

# Using the Tools of Structure

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## Abstract

*The psychologist George Miller concluded that people can mentally handle a maximum of 7 (+/- 2) items at any one time. Planning and design problems are considerably more complex than that, even seemingly "simple" ones. The solution is to find or impose structure so that complex problems can be rationally addressed piecemeal.*

*Two important tools for creating structure are graphs and hierarchies. Graphs establish links between elements where relationships exist. Hierarchies "chunk" highly related elements into clusters, and then cluster the clusters to create multi-level structures.*

*Graphs alone can reveal insight by exposing patterns of relevant arrangement. Hierarchies produced from them are "typologies" associating elements in a structure defined wholly by the relationships establishing linkages. Much as biologists create taxonomies to study associations among species, planners can use relationship and structure to understand associations among the elements of a problem.*

Problems worthy of innovation range across the map from seemingly simple ones like the design of low-function objects (think tableware) to complex systems so multifunctional it's hard even to know where to start. For complex problems, as you might expect, we usually insist on some kind of structure to work from; but for the "simple" ones, we almost never feel the need. Somehow it seems right to innovate within structure for a big problem, but it's OK to treat lesser problems as one-shot idea generation exercises.

The reality is that structure is the tried and true friend of innovation. For big problems, it can show not only where to begin, but how aspects of the problem fit together, how the context of the problem is organized, how solutions can be best communicated, how systems can be modeled for evaluation and comparison, and much, much more, as they say. The interesting thing is that, from the planner/designer/innovator's point of view, the same constructs that help us to bring order to big problems work to expand our thinking for the seemingly simple ones. The tools of structure are tools of innovation.

## Graphs and Hierarchies

What I mean by "structure" is (1) an organization that abstracts the real world to a chosen set of things we wish to think about, and (2) one or more ways to think about those things that creates the organization. There are more ways than one to represent structure. Two that I think make great sense for concept building are graphs and hierarchies. By graphs, I don't mean the x/y plots, bar charts and pie charts familiar to everyone, but the network-like models that show how elements in a set are linked to each other. Hierarchies are probably more familiar—they should be; they exist all around us—but, like graphs, the information they convey is dependent on what they organize and what relationships they use to do the organization.

Both graphs and hierarchies have been subjects of mathematical appreciation since Leonhard Euler invented graph theory in 1736. Euler put together the first principles while explaining to the burghers of Königsberg, Prussia why they couldn't find a way to walk from their homes around the city and back again while crossing all seven bridges spanning the river Pregel only once each. The challenge had been a traditional Sunday after-church exercise for many years (try it—Figure 1 is a diagram of the river and bridges in Euler's time).

In November 1968, under the auspices of the McDonald Douglas Corporation and the University of California Irvine, the first scientific gathering on *hierarchy* was held in California, "bringing together scientists, engineers, designers and others interested in the function of hierarchical structure in nature, concept and design" (*Hierarchical Structure*. Whyte, Wilson and Wilson. eds. NY: American Elsevier, 1969). Some 47 speakers presented papers from nearly as many disciplines, all exploring hierarchy as seen in their domains of study. Whether it exists in an identifiably real sense or is a conceptual overlay to bring order to complexity, structure is fundamental to human comprehension.

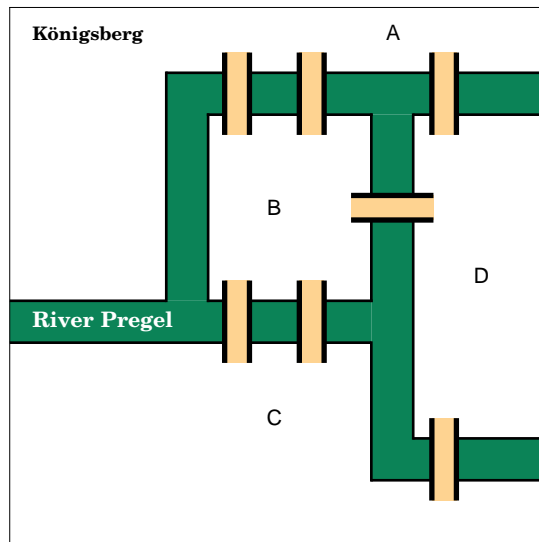


Figure 1 Bridges over the River Pregel, Königsberg, Prussia, 1736

### Mental Manipulation

Two interesting numbers relate to this. First is George Miller's famous "magic number 7 plus or minus 2". In his well-known 1956 paper, Miller discussed human capabilities for dealing with amounts of information. From a number of studies, he concluded that our capacity is limited (perhaps to 7 items plus or minus 2), but that we can increase our ability by coding information into chunks that can be remembered and manipulated as individual information elements and then decoded (an example of superimposing hierarchy). Among many uses of this information is the general admonition to executives to organize with no more than 7 (plus or minus 2) individuals reporting to a single superior.

A second number of interest is 3. This one came forcibly to my attention at a cybernetics conference some years ago. After watching a government researcher illustrate his entire talk categorically with each category containing three sub-categories—at every level of every topic—I asked (not too innocently) if there was any significance in that. I got what I deserved when he told me it was just an example of "Peirciadic triadomania". A little private research later revealed that Charles Sanders Peirce, the eminent logician, philosopher and founder of semiotics and pragmatism, was fond of three-part categorization in his writings. . .

From a psychological point of view, though, the use of 3 makes sense (Figure 2). When we have to choose sub-categories for a category, we look for word descriptions that "feel right" in

balancing the choices with each other; parallelism, consistency, coherence and other principles for comparison come into play. Two sub-categories is too easy—only one relationship to consider. Three requires three evaluations, not at all difficult and much more satisfying. Four, on the other hand, requires *six* relationships to be considered, twice what were required for three—up around Miller's magic number and not too easy to do. Five requires ten comparisons, and we begin to lose control. With sub-categorization of more than three, the list is increasingly less likely to be well-balanced. The four graphs of Figure 2 visually demonstrate the rapidly rising complexity of the task.

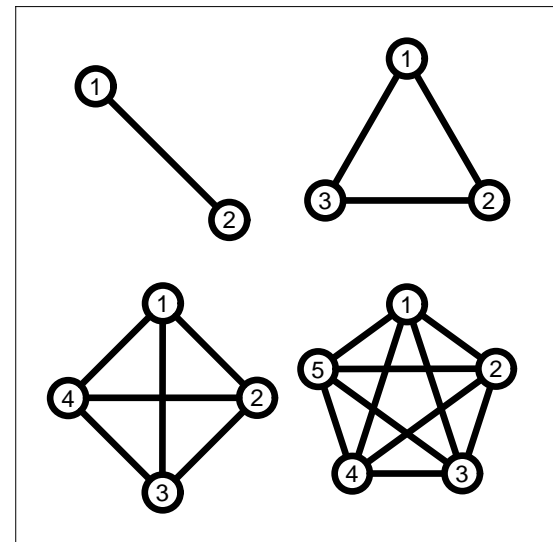


Figure 2 Considerations required for balancing descriptions of 2, 3, 4 and 5 items.

So what does this have to do with structure and innovation? First, it explains again why it is hard to deal unaided with complexity; second, it suggests a tool that can help. Graphs give us a way to visualize complexity with a precision brought about through abstraction. They afford us a tool for selectively examining the effects of specific relationships in organizing elements of a problem. Figure 2 shows forcefully how increasing the number of elements exponentially increases the relationships to be considered among them.

Relationships can be virtually anything as long as they can be expressed clearly enough to be tested against the elements. Insights gained usually derive from seeing how groupings assemble for a specific relationship; however, there is often insight to be gained in seeing which items are *not* linked as well as seeing which ones are.

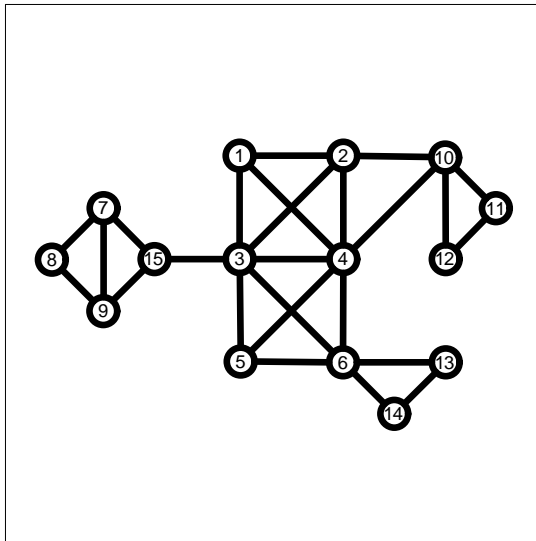


Figure 3 Relationships among elements revealed with a graph.

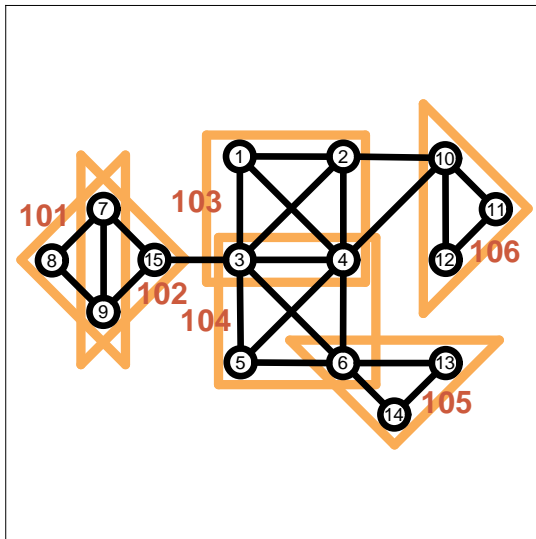


Figure 4 Clusters of highly related elements in a graph.

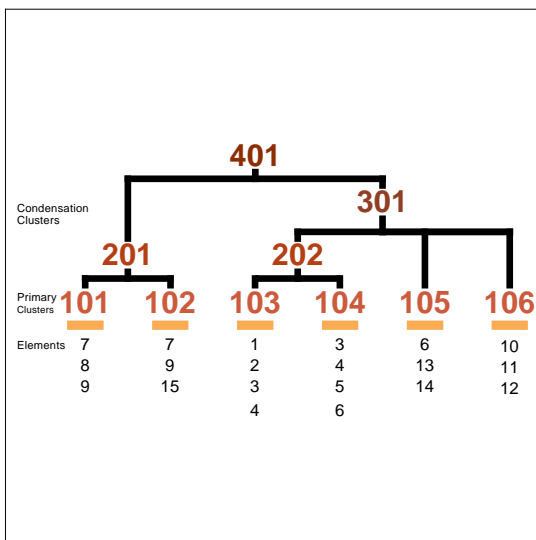


Figure 5 Clusters grouped into a hierarchy.

### Using the Tools

Figure 3 shows a graph that organizes a set of fifteen elements. A link between elements indicates that the organizing relationship is satisfied. The set of elements might be fifteen controls, gauges and warning lights on a piece of equipment under development, and the relationship might be "in emergency, is used together with". The tests are made by plugging in successive elements and asking, is it true or false that: *x "in emergency, is used together with" y* ?

A graph often provides enough structure to reveal insights not otherwise readily obvious. If the graph is large, however, Miller's magic number comes back into play, and it is useful to bring in hierarchy to help. Figure 4 shows the same graph with superimposed boundaries that "chunk" the elements into six clusters of highly interrelated elements. In this case, the graph is small enough that this single level of hierarchy is probably enough structure to provide all the insight necessary (groupings for the controls, gauges and warning lights, for example). If that isn't enough, however, the clusters can themselves be clustered as shown in Figure 5. In this case, the form generally shifts to one of the familiar tree-like structures better suited to communicating complex hierarchical information.

Hierarchies allow us to represent and look intelligently at very complex collections of information. Since the 1960's when computers became relatively capable and available, it has been possible to use the tools of structure effectively for many purposes, including innovation. The invention of numerical taxonomy in the '60's furthered this considerably. Computer programs implementing numerical taxonomy concepts (such as RELATN used in Structured Planning) enable us to construct typologies organizing sets of elements according to almost any characteristics we see as important. For example, if we were contemplating the development of the next generation of cell phones (maybe better described as "personal communication devices"), we might wish to see how existing kinds of informal communications organize themselves against a series of characteristics possibly important for potential users. These could include formality required, privacy afforded, transmission fidelity, emotive capacity, simultaneity, spatial reach and many more possibilities.

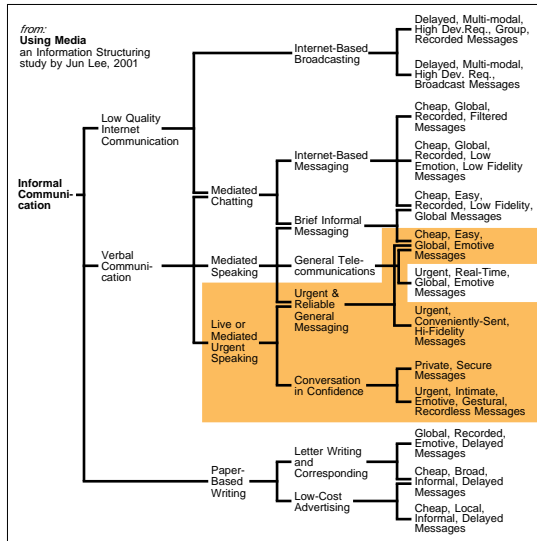


Figure 6 A hierarchical typology of informal message types.

The study diagrammed in Figure 6 used 39 such characteristics. The computer calculates the amount of similarity between message types based on the characteristics scored and establishes a graph with links where the similarity is strong. *The important thing is that similarity is what we say it is*—we choose the characteristics that define it, and we decide how important each is. When the graph is complex enough to benefit from hierarchical structuring (usually), the computer is called upon to build a hierarchy (the VTCON program is used in Structured Planning). The final structure is tree-like, but not necessarily a tree because elements (and clusters) can belong to more than one higher level cluster. The name for this kind of hierarchy is a "semi-lattice". It is a more general form of hierarchy than a tree and is usually more appropriate for the kinds of typologies created when exploring the subjects of human innovation.

The structure in Figure 6 is a semi-lattice organizing types of communications from the previously mentioned 2001 study on media. Labels on the far right summarize the first level media clusters formed using the 39 characteristics. As an example of interpretation, the shaded area suggests an emerging market for delivery of ur-

gent, confidential messages with high fidelity and reliability—an early warning of the social communication revolution now overtaking youthful cell phone users.

Similarity is useful for generating structure in many of the phases of innovation. But one of the most powerful uses of structure for innovation is in the organization of the synthesis phase when the relationships among Functions are reconsidered. In Structured Planning, a special measure has been developed to link elements that should be considered together (the Functions discussed in "Covering User Needs") not on the basis of similarity or categorical likeness, but on the basis of whether there is a strong likelihood that they would be affected by the same solution concepts. I will discuss this in the next article.

For those still wondering about the burghers of Königsberg, Figure 7 abstracts the bridges and city neighborhoods to a graph such as Euler used to show why it was impossible to make the "once each bridge" journey and get back home. I don't think he told them, though, that if they just built two more bridges—or took two away—they could. Try it again.

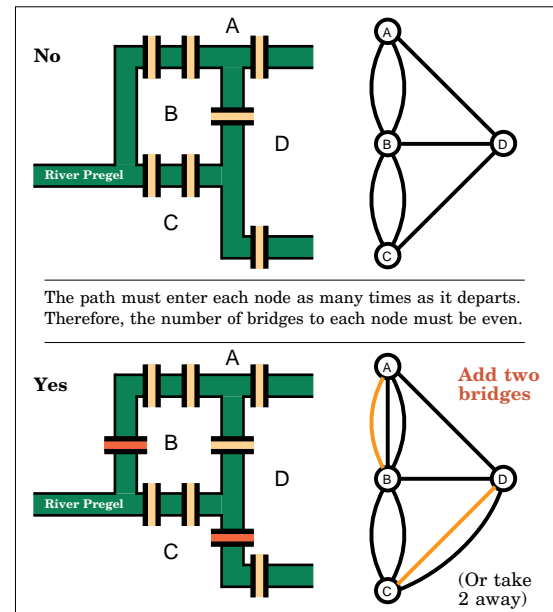


Figure 7 Revisiting Königsberg and the bridge problem.