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A MODEL FOR INVENTIVE IDEATION IN PHYSICO-MECHANICAL SYSTEMS

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ABSTRACT

Motivation

Significant progress has been made over the past six decades in the development and use of techniques and tools to assist in problem solving and invention. However, obstacles still exist as far as their understanding and application are concerned. Selecting a suitable creative thinking technique(s) from the plethora of options that are available creates a dilemma to especially inexperienced users, and methods to assess the completeness of thinking also are lacking. Invention heuristics, on the other hand, offer problem solvers and inventors more guidance in dealing with particular types of problems. However, being based on past experience, they are perceived to only represent best practices and therefore less likely to lead to novel ideas. Also, they are not always efficient and can be cumbersome to use.

The purpose of the research documented in this thesis was therefore to develop a model to improve the understanding and thereby enhance the use of inventive ideation techniques. This model would incorporate the various *mechanisms* that underpin these techniques and thus integrate the areas of creative thinking and invention heuristics. Since many problems in the technology and engineering arenas involve systems and tangible objects, their properties and functions, the model would be tailored to the *attributes* of physico-mechanical systems. Whilst being predominantly theory building in nature, the work was also targeted at demonstrating the practical value of the model in a variety of areas.

Model development

The *mechanisms* of inventive ideation were identified by analysing a diverse range of creative thinking techniques, invention heuristics, as well as a number of historical examples in science

and technology. As shown by way of example in **Figure 1**, the analysis of creative thinking techniques involved a study of their structure as well as the way in which the various mechanisms are applied. Each node in the figure represents a concept that was derived by applying, to the previous node, the mechanism depicted.

From the analysis, ten generic mechanisms of inventive ideation have been identified. These mechanisms, which can also be interpreted as 'keywords' that describe the various techniques, can be grouped into five conceptually distinct 'themes', *viz* Change, Copy, Combine, Separate and Convert. They involve thinking at different metaphorical distances from the problem and thus demand different degrees of creative intuition to lead to new ideas. Furthermore, they are used with different frequency and tend to be applied preferentially to certain types of problems. For example, both Osborn's Checklist and the 40 TRIZ inventive principles make use of only five of the ten mechanisms and areas where the creative thinking could be complemented have thus been identified.

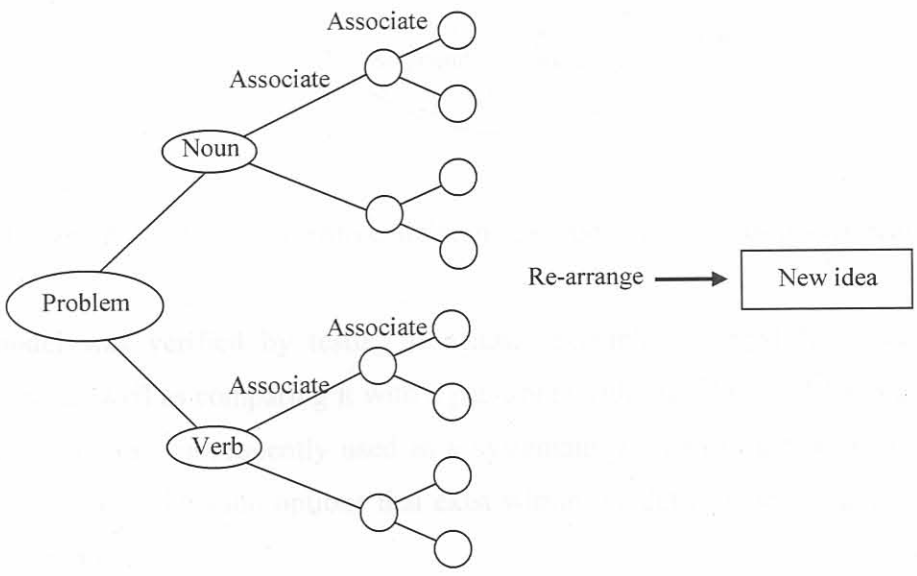

Figure 1 Analysis of the Attribute Splitting technique.

An ideation model for use in physico-mechanical contexts (**Figure 2**) was derived by integrating the generic mechanisms with a system model. The system model comprises 16

attributes that describe the physical, temporal and spatial dimensions of objects and their environments. The mechanisms have been positioned such as to reflect their respective themes (enclosed in broken lines), the metaphorical distance that they remove the thinking from the problem (represented by their distance from the centre), and their frequency of use (decreasing in a clockwise direction).

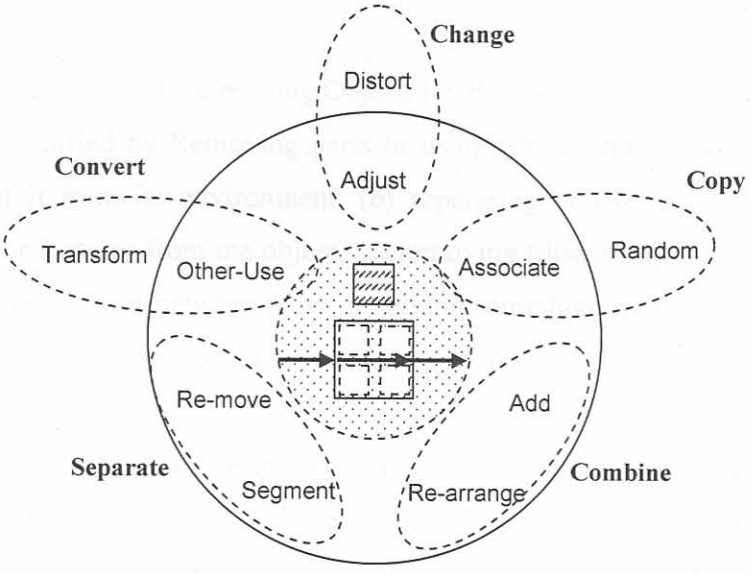

Figure 2 Model for inventive ideation, tailored to a physico-mechanical context.

The model was verified by testing it against examples sourced from the literature and elsewhere, as well as comparing it with a parsimony rule-based model derived from invention heuristics. It was subsequently used in a systematic fashion to establish, in detail, the full range of inventive ideation options that exist within the defined system and thus can be used to solve problems.

Application

In addition to providing a better understanding of the mechanisms underlying inventive ideation techniques, their use and relationships, the model enhances inventive ideation in a

number of areas. This includes (1) the development of ideation strategies best suited to the skills and needs of the individual or problem solving group and the type of problem, (2) the definition of Ideation Domains (IDs), describing the full range of inventive possibilities that pertain to each inventive mechanism and system attribute, (3) a methodology to audit the ideas that have been produced during ideation sessions and thus identify areas of the problem that may yield additional ideas, and (4) an ability to create novel ideas systematically, rather than relying on 'off-the-wall' inputs such as for instance advocated by Random stimulation.

By way of example, the ID of Re-moving Object, i.e. the various ways in which an Object and its parts can be modified by Removing parts or using Movement, includes (a) removing an object or part of it from its environment, (b) separating or extracting useful, required or interfering parts or features from the object, (c) removing (discarding) used or spent parts, (d) allowing relative movement between parts or making something movable, and (e) preventing, or limiting the need for, movement of the object or parts.

The IDs were used to develop a simplified version of the TRIZ Contradiction Matrix (CM), which eliminates the need of having to define a problem in terms of system contradictions. This tool was applied to a random selection of 40 mechanical engineering patents, using in each case the four system attributes that are associated most closely with the engineering parameter that needs to be improved. An overall success rate of 79% was achieved, comparing favourably with the 54% of the classic CM under the same conditions. In the cases where the 4-attribute strategy was unsuccessful, the additional use of the Dimension and Function attributes improved the success rate significantly.

Contributions

The main contribution of this work lies in the fact that it has provided a conceptually sound framework for inventive ideation. Being based on the mechanisms that underpin a wide range of creativity techniques and invention heuristics, it has provided a unifying platform for the two areas of practice. Not only has it improved the understanding of the mechanisms of inventive ideation and their relationships, and thus could result in a more systematic approach

to problem solving, but it has also been demonstrated that it can enhance inventive ideation in four key respects.

A secondary contribution of the work is the development of a consistent description of the nature of, and the relationships between, the four sources of inventive ideas, *viz* Inspiration, Experimentation, Intervention and Serendipity (**Figure 3**). As far as could be ascertained, this is the first time these have been integrated into such a defining framework. This framework has also provided an essential platform for understanding the role of 'deliberate creativity' – the conscious application of thinking techniques and tools – in inventive ideation.

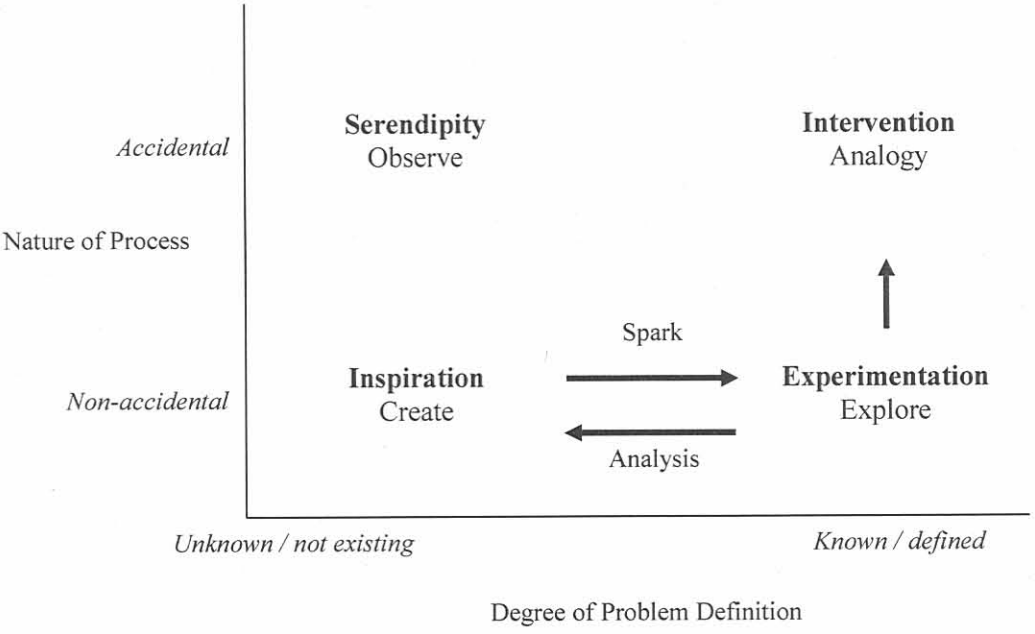

Figure 3 The four sources of inventive ideas.

Further work

The research has also highlighted a number of study areas that could further improve the model as well as the use of ideation tools and techniques. This includes (1) empirical studies focused on the application of the ideation model in a range of areas, (2) developing of system models for a range of disciplines, thus allowing the generic inventive mechanisms to be

applied more widely, (3) deeper investigation into the structures of creative thinking techniques and establishing whether there is a relationship with respect to the novelty of the ideas they produce, and (4) the further development of the simplified (contradictionless) version of the CM. Significant progress has already been made by the author on the latter, including the development of a visual tool to enhance teaching and user-friendliness.

KEYWORDS

inventive ideation, problem solving, mechanism, creative thinking, invention heuristics, TRIZ Contradiction Matrix, systems model, attributes

SYNOPSIS

Significant progress has been made over the past six decades in the development and use of techniques and tools to assist in problem solving and invention. However, several obstacles still exist as far as their understanding and application is concerned. The purpose of the research documented in this thesis was therefore to develop a model that integrates the key aspects of these tools into one unifying framework.

The *mechanisms* of inventive ideation, *viz* the ways in which the parameters of the problem can be manipulated, were identified by analysing a diverse range of creative thinking techniques, invention heuristics, and a number of historical examples in science and technology. From the analysis, ten generic mechanisms have been identified, which can be grouped into five conceptually distinct 'themes'. An ideation model for use in physico-mechanical contexts was derived by integrating the generic mechanisms with a system model. It was subsequently used in a systematic fashion to establish the full range of inventive ideation options that exist within the defined system and thus can be used to solve problems.

The main contribution of this work lies in the fact that it has provided a conceptually sound framework for inventive ideation. Not only has it improved the understanding of the mechanisms of ideation and their relationships, but it has also been demonstrated that it provides an enhanced ideation capability in a number of areas. This included the (1) development of inventive ideation strategies suited to the skills and needs of the thinker or group, (2) the use of Ideation Domains (IDs), detailing the full range of inventive options that pertain to each system attribute and mechanism, (3) a methodology to audit the ideas that have been produced by brainstorming and thus identify parts of the problem that may yield additional ideas, and (4) an ability to create novel ideas in a structured fashion.

A secondary contribution of the work is the development of a consistent description of the nature of, and the relationships between, the four sources of inventive ideas, which has provided an essential platform for better understanding the role of 'deliberate creativity' – the conscious application of thinking techniques and tools – in inventive ideation.

SAMEVATTING

Beduidende vordering is oor die afgelope ses dekades gemaak in die ontwikkeling van tegnieke wat probleemoplossing en innovasie vergemaklik. Daar is egter nog verskeie beperkinge sover dit die insig in die tegnieke en hulle toepassing aanbetref. Die doel van die navorsing in hierdie verhandeling was dus om 'n model te ontwikkel wat die belangrikste aspekte van hierdie tegnieke in 'n bruikbare konteks saamvat.

Die meganismes waardeur innoverende idees ontwikkel word, naamlik die maniere waarop die parameters van die probleem gemanipuleer kan word, is geïdentifiseer deur 'n analise van 'n diverse reeks van kreatiwiteitstegnieke, innovasie heuristieke asook geskiedkundige voorbeelde in die wetenskap en tegnologie. Die analise het aangedui dat daar tien generiese meganismes bestaan, wat in vyf konsepsueel-onderskeibare 'temas' gegroepeer kan word.

'n Model wat in fisies-meganiese kontekste gebruik kan word om innoverende idees te genereer, is ontwikkel deur die generiese meganismes met 'n sistemiese model te integreer. Dit is daaropvolgens gebruik in a sistematiese wyse om 'n gedetaileerde oorsig te ontwikkel van die volle reeks van opsies vir innoverende idees wat binne die gedefinieerde sisteem bestaan en dus gebruik kan word in probleemoplossing.

Die primêre bydrae van die navorsing is gesetel in die feit dat dit 'n konsepsueel-betroubare raamwerk vir innoverende idees daarstel. Dit verdiep nie bloot die insig in die meganismes van idee-ontwikkeling en hulle verwantskappe nie, maar demonstreer ook, in 'n aantal areas, die verhoogde innovasie moontlikhede wat dit teweegbring. Dit sluit in (1) die ontwikkeling van geskikte strategieë vir idee-generasie, (2) die gebruik van Idee Domeins (IDs) wat die innovasie opsies rondom elke eienskap van die sisteem uitlig, (3) 'n metodologie om die idees wat gedurende idee-sessies geproduseer is, te oudit en dus areas te identifiseer waar addisionele idees gevind mag word, en (4) 'n metode om innoverende idees op 'n gestruktureerde wyse te onwikkel.

'n Sekondêre bydrae van die werk was die ontwikkeling van 'n robuuste beskrywing van die eienskappe en die verwantskappe van die vier oorspronge van innoverende idees. Dit verseker 'n belangrike platform waarvolgens die rol van 'doelbewuste kreatiwiteit' - die gefokusde toepassing van tegnieke en metodes in innoverende denke - beter verstaan kan word.

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DECLARATION

I hereby declare that, unless stated otherwise, the work contained in this thesis is my own original work. It has not been, either in its entirety or in part, submitted at any institution for any academic or other qualification.

Victor Emul Ross

September 2006

DEDICATION

To P-T and E

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I would like to acknowledge the following people for making this work a reality.

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2. De Beers Technology, for providing the opportunity to develop some of the concepts in this study.

3. Francois Grobler, for introducing me to TRIZ.

4. Indirectly, but significantly, the work of Douglas Hofstadter, Margaret Boden, Vera John-Steiner and others in the field of cognitive science and psychology has shaped my interest and insight into creativity and inventive problem solving. To them, I am much indebted.

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PREFACE

In *Variations on a Theme as the Crux of Creativity*, Douglas Hofstadter writes about the French saying '*Plus ça change, plus c'est la même chose*', which loosely translates to "The more it changes, the samer it gets." He interprets this apparently non-sensical statement to mean that, the more different manifestations one gets to observe of a phenomenon, the more deeply one gets to understand it, and therefore the more clearly one can see the 'vein of sameness' that runs through all its manifestations.

This thesis was sparked by a desire – that later became a bit of an obsession - to understand the 'veins of sameness' that run through 'inventive ideation', namely the process by which novel, potentially useful ideas are produced to solve existing problems and create new things. Having graduated as a chemical engineer, educated in logic and analysis, I soon understood that the technological research environment demanded problem solving skills that were not part of this education. This brought me in contact with creativity, and the use of 'creative thinking techniques' and other tools for invention, problem solving and producing new ideas.

As I started delving into the creativity literature, I found a myriad of techniques, in total probably around one hundred. However, only a relatively small number were encountered on a regular basis in the literature and cited by the leading practitioners in the field. On closer inspection, some techniques appeared to be very similar to others in structure and application; some authors have borrowed freely, either unknowingly or without acknowledgement, from established approaches and principles. What has resulted is a field that in terms of tangledness is beaten only by a sizeable plate of spaghetti and has done the image and application of creative thinking as much good as Mike Tyson's dentals did Evander Holyfield's ear at Madison Square Garden.

The main aim of the work documented in this thesis was therefore to untangle the many different manifestations of creative thinking techniques and other ideation tools to such an extent that they could be represented in the form of an understandable, usable framework. A

study as broad as this invariably takes the researcher into other areas of interest; I have tried to incorporate salient aspects of these in the thesis in places where it could serve to provide a deeper and more complete view of this wonderfully exciting topic.