Using Heuristics to Solve Problems

Ed Sickafus

Heuristics are ubiquitous in technology. This essay addresses the use of heuristics in problem solving methodologies (PSMs) in ways that make them effective. Issues discussed are what to expect of heuristics, their limitations, and how to think during their use, i.e., how to voice to yourself what you mentally focus on.

Cognitive scientist's research in this century has discovered that the brain doesn't use logic in problem solving. [1] The subconscious discovers solution concepts, which it proffers to the conscious for logical voicing both internally and externally – a bilevel model. Introspection is a key ingredient of exercising heuristics. In part, the motivation for this essay relates to the new appreciation for introspection revealed by cognitive scientists. References to logic herein allude to the new bilevel model of thinking.

PSM Heuristics

Using heuristics to solve any type of problem is the fact and the art of discovering and constructing solutions to problems. It's the fact because the definition of a heuristic is an *aid* to thinking – it provides for the logic of analytical-type solutions to problems. It's the art because it imbues intuition, dodges unaware constraints of logic, and thereby discovers the unexpected insights of innovation. Hence, it covers both the technologist's need of a rational algorithmic path to meaningful construction of solutions and the inventor's need of freethinking for new insight. Those are the good parts of heuristics. Missing in this simple definition is any explanation of what a heuristic is and how to use it.

In the opening sentence of the above paragraph 'any type of problem' was mentioned. My preferred definition of a problem is *any* unanswered question – implying scope. Hence any is covered. A key to broadening scope of PSMs is the use of metaphors to generalize problem statement and analysis – a move in the opposite direction of using the argot of specialized technologies. Heuristics are plastic aids not rigorous rules.

A question produces some kind of disturbance in one's otherwise quiescent neuronal network. Instantaneously, the subconscious addresses this disturbance to cull for threat to one's homeostasis. Passing that test the subconscious sets out to find instances in memory that may resolve the disturbance; i.e., solution concepts or pieces of them.

Strategies of heuristics

Since heuristics are aids to thinking in problem solving they usually have implied or stated strategies. For example, seeding is a common heuristic for recalling a person's name. It involves mentally stepping through the alphabet one letter at a time and awaiting a suggestion from the subconscious. It works sometimes but not always. The assumed strategy in seeding is that a voiced clue (a letter in this case) somehow steers, or links, the subconscious to a potential answer or relevant concept.

No heuristic problem-solving methodology having a selection of heuristics can be completely comprehensive, in the sense of having covered all of solution space (whatever that may mean). So when seeding fails, for example, the problem solver moves on to other heuristics. There are many.

PSMs are collections of selected heuristics designed to generalize the scope of problems they can be used on, to accommodate different problem-solving situations, to adapt specific PSM tools, to unify the way they are applied, to emphasize the style of their application, or to use different underlying philosophical theories.

PSMs include brainstorming

A particular real-world industrial problem-solving situation that I am familiar with is so called 'fire-fighting'. The name implies urgency requiring speed and innovation. For example, discovery of a product defect or failure that affects safety requires immediate attention. Brainstorming teams are effective for this purpose and the method requires only plausible solution concepts – i.e., no filtering.. Proof can come after ideas have been captured.

Typically, an ad hoc brainstorming team is brought together to find as many solution concepts as it can as quickly as it can. Brainstorming, a fundamental, automatic way that technical brain operates is the PSM of choice for generating ideas rapidly. Its strength relies on its user's technical training, experience (specialized memory), and imagination.

My most memorable experience with brainstorming (not a fire fight) occurred in a group of about 25 scientists and engineers from the research staff of Ford Motor Company. Management had a prepared a random list of potential technical problems and new product opportunities for us to attack – and interesting test of closed-world thinking. We were given a meeting time and place but no advanced information about the meeting's contents. It was a very interesting meeting that had a slow start and ended in high spirits. However, it was noticeable how quickly fresh ideas waned. This was handled by moving on to the next topic. A philosophical insight I got from the meeting was that we seemed to consist of two types of brainstorm thinkers, those who offered ideas instantly and those who improved on them. This meeting led to my interest in development of PSMs.

Philosophies

An example of differing underlying philosophy of PSMs is the difference in the Russian theory of solving inventive problems (TRIZ, ca 1970s [2]) and a fourth generation spin-off called unified structured inventive thinking (USIT, ca 1990s [3-2014]). In essence, the underlying philosophy of the former is to glean inventive concepts from the patent literature and reverse-engineer them to infer the inventor's thinking strategies. Consequently, it would seem, resulting insights arise from inferred strategy based on past experience of the inventor; i.e., someone other than the current problem solver. It uses a database of patent information and software to assist its application. It works.

In contrast, the USIT's underlying philosophy is to make the problem solver self sufficient without the need of mental crutches. It works.

Advanced USIT: After completing a working first version of USIT [3], I began teaching it and started an effort to simply it further. This effort led eventually to a modernized version using one verbal/graphic, the 'OAF' heuristic, and the method was referred to as advanced USIT. It was designed for problem solver's experienced with heuristics, USIT's or others. The method capitalizes on a problem solver's experience with heuristics and problem statements using metaphors (such as OAF). PSMs of the last century, USIT included, rely heavily on logic.

A new player on the block: In this century cognitive scientists discovered the bilevel brain. Its model replaces the lateralization model already deprecated years ago. The bilevel model has been adapted in a new PSM called I3 for introspection, insight, and innovation. [3(2015)] Following the cognitive scientists discovery, I3 operates without logic and thus is not constrained in its search of solution space. It applies introspection to capture fleeting insights. (See its prequel; 'Subconscious Problem Solving Using Hazy Heuristics', 3(2014))

Expectations of PSM heuristics

Problem-solver expectations of heuristics have at least two variations. Some expect a heuristic to be a closed-loop algorithm. A problem statement is written according to a selected heuristic's requirements, it is processed according to the imagined algorithmic steps of the heuristic, and then the problem-solver sits back and awaits inventive solutions to come to mind – a form of seeding. This is like filling in the blanks and waiting for results *without* turning the crank.

The other variation is to voice a problem with mental variations, per the expectations of the heuristic, testing each word while watching for mental images and words that produce insight into solution concepts (introspection). The latter is effective because the problem solver is more likely to vary and test all aspects of a heuristic using personal on-the-job relevant intuition. A variable heuristic is not roadmap to a hidden treasure. It is a thought provoking set of symbols, words, and images that bring unexpected bits of memory to the fore for vetting.

Demonstration of applying a heuristic to a specific problem

An example of a variable heuristic is the object-attribute-function heuristic (OAF) unit of the heuristic innovation (HI) PSM. [4] An object that contains a problem is simplified to a single unwanted effect (the problem), the object, and a single active attribute of the object that is causal of the unwanted effect. The words attribute and causal, as well as function and effect, essentially are synonymous pairs allowing flexible voicing. In the O–A–F graphic, O is the object and A is an active attribute of the object that supports the original design function, F. If a failed function is involved, the F can show a strikethrough; ~~F~~. Solution concepts are found using this graphic by mentally visualizing what would happen if one of the two unions (–) were broken or an O or A were eliminated, altered, replaced or duplicated. An example OAF application for a single object follows.

A cook at risk

Consider this problem situation, which we can simply by reducing it to a single problem.

A cook has an egg in a pan of water being heated to boiling.

This situation poses several potential problems for the cook. Problems such as boiling too long ruining the egg; boiling to dryness risking egg explosion; contact with the hot pan risking personal injury; contacting spattering water risking personal injury; and possibly others. Spattering water looks like a single-object problem containing the heart of this problem situation. So I'll select it and see where application of the OAF heuristic leads.

Here's my Introspection. I noticed immediately that strictly, injury is not a designed function, and it is not a failed function. It's an undesired effect. Note the flexibility of voicing OAF, versus potential rigidity of its literal interpretation. Voice flexibility is the fodder of innovative thinking.

This situation's one-object O-A-F heuristic is … I had to think a moment. F means function – a word having 'design' connotation. Effect is a word having causal connotation. Injury is a non-designed, unwanted effect. So I chose that latter and its metaphor:

Generic statement; object – attribute – unwanted effect

Metaphoric statement; spattered liquid – hot – to mar.

To injure could have been selected as the unwanted effect, but it seems to imply human presence. Whereas to mar is more generic and could also involve non-human contact. Contact seems to be the causal essence of this problem.

A simple image of spattering water comes to mind; that of an exploding bubble ejecting hot water drops from the boiling-water's surface, as illustrated in Fig. 1

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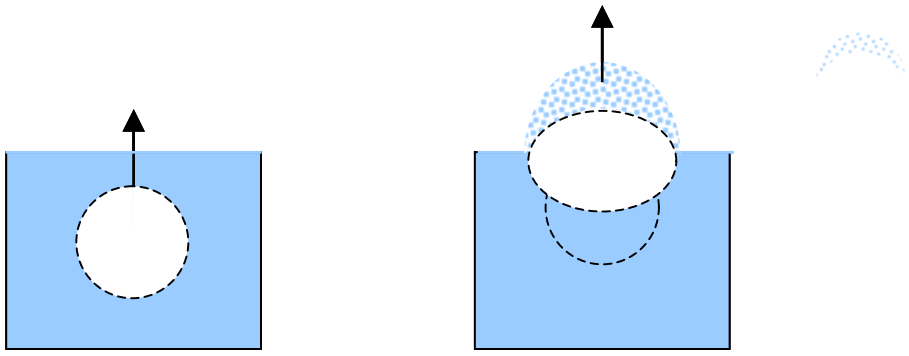

Figure 1. The left image shows a volume of liquid (blue) with a rising bubble. The right image shows the bubble bursting through the surface of the liquid releasing a spray of hot droplets and vapor. Dashed lines indicate changing positions of a rising bubble

As I drew these two sketches I immediately realized how simplified they were and that caused me to rethink what they may indicate.

1. The left-hand image of Fig.1 shows a hole in a volume of liquid. I drew it without a boundary because hole is not an object. You can't pick up a hole; it's an attribute of an object's shape. That woke me up to realize that liquid can't have a hole in it, it would collapse if it were vacuous! Obviously, an equal volume of vapor must support the hole. So I now have two objects, liquid and vapor. They are different objects having the same molecular attributes but distinguished by different phase attributes. The arrow shows the bubble rising, implying, evidence of outward internal pressure. Fortunately, I had not colored in the hole in the sketch. Vapor has no color; it's invisible.

2. The right-hand image of Fig. 1 represents the bubble bursting through the liquid-gas (air) boundary and spewing droplets upwards and outwards as a cloud of condensing vapor. As drawn, this is a very simple rendition of a bubble bursting through the liquid-gas interface. For instance, when the surface ruptures, it destroys the boundary of more tightly bound liquid molecules, i.e., the molecular layer of surface tension. Furthermore, in this case, sudden expansion is a local cooling process – a driver of condensation. Also not shown is the roiling, boiling state of liquid in a pan being heated. The liquid's surface is anything but flat. Surface tension can be expected to momentarily bulge the liquid's surface exposing some lateral region of the bubble as it bursts. This is hinted slightly in the figure. The roiling chaotic motion of the liquid's irregular surface during boiling also produces globules of liquid in addition to a mist of vapor, not shown.

Those are the ideas that came to my mind as I voiced my way through analyzing the two figures. Now I can see a plausible solution concept. As the surface erupts exposing a bubble's former interior water the walls collapse into curved surfaces as a result of surface tension. And there in lies a solution concept. Surface tension!

It takes more energy to form tighter surface bonds in liquid than is needed for the amount of energy to keep liquid from evaporating. This energy is released during the chaotic eruption of a boiling surface. If we could reduce the amount of surface tension energy, we might mitigate the seriousness of spattering.

Solution concept A single tiny drop of surfactant (e.g., soap) added onto the liquid's surface would spread into at least a monolayer, thus replacing the surface tension of the liquid-gas interface with the lower surface tension of the surfactant-gas interface.

This is not a thorough analysis since it is intended simply to illustrate introspection in mental problem solving. Further analysis and other solution concepts might be found if this train of thought was continued.

Review of heuristic application example

Now I'd like to review what I've illustrated with my voicing and graphic sketching; namely, how I applied a heuristic, the OAF heuristic, in analyzing and solving a problem of a potentially hazardous water-boiling situation. What were your thoughts as you read this discourse?

As you read (internally voiced) what I wrote you also voiced my description in your mental interpretation. Two things surely happened. You saw other possible interpretations, and you agreed with parts of mine. So why did we have differences? One reason is that we have different technical learning and practicing experiences from which to draw explanatory concepts from our long-term memories. Another reason is that the same written words and illustrative sketches are also interpreted using different personal experiences – our genes differ. Another possible reason (God forbid!) is that I'm wrong.

(Well, as they say, you get what you pay for. ☺.)

Such differences are the fun and enlightenment of brainstorming teams.

Another aspect of flexibility or variability of heuristics is the depth and scope of their utility – a totally personal phenomenon. The thought process that I related above, as my introspection of the boiling liquid problem, is an abbreviated version of the more detailed experience that I continued for a few moments.

While mulling the presence of vapor supporting a bubble it came to mind to consider how the vapor got there; i.e., how does a single bubble form? Instantly, I was drawn into a description of molecules in increasing chaotic motion in the solid-liquid interface layer of near boiling liquid (on the bottom of the pan). Molecules enter and leave the layer with nearly equal probabilities until boiling is eventually nucleated. Once the leaving-flux (number of molecules per unit area per unit time) exceeds the returning-flux a local environment is created where fluctuations of vapor density eventually nucleate a stable bubble – albeit one still attached to at the solid-liquid interface, but soon to separate from the solid and rise while expanding to the liquid-air interface.

The more I thought about this phenomenon the more I was drawn to postulating additional detail including molecular mean-free paths, energetics of surface-to-volume ratios of free energies, and statistics of molecular kinetics. However, that exceeds the purpose of this illustration. It suffices to show that variable heuristics offer a problem solver much freedom of modeling and testing ideas. They also allow plausible solution concepts to be proven after idea generation ceases. I have proved none of the ideas presented here.

By the way, another idea came to mind. Position a fine-mesh screen near or at the liquid-air surface to reduce a bubble's size so it doesn't release as much energy on bursting. A floating screen comes to mind.

A heuristic for applying heuristics: Generify; i.e., think metaphor.

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(Also the blog; Theories of Problem Solving: edsickafus.wordpress.com)