Better Business and Technology Evolution Forecasting Using Systematic Innovation Methods

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Abstract

It often seems that the only sure thing about any form of technology forecast produced by any of the currently known techniques is that they will be wrong. The biggest single cause why they are wrong is that they assume the world to be mappable using linear models. Prevailing logic dictates that non-linearities are fundamentally non-predictable. While this may be true in certain instances, in the large majority of cases, research on systematic innovation methods has demonstrated that non-linear disruptions can be reliably and accurately predicted. The basis for this – perhaps difficult to believe – claim emerges through a programme of research built from the analysis of over 3 million patents and scientific advances. This research – part of the biggest study of creativity ever conducted – has demonstrated that systems evolve through a number of distinct and predictable stages. Thus far, 35 known trends of evolution have been uncovered. The paper demonstrates how these trends could have been used to predict disruptive technology shifts like the digital camera, ultrasound-based washing machines, and many others, and, more importantly, how leading companies are beginning to use them to systematically identify new disruption opportunities.

The uncovered trends offer a very clear picture of the 'what's' of disruptive innovation. Using these trends as the foundation, the paper then proceeds to examine how they can be used in conjunction with business and market trends in order to also predict the 'when's'. In discussing the subject of innovation timing, the paper defines the tension between market pull and technology push as the principle disruption driver. With regard to 'market pull', the paper further demonstrates that even when those market forces are hidden (as was the case with the digital camera), disruptions can still be uncovered in a systematic and reproducible manner.

Introduction

The Dynamics of System Evolution

The evolution of systems of any description – be they natural, technical or business – is generally recognised to occur through a succession of s-curves. Systematic innovation has uncovered the fact that systems hit fundamental limits due to the emergence of conflicts and contradictions, such that the desire to improve a measure of success of the system is prevented by something else in or around the system (for example; animal populations are limited by the availability of food, the top speed of an aeroplane is (currently) limited by the ability of the engines to accelerate gases sufficiently; the growth of a company is limited by competition and/or the finite availability of customers who want the product or service being offered). Thus, the dynamic of evolution requires the elimination of contradiction in order to progress beyond such 'fundamental' limits to another s-curve. As illustrated in Figure 1, systematic innovation research has uncovered three mechanisms by which the jumps from one s-curve to the next are able to occur. The first of the mechanisms involves the direct challenge of the emerging contradictions, the second involves the transfer of solutions from one industry or scientific discipline to another (as for example in the recent emergence of 'novel' vacuum cleaner concepts that have transferred long-established cyclone technology from other sectors), and through the systematic study of the patterns of evolution and the consequent identification of a number of generic technology and business evolution trends [1].

Our awareness of these mechanisms, and the parallel development of systematic innovation tools, is beginning to alter the way in which organisations think about their future. In particular it is offering the potential to not only accelerate the evolution of products and services, but – through the ability to better predict disruptive trans-s-curve jumps – to also obtain a much more accurate handle on forecasting what will and will not happen in the future.

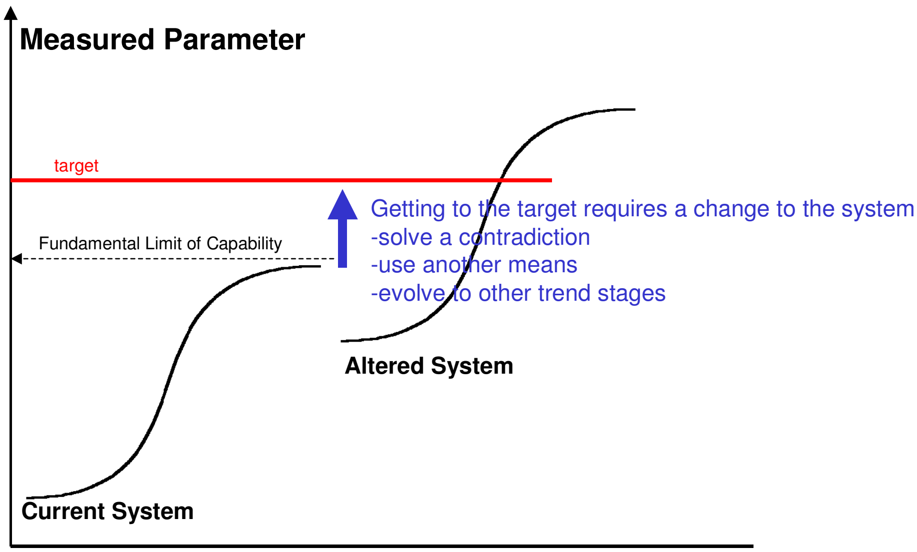

Figure 1: Evolutionary S-Curves and the Mechanisms by which Systems Jump From One to Another

The figure records the parallel important feature inherent to s-curves that when the fundamental limits of an s-curve are inconsistent with the business or performance targets we set for the system under consideration, no amount of 'continuous improvement' or 'optimization' of that system will bridge the gap from one to the other. In these situations, the only available course of actions involve either reducing the target (a very commonly applied strategy!) or making a disruptive shift to the system (or one of its sub-systems).

Evolutionary Potential

Previous work by the author has seen the creation of the concept known as 'evolutionary potential [1,2]. In simple terms, the evolutionary potential of a system may be described as the difference between the current state of evolution of the system relative to the limits described by the known systematic innovation trends of evolution. A component or system that has evolved all the way along each of the TRIZ trend may be said to have reached its evolutionary limit. Any unexploited evolution steps then represent 'evolutionary potential'. The evolutionary potential radar plot – Figure 2 – has been conceived as a means of presenting this information. Each spoke in the plot represents one of the TRIZ trends relevant to the given component. The outside perimeter of the plot represents evolutionary limit, and the shaded area represents how far along each trend the current system has evolved. Thus the area difference between shaded area and perimeter is a measure of evolutionary potential. Then, because the known trends of evolution have been uncovered by examination of systems across the full spectrum of industries and disciplines, the radar plot concept provides the opportunity for users to compare the evolutionary state of their system against a global benchmark.

Reference [2] provides a series of examples of how the radar plot can be used to determine the evolutionary state of real systems.

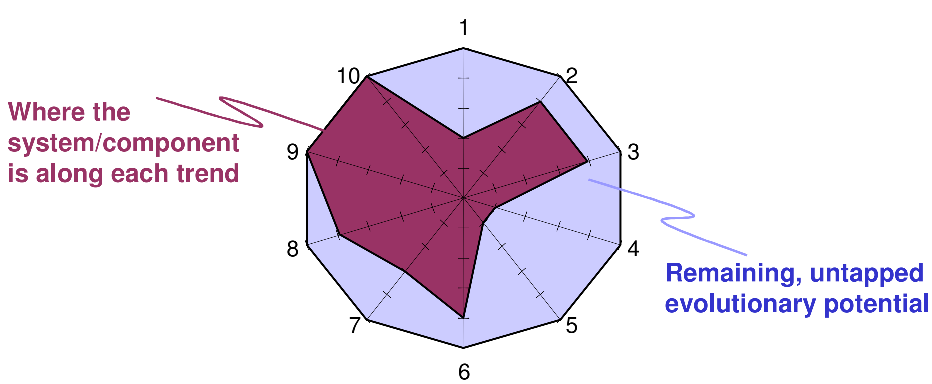

Figure 2: Evolutionary Potential Radar Plot.

As evidenced by the rapidly growing interest in the concept, it appears clear that it is emerging as a useful addition to the systematic innovation methodology. It has always been the belief of the author, however, that the initially published work was very much a first step towards a much more comprehensive and effective tool for both problem solving, opportunity finding and strategic study applications. This paper describes some of the next evolution steps conceived by the CREAX research team. These comprise:-

1) Incorporation of time effects
2) Incorporation of system hierarchy effects
3) Incorporation of trend interaction effects
4) Consideration of innovation timing effects, and, finally,
5) Consideration of recursion effects

Before describing each in turn, it is necessary to provide a little further information on the underlying philosophical elements that have had an influence on the evolution directions followed. Primarily, these centre on the topic of ideality. One of the main pillars in the systematic innovation philosophy is the concept of systems evolving in the direction of increasing ideality (defined as the sum of the good things in a system divided by the sum of the bad things). The concept also includes the idea of an 'ideal final result (IFR)' – defined as the evolutionary limit of a system in which all of the good things are delivered, and all of the bad things have disappeared. While this might sound somewhat fanciful on many levels, there are nevertheless many cases where such an IFR has been realised; this is particularly so when considering components within a bigger system. Irrespective of whether it is fanciful or not, the recognition that evolution is directed towards this end point is at least if not the more important philosophical point. We often draw this IFR end point as the tip of a cone – Figure 3 – in which the distance from the circular base of the cone to the tip is used to represent the passage of time; the base representing the present day.

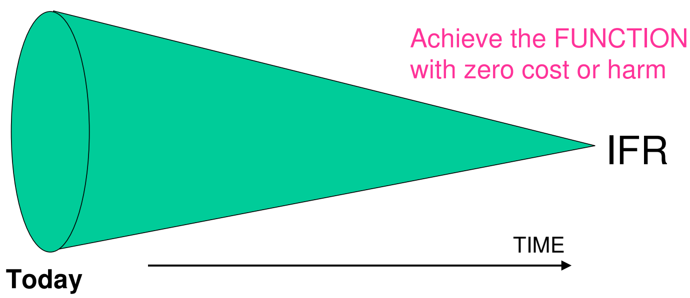

Figure 3: Evolution and Ideal Final Result as a Conical Process.

The cone image may appear to run counter to our natural instinct, as it seems to imply that evolution is a convergent process rather than a divergent one. With the proviso that, of course, there are many different functions (and thus, if one cone represents one function, many cones) and many undiscovered means of delivering those functions (space around the cones), the author believes that the convergent image is the more appropriate and more useful one.

Previous discussions of the evolutionary potential concept have shown how the systematic innovation trends offer users the opportunity to advance the evolution of an existing system in the direction of the point of the cone (or 'IFR') – Figure 4.

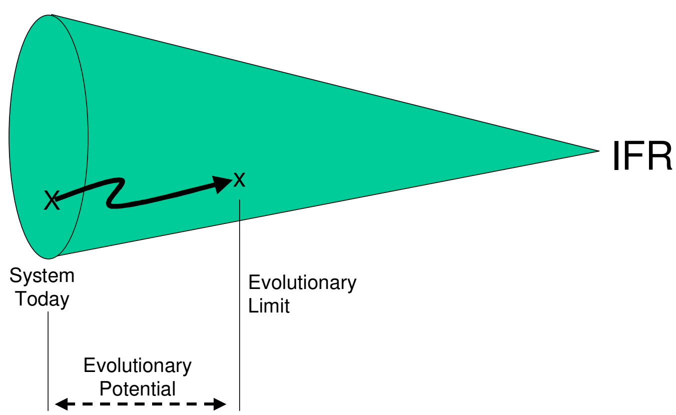

Figure 4: Ideal Final Result and 'Evolutionary Limit' Concepts.

In this respect, the evolutionary potential concept works in a manner similar to some of the other systematic innovation tools – in that it takes today's system as its start point and works 'forwards' towards the IFR. While this is often exactly the right way to proceed for a given problem situation (imposed constraints, for example, may prohibit anything other than small changes to the current system), it is important to recognise that there are two other very important mechanisms by which problem solvers can evolve the system under consideration.

As illustrated in Figure 5, the other two primary mechanisms emerge from use of the ideality tool (jump to the IFR and work backwards until a practical solution emerges) and the knowledge/effects part of the systematic innovation toolkit (where we are using knowledge already existing in other industry or scientific disciplines than our own to 'jump' to another place on the base of the cone).

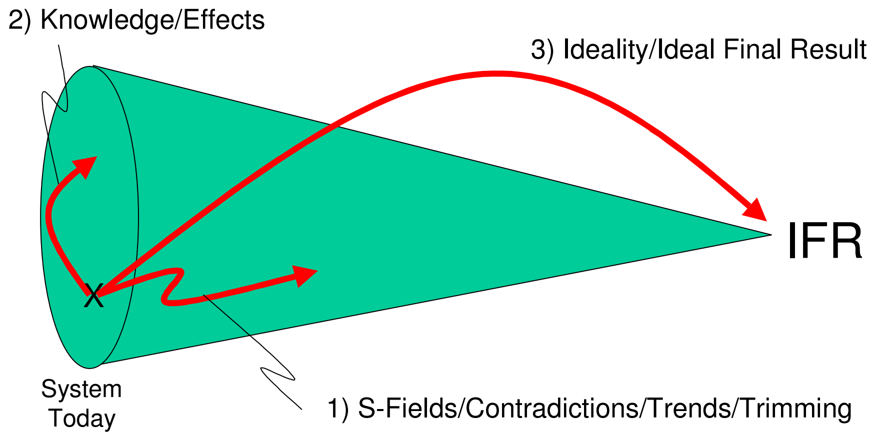

Figure 5: Three Primary Mechanisms of System Evolution.

The knowledge/effects route, is perhaps best observed by looking directly onto the base of the cone – Figure 5 – which we may see can be segmented into different areas of scientific endeavour as are traditionally defined (these distinctions are in truth more for convenience than factually relevant).

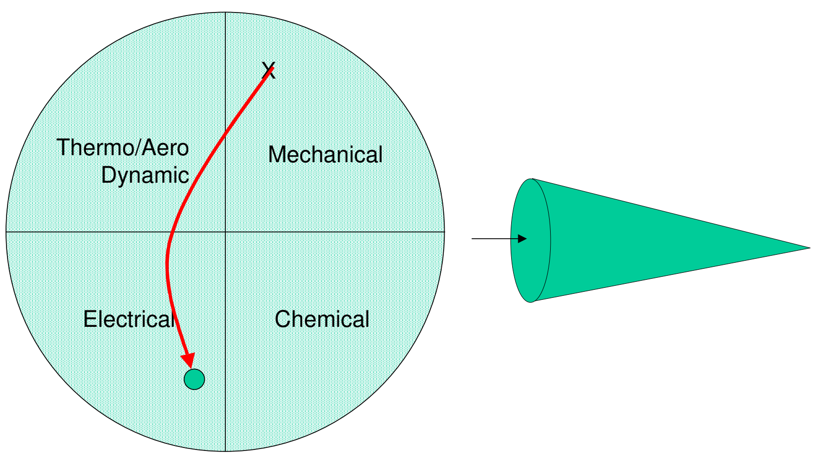

Figure 6: End-on View of Cone Highlighting Different Scientific Disciplines.

The cone analogy may be extended further by including the fact that mankind's awareness of the total array of knowledge and effects is still relatively incomplete. We might describe this state by drawing a cone with a larger base-diameter to represent the full scope of available knowledge – Figure 7.

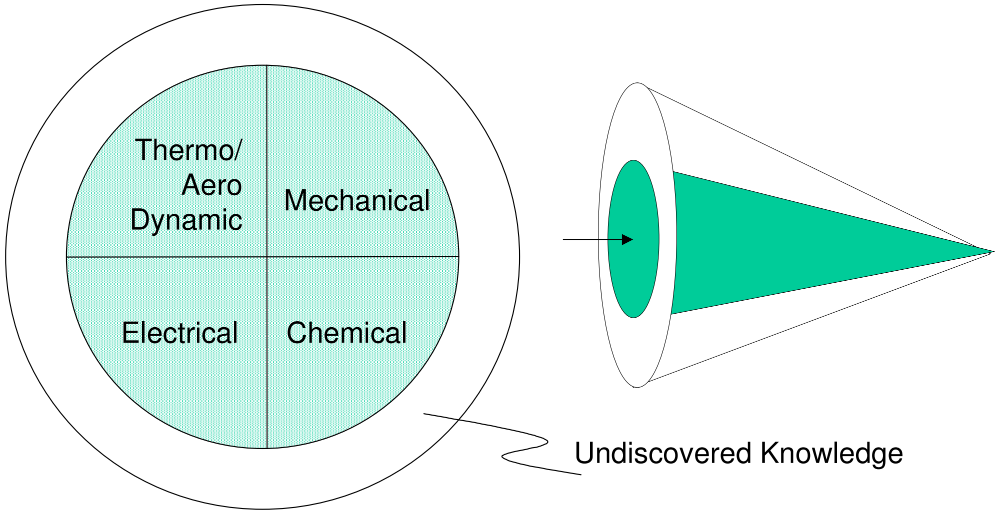

Figure 7: Cone Analogy Extended to Encompass as yet 'Unknown' Knowledge.

All three problem solving strategies – moving forward from the current system, shifting to another system, and starting from the IFR – are relevant evolution routes and, for any real situation therefore, all three should be considered. With this health warning and these effects in mind, the paper now returns to examine the evolution of the evolutionary potential concept, and how the other two routes might be expected to influence their use.

Time Effects

The geometric evolution trend suggests that the current evolutionary potential plotting system is 2-Dimensional in nature, and has thus not taken advantage of the available third dimension. With this in mind, all that was necessary was to imagine how the third dimension could be used to most beneficial effect. To this end, we have determined that introducing a time axis to the basic plot offers users the most value. The radar plot spokes themselves contain 'time'-related evolution trends, and so it is necessary to be clear that 'time in the context of this new third dimension means the passage of time over which the evolution of the system takes place. An example will help to clarify the meaning – Figure 8 thus shows a sequence of radar plots for a simple (toothbrush bristle) system. A more complete description of the evolution stages taking place in this hypothetical evolution sequence may be found, in [3].

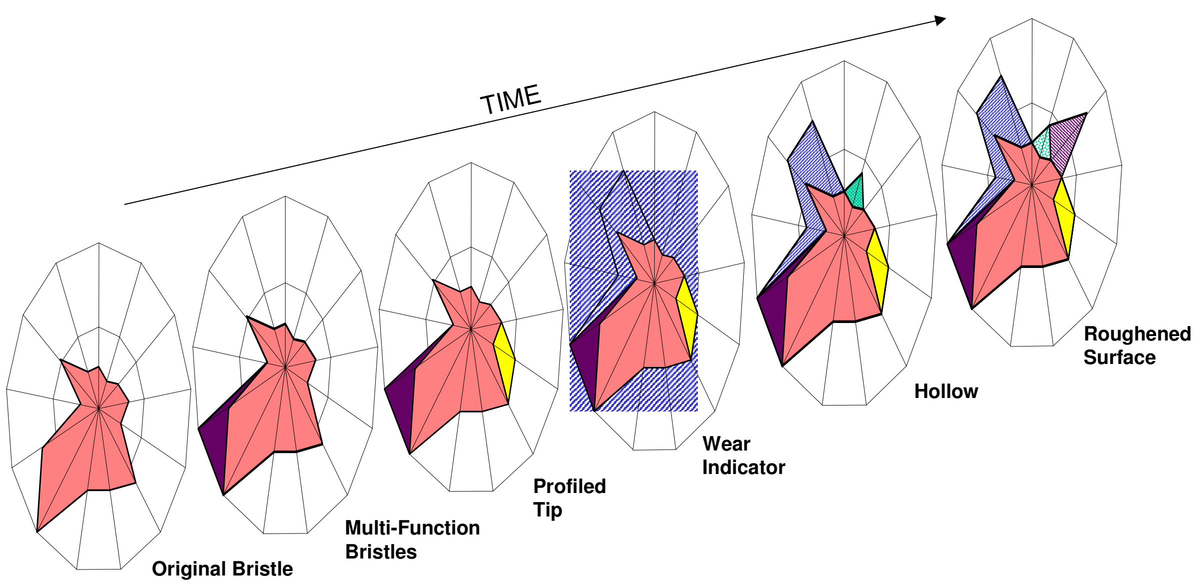

Figure 8: Evolution Potential of Toothbrush Bristle As A Function of Time.

The actual sequence of events depicted is in this case hypothetical. The main thing to note from the image is that as time progresses, and as the system evolves, the radar plot fills-out as evolutionary potential is progressively used up. We believe this 'flowering' effect of the plot is a useful image to keep in mind when thinking about the mechanics of system evolution.

Hierarchy Effects

Remaining with the above toothbrush bristle example, its direction of evolution should always be towards the ideal final result in which the useful function is delivered without the presence of an actual bristle. If we consider the evolution of the bristle along the 'dynamisation' trend (immobile evolves to jointed evolves to fully flexible evolves to fluid evolves to field), for example, we may observe that as it advances from its current 'fully flexible' state towards a field, it will actually disappear. The recent wave of brushes operating using ultrasound would represent such a jump along the dynamisation trend. In this design, the ideal final result bristle design has actually been achieved – in that the useful function is performed without the need for a bristle. In this case, what has actually happened is the function delivery means has migrated to a higher level – such that the function of the bristle (a sub-system element of the system known as 'brush') has been taken over by the higher-level system. The function migration effect is illustrated in Figure 9.

What the figure also shows is that the system 'brush' is in turn just a part of a higher level 'super-system. With this in mind, as we consider the evolution of the brush towards its own ideal final result – clean teeth without the brush – it becomes apparent that this end-point is most likely to be achieved by something in the super-system performing the function. In other words, the delivery of the function will again migrate to something at a higher hierarchical level. It is already possible to see this migration taking place with the recent emergence of tooth-cleaning chewing gums (a sub-system element of the broad system category 'food'). They in turn could be replaced by the system 'food' itself – i.e. foodstuffs that clean your teeth as you eat.

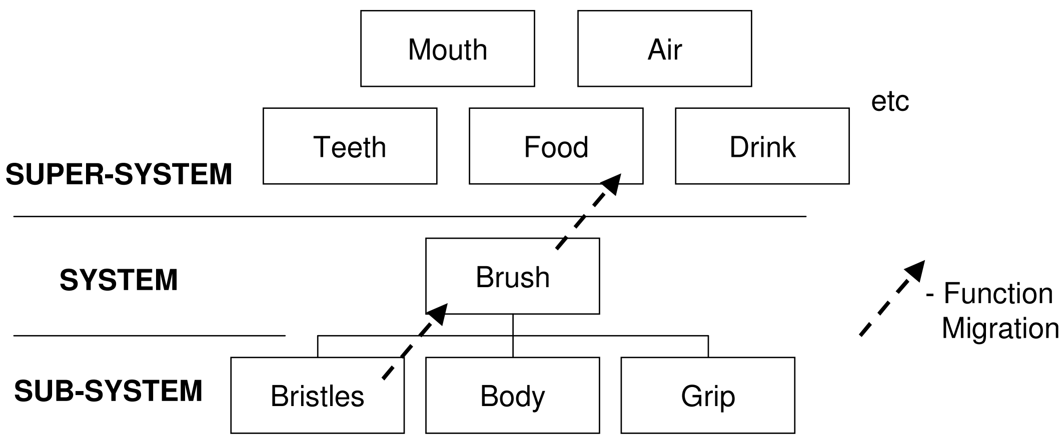

Figure 9: Toothbrush Bristle/Toothbrush/Clean Teeth/Self-Cleaning Teeth Hierarchy Effects.

It is useful to note in this case study that the need for the bristle – or indeed any other sub-system component, or even the system itself may 'disappear' before all of its evolution potential has been utilised. This is a commonly observed phenomenon. Related to it are the parallel observations that

a) it will usually be a new-player that causes the demise of the system (e.g. in this case it looks set to be the chewing gum or food manufacturers)
b) the incumbent toothbrush manufacturers will typically respond by continuing to evolve the bristle and other parts of the brush along the paths suggested by the evolutionary potential plots in an (eventually futile) bid to prolong the life of their product. This phenomenon helps to explain the commonly observed rise in intellectual property generation by incumbents just before the end of the life of their system.

Recursion Effects

Similar to the idea of hierarchical effects described above, it is also worth extending the cone analogy to include the important systematic innovation concept of recursion. Recursion in innovation involves several ideas. In simplest terms it suggests that as we zoom-in and out to look at systems from different hierarchical levels, we will find a hierarchy of viable systems (i.e. in systematic innovation and Viable System Model terms, one that contains the five requisite elements of engine, transmission, tool, interface and control). This means that we may consider atoms and molecules as viable systems in the same way that a toothbrush bristle made up of those atoms and a toothbrush incorporating those bristles are also viable systems.

Rather than wishing to explore this phenomenon in any great depth here, we merely wish to introduce the recursion concept into the conical evolution analogy by drawing Figure 10. The figure extends the toothbrush hierarchy discussion from the previous section to recognise that it is possible to draw a cone to represent the evolution of the toothbrush bristle, which sits inside a bigger cone representing the toothbrush; which in turn sits inside another cone representing the function clean teeth. The concept of evolution cones being constructed from multiple cones which in turn are made up of other cones is believed to present a useful image to assist in the visualisation of the overall evolution process.

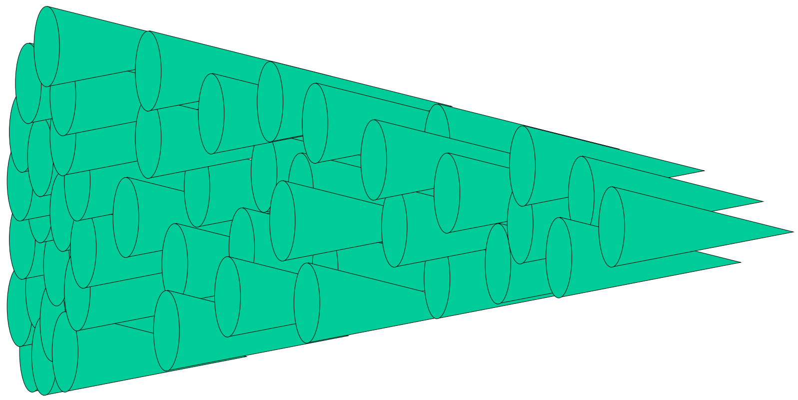

Figure 10: Recursion Effect in Conical Evolution Model – Cones Made up of Cones.

We will return to this area of discussion in future papers and articles.

Trend Interaction Effects

Previous work by the authors [4] has hinted at the links that exist between different components in a system where the evolution of one component influences the evolution of another. In that instance it was seen that the emergence of a fork influenced the evolution of the knife it was used in conjunction with. We might think of this case as one of 'complementary' evolution – one system element evolves to eliminate an inadequacy; and this evolution then 'frees' another part of the system to also advance – Figure 11.

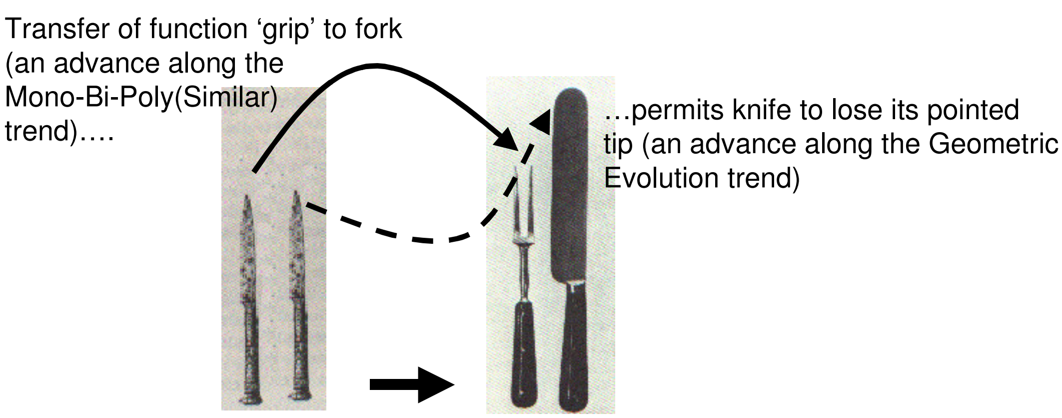

Figure 11: Knife and Fork – The Evolution of One Part of the System Affects Another.

In this case, we see the 'inadequacy' or 'failure' (eating with two knives gave inadequate control over the 'grip' function when trying to cut the food being consumed) prompting the original pointed tip knife design to advance along the mono-bi-poly trend to create a fork that would take over that 'grip' function. Then, as soon as the knife no longer needed to perform this function, it was free to advance along the geometric evolution trend to lose its point and take up a rounded end profile.

A general point that may be gleaned from this picture, too, is that systems evolve (i.e. 'use up' their evolution potential) when a 'failure' becomes apparent or perceived by the customer. In other words, systems will advance along the trends as and when there is a need to be fulfilled. Without such a 'need', systems may well stay at the same level of evolutionary potential for considerable periods of time – for example water filters based on the sand-bed type (as used in many swimming pool and water treatment works) have seen no advance since Roman times as there has been no customer perception of inadequacy. It is only now that new threats like the crypto-sporidium larvae – which are not adequately separated by the sand-filter – have emerged that the motivation to advance along the trends has begun. This 'evolution follows failure' subject is discussed further in the next section.

The knife and fork story, meanwhile, concerns 'complementary' evolution in which the advance of one part permits advance in other parts. The other – more common – evolution mechanism involves non-complementary or 'arms-race' type situations. These are instances discussed more frequently in the TRIZ literature in, for example, discussions of the evolution of the bicycle [1] or, more generally, descriptions of the evolutionary process in nature [5] – usually involving the continual struggle that takes place between hunter and prey. As discussed in [6], it is often the case that in these non-complementary evolution cases, it can become necessary for one part of a system to evolve away from its own ideality in order to serve the greater need of the system as a whole.

A vivid example of this process in action comes via the recent emergence of 'washing blocks' for either dishwashers or clothes-cleaning tasks. The evolution from washing powder or liquid to a solid block represents several steps away from ideality in the terms of the 'object segmentation' trend. This apparently 'backward' step is explained, however, by either consideration of the higher level system of delivering the cleaning agent to the machine (there is less mess involved in placing a single block into the machine, and the need to measure the right amount is removed from the user), or, more significantly, the introduction of pre-wash, wash and condition functional requirements into a single system. Put simply, the liquids or powders do not (yet) permit any control over when different cleaning actions take place; while the block can be constructed in layers such that an inside layer remains inactive while the layer that surrounds it performs its function. This 'trend directions getting worse to support the greater good' idea is illustrated in Figure 12.

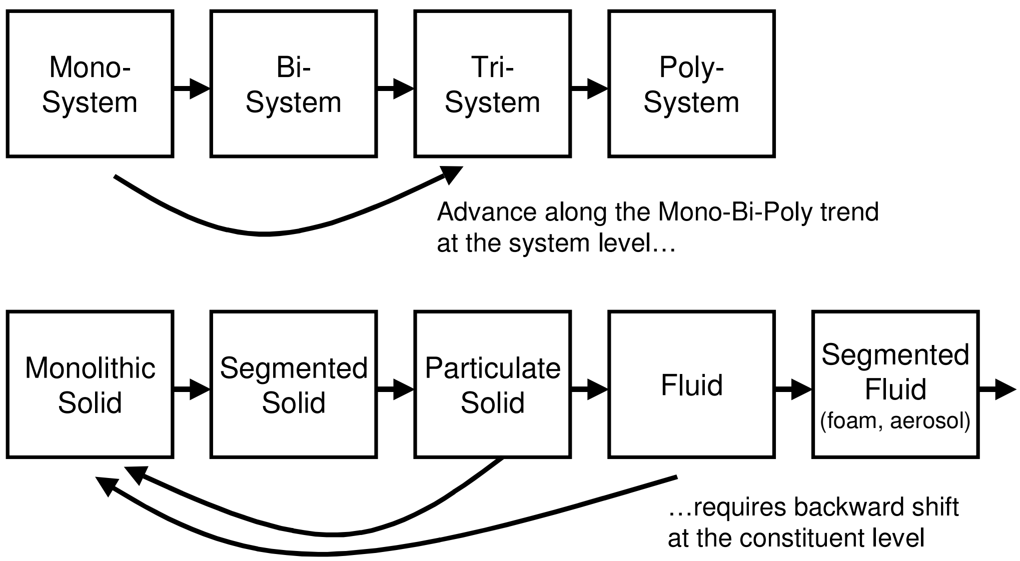

Figure 12: Washing System Example of 'Getting Worse' To Support Advance at a Higher Level.

In this particular case, it is possible to see that at the system level, the new washing blocks represent advances along the 'Action Co-ordination' (uncoordinated actions advance to co-ordinated) as well as the Mono-Bi-Poly trend. The Mono-Bi-Poly trend is the one used in the Figure, as it is the most common of all the TRIZ trends to create a backward shift in the evolution direction of sub-system elements.

Innovation Timing Effects

Innovation timing is one of the more difficult aspects of the evolution process to predict accurately. The authors have previously the subject in the context of differences that occur when technology advances out-pace customer expectations versus situations when customer expectations exceed technology capability [7]. In the former case, it may be observed that the market becomes open for disruptive innovations pitched at a 'lower' technological level. In the latter case – where customer expectations exceed technology capability – the resultant contradiction provides the necessary innovation impetus. It is this latter case that we explore in greater depth here.

The start-point for this exploration was an extension to the conical evolution analogy detailed earlier in the paper that emerged through a connection made with the spiral evolution process analogy found in WOIS [5]. The WOIS analogy uses a rising spiral geometry form comprised of parallel technology, customer and nature lines. Thinking about the geometric evolution trend again – and the fact that the WOIS model is not fully three-dimensional – we connected the spiral idea to the conical one. The result, after additionally dropping the 'nature' line – which we found it difficult to separate from the 'technology' line based on the ongoing work to integrate biology into the TRIZ framework [8] – is illustrated in Figure 13.

In this conical spiral model we see the primary driver of innovation as the 'tension' between customer demand and the ability of technology to supply that demand. In all instances, that tension must be the thing that provides the impetus and direction for innovation – without it, anything technological innovation would be doomed to failure.

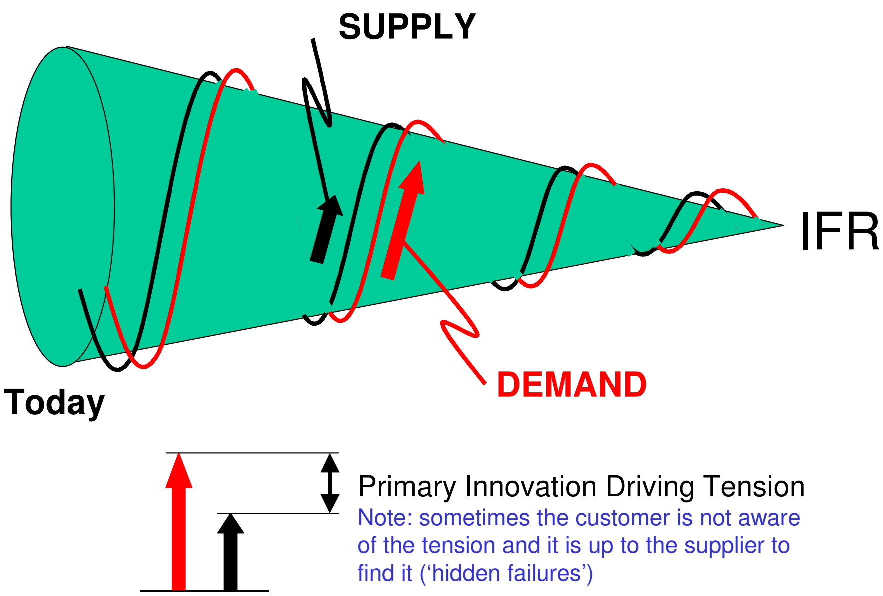

Figure 13: Tension Between Supply and Demand Drives Innovation.

If this point appears to be over-stated, it is important to recognise the fact that very often the tension may not be apparent to the customer. By way of example of this, perhaps at first sight paradoxical, statement we might consider the case of the digital camera. As has been stated several times in other places, no photographer would have had the foresight to ask for a digital camera in a world in which they had only known about cameras using film (TRIZ trends would have predicted the jump of course). This lack of awareness, however, did not equate to a lack of innovation driving tension; merely that the customer was unable to articulate their desires. Reference [9] is built on the theme that 'form follows failure' is the principle driver of evolution. We might extend that analogy here to include those situations where the 'failure' is hidden. Having to end an exposed film away to be processed somewhere else represents precisely one of those 'hidden failures' that, as soon as the digital camera appeared, customers could suddenly see.

The jump from conventional film-based camera concepts to the digital camera is, of course a jump predicted – at least in a generic sense by the trend directions towards increasing use of 'field' solutions (i.e. electrical, magnetic, digital, etc) over the use of mechanically based systems – Figure 14.

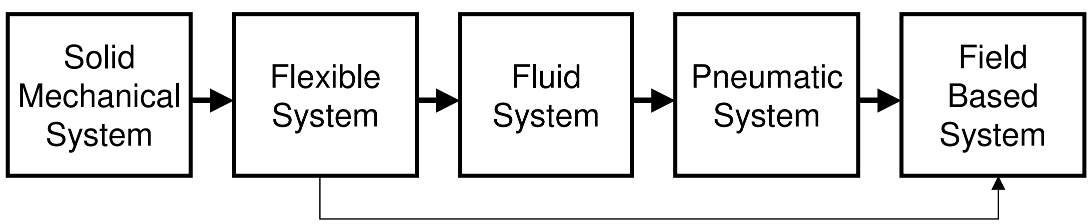

Figure 14: Evolution of Digital Camera as Suggested by Systematic Innovation Trends.

In fact, probably a very large part of the whole innovation picture may be seen to be driven by the successive uncovering and exploitation of these hidden failures or driving tensions. Visible tensions are visible to suppliers, who usually have no option but to then try and resolve them before their competitors; hidden tensions, on the other hand, will only be spotted by those that specifically go and look for them. Historically, those that go looking are the new-players; today, enlightened organisations are beginning to get the message that they too must seek out the invisible.

Summary and Conclusions

The concept of evolutionary potential has been extended from its initial trends-only roots to now include time, hierarchy, recursion and trend interaction effects. The author believes that the concept now offers a more substantial basis upon which evolutionary processes can be modelled and understood, albeit recognising that there is still much to be done in order to achieve any kind of ‘completeness’. In the meantime, it is believed that in it current form, it offers users a valuable problem solving and disruptive innovation identification strategic development tool.

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