The Space Between 'Generic' and 'Specific' Problem Solutions

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Abstract

Since its introduction to the West around a decade ago, TRIZ has proved itself to be an extremely potent problem solving and product innovation method.

The key to successful problem solving usually starts with the definition of appropriate physical and technical contradictions. To a large extent the 'Contradictions' part of TRIZ then ends with a number of candidate Inventive Principle recommendations from the list of 40 currently known possibilities.

The Inventive Principles are necessarily generic in nature. Subsequent application of this type of generic statement to the inevitably specific conditions of a particular problem can often be a process fraught with uncertainty and unpredictability.

This article takes a close look at what happens in this gap between generic Inventive Principle and specific problem solution in order to establish whether there might be some general rules applicable to a more automated systematic innovation process.

1.0 Introduction

The number of texts on human creativity and creative problem solving is vast. Before TRIZ, the quantity of useful - in the context of the world of the engineer 'useable' - output from all of this activity amounts to very little.

The work of TRIZ researchers on problem classification and the discovery that inventors have thus far used only a very small number of Inventive Principles is already profoundly changing this picture. That there are only these small number of Principles has meant their systemisation in software form has been relatively easy. The emergence of a number of commercial packages built around TRIZ ideas is therefore not surprising.

With or without software, TRIZ offers a systematic innovation process built primarily on the concept of abstraction - in which a problem owner maps from a specific problem to a generic framework, out of which comes a generic solution requiring translation back to the specific. The process is illustrated in Figure 1.

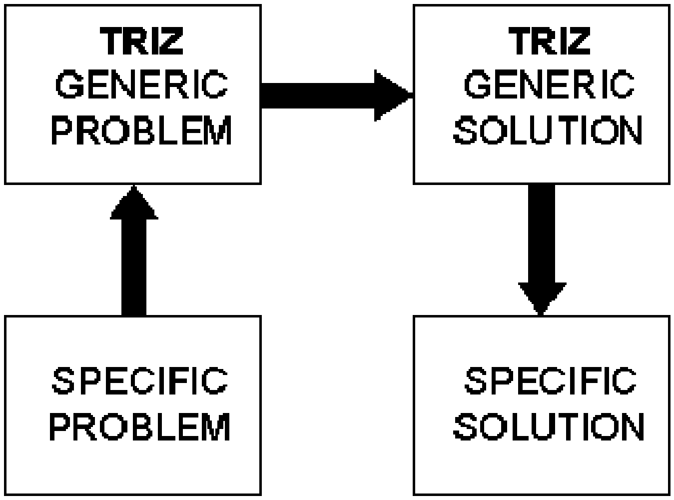

Figure 1: The General Model For TRIZ Problem Solving

Unfortunately, with the exception of work on analogies (Reference 1), the systemisation process effectively ends at the delivery of the Generic Solutions. In the case of the Contradictions part of TRIZ, this means the delivery of one or more of the 40 Inventive Principles. Although highly valuable, many problem solvers still find there is a considerable gap between these generic solution triggers and the desired specific solution. This gap is illustrated in Figure 2.

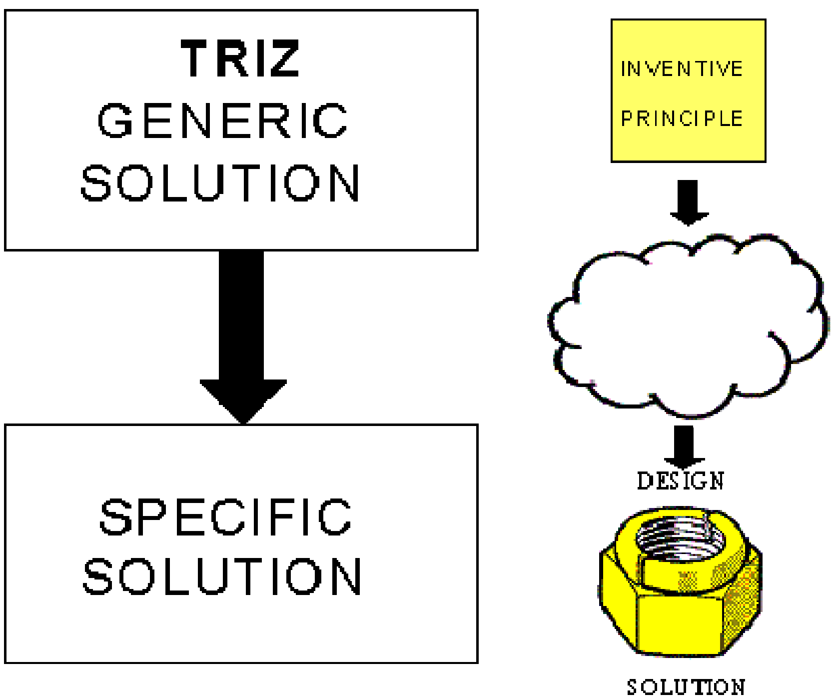

Figure 2: The Space Between Inventive Principle and Design Solution

TRIZ is being used successfully in a wide and widening variety of fields. The space - this ‘gap’ - between Principles and design solutions is obviously therefore not a vacuum. Whatever it is, however, is at present obscured by clouds. The question is what is behind those clouds, and whatever it is, is it in any way mappable?

2.0 The Irreversible Nature of Good Ideas

The best if not only way of usefully looking beyond the clouds is through examination of case study examples. Every successful patent and every successful innovation offers potential data. There is thus an awful lot of case study material from which to choose.

Unfortunately there is a problem, and it is a fairly fundamental problem associated with each and every case. It is a problem of irreversibility:

Moving forwards from problem to solution - in effect the process hidden behind the cloud - is a highly nebulous, highly intractable path. Before that moment when the light-bulb finally lights, the engineer is often literally as well as metaphorically in the dark.

The other way around - looking back at the problem after the solution has been discovered - however, is a completely different matter. Now the solution is viewed as ‘obvious’, often to the point of being almost facile. It’s the ‘why didn’t I think of that’ experience. In fact the very ‘obviousness’ of a solution is very often used as a test of how ‘right’ the solution is. The more ‘obvious’ the answer, the better the solution.

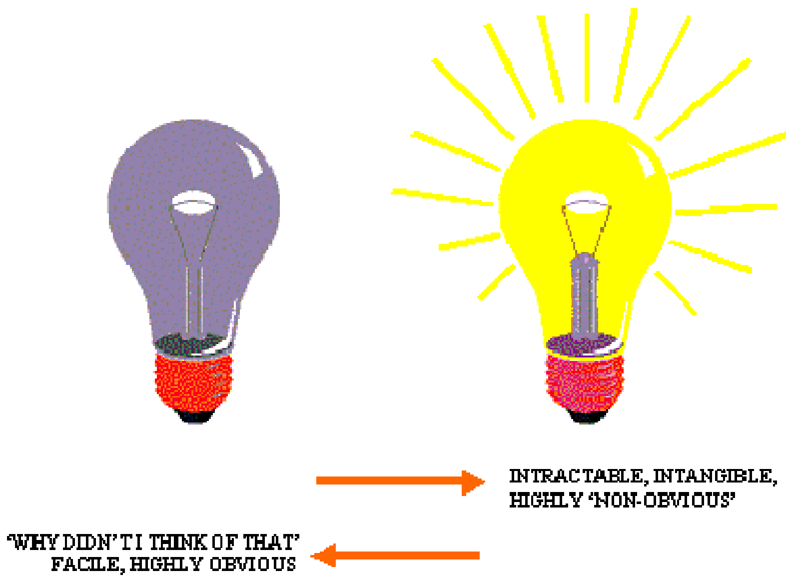

Figure 3: The Irreversible Nature Of Creative Ideas

Think, for example, of how obvious a solution the wheel is. Then think how non-obvious it was for the first 95% of human existence. Or think how it is now taken for granted that a Benzene molecule takes the form of a ring.

This ‘obviousness’ irreversibility and the speed with which the light gets turned on once the switch is found makes it extremely difficult to establish what the turning on process actually was. Most famously with Kekule and his solution of the Benzene ring problem, the solution process took the form of a dream about a snake chewing on its tail (Reference 2). It is difficult to see how this might be a mappable process. Without direct access to the problem solver - as was the case with TRIZ researchers looking at the patent database - likely as not the problem will be even greater.

In trying to get 'behind the cloud', the irreversibility problem can be expected to be a fairly major one.

First, however, let us have a look at a number of case studies in order to gain a more specific feel for the size of the unknown behind the cloud:-

3.0 Case Study 1: Flanged Joint

Flange joints are used widely across a number of industry sectors for joining adjacent sections of pipe or casings. In the aerospace gas-turbine industry, flange joints are expected to seal high temperature, high pressure gases at quite large diameters. A typical flange joint for the powerplant in a large civil airliner may well require over a hundred bolts to achieve adequate sealing performance. From the perspective of reducing weight and improving maintainability of the engines, it is desirable to reduce the number of bolts required. 'Halving the number of bolts on a flange joint' was a TRIZ case study described in Reference 3. The solution to the problem was patented in the US as patent number 5,230,540 and is reproduced here in Figure 4.

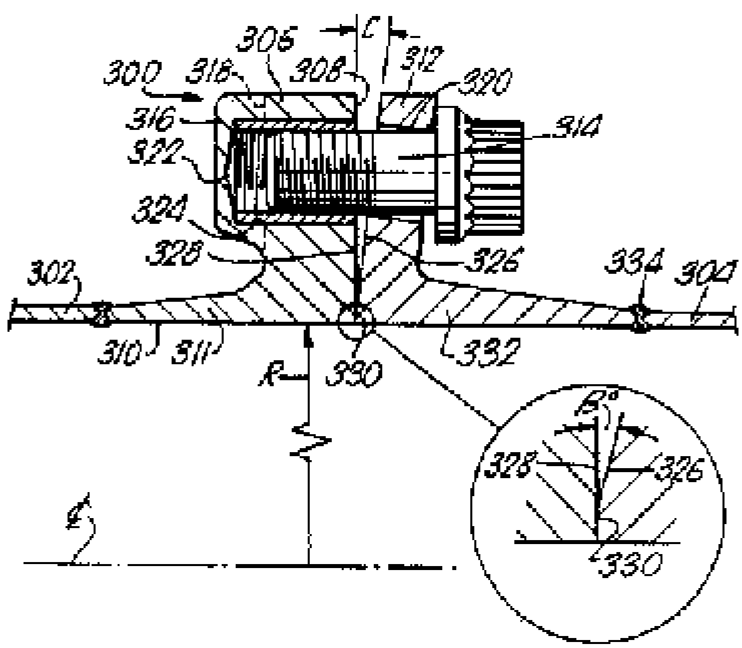

Figure 4: Fluid-Tight Joint With Inclined Flange Face, US Patent 5,230,540

The Inventive Principle used to derive this highly elegant and simple solution was Inventive Principle 17, 'Another Dimension'.

Case Study 1 then leaves us with 'Another Dimension' and patent number 5,230,540 as the entry and exit points respectively of any process that may exist behind the cloud.

4.0 Case Study 2: Bicycle Seat

Bicycle seats are, generally speaking, uncomfortable things to sit on. The bifurcated bicycle seat (Figure 5) is conceptually at least, a means of achieving both comfortable sitting position and freedom to pedal.

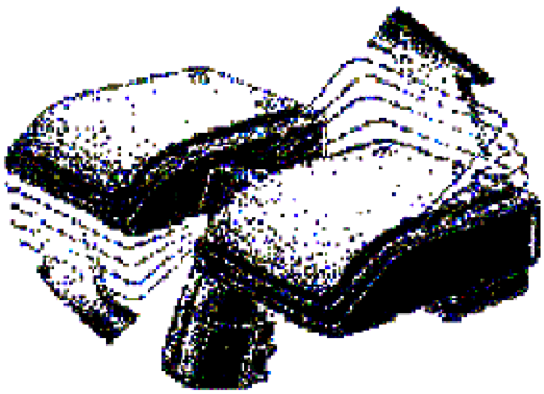

Figure 5: ABS Sports Bifurcated Saddle

While not a new idea, the bifurcated seat does offer an effective demonstration of the power of TRIZ and the Contradiction Matrix (Reference 4).

Case Study 2 sees the bifurcated bicycle seat as the specific design solution emerging from simultaneous application of Inventive Principle 15, 'Dynamic Parts'.

5.0 Case Study 3: Particle Separator

Reference 5 describes a more complex problem concerning a novel design solution to the problem of particle separator systems for helicopter engines.

There are a number of separator types available. Engine mounted forms are probably the most common. All current engine mounted separators look like the device illustrated in Figure 5; essentially an axi-symmetric, bifurcated duct taking clean air around a sharp bend into the engine, and using the inertia of contaminants to expel them through a scavenge duct.

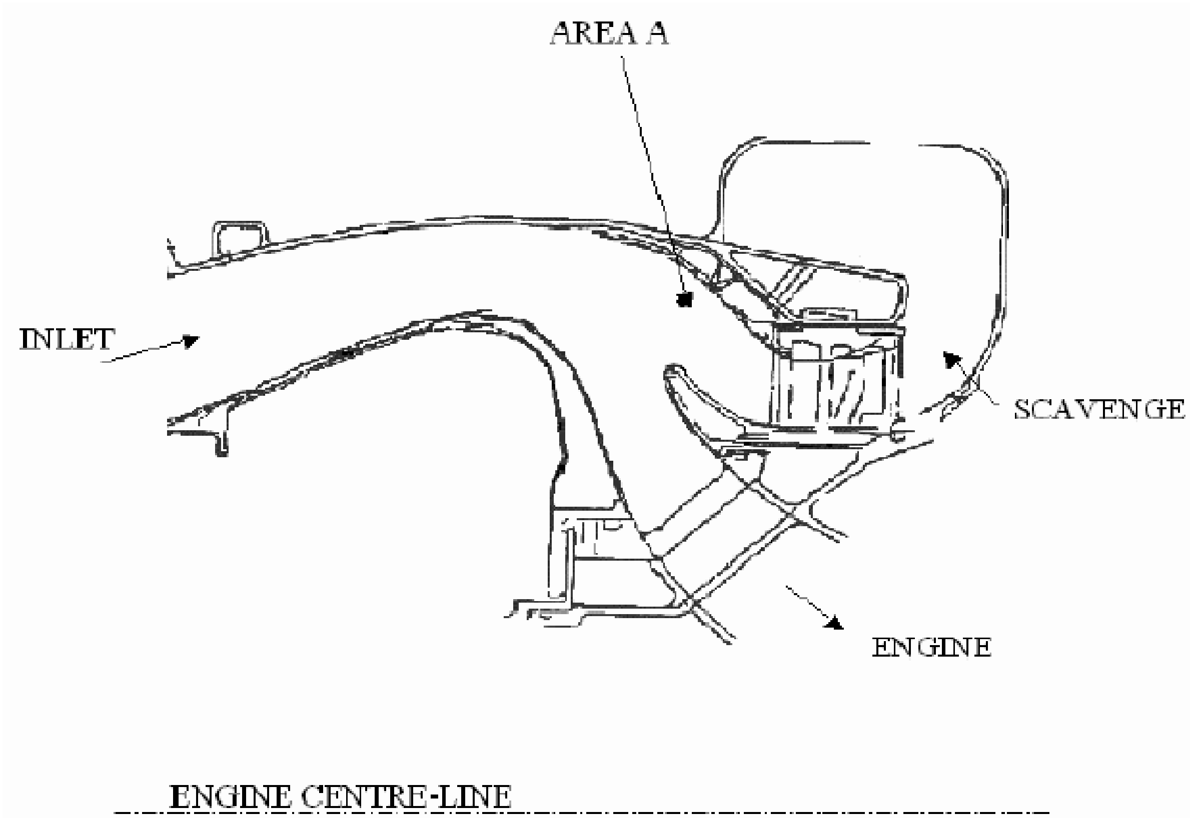

Figure 6: Typical Engine Mounted Particle Separator

Much effort has been expended trying to improve the performance of these designs. Reference 5 describes the background to the realisation of the novel solution shown in Figure 7. This new design offers the potential to not only double contaminant separation efficiency, but also to offer significant reductions in volume, weight, aerodynamic losses, and power requirement.

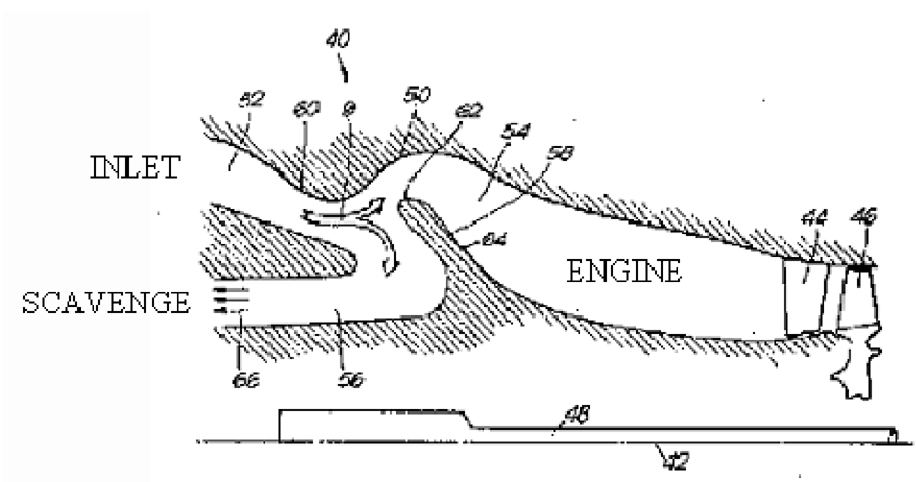

Figure 7: US Patent 5,139,545 Particle Separator

While the improved design may be seen to be relatively simple - the innovation comes about by simply transposing the position of the engine and scavenge ducts - the process of deriving it was rather more complex. The Inventive Principle used was Number 13 ‘The Other Way Around’.

6.0 Mechanisms of Mind: Pattern Recognition

To solve the mystery of what lies behind the cloud in the gap between generic and specific would be to solve a problem that has confounded many hundreds of man-years of effort. To suggest that a solution exists here, therefore, would be an action of extreme folly.

That being said, it is apparent that TRIZ has already done much to de-mystify the creative process. Wonder, for example, whether Kekule might have discovered the ring structure of Benzene any quicker if he had been aware that there were Inventive Principles called ‘Merging’, or ‘Self-Service’, or ‘Curvature Increase’? The Inventive Principles of TRIZ provide 40 very good start points from which to search for problem solutions.

TRIZ provides a powerful foundation point. A pointer to how the steps between Inventive Principle and design solution might then be plotted perhaps comes from some of the research on how the human brain functions and, particularly, on its pattern recognition capabilities.

By way of demonstration, and adapting the ‘Connect-Up’ idea first written about by Edward de Bono (6), if any two words are picked at random, the brain will almost without fail manage to come up with another word or collection of words that connects them. The process is often expressed in a manner like that shown in Figure 8. Here the two chosen random words are DOG and WING - at first glance neither word has anything at all to do with the other, but the brain will almost inevitably make some kind of connection. Indeed, given a couple of minutes, most people will be able to make associations with ten or more connecting words.

Figure 8: Connecting Words

This pattern making capability is an undoubtedly powerful one. Perhaps not so powerful, however, that some kind of mammoth artificial intelligence computer-code might be constructed to mimic the process? Even with only ten words connecting any pair and a typical individual’s word vocabulary, though, mammoth would certainly be the word.

Unfortunately, the situation becomes even more complicated if a number of people are asked to perform the same exercise. Research in this field (7) suggests that if ten people are asked to write down ten connecting words each, the level of duplication of words between individuals would be very small. On average, the number of duplicated words would be around 5%. In other words, ten people writing down ten connecting words each would tend to produce a total of over 90 different connecting words. *(Try it as an exercise sometime and watch it happen.)*

Knowing there to be a finite number of words, maybe some people can still imagine this being a situation amenable to a software implementation - albeit one in which we might hope the software itself does the large majority of the 'learning'/programming.

Unfortunately, even this scenario is a very long way away from the full story. A very long way because given a series of pictorial images to connect, one brain is usually capable of making even more connections. Take a population of brains and the number of connections may well be as close to infinite as makes any difference to even the biggest imaginable computer code.

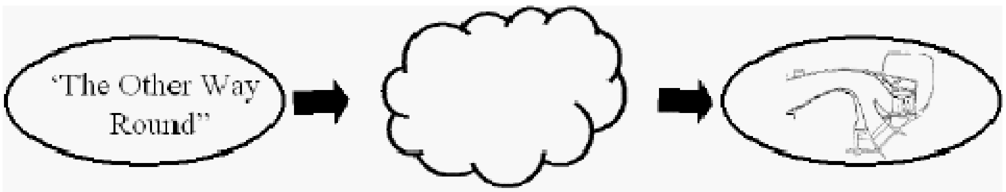

Figure 9: Case Study 3 Connections

So what does this mean from the perspective of TRIZ and the need to solve problems?

On the positive side, it means that given a problem and an Inventive Principle - for example the Case Study 3 scenario as re-drawn in Connect-Up form (Figure 9) - the brain **will** make interesting connections.

Knowing the eventual solution to Case Study 3 and seeing this picture, it is already extremely easy to see how the solution came about. Recognising the Irreversibility phenomenon described in Section 2.0, perhaps it is too easy to be believable? (The historical facts, however, show that the gas-turbine industry collectively spent several tens of millions of dollars **not** finding the solution.)

The same may be seen to apply to the other two Case Study examples.

So what about another case study? One where the 'answer' may not previously been seen? Your turn to have a go!

Figure 10: Connecting Inventive Principle and Desired Design Outcome

The (an?) answer to this one can be found in Reference 8.

Of course, even this example is over-simplistic. Over-simplistic in two important ways:-

1) There are 40 Inventive Principles. 'Local Quality' happened to be one that gave an excellent answer to this problem, but that was not known a priori. In reality, there will have been at least three - and quite possibly all 39 - other Inventive Principles to also try to connect.

2) More significantly, who is to say that the picture and its corresponding problem definition ('re-usable self-locking nut') is either the 'right' picture or the 'right' definition?

In other words, although it is possible to demonstrate that the brain is able to make the right connections, the 'Connect-Up' idea is still some considerable distance from being a systematic procedure.

7.0 Use of System Operator

Reference 9 discussed the connections between TRIZ and mind-mapping in an idea generating context. Discussed then was the concept of combined use of the generic solution triggers (in the case here, the Inventive Principle 'Local Quality') and the need to think in TIME and SPACE. The System Operator is seen to provide an excellent framework for focusing our thinking when trying to make the connections we require between generic and specific solution.

Thus, in the case of the self-locking nut, in order to make best use of the solution trigger 'Local Quality' we need to apply it not just to the nut - the thing our brains would tell us to do! - but to the nut in its bigger (super-system) and smaller (sub-system) contexts, and in terms of how the nut's behaviour and function changes with time. The thinking in space context - and the idea of our viewing perspective continuously zooming in and out - is particularly important with the Local Quality Principle.

In order to make most effective use of the Principle, we need to be looking to apply it at each viewing perspective. In essence we are looking for any element of the system where there is homogeneity. The presence of homogeneity means the current solution has not used the 'local quality' Principle. In actual fact, therefore, anywhere we see homogeneity, Local Quality is telling us we have a potential resource:

- The nut has parallel, unbroken threaded surfaces - homogeneity and therefore a resource.
- Each thread is the same as the one next to it - more homogeneity
- The external sides of the nut are parallel and continuous - ditto
- And so on

The perspective shifting capabilities offered by the System Operator, and the use of DeBono's 'connect-up' idea in each of the 9 windows (e.g. '*what does Local Quality mean in the context of thread design when the nut is being assembled?*'), offer potent ways of structuring brainstorm sessions filling the gap between believing 'Local Quality' is a good solution direction, and actually applying it to good effect on the problem.

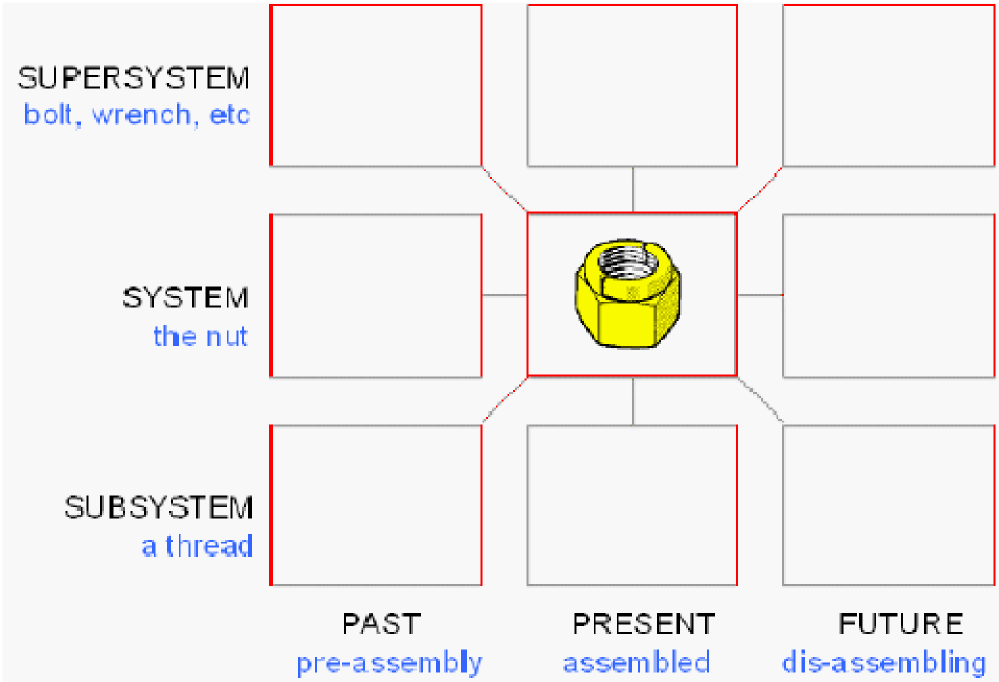

Figure 11: 9-Windows/System Operator Helps Focus Use Of Inventive Principles

It may also offer a structure useable in an automated design process:

8.0 Connections With Automated Mechanism Design Software

Whether it will ever be possible for a piece of computer software to automatically perform the actions necessary to achieve the answers to any of the Case Study examples - or indeed **any generic** problem - currently appears to be unlikely.

Whether or not it might be possible for **particular** types or groups of problem, to be solved automatically, however, may be a different matter.

Recent work at the University of Bath on mechanism design (10) may be one area where such a formal link between algorithms based on TRIZ principles and automated mechanism design software (e.g. CAMFORD) may produce a powerful design capability:

The Beginnings of a Systematic Methodology? - Mechanism design is amenable to an automated design approach in areas where design rules are able to be described in a logical, mathematical form.

The bicycle seat example described in Case Study 2 may be just such an example:

The bicycle seat has a number of functional requirements that, in the context of configuration design (as opposed to detail design), may be expressed mathematically:-

- range of positions at which the human frame is designed to carry seating loads,
- range of loads at these positions,

- range of torque (cornering) loads,
- range of seat/bicycle connection positions,
- range of relative positions between seat loading points and pedals,
- range of leg movements associated with pedalling action,
- etc.

Figure 12 illustrates these loads and loading positions in diagrammatic form.

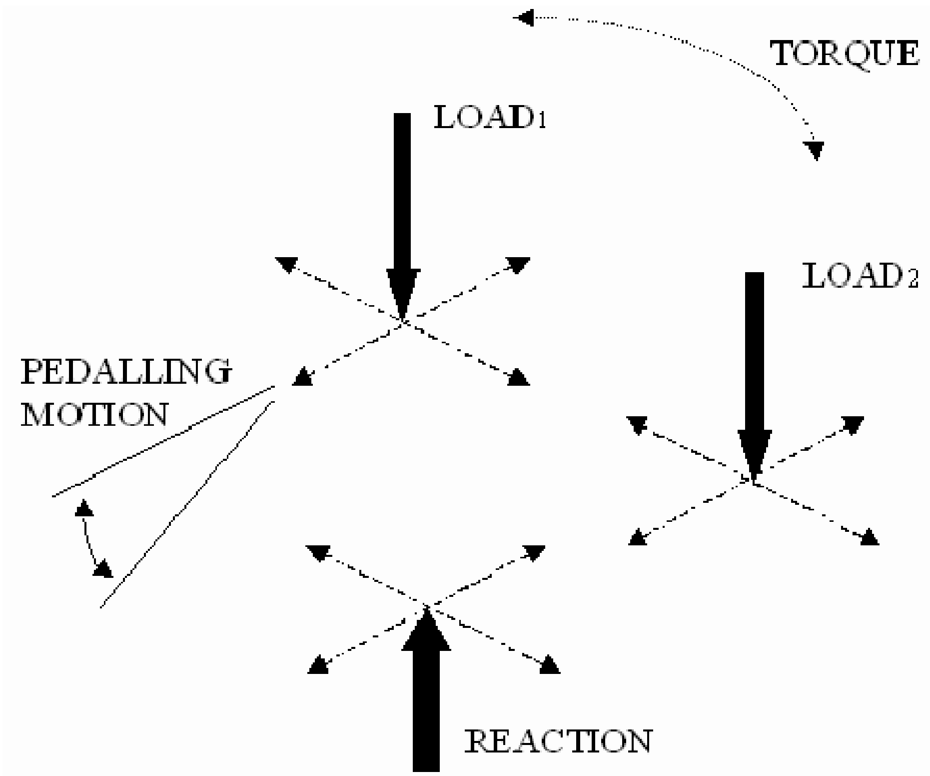

Figure 12: Example Bicycle Seat Design Domain Knowledge

In terms of a cognitive design approach (11), this information represents *domain knowledge*; the knowledge which provides the functional boundary conditions within which the design solution must lie.

The cognitive approach also requires *inference knowledge* - the 'how' rules (e.g. 'carry load using cantilever') and *strategic knowledge* - how the 'how' rules may be applied. In the ongoing automated design approach developments at Bath, this *strategic knowledge* set is the one in which the Inventive Principles of TRIZ are being projected. At least those amenable to mathematical (software implementable) interpretation in the mechanism design context. For example:-

* Segmentation	* Extraction
* Asymmetry	* Merging
* Nested Doll	* Counterweight

* Prior Action	* Other Way Round
* Spheroidality	* Dynamics
* Partial Action	* Another Dimension
* Periodic Action	* Intermediary
* Self-Service	* Local Quality

The work is some way from complete for even this simple case, not least because of the difficulties associated with the systemisation of *working knowledge* - i.e. the rules used by designer's when gauging whether a candidate solution is successful or not.

In this regard, the current research philosophy, is pointing towards use of an evolutionary design approach (12) in which the designer manually applies this *working knowledge* to select the 'fittest' solution from a series of algorithm generated mutations.

Despite such shortfalls and deficiencies in the method, preliminary evidence suggests it is actually possible to generate the bi-furcated bicycle seat solution from such an approach. We will demonstrate this - using a different problem - in a future article.

9.0 Conclusions

1. The space between Inventive Principle and problem solution is not a vacuum. If a formal route between the two exists, it is very unlikely to ever be mappable (software implementable) in a generic sense.
2. For specific problem types - such as mechanism design - a formalised, mappable systematic innovation tool based on TRIZ principles may well be constructable.
3. Meanwhile, the 40 Inventive Principles of TRIZ provide a very powerful tool for breaking out of existing design paradigms and into new and exciting ones.
4. The de Bono based 'Connect-Up' idea - getting engineers to find connections between Inventive Principles and the problem at hand through the viewing perspectives offered by the System Operator offer very powerful means of deriving inventive problem solutions.

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