Transcepts: Connecting Entity Representations across Conceptual Views on Spatial Information

Eric J. Top[1]
Department of Human Geography and Spatial Planning, Utrecht University, the Netherlands

Simon Scheider
Department of Human Geography and Planning, Utrecht University, Princetonlaan 8a, Utrecht, the Netherlands

Abstract

Analysts interpret geographic and other spatial data to check the validity of methods in reaching an analytical goal. However, the meaning of data is elusive. The same data may constitute one concept in one view and another concept in another. For example, the same set of air pollution points may be regarded as field values if they are considered pollution measurements and objects if they are considered locations of measurement devices. In this work we adopt a framework of conceptual spaces and viewpoints and show how entity representations in one semantic interpretation may be related to entity representations in others in terms of what we call transcepts. A transcept captures which things represent the same entity. We define and use transcepts in the framework to explain how different views of geographic data may relate to one another.

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1 Introduction

Geodata analysts usually have a choice between multiple valid conceptualizations of their data. As a result, different analysts may have different interpretations, which could lead to disagreement about the underlying concepts. Considering conceptual discussions are usually at high levels of complexity and abstraction, finding common ground is challenging. Also, for the automation of analytical tasks, e.g., with artificial intelligence, knowledge representations need to align with the conceptual view of the analyst. Understanding the interpretations of analysts and how they align is important for both these problems. Next to knowledge representation, there is a need for entity representation. In other words, we need *transcepts*.

Before we explain what transcepts are, briefly consider the word *concept*. It can be traced back to the Latin verb *concipere*. This verb can be dissected into the prefix *con-*, which means approximately *with* or *together*, and the verb *cipere* (or *capere*), which roughly translates to *take*, *take on* or *take in*. According to this, a concept can thus be understood as something that is, e.g., *taken with*, *taken together* or *taken on with*. Similar constructions of a prefix and the suffix *-cept* are found in the words *deception*, *perceptual*, *receptor* and *acceptance*, and in each case the prefix seems to add additional meaning to the process of *taking*.

The word *transcept* also has this structure. The prefix *trans-* is best translated to *across* or *over*. For example, the term *transdisciplinary* means *across* or *over disciplines* and the

[1] Corresponding author

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term *transgender* means *across* or *over genders*. In similar fashion, a transcept can be understood as something that is taking [things] across [something or someplace]. The notion of transcepts is useful as a connection between different representations of the same entities or phenomena in different interpretations. For example, a well-known comic circulating the internet (See Figure 1) depicts how two valid conceptualizations of a shape are incompatible. In one conceptualization the shape seems to form the symbol *6*, while in another it forms the symbol *9*. In a single interpretation, these conceptualizations are not compatible. An interpretation of the shape as *6* contradicts any interpretation of the shape as *9*. However, it is still useful to note that the shape may be both *6* or *9*, e.g., when considering possibilities or hypothetical scenarios. Things that form a transcept do not necessarily contradict one another. It could for example also be useful to know that two people standing side-by-side interpret the shape as being *6*.

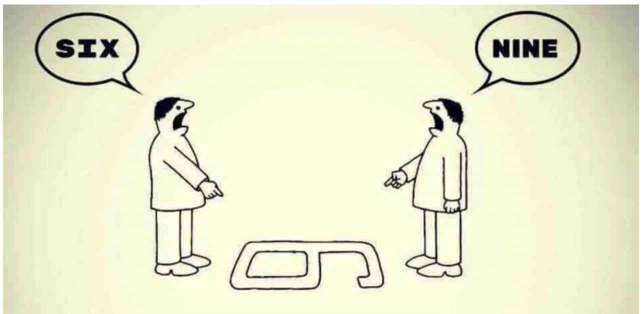

Figure 1 Two incompatible concepts in two interpretations represent one shape on the ground. The concepts *6* and *9* form a transcept across the two interpretations. (Author of image unknown)

In the practice of geographic information it also occurs that a single entity or phenomenon can be interpreted in multiple valid ways. We give three (hypothetical) example cases and we elaborate on them after we establish the conceptual space framework. The example cases are:

- **Volcano eruption**: A two-dimensional cartographic view may hold *where* a volcano eruption took place and a temporal view (e.g., with a calendar) may hold *when* the eruption took place. In terms of conventional geographic information concepts, in the first view the volcano eruption is an object and in the second view it is an event. However, the object on the cartographic map and the event on the calendar represent the same eruption.
- **Trees in the Amazon rain forest**: If we assume that the Amazon rain forest is identifiable by the set of its trees, then it can be identified by collecting all trees that are part of it [7]. However, the set of all trees is not equal to the rain forest because the latter is atomic (e.g., half of the Amazon rain forest is not the Amazon rain forest). Nonetheless, they do represent the same phenomenon.
- **Road network**: A road network can be considered a relation over a set of street junctions. It can also be considered a set of objects, because each of these roads are tangible and have qualities, e.g., they may be paved with concrete. The relation and the set of objects both represent the roads.

Hautamäki [9] proposes a knowledge representation framework with a conceptual space that may be partitioned into various views. A conceptual space is a geometric structure that may be used for knowledge representation and views are in this respect partial or incomplete substructures of the conceptual space. In this paper we introduce transcepts as a notion in geo-analytical cognition in context of conceptual spaces. We first give a quick background of conceptual spaces and shortly reflect on the importance of concepts to geographic information. Following, we provide examples of transcepts in geography. We then define transcepts in the philosophical framework proposed by [9]. In this framework a transcept serves as a connection between different things that represent the same thing across these various partitions. We then show how the conceptual space framework can be used to model the transcept examples.

2 Background: Conceptual spaces and geographic concepts

Gärdenfors [5] introduces conceptual spaces as an alternative to the symbolic and associative approaches to knowledge representation. The idea of a conceptual space is that concepts can be represented as regions of objects in a space consisting of one or more quality dimensions. For example, a quality dimension 'taste' could host the qualities 'salty', 'sour', 'sweet', 'bitter' and 'umami' and a quality dimension 'physical state' could have the qualities 'solid', 'liquid', 'gaseous' and 'plasma'. Then the concept of sweet liquids would be the set of all objects with the qualities 'sweet' and 'liquid'. A conceptual space is a metric space, meaning there is a notion of distance between qualities and concepts, and thereby implicitly a topological space, meaning there is a notion of neighborhoods of concepts.

Conceptual space-based learning models are shown to outperform models based on multidimensional feature spaces [12] and conceptual spaces have been used for a variety of applications, including spatial cognition [1], AI-learning, and (vague) classification and categorization [3]. Hautamäki [9] provides an alternative framework that makes it possible to partition a conceptual space into multiple "points of view". We use Hautamäki's framework to model how analysts may hold different views with regard to the same data.

A search for concise and correct conceptualizations characterizes many theoretical contributions to GI-science. This search particularly took off after the publication of Couclelis' work [2], which redirected a discourse on syntactic data types to one on objects and fields, two important semantic concepts of geographic information. Goodchild, Yuan and Nova [6] argue that all concepts in geographic information science are generalizable to so-called geo-atoms. Galton [4] extents the discourse beyond spatial concepts and suggests a temporal framework of concepts with a "*process-priority view*" (p.1). Kuhn [10] and Kuhn and Ballatore [11] introduce a set of core concepts of geographic information.

3 Conceptual spaces and views

A conceptual space is an abstract notion that encompasses all concepts given some determination base, i.e., a base structure that establishes the building blocks of concepts and relations between them. A view is a structure that limits the elements in the determination base to those 'within view'. Those 'outside of view' either merge into a single element or simply stay out of consideration. If two different views are based on the same determination base, they can be compared by means of the elements of the base. In this section conceptual spaces and views are defined in more detail using Hautamäki's work [9].

A conceptual space can be defined with respect to a *determination base*, which is a structure $\langle I, D, E, S\rangle$, where I is a set of *determinables*, D is a set of *determinates*, E is a set of *entities* and S is the so-called *state function* $S : E \to D^I$. The codomain D^I is the *conceptual space* for the entities of E. The notation of D^I denotes a set of functions from the determinables I to the determinates D, i.e., $D^I := \{f | f : I \to D\}$. An example of this is a function $Belgium : I_B \rightarrow D_B$ where $I_B \subseteq I$ and $D_B \subseteq D$ such that for example $Size \in I_B$ and $30689\ km^2 \in D_B$. Then an instance of this function could be $Belgium(Size) = 30689\ km^2$. An element of D^I is called a *state* and any set of states, i.e., any subset of D^I, is called a *concept*. Note that concepts can be subsets of other concepts. As such, they form a concept lattice (c.f., [13]).

According to Hautamäki [9], a conceptual space can be approached from different points of view or viewpoints. Viewpoints can be defined as structures of subsets of determinables and theories. We choose to refer to viewpoints simply as *views*. More specifically, a *view* relative to some determination base is a structure $V = \langle K, T \rangle$ where $K \subseteq I$ and $T \subseteq D^K$. The set of functions T is called a *theory* and the set D^K is a *subspace* of the conceptual space D^I. For example, a temporal view is one where some time determinable (e.g., *date*) is an element of K and the state function and the theory relates certain entities (e.g., birthdays) to certain determinates, e.g., some dates. A view-specific state function S_K for the subspace D^K is defined as follows: $S_K := \{(x, y) \in S | x \in K\}$.

Each view has a *scope*, which is the set of entities that have some distinguishable state within the view. The notion of scope is necessary because entities may be indistinguishable in some views. For example, if a conceptual space has no temporal states, it is impossible to distinguish over time, meaning the observation of a tree at 10 o'clock is indistinguishable from an observation of that same tree at 11 o'clock. A subtle consequence of this is that in a view a single state may represent more than one entity. For example, time could be aggregated to years, meaning that each (non-leap year) year state represents 365 day entities. Two states from different views may correlate with one another, which means they have the same entities in their scope. For example, Peking and Beijing both refer to the capital of China and may be considered synonymous, although the former is of a more historical view while the latter is of a more contemporary view.

Objects, fields, events and networks are common concepts in geographic information [2, 10, 6, 4]. In the context of conceptual spaces these concepts can be defined as mathematical objects from or structures over the elements in the determination base along with a semantic interpretation. With respect to a conceptual space, an object can simply be defined as a state with some geospatial definition. Let x be any state and g the concept of all geospatial things. If $x \in g$, then x is an object. Similarly, x is an event if $x \in t$ where t is the concept of all temporal things. Note that in both cases x is a function. For example, if x represents the 2022 winter olympics, then $x(City) = Beijing$, where $City$ is a determinable and $Beijing$ is a determinate.[2]

Fields and networks can both be defined as relations between sets of states, i.e., between concepts. Any relation between any concept on the one hand and a spatial concept on the other is a field, whereas a relation of a concept to itself is a network. For example, a relation between the concept of temperatures and the concept of locations in Spain could be a temperature measurement function (Conventionally considered a field) and a relation on locations in Spain to itself could indicate connections between those locations (A characteristic of, e.g., any road network).

With respect to the conceptual space framework, we define a transcept as a set of any multitudes of states and concepts and relation tuples between them. We denote a transcept with θ. A transcept suggests that any of its elements represents the same entity

[2] This second example with Beijing shows how something can be a state in one context and a determinate in another. The instances $x(City) = Beijing$, $Beijing(Country) = China$ and $Country(Beijing) = China$, where $Beijing$ takes each of the three possible roles, could occur within the same view.

in E as all other transcept elements. For example, the state of a particular *Crowd* and the concept $\{Person_1, Person_2, ..., Person_{500}\}$ may represent the same crowd entity, so a transcept of them could be $\theta\{Crowd, \{Person_1, Person_2, ..., Person_{500}\}\}$. Transcepts thus link representatives of the same entity across different views. If one view includes the state and not the concept and another view includes the concept and not the state, then the transcept serves as a 'bridge' between the views.

4 Modeling the examples with the framework

We can now define a transcept for the volcano eruption case across the cartographic and temporal views. Let *Space* be the cartographic view $\langle A, X\rangle$ where $lat, long \in A$ are latitude and longitude determinables and where $x \in X$ is the state representing the volcano eruption in space. Also, let *Time* be the temporal view $\langle B, Y\rangle$ where B has the determinable *Date* as element and where $y \in Y$ is the state representing the volcano eruption in time. Across these two views $\theta\{x, y\}$ is the transcept of the volcano eruptions. Figure 2 shows a schematization of the example. The determinates that relate to the determinables form quality dimensions and are indicated by the corresponding determinables. Because respectively x is in a spatial view and y is in a temporal view, x is an object and y is an event.

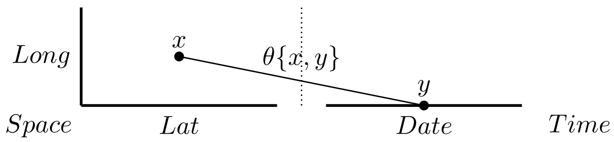

Figure 2 States in two views connected by a transcept

The example shows how a transcept can bundle multiple states that represent the same entity. That is the case if x and y are actually the same state in the conceptual space. If x and y represent the exact same entity (i.e., $\forall e \in E\ S(e) = x \iff S(e) = y$), then $x = y$ and $\theta\{x\} = \theta\{y\} = \theta\{x, y\}$. However, x and y can be different states because an entity that is represented by one state in one view may need to be represented by multiple states in another. This becomes apparent in the next example.

The Amazon rain forest example can be modeled either using one view or two views. We start by modeling the example with two views. Let $V = \langle K, T\rangle$ be a view where $lat, long \in K$. For the sake of the example, assume that $t_1, t_2, t_3 \in T$ are all the trees in the Amazon rain forest. The concept of the three trees $\{t_1, t_2, t_3\}$ may be denoted as *Trees*. Let $V' = \langle K, T'\rangle$ be another view where $Amazon \in T'$. Then $\theta\{Trees, Amazon\}$ is a transcept across V and V'. The example is visualized in Figure 3. To see that they can also be in one view, let $V* = \langle K, T^*\rangle$ be a third view where $Amazon, t_1, t_2, t_3 \in T^*$. Then $\theta\{Trees, Amazon\}$ is also a transcept across the single view V^*.

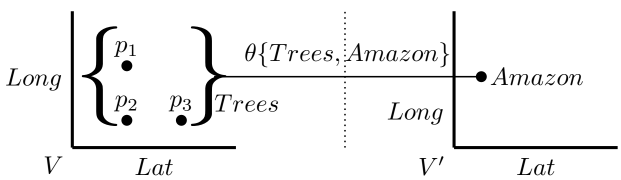

Figure 3 Between state and concept transcept

This example shows how a concept and a state can represent the same entity. This is useful for understanding how qualities are assigned to collections. It would be confusing to assign qualities *'endangered'* to a set of trees to indicate the Amazon rain forest is endangered, because it is then unclear whether the trees or the forest is endangered. With transcepts the distinction between the set of parts and the whole can be made, thereby handling mereological problems (c.f., [8]) without losing the information that they represent the same thing.

There are at least three different views with which the road network can be modeled. In the first the road network is viewed as a relation over vertices, in the second it is viewed in terms of road objects and in the third it is viewed as a single roads object. Roads can also be modeled as sets of location states (e.g., to model lines), but we choose not to do so here. Let $lat, long \in K$ and let the views be respectively $V^J = \langle K, J \rangle$, $V^O = \langle K, O \rangle$ and $V^N = \langle K, N \rangle$ where $j_1, j_2, j_3 \in J$ are road vertices, $Road_1, Road_2 \in O$ are roads and where $Roads \in N$ is the entire road network. Multiple transcepts can be defined across these views. Across V^J, V^O and V^N we find the transcepts $\theta_1 = \theta\{(j_1, j_2), Road_1, Roads\}$ and $\theta_2 = \theta\{(j_2, j_3), Road_2, Roads\}$. These two transcepts are visualized in Figure 4. Another transcept is found by creating concepts. That is, the concepts $\{(j_1, j_2), (j_2, j_3)\}$ and $\{Road_1, Road_2\}$ and the state *Roads* all represent the same entity, so we can also define a transcept $\theta_3 = \theta\{\{(j_1, j_2), (j_2, j_3)\}, \{Road_1, Road_2\}, Roads\}$. This third transcept is visualized in Figure 5.

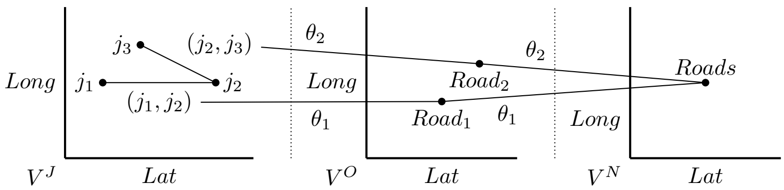

Figure 4 Transcepts of road entities

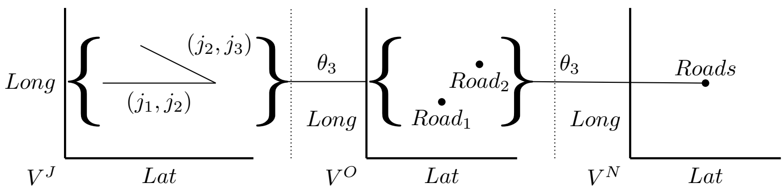

Figure 5 Transcept of network entity

This example stresses how transcepts are different from concepts. Where a concept is a set of states representing different entities that are understood as one theoretical thing, a transcept is a set of states representing exactly one entity across many understandings of their theory. In the example, $Road_1$ and $Road_2$ are bundled in a set while they represent two different road entities in a single view. The same is impossible for a transcept. On the other hand, in θ_1, $Road_1$ and *Roads* are part of the same transcept. No concept within the views can have all these elements because no view includes all these elements.

Furthermore, the set of tuples in V^J can be considered an example of the network concept in geographic information, which is characterized by connections between nodes [10].

5 Discussion and conclusion

Transcepts seem to be a new notion in the context of conceptual spaces. Where concepts are instrumental to knowledge representation, transcepts seem to be central notions of entity representation. They are useful for talking about different representations of the same entity without either confusing or forfeiting the semantics of those representations, which are captured in concepts. Interestingly, some of the well-known concepts of geographic information seem to be implicitly represented in Hautamäki's framework. Any objects and events can both be modeled as states in respectively spatial and temporal views, networks arise from relation tuples between states in the same view, and determinables seem to have applicability comparable to fields. It may prove worthwhile to further investigate these resemblances in future work, as well as to further develop the framework. For instance, it may be useful to have a theory of transcept functions and to extend the notion of concept lattices to transcepts. Also, Hautamäki proposes a logic of points of view which has mostly been ignored in this work, but which could also increase the applicability of transcepts in knowledge and entity representation tasks.

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