HEURISTIC NOLLI MAP: A PRELIMINARY STUDY IN REPRESENTING THE PUBLIC DOMAIN IN URBAN SPACE

Jie-Eun HWANG
Doctoral Candidate
Graduate School of Design
Harvard University
48 Quincy Street
Cambridge, MA
USA
Tel: +1 857 389 6199
Fax: +1 617 496 1294
E-mail: jhwang@gsd.harvard.edu

Kimberle KOILE
Research Scientist
Computer Science and Artificial Intelligence Laboratory
Massachusetts Institute of Technology
32 Vassar Street
Cambridge, MA
USA
Tel: +1 617 253 6037
Fax: +1617 253 0778
E-mail:kkoile@csail.mit.edu

Abstract: This study introduces a comprehensive representation of the public domain in urban space, discusses the role of machine learning techniques in such a representation, and presents a preliminary experiment. We define "public domain" as all places that people actually perceive as public space—traditionally identified spaces such as streets, squares, parks, as well as privately managed collective spaces that function as public space. In representing this broad definition of public domain, we suggest that the vast amount of information available to designers can be managed with our proposed data model. We further suggest that interpreting the public domain requires representing experiential aspects, which few methods have attempted. We illustrate our experiential representation by discussing the concept that we call a Heuristic Nolli Map. We discuss its use in identifying characteristics that contribute to the "public-ness" of a common public domain type—main street, a typical linear commercial district in the centre of a residential area. We suggest that a data model of main street contain the GIS data that cities in the United States generally maintain: land parcel, building footprint, and street centre line. We also suggest that the data model contain additional data at a finer level of detail, e.g., tax assessment data. Finally, we describe our Heuristic Nolli Map methodology in terms of two steps: collecting opinion data about a user's interpretation of public-ness, and using that data to build a user's model of public domain. The model consists of a typology of public domain, e.g., characteristics of main streets,

department stores, town centers; a classifier that employs machine learning techniques to interpret the public-ness of user-supplied data models; and a component that provides explanations for results of classifying particular data models. Finally, we discuss expected contributions of this research and the current status of the research in progress.

Keywords: Public Domain, Main Street, Nolli Map, Machine Learning

1 Introduction

Public space has been an essential subject for architects, urban designers and planners for centuries. The definition of "public space", which has traditionally meant streets, squares, and parks in urban context, is a topic of lively debate. We use the term "public domain" and define it as all places that are perceived as public—streets, squares, parks, as well as privately managed collective spaces that still function as public space (Hajer and Reijndorp 2001, Kayden 2000). This study introduces a comprehensive representation of the public domain in urban space, discusses the role of machine learning techniques in such a representation, and presents a preliminary experiment.

Our representation draws inspiration from Giovanni Battista Nolli's elaborate plan-map of Rome, which was created in 1748. With this map, Nolli created a unique view of a city as a mosaic of public and private spaces, with boundaries defined not only by streets and parks, but also by privately owned interior public spaces. Modern urban planners have adopted this approach (Rowe 1978, Caniggia and Maffei 1979, Habraken 2000), and the Nolli map has proven a powerful instrument for urban design and study. The modern Nolli map, however, has two problems: (1) it remains primarily a graphical visualization similar to Nolli's map of 250 years ago despite the advantages afforded by computer-aided design tools and Geographic Information System (GIS) technology (Barra 2001); and (2) it does not take into account the wealth of data available to modern urban designers and planners. As Leong (2001) points out, "no longer is the city visualized or composed as much as it is empirically computed." The amount of data available for such empirical computation is overwhelming, but new information technology can be brought to bear on this problem. Such technology holds the promise of fulfilling the informational requirements of contemporary urbanization.

This study proposes an information technology that is a new kind of Nolli map. We call it a Heuristic Nolli Map, and it represents and identifies public domain in urban space. The concept of the Heuristic Nolli Map encompasses the creation of a user's representation of the public domain and the subsequent modification of that representation during the urban design process. The representation includes a data model, based on GIS data; and a machine learning component. The results of the machine learning component are a classifier, which maps urban characteristics to measures of "public-ness"; and a user's customized typology of the public domain. This typology includes mappings of urban characteristics to public-ness measures for such urban types as main streets and malls. As such, it embodies the human-readable

"rules" for public-ness that are discovered by the machine learning component.

This paper describes the concept of a Heuristic Nolli Map and the methodology for designing with one. It illustrates this methodology by describing the Heuristic Nolli Map's use in interpreting the public-ness of a common urban type: a main street—a typical linear commercial district in the centre of a residential area. It discusses the Heuristic Nolli Map's data model, and the proposed system framework and machine learning techniques. It concludes with a description of a preliminary experiment in data collection and a discussion of current and planned work.

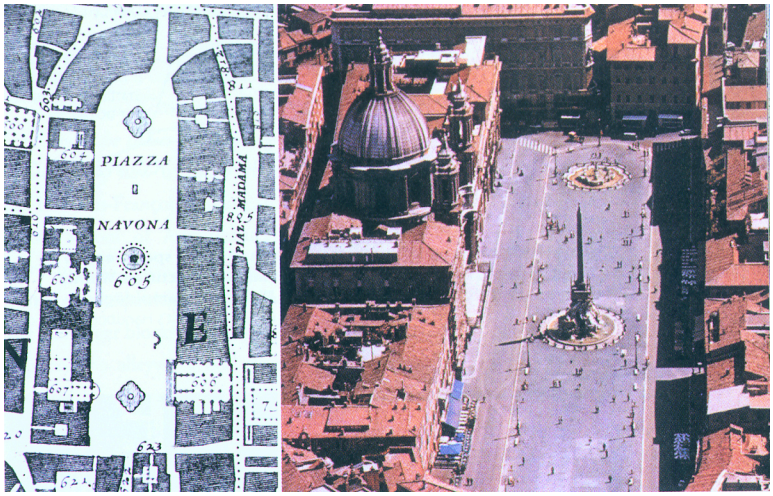

Figure 1 (a: Left) Nolli's Roman Plan, (b: Right) Piazza Navona

2 Nolli's Approach: Experiential Representation of Public Domain

Representation of the design problem and solution is essential for any design process (Rowe 1987). There are different approaches to representing design problems; Chow (2002) outlines three—built-unbuilt, hierarchic, and experiential. Chow (2002) categorizes Nolli's approach as the archetype of experiential representation: By including privately owned collective spaces as public space, Nolli maintained the connection between public spaces and attributes that contribute to the perception of those spaces. In doing so, he demonstrated his map's utility as an interpretation of urban context (Rowe 1978, Caniggia and Maffei 1979, Habraken 2000). (Figure 1).

Despite its advantages, the experiential representation has significant drawbacks as a projective tool: the interpretation of subjective experience and the density of information. For instance, as shown in Figure 2, we can commonly agree to interpret the corridor in the Holyoke Center as public domain, surmising the architect's interpretation through our observation and experience of the functional role and physical execution of this space. In the same sense, the stores and restaurants adjacent to the streets and outdoor open spaces might be assigned a certain degree of public-ness (or not): There exist differences in interpretations no matter what was intended by architects.

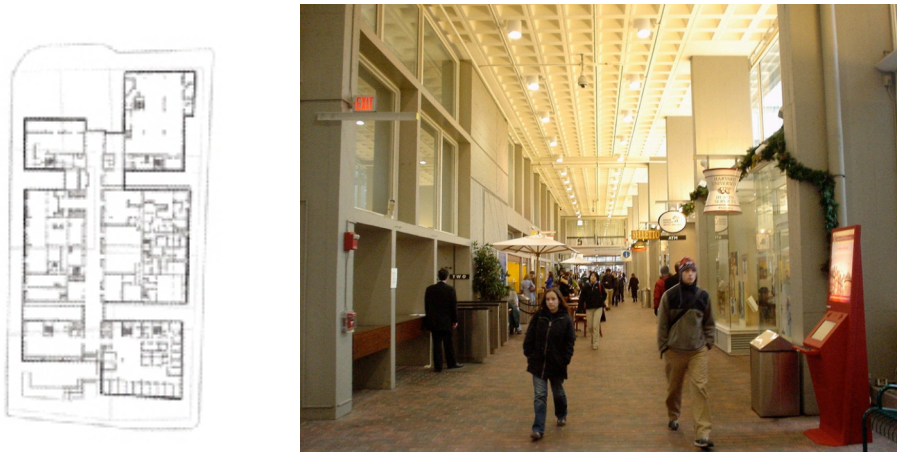

Figure 2 (a: Left) The Holyoke Center Floor Plan,
(b: Right) The Corridor of Holyoke Center

Figure 3 (a: Above Left) Figure-and-ground Representation; (b: Above Right) Nolli's Representation; (c: Below Left) Data Model Representation of Buildings; (d: Below Right) Data Model Representation of Streets

The district around the Holyoke Center could be rendered as Figure 3(a) or 3(b), depending on the criteria used. The criteria might vary by person (Gifford 2002), time period (Caniggia and Maffei 1979), and other more complex factors. The differences lead to the diverse understandings of context, which fundamentally influences the design of collective individual

spaces. The problems stem from the interpretation methods' limitations in dealing with complex factors of the experiential representation.

The Heuristic Nolli Map avoids the above limitation because it employs a semantic data model that is capable of representing experiential factors. Such a data model enables designers to represent their interpretations explicitly thereby moving a beyond a modern Nolli map's visualization with graphical symbols. The semantic data model facilitates the articulation of Nolli's experiential approach in a comprehensive way (Figure 3(c), 3(d)).

3 Public Domain on Main Street

3.1 Overview

Commercial activities are essential in contemporary civic life (Satterthwaite 2001). We argue that commercial spaces are part of the public domain in the urban context. In this light, we use a common and significant commercial type to illustrate our approach: main street—a typical linear commercial district in the centre of a residential area. Generally, main street is a type of commercial district that serves goods, services, and public activities in a residential neighbourhood. Throughout the history of urbanization in the United States, main street has repeatedly advanced and declined, and currently, revitalization of main streets is a compelling urban planning issue. Since the National Trust established the National Main Street Centre in the 1970s, many American cities have developed an innovative policy that combines historic preservation with economic development to restore prosperity and vitality to downtowns and neighbourhood business districts. Currently, over 1,000 main street communities have adopted this approach's four-point program, which includes organization, promotion, design, and economic restructuring (Lopilato 2003).

We investigated main streets in Boson for this study. Even though each main street has unique characteristics identified by the neighbourhood to which it belongs, the general morphology of a main street is linear along the street and consists of relatively even and small sized lots and buildings. The general types of businesses and buildings on main streets are shown in Table 1. Those ingredients identify the characteristics of each main street.

The effectiveness of a main street depends on the answer to the question: What creates a sense of community? The sense of community is manifested in both the functional role and physical execution of the main street's ingredients. In this study, we concentrated on identifying aspects of the public domain that contribute to the sense of community. Since city life and urban activities are reflected in the built environment, we aim to define the characteristics of built form that convey the sense of community on main streets.

3.2 Collective Interpretation of Public-ness

To apply Nolli's approach, we need to judge public-ness in the context of main street. We define the public-ness of a main street in a collective process: After the public-ness of ingredients—stores, buildings, and parking lots—are

examined individually, these collective spaces and their characteristics identify the public domain of main street.

Table 1: Types of Business and Buildings on Main Street

Big-Box Style Grocery Store	Franchise / Chain Store
	
Local Retail	Office
	
Institutional Facility	Historical Landmark
	

This examination looks at three factors that affect the sense of community (and public-ness): sociology, economy, and built form. In the realms of psychology and sociology, the sense of community is measured by methods that mainly rely on observing and surveying people's behavior (McMillan and Chavis 1986). From the viewpoint of economics, the sense of community is sustained by the economic vitality indicated by business geography and capital stream (Hankins 2002). As for built form, in architecture and urbanism, the spatial configuration denotes the function and role of the space (Hillier 1994, Lynch 1981).

3.3 Reasoning from Decision Criteria

For each of the three factors we consider in interpreting sense of community—built form, types of business/service, pattern of use by people—we can identify decision criteria (Table 2). Rephrasing Lynch's (1981) notion of the city model for our purpose, "The model is a picture of how the public domain ought to be made, a description of a form or a process which is a prototype to follow." Criteria are the means by which models of public domain are evaluated. Similarly, the model of public domain can be described by reasoning from decision criteria.

Table 2: Decision Criteria of Public Domain on Main Street

Category	Sub-category
Built Form / Design	Site Layout (Streetscape / Parking / Landscape)
	Building Height/ Volume
	Architectural Style
	Distance from the Street
	Types and Width of Entrance
	Length of Active Façade
	Transparency of Front Windows
	Façade Materials / Signage
Types of Land Use / Business / Service	Business/Service Characteristics
	Brand Popularity
Patterns of Use by People	Number of People
	Quality of Maintenance
	Behaviors of People

4 Data Modelling

4.1 Geographic Information System Data Infrastructure

Geographic Information System (GIS) technology is rapidly becoming the standard by which the city is spatially understood (Barra 2001). The city of Boston is one of the cities in the United States that manages its GIS data resource very well. From the enormous number of available data layers, Figure 4 depicts the data that can be used to determine values for our proposed decision criteria. We intend to use three basic shape layers: land parcel, building footprint, and street centerline, because these are three layers that a majority of cities maintain at the very least. Based on the basic layers, we manipulate geometrically related data, and overlay attribute data from exclusive databases such as tax assessment and phone books in order to obtain data at the appropriate level of detail for representing the public domain. It is not sufficient, for example, to represent only a building's footprint. In order to determine whether a building is perceived as part of the public domain, we also need building characteristics such as building type, number of stories, façade material; and pedestrian network characteristics such as material and presence of sidewalk, crossing, and/or footpath.

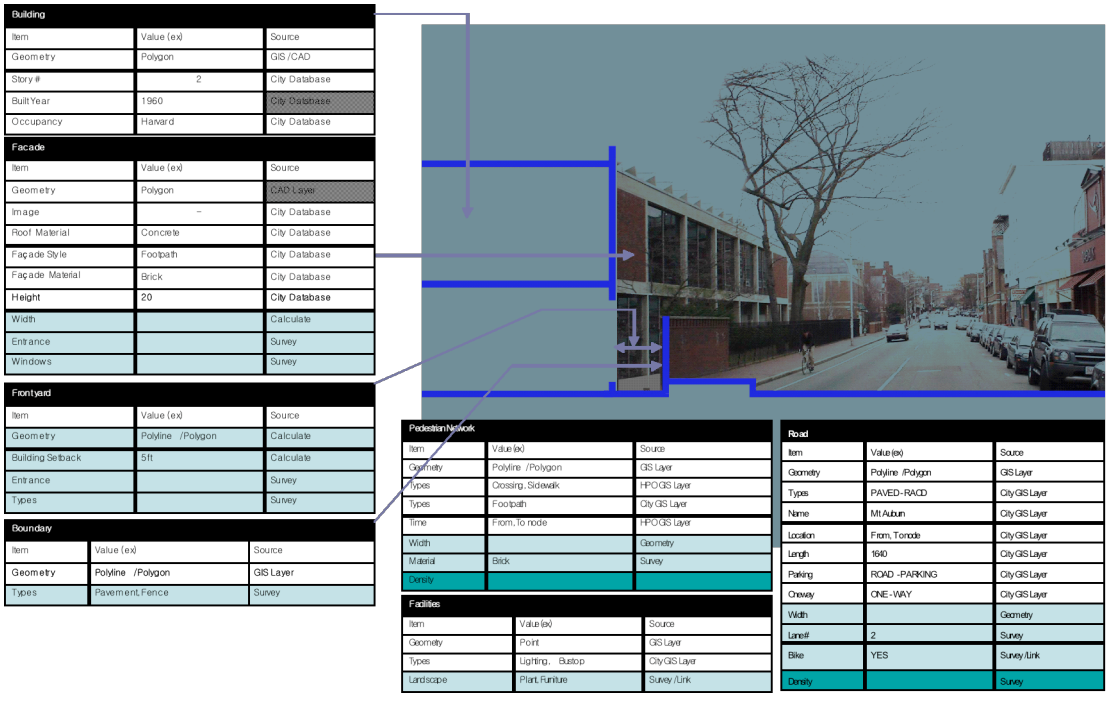

Figure 4 Data Infrastructure for representing public domain model

4.2 Level of granularity

As implied in the previous section, to get the empirical data for representing the public domain, we face the problem of lack of data at the necessary level of granularity. We need the range of detail from the room to the street; however the finest granularity conventionally available via current GIS data is at the level of building. Therefore we suggest that more detailed information about buildings be added as new layers to commonly available GIS data.

4.3 A Semantic Data Model of Main Street

We propose to create a model representing a user's interpretation of the public domain by reasoning from decision criteria. To this end, the decision criteria should be reflected in the semantic data model. We establish a semantic data model of main street consisting of geo-reference[i] architectural element nodes, based on the building information model (Hwang and Choi 2002) and GIS data model (IFG 2005). Using this data model, we can develop a model of the public domain and an ontology of public domain types on a main street.

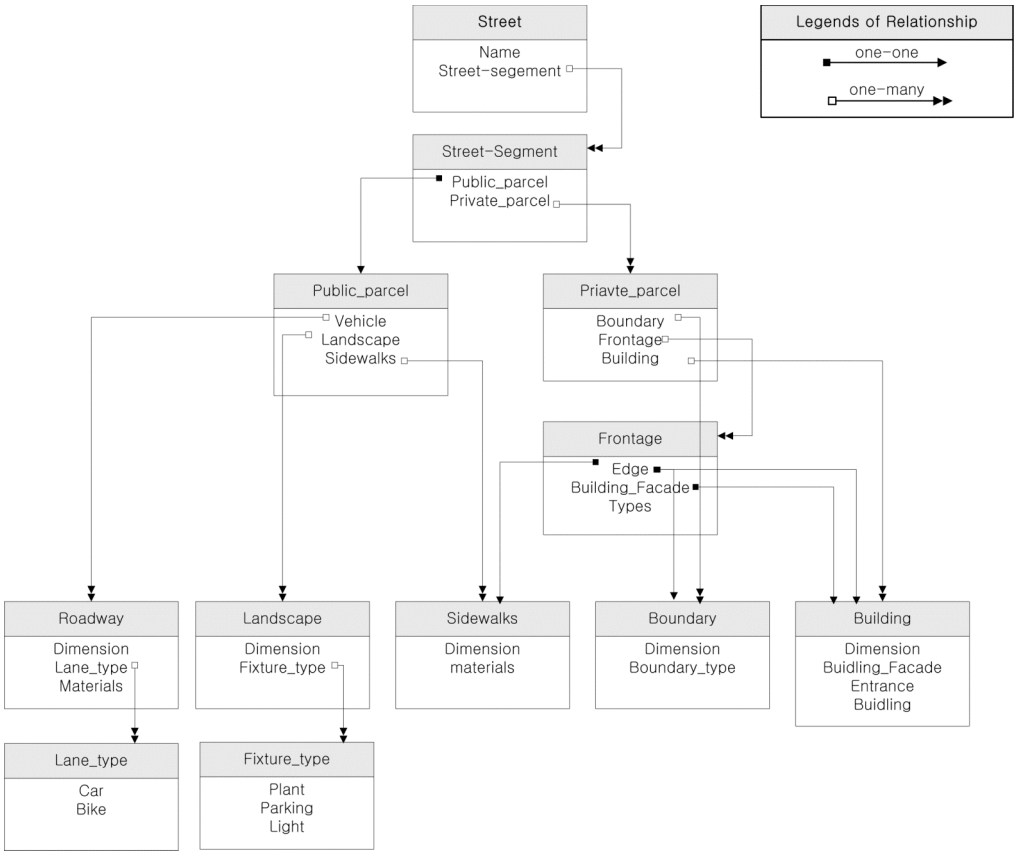

Figure 5 Semantic Data Model of Main Street

5 A Prototype System and the Concept of Heuristic Nolli Map

5.1 The System Framework

Our Heuristic Nolli Map methodology consists of two parts: collecting opinion data, and using that data to build a user's model of public domain. The model consists of a typology of the public domain, e.g., characteristics of main streets, department stores, town centers; a classifier that interprets public-ness of user-supplied data models; and an explanation component which provides explanations for results of classifying particular data models.

We envision the following user interaction with the system. Based on the geo-referenced data interface, users can input their own Heuristic Nolli Map with their decision criteria. The user's Heuristic Nolli map consists of the designation of whether individual ingredients are public or not. This opinion data is stored as a training data set for the machine learning component. In the training process, the system identifies decision criteria that contribute to the user's interpretation of public domain. These decision criteria are stored in the user's public domain model as characteristics of the public domain typology. Once the characteristics have been identified, the system can interpret the public-ness of other sites. At this point, the user can interact with the machine-modified Heuristic Nolli Map to further modify the public-ness interpretation of particular ingredients and store that information as new training data. In this manner, the system adapts its classifier to better match the user's notion of public-ness, i.e., it improves the heuristics that it uses when interpreting public-ness for user-specified data models. Finally, for each interpretation, the system offers an explanation, which is generated from the human-understandable classification rules of the classifier.

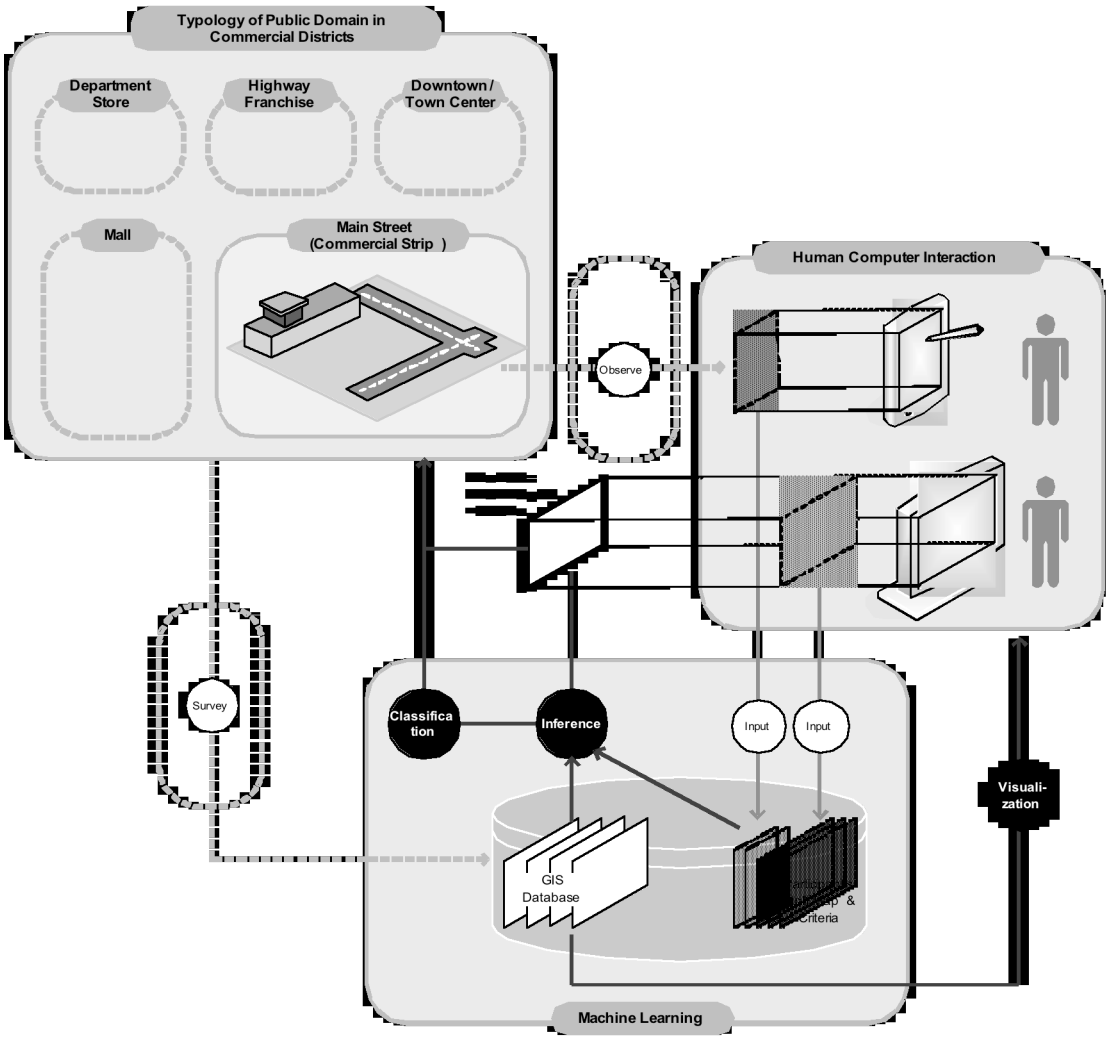

Figure 6 The System Framework

5.2 Machine Learning Technique

We have established guidelines for the machine learning component. It will be a data-oriented learning system, and thus an example of a "…practical program[s] that can mine database for exploitable regularities" (Winston 1992). It will be a supervised learning method, since it will be provided with examples of a user's interpretation of public-ness. It will not be a "black box" statistical learning method, since it will need to provide human-understandable explanations for its classifications. An example of a machine learning method that fits these criteria is the decision tree technique ID3, which induces rules from a training data set. (Mitchell 1997, Quinlan 1993). An important next step in our study is to select a machine learning technique.

5.3 Heuristic Nolli Map

As described in the system framework, the Heuristic Nolli Map is the core concept of this system. The concept of the Heuristic Nolli Map includes the process to represent user's opinion and interact with the machine. In other words, it means the machine learning process that the system generates the customized rules and ontologies of public domain through inference from user's given data and inbuilt database. Therefore the Heuristic Nolli Map addresses the way to manage the essence of knowledge in the systematic way.

6 A Preliminary Experiment: A Survey for collecting user's data

6.1 Purpose

The first step in using our proposed system is to provide the system with a training data set that represents the user's opinions of what constitutes the public domain. Thus, our first experiment was to examine the process and result of collecting such data. One of the authors conducted a survey, the purpose of which was to test:

- whether the designation of public-ness follows identifiable tendencies for particular users or groups of users
- whether there exist decision criteria common among different users
- whether there exist the identifiable differences between people in their use of decision criteria

6.2 Outline

We interviewed seven Master of Architecture students at Harvard Graduate School of Design. We took them to the site on the main street in South Boston, which they had been studying for their term project. The interviewees were relatively familiar with this site (average of four visits each). We asked them to classify 56 stores (in 37 buildings) and gave them three kinds of information:

- 10 layers of mapping information (commercial property classification, residential property classification, streetscape, building heights, population by age, race, income median, property values, tax revenue, built year)
- 2 sets of panoramic pictures along the street

- 56 pictures of individual shop fronts

With a photographic slide show of each of the 56 individual shop fronts, we asked them to perform two tasks:

- designate whether they thought it public or not
- mark the factors that contributed to the designation.

For the second task, we provided the decision criteria listed in Table 2, and allowed them to make multiple choices. Each interview took approximately 30 minutes.

6.3 Results

We complied the interviewee's answers and assigned 0 for "public", 1 for "private". After summing up, we designated a space "public" if it was assigned a value less than 3. Figure 7 shows the results for designation of public-ness at the building level of granularity (37 buildings). Four shops (among 56) had a low degree of agreement, i.e., three or four people categorized the shops as public, the rest categorized them as private.

Figure 7 The Result of Designation of Ingredient's Public-ness

As for the decision criteria used, we calculated the mean number to be chosen for each degree of public-ness (0 through 7). As shown in Figure 7, "Type of Business" is the most dominant factor for designation of public domain. "Patterns of use by people" is a relatively less dominant factor for designation of public domain. Among Built Form/ Design, "Façade Materials /Signage", "Architectural Style" and "Transparency of Front Windows" are dominant, and "Site Layout" and "Building Height/Volume" are relatively less dominant.

6.4 Findings

Looking at the original goals of the study:

- whether the designation of public-ness follows identifiable tendencies for particular users or groups of users
- whether there exist decision criteria common among different users
- whether there exist the identifiable differences between people in their use of decision criteria

We found the following:

- Approximately 70% (40/56) buildings meet within 85% (6/7) degree of agreement.

- There can be common criteria for designation of public domain.
- There exist the differences by participants.

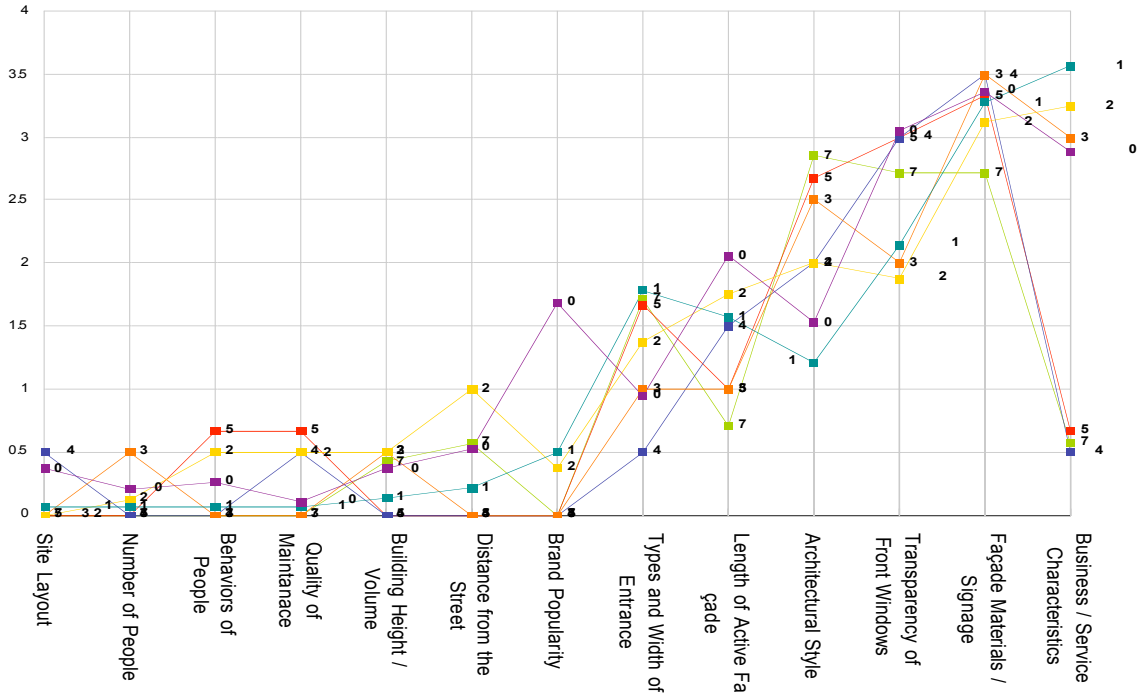

Figure 8 The Result of Decision Criteria Usage

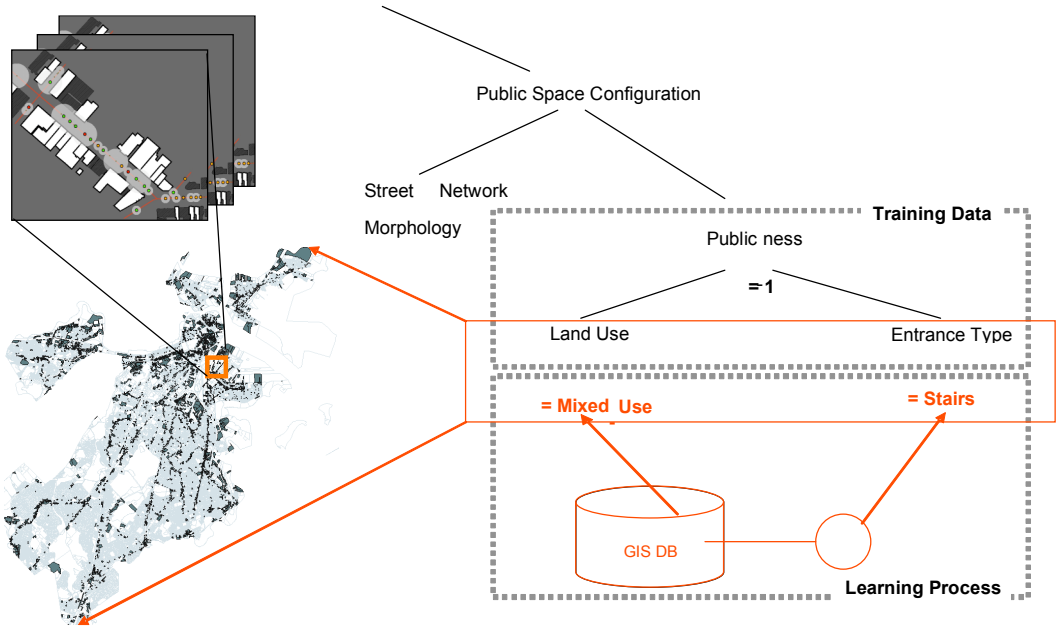

Figure 9 Applying Machine Learning

7 Discussion and Future Work

This paper describes the concept of a Heuristic Nolli Map and a methodology for creating and using such a map to identify the public domain in urban space. It illustrates this approach by describing the use of a Heuristic Nolli Map in interpreting the public-ness of main streets—typical linear commercial districts in the centre of residential areas. It discusses the Heuristic Nolli Map's data model, which includes GIS data, as well as data gathered from a variety of other sources; the proposed system framework and machine learning techniques; and a description of a preliminary experiment in data collection. In this experiment, we surveyed a group of designers about their definitions of public-ness. We mapped their designations of public or private to urban characteristics that they considered to have influenced their designations. In this preliminary study, we represented public-ness as a boolean value, either true (1) or false (0). In our next experiments, we plan to use a quantitative representation that will correspond to a measure of "degree of public-ness", i.e., how public a designer considers an entity to be. We then plan to use this representation to build a model representing a designer's interpretation of public-ness, and use that model to determine public-ness of entities in examples of urban areas. This model of public-ness is at the core of our Heuristic Nolli Map methodology.

We expect that this research will contribute an innovative method to aid urban designers and architects in understanding the urban context and in communicating their opinions in a rational way. The system we propose will provide the following benefits:

- Saving time and effort: The system will provide a vehicle for a faster and more intuitive survey for designers handling massive amounts of city data.
-
- Rationalizing design process: The system will identify the user's rationale automatically through the inference process. While interacting with the system, the user can rationalize his/her opinion and have an account of the results of whole process at the end.
-
- Customizing design process: This approach deals with heuristics that enable user customization. Defining public space, for instance, is very subjective, so the system will provide an opportunity to encapsulate the user's own way of thinking.

From the perspective of Urbanism, this approach will provide the following innovations:

- Providing integrated perspective on urban context: As a contemporary version of Nolli map driven by much more complex information, this approach represents and identifies the urban context in a more comprehensive way.
- Articulating contextual information with architectural semantics: This study will attempt to connect architectural components to urban scale. The contextual information surrounding the buildings will be translated into a formal description.

This paper describes research in progress. This research is at the beginning stage, and we currently are working on building a GIS database, implementing the input module for user data, and experimenting with machine leaning techniques using conventional GIS data. The next steps are to develop geo-referenced building data model to link to main street model, and to implement a prototype system that builds a model of public domain given user-specified data models and designations of public-ness.

ACKNOWLEDGEMENTS

We would like to thank Prof. Spiro Pollalis, Joan Busquets, Paul Cote, and Kostas Terzidis at Harvard Design School for their invaluable advice, and Hye-Jin Oh, a doctoral candidate at AI lab, Carnegie Mellon University, for her dedicated collaboration.

REFERENCES

a) Books and Books chapters

Barra T. (2001) Integrated Land Use and Transport Modeling: The Tranus Experience, in Brail R.K and Klosterman R.E., **Planning Support Systems**, ESRI, Redland, CA, p.129-156.

Caniggia, G. and Maffei G (1979) **Architectural composition and building typology: Interpreting basic building**, translated by Faser, J. (2000) Alinea Editrice, Firenze.

Habraken, N.J. (2000) **The Structure of the Ordinary**, MIT Press, Cambridge, MA

Hajer, M. and Reijndorp, A. (2001) **In search of new public domain,** NAi Publishers, Rotterdam.

Hillier, B. (1996) **Space is the machine: A configurational theory of architecture**, Cambridge University Press, England.

Kayden, J.S. (2000) **Privately owned public space: the New York City experience**, John Wiley & Sons, Inc., New York.

Leong, S.T. (2001) Ulterior Spaces in Koolhaas, R., and et als (eds.), **Harvard Design School guide to shopping**, Taschen, Koln.

Longstreth, R.W. (2000) **The buildings of Main Street: a guide to American commercial architecture**, AltaMira Press, Walnut Creek.

Lopilato, L. (2003) **Main street: some lessons in revitalization**, University Press of America, Inc., New York.

Lynch, K. (1984) **Good city form**, MIT Press, Cambridge, MA

Mitchell, T. M. (1997) **Machine Learning**, McGraw Hill, New York

Quinlan, J. R. (1993) **C4.5: Programs for Machine Learning**, Morgan Kaufmann Publishers, San Mateo, CA.

Rowe, C. (1978) **Collage city**, MIT Press, Cambridge, MA.

Rowe, P. (1987) **Design thinking**, MIT Press, Cambridge, MA.

Satterthwaite, A. (2001) **Go shopping: Consumer choices and community consequences**, Yale University Press, New Haven.

Winston, P. H. (1992) **Artificial intelligence** Addison-Wesley, Reading, MA.

b) Journal papers

Barr S. Barnsly M.J. and Steel A. (2004) On the separability of urban land-use categories in fine spatial scale land-cover data using structural pattern recognition, **Environment and Planning B: Planning and Design**, Vol 31, p.397-418.

Chow, R. Y. (2002) Representing detached dwelling: a survey, **Journal of Architectural and Planning Research**, Vol. 19 No. 2, 149-164.

Gifford, R. and et al. (2002) Why architects and laypersons judge buildings differently: cognitive properties and physical bases, **Journal of Architectural and Planning Research**, Vol. 19, No. 2, 131-148.

Hankins, K. (2002) The restructuring of retail capital and the street, **Tijdschrift voor Economische en Sociale Geografie**, vol. 93, no. 1. p. 34-46.

McMilan, D.W. and Chavis D.M. (1986) Sense of community: A definition and theory. Special issue: psychological sense of community, I: Theory and concepts, **Journal of Community Psychology**, Vol 14, p.6-23.

Robertson, K.A. (2004) The mine street approach to downtown development: a examination of the four-point program, **Journal of Architectural and Planning Research**, Vol. 20, No. 1, 55-72.

Steadman, P., Bruhns, H. R. and Gakovic B. (2000) Inference about built form, construction, and fabric in the nondomestic building stock of England and Wales, **Environment and Planning B: Planning and Design**, Vol 27. 733-758.

c) Papers presented to conferences

Hwang, J-E. and Choi, J-W. (2002) SpaceCore: Metadata for Retrieving Spatial Information in Architecture. **Proceedings of Association for Computer Aided Design in Architecture**, California State Polytechnic University, Pomona, USA, 24-27 October 2002.

Koile, K. (2004) An Intelligent Assistant for Conceptual Design. **Proceeding of Design Computation and Cognition 2004**, Massachusetts Institute of Technology, Cambridge, MA, 19-21 July 2004.

d) Other documents

IFG: Industry Foundation Classes for GIS (2005), IFG Outlines, hhttp://www.iai.no/ifg/index.html.

[i] In general, geo-referencing means the procedure that registers attributes on the map with the coordinates. We include the geo-refereced architectural element nodes in the semantic data model in order to connect between architectural form and contextual information.