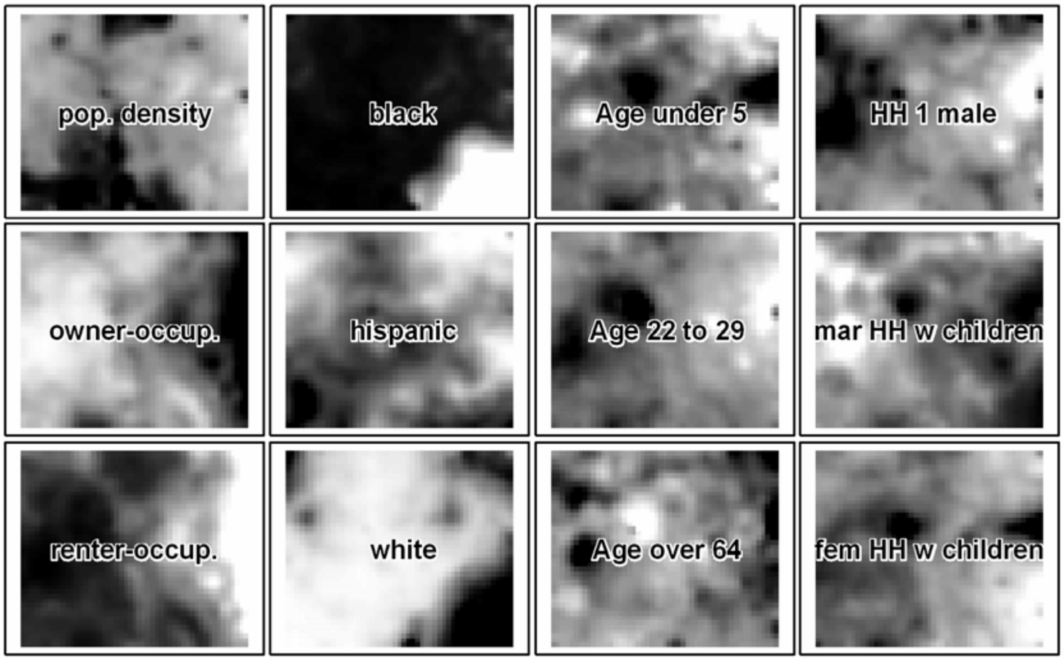
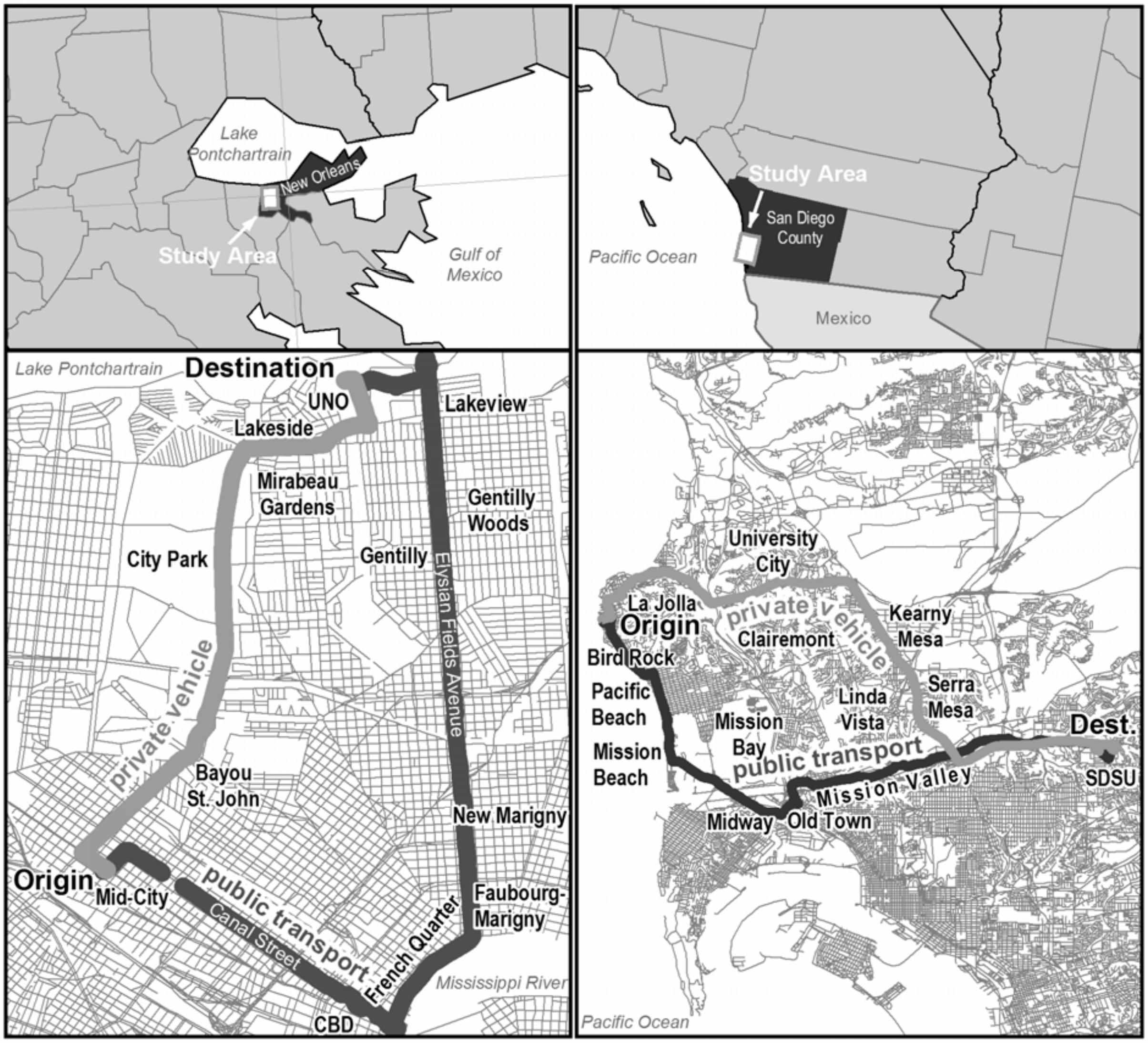


Figure 5. Some component planes of a self-organizing map trained with all 200,000+ U.S. census blockgroups. Lighter shading indicates higher values.



(a) New Orleans (b) San Diego

Figure 6. Routes through two different study areas - geographic overview.

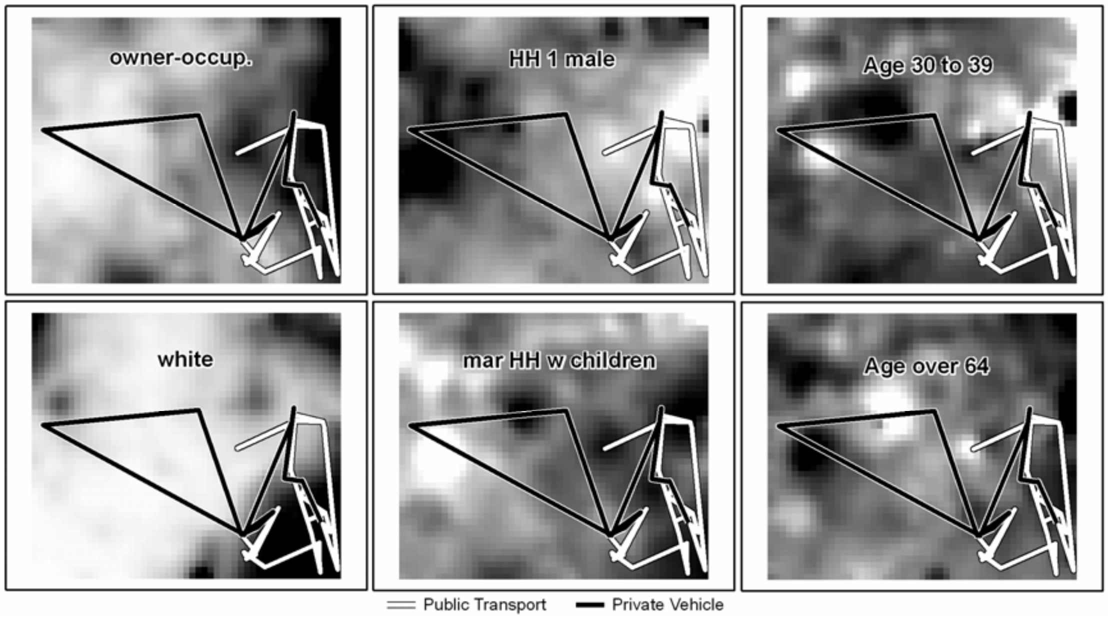


Figure 7. Single site traversed by multiple paths. Example of commuting in New Orleans.

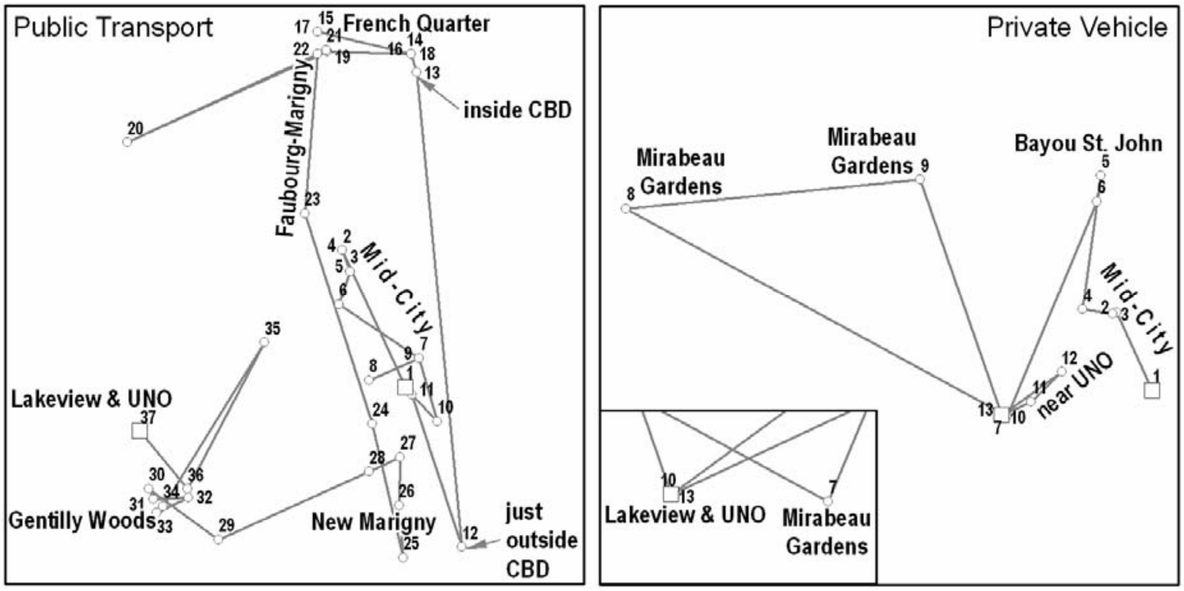


Figure 8. Commuting in New Orleans - overview of traversed neighborhoods in SOM space.

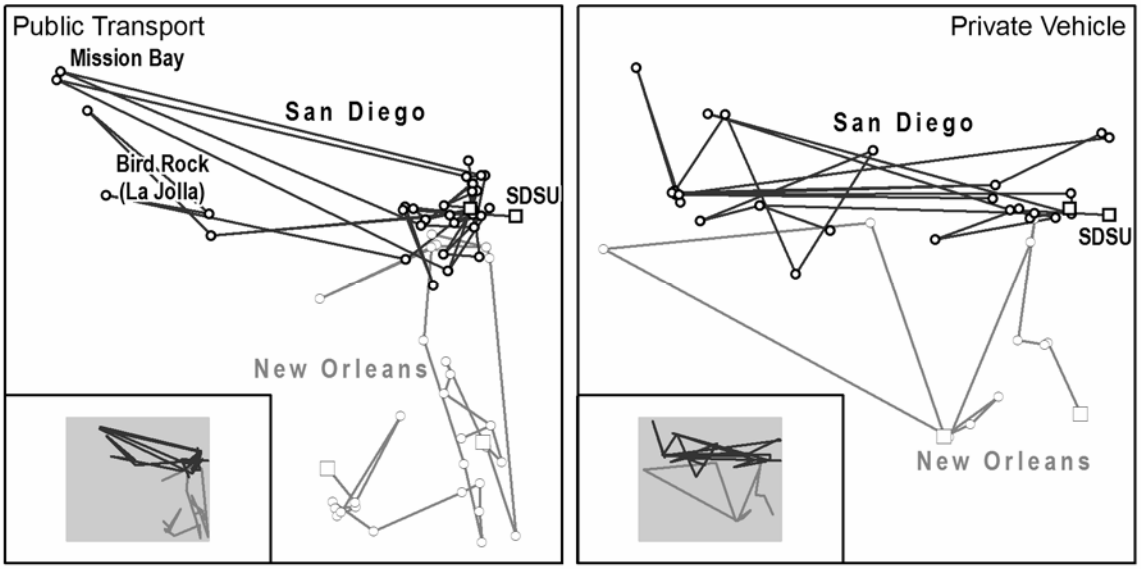


Figure 9. Multiple sites traversed by multiple paths - comparison of commuting in New Orleans and San Diego.

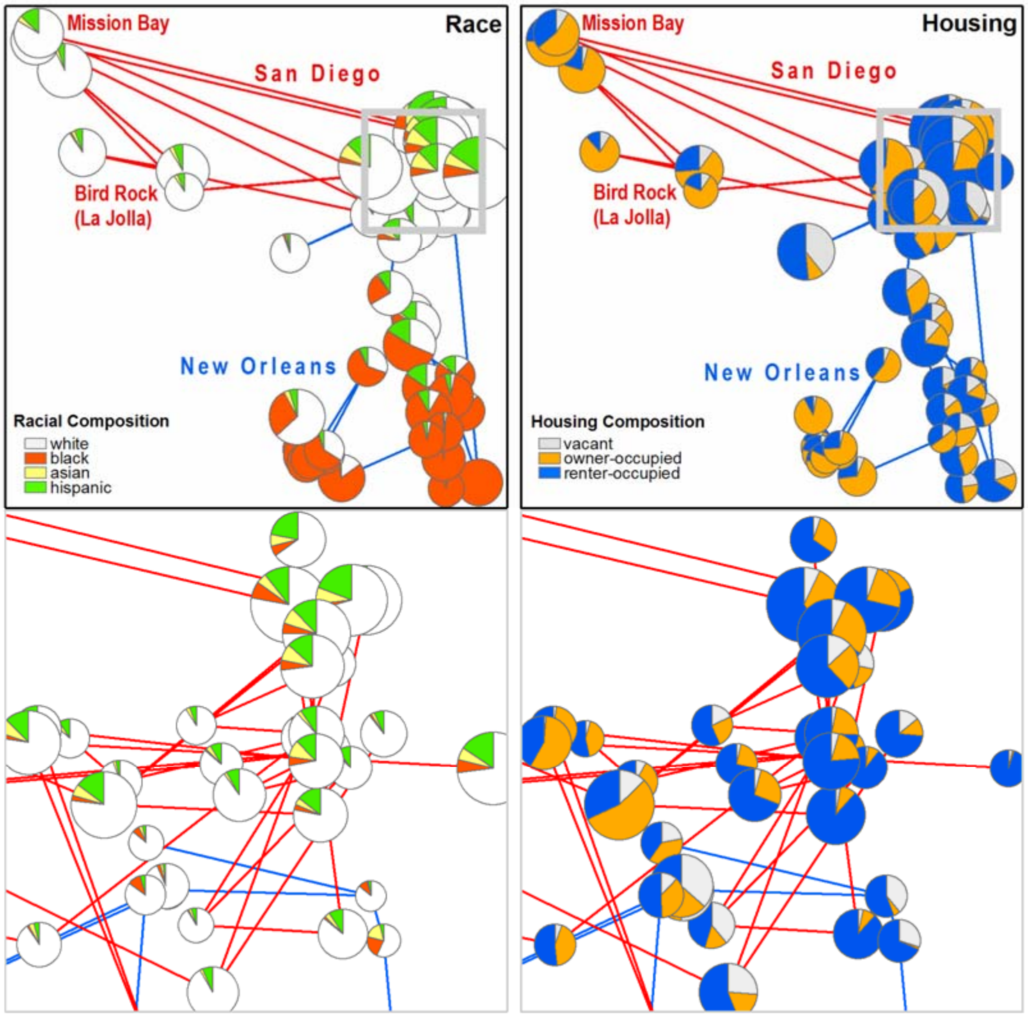


Figure 10. Commuting via Public Transport in New Orleans and San Diego - Race and Housing Variables. Overlap Zone Shown in Detail.

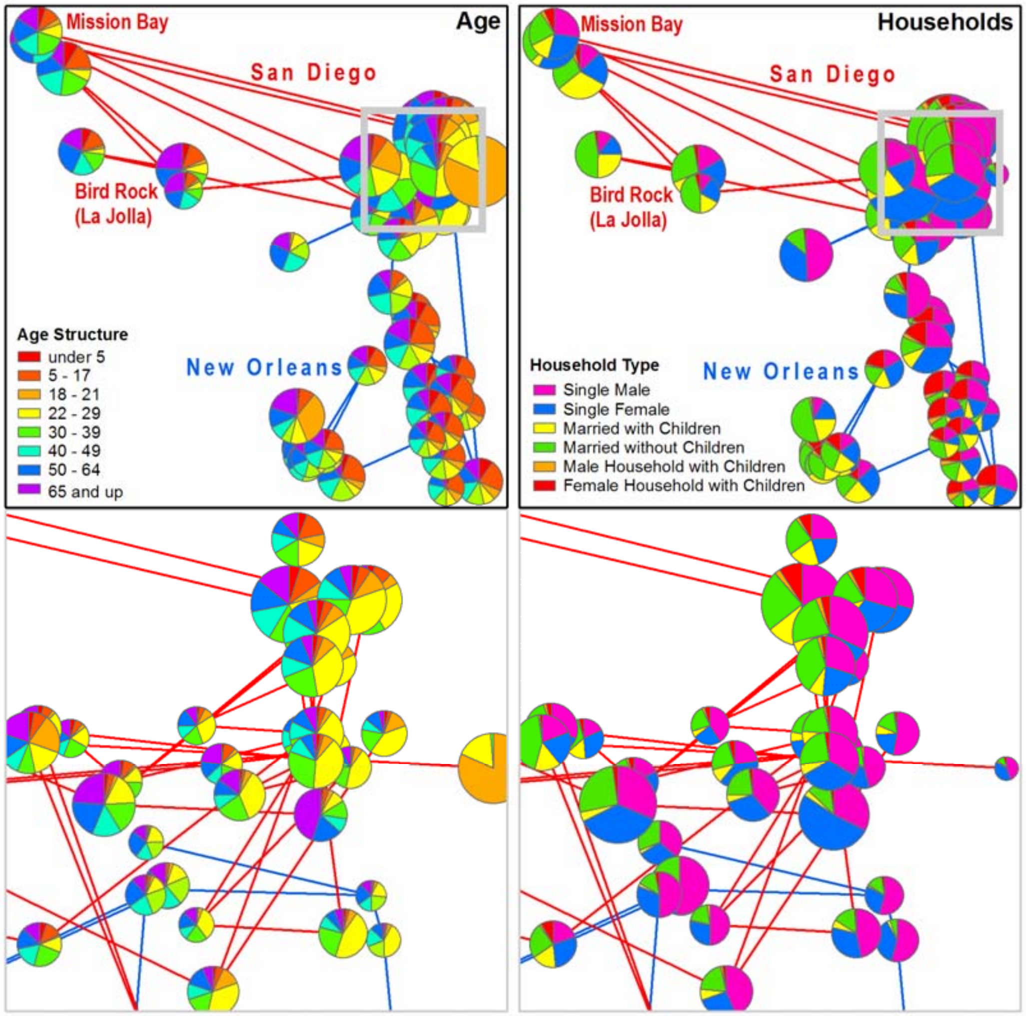


Figure 11. Commuting via Public Transport in New Orleans and San Diego - Age and Household Variables. Overlap Zone Shown in Detail.