Knowledge-Based Systems 35 (2012) 290–303

Contents lists available at SciVerse ScienceDirect

Knowledge-Based Systems

journal homepage: www.elsevier.com/locate/knosys

Analysis of the problem description in the Algorithm for Inventive Problem Solving using Petri nets

Victor R.L. Shen [a], Cheng-Ying Yang [b,*], Jia-Hong Lee [c]

[a] Department of Computer Science and Information Engineering, College of Electrical Engineering and Computer Science, National Taipei University, 151, University Rd., Sanhsia, New Taipei City 237, Taiwan

[b] Department of Computer Science, Taipei Municipal University of Education, 1, Ai-Kao W. Rd., Taipei 100, Taiwan

[c] Graduate Institute of Electrical Engineering, College of Electrical Engineering and Computer Science, National Taipei University, 151, University Rd., Sanhsia, New Taipei City 237, Taiwan

ARTICLE INFO

Article history:
Received 16 November 2011
Received in revised form 3 March 2012
Accepted 3 April 2012
Available online 17 April 2012

Keywords:
Petri net
TRIZ
ARIZ
Markov chains
EARIZ

ABSTRACT

The Theory of Inventive Problem Solving (TRIZ) has been widely employed in the fields of business and industry. The degree of difficulty in a problem usually depends on its description and degree of standardization. Using an appropriate description and maintaining standardization can minimize the scope of the problem and significantly increase the likelihood of resolving it successfully. Most problems can be resolved easily with innovative principles and standard resolutions. However, non-standard complex invention problems must be analyzed and resolved using the Algorithm for Inventive-Problem Solving (ARIZ), which contains numerous systematic tools of the TRIZ. This study applies the behavioral properties of a Petri net to the description of a problem to establish a problem model and perform scenario analysis. When describing the problem, the developer was provided with suitable directions of thinking or with wrong messages for reference. To create more specific effects on the varied problem models and scenario analyses of the TRIZ, this study combines the TRIZ with Petri nets and Markov chains to help new learners of TRIZ or professional researchers obtain appropriate resolutions rapidly.

1. Introduction

Millions of successful examples of the Theory of Inventive Problem Solving (TRIZ) appear in the fields of industry and business, and this theory performs perfectly in applications involving in various business, including Taiwan TRIZ Association, CMC MOTOR, M&M'S, and Samsung. Other industrial institutions are continuously introducing new findings of the TRIZ.

Systemic innovation helps many people resolve problems systemically and creatively, and further helps industries create new power. It is very helpful to individual knowledge growth and career planning [3,4,7]. When describing the problem, the developer was provided with suitable directions of thinking or with wrong messages for Refs. [8,14]. A company must obtain excellent experienced instructors and practical examples if it wants to help its employees apply and learn more on the TRIZ. Thus, expenditures on training human resources in a company cannot be ignored. Because patent protection involves many technological examples, it is often difficult to obtain the content of patents. Therefore, learning on the TRIZ is a difficult but important task. Computer assistance can reduce the cost of TRIZ training. Trainees can also establish a project by themselves and try to resolve innovative problems. Liu and his colleagues [18,19] indicated that a simplified measure combining TRIZ with green design was suitable for small businesses to promote the competitiveness of business and improve the environmental performance of a product. Previous research used engineering correspondence to seek innovative principles that are suitable for green design, helping engineers achieve product innovation rapidly [11].

The Theory of Inventive Problem Solving (TRIZ in its Russian abbreviation) was developed by a former Russian scientist, Dr. Genrich Altshuller, in 1950. As Dr. Altshuller stressed, if a developer can obtain the knowledge of resolution earlier, the process of invention will become easier. The purpose of the Algorithm for Inventive-Problem Solving (ARIZ), which is an important analysis tool for the TRIZ, is to resolve the problem of physical contradiction, and to simplify or eliminate systemic problems with complex scenarios. The ARIZ uses numerous TRIZ tools, including the mandatory inspection instruments of validity and applicability [24,26,27]. This characteristic is critical to the TRIZ because it emphasizes the meaning of a problem. The first step of the ARIZ process is to establish the smallest problem of the developed system that matches the points that the TRIZ emphasizes. Once the smallest practical problem is found, the systemic problems are

* Corresponding author. Tel.: +886 2 23113040x8921; fax: +886 2 23118508.
E-mail addresses: rlshen@mail.ntpu.edu.tw, victor.rlshen@msa.hinet.net (V.R.L. Shen), cyang@tmue.edu.tw (C.-Y. Yang), au346.t50@msa.hinet.net (J.-H. Lee).

0950-7051/$ - see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.knosys.2012.04.008

resolved using TRIZ tools. Therefore, understanding the initial description of a problem is critical to the TRIZ.

The key to the success of the ARIZ is to continue refining a problem until the physical contradictions contained in the systemic problem can be identified before understanding the nature of a problem. Standardization and problem description are the two key elements of efficiency evaluation [2,21]. Standardization can be achieved with TRIZ analysis instruments. However, problem description is more abstract and requires continuous re-explanation and problem definition. The first part of the algorithm, "Restructuring of the Original Problem," affects the success rate of resolving a problem. The efficiency of resolving problem contradiction is substantially improved if one explains the problem and defines the physical contradiction before describing the problem. In other words, one can use TRIZ instruments to refine the problem.

This study aims to apply the problem description of the ARIZ and uses the behavioral properties of a Petri net as a guide to obtain an appropriate resolution with Markov chain speculation and the superiority of parameter correspondence. The resulting algorithm can act as a systematic evaluator when a developer describes and defines a problem. The evaluator can communicate with the developer on the problem description and systematic demands through questions, answers, and suggestions. This study also helps trainees use basic or advanced analysis instruments and the knowledge database in the areas of teaching and learning, and strengthens their ability to resolve innovative problems. Using the proposed approach, a company can provide its employees with more teaching materials and more experience in the TRIZ.

The remainder of this paper is organized as follows. Section 2 discusses several important theories, and provides the definitions and principles used in the proposed approach. For more details, please refer to [2,15,20,21]. Section 3 presents the proposed approach and defines the systematic framework and guided content of a Petri net. Section 4 presents systematic models and test data. Finally, Section 5 provides concluding remarks.

2. Literature review

This Section presents the main characteristics and related definitions of a Petri net, TRIZ, ARIZ, and Markov chains of probability theory. Petri net theory explains the process of the ARIZ and problem description. For more details, please refer to [1,6,9,10,12,16,17,20–23,28].

2.1. Petri net

Petri net theory has been widely applied in industrial and commercial areas. A Petri net is a directed graph that consists of elements such as the place, the transition, and the directed arc used for connecting a place with a transition. A Petri net is similar to a flowchart, which has both parallel and concurrent modeling abilities, and is widely used in the fields of construction, analysis, and systematic modularization.

Definition 1. A Petri net is a 5-tuple, $PN = (P, T, F, W, M_0)$ where

(1) $P = \{p_1, p_2, \ldots, p_m\}$ is a finite set of places;
(2) $T = \{t_1, t_2, \ldots, t_m\}$ is a finite set of transitions;
(3) $F \subseteq (P \times T) \cup (T \times P)$ is a set of arcs (flow relation);
(4) $W: F \rightarrow \{1, 2, 3, \ldots\}$ is a weight function;
(5) $M_0 = \{M(p_1), M(p_2), \ldots, M(p_m)\}: P \rightarrow \{1, 2, 3, \ldots\}$ is the initial Marking, $M(p_i)$ is the number of tokens in place p_i;
(6) $P \cap T = \phi$ and $P \cup T \neq \phi$.

A Petri net structure $PN = (P, T, F, W)$ without any specific initial marking is denoted by PN. A Petri net with the given initial marking is denoted by (PN, M_0).

Suppose that there is a $1 \times n$ (where n denotes the number of movements) vector u_k, and its element in incidence matrix A is 1, whereas the others are 0s. If the movement of K in the trigger sequence is t_h, then the state equation is

$$M_d = M_0 + \sum_{k=1}^{d} u_k + A \quad (1)$$

Definition 2. A transition t is enabled in a marking M, denoted by $M[t\rangle$, M_d is reachable from M_0, $\forall M \in [M_0\rangle : M_d \in [M\rangle$

(1) Reachability: $M \in R(M_0)?M = A^T x + M_0$.
(2) Boundedness: $M(p) < \infty$, $\forall p \in P$, $\forall M \in R(M_0)$ (or safeness: 1-boundedness).
(3) Liveness: different levels of liveness, L0, 1, 2, 3, 4.
(4) Reversibility and Home State: $\forall M \in R(M_0)$, $M_0 \in R(M)$.
(5) Coverability: $\forall M_1 \in R(M_0)$, $M_1(p) \geqslant M(p)$, $\forall p \in P$.
(6) Persistence: any enabled transition can be disabled by its own firing.
(7) Synchronic distance: distance between two transitions t_1 and t_2, $d_{12} = \max\{\sigma(t_1) - \sigma(t_2)\}$.

After being modularized, a Petri net must be analyzed and examined to determine if the process conforms to its attribute(s). The following approaches are available to examine attributes such as the reachability trees for restriction, accessibility, and activity [13]; the simplified technologies for boundedness, accessibility, and activity; the state equations for accessibility [21]; and the correlational matrices for activity [25].

2.2. Theory of Inventive Problem Solving

TRIZ is an acronym for the Russian words "Teoriya Resheniya Izobretatelskikh Zadach," which means Theory of Inventive Problem Solving. Innovation theory and the TRIZ are widely used in the fields of engineering and technology.

Altshuller experimented on a l arge number of patents from 14 different classes published in Russia and analyzed the levels of their invention as listed in Table 1 [2]. Altshuller classified patents into five levels of invention. The percentages of the inventions in different levels are based on a study conducted by Altshuller in 1982. Most inventions are routine design solutions or improvements on existing systems. Few inventions (less than 1%) are truly novel scientific discoveries.

Although the TRIZ emphasizes that the obstacles of technology contradiction must be eliminated, the contradiction is always hidden in the problem description. Therefore, it is necessary to find an approach to eliminate contradictions. However, it is difficult to proceed from problem description to the answer. Resolutions must be gradually obtained using reasonable strategies. The ARIZ is an excellent approach to implement strategies. Different developers use the ARIZ to identify different resolutions to the same problem. The personal characteristics of a developer are ignored, which means that the ARIZ can take advantage of the nature and experience of a developer.

Fig. 1 shows the major elements of the TRIZ, which make it distinctive and powerful: contradictions, ideality, resources, and functionality. These four elements are often called the four pillars of the TRIZ.

(1) *Contradiction*: The strongest inventions are those in which the inventor has successfully removed contradictions. The most important philosophy of the TRIZ is to remove contradictions. The contradiction matrix is a popular TRIZ tool that eliminates any possible contradictions.