An Affordance-Based Model of Place in GIS

Troy Jordan, Martin Raubal*, Bryce Gartrell, and Max J. Egenhofer

National Center for Geographic Information and Analysis

and
Department of Spatial Information Science and Engineering

University of Maine
Orono, ME 04469-5711, U.S.A.
Email: { tjordan, mraubal, gartrell, max}@spatial.maine.edu
Fax: (207) 581-2206

Abstract

People deal with places in their everyday lives. Interactions with places are based on the meaning people assign to them. In order to integrate the concept of place into geographic information systems (GIS), places have to be modeled. This paper presents a methodology to model places with affordances. Affordances are what objects or things offer people to do with them. Our methodology of modeling places with affordances integrates cognitive and engineering aspects, therefore leading to a knowledge-representation that comes closer to the user. An example is used to show the applicability of the model. Our conclusion is that the integration of affordance-based models of places into future GIS will lead to a better communication between users and systems.

1. Introduction

People from a variety of disciplines lament the general erosion of a "sense of place" (Boyer 1996; Sorkin 1991; McCullough 1996). While great energy has been devoted to reflecting on and measuring the specific effects of these phenomena on our sense of place in the material world, it would seem equally important to explore possible ways for improving the representation of place within the digital environment.

This paper addresses the question of how the concepts of place might be represented within a geographic information system (GIS). A GIS is by definition an information system where digital information can be referenced to geographic locations towards the objective of modeling phenomena, dynamics, behavior, and potentialities in geographic space. And more often than not, GIS data are concerned with a specific geographic space. If a model of place can be formalized, it will become useful in computational environments, such as a GIS, where the concerns over the specifics of location and environment are inherent.

We advocate the use of affordances—those things which an object, an assemblage of objects, or an environment enables one to do—for modeling place within GIS. Through reference to

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* current address: Department of Geoinformation, Technical University of Vienna, Gusshausstrasse 27-29/127.1, 1040 Vienna, Austria.

writings from several disciplines such as geography, ecological psychology, and architecture, we elaborate a working definition of what is important about and what is meant by "place." We also provide a definition of affordances and discuss some advantages an affordance-based model of place would add to the models presently deployed in GIS. Current GIS define place as attributes attached to coordinate locations. We pay particular attention to user criteria and the dynamic, action-oriented qualities in our model. With this groundwork, we discuss the details of the proposed affordance-based model, and we provide an example of how important aspects of place can be captured and described through the use of this model. Thereby, we demonstrate how the use of the affordance-based model of place would represent a significant step forward in the migration towards more intuitive and individualized digital environments.

The remainder of this paper continues with an overview of the concept of place (Section 2). We discuss the objectives of a scientific study of place, review viewpoints from several disciplines, and explain why place is important in GIS. Section 3 introduces the term affordance. Section 4 presents the 3 part affordance model. In Section 5 we elaborate on the application of the model to important aspects of place. Section 6 presents conclusions and suggests directions for further research.

2. The Concept of Place

People interact with places in their everyday lives: they are constantly moving in places, working in them, and most importantly for GIS, making decisions in and about places. Places provide a context for everyday action and a means for identification with the surrounding environment. They help inform our own sense of personal identity—such as national, regional, cultural identity, socioeconomic identity, or religious identity (Entrikin 1991)—and they make us identifiable to others. For example, it is often the case that people's behavior can be linked to the places they come from. Also, judgments of what is good as opposed to what is bad vary according to the place of a particular act (Therborn 1980): Oddly, some people's reactions to graffiti indicate that graffiti is "in place" in art galleries, but "out of place" in public places such as subway stations (Cresswell 1996). Therefore, the meanings given to places are fundamental components of social interaction (Goffman 1959).

2.1 Scientific Study of Place

Scientific studies of place investigate questions such as what makes a place important, how people assign meaning to it, and how people select among the multitude of phenomena that constitute a place (Entrikin 1991). These studies form a difficult task, because in order to come up with a scientific concept of place it is necessary to accommodate the relatively objective view of the theoretical scientist (i.e., a decentered view) as well as the subjective view of the individual (i.e., a centered view) who directly experiences a specific place. Entrikin (1991 p.133) suggests that "understanding place in a manner that captures its sense of totality and contextuality is to occupy a position that is between the objective pole of scientific theorizing and the subjective pole of empathetic understanding." Experiences of places involve perception, cognition, and affection. Therefore, a place cannot simply be described as the location of one

object relative to others. The concept of place has to integrate both its location and its meaning in the context of human action. As Tuan (1977) puts it: place is space infused with human meaning.

2.2 Overview of the Concepts of Place

Geographers have become increasingly concerned with human experience and action (Cresswell 1996). Therefore, their interest in the concept of place has also increased. The geographical concept of place refers to the areal context of events, objects, and actions, and includes both natural elements and human constructions. It also incorporates the notion of change through time. Entrikin (1991 p.25) places special emphasis on the importance of narrative understanding for capturing the significance of place and argues that such relative centeredness allows us to capture elements of both objective and subjective reality.

Relph (1976) describes place as a unique instance of a pattern, generally composed of physical features and appearances (e.g., the setting landscape), observable activities and functions (e.g., ritual routines), and meanings or symbols (e.g., personal experiences). He says places can overlap and interpenetrate, and also includes the notion of insideness v. outsideness—for instance, a gypsy camp is a place regardless of its surroundings and location coordinates.

Curry's (1996) elaboration of a theory of place asserts that places do not have any sort of natural boundaries that "somehow existed long before people were there," but that place is a "location that has been given shape and form by people." He quotes Carl Sauer who stated that there are no natural places. Places are a human invention, engendered in a number of ways:

- *Naming*: The first thing settlers/explorers do when they arrive in new territory allows them to "carve out a portion of what was inchoate and turn it into a place, of which they can talk and to which they can return."
- *Applying Typologies*: Categorizing—"We make places by coming to see what is new to us as a case of what is familiar … this is a stream … river … inner city … ghetto … suburb."
- *Making/Picking out a Symbol*: Aggregating the infinite details of an area behind a representational icon. "The part stands for the whole: Pyramids—Egypt, Statue of Liberty—America, etc."
- *Telling Stories*: Narratives define literature place. The selection/popularization of these stories says much about the dominant characterization of a place—what "belongs" in a place and what may be marginal or marginalized. Stories of heroic battles against American Indians, Columbus, etc. turned "a nation into a place."
- *Doing Things*: Especially in a ritualized fashion: Curry talks about Cortez's ritual for claiming discovered lands for the Spanish Crown: "He supposedly moved walking on the said land from one part to another, and throwing sand from one part to another, and with his sword he struck certain trees … and did other acts of possession." Curry also mentions those things one does when moving to a new town, to gain familiarity and feel more comfortable there, as well as the matters of everyday habit and routine.

Architects and urban planners are naturally interested with the impact of the built environment on our sense of place, be it small scale (e.g., a chair or a room), or larger scale (a building or a city block). “As much as built space lets us move in some ways, but not in others, so it is the nature of all spatial constructions to encourage some experiences and discourage others” (McCullough 1996 p4). Buildings themselves, being intentionally produced, have a great impact on the subsequent behavior that happens in and around them.

Boyer’s (1996) essays are settled on the premise that in post-modern times computers guide the way we model the world and grasp reality in the same way that “the machine” provided the fundamental means by which people imaged the world over the greater part of the last century. By analogy, the machine and the computer inform the way people “pattern the city.” In the case of the computer, this is really a re-patterning of an alternative city, as the post-modern audience finds things “behind the screen” far more interesting than things in front of it, and tends to be beckoned into the escapist “receding space of the electronic matrix” (Gibson 1984; Dieberger 1995). In the Cybercity place is relatively non-existent, because the specifics of time, space, and architecture which are required to define and distinguish places have been eradicated. The Cybercity lacks a center, standing it in stark contrast with the material city, which guides travelers on its outskirts toward the “downtown” and “center.” The Cybercity offers highly mediated forms of communication over centerless, network-like structures—”the space of flows.” One of the greatest differences between place in the material world and space in the cyber realm is that the real world is very analog—it is continuous from a macroscopic point of view, whereas cyberspace is digital, Boolean, changing from one state to another with no transition.

2.3 Place in GIS

The concept of place has thus far been neglected within GIS. Present GIS are built on two basic standard data structures, vector and raster (Frank 1992), and model space with reference to the coordinates of a location. Such a way of mapping space, though useful, does not always match the way people think about their world. The spaces defined by mathematics and physics are enriched with human experience and become what we call “places” (Couclelis 1992). People assign complex meaning structures to places and based on such meaning they decide about subsequent actions and behavior. Current GIS do not easily allow mappings of these activities done in places. Integrating a model of how people conceptualize and perceive places into GIS will, therefore, increase the usefulness of these systems. If concepts of place become a fundamental component, we will then be able to use GIS to make these important decisions about places.

3. Affordances

The term *affordance* was introduced by Gibson (1979) who investigated how people perceive their environment. Gibson described the process of perception as the extraction of invariants from the stimulus flux and called these invariants affordances. Affordances are what objects or things offer people to do with them. Therefore, they create potential activities for users. Gibson’s theory of affordances is influenced by Koffka's (1935) work on Gestalt psychology, where he states that “each thing says what it is.” Gibson argued that by looking at objects people perceive

their affordances and not their physical qualities (e.g., size, color) as proposed by orthodox psychologists.

Much work with affordances builds on a fundamental tenet of ecological psychology, called *agent-environment mutuality* (Gibson 1979; Zaff 1995). This suggests that at a fundamental level, various aspects of agents and their environment need to be understood in terms of the relationships between them. Neither can be modeled without reference to the other. According to Zaff (1995), "They [affordances] are measurable aspects of the environment that can only be measured in terms of the individual." Particularly, it is important to understand the *action relevant* properties of the environment in terms of values intrinsic to the agent. For example, Warren (1995) shows that the "climbability" affordance of stairs is more effectively specified as a ratio of riser height / leg length (R/L). Experimentally, subjects of different heights perceived stairs as climbable depending on their own leg length, as opposed to some extrinsically quantified value (e.g., 18 inches, 2 feet). A ratio of .88 (R/L) was found to be the critical point where subjects, regardless of height, shifted their estimate from climbable to not climbable. Other low level affordances for objects, including object height, "sittability", and "graspability" have been studied to determine similar body-scaled ratios (Warren 1995; Mark 1987; Bingham and Muchisky 1995).

Additionally, dynamic or task specific conditions must be considered. In his discussions of walking through apertures, Warren (1995) points out the necessity of these considerations. Anatomical measurements of individuals can't simply be matched with door dimensions to determine aperture "passability." The act of walking produces movement that impacts one's ability to pass through a door, and accordingly to perceive this affordance. It's likely that other dynamic factors such as walking speed would also impact the perception of "passability."

Gibson was later criticized for grounding his theory of affordances only on perception and neglecting processes of cognition. Lakoff (1987 p.216) states that "the Gibsonian environment is not the kind of world-as-experienced that is needed in order to account for the facts of categorization … his account only deals with *individual* phenomena, not *categories* of phenomena." Norman (1988) investigated affordances of everyday things, such as doors, telephones, and radios, and argued that they provide strong clues to the operation of such things. He adapted Lakoff's view and recast affordances as the results from the mental interpretation of things, based on people's past knowledge and experiences which are applied to the perception of these things. Affordances, therefore, play a key role in an *experiential* view of space (Lakoff 1988; Kuhn 1996) and place, because they offer a user-centered perspective. Similarly, Rasmussen and Pejtersen (1995) have pointed out that modeling the physical aspects of the environment, provides only part of the picture. "The framework must serve to represent both the physical work environment and the 'situational' interpretation of this environment by the actors involved, depending on their skills and values." (p122). This can be broken into 3 relevant parts, the mental strategies and capabilities of the agents, the tasks involved, and the material properties of the environment.

Kuhn (1996) applied the theory of affordances in the area of human-computer interaction to spatialized user interfaces. Affordances of physical space are being mapped onto abstract

computational domains through spatial metaphors in order to bring human-computer interaction closer to people's experiences with real-world objects. Spatial affordances were grouped into four categories—affordances for (1) an individual user (e.g., move), (2) a user and an individual entity (e.g., objectify), (3) a user and multiple entities (e.g., differentiate), and (4) groups of users (e.g., communicate)—reflecting different task situations.

Heft (1996) briefly considered the role of the affordances of places in navigational processes. He argues that places have functional significance for us, e.g., we travel to places to utilize and engage their affordance possibilities. When considering people's recollections of previous environmental experiences, functionally meaningful places were the most salient features.

4. Agents, Tasks, and Environments

In an affordance-based model of place, 3 aspects of affordances must be considered: the agent, the environment, and the task (Warren 1995). Since the concept of place has to accommodate subjective views of individuals, their activities, as well as the environment in which they act, the definition of a place can be different for each individual (Figure 1). Our general model is as follows:

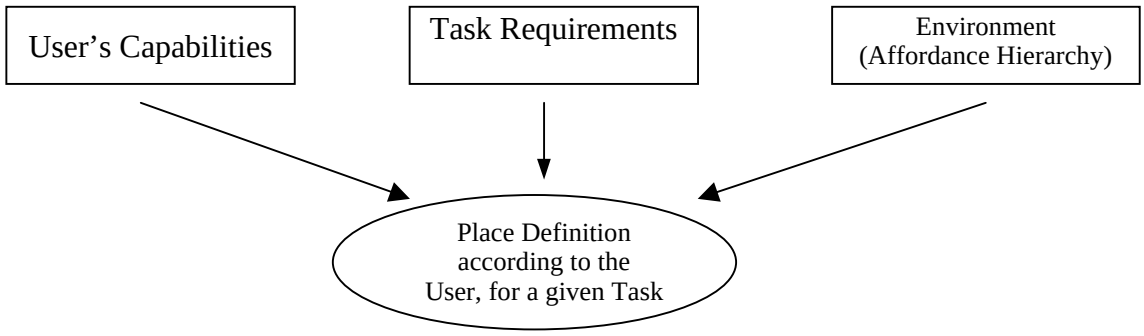

Figure 1 User and task-scaled definition of place

4.1 Environments

We apply Rasmussen's (1986) means-end abstraction hierarchy as a method of representing the environment, along with an object aggregation model. Together they provide a two dimensional mechanism to determine a set of possible purposes or functions of some configuration of objects such as might exist in a GIS (e.g., location and feature attributes). Conversely, possible configurations of physical objects that would suit a user's place needs would be derivable from a set of functional requirements.

The goal is to represent each level of the abstraction using metrics intrinsic to the agent. Therefore, it is desirable, as in the case of 'climbability', to uncover the relations between agent

and environment at physical, functional, and intentional levels. (See Dennett (1987) for discussion of the intentional nature of human agents).

The original abstraction levels are as follows (Rasmussen and Pejtersen 1995):

Functional purpose	Purposes and Values
Abstract function	Flow of Mass, Energy, Information, People, and Monetary Value
Generalized function	General Work Activities
Physical function	Specific Work processes and Physical Processes
Physical form	Appearance, Location, and Configuration of Material Objects

At each level, there is an important relationship between its two adjacent levels in the hierarchy. The level above suggests the proper or intended function for this level. The level below suggests how the functions of this level are to be implemented. The hierarchy is purposefully broad to suggest the full range of representational transformations that can be captured, yet is not meant to be absolute. More detail or abstraction may be added at the end levels or between levels as the application requires.

Object aggregation (or whole-part relations) is another important aspect of modeling place. In various contexts users require knowledge of whole-part relations. Knowing that a restaurant has a counter, booths, bathrooms, etc. helps the user determine what is to be expected at a restaurant. This allows the user, and should likewise allow a GIS, to reason about the functional environment to be found there. Additionally, object aggregation allows us to describe objects using the same abstraction level, while reducing the complexity of the model. For example, it may be useful to describe the physical form of tables, chairs, walls, food, and restaurant goers for a particular restaurant, but only the location and size when considering all the restaurants in a city district. Reducing the complexity allows the user to consider a larger set of restaurants, without considering all the details. Knowing the set of constituent parts that restaurants have allows this reduction to occur. According to Rasmussen (1986), this is "one way of coping with the complexity of the real-life environment … when the span of attention is increased" (p. 118).

4.2 Actions/Goals

We offer the following interpretation of the means-end hierarchy for a place, such as a store or restaurant:

Purpose:	Prosperity of the establishment, satisfaction of its customers, profit for owners
Abstract Function:	Flow of money, income, people (customers and employees), goods
Generalized Function:	Trade, inventory management, food consumption, socializing, getting informed

Physical function: Moving goods, eating, sitting, talking, smoking, reading, observing

Physical form: Location and appearance of people, furniture, and equipment

Many-to-many mappings can exist between levels and are important for our purposes since they indicate opportunities for multiple interpretations. There is an additional important interaction between levels. The perception of affordances at the lower levels are constrained by affordances at higher levels. If, for example, a person is looking for a table for lunch, he or she would perceive "sittability" according to the current task. Therefore, sitting in a smoking section may be the only location that affords smoking and sitting for a smoker, and under the current constraints, the only location that truly affords sitting.

4.3 Agents (User models)

Modeling an agent's capabilities provides knowledge about users that can be used to understand the action potential of the environment, in the same manner as measuring leg length helps us understand the perception of "climbability" of stairs. As we describe the user's cognitive resources and strategies, we are uncovering intrinsic metrics for higher level affordances of place.

Previous work in user modeling covers a wide range of affordance levels. Some work has focused on low level affordances such as image schemata (Lakoff and Johnson 1980). Others have looked at the scale of space, from small-scale to large-scale (Kuipers 1978; Zubin 1989; Downs and Stea 1973), often in sizes relative to the human body. Research on wayfinding (Siegel and White 1975; Passini 1992) has described the cognitive models of large scale space under the task of wayfinding. This is pertinent since it involves understanding space under the constraints of a particular task.

Couclelis (1992) also considers a continuum of spaces, augmented with increasingly complex layers of meaning. Like Tuan, she suggests that many types of spaces (socioeconomic, cultural, experiential) add experiential and subjective meaning to abstract spaces, making better approximations to the commonly used term 'place'. Likewise, the cultural variations in human understanding of space have been explored (Campari and Frank 1995; Gould 1995).

4.4 An Example

These various interpretations allow for user-scaled and task-scaled definitions of place. Using some of the examples above, we'll consider some possible links between levels in means-end hierarchy. For clarity we'll reduce the hierarchy to the 3 immediately relevant levels , referred to as the Why, What and How levels by Vicente and Rasmussen (1990). Though each level refers to the same material world, each level has more significance to a particular set of actors in context of a particular task. We would like to represent each level in a GIS to support decisions in the appropriate context. These authors suggest that for a given task, an agent enters the hierarchy at the What level.

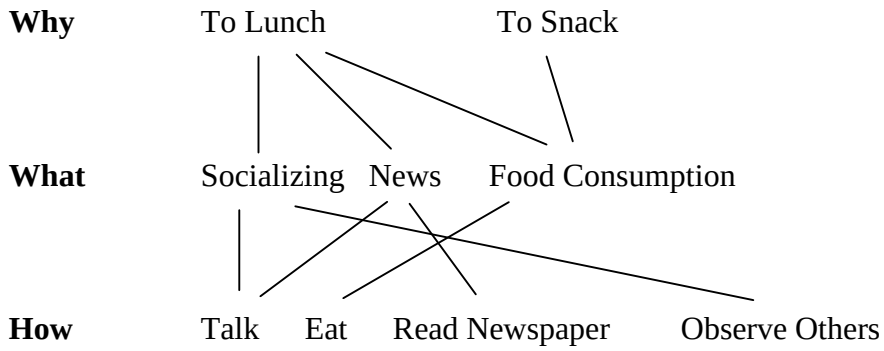

Figure 2 One possible Why, What, and How level description of a Restaurant

A final interpretation of the place as a suitable (or not suitable) restaurant is determined based on an agent's capabilities/preferences and current tasks. For example, an individual may consider eating, socializing, and getting the latest news to be the 3 essential ingredients for a successful lunch at a restaurant. For a quick snack, socializing may not be important, and for another individual of a different culture, socializing, if important, may entail different types of interactions, not afforded by some eating establishments.

Places such as towns, offices, or restaurants, can be defined by agents according to the activities which happen there, as we have discussed. Rasmussen and Pejtersen (1995) suggest that these types of places are "loosely coupled" systems. As such the affordances available rely more heavily on the intentions and profiles of the actors involved. That is, *other people* are an important part of the functional landscape for a given actor. Where functional and procedural norms may be highly dictated by technical and physical requirements of a system like a nuclear power plant, the desires and intentions of actors greatly impact the social norms of behavior in public places.

5. An Affordance-Based Model of Place

As discussed earlier, many domains of inquiry have focused on defining place. It is beyond the scope of this paper to consider them all, but we'll focus on several aspects that would provide advantages for a GIS if properly integrated. We suggest the following 6 aspects of Place:

- Physical features: Places consist of collections of objects. Each person perceives some set of affordances for a given small-scale object (e.g., a cup, a door handle, or a coffee pot) or collection of objects in large-scale space (e.g., a room, a house, or a restaurant).
- Actions: People perform actions in places. As we have seen, actions are one of the most important aspects that gives meaning to a place. Personal actions can create personal histories. Personal actions allow users to participate in accepted patterns of behavior, as well

as to personalize the place by performing individualizing actions. For example: "Whenever I'm at this mall, I go to store X because I always found nice and cheap clothes there."

- Narrative: Stories are told in order to help characterize the uniqueness of a place as well as to define normative/acceptable behavior, by revealing the past actions of others. On a continuum with a place defined by an extensive narrative history, is a place defined by a single event (e.g. Chernobyl, Lockerbee, Three Mile Island).
- Symbolic representations/Names: Certain places are referenced by symbols (e.g., New York City is often referenced as the "Big Apple") having symbolic and/or mythical meanings. (Entrikin 1991). Similarly, the Statue of Liberty is a common symbol for New York, related to its history as point of entry for many U.S. immigrants.
- Socioeconomic and Cultural factors: People identify themselves with places socioeconomically. For example, sea ports are special socioeconomic places since they afford transportation and trading, therefore, they afford a certain type of economic climate. Ports need people to work there (e.g., loading and unloading ships), but at the same time they attract those who are buying and selling goods. Similarly, different cultures afford different behavior in places. For example, black is the color of mourning in the west, whereas in China it is white. Williams (1981) views culture as a system through which a certain order is communicated and experienced.
- Typologies: People categorize places (see Curry above) in order to understand what is new, in terms of what is already understood. This represents an important mental strategy for dealing with complexity and new situations (Rasmussen 1986).

Based on our previous discussions of agents, tasks, and the environment, we offer the following suggestions for representing the above aspects of place in terms of our affordance model. In a GIS, such representations would then allow us access important features of places in support of users place-based queries:

- *Physical features* are captured by at the lower end of the means-end hierarchy. These are the affordances that have been most thoroughly considered and researched.
- *Actions* are directly represented by the ends-means hierarchy. By defining the relationships between intentions, functions, and physical features, we uncover which actions are possible, and which are constrained.
- *Narrative descriptions* (stories telling) establish a historical record at all levels of the abstraction hierarchy. What a place looked like, who was there, what they did, and why they did it. Since agent goals and intentions are more important in loosely coupled systems, this is an important way behavioral norms are established.
- *Symbolic representations* can be seen as an important cognitive adaptation. It allows users to represent complex objects with a simpler (abstract) representation. Our use of object aggregation allows us to perform similar reductions (or augmentations) of complexity.
- *Socioeconomic and cultural factors* that influence place definition are considered under user models. Important cultural characteristics determine what affordances are perceived at all levels of the abstraction hierarchy. As Rasmussen and Pejtersen (1995) suggest, the more

loosely coupled a place is, the greater the impact of the agents' values and norms, such as are represented under the term "cultural."

- *Typologies/Categorizations* represent another important cognitive strategy of users (Rasmussen 1986). Our model of place would allow for comparisons of places based on the means-end hierarchy. If two places have very different physical features, and yet provide the required affordances for a given agent and task, then they can be classified as similar places.

6. Conclusions and Future Work

This paper presented a methodology to model places with affordances. Affordances are what objects offer people to do and, therefore, represent potential user activities. We suggest that the integration of places into GIS would lead to a better match with people's real-world spatial interactions than do coordinate-based models and, therefore, to a more user-friendly GIS. Our approach outlines the broad categories of information that must be gathered in order to successfully answer place-based queries. The actual work of establishing a useful affordance hierarchy is formidable. Much work needs to be done to consider the perceptual aspects of place affordances, especially as they need to be mapped into the electronic domain of GIS. Fortunately, research on affordances for the supporting concepts of space in the computer medium has begun. The extensive work of modeling the interactions between agents, their actions, and environments, should be initiated to provide more understanding of the advantages and limitations of the affordance-based approach.

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