AhaNets: Structuring Semantic Networks to Enhance Innovation

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Abstract

An *AhaNet* is a semantic network that has been structured to increase the probability of finding the key information required for an innovative solution—which helps produce more *aha moments*. Principles to structure the semantic network primarily flow from a new theory of innovation, the *Obscure Features Hypothesis* (OFH), which states that almost all innovative solutions result from two steps: (1) noticing a rarely noticed or never-before noticed (i.e., obscure) feature of the presented entities (e.g., physical objects and materials) of a problem, and (2) interacting the obscure feature with other entities to produce the desired effects to solve the problem [2]. The resulting structured semantic networks (or *AhaNets*) can improve the success rate of both steps of the innovative process. Both empirical evidence with benchmark innovation problems and anecdotal evidence solving unsolved engineering and design problems suggest that the use of *AhaNets* leads to more innovation.

Keywords

innovation, semantic networks, semi-automated creativity

Why Focus on the Obscure?

The *AhaNet* approach to enhance innovation is based on the common sense observation that if an unsolved problem ultimately has a solution then people are overlooking something. If the solution were based on something commonly noticed; then, more than likely, the problem would have been solved by now. For this reason, we focus on what is infrequently noticed or never-before noticed (i.e., obscure).

What kinds of obscure things should we look for? Deepening the analysis of the traditional structure-function-behavior framework, we describe a solution to a physical problem as follows: some collection of *objects, materials*, *energies* (e.g., magnetic), and *forces* (e.g., centrifugal) that interact to produce the desired *effects* needed to solve the problem [5]. These four types of *entities* have *features* that inform how they can interact and what effects they can produce [5]. For example, a rubber band can interact with my fingers in a particular way so that it can fly across the room. The thickness of the rubber band is one of the features that influences how far it can ultimately fly.

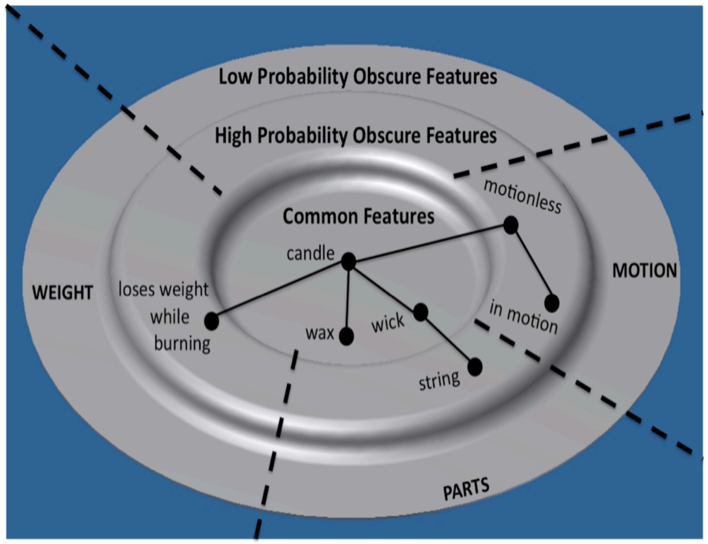

figure 1: Small part of an *AhaNet* for a candle. The semantic network is structured by two principles: (1) the *Feature Types Taxonomy* (dotted lines) divides the feature space into regions and (2) the *Just Outside the Basin Hypothesis* (JOTB) states that the features on the raised ridge have the highest probability of contributing to innovative solutions.

From a Semantic Network to an *AhaNet*

Figure 1 shows a small part of a semantic network for a candle. The common features (e.g., *wick*) are in the low inner basin, while the obscure features (e.g., *string* and *candles are motionless while burning*) are on the high ridge or in the low region beyond the ridge. A feature's commonality is measured by how often the feature is mentioned by subjects in a feature-listing task for that entity. A cutoff for distinguishing a common feature from an obscure one is somewhat arbitrary; but for our initial presentation, we will assume a clear division. The height of a feature in Figure 1 denotes the probability that the feature will be helpful in crafting an innovative solution. Based on our analysis of benchmark problems and a large collection of real-world problems, common features have a low probability so reside on the low inner basin [2, 5]. Obscure features one or two steps beyond the common features have the highest probability of being helpful and reside on the ridge. Obscure features beyond two steps have a low probability and reside on the low outer rim.

We call this idea the *Just Outside the Basin Hypothesis* (JOTB) because the features in that location (i.e., on the ridge) are generally the most helpful for innovation. (It is called the *Just Outside the Box Hypothesis* in a previous article that represents the circular basin as a square [5].) The JOTB is related to two other ideas in the literature. First, it operationalizes the idea of innovation standing between order and randomness, as articulated by Duncan Watts in his book *Small Worlds: The Dynamics of Networks between Order and Randomness* [6]. A concept in the basin is too strongly connected to the initial concept (i.e., too much order) to contribute to innovation, while a concept many links away is too weakly connected (i.e., too much randomness). A concept on the ridge is on the boundary between order and randomness, has a middle strength of connection, and seems to be ideal for innovation. Second, in Stuart Kauffman's terms [1], the *actual* corresponds to what is in the basin while the *adjacent possible* corresponds to what is just beyond the basin on the ridge. The *adjacent possible* is the innovation that is currently most readily achievable.

While the JOTB limits the search by specifying the ideal distance to search from the initial concept, another structure helps guide the direction of the search. We have devised an extensive taxonomy of possible feature types that an entity can possess. Our current taxonomy (i.e., *Feature Type Taxonomy*: FTT) contains 32 features types. This taxonomy divides the space outside the basin into 32 regions. By systematically examining each feature type of the FTT, we can make sure to unearth obscure features in all regions of the *AhaNet*. The diagonal lines in Figure 1 are a caricature of the FTT in that they only divide Figure 1 into four regions. The FTT contains many of the obvious feature types (e.g., parts, size, shape, weight, and motion) as well as many other non-obvious types.

Sample Innovative Solutions using *AhaNets*

We will present innovative solutions to two problems. We will design many new types of candles and solve the problem of adhering a coating to Teflon.

Experimental results indicate that when listing features of objects people tend to overlook about half of the possible feature types [2, 3]. We easily constructed many novel candle designs by first considering the overlooked feature types for a candle and then building designs based on the overlooked types. Figure 2 shows the results of a survey of 96 people who were given four minutes to write down as many features and associations for a candle as they could. We classified their answers among the 32 feature types of our taxonomy. The y-axis represents the average number of times these subjects listed a feature of a particular type. The x-axis shows the 32 feature types presented by number. Because a patent application is currently being prepared for software that implements searches on this taxonomy, we are currently not at liberty to disclose all of the 32 categories.

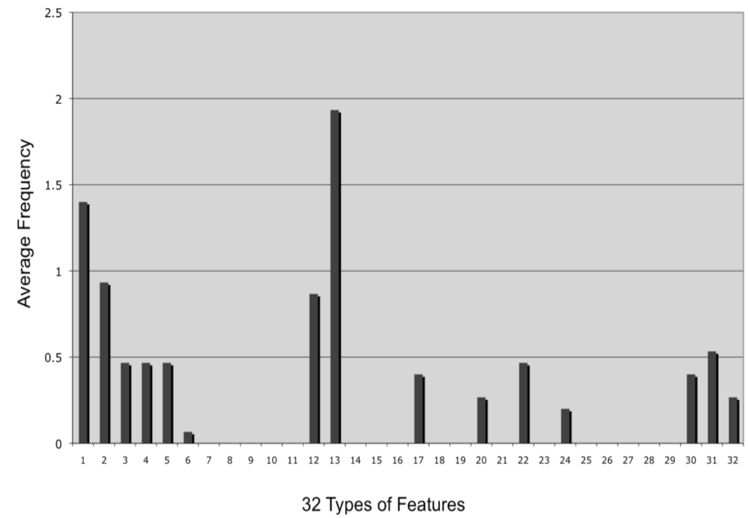

figure 2: The commonly listed feature types for a candle. The y-axis reports the average number of features listed for a particular type of feature. The x-axis lists the numbers of the 32 feature types currently used in our *Feature Type Taxonomy* (FTT) [2, 3].

Figure 2 shows that some types of features are commonly noticed (e.g., types #12 and #13) while many feature types are either infrequently (e.g., type #6) or never noticed (e.g., type #7). In our survey, not a single person mentioned anything about the motion (type #28) of a candle (e.g., "candles are motionless when they burn") or anything about the weight (type #9) of a candle (e.g., "candles lose weight when they burn"). After concluding that candles could move vertically as they lose weight, software can then search for other entities in the extensive semantic network whose common features include vertical motion (e.g., justice scales and elevator). By adapting the basic mechanisms of these devices to our burning candle, we created numerous new designs in which a candle moves vertically based on weight loss. For example, a candle is placed on one side of a scale-like structure and is counterbalanced by a weight on the other side. Just for fun, we put a snuffer at the top so the candle would eventually move into the snuffer as it lost weight and extinguish itself. This design has been licensed from us by *Pilgrim Candle*. Using the many underexplored feature types in Figure 2, we have created many other new designs that we can license.

This candle example illustrates how an *AhaNet* can be used to help with both steps of the innovative process: finding obscure features and finding promising entities to interact with an obscure feature. Besides new designs of commercial products, the *AhaNet* approach has helped solve difficult engineering problems [4, 5], including adhering a coating to Teflon. For this problem, we built an *AhaNet* for Teflon as well as an *AhaNet* for the verb *adhere*. The particular verb used to describe a goal makes many assumptions about what features we expect a solution to possess. Building an *AhaNet* for the goal verb permits us to unearth many of those assumed features. The unearthed features can be negated in order to open up new options to explore. In this case, the key assumptions of *adhere* were using a chemical process between two surfaces that are in direct contact. Our solution is to stick a coating "through" Teflon to a magnetic surface beneath the Teflon (i.e., a sandwich of three surfaces in which the coating indirectly sticks to the Teflon due to its attraction to the magnetic surface). The coating, of course, needs to possess the proper make-up in order to induce sticking. In sum, building *AhaNets* for goal verbs can also help solve difficult unsolved problems.

Summary

Using the JOTB and the FTT, a semantic network becomes an *AhaNet*. Software that assists with the two steps of the innovative process can help solve open-ended design problems (e.g., design a new candle) and engineering problems with specific goals (e.g., adhere a coating to Teflon). We will continue to expand the ability of *AhaNets* for solving difficult problems.

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