Differences and Complementarities Between C-K and TRIZ

Sébastien Dubois(✉), Roland De Guio, and Hicham Chibane

CSIP, ICube Laboratory, Strasbourg, France
sebastien.dubois@insa-strasbourg.fr

Abstract. TRIZ and C-K are both presented as theories aiming to facilitate innovations. In recent years several authors have published articles enlightening differences between TRIZ and C-K. C-K was initially a descriptive theory of innovation, which has gradually been developed into methods with an operational focus.

To clarify if both TRIZ and C-K could be recognized as theories, a first question will be considered, what is a theory? Are then TRIZ and C-K design theories, and if so, is it possible to consider two different theories of a single subject? This article is a first step in a more global perspective aiming at clarifying what a design theory should be and how these two proposals give part of answers, and they could be complementary.

Keywords: Design theory · TRIZ · C-K

1 Introduction

Design methods have been widely proposed in literature, widely spread, and widely used in industries. One can cite, among the most famous ones, Axiomatic Design, Value Analysis, Quality Function Deployment, and so on… But a question remains about what is really designing, and can a theory of design be proposed? Speaking about theory is quite common in sciences such as mathematics, physics, … but as soon as we consider human-centered subjects, lot of divergences could appear. Is designing a human activity? If so, has it to be considered as a cognitive description of activities? Lot of approaches, even based on TRIZ, aim at automatizing the design process, thus making this question a question of algorithms, and computerization. In this article, the authors propose to consider the design as a human activity.

On the basis of this hypothesis, we consider on the one hand C-K as a design theory, and on the other hand, TRIZ as a theory of inventive problem solving which is often presented as a design theory… Are they really design theories, and if so, do they differ? Do they contradict each other? Or are they complementary? To answer these questions, this article proposes to first give a presentation of these two theories, and then to give a pattern to analyze the requirements a theory should satisfy. Then C-K and TRIZ will be described through this list of requirements. Finally, a comparison and conclusion for discussion will be proposed.

Published by Springer Nature Switzerland AG 2019
R. Benmoussa et al. (Eds.): TFC 2019, IFIP AICT 572, pp. 135–143, 2019.
https://doi.org/10.1007/978-3-030-32497-1_12

2 Materials and Method

2.1 C-K Theory

"The name "C-K theory" reflects the assumption that Design can be modelled as the interplay between two interdependent spaces with different structures and logics: the space of concepts (C) and the space of knowledge (K)." [1] This theory has been introduced in 2003 by Hatchuel and its main assumption is that designing, and in particular innovative design, is based on cognitive processes between true facts, true assumptions, that composed the space of Knowledge; and undecidable propositions, that composed the space of Concepts.

Moreover, these two spaces are defined as being expandable, the space K containing all established, true, propositions, whereas the space C contains "concepts" which are undecidable propositions in K (neither true nor false in K). These two spaces can also be partitioned, and two kind of partitions have been proposed [2]:

- Restrictive partitions add to a concept a usual property of the object being designed.
- Expansive partitions add to a concept novel and unprecedented properties

The expansion of the two spaces are enabled due to 4 operators [3]:

- K → C operator, which adds or subtracts properties from K to concepts in C, a way to create alternatives;
- C → K operator, which seeks for properties in K that could be added or subtracted to reach propositions with a logical status;
- C → C operator, which is at least the classical rules in set theory that control partition or inclusion;
- K → K operator, which is at least the classical rules of logic and propositional calculus that allow a knowledge space to have a self-expansion.

Thus, the design process could be represented as conjunctions and disjunctions between the two spaces as illustrated on Fig. 1.

2.2 TRIZ Theory

Another theory well known in design, and more specially in creative design is TRIZ. TRIZ has been developed by G. Alsthuller to help designers to be more creative and it has first been a set of tools, which were later organized in a method, before being defined as a theory [4]. The last step of method development, under Altshuller's supervision is ARIZ-85C. G. Altshuller concluded that ARIZ- 85C was a complete tool for solving inventive problems, and did not need to be improved further very much since its application had been tested on thousands of real problems and proven to be effective [5]. This version contains considerable generalizations of all the underlying elements of TRIZ and has been recognized as a Meta-Algorithm [6].

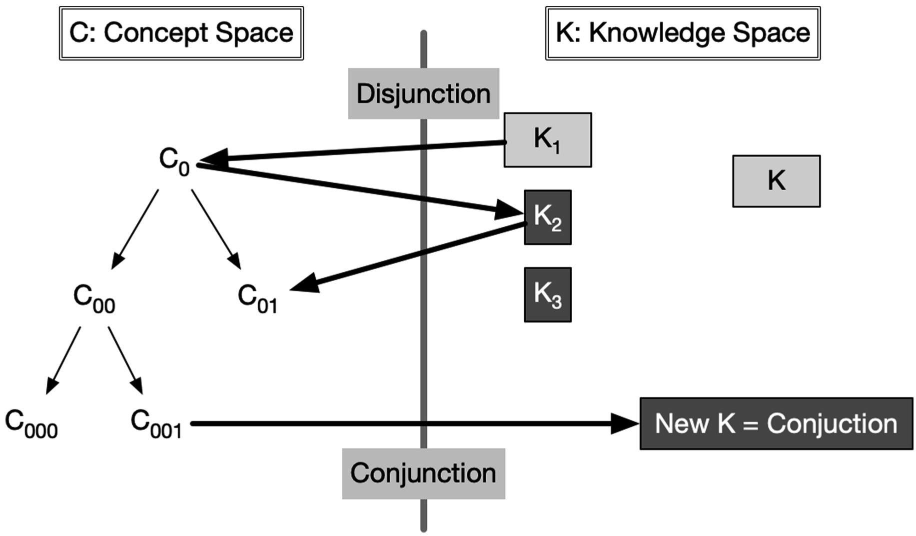

Fig. 1. C-K design process and its operators

Following the elements constituting the TRIZ theory, which are recognized as being the 3 main axioms on which any TRIZ based method has to be built:

- The laws of technical systems evolution: the evolution of a technical system is guided by a set if tendencies that are common to any system;
- Any problem has a hidden contradiction: to evolve a technical system has to overcome the contradictions related to its level of maturity and in accordance with its environment;
- Specific conditions: the way a technical system will solve the contradiction depends of the available resources, as formulated by the Ideal Final Result.

The elements have historically defined throughout the evolution of ARIZ and could be found in [7, 8]. Some authors recognize TRIZ as "the only constructive theory of invention and, based on its essence, of engineering creativity." [6] Moreover TRIZ is described as a theory providing models, rules, for thinking.

2.3 Method of Analysis

To analyze and compare TRIZ and C-K, the authors propose to first give a definition of what should be a theory, and then analyze C-K and TRIZ methods in regard of the definition. A theory should have a predictive and explicative role about the world, being thus a representation and inference tool [9]. Based on this working definition of what is a theory it is necessary to clarify the object of the world a theory should explain. Our general topic is inventive design, thus how can we define exactly what is inventive design?

In engineering domain, a creative product is often called an invention [10]. Both creative and inventive design problems are considered as requiring creative and inventive thinking in order to propose new, original, different and efficient solutions. Inventive design involves the creative thinking, and are considered as non-routine and ill-defined activities by Reitmann [11]. For Simon [12] to design is to solve ill-structured problems. Boden [13] suggests that achieving creativity is only possible by going beyond the bounds of a representation, and by finding a design that could not have been defined by that representation. If referring to a more engineering point of view, and according to Gero [14], creativity in design is concerned with the introduction of something new leading to a result that is unexpected.

In general, the cognitive scientists rely the creativity to three main concepts [15]: the creative person (defining a creative person as one who can tolerate ambiguity), creative product (defining a creative product as a new product qualitatively different from other products of the same type) and creative process (defining a creative process as a process involving integration of new knowledge in a problem model).

Then, if considering a theory about inventive design, this theory has to clarify the subject; is it the person, the product or the process? For Altshuller, TRIZ "is a system of many approaches and methods providing for a goal-oriented direction of the process of problem-solving based on knowledge of the laws of development of the objective reality" [7]. If considering one of the pioneer in design theorizing, Simon considered designing as a problem solving activity [16, 17]. One of the similarities for the two approaches of C-K and TRIZ is to be human-centered and not to aim at proposing an automatization of the process. It seems then interesting to consider designing, and so, problem solving, under a cognitive point of view. In [18], 4 general strategies: means-end analysis, subgoals, analogy, and diagrams are described that can be solicited during problem solving. Designing, as an open-ended and ill-structured problem [19], can then easily be regarded throughout the solicitations of these 4 strategies. Another key aspect is the co-construction of the problem and search space [18, 20], the problem defining the number of possible choices and paths that could be followed in searching for a solution (the search space), whereas the problem solver determines which of these he will explore (the problem space).

Considering these last points, problem solving and problem formulating could not be considered separately. Nevertheless, Novick pointed out that it is "important to distinguish, to the extent possible, how solvers represent the information in a problem from how they use that information to solve the problem" [21]. Novick also proposed that a good representation is one for which all of the important components of the problem are interconnected.

In conclusion of the elicited characteristics of design, and if aiming at proposing a design theory, we will confront both proposals, C-K and TRIZ throughout the following points:

- Object: what exactly do the proposed theory study?
- Problem/search space: do the proposals consider the construction of these two spaces, and do they make the link between them?
- Explicative: do the theory enable to explain how the design occurs?
- Predictive: do the theory propose means to foresee how solutions will appear and propose a formal model to make these predictions?
- 4 strategies, do the theories consider the 4 main strategies of problem solving?

3 Analysis of the Theories

3.1 Critical Analysis of C-K

Object of C-K

The C-K theory aims at describing how information are treated throughout the problem resolution process, characterizing information in regard of its and how to build partitions and make the information evolve by the use of the 4 operators. Thus the question of what does the C-K theory model and analyze and what it enables to study would rather find an answer in regard of the cognitive process. One can say that the C-K does not really consider the design process itself but rather the way the designer is thinking during the process. Indeed, the 4 operators do not describe the way information has to be processed to transform a problem into a solution, but they rather clarify how the information status (is it a concept? Is it a knowledge?) evolve during the resolution process.

Problem/Search Spaces and C-K

If considering that a problem is an objective which the designer does not know how to satisfy, one can easily recognize that a problem is such an information that cannot be considered neither true nor false, thus the Concept space could be referred as the problem space.

Is then the Knowledge space the search space? It is obvious that these two spaces are connected, as any satisfying and feasible (or not) solution found is both an element of the search space and of the K space (as the value of the element will be true if it is feasible, or false otherwise). But the search space is not necessarily composed of valued information, and the K space could be full of information not directly linked to problem. To conclude solutions concepts for which feasibility is known are common elements of both K space and search space, but these two spaces are not similar.

Is C-K Explicative?

Does the theory enable to understand how a design problem is solved? It, at least, enables to illustrate and follow the way ideas are generated and valuate the information in regard of their feasibility. Based on this, the C-K does not detail the mechanisms of change; but it could rather be defined as a macro model of cognitive processes to explain how the flow of information is processed during the design process.

Is C-K Predictive?

This question arises another one, what does it mean being predictive? In regard of what a theory should be, it should give the rules and a model to predict how a phenomenon will occur. As explained previously the object of C-K is more the cognitive process of the designer rather than the object of design, so, one can consider that C-K is predictive, as it specifies the mental operations the designer will have to follow to progress from a problem, a concept in C space, to a feasible solution, an information in K space.

Strategies of Problem Solving and C-K

Considering the strategies again in regard of C-K, the 4 operators do not consider how to progress from a given problem to a solution, but rather explains how the use of any of these strategies will impact the value of the information. It can be seen as a meta model modelling the way new information is built, this point is seen by C-K authors as helping in the exploration of new alternatives [3].

If considering the 4 main strategies, one can consider that both sub-goals and diagrams could be recognized as partitions in the Concept Space. But either means-ends analysis, or analogies could imply any of the 4 operators of the C-K theory. The operators will enable a description of the nature of the information generated by the strategies.

As described in [22], C-K theory proposes a model to evaluate creative design, it introduces metrics, it "offers a controllable model on the evaluation of creative design." This idea is reinforced in [23] by the terms of C-K theory offering an interpretative tool supporting critical discussion on design and creativity.

Critical Analysis of TRIZ

Object of TRIZ

The first aim of G. Altshuller was to start to develop tools to help engineers to be more creative [24]. Step by step, he understood that not only the tools were required, but also the good way to use them, and then the need of methods arose. The last method developed by Altshuller personally is ARIZ-85C [25]. This is the result of many versions throughout the years, which have been built and tested by hundreds of engineers on many problem resolutions [8]. TRIZ gives the axioms on which any method has to be built, if aiming at proposing robust concepts to solve technical systems problems.

Problem/Search Spaces and TRIZ

In TRIZ methods, in the different versions of ARIZ, two main processes are recognized, problem formulating, and problem solving. The formulation of problem is the identification of a goal, a specs, that have to be fulfilled, and also a set of constraints that have to be considered. The set of specs, of constraints, could be recognized as a list of Evaluation Parameters, on which Systems of Contradictions will be built, and this list of Evaluation Parameters (and their required value) and of Systems of Contradictions is the problem space.

Then the solution space could be recognized as the way one particular System of Contradictions will be chosen and how it will be treated throughout its resolution.

Is TRIZ Explicative?

Does TRIZ enable to understand how a design problem is solved? ARIZ-85C, for example, proposes a set of steps that have to be performed to step-by-step transform the mental representation of a problem till the formulation of a feasible concept of solution. It, thus, explains, the path followed from a given problem to a solution concept, based on a well-formulated System of Contradictions. For this, one can say that TRIZ plays an explicative role in design problem solving.

Is TRIZ Predictive?

Does TRIZ methods give the rules and a model to predict how a phenomenon will occur? The assumption of G. Altshuller is that any problem, to be solved, has to first be formulated in the shape of a contradiction. This is the predictive model of TRIZ. Solving a problem thus require to identify, formulate and solve the inherent contradiction. Does TRIZ give a set of rules? For sure, ARIZ-85C proposes the ways to well formulate and solve the problem, each step giving a pattern for respecting these rules.

Strategies of Problem Solving and TRIZ

Talking about TRIZ and about the 4 main strategies highlights immediately the question of analogies. It is obvious that the way the inventive principles, the methods of separation of physical contradictions, and also the 76 standards have been defined and are used is an illustration of analogies.

Does TRIZ use the 3 others strategies? One can recognize some aspects of means-ends analysis or sub-goal strategies in the methods used for the Analysis of Initial Situation, but these strategies here are more used to well choose a priori problem to be considered, rather than to search for solution. It seems thus that TRIZ consider mainly only one of the 4 strategies.

3.2 Comparison

The Table 1 summarizes all the previously described elements of C-K and TRIZ in regard of the required elements for a theory.

An analysis of one TRIZ-based method, ASIT [15], throughout the C-K paradigms has been proposed in [22]. It reveals how C-K theory enables to well capture "the activities of a creativity method" and also that the theory "says nothing about 'how' expansive partitions should be generated from K". This could be recognized as a limitation, but in fact it is quite consistent, as the object of the C-K is not the design process itself, but rather the cognitive processes and their impact on the information, during this design process.

Table 1. Table captions should be placed above the tables.

		C-K	TRIZ
Object		Design cognitive process	Design process
Problem space		The Concept Space could be recognized as the problem space	The problem space is built on the list of Evaluation Parameters and of Systems of Contradictions
Search space		The search space is a combination of both the Knowledge and the Concept Spaces	The search space is defined by one chosen System of Contradictions and how it is resolved
Explicative		It defines a macro model of the cognitive processes	As a meta-algorithm it gives the clue to explain the design process
Predictive		The 4 operators specify the kind of operation have to be performed during design process	The methods of TRIZ (ARIZ-85C) give a predictive description of the process
Strategies	Means-end	The 4 operators describe the results in regard of the quality of information but do not define the way to act on information	Partially performed by the Analysis of Initial Situation
	Subgoals		
	Analogy		Resolution tools
	Diagrams		Not used

With TRIZ, the object is the design process itself, it has the explicative and predictive aspects, but one interesting question is, could TRIZ methods take benefits of using the 4 generic operators for problem resolution?

4 Conclusion and Discussion

One of the main conclusions of this analysis and comparison of C-K and TRIZ is that both are non-conflicting theories as they do not focus on the same object. An interesting question is thus about their complementarity. Could each theory benefit of the other? Is it possible to propose cross-fertilization between both? It seems that the answer is yes, as TRIZ proposes, with the resolution tools, precise processes to act on information, and as, on the other side, C-K, gives a way to analyze the completeness of a design process in regard of the 4 proposed operators.

A future study will be performed to analyze, during a case study performed with TRIZ-based methods, how C-K elements give elements to describe more precisely and to give clues to be more complete, in regard of the way information are treated.

References

1. Hatchuel, A., Weil, B.: C-K design theory: an advanced formulation. Res. Eng. Des. **19**(4), 181–192 (2009)
2. Kazakçi, O.A.: A formalization of CK design theory based on Intuitionist Logic. In: Chakrabarti, A. (ed.) ICORD 2009, 2nd International Conference on Research into Design, Bangalore, India (2009)
3. Hatchuel, A., Le Masson, P., Weil, B.: C-K theory in practice: lessons from industrial applications. In: Marjanovic, D. (ed.) DESIGN 2004, the 8th International Design Conference, Dubrovnik, Croatia, pp. 245–258 (2004)
4. Souchkov, V.V.: A brief history of TRIZ. TRIZ J. (2015)
5. Madara, D.S.: Theory of inventive problem solving (TRIZ): his-story. IJISET-Int. J. Innov. Sci. Eng. Technol. **2**(7), 86–95 (2015)
6. Orloff, M.A.: Inventive Thinking Through TRIZ: A Practical Guide, 2nd edn. Springer, Heidelberg (2006)
7. Altshuller, G.S.: Creativity as an Exact Science. Gordon and Breach, New York (1988)
8. Altshuller, G.S.: The Innovation Algorithm: TRIZ, systematic innovation and technical creativity. Technical Innovation Center, Inc., Worcester (1999)
9. Vorms, M.: Qu'est-ce qu'une théorie scientifique? Philosophie des Sciences. Vuibert (2011)
10. Maimo, O.Z., Horowitz, R.: Sufficient Conditions for Inventive Solutions. IEEE Trans. Syst. Man Cybern. Part C Appl. Rev. **29**(3), 349–361 (1999)
11. Reitman, W.R.: Heuristic decision procedures, open constraints and the structure of Ill-defined problems. In: Shelly, M.W., Bryan, G.L. (eds.) Human Judgments and Optimality. Wiley, New York (1964)
12. Simon, H.A.: The structure of ill-structured problems. Artif. Intell. **4**, 181–201 (1973)
13. Boden, M.A.: What is creativity? In: Dimensions of Creativity, pp. 75–117. Massachussets Institute of Technology (1994)
14. Gero, J.S., Computers and creative design. In: T.F.A.o.A. SAFA (ed.) ArchComp 1995, Helsinki, Finland, pp. 1–13 (1995)

15. Horowitz, R.: Creative problem solving in engineering Design. Tel-Aviv University, Tel-Aviv (1999)
16. Newell, A., Simon, H.A.: Human Problem Solving. Prentice-Hall, Englewood Cliffs (1972)
17. Simon, H.A.: Problem forming, problem finding, and problem solving. In: 1st International Congress on Planning and Design Theory, Boston, USA (1987)
18. Reed, S.K.: Cognition. Theory and applications, 7th edn. Thompson/Wadsworth, Belmont (2007)
19. Bonnardel, N.: Towards understanding and supporting creativity in design: analogies in a constrained cognitive environment. Knowl. Based Syst. **13**, 505–513 (2000)
20. Rasovska, I., Dubois, S., De Guio, R.: Mechanisms of model change in optimization and inventive problem solving methods. In: International Conference on Engineering Design, ICED 2009, Stanford, CA, USA (2009)
21. Novick, L.R.: Representational transfer in problem solving. Psychol. Sci. **1**(2), 128–132 (1990)
22. Reich, Y., et al.: A theoretical analysis of creativity methods in engineering design: casting and improving ASIT within C-K theory. J. Eng. Des. **23**(1–3), 137–158 (2012)
23. Hatchuel, A., Le Masson, P., Weil, B.: Studying creative design: the contribution of C-K theory. In: Studying design creativity: Design Science, Computer Science, Cognitive Science and Neuroscience Approaches, Aix-en-Provence, France (2008)
24. Starovoytova, D.: Theory of inventive problem solving (TRIZ): his-story. IJISET Int. J. Innov. Sci. Eng. Technol. **2**(7), 86–95 (2015)
25. Altshuller, G.S.: Algorithm of Inventive Problem Solving (ARIZ-85C). OTSM-TRIZ Technologies Center, Minsk, Belarus, p. 32 (1985)