U-SIT And Think News Letter - 78

Unified **S**tructured **I**nventive **T**hinking is a problem-solving methodology for creating unconventional perspectives of a problem, and discovering innovative solution concepts, when conventional methodology has waned. **H**euristic **I**nnovation is an extension of **USIT** with continued simplification.

Subject Keys

PD = **Problem definition**
H = **Heuristics**
T = **Theory**
M = **Metaphors**
A = **Analysis**
BH = Brain hemispheres
EX = **Examples**

Dear Readers:

· This mini-lecture continues the discussion and demonstration of the simplification heuristic. It starts by addressing the conclusions developed in the lecture that did not agree with observation.

· If you have ways to make ice cubes under different growing conditions, and can photograph the results, please share them with us.

Mini USIT Lecture – 77

Heuristics

SIMPLIFICATION
USIT and Think Mini-Lecture 78

A gedanken analysis of ice formation was begun in the last mini lecture to demonstrate how extensively and effectively we use the simplification heuristic in our problem solving procedures. It is continued here as we attempt to explain ice formation and its characteristics.

The path being followed is guided by curiosity – namely, mine, which I trust is found to be reasonable by you the readers. By reasonable, I mean a path not too different from your own. As curiosity suggests questions, their answers are attempted by posing simplifications that lead to tractable and plausible understanding.

Keep in mind that 'plausible' has uncertain limits, which can lead to unwarranted conjecture. The only way to ferret out the underlying truth is through mathematical modeling and laboratory research. But that is not my goal in this series. Rather, it is to discover how much plausible understanding we can achieve through simplification. The entire example being discussed is a hypothetical situation representing how we begin a major problem analysis. The process being used is heuristic innovation (see textbook at www.u-sit.net).

Please be patient; we are moving toward the world of real ice.

A Gedanken Ice Cube Continued

In the last mini-lecture several conclusions were reached concerning a gedanken ice cube being grown in an ice tray in the freezer compartment of a refrigerator. Each conclusion was reached by a simplification. A table of these will be constructed as we proceed (see table).

Slush: As I reviewed the last lecture it came to mind that slush was neither defined nor its appearance characterized. Thinking about it now raises at least two questions. One is what makes slush visible since ice, water, and air are transparent? The other is where do the particles of ice first appear; on the already solidified boundary ice or within the water itself, or both? The latter question raises a deeper issue of how and where nucleation occurs? This was touched on in the last lecture.

And here's another unanswered question. It was mentioned (or alluded to) that water vapor, rain drops, and clear areas of hail stones are transparent. But clouds, snow flakes, and opaque area of hail stones are not. Why?

Visibility: Light passes through clear water and clear ice with only slight deviation of its path at the liquid-solid interface because the refractive index of both phases is nearly the same. To appear opaque light must either be absorbed or scattered from its initial path, thus reducing the intensity of light reaching one's eyes. You probably have noticed how the clear regions of an ice cube are hardly detectable in a glass of water.

We can explain opaqueness of slush by assuming that air bubbles are formed at the surface of newly forming ice as a result of the solubility of air in ice having reached its saturation limit. Gas molecules not containable in the forming ice collect on its surface and form bubbles which become incorporated in the bounding slush.

Light passing from liquid to air and solid to air is abruptly bent into new paths. Thus, a cluster of ice particles and air bubbles confined in a volume of viscous water will cause large diversions of light passing through each tiny bubble. In both transmitted and reflected light, slush will appear opaque due to the presence of air bubbles. As the density of air bubbles increases in the slush, the more opaque it will become because multiple reflections of transmitted light rapidly reduce the intensity of exiting light that reaches one's eyes.

Furthermore, since air is being excluded from ice during freezing of water, the ice will be clear, except for entrained bubbles. Air molecules remaining dissolved in ice are too few and too small to produce noticeable scattering of transmitted or reflected light. Hence, slush is bounded by clear ice adding contrast making the slush visible.

Nucleation: For a solid to form from a fluid (liquid or gas) the molecules must loose enough energy to form bonds with each other. When a liquid or gas molecule collides with another one they may exchange energy giving more energy to one and decreasing the energy of the other. While the lower energy one may be momentarily in a state conducive to bond formation, the other is dashing away with more energy than it had before the collision; not a condition appropriate for nucleation. This path of reasoning appears to be interesting, and even necessary for in-depth understanding of ice formation. But I don't see an immediate need for this information. So I'll abort this path and simplify the problem by ignoring nucleation until it becomes necessary to consider, if ever it does.

Slush could be simply a mixture of water near freezing and particles of ice. This may be true part of the time or in certain locations. But unless index of refraction of water and ice differ, it would be difficult to see this kind of slush for lack of change in direction or scattering of light as it passes through one phase and enters the next. Refractive index of ice and water at 0^oC differ by only 2 parts in 130. We probably wouldn't notice such slush. On total freezing of this kind of slush one could expect to have a nearly clear block of ice.

On the other hand, if the water contains dissolved gas, most of it will be excluded from the ice phase as the water freezes. The gas can nucleate as bubbles and then a mixture of ice particles, gas bubbles, and water will exist as slush. Bubbles will tend to be entrained in the solidifying slush forming opaque liquid and solid phases. Thus, we can conclude that the opaque regions of ice cubes are produced from frozen slush containing air bubbles. Entrained bubbles make slush (frozen or not) visible, in transparent surroundings, as whitish areas in reflected white light and grayish areas in transmitted white light.

Predictions

Given the conclusions reached so far, we can make some predictions about the appearance of a gedanken ice cube. Perhaps these will raise more questions.

Consider a volume of water being cooled to freezing by conductive loss of its internal energy through its bounding surfaces.

P1. Freezing will begin on the outside surfaces and proceed to the center of the volume with clear ice surrounding frozen slush (Fig. P1).

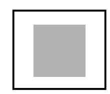

Fig. 1. Clear ice encasing frozen slush.

P2. If the water is confined in an ice tray with its top exposed to air, the upper surface will freeze last. This would provide more time for convective flow to enable slush to rise toward the top (Fig. P2).

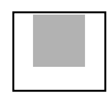

Fig. 2. Frozen slush in the upper part of an ice cube.

P3. As ice thickens it displaces unfrozen slush upwards. Since it freezes from outside inward, the center of an ice cube will tend to protrude upwards.

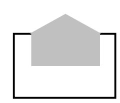

Fig. 3. Clear ice encasing frozen slush with a protruding bump.

The Real World

I think it's time to 'get real', as they say. Let's have a look at a real ice cube. I trust you have already made yours and have drawn some conclusions.

Figure 4 is a photograph of an ice cube from my refrigerator. On examining this ice cube I find a need of more careful thinking. Does it look anything like your ice cube? Where does it differ? Why?

The ice cube in Fig. 4 has about half of its volume basically clear (some bubbles are evident) and the remaining is a dark opaque region surrounded by clear ice. Any ideas?

The distorted areas in the upper left-hand and right-hand corners were caused by chipping of the ice when it was removed from the ice tray.

Note that the large opaque region is in the lower half of the ice rather than in the upper as I have predicted. Hmmm! Has simplification gone awry?

Fig. 4. Photograph of my ice cube.

Properties and Formation of Gedanken Ice	
Simplification	Conclusion
Heat flows down a thermal gradient	1. During ice-cube growth its central water is always warmer than the water at its outer surfaces, otherwise no heat could be extracted from the water by conduction. 2. Thus, in an ice tray, colder water will line the fringes of each cell while warmer water lies toward the center of each cell's volume.
Anomalous expansion of water increases its buoyancy as it nears 0^{o} C.	3. While cooling below 4 ^{o}C, water becomes increasingly buoyant, at the bottom and side walls of an ice tray, as compared with the central water. 4. Thus, a tendency exists for convective flow of water.
Viscosity of water increases with cooling	5. While freezing ensues, part of the ice forming on the outer surfaces will adhere to the solid walls, and to preformed ice, and part will mix with the viscous water to become slush, a mixture of ice particles and unfrozen water. 6. Freezing slush accumulates at the center of an ice-tray cell and becomes totally entrained within a newly formed ice cube.
Solubility limit of air in ice is much lower than that in ice water	7. Air dissolved in water is excluded for ice that forms from this water. 8. Air appears as bubbles in the cold water bounding the forming ice.
Refractive indices of water, ice, and gas	9. Slush composed of particles of ice and bubbles of gas in ice water is only slightly discernable as a result of differing indices of refraction in ice, gas, and water.
Multiple scattering of light weakens its intensity.	10. Frozen slush contains small bubbles and particles of ice that cause multiple scattering of transmitted and reflected light giving slush a lower contrast relative to its surrounding ice. This makes slush readily visible.
Details of nucleation are ignored.	11. It is assumed that air bubbles and ice formation from water simply occur with out concern for molecular details such as nucleation.
Dissolved gas is not identified.	12. Species of gas molecules are ignored. The word air is used interchangeably with gas as generic references.

To be continued…

Other Interests

1. Have a look at the USIT textbook, "Unified Structured Inventive Thinking – How to Invent", details may be found at the Ntelleck website: www.u-sit.net
2. See also "Heuristic Innovation", which further simplifies USIT.

Publications	Language	Translators	Available at …
1. Textbook: Unified Structured Inventive Thinking – How to Invent	English	Ed Sickafus (author)	www.u-sit.net
2. eBook: Unified Structured Inventive Thinking – an Overview	English	Ed Sickafus (author)	www.u-sit.net
	Japanese	Keishi Kawamo, Shigeomi Koshimizu and Toru Nakagawa	www.osaka-gu.ac.jp/php/nakagawa/TRIZ/
	Korean	Yong-Taek Park	www.ktriza.com/www/usit/register_form.htm
"Pensamiento Inventivo Estructurado Unificado – Una Apreciación Global"	Spanish	Juan Carlos Nishiyama y Carlos Eduardo Requena	www.u-sit.net
3. eBook "Heuristic Innovation – Engaging both brain hemispheres in rapidly solving technical problems for multiple solution concepts"	English	Ed Sickafus (author)	www.u-sit.net
4. U-SIT and Think Newsletter	English	Ed Sickafus (Editor)	www.u-sit.net
	Japanese	Toru Nakagawa and Hideaki Kosha	www.osaka-gu.ac.jp/php/nakagawa/TRIZ/
	Korean	Yong-Taek Park	www.ktriza.com.
Mini-lectures from NL_01 through NL_74	Spanish	Juan Carlos Nishiyama y Carlos Eduardo Requena	www.u-sit.net click on Registration

Please send your feedback and suggestions to Ntelleck@u-sit.net and visit www.u-sit.net

To be creative, U-SIT and think.