Place-based GIS: Functional Space

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Abstract

Place-based GIS allow digital systems to provide a human-centred representation of the geographic world, by complementing traditional spatial representations with the notion of human meaning. An emerging question of such an integration and hence digitization is the level of formalization and generalization that the human meaning can undergo, along with the pragmatic value of associating informal and vague constructs with the formal and precise environment of a Geographic Information System. We propose a function-based model of place, which depicts place as a space ascribed with functionality. The model treats place as a topological graph of spatial entities that enables a set of functions, which in return define functional spaces. Furthermore, utilizing the idea of functional space we suggest a practical application of a Place-based GIS, such as function-based search of space, that is demonstrated using the example of a shopping area. Future research includes the extension of the model by associating place with purposes and emotions, automated generation of composition patterns of place and extraction of function-based data.
Keywords: Place, Space, Functions, GIS

1 Introduction

A geographic information system (abbr. GIS) represents geographic information utilizing various forms of data structures. From "a puzzle of polygons to a sandwich of data layers" [3], every method creates a formal, objective and precise [5] view of the geographic world, known as mathematical space [1] or just space. On the other hand, geographical space as it is perceived by humans refers to the intuitive, unanalyzed and unarticulated spatial understanding [1]. Driven by the perception, humans refer to space as an informal, subjective, vague and structure-less view of the world, known as experiential space [5], or simply place. The place-based GIS is an attempt to bridge these two extreme views of the geographic world. It attempts to incorporate the human perception of the geographical world within digital systems enabling the formalization and association of place with the mathematical space.

This integration forces researchers to focus on the essential difference between space and place. It stems from the intuitive mental ability of creating symbols by ascribing meaning to the physical constructs. With respect to our discussion about space, humans create symbols, which are the places, to assign context to space. The main research question that emerges focuses on the limitations of formalizing the context of space. Particularly, which parts of the human context ascribed to space facilitate generalization and allow formalization; furthermore, what is the pragmatic value of such an integration within GIS, in terms of practical applications and solutions. This work proposes a multidimensional definition of place as functional space and suggests a pragmatic application that utilize the gradual transition from human context to pure spatial representations displayable in GIS platforms.

The rest of this document is organized as follows. The next section introduces the leading definitions of place and continues with a brief literature review of the existing methods that associate space with place. Afterwards, a definition of place is given that is derived from the theory of the Object of Discourse [2] followed by a demonstrating example. Finally, we provide some concluding remarks along with potential directions of future work.

2 Background – Related work

The academic definition of the concept of place is a research problem that has puzzled scientists for many years. Relph [9] construes place as a unique pattern of physical features, appearances, activities and functions. Its unique quality is the power to focus on human intentions, experiences and actions in the spatial dimension. Curry [4] describes place as a notion free of natural boundaries. More specifically, space existed long before people were there, whereas place is a location shaped and formed by the human mind. Consequently, places are human inventions to describe space. Tuan [11] plausibly claimed that "place is space infused with human meaning".

Since human meaning is broad, purely subjective and disruptively vague, any attempt of formalizing it, should be compliant to reasonable abstractions. These facilitate the distinction of indicators that outline the human meaning from those that are not worthy of modelling and determine whether inter-subjectivity can be applied. Adhering to such abstractions facilitates the declarative formalization of meaning. This simplified version of meaning is referred to as context of space and affords semantics representation.

There are two notable directions when conceptualizing and formalizing place: either infusing spatial representations with semantics or projecting semantics on space. A leading approach of augmenting space with semantics is the objectification of space [10]. According to this, spatial

structures are converted into sophisticated objects with ascribed properties, attributing a context to them.

In the opposite way, digital gazetteers [5] offer a linkage between place names and semantics to spatiotemporal footprints. This approach is usually extended with semantic enrichment resulting to ontology-based gazetteers or ontologies equipped with properties that lead to spatial descriptions. For instance, CIDOC CRM is an upper level ontology that defines place as a qualitative spatial description of semantic-driven entities, such as events. A place entity is identified by a representative place name and provides the intermediate (human-friendly) node between events and their spatial projection. Finally, the affordance-based model of place [6] focuses on annotating space with context derived from people's actions. Particularly, space, expressed as a set of affordances, is imbued with meaning expressing the ability to serve human intentionality on achieving a final goal.

Most of the aforementioned methods do not fully utilize the expressive power of place. The first three methods associate space with simple semantics, in the sense of properties, which does not always reflect the given human context. On the other hand, the affordance-based model sufficiently approximates the context of place. However, affordances are perception-centric and provide limited and individual-driven knowledge. This limits the model's capabilities on defining whether space affords a final goal, which, in turn, impedes the model's operationalization.

3 Methodology – Demonstration

The objective of this work is to propose a model that facilitates an adequate conceptualization of place, which allows its representation using a rigid, digital alphabet. This consequently allows the integration of place into GIS platforms. Considering the complexity of the problem, the initial research question is analysed into several coarse-grained challenges. Before listing and addressing the individual challenges, a brief introduction of the theory about the object of discourse is provided, which is the basis of the proposed approach.

An object of discourse is "whatever people can talk about regardless of its nature" [2]. Since place is a product of human thinking, it can be rightfully considered as an object of discourse. Hence, a place is described by four levels of semantic resolution, inherited by the definition of the object of discourse, as follows. A place serves one or more purposes. These purposes are supported by the functions the place provides. A composition, in the sense of spatial organization, enables the aforementioned functions and finally, the composition pattern introduces a set of properties that realize the place under consideration.

The most crucial challenge when it comes to place modelling is the conceptualization of the spatial context. Inspired by the argument that place is an object of discourse, we address this by assuming place is space that offers particular functionality. This allows a more sophisticated and formalizable view of the spatial context that goes beyond simple properties, such as names or attributes. In addition, functions allow operationalization by facilitating objectivity. They provide an inter-subjective understanding on how places operate as a system, rather than following affordances-driven questions such as how the place can be interacted with, which entails individual spatial perception. It is worth noting that functionality expresses only a subset of spatial contexts. Places can be more complicated when they are related to emotions, experiences and so on. For that reason, we list the following assumptions: the proposed model represents only places that exist in the real world, are marked by human intervention and are designed for certain goals.

The next challenge that arises is the encapsulation of the context of place (that is, functionality) in a system of entities that affords realization and spatial representation. This is addressed by following the principles of the object of discourse based on which, functions are enabled by a particular spatial organization. Our approach follows this idea by introducing the composition of place. More specifically, composition suggests a network-based view of place. Every vertex is considered as an entity, denoted as component, and every edge resembles possible associations between components. The components depict physical entities with ascribed properties and rules that offer a generalized description of their potential geometry. The components are associated with spatial relations revealing a possible topology. This topology implies a spatial organization that enables the functions of the modelled place to be offered.

The final challenge that needs to be addressed is the projection of place on space. This can be addressed by utilizing the dual nature of the composition of place that was described above. With respect to the object of discourse, the level of properties realizes a composition by assigning values and creating a tangible representation of the individual object on space. Particularly, the composition of a place is regarded as a blueprint. This includes descriptions of required and optional components along with their topological rules that enable the functions, which form the context of the place under consideration. Since the components are equipped with their geometrical descriptions, they can be populated with real data and spatial objects. As long as these components are spatially organized based on the composition rules, it is then possible to assign the initial context on space and hence project the place itself on space.

Considering all the above, we propose a multi-faceted definition of place incorporating the dimensions of spatial properties, composition and functions. The dimension of spatial properties describes place as a semantically enriched spatial object with ascribed properties and geometry-related information. The dimension of composition describes place as a system in the sense of a topology network. This graph-oriented representation resembles the spatial organization of the components that constitute a place. Finally, the dimension of functions provides a sense of context by depicting the set of operations that a place can offer.

For the proposed model to support domain independence, its formalization should be flexible, reusable and extensible. This can be achieved via an ontology design pattern [8], which treats the model of place as a self-contained building block able to be integrated into other ontologies. A concise version of the ontology is shown in Figure 1. There are two notable operations that this model of place can offer: (a) projection of functional context on space and (b) infusion of space with functional context. Each operation depends on the information

flow, either following a top-down approach and moving from functions to spatial properties or adapting a bottom-up procedure from spatial properties towards functions. These operations are denoted as spatial design and functional infusion, respectively. A graphical representation of both procedures is illustrated in Figure 2, using the example of a shopping centre.

The composition pattern of the shopping centre (Figure 2a) is used for the functional infusion of an area in Santa Barbara County. Particularly, this example demonstrates the search of place and specifically the function-based search of space. The objective is to locate all places that offer the functions of a shopping centre using OpenStreetMap data. Figure 3 shows the results of the procedure along with the corresponding query of "shopping centre" using the Google Maps platform.

There is a satisfying similarity between the two result sets. However, as opposed to the traditional place name search, the functional infusion includes all places that adhere to the same rules, even if they are not registered as shopping centres. As a result, there are places that are not included in the results of the Google Maps query, such as the area close to the University Campus and the place "The Shop". In addition, functional infusion is not limited to locating a place but also provides an estimation of its spatial extent.

Figure 1: Model of Place.

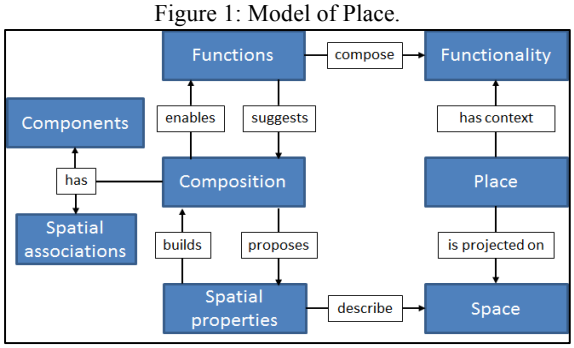
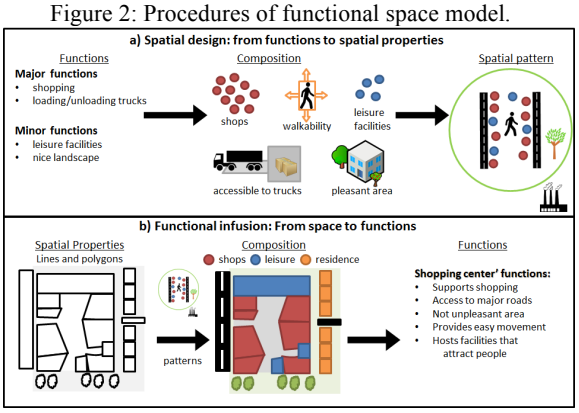
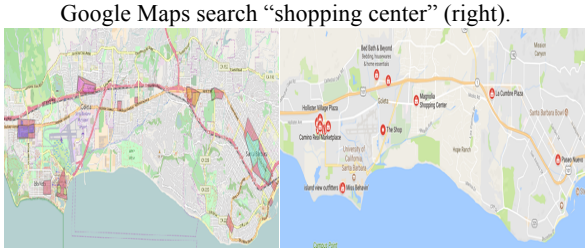


Figure 2: Procedures of functional space model.



The current state of this work focuses on the detailed formalization and evaluation of the dimension of composition. Particularly, we emphasize on specializing the components' geometric descriptors by including features such as scale, fuzzy boundaries and image schemas [7]. The idea behind this is the potentiality of unsupervised functional infusion using recurring structures and patterns in order to categorize components from semantically poor information such as remote sensing data and so on. In addition, we examine the possibility of extending the spatial relations between the components of a place by including mereological association, in order to describe part-of dependencies between them.

Figure 3: Function-based search shopping center (left) and Google Maps search "shopping center" (right).



4 Conclusion

Assuming that place is a space that offers functionality, we propose an ontological model of place that complies to the theory of the object of discourse. This model defines places using the dimensions of spatial properties, composition and functions. Particularly, a place offers a set of functions that are enabled by a set of components that adhere to a particular topology, which in turn is realized by spatial properties. This model introduces two fundamental procedures: the extraction of spatial patterns, known as spatial design and the infusion of space with a functional context. Finally, we demonstrate the spatial design of a shopping centre followed by a function-based search of shopping places at the area of the Santa Barbara County.

An interesting direction of future work is the extension of the model of place to the planes of intentionality and emotions. More practical future directions include the automation of the following tasks: (a) acquisition of function-based data; (b) extraction of functions based on purposes that people assign to places; (c) extraction of place composition patterns based on a set of functions.

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