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The Systematic Innovation e-zine is a monthly, subscription only, publication. Each month will feature articles and features aimed at advancing the state of the art in TRIZ and related problem solving methodologies.

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Readers' comments and inputs are always welcome.
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Case Studies In TRIZ – Clothes Peg

Part 1: System Completeness

This article forms the first of a series of three focused on the application of TRIZ to the improvement and evolution of the clothes-peg. Guessing that not every reader is passionate about such objects, the emphasis is likely to stay pretty close to processes rather than breakthrough product ideas… we do know a peg manufacturer though, so who knows where we might end up. The nice things about clothes-pegs are that they are familiar to all, and, as we shall hopefully soon see, despite their apparent simplicity, they will allow us to examine and exploit some quite sophisticated thinking processes. The emphasis of this first part in the series is the TRIZ Law of System Completeness. The two subsequent parts – to be featured in the next two issues of the e-zine – will focus respectively on the increasing-decreasing complexity trend and its relevance to Inventive Principle usage, and then evolution by migration to sub and/or super systems.

But first, the Law of System Completeness:

The Law in its modern form states that any functioning system must contain five essential elements: There must be an engine providing a source of energy, there must be a Tool to utilize that energy to deliver the useful function, there must be a Transmission to connect the two together. The Tool must act on something; whatever the Tool delivers its useful function to we can call the Interface. And then finally, there needs to be some means of Controlling the interactions between each of the elements.

We can see how the Law applies to the most common type of clothes-peg – the three component, sprung version – in Figure 1:

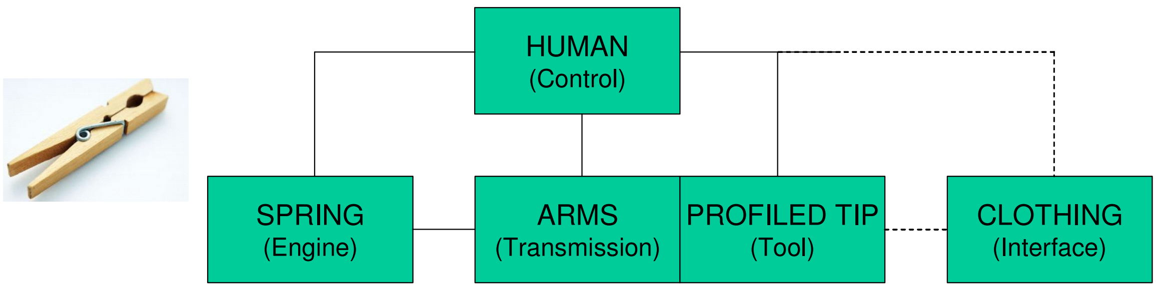


Figure 1: Law Of System Completeness Applied to Spring-Type Clothes Peg

The Law is not often considered explicitly when examining technical systems like our clothes peg. This is because quite simply a design will not function if any of the five elements is missing. In creating any working artifact, therefore, any engineer or designer must instinctively 'know about' the Law. Attempts to introduce or discuss the Law in any kind of technical workshop or problem solving session is usually a very good way of achieving a room full of blank stares and 'so what's'. The paradox here is that even though the Law – technically at least – appears 'obvious' to us, it is not always obvious when we ask people to match components of the system they are working on to the five basic elements.

Even for a system as simple as a clothes-peg, it is not totally obvious. In the Figure 1 definition, for example, are the two wooden components both 'the tool'? Where is the 'transmission'? Why isn't the human pressing on the two arms the engine? We have the clothing, but why isn't the clothes-line in the system? (Actually this latter question is worth spending a couple of seconds thinking about – the clothes-line is performing a different function to the clothes-peg (the peg keeps the clothes attached to the line, while the line supports the clothes off the ground) and so the clothes-line must also satisfy the Law of System Completeness.)

The story doesn't become too much clearer when we make a similar 5-component breakdown of the simpler single-component clothes peg show in Figure 2:

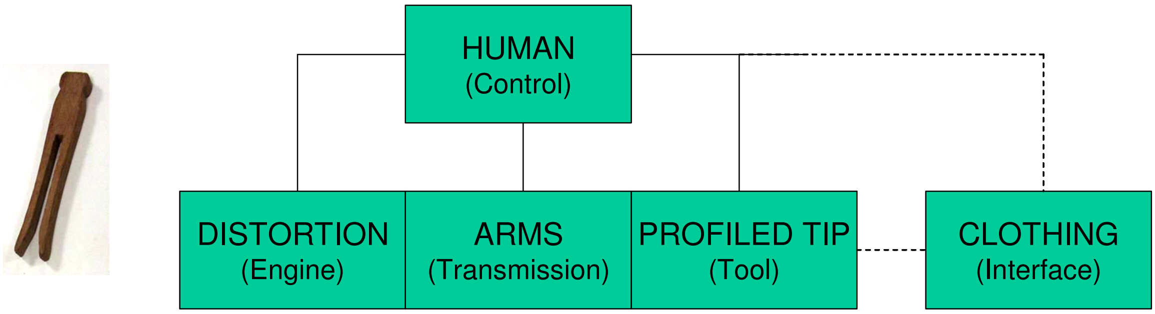


Figure 2: Law Of System Completeness Applied to Single-Piece Clothes Peg

This clothes-peg has gone from three components down to one, and yet it still performs the desired function ('grip clothes'), and therefore must still contain the five essential components as defined by the Law.

We could argue, of course, that all of this is just semantics. There is, however, a point. The point, simple as it is, is this:

The five essential elements of the system are the things we need to focus our attention on in order to improve the system.

So, for example, if we are looking to resolve a contradiction or conflict associated with the peg and are looking, therefore, to utilize the Inventive Principles, it is a good idea to connect the suggested Principles to each of the five elements. In such a way, if the Matrix suggests the use of Principle 1, Segmentation, then it is in our interests to ask questions like should I segment the engine? Can I segment the transmission? Can I segment the interface? And so on. The Principles essentially depend on us to make *connections* between the instruction contained in the Principle and our system (Reference 1).

Not only that, given the importance of 'interfaces' in general in the Systematic Innovation toolkit, it is also useful to think about the links between each of the five essential elements as well as the elements themselves – Figure 3.

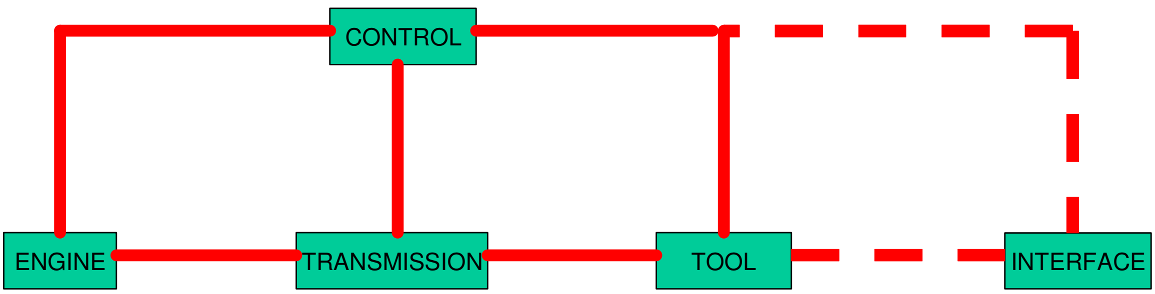


Figure 3: Law Of System Completeness – Connections Between Elements

Thus when we are using the Principles, we should also be asking questions like 'can I segment the connection between Engine and Transmission? Can I segment the connection between Control and Tool? Can I segment the connection between Control and Transmission? And so on again.

At this point in the problem solving process, using the Law of System Completeness to help guide where we focus the Inventive Principles (and indeed other solution generation tools) represents a tangible and effective use of the Law. By thinking about each of the five essential elements and all of their links, we are opening up the possibility of making many useful system improvement connections. We may consider this is in fact sufficient justification for thinking about the Law.

We may well generate more ideas using such an approach. It is not clear yet, however, that they will necessarily be better ideas. In Part 2 we will shift our attention to this issue and how we might ensure *both* quality and quantity of ideas.

Reference

1) Systematic Innovation e-zine, 'Connections & Directions Towards The More Ideal System', Issue 33, December 2004.

Complexity Increases…. *Because*

An Examination Of Long Term System Complexity Evolution

All systems pass through recurring cycles of increasing and then decreasing complexity. This is one of the important findings of the original TRIZ research into trends of evolution. The cycle applies to any kind of system, be it technical or non-technical, physical or virtual, sometimes over the course of many decades and sometimes rather more quickly. The increasing-decreasing complexity cycle is closely correlated with the evolutionary S-curve as shown in Figure 1. Each s-curve cycle corresponds to one of these increasing-decreasing cycles.

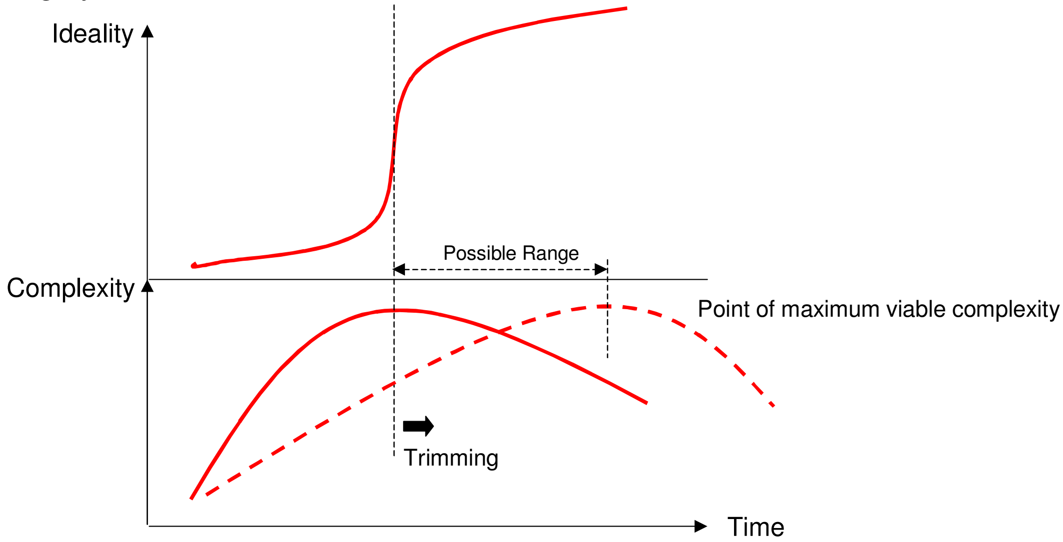


Figure 1: Correlation Between Increasing Decreasing Complexity Cycle And S-Curve

There are many underlying reasons behind the complexity cycle. We have discussed several of these in previous e-zine articles. In a future article we will attempt to bring all of these reasons together in order to provide a comprehensive understanding of both why it happens and what implications the characteristic might have on the way in which we design systems.

Our theme in this article is to explore another phenomenon of the complexity cycle. The idea that over the course of several cycles, the overall complexity tends to increase – Figure 2.

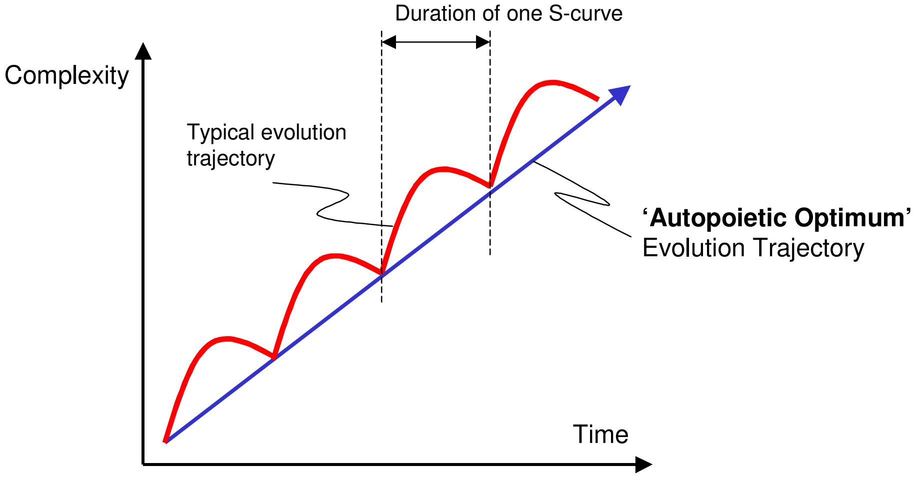


Figure 2: Complexity Increases-Decreases Cycles And Net Increase Over Time

We first discussed this characteristic in a paper comparing the evolution of man-made versus technical systems (Reference 1). The inspiration behind that article was exploring whether the general increase in complexity in biological systems had a corollary with the evolution of technical systems. That article received some criticism (Reference 2). Examining the Reference 2 response to the Figure 2 hypothesis now suggests one possible correction to our original article. In that article, we stated that all biological systems followed the increasing complexity direction. In retrospect we should have listened to our own advice and avoided using that word 'all'. More correctly we should have said 'the vast majority of biological systems have evolved to increasing levels of complexity'. In very rare instances when the environment changes, some biological systems have been seen to decrease in complexity. A good example is the human brain. One of nature's greatest achievements, the human brain is a tremendously complex system. There has been a period in mankind's evolution, however, when the complexity of the brain decreased. Brain size decreased by around 10% when man 'teamed' with pack animals. Domesticating dogs and the formation of social networks meant that we could delegate some of our individual brain function to the 'pack' (Reference 3). So here is an example where the complexity of the individual system decreased. The complexity of the overall system, however, did not. Function was rather transferred from an individual to the social group. So overall group complexity did not decrease. Indeed over evolutionary time, social group complexity continued to increase. As did brain size. The decrease in individual brain complexity was, in other words, a temporary event. Look hard enough (Reference 2 includes one nice example) and we can see similar examples in other areas of biology. Again that is not so relevant to our discussion here.

What we are interested in is how does the Figure 2 characteristic manifest itself in technical systems. We will use as our example the evolution of flight control systems – Figure 3.

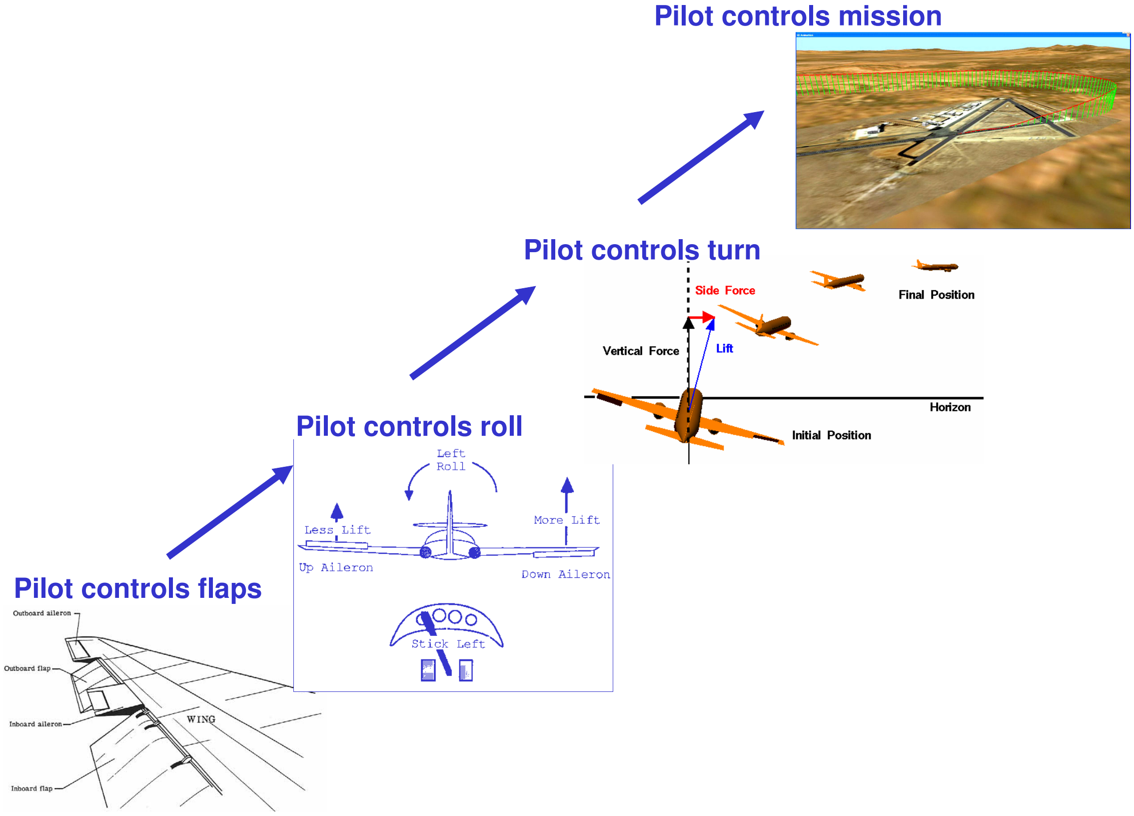


Figure 3: Example Of Net Complexity Increase – Flight Control Systems

The figure shows four major cycles in the evolution of this aerospace system. Each of the cycles can be thought of as an s-curve. Therefore, each of the four cycles can also be represented as an increasing-decreasing complexity cycle.

The first stage of the progression was a stage in which the pilot was essentially controlling wing flap angle. This is a relatively easy thing to do: mechanically connect the joy-stick to the flaps and provide some kind of feedback and the pilot is then able to prescribe a desired angle and the system will set the flaps (within a margin of error) to the desired angle. In the earliest wing-flap systems, the connection was little more than a cable. Later in the cycle, the system becomes more complex as more sophistication gets built in – a desire for quantified feedback, for example, or the addition of a second back-up cable to offer the ability for the system to still work if the first cable fails. Then means to compensate for stretch of the cable, or variation in length that occurs as temperature changes. And so on, until….

The second major evolution cycle occurs when the wing-flap angle function migrates to a higher level. In this second phase we realize that the pilot wants a certain flap angle in order to achieve a certain amount of pitch, yaw or roll of the aircraft. In the first evolution stage, the pilot has to perform the 'calculation' that maps flap angle to the desired level of roll. In the second generation flight control system, the system takes on this responsibility – all the pilot needs to do is work out what degree of roll they want, and the control system works out what flap angle is needed to achieve it. The complexity of the control system has thus increased. Admittedly much of this complexity is hidden from the pilot, but essentially the system has increased its complexity by 'nesting' (Reference 4) a roll-angle-wing-flap angle algorithm into the control architecture. Again, then, over time, the sophistication of this basic idea passes through its own increasing-decreasing complexity cycle.

The third major jump occurs when another 'nesting' complexity migration occurs. In this third stage, the pilot no longer specifies a roll angle, but merely informs the control system that they wish to make a specified turn. The control system then makes the necessary calculations to work out how much roll is required and then what wing-flap angle is required to achieve that amount of roll. Again another increasing-decreasing complexity cycle ensues.

More recently some aircraft control systems have now jumped a step further. Another complexity nesting action takes place. The complexity of the flight control system again increases. In this fourth stage, the pilot defines a defined mission or part of a mission. For example, 'land on runway 150'. Now the flight control system has to work out the required routing to get from the current position to the desired end position; it has to work out how to make the necessary turns; it has to work out what degree of roll is required at any time; and finally it has to set the appropriate wing-flap angles. If history and our increasing-decreasing cycle repeats as per convention, then we will see the same type of evolution of this system in the future.

Taking the four stages together, the Figure 2 progression emerges. Strictly speaking there is some overlap of the different stages so the picture is not quite so clear cut as the Figure 2 model. The model however, is the useful generic image that we think is the one to keep in mind as we start to apply the complexity evolution pattern to whatever system we may be interested in.

In essence what is happening in this system – the 'why?' if you like – is closely related to another TRIZ trend. That trend being the one relating to 'decreasing human involvement'.

What has happened in flight control systems is precisely what has happened in many other systems; control of the system has progressively migrated away from the human and towards the supporting technology.

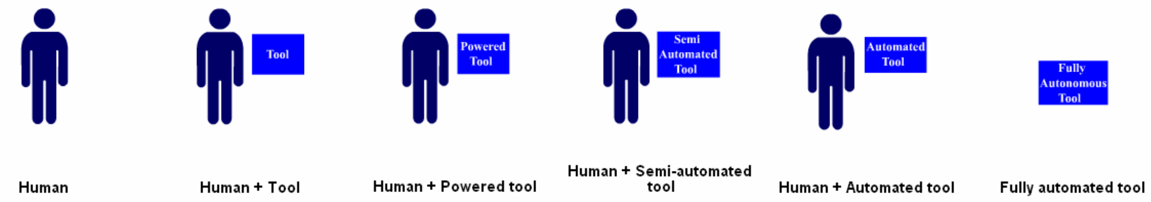


Figure 4: Decreasing Human Involvement Trend

If this trend comes good for flight control systems then it appears highly likely that we will see another evolution jump to a system in which the pilot disappears altogether. In fact we can already see the seeds of this jump in the new wave of unmanned military aircraft – Figure 5.

Figure 5: UAV - The Next Wave In Flight Control Systems (Reference 6)

When mankind first evolved social networks and complexity migrated from the individual brain to the collective one, an individual human brain had less to do and so brain size reduced. As more and more responsibility for flight control has migrated from human to the control system, we wonder if a similar brain-size reduction can be observed in pilots (only joking pilots!). Meanwhile, we hypothesize that system complexity will continue on its upward trajectory as suggested in the important Figure 2 image.

References

1) Mann, D.L., 'Complexity Increases And Then… (Thoughts From Natural System Evolution)', TRIZ Journal, January 2003.
2) Kaplan, P., 'Adaptive Evolution In Biology And Technology: Why Are Parallels Expected? – A Comment On Mann(2003), TRIZ Journal, May 2003.
3) Margulis, L., Sagan, D., 'Microcosmos: Four Billion Years of Microbial Evolution', University Of California Press, 1997.
4) Systematic Innovation e-zine, 'New Trends – 'Nest-Up' And 'Nest-Down', Issue 51, June 2006.
5) http://uas.noaa.gov/altair/docs/Fahey_Altair_EOS_16May.pdf

Humour – Shoulders Of Giants…

'If I have seen further, it is by standing on the shoulders of giants.'
Sir Isaac Newton…

'If I have not seen as far as others,
it is because I was standing in the footprints of giants'
Mr P. Inertia

Patent of the Month – Light Emitter For A Display

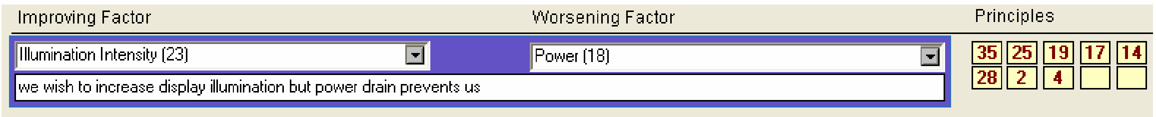
Patent of the month this month is US7,081,307 awarded to inventors of the organo-photonics group at the University of Hull in the UK. (Check out their website at www.organophotonics .co.uk.) The basic invention relates to a light emitter for a display for use in electronic products and a method of forming the light emitter and display.


As described in the invention disclosure:

Modern consumer electronics require cheap, high-contrast displays with good power efficiency and low drive voltages. Particular applications include displays for mobile phones and hand-held computers.

Conventional displays comprise twisted nematic liquid crystal displays (TN-LCDs) with active matrix addressing and super-twisted nematic liquid crystal displays (STN-LCDs) with multiplex addressing. These however require intense back lighting which presents a heavy drain on power. The low intrinsic brightness of LCDs is believed to be due to high losses of light caused by the absorbing polarizers and filters which can result in external transmission efficiencies of as low as 4%.

The problem is a classic contradiction situation; we want to increase brightness, but we don't wish to consume power to achieve it. This is an easy one to map onto Matrix2003:



Now here's what the inventors have done to create their solution:

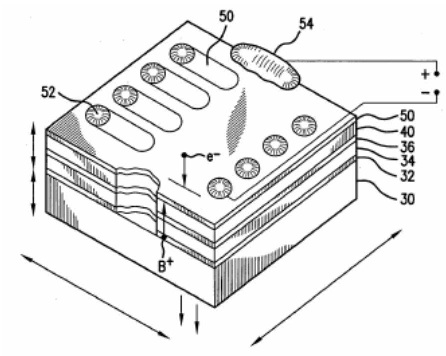
The Applicants have now devised a new kind of light emitter for a display which offers the prospect of lower power consumption and/or higher brightness. The display utilises an alternative light source which can in embodiments be used instead of the conventional polarizers and/or back light. The alternative light source comprises a light emitting polymer or polymer network aligned on a photoalignment layer. The combination of this alternative lighting source with existing LCD technology offers the possibility of low-cost, bright, portable displays with the benefits of simple manufacturing and enhanced power efficiency.

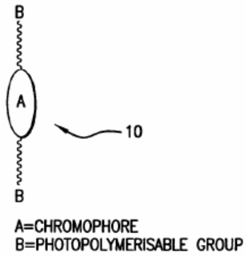
According to one aspect of the present invention there is provided a light emitter for a display comprising a photoalignment layer; and aligned on said photoalignment layer, a light emitting polymer.

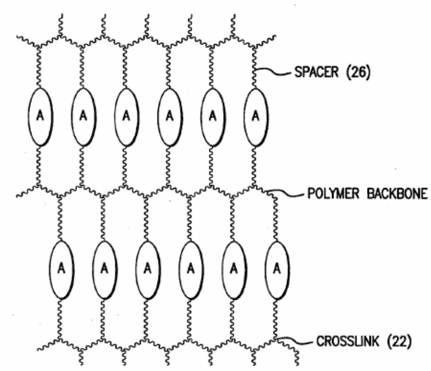
The photoalignment layer is comprised of materials that photoalign (e.g. by cross-linking) to form anisotropic layers when polarised light (e.g. UV) is applied.

The photoalignment layer typically comprises a chromophore attached to a sidechain polymer backbone by a flexible spacer entity. Suitable chromophores include cinnamates or coumarins, including derivatives of 6 or 7-hydroxycoumarins. Suitable flexible spacers comprise unsaturated *organic chains, including e.g. aliphatic, amine or ether linkages.*

Here are some of the pictures from the disclosure:





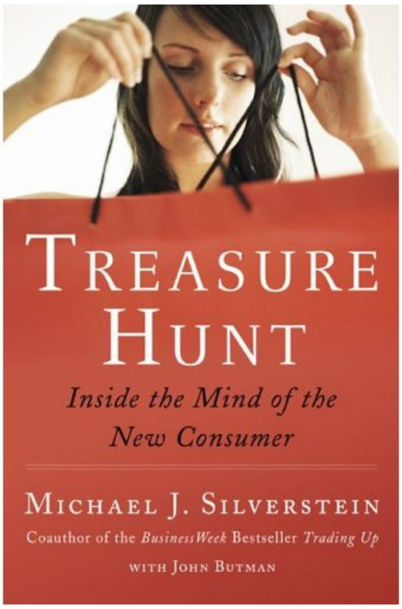


The invention is primarily driven, if we have interpreted the disclosure correctly, by a shift from one light generating method to another (Principle 35) and the use of multi-layering (consistent with the recommendations of Principle 17 (specifically 17c 'use a stacking arrangement')). The photo-alignment aspects of the invention represent a good example of a combination of Principles 25 ('Self-Service' – '*The self-assembling properties of liquid crystals give improved carrier transport and polarised electroluminescence*') and Principles 28 (Mechanics Substitution – here relevant in that UV is used to deliver the desired self-alignment).

The inventors don't reveal precisely how much more efficient their solution is than existing organic LED technologies. Reverse engineering a few numbers suggests an improvement factor of at least two relative to the state of the art. The fact that they are collaborating with Sharp also suggests there is something important in what the team has achieved.

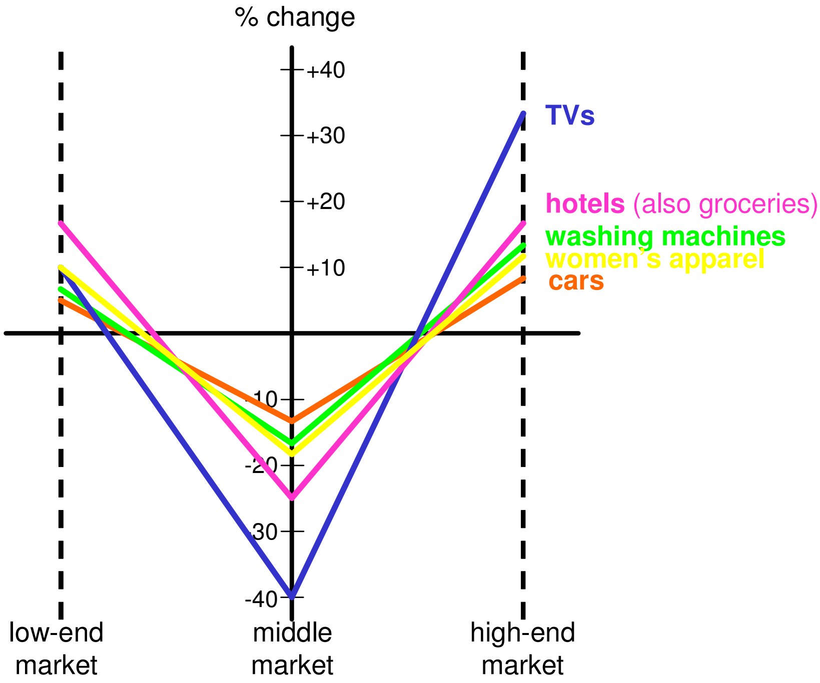
Best of the Month – Treasure Hunt: Shopping Habits Of The New Global Consumer

Treasure Hunt by Boston Consulting Group's Michael Silverstein is our recommended read for this month. Since many readers may be planning some vacation time, we felt it was a good idea to pick something a little lighter in nature than our normal selection. This book certainly fits into that category, being easily digestible in a few hours of beach-time (we were in Puerto Vallarta when we did it!)



The book will be of greatest interest to those involved in the business of tracking consumer trends. It should also be of interest to those interested in TRIZ trends, and particularly the 'Increasing Asymmetry' trend featured in the business edition of Hands-On Systematic Innovation. One of the featured examples of that trend in our book relates to the 'winner-takes-all' bi-furcation of people and markets. This bi-furcation essentially leads to often distinct polarization of markets and customers. It is a trend that says 'players in the middle ground beware'. Silverstein's book offers ample evidence of the truth of this bifurcation effect in action across every form of consumer activity. The book is in fact an examination of the economic countertrend whereby middle income consumers have made the art of bargain hunting into a major business opportunity. The basic underlying idea behind the bifurcation into premium 'trade-up' and 'low-cost' (as opposed to 'low-value' – value must still remain at an acceptable level) 'trade-down' extremes is that some people choose to pay premium prices for goods and services they care passionately about, but chose to travel in the opposite direction for those that they don't. In other words, when I value something, I really value it, and when I don't value it, I either go without or get away with the minimum cost offering that I can find. In this latter sector, people - most people, in fact - have been choosing, since the advent of the Internet and the global marketplace, to shop lower and lower for the indispensable things in life, leaving more cash free to splurge on the luxury items they really care for.

A big theme of the book is how suppliers need to respond to this market migration. Some companies can be seen to thrive by playing up to the high-end consumers (Prada, Gucci, Starbucks, etc), others by chopping down to the low (Wal-Mart, Aldi and Dollar General being prime examples). At both ends, the 'Treasure Hunt' described in the book relates to the world of increasingly knowledge-rich and more specifically price-aware consumers – through the likes of eBay and a myriad price-comparison navigator websites – and their desire to 'find a bargain'. Whether it be a rare left-handed Fender Telecaster guitar or a jar of coffee, what increasingly inspires us to make a purchase is the thrill of the chase for an extraordinary find or deal. Almost the antithesis of the middle market ethos. Taken further, related to the polarizing migration, thus comes the threat to traditionally middle-ground players like Chevrolet, Maxwell House and Kraft. The figure below – distilled from the words in the book – vividly shows the level of migration away from the middle ground that certain sectors have taken, across the whole globe (important to note is Silverstein's belief that 'treasure hunting' is a truly global trend rather than a purely North American one).



Migration from the middle ground - % of market value 1994-2004

Silverstein proposes that without a push in the right direction there is only one outcome for these stick-in-the-middle outfits, as their market is eroded by the counterweights of the up-traders and the down-traders - change or die. One of the great features of the book is a series of in-depth consumer interviews aimed at eliciting and explaining why the bifurcation is taking place. A lot of the answer seems to relate to the demographic trends described in another of our favourite books 'The Fourth Turning'. This book and its definition of the newly-maturing 'Generation Y' hero generation has much to say about the underlying dynamics of what motivates different people at different stages of their life. Although Silverstein never references the Fourth Turning work, there is an extraordinary parallel between the two works. 'Treasure Hunt' thus offers an insightful prescription for the salvation of the mid-market company faced with the prospect of a rapidly disappearing customer base.

Middle-market players beware, according to Silverstein and (especially) The Fourth Turning, the treasure hunt phenomenon is set to be with us for some time yet. In actual fact the phenomenon looks set to accelerate further before it levels and reverses – as more companies become aware of the trend, the more they will respond to it. Which in turn means more treasure for consumers to find. Sounds like a pretty important self-re-enforcing cycle as far as we can see.

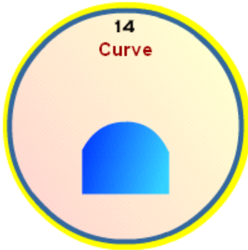
Conference Report – 11th Mexican Electronics Technology Congress

This conference was held in the beautiful coastal resort of Nuevo Vallarta, Mexico from 27-30 July. The conference was organized by CANIETI, the Mexican National Chamber of the Electronics, Telecommunications and Informatics Industry. The organisation has more than 25 years in Mexico promoting the development of said sector in a global environment. The 11th electronics Technology conference was attended by over 100 senior representatives from mainly Mexican industrial companies. Amongst the sponsors and attendees were HP, Intel, IBM, Siemens, ProSoft and MexicoIT.

The conference featured thirteen extended presentations from a variety of speakers. Although the majority of the presentations were given in Spanish, the organizers had very kindly provided parallel translation. We were there presenting a 90 minute overview of TRIZ. Other presenters included James Womack from the Lean Enterprise Institute, Bruce Rayner from the Technology Forecasting Institute (speaking on what a balanced strategy for global manufacturing might look like from a Mexican perspective), and Hollywood producer (??) Rick Ungar.

Our session, alas, turned into one of those occasional nightmares that presenters sometimes find themselves in. Firstly we're placed right at the end of the Saturday morning session. Immediately following our session is a programme entry called 'torneo de golf'. And then the preceding speakers overrun by 45 minutes. Hmm. How to alienate yourself from an audience? Keep them from their golf match sounded like a pretty good way. Time pressure aside, the biggest problem turned out to be that speaking immediately before us was the Hollywood producer dude (dude being the operative word). Not only did Mr Ungar assume he was the last speaker ('I'm not leaving the stage until you give me several strokes at the golf' – thanks!), but his topic appeared to be 'how to patronize an audience of senior people'. For those that care to google his name, Rick Ungar is one of the brains behind 'Biker Mice From Mars' and the latest series of Spiderman movies. The only question he received from the audience was 'what will be in the next film?' which should probably give some indication of the level he pitched his diatribe. Apparently he wasn't able to tell us. He did inform us that the way for Mexico to get into the animation business was to buy a well known US or European company then bring the job of doing the animation to Mexico. Yes, right. Thanks for that. Anyway, we thrive on a challenge, and so onto the stage we went with our usual desire to try and connect what we were about to say to what had been said earlier. Out go 75% of our planned slides thanks to the reduced time available, insert a bunch of '40 Principles for Biker Mice' slides formed from images downloaded from the Internet during Ungar-dude's presentation. Not the most bizarre situation ever. But close.

Never mind, Nuevo Vallarta was an absolute delight. As was the opportunity to network in some very amenable surroundings with important figures from Mexican companies… many of whom were either coming or sending someone on the TRIZ workshop we were running in Guadalajara a couple of days after the conference. Over 50 people in fact attended that workshop. So maybe the Biker Mice stuff is the way forward?



…arrange the Biker Mice into a circle

Investments – Nano-Lubricant

Investment of the month this month is ApNano Materials, Inc., a provider of nanotechnology-based products. The company recently announced that its NanoLub lubricant, the world's first commercial nanotechnology-based solid lubricant, was found to be non-toxic in testing performed by Harlan Biotech Israel Ltd., an accredited testing laboratory for pharmacological toxicity studies, located in Rehovot, Israel. These tests are in addition to excellent results obtained from field and beta site tests performed by major global lubricants and automotive manufacturers.

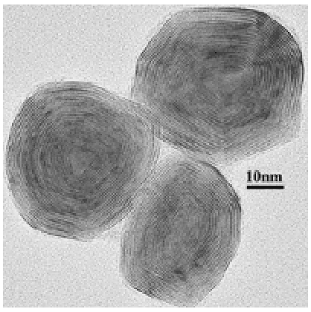
"Harlan Biotech is certified to be in complete compliance with international standards of the OECD (Organization for Economic Co-Operation and Development). The acute toxicity testing was done in full accordance with European Commission directives for Good Laboratory Practice (GLP)," said Dr. Niles Fleischer, Vice President of Business Development and Product Development of ApNano Materials. "The lab results recognize the environmental friendly nature of NanoLub."

"The findings show that NanoLub is safe and using this revolutionary material as a solid or dry lubricant to replace common liquid lubricants or as an additive to enhance the performance of regular lubricants is not only extremely beneficial but also not harmful," said Dr. Menachem Genut, President and CEO of ApNano Materials. "There is always a concern when new materials are introduced to the industry, especially these days with regards to the use of nanotechnology based materials. We are glad that our material was clearly shown to be non-toxic and can be used in a variety of applications."

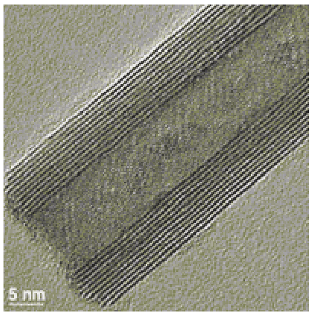
Genut added that "using NanoLub enhances the performance of moving parts e.g. in gear boxes, transmission systems and axles. This will significantly reduce the fuel consumption which will lead to less air pollution. Furthermore, NanoLub can replace current used additives to oils and greases which some are very toxic, which due to health regulation are about to be banned in many countries. In addition, the laboratory's findings open new horizons for NanoLub in medical applications."

"The non toxicity confirmation is great news as it guarantees that the production of NanoLub in our planned semi-industrial facility, to be built shortly following the successful completion of our recent $6 million fundraising, will produce an environmentally friendly material," said Aharon Feuerstein, ApNano Materials' Chairman of the Board. The new plant will produce 150 kg a day of NanoLub.

NanoLub is based on nano-spheres and nanotubes of inorganic compounds that were discovered at the Weizmann Institute of Science, Israel. NanoLub particles have a unique structure of nested spheres that lubricate by a special mechanism that can be considered as the rolling of millions of miniature ball bearings, thus greatly reducing friction and wear.

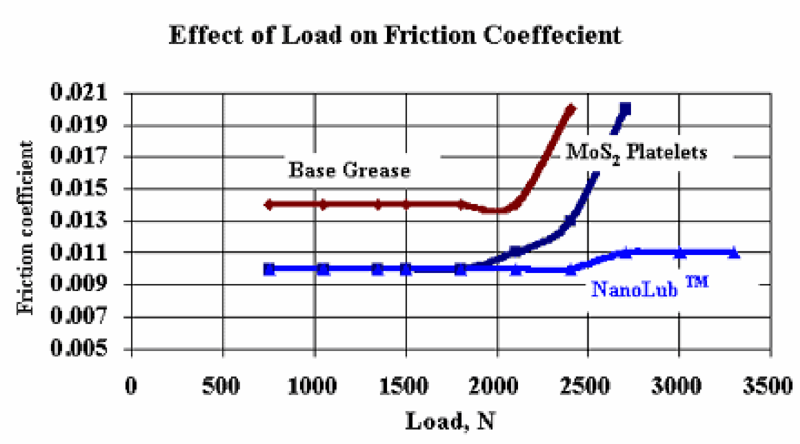


Nano-sphere and nano-tube versions of Nanolub



The synthesized nano-spheres and nano-tubes overcome problems associated with the platelets, such as reactivity, since the curved, nested nanostructures have no exposed reactive edges. The small size, shape, composition and structure of these nano-particles make them superior lubricants and advantageous in various micro-electronic applications.

The nested structure of these particles has been compared to that of an onion or a Russian doll where inside one shell there is a slightly smaller one and within this one an identical smaller shell and so on. The structure of each shell resembles the geodesic dome design of Buckminster Fuller (and are thus termed 'fullerenes'). Up until the discovery by the Weizmann group it was thought that fullerenes could only be made with carbon atoms. The group was the first to discover that certain inorganic materials could also be formed into fullerene-like structures, hence the name inorganic fullerene, nano-particles.



Recently ApNano Materials has been selected as a Top 100 Innovator by Red Herring and has been named by InnovationWORLD as one of the 21 companies that are poised for growth in the 21st century.

Check out the company's website for more details: http://www.apnano.com

Biology – Chameleon (*Chamaeleo jacksonii*) Tongue

Chameleon tongues are extremely fast and long. They can be anywhere from one to $1^{1/2}$ times the body-length of the owner and can rocket in and out with blinding speed. A $5^{1/2}$" tongue reaches full extension in $^{1/16th}$ of a second, which is fast enough to snatch a fly in midair. Exactly how they propel their tongues with such power has never been convincingly explained.


Using high-speed video and x-ray film, two Dutch biologists (Reference 1) have recently found that the chameleon's tongue accelerates from 0 to 20 feet per second (0 to six meters per second) in about 20 milliseconds—a rate so fast it defies the general principles of power production in muscles.

'If you do the calculation, you know that the muscle alone cannot be responsible for this rapid acceleration', said Jurriaan H. de Groot, a biomechanist at Leiden University in the Netherlands.

De Groot and project leader Johan L. van Leeuwen, a biologist at Wageningen University also in the Netherlands, looked for a hidden structure in the tongue that could power this extreme athletic performance. They believed that there must be some sort of biological spring or catapult that launches the tongue on its culinary quest.

Muscles are limited in their power output. These limits stem primarily from limitations elastic stress limitations. To hit speeds exceeding these limitations, many animals have coupled their muscles with biological "catapults." These catapults store energy and release it when triggered, allowing them to help produce much higher speeds than could be achieved by muscle alone.

Scientists have known the basic anatomy of the chameleon tongue for some time now: a "U" shaped hyoid bone anchors the tongue to the back of the mouth. A hollow tongue then sheathes over a long, tapering cartilaginous spike called the hyoid horn. The horn attaches to the centre of the hyoid bone. The tongue consists of three primary components: The sticky tip, the retractor muscles and the accelerator muscles. When at rest, the whole assembly sits at the bottom of the mouth, the base placed down in the throat behind the head. Before striking, the lizard moves it toward the front of the mouth and muscles raise the hyoid bone above the lower jaw. After aiming with the entire head, the chameleon is ready to fire.

The high speed capability is primarily then due to the muscle architecture. Dissection of chameleon tongues by the Dutch team revealed an elastic collagen tissue sandwiched between the tongue bone and the accelerator muscle. The collagen is wrapped in sheathes around the tongue bone at one end and to the accelerator muscle at the other. De Groot and van Leeuwen discovered that this collagen structure is the biological catapult that propels the tongue tip in much the same way a bow delivers an arrow.

Just as an arm muscle moves slowly to stretch a bow—storing power in the taut string—the chameleon's accelerator muscle also stores energy in the collagen tissue. When triggered, the concentric, overlapping sheaths of collagen telescope outward, allowing the adhesive tongue tip to extend rapidly toward the prey.

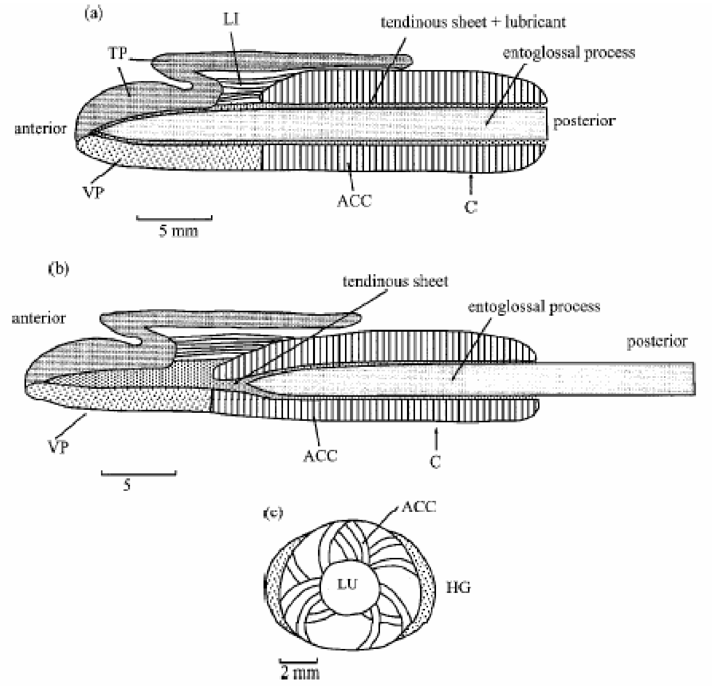
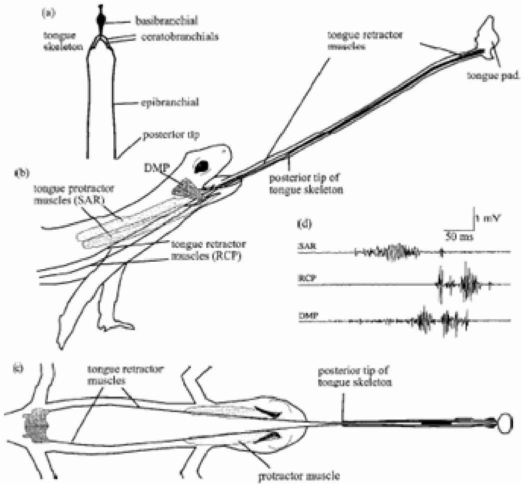


Fig. 8. Schematic drawing of the tongue pad and accelerator muscle of the chameleon tongue. (a) Parasagittal section through the tongue of the chameleon (*Chamaeleo jacksonii*). (b) Similar to (a), but tongue pad and accelerator muscle has elongated and extends partly beyond the tip of the entoglossal process. (c) Cross-section through the tongue at arrow C in (a). Panels (a)-(c) based on figure 1 of VAN LEEUWEN (1997) and figures from WAINWRIGHT & BENNET (1992a) and BELL (1989). Abbreviations. ACC: accelerator muscle; HG: hyoglossal muscle; LI: longitudinal adductor muscle; TP: membrana glutinosa of tongue pad; VP: ventral projection of accelerator muscle.



Until now many scientists had concocted fanciful explanations for the powerful tongue movements, like the presence of a "supermuscle" that had chemical and mechanical properties as yet undiscovered. Other explanations dating back 150 years suggested an influx of air or blood allowed the tongue to rocket out of the chameleon's mouth, Müller said.

The collagen catapult turns out to have a "weird helical [or spiral] structure" that allows it to store energy, said van Leeuwen. "So far we have not seen a parallel structure in biology or mechanics—it is a completely novel design." The unusual structure maybe one reason that the collagen tissue was not recognized as a spring.

Of course, what we have here is a good example of nature creating a breakthrough solution to a design trade-off. The trade-off centres around the need for high speed (in order to be faster than a fly) being prevented by innate muscle capability. We can map this conflict onto Matrix 2003 as follows:

Improving Factor	Worsening Factor	Principles
Speed (14)	Stress/Pressure (19)	28, 14, 6, 40, 38, 18, 12, 35
the chameleon needs to project its tongue very quickly, but physiologically muscle stress limits prevent rapid enough deployment		

Not only does the Matrix seem to capture the basic combination of different types of muscle and collagen structure (Principle 40, Composite Structures), but it also (perhaps surprisingly) also includes the suggestion to use curvature (Principle 14) a.k.a. helical or spiral structures.

Alas the chameleon has not as yet been able to evolve a Principle 28, 'Mechanics Substitution' solution. This tops the Matrix list of recommendations as all mechanical systems hit fundamental limits in terms of stresses and inertias. Fields tend not to suffer the same problems.

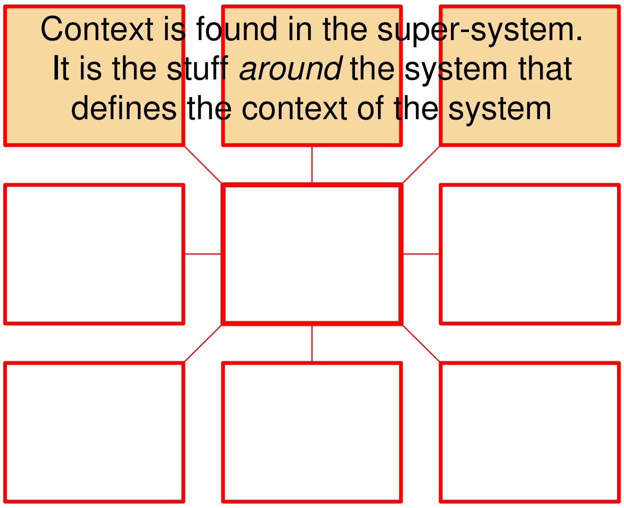
Nevertheless, the chameleon's 'helical collagen catapult' is beginning to receive attention from engineers who believe it may have a variety of medical applications.

Reference

1) Van Leeuwen, J.L., De Groot, J.H., 'Evolutionary Mechanics Of Protrusible Tentacles And Tongues', Netherlands Journal of Zoology, 50 (2): 113-139 (2000)

Short Thort

WISDOM = KNOWLEDGE x CONTEXT…



News

Matrix+ Software
September will see the launch of our new Contradiction Matrix software tool. The software will feature all of the latest Contradiction Matrix tools for technical, business and software problems. It is the only software tool to feature the latest versions of each tool. Initial versions will be in English, with Chinese, German and Japanese to follow in the coming weeks.

Mexico
Following the success of our general technical TRIZ workshop in Guadalajara at the beginning of August, it looks like we will be back in the city in early 2007 to conduct a specific 'TRIZ for Software' workshop. Guadalajara is at the centre of the Mexican software industry, which has been setting records recently for fastest growth (0 to 1.5% of Mexican GDP between 2001 and 2005!)

TRIZ for Process Improvement
Seems we learned an important lesson in Malaysia recently – use the word 'innovation' when trying to sell a TRIZ workshop to process engineers and have a tough time; call it breakthrough improvement' and sell out all the available spaces two weeks before the end of the selling cycle. Hmm.
(PS all the workshop materials are new – we didn't just change the flyer!)