A TRIZ Tool for Engineering Education

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Abstract –
A TRIZ design tool is developed to enhance the quality of student design projects and to attract students' interest in the aerospace engineering program. TRIZ is the acronym for the phrase "Theory of Inventive Problem Solving" in Russian. The TRIZ design tool contains the contradiction matrix and inventive principles with extensive examples of aerospace innovations.

The TRIZ inventive principles are abstract in description in order to fit in a wide variety of disciplines. The vague description becomes an obstacle to understand these principles. The design tool developed contains many engineering examples to help students learn these principles and apply them effectively.

The tool is developed with Visual Basic to interface with the contradiction matrix stored in an Excel file. The matrix resolves contradictions of 39 parameters to selective inventive principles. Each inventive principle in the tool developed is on a web page containing text, pictures, and web links, with examples collected from literatures and internet resources. In addition, many case studies have been generated to walk through examples of using the matrix of contradiction and inventive principles.

Keywords: TRIZ, engineering design, capstone design projects, creativity, and aerospace engineering

TRIZ

TRIZ [1] is the acronym for the phrase "Theory of Inventive Problem Solving" in Russian. TRIZ research began with the hypothesis that there are universal principles of invention that are the basis for creative innovations that advance technology, and that if these principles could be identified and codified, they could be taught to people to make the process of invention more predictable.

TRIZ offers a wide range of tools and methods to help designers to solve problems in creative and powerful ways. Among the tools and concepts that TRIZ provides are: 40 inventive principles, the contradiction matrix, and separation principles. They provide an algorithmic approach to formulate, analyze, and solve complex engineering problems.

In traditional engineering thinking, if there is a conflict, it is common to accept a trade-off. TRIZ thinking leads to the analysis of the conflict and to a solution satisfying both conflicting requirements, an "out-of-box" approach. TRIZ solves technical conflicts (contradictions) by applying a set of 40 inventive principles. These principles can be used with or without the contradiction matrix. Rows of the matrix represent the 39 features that one typically wants to improve, such as speed, weight, force, stress or pressure and so on. Columns represent worsening features. Based on worsening and improving features, a cell is selected representing the pair of conflicting features, and each cell contains several inventive principles recommended to resolve the contradiction. Figure 1 shows a portion of the contradiction matrix with improving and worsening features and respective inventive principles.

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To illustrate the process of using the matrix and principles, one can use spoilers on sports cars are as an example. The issue to address is that at high speed, the airflow over the top of a car tends to create a low pressure area at the rear and thus the car is reducing traction and losing stability. In order to increase traction and therefore the downward force (improving feature #10 – force) of a car at high speed while not increase its weight (worsening feature #1 – weight of a moving object), one can use the contradiction matrix to select the inventive principle #8 counterweight (to compensate for the weight of an object, make it interact with the environment – e.g. use aerodynamic, hydrodynamic, buoyancy and other forces). The spoilers used in airplanes for descending are adopted here on cars to reduce lift and thus improve traction while not increasing the car's weight.

This example illustrates the problem solving process. It starts with mapping the problem from a specific scenario to a set of conflicting features (force and weight), and then it maps generic inventive principles to specific solutions (the counter weight principle yields the solution of spoilers.) Obviously, creating more examples will help users understand the mapping process and help them to work on their own problems.

TRIZ in Teaching Engineering Design

There is a definite need to provide students with helpful strategies and guidelines to solve design problems. The ultimate student design experience in an engineering curriculum is the senior capstone design course. Some of our senior capstone projects like SAE Mini Baja and SAE Aero Design are annual competitions, and designs are evolutional changes, as prior work is available and students can learn from mistakes made earlier. In other projects like ASME Student Design Competition and industrial sponsored projects, students often need to design from scratch. With the pressure of timeline to firm up their designs, students sometimes commit to their designs that are not well thought out, leading to arduous redesigns later on. As the design stage impacts the design projects significantly, a good design tool fostering innovation and creativities should enhance the quality of student designs.

TRIZ has been introduced in engineering education on many campuses. Rivin and Fey [2] introduced TRIZ methodology in the capstone design course and also developed an elective course on TRIZ at Wayne State University. Bzymek [3] of University of Connecticut also introduced TRIZ in his design courses. Raviv [4] developed a successful course to teach inventive problem solving methods including TRIZ at Florida Atlantic University.

These successful courses did not lead to widespread emulation, as they are difficult to duplicate in other campuses for two reasons: lack of appropriate software packages and textbooks. Until the recent emergence of the free software[5], commercial software packages [6,7] are too costly for academic adoption. Without the software, it is just too cumbersome to use the paper form to deal with the 39x39 matrix when each cell may contain up to five suggested inventive principles. In Kaplan's book [8] for example, the matrix is spread into six pages.

The number of books, journals and online resources on TRIZ is increasing. In particular, the online TRIZ Journal [9] provides a wealth of information. However, only a limited number of engineering examples is available. At least two design textbooks [10,11] contain sections on TRIZ, but engineering examples are still limited. The TRIZ design tool developed by this author is intended to be a supplementary courseware for engineering design courses to assist students in design.

TRIZ DESIGN TOOL

The free software - Interactive TRIZ matrix and 40 principles[5], as shown in Figure 2, is easy to use and it contains information comparable to a typical introductory TRIZ book. However, it lacks sufficient engineering examples and pictures for engineering students. In addition, the source code is not available to the public, and therefore it does not permit modification and expansion. The author of this paper therefore decided to develop a new software program, similar to this web software, with an objective to substantiate those inventive principles with engineering examples.

An Excel file is used to store the contradiction matrix, as shown in Figure 1, and Visual BASIC is used to write a program with a user interface to identify the desired inventive principles based on conflicting attributes. The html files of inventive principles can be used independent of the Visual BASIC program to browse the examples. Visual BASIC is chosen as the programming language for its graphic user interface, as shown in Figure 3, and ease of link to an Excel file.

The current version of the software distributed is an exe version of the Visual BASIC program. The next version will use Excel with VBA (Visual BASIC Application) to replace the Visual BASIC program. This way only one Excel file with multiple worksheets is needed, with one of the worksheet contains the contradiction matrix and the other worksheet contains 39 features. One Excel file will simplify the file download and usage.

Aerospace Engineering Program

The undergraduate Aerospace Engineering track in the Mechanical Engineering Program has been established for over a decade. Our students are heavily recruited from aerospace industry and government agencies, and the department has received numerous contracts and grants from NASA and industry. Major grants from NASA include NASA CAR (Center for Aerospace Research), NASA PAIR (Partnership Award for the Integration of Research into Mathematics, Science, Engineering and Technology Undergraduate Education), Mars Mission Research Center, and NIA (National Institute of Aerospace). Other funding agencies include FAA (Federal Aviation Administration) and The Air Force Research Laboratory. In addition to research funding, a new off-campus aerospace research facility is scheduled to open in spring 2007.

Despite the successful track records in aerospace research, it has been a struggle to increase the undergraduate enrollment in the aerospace engineering track. Our senior design project course has one group in SAE Aero Competition every year, and one elective course "Aircraft Performance" is very popular as it is taught by a professor who is an experienced pilot. Other than these two courses, aero courses like propulsion and aerodynamics have difficulties to get sufficient undergraduate students.

The TRIZ design tool is intended as a supplement for all design courses, from freshman to graduate level courses. In the initial phase, the inventive examples are selected from aerospace innovation, and hopefully these innovation examples will attract more students interested in this important field. This TRIZ design tool is one of our multi-prong efforts to strengthen this education program.

Aerospace Innovations to Highlight Inventive Principles

Examples of recent and historical aerospace innovation for TRIZ inventive principles are chosen from books, magazines, and websites. Selecting aerospace innovation examples is made easy as many articles are written to commemorate the centennial of flight in 2003. Resources used include U.S. Centennial of Flight Commission's website [12], The Beginner's Guide to Aeronautics from NASA [13], Popular Mechanics [14], ASME (American Society of Mechanical Engineers) Mechanical Engineering Magazine's "100 Years of Flight" supplement [15], and Invention & Technology by American Heritage of Invention & Technology [16].

Each innovation example used contains pictures and stories. For example, to illustrate the inventive principle #7 nesting (contain the object inside another which in turn is placed inside a third object), we can use slotted wings, as shown in Figure 5. Flaps are deployed to increase lift for takeoff, and the slats and flats are retracted and stored inside each other, maintaining the optimal airfoil shape for cruising.

Another example of aerospace innovation is using a wind tunnel to illustrate inventive principle #13 - the other way round (invert the action; make movable parts fixed and stationary parts mobile.) Collecting data is difficult during flight. Therefore, instead of moving the object through the air, tests could be performed by moving the air around the object. A wind tunnel is a chamber through which air is forced at controlled velocities in order to study the effects of aerodynamic flow around airfoils or other objects. When published aeronautical data turned out to be unreliable, the Wright brothers built their own wind tunnel to test airfoils and discovered that a long, narrow wing shape was ideal for flight.

The winglet, as shown in Figure 4, is another example of aerospace innovation. A large aircraft with long wings would make the aircraft too large for a standard airport gate. The conflicting features are improving feature #3 (length of moving object – lengths of wings) and worsening feature #5 (area of moving object, which affect lifting capability.) From the contradiction matrix, inventive principle #17 (another dimension) can be identified, and the winglet is the solution.

Principles of Separation

In addition to the contradiction matrix and inventive principles, another useful principle to solve conflicts is principles of separation: separation in space and separation in time. Separation in space is that a characteristic is present in one place and absent in another. An overpass in an intersection can be used to demonstrate this principle. Separation in time is that a characteristic is present at one time and absent at another. A traffic light at an intersection can be used to demonstrate this principle. We can also use the air traffic control to illustrate these two principles.

The air traffic control example of separation in space can be demonstrated that different planes (jets, regional jets, and single engine airplanes) are cruising at different altitudes to avoid collision when flying on the same route. The example of separation in space can be demonstrated as planes are controlled by air traffic controllers for taking off and landing on the same runway to avoid collision.

DISCUSSION

Design methodologies like TRIZ seem very abstract and difficult to understand. The creation of the TRIZ design tool with extensive aerospace innovation examples will bridge the gap between theory and practice and encourage more engineering students and practicing engineers to adopt the systematic and disciplined design approach.

The primary purpose of this TRIZ design tool is to enhance the quality of student design projects. As the design stage impacts the design projects significantly, a good design tool could help student designs by fostering innovation and creativities. The extensive aerospace innovation examples should help attract more students into our aerospace engineering track.

The TRIZ design tool is currently posted on the Blackboard [17] for internal (student) use. It will be placed on a dedicated website for external users once improvements are made based on users' input. More examples in other areas like automotive and consumer products can be generated in the future as class projects to broaden the collection of engineering innovation.

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	1: Weight of moving object	2: Weight of stationary	3: Length of moving object	4: Length of stationary	5: Area of moving object	6: Area of stationary
1: Weight of moving object	*	-	15 8 29 34	-	29 17 38 34	-
2: Weight of stationary	-	*	-	10 1 29 35	-	35 30 13 2
3: Length of moving object	8 15 29 34	-	*	-	15 17 4	-
4: Length of stationary	-	35 28 40 29	-	*	-	17 7 10 40

Figure 1 Contradiction Matrix

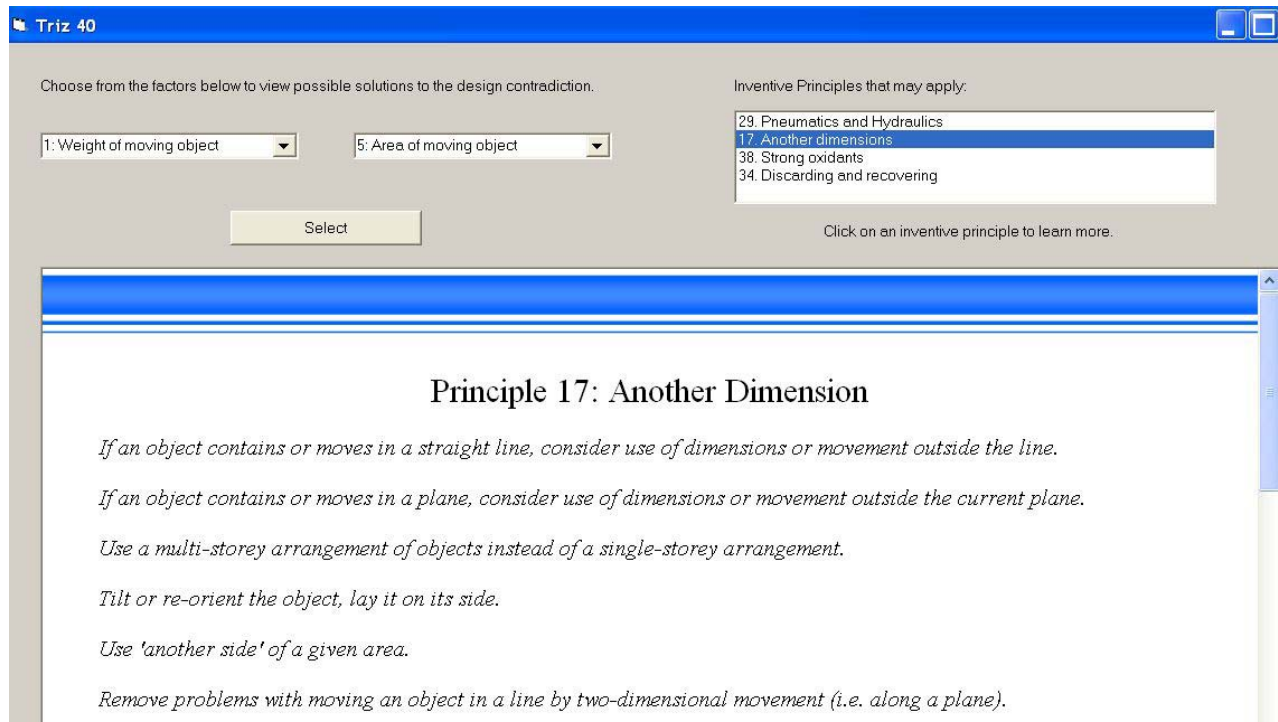Figure 2 Interactive TRIZ matrix and 40 principles

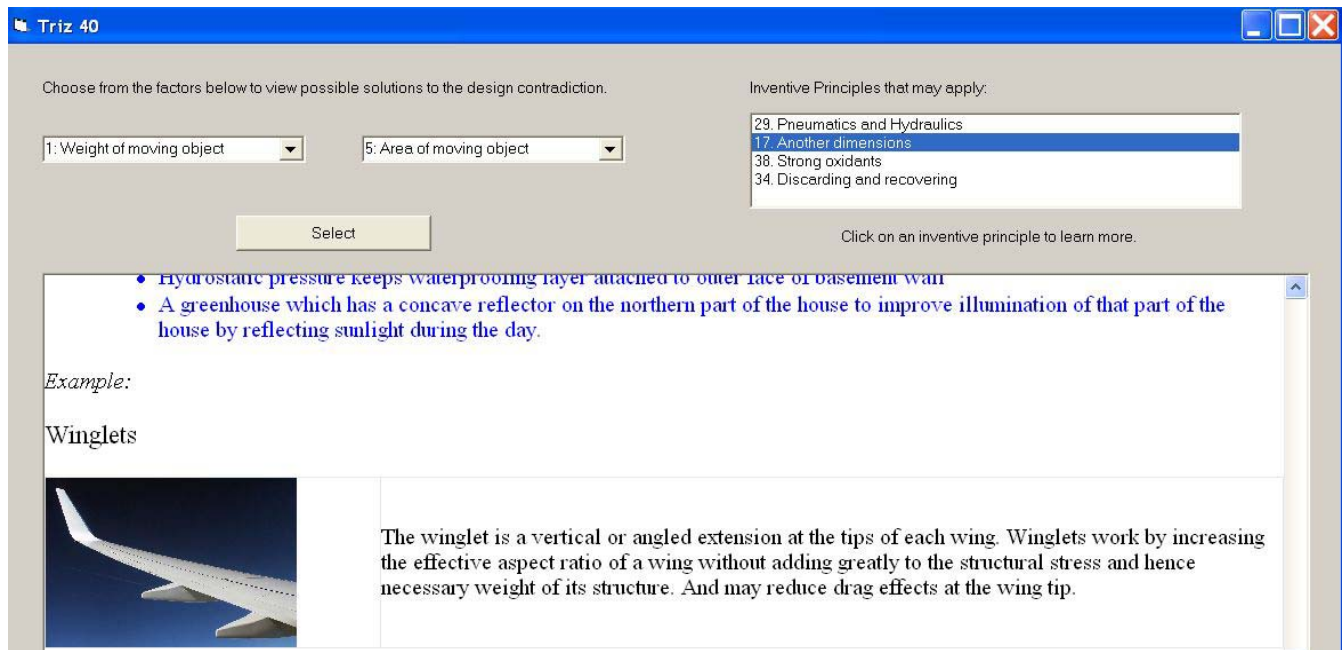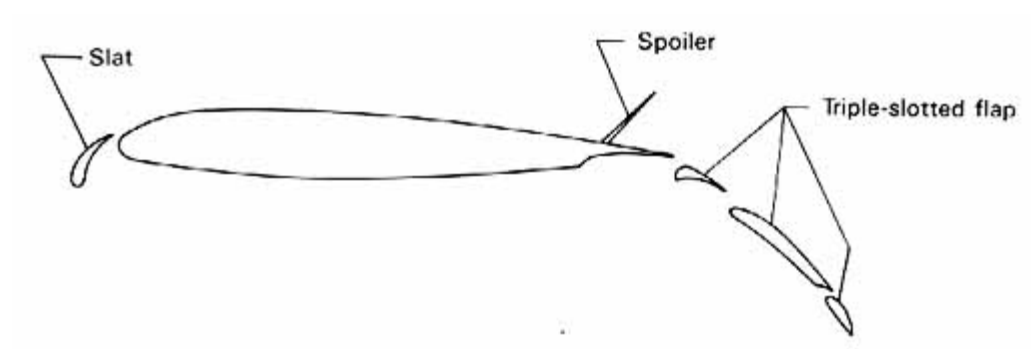Figure 3 Visual BASIC Program

Figure 4 Principle 17 – continued

Figure 5 Flaps – an example of inventive principle #7 nesting