A cognition-based approach toward a general theory of map signs

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A carto-semiotic method for designing more effective map symbols is being proposed. After a brief review of major methods of communication, the cognitive processes of seeing, identifying, defining, naming, grouping, ranking and storing information are discussed. After pointing out real-world structures, concepts of superordinate-, basic- and subordinate categories and taxonomies are introduced. Following the proposed algorithm of semiotic transformation, the basic category's semantic component of symbol information emphasizes the referent's prototypical or defining properties. According to syntactics, the relational structure of all symbols belonging to the same category corresponds to perceived real-world structures, and as pragmatic component a symbol design's visual forms aim to match the average user's mental constructs to achieve the intended mental response.

Keywords: defining property; prototypical entity; unit economy; perceived real-world structures; superordinate-, basic-, subordinate categories; taxonomies; algorithm of semiotic transformation: semantics, syntactics, pragmatics; symbol information; symbol structure; symbol form; mental constructs.

Most painters, who paint for art's sake, resent being asked what their painting represents. Cartographers, on the other hand, design maps to convey what they intend to communicate. Ideally, the map's user should not have to ask any questions. But how could this ideal communication be attained? To explain the cartographer-map (sender) and map-user (receiver) communication, a number of papers have illustrated this process with various diagrams. Generally two overlapping circles are used with the first circle representing the information sent by the sender (map), the second standing for the receiver (map user), (cf. Figure 1).

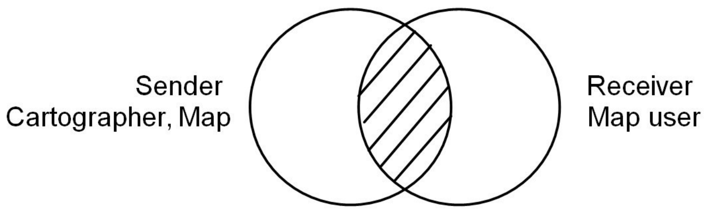

Figure 1: A simplified model of map communication.

The overlapping portion represents the transmitted information. The map's circle outside the overlap stands for information on the map that the user did not retrieve. If we compare this model of communication with language, a more familiar medium of communication, we find three prerequisites that need to be met. The sender and receiver must know the same *language*, use the same *syntax* and must have a similar level of knowledge (*vocabulary*, *subject matter*). Although language is considered one of the most effective means of communication, those who can't read will get nothing and readers with a minimum level of literacy will receive only part of the information encoded in newspapers, books, and so forth. Thus, it appears that methods of communication, using even the most efficient mode, do not always achieve perfect transmission. Similar principles apply to mathematics, chemistry, music and other fields that have an established symbol system, defined symbol meanings and a symbol syntax.

Therefore, we can assume that if cartography wants to achieve a good level of communication, it would need a similar system. A language presents its symbols of letters as words which have defined meanings, in concatenation to form sentences, paragraphs, pages and even volumes of information. The information encoded in maps, on the other hand, is restricted to one page representing a much-reduced geographic reality. Its symbols, or graphic forms that express information (Stolle, 1984, pp. 88-102), are very small, their variations are limited, and symbol groups can be read in any direction. Thus, the analogy of language does not seem to fit the map very well and a communication paradigm for maps needs to be found elsewhere.

Looking to cognition, we find that as the eye sees the world, processes of interpretation segment the visual field into entities (see Figure 2). Just as with the interpretation of aerial photographs, these processes use perceived cues of size, shape, texture, pattern, color, shadows, associations and others to identify *entities* and segregate the ones that are alike from those that are different to form *categories* (Rosch, 1978).

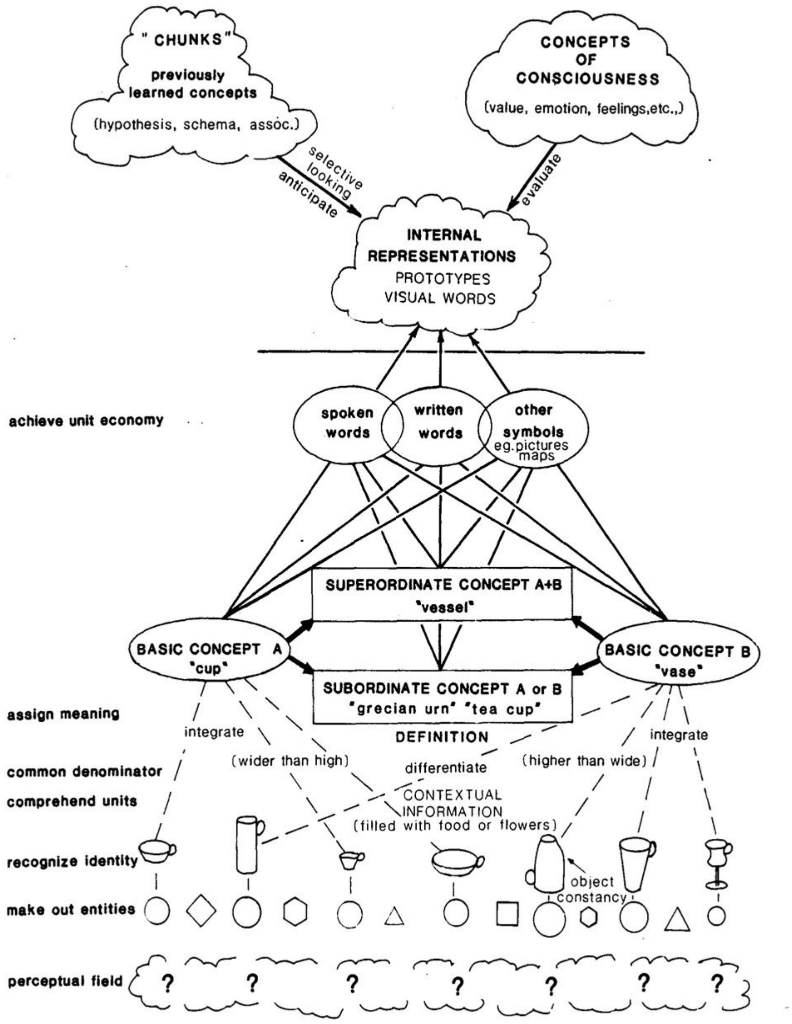

Figure 2: The processes of cognition (Stolle, 1984, p. 71).

Whatever these entities or *referents* stand for must be learned. The uninformed observer (child or adult) learns to associate a perceived referent with a visual description, name and definition, which is stored for future use. The *unit economy* of one mental form standing for, or subsuming, a detailed definition is extended further by integration into multi-level quad tree-like *mental structures* of related information, which can be accessed, revised and expanded at will. Rand (1979, pp. 83-85) calls the process of observing facts of reality and integrating them into new concepts *induction*. The process of subsuming new instances under a known concept, she refers to as *deduction* (ibid., pp. 36, 71). Thus the perceived world has been learned as internalized representations of mental images, names, definitions and rules, organized and stored by precepts of relationships.

When map users look at a symbol they assess its visual characteristics and try to match it with learned/stored information. To investigate some basic object-internal representation affiliations, a simple test, Figure 3, was devised (Stolle, 1984, pp. 105-111). It asked sixteen geography freshmen to draw a house inside a 1” circle. To strip away the drawing’s nonessential characteristics, participants were asked to copy the drawing into smaller areas. It was found that the largest drawings showed details like roof, siding, window panes and a door, while most of the smallest ¼” renditions had been reduced to simple shapes of striking similarities. For a closer look, all ¼” renditions were enlarged and traced on one compound drawing. The emerging dark-gray shape of coalescing lines, seen at the bottom of Figure 3, may very well be the *basic* or *prototypical* form of ‘house’ held by most members of this culture at this time. The drawings of the test’s other objects: road, railroad, tree and bridge, produced similar outcomes. Since the class had not been shown any pictures of the test’s objects it can be assumed that the students’ drawings were externalizations of learned and memorized information.

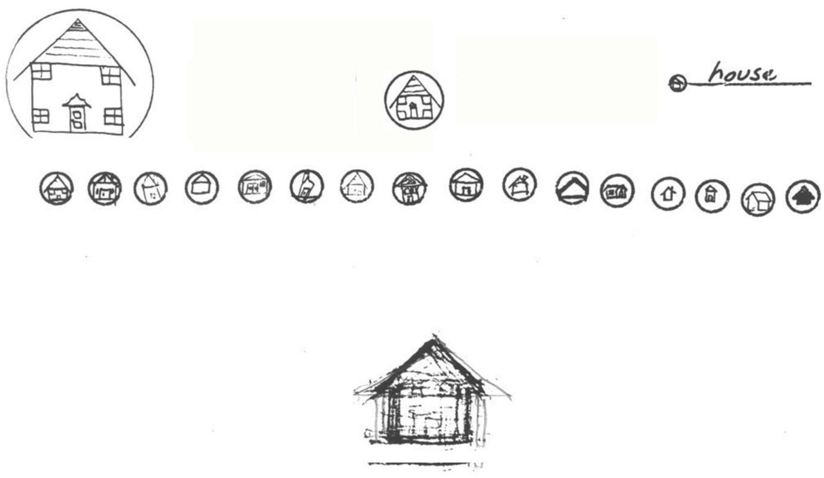

Figure 3: Shared forms of a ‘prototypical house’

Ideally, the designer of map symbols should not only be aware of, but tap this universal code with map symbols “that mesh closer with our cognitive system” (Olsen, 1979, p. 40). A look at the concepts of semiotics can shed some light on how this might be possible. Figure 4 illustrates and explains cartographic semiotics and the functions of its three components: *semantics*, the relationship between a mapped referent and its symbol, *syntactics*, the relationships between all symbols of a given category and *pragmatics*, the relationships between a symbol and its viewer’s perceived/ internalized representations (Morris, 1938; Stolle, 1984).

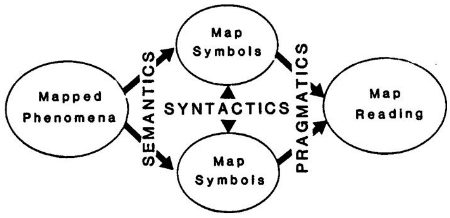

Figure 4: Semiotics: A cartographic interpretation of the theory of signs (after Muehrcke, 1972).

The example, seen in Figure 5, represents the category buildings (house of students' test) as a basic mark which has the distinguishing angles (rectangular or circular) of man-made structures. As semantic component (symbol>referent) a symbol's appearance should display the *prototypical* (most typical or basic) property of a referent's learned world category to identify its defining property. As syntactic component (symbol>symbol) a symbol's visual status in the mapped world should not only reflect its category membership but its rank and order in the learned world's correlational structures. For example, smaller buildings are shown as standard size rectangles or squares. To distinguish identical shape symbols, such as dwelling, school or church, a small defining sign like flag, cross, etc., is added. To emphasize rank, larger ones are mapped to scale as footprints. Towers and tanks are represented as circles. Filled with a cross hatching, large dwellings or places of employment look more prominent than large barns, warehouses or tanks which are filled with a simple line pattern.

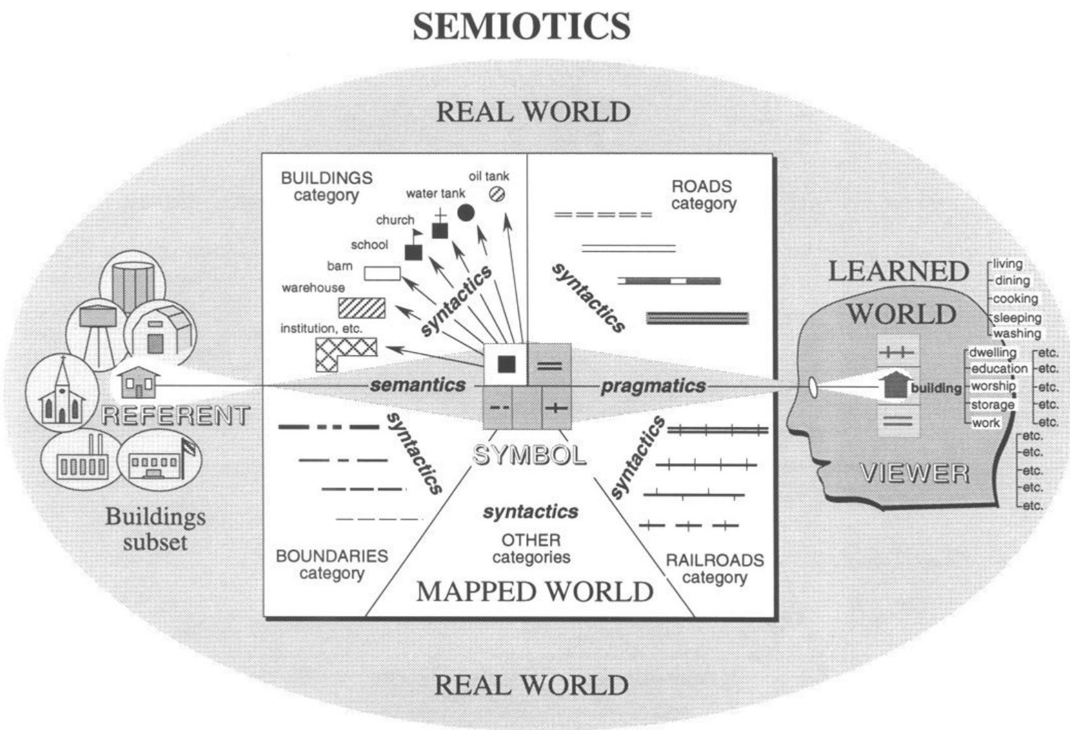

Figure 5: A depiction of Semiotics, its components and their functions.

Thus, these symbols portray a referent category's prototypical property to signify shared characteristics and a defining property (function, or shape) to distinguish symbols of individual referents from fellow members of the same category. As pragmatic component (symbol>viewer) the graphic code of a mapped referent should aim to mesh with the viewer's mental construct to access his/her learned information and meaning. Pragmatics, of all branches of semiotics, has by far received the greatest share of researchers' attention. For example, investigations of differences between actual and perceived magnitudes of symbols, between actual and perceived equal increments of gray scales and others have generated a general understanding as well as solutions, that overcome these psychophysical phenomena on maps.

Of equal importance, but so far much neglected, is finding some answers to how one can create *symbol forms* that signify a *visual message, which achieves an intended mental response.*

While the intuitive skills of the cartographer, based on his training and many years of experience, have coped with that challenge, their traditional role as sole design decision maker is being contested. Changes in training and modes of production, as well as the ever-increasing opportunities for map users to make their own maps, have changed the field of map making. Therefore, the conventional mechanism for pre-processing map information needs to be articulated to assist mapmakers with little or no training. In search for this instrument, reviewed principles of cognition have provided some operational heuristics which helped arrive at algorithms and strategies for a cognitive or *carto-semiotic method* of designing map symbols. Perhaps the major obstacle to good symbol design is the stronghold of one's every-day's mode of cognition. Hence, the proposed method aims to overcome the word for word or item by item approach toward symbolization, by first identifying the real-world's perceived defining properties of objects before portraying them on maps. Based on the defined branches of semiotics, Table 1 helps conceptualize the proposed method's *algorithm of transformation* (Stolle, 1984, pp. 126). By identifying each semiotic branch's conditions of transformation and symbolic analogies, it defines the proposed method's *rules* or *cognitive grammar.*

Table 1: An algorithm of transformation.

Semiotic Relationship	Conditions of Transformation	Symbolic Analogy
Semantics (referent > symbol)	symbol's attribute(s) must express defining properties of object and/or its referent's mental constructs	symbol information
Syntactics (symbol > symbol)	Symbol structure must correspond to perceived correlational object structures	symbol structure
Pragmatics (symbol > viewer)	symbol's stimuli must have desired visual impact and achieve intended mental response	visual form

Returning to the results of the students' test, their largest drawings most likely reflected the individual's contents of his/her mental construct 'house'. An individual's knowledge consists of different categories (details) of information, which range from all-inclusive to specific, and varies with an individual's interest and education. Beyond the level of house types comes the level of house parts like basement, walls, roof, windows, doors, etc. Lower yet, components like locks, hinges, electric wiring, etc. are stored. The structured order can be extended upward to form subdivision, village, and city portrayals of the learned world (see Figure 6). In her article 'Principles of Categorization', Eleanor Rosch (1978) identifies three major levels of categories: *superordinate* (buildings), *basic* (house), and *subordinate* (bungalow, cape cod, etc.). Extending the taxonomy 'building' upward, by including houses, a church, school, factory, and so forth, forms a village (level n+l). As *genera*, the basic level object has an universal definition as a functional entity. It has physical structures and a population, has an economic structure, provides a number of services, and so forth. As *differentia*, 'Village ' has its very own characteristics, including spatial anatomy and location. Recognized first by

Gestalt psychologists, Village A, when viewed as a whole, provides more information than the sum of all parts. There is no other village exactly like it. The uniqueness of place and location in space, or the study of geography, becomes more complex at higher levels of regional and global taxonomies, as they subsume categories of greater magnitudes and diversities.

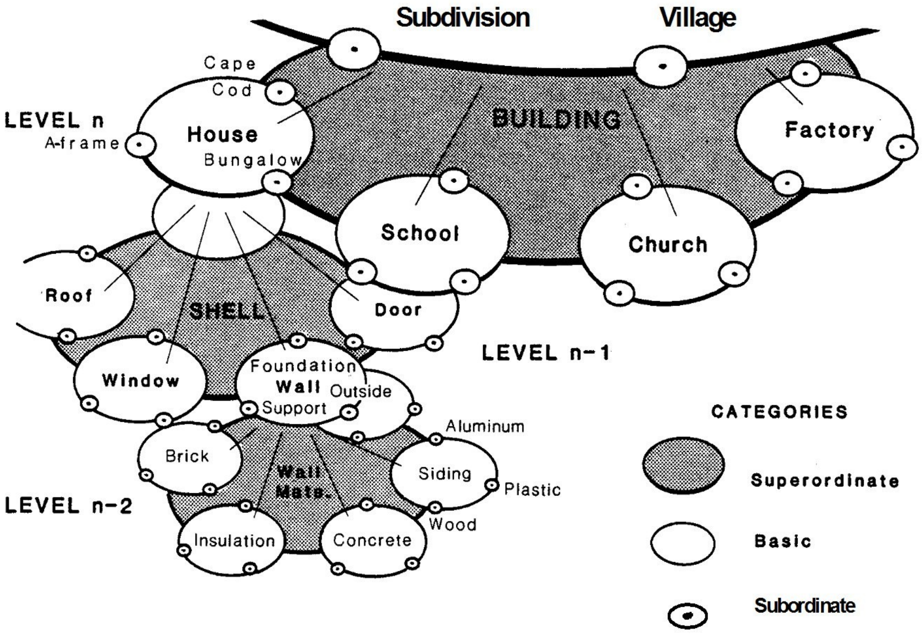

Figure 6: Multi-level taxonomies (Stolle, 1984, p. 118).

While basic levels of categories are shared by most individuals, subordinate levels vary with training or interest and may be stuffed or sparsely filled with information. For example, all individuals can differentiate between trees and bushes, many can differentiate between coniferous and deciduous trees. A few can recognize major coniferous types like pine, spruce, etc., but only specialists know the taxonomies of all the coniferous and deciduous trees.

Thus it appears prudent that the designer concentrates on basic categories and the challenge to identify all of the map referents' prototypical characteristics that can be mapped and to match them to the average user's mental constructs. This task can be assisted by a writing technique introduced by Gabriele Lusser Rico. In her book *Writing the Natural Way*, or writing with the right side of the brain, she describes clustering, which "is a nonlinear brainstorming process akin to free association … [we] naturally come up with a multitude of choices from a part of our mind where the experiences of a lifetime mill and mingle. Selecting a nucleus word as stimulus 'for the *Design-mind* [right hemisphere], each association leads inexorably to the next with a logic of its own even though the *Sign-mind* [left hemisphere] does not perceive the connections" (Lusser Rico, 1983, pp. 28-31). In other words, focusing on the nucleus word (name of a map entity) enables the designer, or team of designers, to mentally peruse their multi-layered information repository of a lifetime and tease out and write down all attributes that have come to mind. The author stresses that one must move the pencil at all time to keep the ideas flowing. To become proficient, this technique needs to be practiced as it has not been part of a cartographer's training. Once the characteristic attributes have been tabled and evaluated, the unsuitable ones are eliminated. The designer's second task is to ascertain graphic parity by searching themselves (like the students' test) for matching mental images/constructs. Entering unknown territory, the designer looks at one characteristic and tries to conjure up graphic associations, i.e.: mining >picks and/or shovel, mineshaft, hospital >red cross, etc. Once all possible images have been extracted they are ranked by suitability for representation and effect of communication. Again, cartographers may want to consult an experienced graphic designer.

To help demonstrate this process, the well-known symbol for a handicapped person is used. The externalized characteristic attributes found for this entity are: cane, crutches, walker, wheel chair, etc. A rank by suitability identified the wheel chair having the highest suitability for representation and communication. As seen in Figure 7, the symbol design may have started, very much like the students' drawings of a house, with a larger, detailed sketch of a person sitting in a wheel chair. Making progressively smaller sketches helps illustrate the mental process of eliminating all unnecessary attributes until the most essential, cartoon-like rendition has been carved out. The final symbol, seen in Figure 7 right, has succeeded in capturing the condition of a person who is totally dependent on a wheel chair (person and chair have become one), for support (passively leaning back) and transportation (wheels). This remarkable symbol does not only have refinement and simplicity but it also communicates its message with an unmistakable clarity.

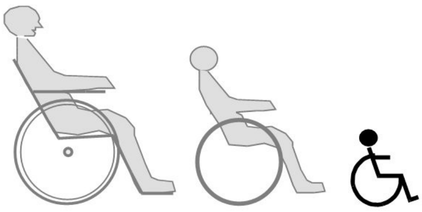

Figure 7: Conceivable stages of a symbol's design.

Besides road signs and signs for facilities in public places, the general public finds symbols on car dashboards, in garments' washing instructions and so forth. With increasing use of the computer, tablets, smartphones and the internet, new symbols, such as the Emoij signs, are offered and learned by an ever-growing number of users. While nearly all can recognize and understand the meaning of good symbols, designers are constantly challenged to be innovative and create new symbols. Hence many would welcome the availability of a resource that contains a comprehensive collection of common symbols, acronyms, signs and their meanings. Besides inspiring and assisting the design of new symbols, it would help avoid needless redesigns or changes of any well-established symbols.

To enhance communication and avoid confusion, it is imperative that once symbols, colors, patterns and their designations have been designed for a given project, they must be kept the same for all maps belonging to one series or an atlas publication.

References

Morris, Ch. (1938). *Foundation of the Theory of Signs.* Chicago: The University of Chicago Press.

Muehrcke, P. (1972). *Thematic Cartography*, (Commission on College Geography Resource Paper No. 19). Washington, D.C.: The Association of American Geographers.

Olson, J. M. (1979). Cognitive cartographic experimentation. *The Canadian Cartographer, 16*(1), 34-44.

Rand, A. (1979). *Introduction to Objectivist Epistemology.* New York: A Mentor Book, New American Library.

Rico, G. L. (1983). *Writing the natural way: Using right-brain techniques to release your expressive powers.* Los Angeles: Tarcher.

Rosch, E. (1978). Principles of categorization. Cognition and categorization. In E. Rosch & B. B. Lloyd (eds.), *Cognition and Categorization* (pp. 27-48). Hillsdale, N.J.: Erlbaum.

Stolle, H. J. (1984). *Symbol Structure, Information Content and Visual Form: A Carto-semiotic Theory of Map Signs* (Unpublished doctoral dissertation). University of Wisconsin, Madison, USA.

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