

AUTOMATIC EVOLUTION OF IDEAS THROUGH MULTILAYER EVOLUTIONARY SYSTEM TO SUPPORT CREATIVE THINKING

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ABSTRACT

Creativity is a tool that helps in effective problem solving utilizing optimum scarce resources in any business. This paper presents a conceptual framework of a multilayer evolutionary system that supports creative thinking. The system evolves, using a genetic algorithm, new ideas from a set of basic ideas that are casually provided through an interactive editor or selected from past transaction records. The architecture proposed here encompasses three layers called system layer, database layer, and query producer and user interface layer. Besides the general architecture, the paper also describes the detailed methodology, genetic procedure to evolve ideas, reproduction operators like modified mutation, cross over and selection; and fitness functions to evolve suitable and strong ideas. The system layer further describes algorithm of stimulus-generation process. The proposed architecture is easy to develop, generic, domain independent and works with databases, which increases scope and usability of the system. Above all, the interactive user interface makes the system friendly and easy to operate.

KEYWORDS

Idea Generation, Anchor and Gestalt Theory, Genetic Algorithms, Stimulus-Generation.

1. INTRODUCTION

Every business is unique and needed to be handled with special treatment to get better achievement. Success lies in how best one utilizes scarce resources in innovative way. Creative thinking is an essential skill for everyone, for every business. Sufficient degree of such creativity helps in problem solving, designing systems, and understanding human behavior, by drawing on the concepts fundamental to computer science. Techniques of creative thinking try to incorporate psychological and mental models into the area of computer science. One such technique is Idea Generation.

Young (1989) and Robbin (1990) proposed the use of IT systems for generating new ideas and obtained positive results in studies of IT for creativity support. Proctor (1991) suggested the use of computer programs for producing creative thought. Additionally, it is suggested that computer programs can provide “mind maps” or graphical representations for idea generation (Machrone 1994). Boden (1994) proposed that computer software can facilitate the creativity of users by prompting them to search for new ideas. Partridge and Rowe (1994) indicated that computers can be enlisted to remove constraints on creativity and stimulate the development of new ideas. Edwards (2001) examined the impact of IT on creativity. However, a long-lasting question is how organizations can institutionalize IT usage to enhance creativity (Dewett, 2003;

Misue & Tanaka, 2005). However, to deal with idea generation and other techniques which are very difficult to directly map to the traditional computer problem solving techniques, there is a need of a paradigm that is more 'natural' and can efficiently mimic the process of the mother nature. Bio-inspired computing is a field devoted to handle complex problems using computational methods based on the design principles encountered in nature. The aim is to solve problems which are very difficult to handle by the traditional methods in highly effective manner (Akerkar & Sajja, 2009). The idea generation process is more *natural* and is difficult to solve with the traditional information and decision support systems.

The work proposed in this paper is utilizing genetic algorithm approach for idea generation. For mimic the idea generation process, the concepts of Anchor and Gestalt theories have been used. Prior to the genetic algorithm fundamentals and detailed methodology of ideal generation through genetic algorithm approach, the paper presents fundamentals of Anchor and Gestalt theories in its Section 2. Section 3 provides generic multilayer architecture of the proposed system and illustrates detailed methodology. Section 4 further elaborates working of different layers and presents the automatic idea generation process using a genetic algorithm, which includes encoding, reproducing and selecting new ideas. Section 4 concludes the discussion by exploring advantages and application areas where such system can be utilized.

2. THEORETICAL UNDERPINNING

We can make use of concepts of anchor and gestalt theory (Yang and Lee, 2008) to support idea generation.

2.1. Anchor

An anchor is an object used to attach a ship to the bottom of water at a specific point. The term anchor is also used in fields such as learning, geography, and psychology. An anchor is a representation that triggers/linked to another representation. Biologically and psychologically, it is believed that all experiences are represented as some combination of our five senses. There are some events or items that may work as anchor and generates specific action. For example, when the bell rings students feel happy and when alarm clock rings every student is unhappy (generally). Even after a long time, when one had completed the studies, the ringing of bell is welcomed and alarm clock sound generates a little bit unwillingness. Here, the sound is acting as stimulus. When stimulus and response are connected we say they are anchored. That is anchoring is a process by which a specific stimulus is used to connect to, or trigger, a desired emotional response. Anchors can occur naturally or can be set up intentionally. Another example is, when you hear a fire alarm (anchor) you leave the building (response). Music helps you recall feelings related to an event. This is auditory. These are examples of audio anchors. Any image, data, emotion etc. can act as anchor and trigger positive or negative responses. Prices of given commodities are the statistical and financial anchors that generate buying and selling commodities response.

This study applies the concept of anchor points to promote idea generation during the creative process. The anchors of the proposed system are represented by keywords. In an early stage, an initial anchor would be given to a user to set up a starting point and spotlight the inquiry. Human-machine communications can then stretch user ideas around the anchor. Moreover, the system can supply supplementary anchors at the proper time.

2.2. Gestalt Theory

The Gestalt theory is a family of psychological theories dealing with mind and brain. The word 'Gestalt' came from German, which means shape, form, pattern or configuration of an entity. Gestalt Theories are usually expressed as laws, and there are many variants of Gestalt theory

laws devised by different psychologists, for example, According to Boring (1942), Helson in the year 1933, extracted 114 laws of Gestalten. Some examples of such laws are law of closure, law of symmetry, law of isomorphic correspondence etc. For example, the symbol of ‘door’ probably gives us understanding the way to ‘Exit’. Without knowing anything written on the icon, it is still easy to fantasize that it can be used for safe exit from the environment.

Gestalt theory applies to all aspects of human learning, although it applies most directly to perception and problem-solving. Wertheimer (1923) proposed two modes of human thinking - productive and reproductive. Productive thinking solves a problem through insight whereas reproductive thinking solves problems by referring to previous experience and what is already known. This paper considers some rules of idea-generation techniques, which facilitate productive or reproductive thinking of gestalt theory. These rules can initialize rather new and break old rules. Just like anchors, the gestalts can be in audio, visual or emotional form.

Regardless of their form, both the anchor and gestalt can be closely bound to the idea or event to be triggered. Reaction of a human or a system is correct (positive) and quick. Tighter (stronger) the coupling of an idea to its stimulating anchor/gestalt, the response is quicker. Such quick and positive response generating idea can be the attribute which defines quality of the idea. Other parameters can be (i) the form of and (ii) ease of accessing the anchor, or gestalt. That is the anchor, or gestalt which leads to the idea which yields ‘good’ outcome/profit/users’ satisfaction is treated as fit and strong anchor or gestalt.

2.3. Idea-generation Approaches

Idea-generation approaches can prompt certain cognitive activities in users. Such techniques reflect beliefs derived from personal experience, popular assumptions, or scientific research (Akerkar, 2003). These techniques can mentally discharge, stimulate people to respond, or cultivate idea generation. There are hundreds of idea generation techniques (VanGundy, 1988; Smith, 1998). This work presents a “*Challenge*” rule (as one of the genetic operators) to stimulate users with habit-breaking strategies via (i) perspective change, (ii) assumptions challenge, and (iii) negation.

Perspective change persuades users to consider problems from diverse agent perspectives. An assumption challenge drive users to question beliefs associated with a problem. Negation applies counter-assumptions to problem relevant beliefs.

An additional operator rule proposed in this work is “*Jump*”, including the “*Fantasy*” technique, which is an imagination-based strategy for encouraging users to conceive of states in which the constraints of reality do not apply. These two rules are applied to implement the concept of gestalt theory.

In addition to “*Challenge*”, “*Jump*”, and “*Fantasy*” this study also implements a “*Systematization*” operator rule, based on analytical and search strategies. This rule includes numerous techniques: decomposition, translation, association, and analogy. Decomposition reduces wholes into parts and attributes. Translation converts one kind of thing into another.

Association follows associative links among ideas based on a knowledge base. Analogy is the strategy of solving problems by identifying and comparing alike problems and solutions.

3. SYSTEM ARCHITECTURE

The projected system architecture for idea generation is divided into three layers - query producer and user interface layer, database layer, and system layer. The query producer and user interface layer enables entry of initial ideas through an interactive editor. This layer also

encompasses the genetic algorithm approach and evolves different generations of initial population of ideas through reproduction operators and a fitness function based on users' satisfaction and feedback. The database layer includes an ontological base for storing domain knowledge base, a rule base with pre-defined rules for providing stimuli, problem template base for storing the models related to specific problems, and users' profile while generating ideas. The system layer includes two modules, namely a management module, which includes knowledge base management, problem template management and rule base management; and a stimulus-generating module which is the core module for generating stimuli to assist users in thinking about a specific problem. The general architecture is shown in Figure 1.

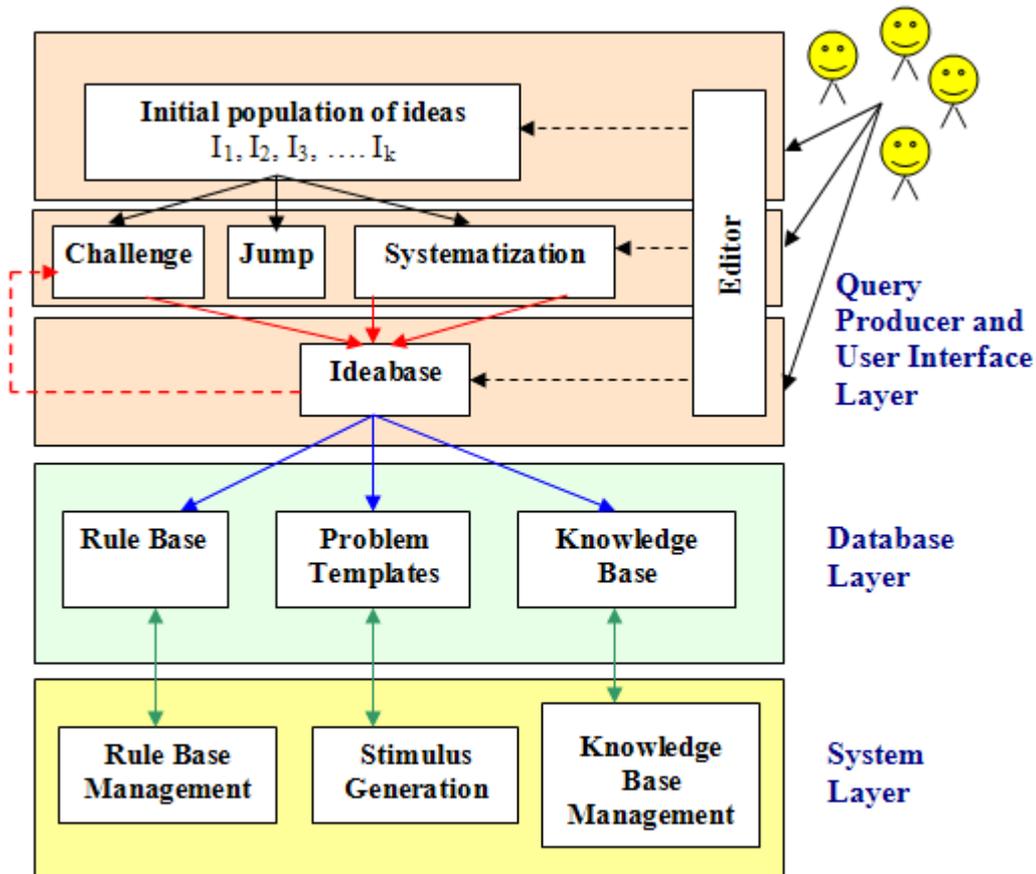


Figure 1: General Architecture of the System

The following subsection demonstrates functions of different layers in the proposed system.

3.1. Query Producer and User Interface Layer

This layer works in conjunction with an interactive editor that works at different levels to interact with users for various tasks within the layer. This layer utilizes technique of genetic algorithm to evolve ideas. The initial population of idea can be created through the interface editor in the layer. Please see Section 4.1 (system architecture) for encoding strategy of ideas and fitness function.

3.2 Database Layer

The database layer includes an ontological base for storing domain knowledge, a rule base with pre-defined rules for providing stimuli, a problem template for storing the models related to specific problems, and users' profile while generating ideas. The knowledge base and problem templates can be considered as independent agents/utilities. The knowledge base contains domain knowledge as well as meta-knowledge - which is the knowledge about knowledge. Here, it considers knowledge representation schemes and inference mechanism. The inference mechanism is a kind of control knowledge which is used to refer the existing domain knowledge and infers new knowledge.

The problem template stores models related to specific problems including the target users' information. The rule base stores pre-defined rules for giving stimuli. The rules are "Challenge", "Jump" and "Systematization". As stated earlier, the idea-generation techniques like *assumptions challenge*, *negation*, *perspective change*, *fantasy*, *decomposition*, *translation*, *association*, and *analogy* are used to provide the user with appropriate stimuli related to the problem.

3.3 System Layer

The system layer manages the rule base, problem template, and knowledge base. The facilities allow update to the knowledge base and rule base. In addition to that, this layer also encompasses the stimulus-generating module, which is the core module for generating stimuli to assist users in thinking about a specific problem. The *stimulus-generation* works in cooperation with process of and *mind-map access*. *Stimulus-generation* is accountable for giving users appropriate stimuli according to rule base. The functions of mind-map access are modifying and tracking user' mind maps.

For generating new ideas from the given stimulus, following steps [<http://www.brainstorming.co.uk/tutorials/methodsofextraction.html>] can be applied:

Step 1. Concept extraction

This deal with clear understanding of how does the stimulus work; how it can be achieved or invoked; what is the purpose and which type of users/situations are bounded with the stimulus. This can be done through firing sufficient interactive queries through system editor.

Step 2. Feature extraction

Here the physical attributes are considered. The shapes, forms, media, and pattern of the stimulus are considered mainly here. One has to consider any transformation procedures, their time and purpose that can be applied on it. The re-use of the stimuli depends on the features extracted.

Step 3. Feature selection and replica management

The required important features are short listed and marked for future use. Depending on the required feature, replica of the stimulus can be made and used frequently.

Step 4. Comparative Evaluation

This deals with extraction of differences between the stimulus and the current solution. One has to consider whether the stimulus and the solution achieved represents the same thing or not (may be in different format or shape).

Step 5. Updating the system layer and user profile

According to the results of the above experiment, the rule base, knowledge base, and user profiles are updated.

The Stimulus generation process (SGA) in *stimulus-generation* is given in Figure 2.

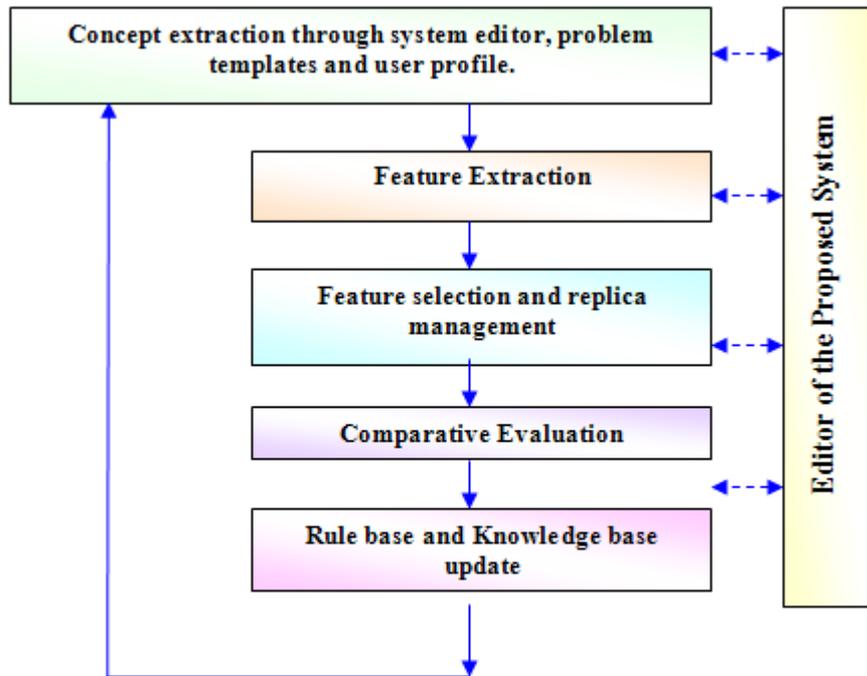


Figure 2: Stimulus Given Algorithm

4. DETAILED METHODOLOGY

This section provides a detailed description of both, the representation used and the fitness functions defined to allow the automatic evolution of ideas.

4.1 Genetic-based Representation of Anchor and Gestalt Ideas

This layer works in conjunction with an interactive editor that works at different level to interact with users for various tasks within the layer. This layer utilizes technique of genetic algorithm to evolve ideas. The initial population of idea can be created through the interface editor in the layer.

To encode the ideas the strategy shown in Figure 3 can be utilized. The ideas are generally descriptive thoughts that may be useful to solve problems in the given domains. These ideas can be further categorized into different classes according to their type, representation scheme, and application area. Besides the idea content, the information like idea category and sequence number can be one item to be encoded along with the ideas to efficiently store and access them. Here, the idea content can be multiple entries concern with text files/reference to the text files, which are distributed and decentralized.

Another important item to be encoded with the ideas is the history and utilization information. That shows usage history of a particular idea like date, time, and user profile. One may add the application/problem identification along with the history to get better knowledge of where the idea can be utilized. Figure 3 presents detailed representation of the idea encoding strategy. Figure 4 represents an example idea utilizing the proposed encoding strategy.

The next step is to test anchors through user’s feedback and discard the poor ideas. Further on the selected ideas, reproduction rules are applied to generate new ideas. Some example rules are “Challenge”, “Jump” and “Systematization”. This process is shown in Figure 5. To implement these rules, this study adopts several idea-generation techniques such as *assumptions challenge*, *negation*, *perspective change*, *fantasy*, *decomposition*, *translation*, *association*, and *analogy*. These techniques are used to provide the user with appropriate stimuli related to the problem.

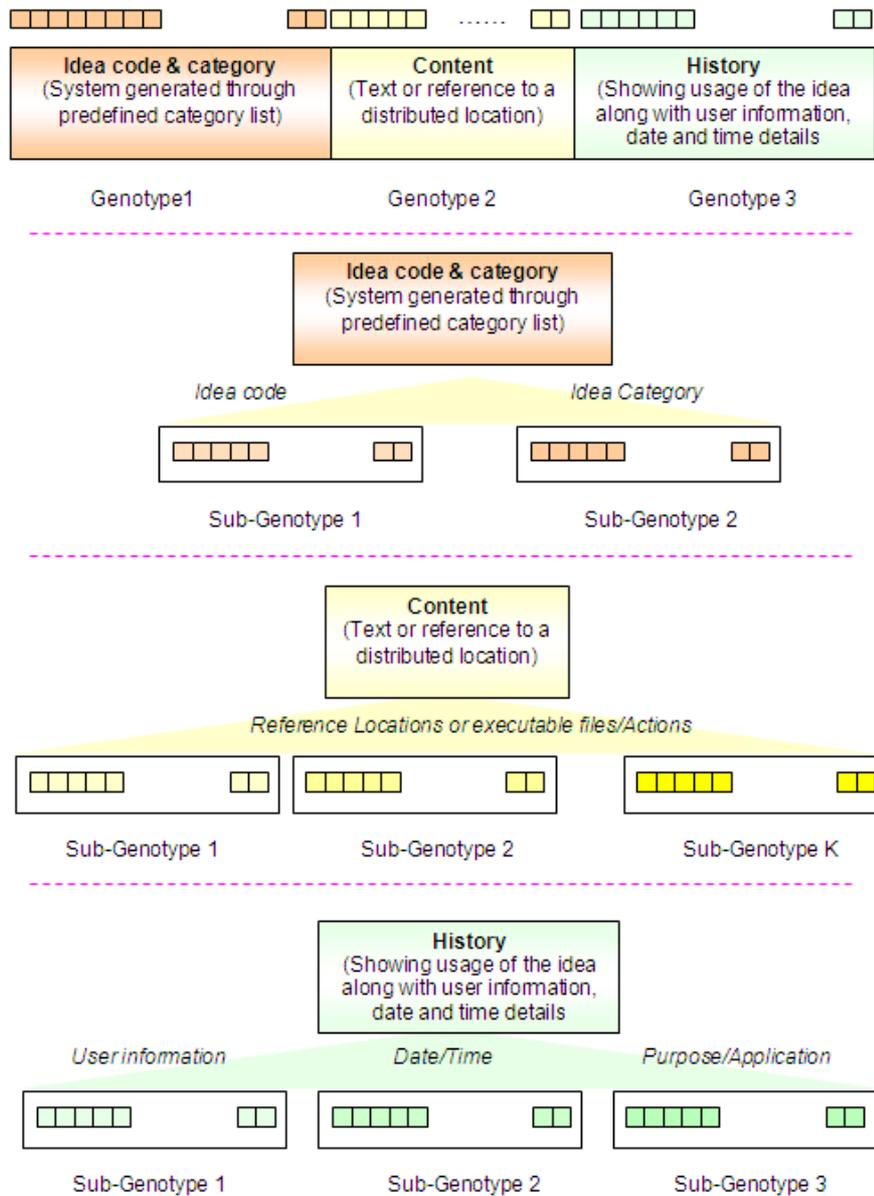


Figure 3: Encoding Ideas

For example, when a traditional small to medium scale product marketing company tries toward improving efficiency of transaction in its business, one idea is that to reduce four copies of a voucher/document and preserve electronic version of the idea. This saves time, effort, and other resources; increases the speed and reliability. Through company's network, the soft copy of the document can be reached to the required section. Only one hard copy is needed which is going out of the company for taxation and other purposes. This idea can be represented as follows:

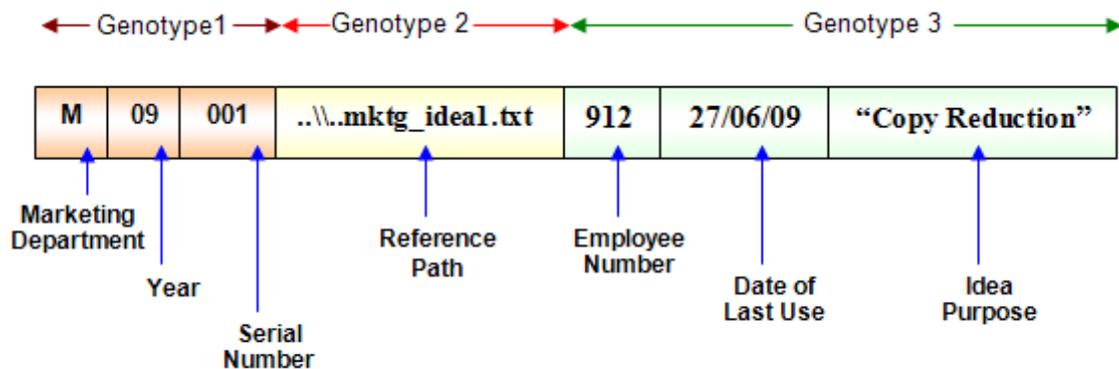


Figure 4: An Example of Idea Encoded

4.2 Fitness function and reproduction operators

As shown in Figure 4, there are several such ideas which are encoded and preserved. To determine the strength and suitability of the ideas, it is necessary to pass them through proper fitness function. The ideas can be ranked according to their history and utilization information. One such fitness function is the rank of idea which is determined through frequency of utilization of idea within the latest time period. The rank is achieved through substring operation (to extract required genotypes) on each idea. The high utilization rank means the idea is really useful and important. Using this criterion, the least useful ideas are discarded and new generation of ideas can be prepared. During this process, the user feedback can be considered before making final decision.

Fitness function can be applied on the strong ideas selected in the next generation. The typical mutation, crossover, and selection operators are redefined as follows:

4.2.1 Mutation

Mutation in this application is restricted the second genotypes called idea description. The mutation utilizes mutation table containing all possible ideas (may be encoded from the previous generation ideas) encoded using the strategy discussed in Figure 2. That is, the ideas which are successfully implemented or strong enough to be considered for implementation in other department/section/application can be considered for experiment at the given section. This is one of the characteristics of natural intelligence – to find similarities in dissimilar situation and vice versa. The mutation results in new individual/idea hence, the new idea code is to be fixed (may be auto generated number). This can be done by the proper interaction with the user of the system through system editor.

4.2.2 Crossover

Crossover operator requires two ideas and works on the second genotype of both the ideas. The crossover operator selects two individuals and interchanges their second genotype. This results in a new individual. As in mutation, here also the idea code for the resulting individual is a new code.

4.2.3 Selection

Selection operator in this system helps in choosing most appropriate idea to be applied in a given situation. For this, it searches in the population for the given department/section and provide ranks to the ideas belong to particular category only. The idea with the higher rank can be selected.

After applying the reproduction operators, the new individual generated are tested with the fitness function. Optionally one may think for the challenge, jump and fantasy rule to fine tune the selected ideas. The selection operator can also be used as fitness function. The iterative process of evolving ideas is shown in Figure 5.

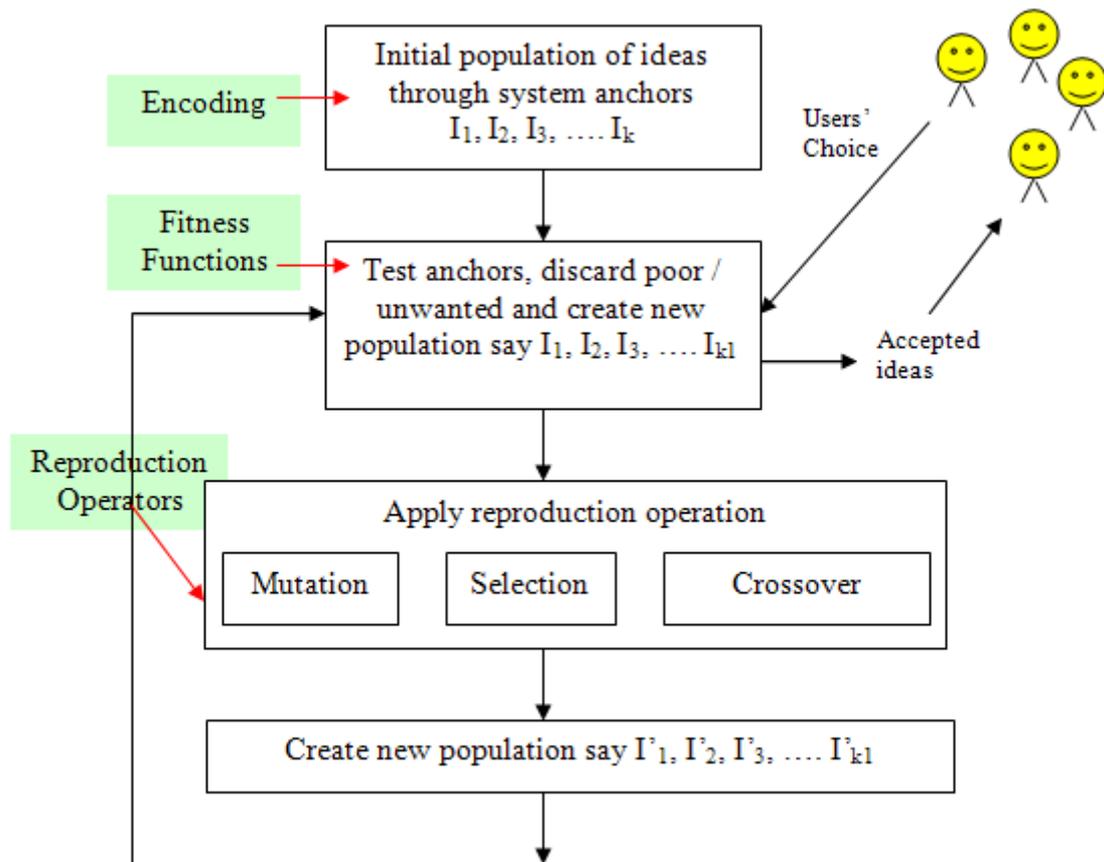


Figure 5: Evolving Ideas through Genetic Procedure

4.3 Experimental evaluation

This section provides some experimental evolution, fitness functions, and reproduction operators using our previous representation. Consider the casual ideas represented in Figure 6 using the proposed encoding strategy.

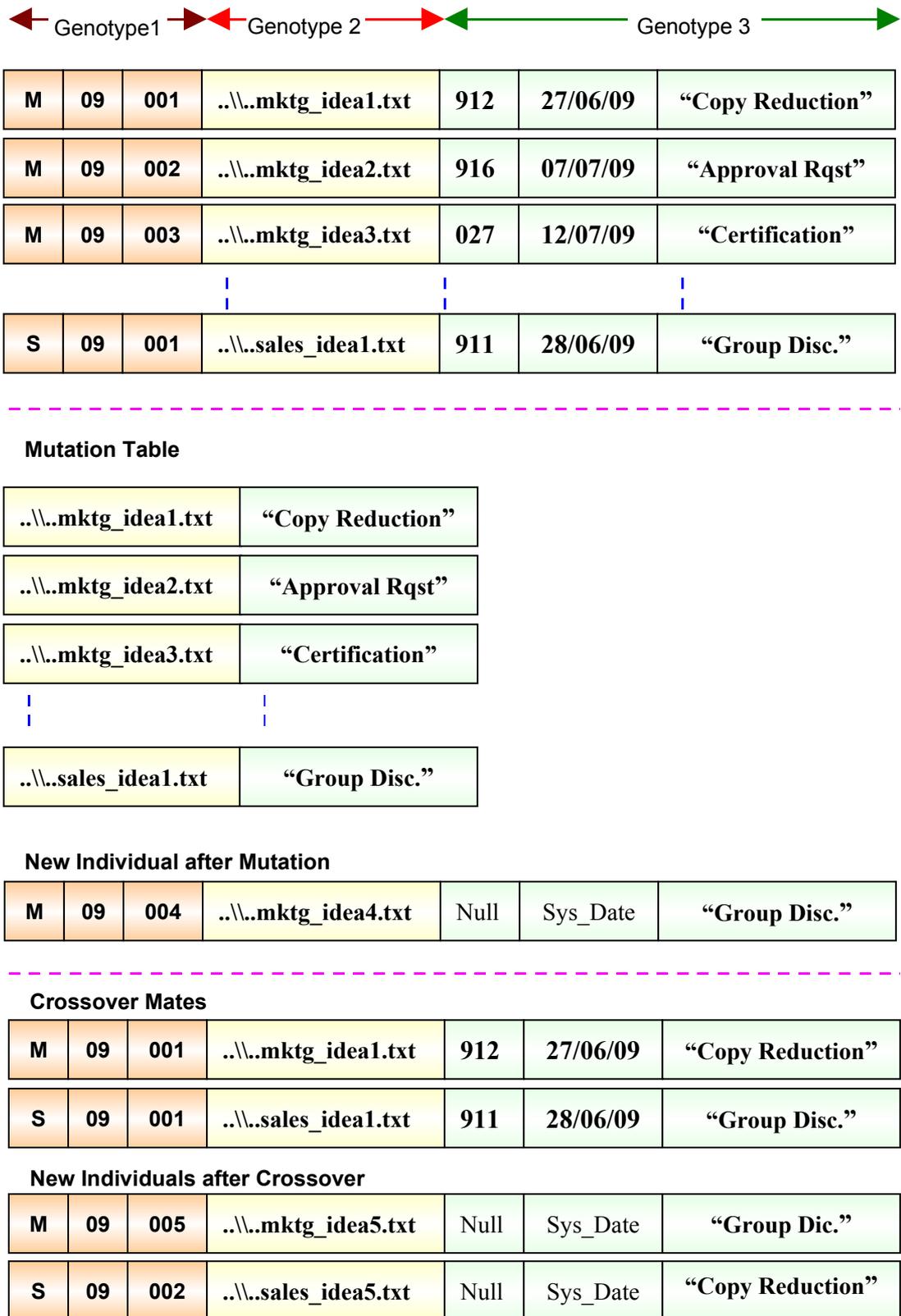


Figure 6: Recombination Application

5. CONCLUSION

This paper presented system architecture for automatic idea-generation according to the modified recombination operators and stimulus-response model of behaviorism, anchor theory, and gestalt theory. According to stimulus-response theory from behavioral psychology, appropriate stimuli can lead user to generate new ideas at initial stages which further evolves into strong ideas. The system interacts with users by dialogue, give stimulus to encourage idea generation and ranks ideas to evolve better ideas. The experimental results included in the system shows the feasibility of the design proposed here and justifies the claims made. It is required to further examine stimuli-generating rules and other selection strategies for building anchors. Nevertheless, the creative process of idea generation is yet vague. Use of additional theories might generate new rules and selection algorithms.

The proposed system is domain-independent. The problem templates and domain knowledge base are replaceable. The user-friendly editor encompassed in the system increases ease of use and hence increases scope of the system. According to Sajja (2009), the system designed by dividing its functionalities into different layers leads to a modular system that is easy to develop and test individually (layer by layer) and offers better control in designing and implementing the system.

System based on concept of total quality management, human resource management systems, knowledge management systems, employee evaluation for employee lay off, attrition systems, etc. are the suitable candidates of the approach proposed here. The evolved idea base through the system serves as a very good source of documented knowledge and can be used in future for problem solving and training.

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