U-SIT And Think News Letter - 53

Updates and Commentary

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.

Dear Readers:

. Nice comments have been coming in regarding the mini-lectures on heuristics – thanks.

. In this mini-lecture two readers analyze the 20000 lights problem. In addition, one reader, Federick Mikusek, proposes an interesting twist on the problem – a three-state light.

3. Mini USIT Lecture – 53 USIT – a Method for Solving Engineering-Design Type Problems

Using the heuristic "SIMPLIFY"

This heuristic is so important I think it should be written with an exclamation mark; Simplify!

How many different ways have you used, or seen used, or suspicioned that Simplify! could be used?

Simplify! obviously addresses complexity – one simplifies a problem statement to reduce complexity and bring into view from the haze of complexity a clearer picture of a problem. I'll try to identify types of complexity that can fog the view of a problem:

- superfluous words, phrases, and sentences;
- irrelevant assumptions;
- multiple unwanted effects;
- too many objects;
- too many unimportant attributes;
- irrelevant root causes;
- filters;
- metrics;
- interesting but irrelevant history;
- consequences if not solved;
- relevance to programs;
- impact on business plan;
- timing;
- and others.

All of these may have a place in the preparations for solving a problem. However, they don't belong in the working problem statement. So we begin the exercise of solving a problem with a first draft of the problem statement that may be verbose, and immediately begin to Simplify! – we begin a problem by identifying superfluous components and other information and removing them.

In the last newsletter I mentioned the 20,000 electric lights as an example of a problem whose solution process benefits from Simplification! Did you solve it? Here it is again to remind us:

> In a long hall are 20,000 electric lights that are operated each by a pull-chain. Initially all lights are turned off. A person walks through the hall and pulls every chain, thus turning on each light. A second person walks through and pulls every other chain – #2, #4, #6, etc. up to, and including, #20,000 – thus turning off those lights. The next person walks through and pulls every third chain – #3, #6, #9, etc. – thus turning off some lights and turning on others. The next person pulls every 4th chain, the next every 5th chain, and so on until the 20,000th person passes through and pulls the chain of #20,000. The question is, after the 20,000th person has pulled the last chain, how many lights remain on? (The answer is not a trivial one.) [I don't know to whom credit for this problem belongs. If you do, please let me know.]

As you read this problem you probably surmised at least three things about it: 1) it is a mathematical problem, 2) it probably involves a pattern that should be determined, and 3) it has many more lights than necessary to discover an underlying pattern.

To begin, let's reduce the number of lights to 1. Initially it is off. The first, and only, person pulls its chain and turns it on. There it remains consuming power. There's nothing profound here.

If there were 2 lights and 2 people: the 1st person pulls each chain while the 2nd person pulls only the 2nd chain leaving the 1st light on and the 2nd one off.

Now several things are evident. Number 1 light will always be on no matter how many lights there are. With two or more lights we have the makings of a pattern: combinations of on and off lights. And we need a few more lights to start with in order to find a pattern. I'll try 10 lights. A matrix will aid in displaying the state changes of the lights.

In the table, x indicates off-lights, o indicates on- lights. Looking down the main diagonal we see the off-lights in groups of 2, 4, …, 2n or 2^{n}; begging the question of whether 6 or 8 is next? 6 is the next even number, 8 the next square of 2. In the column labels, the on-lights are numbered 1, 4, 9, …, which are consecutive perfect squares: begging the question of whether 16 is next? Another pattern on the diagonal is the groupings of x's plus an o, they go as, 1, 3, 5, …, (2m+1), which are odd numbers and sometimes primes – is 7 or 9 next? A larger matrix will show more detail. It's possible that all of these patterns are predictive.

		Light Number									
		1	2	3	4	5	6	7	8	9	10
Person Ordinal Number	1st	o	o	o	o	o	o	o	o	o	o
	2nd		x		x		x		x		x
	3rd			x			o			x	
	4th				o				o		
	5th					x					o
	6th						x				
	7th							x			
	8th								x		
	9th									o	
	10th										x

In this table,

I. Off-lights group as 2, 4, 6, … 2n (n = 1, 2, 3, …,n - 1); These are even numbers, not powers of 2; they go as 2n for n = 1, 2, …, n – 1.

II. On-light No's 1, 4, 9, 16, …, n^2, (n =1, 2, 3, …); These are consecutive perfect squares, n^2.

III. Ex's ending in o patterns go as 1, 3, 5, 7, … 2n+1 (n = 0, 1, 3 …);. Similar to (I) above plus 1 for each o. There is no new information here.

	Light Number																
Person Ordinal Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1st	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
2nd		x		x		x		x		x		x		x		x	
3rd			x			o			x			o			x		
4th	2			o				o				x				o	
5th					x					o					o		
6th						x											
7th							x							o			
8th					4			x								x	
9th									o								
10th										x							
11th											x						
12th												x					
13th													x				
14th														x			
15th												6			x		
16th																o	
17th																	x

We have two potential patterns. Let's compare the next predicted on-light of each one.

I. n = 4; 2*n predicts 8 x's in the next group, plus 1 yields the 25^{th} light as the next on-light.
Hence, 4 lights on in a total of 16 lights and in totals < 25.

II. m = 5; m^2 predicts 25. Hence, 4 lights on in a total of 16 lights and in totals < 25.

Both patterns can be extrapolated to test for agreement and the desired answer.

I. The number of groups of 2n off-lights, ending in an on-light (2n + 1), plus 1 is the number of lights remaining on. This is given by the integer part of,

$$\sum(2n + 1) + 1 = T \qquad \text{for } n = 1, 2, \ldots, m - 1.$$
$$2\sum n + m = T \qquad T = \text{total number of lights, i.e., } 20000$$
$$m(m - 1) + m = T$$
$$m = \sqrt{T}$$
$$\text{Number of on-lights} = \text{INT}(\sqrt{20000}) = 141$$

II. The second pattern of consecutive squares, 1, 4, 9, …, has an interesting property I had never given thought to. *The square root of an integer square is the number of perfect squares up to and including its square root*. In our case, this gives the number of lights remaining on. Again, we need only the integer part of $\sqrt{20000} = 141$.

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6. Feedback

Reader's replies to the 20,000 lights problem

I received two very interesting replies to this problem with comments on the heuristics used.

USA: Matt Smith writes ...

"**141**" That's my assessment of how many lights will be on after person #20,000 goes down the hall. My heuristic - Excel. Maybe it's a digital-age equivalent to your simplification heuristic. I figured this was a pretty simple repeating pattern that I could easily program into excel, so I set up a spreadsheet with a 100 x 100 matrix. In column 1, all entries are "1" (lights on). For each cell, if the number of the light is evenly divisible by the number of the person (lights 2, 4, 6 ... for person 2, etc.) then the formula changes that cell to "not" of the cell to the left. A few minutes of thinking about how to structure the formulas, and whalla! – I can drag and copy the model as big as I want. At 100 x 100, I saw a pattern that the number of lights on seems to be the integer part of the square root of the number of lights. So 20000 lights will give 141 on. I only ran the model up to 100 people with 100 lights, but the pattern seems to hold, so I'll go with that guess.

What's the difference between a physicist and an engineer? The engineer just wants to know what the answer is. The physicist wants to know why. You describe in the newsletter that solving this problem taught you something about numbers you never knew before. That implies that once you found this square root pattern, you figured out why it would be so. Once I found the pattern, I accepted it without caring so much about why, and am ready to move on to another problem.☺

Editor's note: I need to explain the smiley face. Matt is a personal friend whom I have not seen in several years. When he comments on the mini-lectures he sometimes includes comments he may fear will insult me. (I'm old enough to be his father. So he tries to be sensitive.) He is correct about spreadsheet calculations being of the digital age. By now, that's a long time. In discussing the variant of this problem, in the next newsletter, I'll demonstrate a space-age shoftware heuristic! Yes, physicists are nosey. ☺☺

France: Frederic Mikusek writes …

Thanks for this problem, which gave me some fun. The answer seems to be 141 lights on. I used several heuristics: First, I thought prime numbers, but then I thought simplify, so I drew a sketch with "x" for a light on and nothing when the light is off. Example :

```
      1  2
      x  x   (after the first)
      x      (after the second one)
and then
      1  2  3
      x  x  x   (after the first)
      x  x      (after the second one)
      x     x   (after the third one)
```

And then with four, five, six, and so on. Around 9, I thought complement and I completed the previous sketch for 10 and then 11...I checked that the number of lights on increased and did not seem to be random. Then I realized a change in pattern, at 4,9,16,..., I thought symmetry and square root 2^2, 3^2, 4^2. I wanted to make sure nonetheless and kept on with 5^2=25 (and maybe till 6^2=36). Then I thought the answer should be round part of square root of 20000 which is 141 and that we have to wait for 142^2 to see some change because 141^2 < 20000 < 142^2.

First I wanted to use recurrent heuristic "if you can do it for 1,2 and if you can do it for n+1 when you can do it for n, then you can do it for any n (any positive integer number)", but I just assumed that I could keep on till 20000. I wonder if you thought something different. I suppose that if I had never heard of prime numbers I would have not thought about that, and I hope 20000 was the right number, because it is so easy to solve the wrong problem (was it 2000 or 200000 ?). I suppose if you are good at computers programming you can compute that from 1 to 20000 with a big matrix.

> Now what if the light changes from off to green, then from green to red then off again?
> How many green and red lights? (I don't have the answer right now).

In addition to this interesting analysis, F. Mikusek, has posed a fascinating variation in which the lights have three states. It's a worthy challenge. Have fun. We await your replies. (Since receiving this letter, both Fedrick and I have independently solved this problem. Solutions will be discussed in the next newsletter.)

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Happy Holidays

7. Papers and essays

The following materials can be read by clicking on their titles. Links are also available on the USIT website (www.u-sit.net/Publications)

1. "Injecting Creative Thinking Into Product Flow"
2. "Problem Statement"
3. "Metaphorical Observations"

8. 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 (*Note*; not at www.ic.net)
2. USIT Resources Visit www.u-sit.net and click on Registration.

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 "**Heuristics for Solving Technical Problems – Theory, Derivation, Application**" -- **HSTP**	English	Ed Sickafus (author)	www.u-sit.net
"**Heurísticas para Resolver Problemas técnicos – Teoría Deducción Aplicación**"	Spanish	Juan Carlos Nishiyama y Carlos Eduardo Requena	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_51	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.