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Systematic Innovation

e-zine

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In this month's issue:

Article – Measuring The Evolutionary Potential Of Your Business

Article – Root Contradictions

Article – Principle 41?

Humour – Systematic Innovation

Patent of the Month – GPS Application

Best of The Month – Management By Means

Investments – Low-Cost Piezoelectrics

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.

Our guarantee to the subscriber is that the material featured in the e-zine will not be published elsewhere for a period of at least 6 months after a new issue is released.

Readers' comments and inputs are always welcome.
Send them to **darrell.mann@systematic-innovation.com**

Measuring the Evolutionary Potential of Your Business

Anyone familiar with some of our recent publications will be familiar with the term 'evolutionary potential' in the context of evolving technical systems. The concept is emerging as a very powerful indicator to help organisations know when systems are beginning to hit fundamental limits, and where there are opportunities to generate new improvements. This article is about applying the same techniques to business using the business trends uncovered in CreaTRIZ for Business.

In essence, the evolutionary potential concept for business works exactly the same as that for technical systems; in that the user is required to compare the current business situation with each of the trends in turn in order to establish a) whether the trend is relevant (note: they won't all be relevant to a given situation, but we should at least ask the question), and b) how far along the trend the current system is. Figure 1 illustrates an example for the 'controllability' trend.

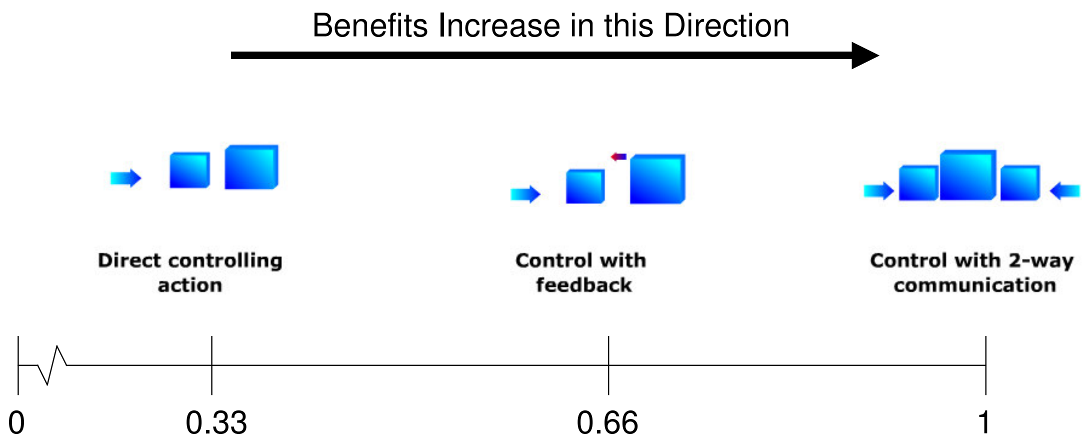

Figure 1: Controllability Trend and Evolutionary Potential

A system receives a score relative to its position along the trend, such that, for example, a system in which feedback is being used would score a 0.66.

Construction of an evolutionary potential plot for the system involves repeating this scoring process for each of the trends relevant in a business context. In line with the importance of space, time and interface awareness within TRIZ, Figure 2 illustrates the list of business trends thus far uncovered segmented into each of these three categories.

Some of the trends – such as 'segmentation' and 'Mono-Bi-Poly' – have relevance in each of the three categories and so are repeated for each in order to ensure that they are examined in each appropriate context. At this moment in time, we have uncovered 23 different trends, which then becomes 31 when we include the different interpretations in the space, time and interface categories.

In order to maintain a degree of consistency between different plots it is usually a good idea to maintain the sequence of the three categories when constructing the plots.

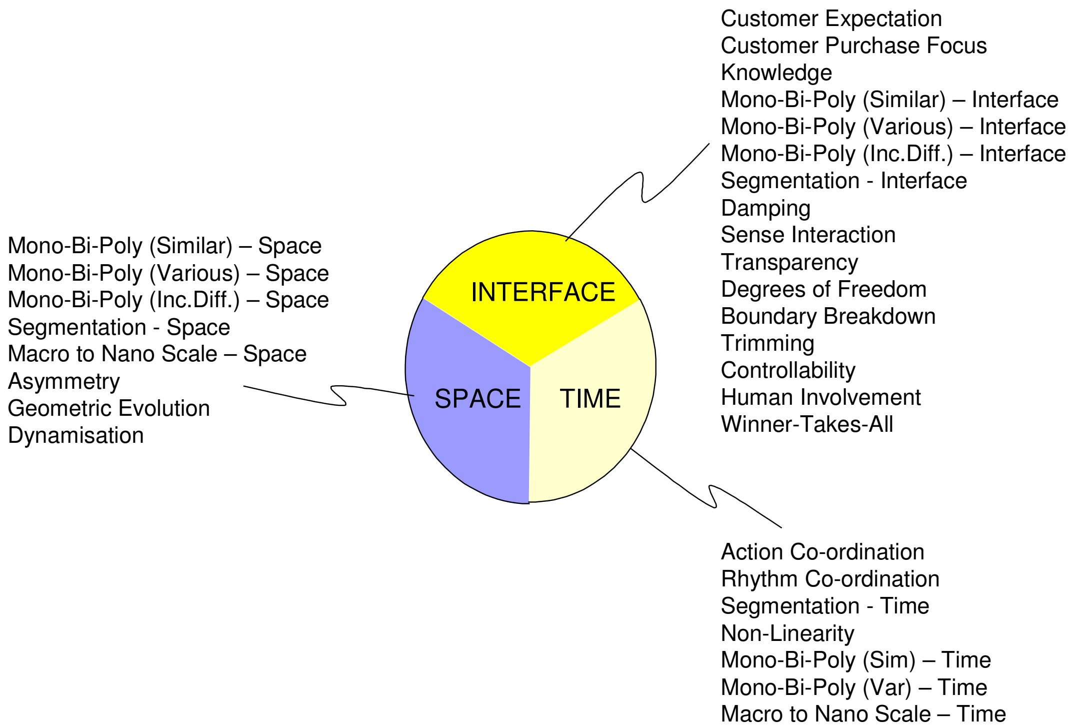

Figure 2: Business Trends Divided into Space, Time and Interface Categories

As with the radar plots drawn for technical systems, the evolutionary potential radar pictures offer an instant snapshot of where a system currently is and where it has unused potential to jump to higher levels of capability – as have been found by someone somewhere amongst the range of published business solutions from around the world.

The example plot illustrated in Figure 3 shows a hypothetical plot assembled for a fictitious organisation. Not all of the trends have been included for the purpose of clarity.

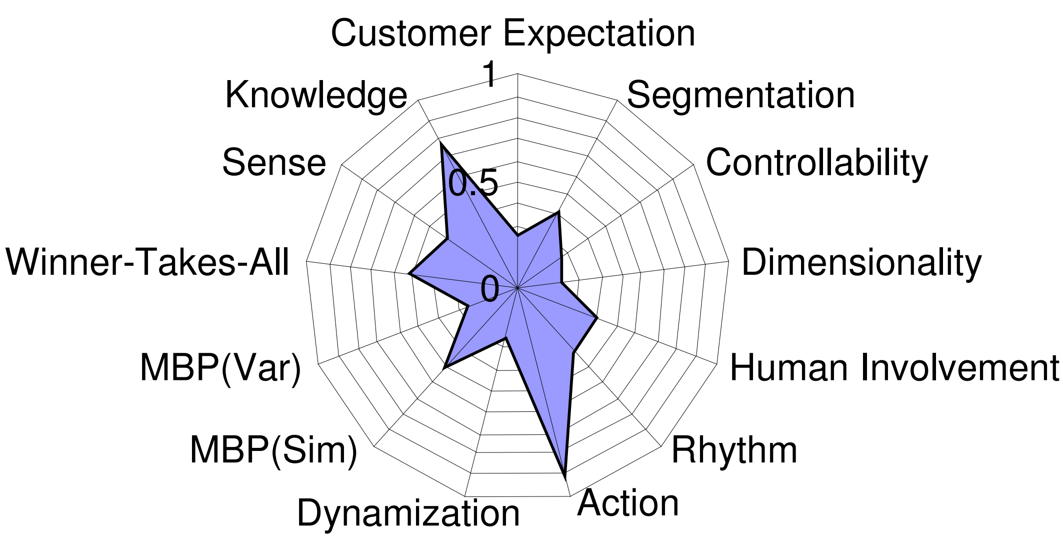

Figure 3: Evolutionary Potential Radar Plot for a Hypothetical Business System

The blue area in the plot is intended to represent the current state of the system under evaluation, while the white area to the perimeter of the plot represents potential that the system has not yet taken advantage of.

As with the equivalent plots for technical systems, the radar plot concept is extendable to examine different parts of a system. This is most likely to offer benefit when plots are drawn for the different sub-systems that make up an overall system – for example for departments or profit centres within an organisation. A hypothetical example is illustrated in Figure 4.

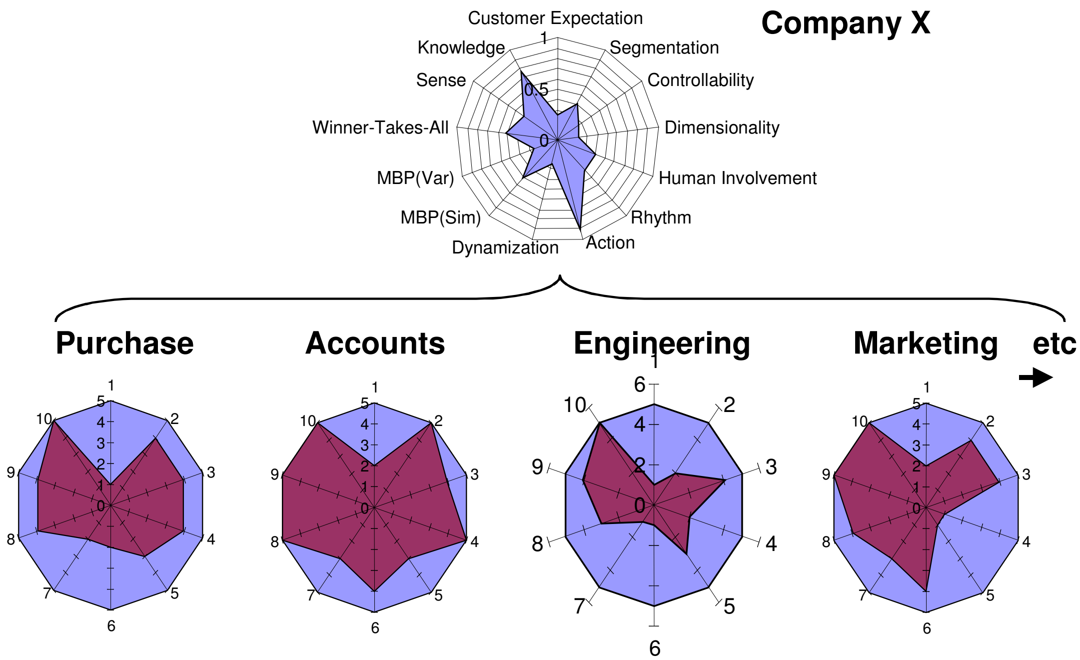

Figure 4: Hierarchical Nature of Evolutionary Potential Plots

Anyone interested in constructing an evolutionary potential plot for their organisation can do so by accessing the trends section of CreaTRIZ for Business (remember to not the possibility of some trends being interpreted in space, time and interface contexts). Alternatively, CREAX offers the necessary analysis as a service for some customers. Contact Simon or Darrell via the creax.com web-site.

In a future month: applying the same evolutionary potential to individuals using human evolution trends.

Root Contradictions

All of the disciplines within any kind of organization routinely seek to solve their problems. All of us who are a part of an organization are problem solvers . . . and root cause analysts, although many of us may prefer to think of our problem solving process as something less fancy than "root cause analysis". But, as we come to our problems in an effort to control and prevent interruptions, obstacles, errors, and counter-quality occurrences, we none-the-less are all looking for the same things: root causes of problems that when removed prevent the problem. So, whether our work is Quality, Engineering, Safety, Production, Maintenance, or just about any other function in the organization, we should be comfortable with the concept of root cause analysis, or whatever we want to call the task of finding the root causes and best prevention solutions to our operations problems.

First let's clarify what it is we are talking about when we say "prevention solutions", or rather what we are not talking about. Fixing things, cleaning up, removing, reworking, redesigning, modifying, and fortifying, are not prevention and control steps. They instead are correction steps. These actions may or may not be a result of prevention actions, but they in themselves are not prevention steps. Prevention has to do with WHY the design was inadequate, WHY the machine needs repair, WHY cleanup is necessary. This is not to say that these correction-step responses are not important to the operation. Certainly we want to discover immediately when things need early repair. Root cause analysis should uncover such opportunities to remedy, but clearly, as our primary goal for analysis, we want to design out of our operation the need for avoidable repair, rework, clean up, and expensive redesign. We are trying to find something that someone can do to keep the problem from ever happening again. Obviously the act of cleaning up the mess every time the problem occurs is not prevention. We must instead design *prevention* and *control* into how we do things. That is what meaningful root cause analysis is all about.

So much for the theory. When we actually get down to the mechanics of root cause analysis, on the other hand, things have a tendency to get out of hand very quickly. Quite simply, root cause analysis requires data. Asking 'why' means we have to understand the system. To understand the system requires data. Very often the cost and time involved in capturing that data can be prohibitive.

One particular example that springs to mind was a case study we were asked to work on regarding a manufacture operation to drill a row of 40 very small (circa 30μm diameter) holes simultaneously through a relatively thick (circa 15mm) structure. The basic problem was that the method used to drill the holes coupled with the length of the holes meant that some of the holes were mis-aligned relative to the others. During the course of finding out WHY this was happening a team of four root-cause analysts spent over 3 months each configuring and running experiments to try and get to the bottom of the matter. Four people times three months each is a lot of man-hours and a lot of money, never mind the cost of running the experiments and all the scrap parts produced.

The team were using a proprietary root cause analysis method (we won't name names) which is both rigorous in its approach and known to generate results in a good many instances.

The problem with it, and root cause analysis in general is that it only stops when the root cause has been found. If this takes a few hours, this is not a problem. But if it means a man-year and still no answer, we should start to ask whether there is a better way.

The suggestion here is that there is indeed a better way. We call it 'root contradiction analysis'. The key similarity between this method and root cause analysis is that both are built on the question 'WHY?' The first key difference is that, while root cause analysis has a voracious appetite for data, root contradiction analysis requires only that we gain a qualitative understanding of what is happening in a system.

The second key difference – one even more important than the first – is that root cause analysis is a method closely allied to optimisation of processes, while root contradiction analysis is about recognising systems hit fundamental limits, beyond which no amount of optimisation will ego. In other words, you could spend an infinite amount of time gathering data to help optimise something that refuses to be optimised any further.

The Contradictions part of TRIZ is the only systematic way in existence for helping us to jump from one optimised system to a better way of doing things. Root Contradiction Analysis is about helping us to find the key contradictions we need to solve if we are to make the jump to that new system.

In the case of the hole-drilling example, the Root Contradiction Analysis took around an hour to establish that a) the current system was at the limits of its fundamental capability and the root cause analysts were simply pushing it over the edge of a cliff, and b) the root contradiction was quickly traced from the fact we knew that there was no problem when the hole length was only 12mm, or if there were only 30 holes to be drilled. The cliff the system had fallen off was a contradiction between the length of the drill and its stability.

Ten minutes later we had a segmented design solution. Two hours after that we had our first working prototype.

The example is not intended to say that Root Contradiction Analysis works miracles. We still have to do a lot of thinking – 'why' is the most difficult of the 5Ws – but at least we don't have to accompany it with a warehouse full of expensive-to-acquire data, and we know that solving contradictions is fundamentally good direction to travel in any event.

Root Contradictions Example - A Better Wind-Turbine

A good example of technical contradictions in action and why it helps to think about 'root contradictions' comes in the form of a look at a real problem associated with the design of wind-turbines. As well as showing TRIZ in action on a problem that has not yet been solved, the example seeks to offer an additional learning point as we transition from conceptual to specific solutions, linking in to other parts of the problem solving toolkit. The problem under consideration concerns an issue affecting all wind-turbines, but especially the large scale (500-750kW) machines – a typical example of which is illustrated in Figure 1.

Figure 1: Typical Large-Scale Wind Turbine

The basic problem concerns what happens to the turbines in high winds, where – perhaps surprisingly – as wind speed rises above a certain level, the turbine wants to rotate too quickly, the centrifugal forces from which then cause the blades to want to fly off. The current strategy for solving this problem is to stop rotation altogether when the wind is too high. Paradoxically, therefore, when the wind contains the most energy, the wind-turbine captures the least. It is desirable to not have to stop the turbine during high wind conditions.

The problem very definitely contains a contradiction; the basic thing we would like to improve in this situation is the ability to operate in high winds; the thing that stops us is that the blade falls off. Relating these two sides of the contradiction to the Matrix, it appears clear that the improving parameter connects best to SPEED. More difficult is the worsening parameter. From 'the blade falls off', we might make connections to Harmful Side Effects, Force, Stress, Area, Reliability or Strength. Maybe even Loss of Substance if we're thinking very laterally. Now, we could chose to look up the conflicting pairs for each of these possibilities – in which case we would end up with the rather high number of 19 different Inventive Principle suggestions, with only three appearing more than once. There is nothing wrong with this approach of course, but it would be rather time consuming and difficult to maintain level of effort at an acceptable level as we try and generate solutions from all 19 of the Principles. The alternative is to think a little more specifically about the problem and try to focus in on exactly what the problem is using a form of 'root contradiction' analysis.

The logic for this goes something like:

The blades fall off. (Matrix parameter = Loss of Substance, Reliability)
Why?
The loads are too high. (Matrix parameter = Force, Stress, Area)
Why?
Insufficient strength of material. (Matrix parameter = Strength)
Why?
Limits of science.

At which point we reach the end of the line. So, what we learn from this ‘ask why five times’ route (apart from the fact we ran out of why’s after three), is that the root contradiction is the one involving Strength. What we mean by ‘root’ is that if we solve the contradiction at this level we automatically solve the other problems (whereas if we solve the contradiction at the ‘blades fall off’ level, we could still have a strength problem).

Generally speaking, if we have a situation like this where the list of possible contradictions and the resulting list of Inventive Principles is unworkably high, then it is a good idea to focus in at root level.

So what happens when we do that, and focus this wind-turbine problem on the speed versus strength contradiction?

For a start, the Matrix recommends the following Inventive Principles:

8	-	Counterweight
3	-	Local Quality
26	-	Copying
14	-	Curvature

Rather than repeat the mechanics of connecting these triggers to possible solutions as we have done in previous examples (if we were doing this for real, we would of course do exactly what we have suggested previously), it is perhaps useful to examine another strategy. In this case, the strategy involves a link with the knowledge/effects part of the TRIZ problem solving toolkit, or rather with the patent-search element thereof.

The basic idea is to see if anyone else has already made the connection between the Inventive Principles being suggested and something like the system under evaluation.

The easiest of the four Inventive Principles recommended from the root contradiction to do this with is ’Curvature’. The question we pose through an on-line patent search engine is, ‘ has anyone developed a blade with a curve?’ To answer the question requires us to investigate searches of ‘blade’ (and synonyms) and ‘curve’ (and synonyms). Simply combining the two words should, irrespective of anything we find on the patent database, suggest to us the idea of a curved blade. The key point of finding other solutions where this connection has already been made is in helping us to pin down exactly what sort of curvature others have applied, and whether, when they have applied it, it has solved a speed versus strength contradiction. Very quickly using the ‘blade’ plus ‘curve’ search idea reveals that quite a few people have already combined the two words to precisely help solve a speed-v-strength contradiction. These include:-

- propeller design
- jet-engine fan blade design – ‘sword-fan’

- a centrifugal compressor
- high speed wing design
- a boomerang-like toy

Not only do these findings confirm the validity of the 'curvature' direction, they give us some pretty good steers on exactly what sort of curvature to use – in this case to curve the blades away from the wind, and also swept back from the direction of rotation.

Applying a similar search idea to 'blade-and-counter-weight' and 'blade-and-copy' also reveals some promising ideas. 'Blade-and-local quality' is a more difficult search to conduct as 'local quality' is a rather generic and unlikely to be described in such terms within an invention disclosure. Here we need to e a little bit more creative in our search strategy. Local Quality – as detailed in the list of Principles at the end of the chapter – is about turning uniform things into non-uniform things; making parts of a system function in conditions most suitable to their operation, changing the local environment. These suggestions might encourage us to search for patents featuring blades with special tip, root, leading edge, or trailing edge geometries, local protrusions or depressions, roughened profiles, different length segments, and so on. The general point being that here we're making hopefully useful connections between problem component and solution trigger and using the patent database to validate those connections. As it happens, several of the above have been used in a variety of industries to solve precisely the contradiction we are tackling.

Summary

'The most important numbers are unknown and unknowable.' So said W.E. Deming. The quote is particularly relevant to traditional root cause analysis – which often has a seemingly never-ending appetite for data. Finding root contradictions is generally easier, cheaper and quicker than finding root causes.

Root cause analysis is great for optimising systems. If the system has been optimised to the limits of its capability (as many manufacturing processes have – thanks to years of 'continuous improvement' initiatives), no amount of additional optimisation will improve the result. The only way to improve a fully optimised system is to change the system. Solving contradictions is a great way to achieve this. Root Contradiction Analysis is a great way to find the right contradictions to solve.

Principle 41 – 'Smart Materials' ?

Our short article this month speculates on the need for a re-examination of the 40 Inventive Principles found in classical TRIZ in light of expansion of the scientific knowledge-base since the original TRIZ research was performed.

Our patent team have seen a growing number of patents emerging which are based on the use of smart materials. To date we have been classifying such solutions in either Principle 35 – Parameter Changes – where we have inserted a new trigger 35E – 'Change Other Parameters' – or in Principle 15 – Dynamics or Principle 37 'Thermal Expansion'. None seems entirely satisfactory, however, and certainly, when trying to use the Principles as solution triggers, it has been far from obvious to problem solvers that Principles 35, 37 or 15 should prompt a look at smart materials.

We are still debating within and outside CREAX whether there is any benefit in introducing a new specific 'Smart Materials' Inventive Principle to the list, and thought we would widen the scope of our discussions by inviting readers to supply their comments and examples.

In keeping with the form and content of other Inventive Principles and their examples, here is what we have so far:-

A. *Use a material capable of changing it's physical shape*

- Shape memory alloys
- Shape memory polymers

B. *Use a material capable of adapting it's properties to suit the prevailing operating conditions*

- Rheopexic gels
- Thermo-chromic or electro-chromic materials
-

C. *Use materials with 'self-x' properties*

- Self-repairing composites
-

D. *Use materials with special properties*

- *Negative Poisson's ratio ('auxetic') materials – materials that expand laterally when placed under tension*
- Negative stiffness composites – material systems that displace in the opposite direction to an applied force
- Shape memory alloys exhibit unusually high ductility

Please feel free to send your comments and suggestions to the editors. We'll publish an update complete with the best examples received in a future newsletter.

Humour – Systematic Innovation

"We're losing patience. Have you come up with anything yet?"

Patent Of The Month

Patent of the month for this month is US6,330,503 granted on 11 December 2001 to Trimble Navigation in New Zealand. The invention concerns the use of global positioning systems to help automate the process of painting lines on roads or athletic tracks, etc.

(12) **United States Patent**
Sharp et al.

(10) **Patent No.: US 6,330,503 B1**
(45) **Date of Patent: Dec. 11, 2001**

(54) **GLOBAL POSITIONING SYSTEM CONTROLLED STAKING APPARATUS**

(75) Inventors: **Kevin Andrew Ian Sharp**, Christchurch; **Charles David Hope Manning**, Coalgate, both of (NZ)

(73) Assignee: **Trimble Navigation Limited**, Sunnyvale, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/678,506**

(22) Filed: **Oct. 2, 2000**

Related U.S. Application Data

(63) Continuation-in-part of application No. 09/516,995, filed on Mar. 1, 2000, now Pat. No. 6,299,934, which is a continuation of application No. 09/255,424, filed on Feb. 22, 1999, now Pat. No. 6,074,693.

(51) **Int. Cl.**[7] **G06F 17/00**; G06G 7/70
(52) **U.S. Cl.** **701/50**; 404/84.05; 404/93; 173/1; 173/90; 701/213; 701/214; 702/5; 342/357.08; 342/357.13
(58) **Field of Search** 427/136, 137; 700/253, 302; 701/213, 214, 50; 702/5; 342/357.06, 357.08, 357.13, 357.17; 404/75, 84.05, 93, 94; 173/1, 90, 91

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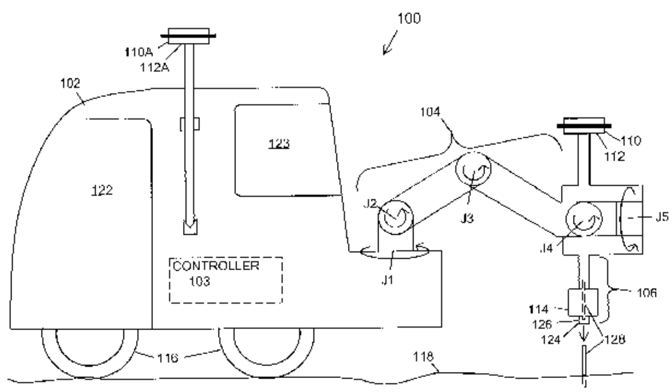
Primary Examiner—Shrive P. Beck
Assistant Examiner—Jennifer Caleagni
(74) *Attorney, Agent, or Firm*—David R. Gildea

(57) **ABSTRACT**

A global positioning system (GPS) controlled marking apparatus for staking and a method of using the apparatus to stake a surface. The apparatus uses a standard architectural or other surface site application program and a stakeout driver program in a standard computer and includes a GPS receiver, a stakeout tool, an autopilot, a vehicle, a geographical drawing converter, and a location comparator. The geographical drawing converter converts an image of a drawing pattern to geographical mark locations. The autopilot guides the vehicle to the geographical mark locations. The location comparator detects a location match between the geographical mark locations of the drawing pattern and a current geographical location determined by the GPS receiver. Information for the location match is used by the stakeout tool for driving a stake into the ground.

5 Claims, 6 Drawing Sheets



It is the latest in a string of patents granted to Trimble in which they have integrated GPS into different products. The thinking behind each patent is described in this sample of text extracted from the 6,330,503 disclosure:

Road markings are produced to a great extent with the assistance of so called "road marking" machines which apply paint under pressure from spray nozzle jets onto the road surface. In marking the road it is quite important that the horizontal registration of the paint be accurate with respect to the position of the road. In the past even experienced machine operators have found it difficult to manually guide a road marking machine with sufficient accuracy even where old markings are available. Heretofore, attempts have been made to *automatically detect the presence of old markings and to use their detection for automatically guiding the road marking machine and switching the spray nozzle on and off as required. However, such attempts have not been wholly satisfactory because a break in the old marking does not give steering guidance during breaks. Moreover, this approach is of no use whatsoever where the old marks have disappeared or for new markings. Various arrangements have been disclosed for solving these problems by automatically guiding the road marking machine along a pre-determined path using light or electromagnetic beams. However, these arrangements require transmitters to be placed along the road, and in the case of light beams, are degraded by the effect of sunlight. In order to overcome these problems, it has been proposed to embed material that emitting radiation in the path that is to be marked. However, this method suffers from the disadvantage that embedding the radiating material in the road surface can be costly. Furthermore, radiating materials tend to lose their effectiveness after a time period. Similar issues pertain to parking lots, air landing fields, and the like*

The patent is selected for two reasons;

Firstly because it makes excellent use of the mono-bi-poly (various) evolution trend. GPS is a level 4 invention in TRIZ terms, and as such it can already be seen to be having both a massive impact on the way we live, and the number of patents like this one that make use of it. It begs the question how can GPS be beneficially added to your system (and has anyone got there first with the patent)?

Secondly, GPS also fits in very effectively into the TRIZ trend towards decreasing human involvement – offering as it does a capability hitherto only a skilled human could have accomplished.

Best of the Month

Bath conference excepted, this month has been another pretty thin month in terms of published reading on TRIZ. So much so in fact that we find ourselves unable to recommend anything with any degree of belief that it will be a good investment of your time.

By far and away the best thing we have read this month comes in the wake of a half-day TRIZ presentation we delivered to the Transformation Forum in the UK on November 22. The presentation came about as a part of our long-term following of the work of W Edwards Deming, and the belief that there is considerable common ground between Deming's thinking and the philosophical elements of TRIZ. One of the delegates attending the presentation made us aware of a previous presentation given by Tom Johnson, renowned systems thinker and operations management educator at Portland State University, on the subject of 'management by means'.

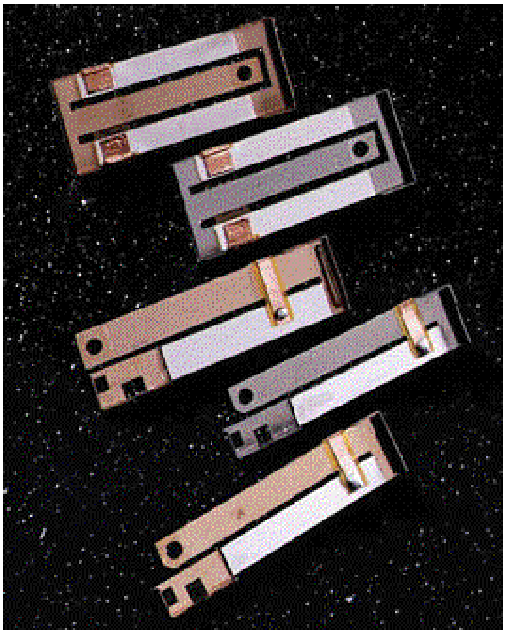
A written version of Professor Johnson's presentation, entitled 'Manage By Means, Not Results' was published in the August 2001 issue of The Systems Thinker, published by Pegasus Communications (www.pegasuscom.com).

The presentation and article describes the author's shift in thinking from the top-down, management by results systems that dominate in the large majority of organizations, to the Toyota 'management by means' model. Management by means involves devolvement of power within organizations to those who are actually doing the job. It means a lot of self-organisation, self-optimisation and self-evolving work practices (anyone sensing a 'self'-like theme to this newsletter won't be too far wide of the mark). It also means a profound shift in thinking away from the management of objects to the management of the interfaces and relationships between objects. There is much in common here with not just the ideality/self aspects of TRIZ, but the conceptual importance of 'interfaces' as a third dimension in the 9-Windows/system operator model (see the article 'System Operator Tutorial 3) Another Dimension in the December issue of TRIZ Journal), and – something we discussed at TRIZCON in 1999 – the management equivalent of the TRIZ S-Fields tool in which the essential 'field' element is precisely that same interface between two 'substances'.

Expect to hear more from us on the commonality between Professor Johnson's work and TRIZ in future months.

Investments – Low-Cost Piezoelectrics

Smart materials are a recurring theme in both TRIZ and CREAX. We rather like piezoelectrics too – an excellent scientific effect that is just beginning to deliver the sorts of forces and motions that make it an attractive option for a number of applications. We particularly liked the solutions at www.pitgoadi.co.uk:



“Engineers are continuously striving to reduce component count in their designs and have often looked at smart materials which change state in response to a signal, as a possible solution for better actuators but have been confounded by high cost and low performance.

”PBT, the Harlow-based hi-tech engineering and invention company has made a leap forward with the introduction of a novel type of piezo-ceramic actuator, called a Planar Bimorph that combines compact dimensions with sufficient motion and force to work within normal manufacturing tolerances as a replacement for conventional wound solenoids.

”Ideal for applications requiring very high pack densities, a PBT patented solid state actuator just 2mm high is capable of a stroke of 5.5mm (+4 to -1.5mm) in resonant mode and 3mm in static mode - a dimensional change of up to 275%! Relative to their size output forces are high and PBT has developed simple force management regimes making it possible to use the lowest rated device to switch loads of more than 10 Newtons.

”Other benefits include:

Low Power - Input of less than 1mW to drive from rest to full defection

High Speed - Typical actuation time less than 1ms.

Durability - Operating life of greater than 100,000,000 cycles.

High Repeatability - better than 5 microns in 3mm (±0.1%) standard driver, or 1 micron with special driver.

Proportionality - Proportional control with an accuracy of better than 0.5 micron, or fully opened/closed.

These novel actuators are price competitive with solenoids and are suitable for a variety of engagement and driving applications including:

Electrical relays (direct acting with up to 3mm air gap)
Mechanism Triggers (trip devices, fire extinguishers, emergency brakes)
Indexing Movers (ratchet motors, timers, linear motion devices, reversing drivers)
Positioning Devices (Mirror movers, X-Y-Z movers, angle changers)
Deflectors and Selectors (automated inspection, coin sorting, knitting, weaving)
Valves (Pneumatics, Hydraulic, one-shot, cutoff)
Interlocks (door locks, button locks, phasing systems, home automation)
Grippers (assembly robots, clutch systems, remote actuators, surgical)
Signalling Devices (Flags, beam deflectors, sounders, whistles, displays)

For Further details contact Simon Powell Tel 01279 621 502”