Computer-Aided Problem Solving: A Dialogue-based System to Support the Analysis of Inventive Problems

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Context

- TRIZ improves individuals and organizations’ innovation capabilities

Source: Presentation at Japanese TRIZ Symposium 2009 by Panasonic
On the other hand assimilating the TRIZ logic requires not negligible learning efforts;

A typical course to gain sufficient problem solving skills requires:
- At least 40 hours front lessons
- Several months of practice with real case studies

As well TRIZ based CAI (Computer-Aided Innovation) tools don’t result to be effective with fellows who have not attended vocational courses
Context

⁻ Creativity and inventiveness, which are crucial for innovation, are not supported by PLM systems [1].

- It is required to extend the support to the whole design process.

The authors propose a prototype algorithm for problem solving viable to be implemented in a software application, taking in consideration the recalled lacks of CAI systems. The framework of OTSM-TRIZ constitutes the core of the theoretical background for the development of such dialogue-based system.
Goal and outline

- **Step-by-step algorithm** for the analysis of the problem and the organization of the related information according to the TRIZ knowledge-base, in order to support the problem solving process.

- **Outline**
  - System Requirements
  - Related art:
    - Problems characterization
    - Problem Solving approaches
    - Computer-Aided tools for Problem Solving
  - Reference models
  - A dialogue-based system for the analysis of inventive problems
    - Detailed structure of the algorithm
  - Validation
    - Preliminary tests with students of Engineering Design
    - Tests in industry
  - Conclusions and future works
System Requirements

- **Step-by-step algorithm** for the analysis of the problem and organization of the related information according to the TRIZ knowledge-base, in order to support the problem solving process.
  - **Capability to face**
    - Difficult problems by giving priorities to the objectives
    - Non-typical problems by highlighting conflicting requirements and depicting the main characteristics of the desired solution
    - Ill-structured problems, turning them into well-structured by means of their proper definition
    - Inventive problems by helping the user in retrieving useful information and data from available resources in various domains
  - **Provide useful stimuli to the problem solver in order to leverage his/her knowledge and creative skills**
  - **Drive the problem solver in useful information searches that may widen its design space and then the space of solution**
    - Definition of search criteria that allows automatization in order to require minimum efforts to the designer
System Requirements

Main characteristics of the dialogue-based system for Problem Analysis:

- limited amount of training
- “natural” language
- speed up the information search
- no patent-mining competences required
Related art: problems characterization

- Common problems to be faced during inventive design activity:
  - **Difficult problems / Easy problems** [2]
    - Intransparency
    - Complexity
    - Dynamics
    - Polytely
  - **Typical problems / Non-typical problems** [3]
    - Non-typical problems require to leverage personal knowledge and wisdom
  - **Inventive problems / Non-inventive problems** [4]
    - Whatever lead to an useful, novel and unobvious solution
  - **Well-structured problems / Ill-structured problems** [5]
    - Six main characteristics define WSP, ISP constitutes a class of residuals.

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Related art: Problem Solving Approaches

- **Cognitive approaches:**
  - **Characteristics [6]**
    - Analogy
    - Abstraction
    - Association of ideas
    - Cross-fertilization thinking processes
    - Leverage on tacit knowledge
  - **Exemplary Cognitive Methods for Problem Solving**
    - Case-Based Reasoning
    - Brainstorming

Related art: Problem Solving Approaches

- Systematic approaches:
  - Characteristics
    - Linear
    - Step-by-step procedures
    - Efficient for just some types of problems (poor versatility)
    - Doesn’t require specific creative capabilities
    - Rely on explicit knowledge (Patents, Handbooks, Scientific Literature,...)
  - Exemplary Systematic Methods for Problem Solving
    - TRIZ
    - Constraint Satisfaction Problems and its evolution
Related art: Problem Solving Approaches

- TRIZ cannot be considered as a purely systematic methods since
  
  “... ARIZ is a tool to aid thinking, but it cannot replace thought itself (...) it is exactly the sparks of imagination that lead humans to produce creative non-typical ideas”. [7]

- The plain differences between cognitive and systematic approaches should be conciliated in a step-by-step method that leverages individual’s tacit knowledge since:
  
  “...design methodology should therefore foster and guide the ability of designers, encourage creativity, and at the same time drive home the need for objective evaluation of the results” [8]


Computer-Aided tools for Problem Solving

Four kinds of aiding the user within Computer systems for problem solving [9]:

- by facilitating the management of the working process, encouraging the perseverance of designer in the research of innovative solutions;
- by easing the communication between design team members, since circulation and integration of ideas play a relevant role in the creative process;
- by aiding the designer with a coaching activity, acting as an expert system that guides the user throughout cognitive processes;
- by cooperating in the creative process, thanks to the Artificial Intelligence systems that contribute to ideas generation.

Reference Models: OTSM-TRIZ

- Hill model (abstraction-synthesis) [*]
- Tongs model (from current situation to ideality, barriers identification) [*]

* source: Nikolai Khomenko
Reference Models: OTSM-TRIZ, TRIZ

- Funnel model (convergent process) [*]
- System Operator (system thinking)

* source: Nikolai Khomenko
The algorithm is structured in logical blocks aimed at investigating different aspects of the system; diversified outputs are foreseen upon the reached degree of formalization and abstraction of the problem.
Main features of the algorithm regarding knowledge search and problem solving opportunities:

- it helps at first the user in exploiting his know how by suggesting proper problem solving paths, that don’t require external expertise, thus facilitating the implementation of the ideas generated;
- the search in external industrial domains is addressed when the abstraction process has been completed (i.e. definition of a physical contradiction);
- it provides indications for suitable solving alternatives through different TRIZ tools, e.g. separating in time/space, trimming useless or low-valued components, etc.
A dialogue-based system for the analysis of inventive problems

- Logical block Initial Situation (IS): it provides a preliminary description of the system and the problem under investigation

Access to the block from

START

NEW SYSTEM DEFINITION

Block INITIAL SITUATION

Introduced Variables and Parameters:
1. the Technical System to be analyzed
2. the overall GOAL to be achieved by the System
3. the Main Useful Function (MUF of the System)
4. the Beneficiary of the System
5. the Object of the MUF
6. the Supersystem
7. the Subsystem (elements and components of the System)
8. Operative conditions such as Operative Space and Time

This block may lead to

Block NEGATIVE EFFECT

Block PERFORMANCE
A dialogue-based system for the analysis of inventive problems

Logical block Negative Effect (NE): it investigates the undesired effect that arises in the system, as well as the negative consequences and impact.

Access to the block from

- Block INITIAL SITUATION
- Block PROCESS
- Block RESOURCES
- Block PERFORMANCE

Introduced Variables and Parameters:
1. the Negative Effect (NE)
2. the Operative Time and Space of the NE
3. the element/component of the System causing the NE
4. check about the real necessity of such component

This block may lead to

- CONTRADICTION NOT FORMULATED
- Block ARIZ
Logical block ARIZ (AR): it is supposed to allow the definition of a physical contradiction in TRIZ terms.
A dialogue-based system for the analysis of inventive problems

- Logical block Performance (PE): it is meant to reformulate the system to be analyzed or the negative effect.

Introduced Variables and Parameters:
1. the unsatisfied or missing Performances
2. the motivations underlying the required modifications
3. the beneficiaries of such further improvements
4. the causes of the current lacks

This block may lead to

- CONTRADICTION
  - NOT FORMULATED
- INITIAL SITUATION
- PROCESS
- NEGATIVE EFFECT
A dialogue-based system for the analysis of inventive problems

- Logical block Resources (RE): it deepens the investigation of the system, in terms of the excessive amount of resources spent during its employment.

Introduced Variables and Parameters:
1. the critical resources of Time
2. the critical resources of Space
3. the critical resources of Information
4. the critical resources of Material
5. the critical resources of Energy

This block may lead to:
- Block COSTS
- CONTRADICTION NOT FORMULATED
- NEGATIVE EFFECT

Access to the block from
- Block ARIZ
- Block COSTS
A dialogue-based system for the analysis of inventive problems

- Logical block Costs (CO): it investigates the reasons of incurring high costs.

**Introduced Variables and Parameters:**
1. the critical resources of Time causing high expenses
2. the critical resources of Space causing high expenses
3. the critical resources of Information causing high expenses
4. the critical resources of Material causing high expenses
5. the critical resources of Energy causing high expenses
A dialogue-based system for the analysis of inventive problems

- Logical block Process (PR): it investigates the criticalities of the manufacturing or delivering process.

**Introduced Variables and Parameters:**
1. the unsatisfactory aspects of production
2. the unsatisfactory aspects of business process
3. the characterization of such aspects
The dialogue-based algorithm have been preliminary tested on three case studies with students from:
- Politecnico di Milano
- University of Florence

**Metrics for results Evaluation**

**GOOD RESULT:**
- Precise description of the problem
- No particular mistakes or misinterpretation
- Definition of useful variables in order to perform a Patent Search by keywords

**SATISFACTORY RESULT:**
- Almost complete description of the problem
- Global comprehension of the problem
- Variable capable to suggest just preliminary directions for Patent Search by keywords

**UNSATISFACTORY RESULT:**
- Poor description of the problem
- Diffused misinterpretations
- Variable not capable to enlarge the space of solution by Patent Search
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**Case Studies**

A. Reducing energy waste from an anodizing tank, without creating obstacles to the process;
B. Extreme wear of the fringe curtain in a X-ray inspection system for food industry;
C. Complete transfer of oxygen from a large cylinder to several smaller ones, without any compressor.

Although each problem structure depends on the user interpretation, it is expected that people model

- Case A as a typical TRIZ contradiction or as a situation where a given performance is required;
- Case B clearly points to a negative effect, but should be preferentially modelled as a contradiction;
- Case C should address the problem solver towards the implementation of a new performance or the improvement of an existing one.
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Results

<table>
<thead>
<tr>
<th>Completion</th>
<th>Percentage of students [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Completed procedure</td>
<td>63.33%</td>
</tr>
<tr>
<td>Good descriptions of the problem situation</td>
<td>43.33%</td>
</tr>
<tr>
<td>Satisfactory descriptions of the problem situation</td>
<td>33.33%</td>
</tr>
<tr>
<td>Unsatisfactory descriptions of the problem situation</td>
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</tr>
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<td>Identification of the most relevant contradiction</td>
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Tests on industrial case studies

- The dialogue-based algorithm has been further tested on three case studies with companies that work in different industrial fields:
  - Loudspeakers production
    - Specific Problem: Manufacturing process for the production of acoustic membranes for loudspeakers
  - Arthroscopic device production
    - Specific problem: Design of an innovative arthroscopic device for human joints
  - Feet and legs prosthesis
    - Reduce weight of prosthesis components in order to increase user’s comfort during sport activities

- Preliminary results
  - Situation analysis clarifies main issues
  - Definition of at least one Contradiction according to TRIZ body of knowledge
  - Definition of the main characteristics of the desired solution

- Further Developments
  - Full validation activity once the Patent search has been fully implemented
Conclusions

- The dialogue-based algorithm shows positive results both with students and with technicians in industry.
- Such Dialogue-based system constitutes a systematic guide to enhance individual’s cognitive capabilities.
- The support to the problem solving process by means of external knowledge is under testing also through integration of customized field thesauri.
- A more extensive validation and improvement process has been planned (industrial cooperations are welcome).