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CREATIVITY AND DESIGN REASONING: HOW C-K THEORY CAN ENHANCE CREATIVE DESIGN

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ABSTRACT
Confronted today to increasing demand for innovation, engineers consider creativity as an indispensable albeit weird technique. How to combine the engineering design requirements for robustness and value achievement with the creativity capacity to get unheard original and varied ideas? How to control a "creative design process" with the rigor praised by engineering design? Based on recent theory of design reasoning, C-K theory, this paper shows that value, robustness, variety and originality can be efficiently combined in a theoretically grounded, well-mastered process. It shows how to avoid two main creative design traps, pseudo-creativity and bounded creativity; and how to manage two different types of creative design, value achievement vs value exploration creativity. These processes are illustrated on one specific case, the design of a "smart shopping cart".

Keywords: creativity, innovative design, C-K theory

1 INTRODUCTION
"Why are my engineers so reluctant to use creativity techniques? Are creativity and design inherently contradictory or is it possible to combine them efficiently?" This question was asked by one of the leading chief engineers of a French global company. It was the starting point of this paper. The relationship of creativity and engineering design is actually paradoxical. On the one hand, (systematic) engineering design has been built on a strong hypothesis of "harnessing" inventiveness, of controlling, and optimizing. In particular it aims at "not relying on chance" [1]. On the other hand, more recent works in engineering design underline the necessity to rely on creativity techniques for certain design steps [see for instance the second edition of Pahl and Beitz reference book 2]. Describing engineering design processes, Kryssanov et al. mention that "in practice", designer's work in conceptual phase is based on creativity [3]. Moreover creativity can be today a criterion to evaluate engineering team performance [4]. *Hence creativity appears as an indispensable but weird technique for engineering design.*

This paper aims at showing that a model of design reasoning, C-K design theory [5], enables 1- to combine the design capacity to efficiently achieve value and the creativity capacity to get radically original ideas; 2- moreover this combination can be monitored and controlled with the rigor praised in engineering design.

We first describe the requirements for creative design and analyze the contradictions that can trap it in either low value or low originality. We show that the great challenge consists actually in expanding simultaneously value and originality. In a second part we show that the *C-K theory of design reasoning accounts for the features expected from creative design*. It provides a theoretical framework to ground evaluation criteria (variety, originality, value,…); in particular it describes what Boden called "radical originality". It helps to monitor the process (competence involvement, divergent and convergent thinking, learning,…), to analyze the main obstacles (pseudo creativity, bounded creativity), to manage two main archetypes of creativity, creativity for value achievement and creativity for value exploration.

Finally (part 3) we illustrate these points on the design of a smart shopping cart

2 REQUIREMENTS FOR CREATIVE DESIGN: FROM VALUE ACHIEVEMENT TO VALUE EXPLORATION

2.1 Obstacles in combining design and creativity

2.1.1 Expectations: enriching design by creativity?

Contemporary design processes aim at being both efficient and creative. Creative design strives for meeting four main criteria: value and robustness, which are the classical criteria of engineering design [1,6] but also originality and variety [4,7,8], to be more innovative and to overcome strong technical obstacles [9].

But historically these criteria were rather contradictory: engineering design does not aim at "ideation" but rather at controlling the wild emergence of ideas! In classical engineering, an "idea" or generally speaking a concept got value and robustness if it could *pass some evaluation tests* (to meet some stakeholder requirements to prove value or to meet some technical or legal constraints to prove robustness). This screening process is based on so-called convergent thinking and requires strong marketing or technical expertise [10].

Conversely, creativity aimed at being original by ignoring or questioning stabilized solutions and competences and is based on divergent thinking: the psychological approach of creativity [11] characterizes a creative reasoning by the type of questions to be answered and the type of expected answers. Whereas "intelligence" consists in giving *the* right answer to a "closed" question ("what is the sum of the angles of a triangle?"-convergent thinking), creativity consists in giving to an "open question" a set of answers that is as large and as original as possible ("what can be done with a one meter cotton thread?"-divergent thinking). The creativity tests (in particular the Torrance Test of Creative Thinking) [12] developed in the path opened by Guilford use four main criteria (fluency, flexibility, originality and elaboration), among which we find originality and variety. Boden has defined the originality criteria in an AI perspective [13]: a radically original idea is one which can not "be described and/or produced by the same set of generative rules as are other, familiar ideas" (p.40). In design, these generative rules can relate to technology or market competences. In creative design originality precisely leads to revise these competences on which engineering design was based.

Several creative processes have been proposed and could be use as a bse for creative design. They are all based on Wallas's model [14,15] (information, incubation, illumination, verification). They all come up against three main difficulties:

- What is the place of competences in creative processes? Creativity techniques require as little expertise as possible to be adapted to young students, whereas design is full of expertise and competences: should expertise be involved and accumulated or not? If yes: when? How to put aside "obvious knowledge" to avoid "routine ideas"? [see for instance the debate in the last design society conference, 16,17].
- How to combine convergent thinking (required by engineering design evaluation of Value and Robustness (VR)) and divergent thinking (to get Variety and Originality VO, expected from creativity)? Creativity experts have already noticed the issue and limits of introducing value-robustness criteria like: "workability", "acceptability" [18], "accuracy, meaning, sense, significance, interestingness" [19]. How to get originality and variety without losing in value and robustness? Or even: how to get originality and variety *in* value and robustness?
- Generally speaking, how to keep in creative design the process controllability obtained in engineering design?

2.1.2 Creativity and design reasoning: strong contradictions

These contradictions have been synthesized into two contrasted pathological processes [19]:

1- ***quasi or pseudo creativity*** [20]: consists in "blind rejection of what already exists" [19], eg systematically ignoring and/or negating some known truths. In this process, expertise and knowledge is systematically put aside. The "creative" designer, taught to ignore constraints, produces a lot of ideas, but with low value and low robustness (VO>>VR). Following Boden, one would say that he revises simultaneously all his generative rules (or, even forgets them). After such "pseudo-creativity" exercises, experts have the strange feeling *not* to have been very creative, finally just reinventing the good old stock stories.

2- To control this effect, several authors [21,22] proposed to complete the novelty generation phase by a novelty evaluation (or exploration) phase. But this could lead the pendulum too far in the other way, reducing drastically variety and originality (VR>>VO). Expertise was denied in pseudo-creativity; expertise (or following Boden: designers generative rules) might never be questioned in this second case. The process ***binds*** creativity, finally ending with known solutions.

The first case actually makes too little use of expertise and gets too little value; at the other extreme, the second case relies too much on existing expertise and gets to little originality. It seems that combining creativity advantages (originality-variety) and design (value-robustness) finally consists in *balancing conservation and revision of designers knowledge (or, in Boden's words: generative rules)*. But what does this "balancing" consist in?

2.2 Combining creativity and design in "value-robustness achievement"

Creativity and design have actually been successfully combined in specific situations like problem solving [9] or specific phases of systematic design [2,23]. In their laboratory studies, Shah et al. precisely combine creativity criteria (novelty, variety, quantity) and design criteria (quality, ie. performance on given value criteria like speed, cost, mass,…). In this exploration, creativity is not restricted to one specific problem solving but can occur at different steps of the design process, from "physical principles" to "detailed design", via working principle and embodiment.

In these cases, how do designers balance conservation and revision of their initial generative rules? Let's analyse one example of Shah and Vargas-Hernandez: students had to build "a device made from a fixed set of materials and powered by a fixed volume of pressurized air. "The device that travelled the farthest from the starting position would be the winner" (p.119). The originality criterion was evaluated on the technical solutions proposed by the students (jet propulsion, water travel, rolling, sliding, tumbling…). The performance (travel distance) criterion was not considered as something to be questioned by the students. This seems self-evident in the engineering design tradition. However Shah et al. underline that the winning solution, an air catapult, overtook largely all the other solutions (220ft whereas all other solutions were under 25ft): interestingly enough, this solution might be *original on the required performance*: instead of making the *whole* device travel the distance it might have just *sent a part* of the device to travel a much longer distance. But this is out of the scope of the originality measurement. Moreover one might even think that a classical evaluation criterion would have refused this solution, coming back to the above mentioned syndrome of bounded creativity.

This example helps to understand that in this combination between creativity and design, *creativity doesn't address value*. It finds original "solutions" to achieve the initially given value. These solutions can be strongly original but they should hack "technical" generative rules and not value.

Keeping a value reference out of the scope of creativity, this process *avoids pseudocreativity*. This process can also *avoid bounded creativity*: after the generating phase, the original ideas are not undermined by evaluation. Since they were all generated to get this value and to meet known constraints. This process works as long as it is possible to identify the generative rules to be hacked (not all generative rules are relevant) and the boundary conditions to be maintained.

To summarize: it is possible to combine creativity and design in what we call *"value-robustness achivement" design*. In this achievement process, value-robustness on the one hand, and originality on the other hand, are strongly *decoupled*, ie originality doesn't address the value generative rules and preserves robustness.

2.3 Combining creativity and design in "value exploration"?

This "achievement" design actually excludes two situations. 1- the robustness of the original idea can't be immediately established; this could happen when relying on a new physical principle to be substituted to well-known technologies (eg: use biotechnology to realize a nano-electronic chipset). 2- value also should be discussed in a creative way. This second case could appear a priori as a strange situation, since value is usually considered as the starting point of the design process. But creativity on value is today required in a lot of industrial situations. Let's mention some examples of a shift in value during a design process: in a Swedish leading mobile telecommunication service company, designers went from designing 3G mobile internet accesses to *remote control devices* [24]; in the Paris bus company, a design team working on bus stations for night designed a *mobile station*; working for the European Space Agency on a rocket engine for Mars missions, researchers finally proposed a *hopper* to travel on Mars surface [25], initially intended to launch low fuel consumption cars, Toyota hybrid

program finally succeeded in selling *"fun to drive" 4-wheel-Drive* [26,27]. In all these cases, new values emerged during exploration.
In this cases, the risk of pseudocreativity increases since there is no intrinsic value criteria to control it. The risk of bounded creativity also increases since the original ideas resulting from the "generating" phase won't be able to resist immediately to validation in the exploration phase.

We now summarize the main requirements concerning a "creative design" process:

1- Regarding performance, creative design has to reach mixed criteria, apparently contradictory: variety and originality seem to related to divergent thinking; robustness and value to convergent thinking. At best an "original", creative idea can *achieve* a *given* value and robustness but this idea doesn't in any way change the *nature* of value and robustness. Is it possible to model a stronger expansion in VO-VR?
2- Regarding process, balancing between VO and VR relates to the process capacity to balance reuse and revision of generative rules. How to target the generative rules to be revised in an "achievement" creative design? In case of a more intensive originality, how to construct new generative rules to cope with emerging value and robustness criteria? This might imply a learning phase that is hardly described.
   Moreover, design in itself requires this balance to be done in a *controlled* way. We can expect the creative design process to help to *control* the generative rules to be hacked, to control the originality creation; and finally to control the general increase in Value-Robustness and Variety-Originality based on knowledge creation.

Based on a recent theory of design reasoning (C-K design theory, C for concept, K for knowledge), this paper will answer these questions with the following propositions:
P1- C-K design theory can account for creative design inputs and outputs; in particular it helps to interpret the four criteria VO-VR.
P2- C-K design theory accounts for creative design processes and helps to describe their conditions.
P3- C-K design theory enables to avoid pathological syndromes and to steer creative design processes towards value achievement or towards value exploration.

3 HOW C-K DESIGN THEORY ENLIGHTENS CREATIVE DESIGN

3.1 Design reasoning approach

To study creative design, our approach consists in analyzing a design process model that would meet the above mentioned performance (VO *and* VR), being useful in both cases (value achievement and value exploration), and still being controllable.
Systematic design can require some creativity at one given level (conceptual design, or embodiment or detailed design). [9,23]. However, classical systematic design relies on a value *given* as the initial requirement. It seeks one single best solution meeting the initial requirements and would favor solutions *without* originality to limit risks and (costly) knowledge production. Hence it is adapted to value achievement (get a given value with creative still well-identified means) but not to value exploration, where value is revised and its revision requires knowledge production.
Axiomatic design [28] aims at decoupling DPs and FRs, without clarifying the process. Hence it account only for a few dimensions of creative design. Braha and Reich approach [29] is based on known ontologies, which is inherently contradictory with Boden' originality criteria [30].
C-K design theory [5,31] claims to account for innovative design situations, ie situations where objects have no fixed identity. This might be a good candidate to discuss the link between originality and value in a design process. This led us to put C-K theory on test. We first present the theory and we analyse how C-K accounts for creativity.

3.2 C-K design theory

3.2.1 The two spaces C and K.

C-K theory has been introduced by Hatchuel and Weil [5]. The name "C-K theory" mirrors the assumption that Design can be modelled as the interplay between *two interdependent spaces* having different structures and logics: the space of concepts (C) and the space of knowledge (K). The structures of these two spaces determine the core propositions of C-K theory.

Space K contains all established (true) propositions (the available knowledge). Space C contains "concepts" which are *undecidable* propositions in K (neither true nor false in K) about some *partially unknown* objects x. Concepts are all of the forms: "There *exists some object x, for which a group of properties P1, P2, Pk hold in K*".). Any design project intends to transform such undecidable proposition into a true proposition of K. Concepts define *unusual sets* of objects called C-sets: they are sets of partly unknown objects *which existence is not warranted in* K. During the design process C and K are jointly expanded through the action of *design operators*.

3.2.2. The design process and the C-K operators.

According to C-K theory design proceeds by a step by step partitioning of C-sets using propositions in K. Beginning with C0, the partitioning operation is repeated whenever there is a partitioning proposition in K and until some partitioned "C-set" becomes a "K-set" i.e. a set of objects which existence is warranted by a true proposition in K. Therefore, the following propositions hold:

- Space C takes necessarily a tree structure which describes the expansion of C0 (see fig 1).

- The expansion of C, the activation of new partitioning propositions, and the validation of a design path are the main operations of Design. They correspond to four types of operators: C-C, C-K, K-K, and K-C. The combination of these four operators is a unique feature of Design.

3.2.3. C-K power: expanding and restricting partitions.

C-K theory allows describing two types of partitions. If the partition expands the definition of an object with a new property, it is called an expanding partition. Conversely, if the partition relies on an existing definition of the object, it is called a restricting partition (speaking of "a house with a red roof" is a restricting partition if "houses with red roofs" are already known in K). The expanding partitions are the instrument of design. C-K theory tells us that if there is no expanding partition, there is no design process or a design process that is limited to the classification (tree structuring) of existing objects.

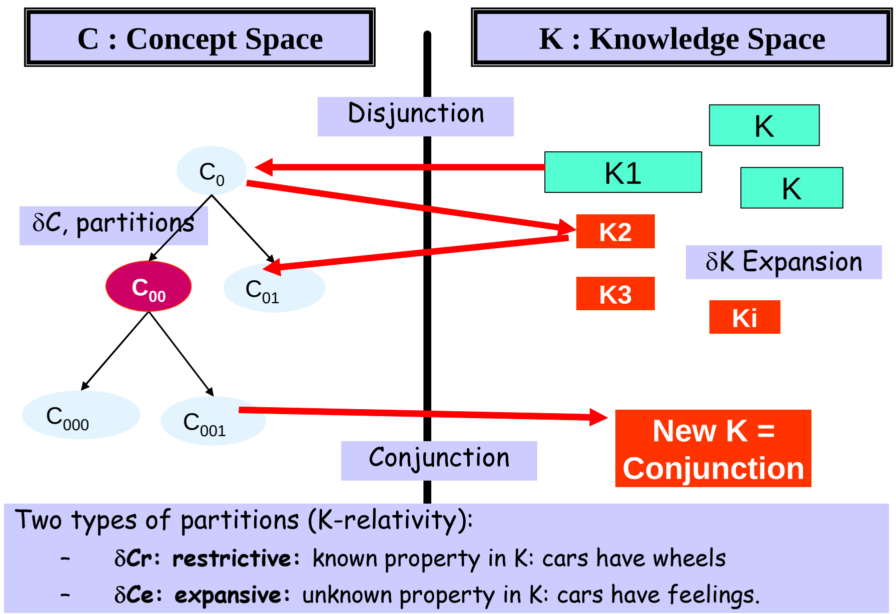

Figure 1. C-K design process and its operators.

3.3 Interpretation of creative design in C-K

Does C-K theory account for creative design?

3.3.1 Creative design criteria: variety-originality, value robustness (proposition P1)

We first compare the inputs and outputs in a creativity process and in a C-K design process.

Regarding **the inputs**, we can consider that each "creativity" question is a concept: it can be a "problem" or a classical engineering design brief. Generally speaking the archetypal creativity question like "what can you do with one meter of cotton thread" or "improve a baby doll" can be reformulated like "design uses for one meter cotton thread" or "design a baby doll providing more value than the existing one". What about the K space? As seen before, creativity can require more or less knowledge, and this knowledge can be introduced at different steps in the process. The C-K framework records these evolutions in K-space.

As for **the outputs**, a creative design process described in C-K will result in a concept tree and expanded knowledge bases. **Variety** refers to the different types of ideas created in the process. In C-K an "idea" is a concept. We can count as "individual" varied ideas all the terminal branches in the C-tree. We could also count all the intermediary steps, or weight them depending on their height in the tree. Shah and Vargas-Hernandez measured variety in this way, the tree levels being given by the classical systematic design categories: physical principles, working principle, embodiment…

Originality is based on the "hacking" of so-called generative rules [13]. The issue is to identify those generative principles. They can be limited to a finite list of "usual" ideas, like in the Torrance Test of Creativity [12]. Shah and Vargas-Hernandez exemplified two ways to define such a list: either ex post (by asking experts providing a list of usual ideas) or ex ante (by analyzing a statistical distribution of the ideas, the most cited ideas being considered as non-original). C-K theory allows being more precise and more general on what is originality: a new idea being a partitioned concept, the piece(s) of knowledge on which the partition(s) is (are) based is (are) the only possible source of originality. If these pieces are generative rules that are usually applied to the objects "caught" by C, then it is not an original idea. Otherwise it is. Hence we can say that *an original idea is the result of an expanding partition*. Note that the partition is expanding *related to the generative rules in K.*

In systematic design, **Value** is given by classical "functional requirements". In C-K, value is not necessarily given at the beginning of the process but can be acquired by a concept along the process. A value V is modelled in K by propositions like "there is a stakeholder S who gives the value V to the property Pv" (eg there are some shopping cart users who put value on shopping cart container volume"); a concept C = {x/ P1…Pnx} gets the value Pv if (i) there is S such that S puts value on Pv and (ii) if C is true then Pv is true for C (formally: if $\exists$ xP(x) then Pv(x); it does *not* mean that C becomes true). Value appears has an *intermediary test* of C. **Robustness** works in the same way: a concept acquires robustness when it passes successfully some "killer criteria" test existing in K.

3.3.2 Creative design process: analysing Wallas process, pseudocreativity and bounded creativity (proposition P2)

We can now describe the **classical Wallas' process** [15] in the C-K framework: the first phase, information, consists in acquiring knowledge more or less related to the initial question (C→K); the second phase, incubation, consists in reworking, re-modelling knowledge in contact with the question: we can represent it as a modelling process in K to identify the "generative rules", to try them on the concept and see whether it can provide interesting concepts without expanding partition (K→K, K→C→K). The third phase, illumination, is an expanding partition, using some knowledge gathered before but not considered as an element of the above mentioned generative rules (K→C). The fourth phase, verification, consists in testing the expanded concept towards some criteria in the knowledge base (C→K).

Let's come now to the **pseudo-creativity** process. According to Cropley, pseudocreativity is based on nonconformity, lack of discipline, blind rejection of what already exists or simply "letting oneself go" [19]. Hence pseudocreativity actually "dries" K (blind rejection) or add to K new propositions that are not necessarily consistent with the existing ones (lack of discipline, nonconformity). Then pseudocreativity consists in a random association process of "non-conform" propositions. We can analyse the consequences of pseudocreativity in C-K: 1- "rejection" might destroy value-robustness propositions in K, preventing evaluation. 2- this random process is very unlikely to produce a sequence x/P1…Pn(x) that would hold for the remaining value-robustness propositions in K.

This explains that pseudocreativity will systematically produce a large variety of concepts, but with poor value and robustness. Strangely enough, originality in pseudocreativity is not self evident, since the usual generative rules might have been rejected out of K: ideas are considered as original by comparison with a dried knowledge base. If compared with restored expert knowledge, ideas might no longer appear original. This accounts for the empirical facts noticed earlier: pseudocreativity produces a large number of ideas, with low value and low robustness; ideas are seemingly original but could be considered as non-original by experts. In C-K, we are led to conclude that knowledge for validation should be kept in the knowledge base. This is precisely what happens in bounded creativity.

Bounded creativity consists in one generating phase and one validation phase. In the first phase, expanding partitions occur on C = {x/ P1…Pn(x)}. For instance (see figure 2 below), one notices in K a usual property of the existing x, Q(x). The concept is partitioned between C with Q (ie, using the generative rule) and C with non-Q (hacking the generative rule). This last proposition is an expanding partition. In a second phase, validation occurs. In that process, the resulting "ideas" are confronted to a lot of validations. Suppose that Q is related to value Pv,(ie there S who gives value to Pv and Q implies Pv) then the validation process will apply Q as a validation criteria ("if Q then Pv"). Consequently {x/P1…Pn.Q} acquires V; but the expert can't conclude on {x/P1…Pn.non-Q}: this concept is not validated. Hence this description accounts for the empirical assessment that bounded creativity creates original ideas but will hardly keep these ideas after the "validation" phase. It maintains Value and Robustness but doesn't increase originality and variety (if Δ is the difference between the end and the beginning of the creative design process, we can write: ΔValue=V_Q; ΔOriginality=0).

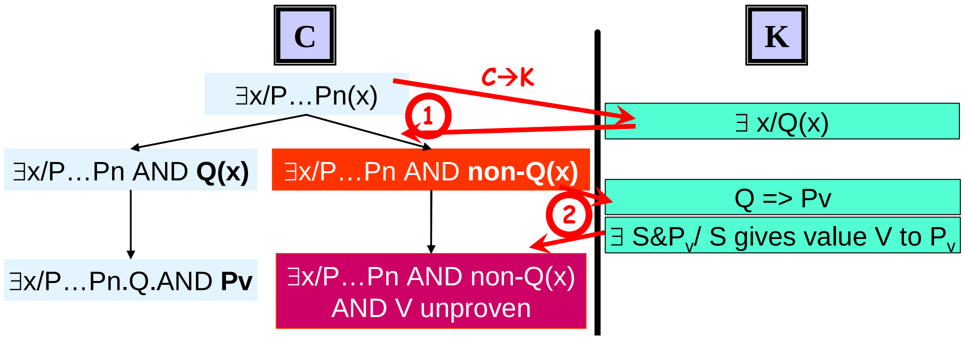

Figure 2. Bounded creativity $\Delta V=V_Q$; $\Delta O=0$ (1 = generating phase ; 2= validation phase)
To read C-K chart: knowledge creation in K is written in white on dark background

However, formulated in C-K, the two phase process sounds quite nonsensical: a hacked generative rule is used for validation, which causes the rejection of the original idea. C-K teaches us two ways to avoid it, by working on the two aspects of the definition of value validation:

- either Pv (related to Q) is known in K ("Q implies Pv and there is S who gives price to Pv") and the issue is to make C "achieve" Pv by adding Q or non-Q. (see condition (ii))
- or, some value (related to Q or non Q) is actually unknown in K (see condition (i)) and the issue is to investigate *what* is the value enabled by non-Q. It should hence include a learning phase on value opened by the hacking of Q. (the same reasoning holds for robustness)

These two cases, corresponding to value achievement and value exploration, are now investigated.

3.3.3 Combining creativity and design process: value achievement and value exploration (P3)

Until now we hardly described processes combining creativity and design, ie increasing both value-robustness *and* variety-originality. We will now analyse the first type combination: value achievement.

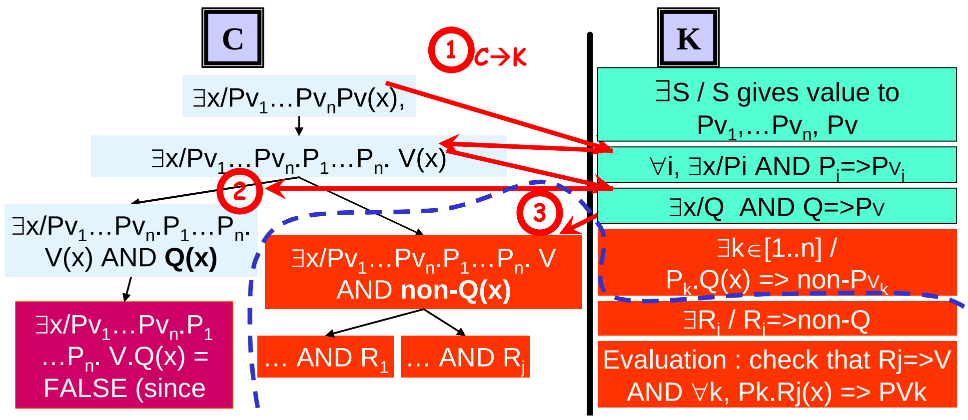

Figure 3. Achievement creativity: ΔV=preserves the value potential; ΔO=non-Q
(1 = value evaluation; 2= trial with generative rule; 3= expanding partition.)

The initial concept "contains" the value (see figure 3). A x-related and Pv-related generative rule (Q) is used and generates a "usual idea". Suppose that this idea is un-satisfycing: for instance there exists k such that Q invalidates Pv_k. Then the creativity process *begins*, "hacking" the generative rule (figure 3, #3) and exploring alternatives (Rj) with strict boundary conditions: Rj is non-Q, gets the value Pv, without invalidating any Pv_k. This process achieves value while being original.
C-K helps us to identify the main conditions for a successful "value achievement" creative design:

1-There is a preparatory phase before creativity: the identification of the contradiction between Q and Pvk. This step is decisive and didn't exist in bounded creativity.

2-value is achieved in the process but it is not created in it (Value=unchanged). There is a first step to "target" the relevant generative rules (Q, related to Pv). This phase is clarified by C-K and was not present in pseudo-creativity and bounded creativity, both beginning with the hacking phase.

3-there is a "true" creativity, revising generative rules (O increases). The condition of the revision is however that *value is not impacted in the process* (Pv holds for Q and some non-Q).

Value exploration precisely aims at keeping a rigorous creative design process while overtaking the above mentioned conditioned:

1-The generative rules to be reused are not given but require knowledge expansion. Here can *emerge generative rules related to emerging value* ($\exists$x/Q(x) and Q(x) => Pv_Q(x))

2-Value is not necessarily known at the beginning but can be *discovered* during the process (Rj discovers Pv_R whereas it achieved a known Pv in value achievement)

3-Corollary, the "originality" (possibly) impacts value (Pv does not necessarily holds for non-Q)

We represent this pattern in figure 4 below. In this configuration, we get $\Delta V=V_Q + V_R$; ΔO=non-Q, hence *combining originality and value exploration*.

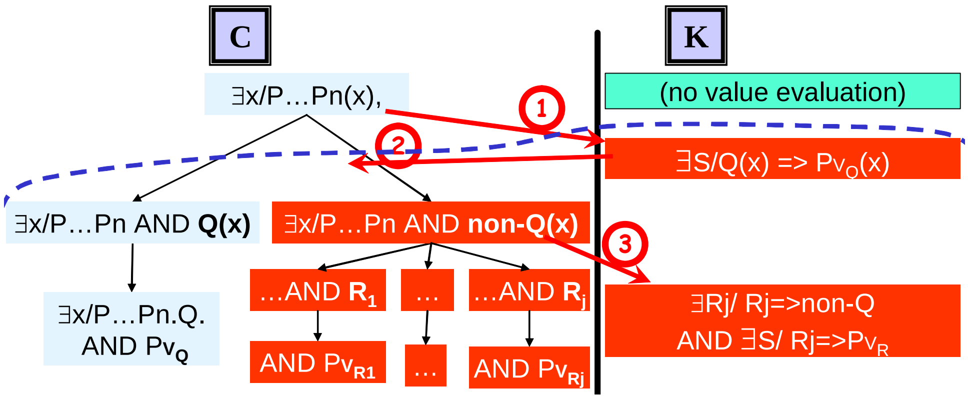

Figure 4. value exploration creativity $\Delta V=V_Q + V_R$; ΔO=non-Q
(1= knowledge creation on value for x; 2= restricting and expanding partition based Q; 3= knowledge creation on value for Pk.non-Q)

The process *avoids bounded creativity* since the expanded concept can explore new values (see last phase on knowledge production on Pk.non-Q leading to Rj). The process also *avoids pseudocreativity* by expanding K rigorously (instead of "drying" it) to introduce new value. We find here a theoretical ground to the classical brainstorming motto: "build on the ideas of the others".

To conclude: 1- C-K formalism accounts for a "creative design" process, combining performance of design (value-robustness) and performance of creativity (variety-originality). It helps to ground fuzzy notions like "ideas" or originality. 2- It enables to control creative design process: in C-K it becomes possible to avoid the two extreme situations pseudocreativity and bounded creativity and to choose between "achievement" creativity and value-generation creativity. 3- It helps to *target generative rules to be hacked* in achievement creativity and *to orient learning on new value generative rules* in value exploration creativity.

4 ILLUSTRATION: DESIGNING A SMART SHOPPING CART

We will now illustrate these results on a design exercise given to to several groups of people (engineering students, industrial design students, researchers, executives). People were told to design a "smart shopping cart", based on C-K theory. They could work 2 hours with a free Internet access. The material provided by the experiences can illustrate each typical process of creative design: pseudocreativity, bounded creativity, achievement creativity and value-generation creativity.

4.1 Extreme cases: pseudo-creativity and bounded creativity

We first check that "smart shopping cart" is a concept: it is interpretable in K ("shopping cart" and "smart" have a meaning in K); the designers considered that the shopping cart they knew were not smart and they could not say whether a smart shopping cart is possible or not. Hence it is undecidable (related to their K-base).

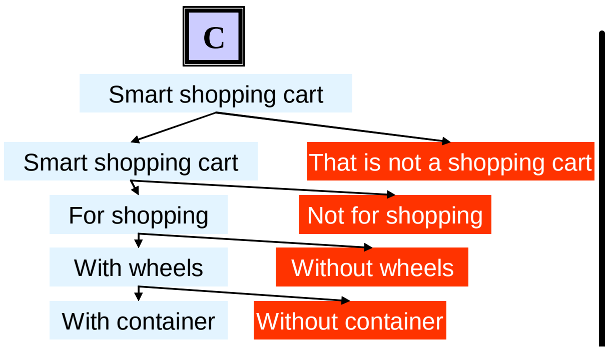

Figure 5. pseudocreativity $\Delta V=0$; ΔO=high

Pseudo-creativity consists in systematically hacking knowledge, like in figure 5. The revision of a lot of properties of the shopping cart increases originality. But value is not discussed at all.
This reasoning can be completed by a novelty-exploring phase. Figure 6 illustrates the specific case of evaluating the alternative with container / without container. The resulting proposition ("a smart shopping cart with a container of type k") preserves the value inherent to having a container. No value can be added to the "without container" alternative. This alternative doesn't succeed in the test "acquire $V_{container}$". Finally this process slightly increases the value (preserves $V_{container}$) but binds originality.

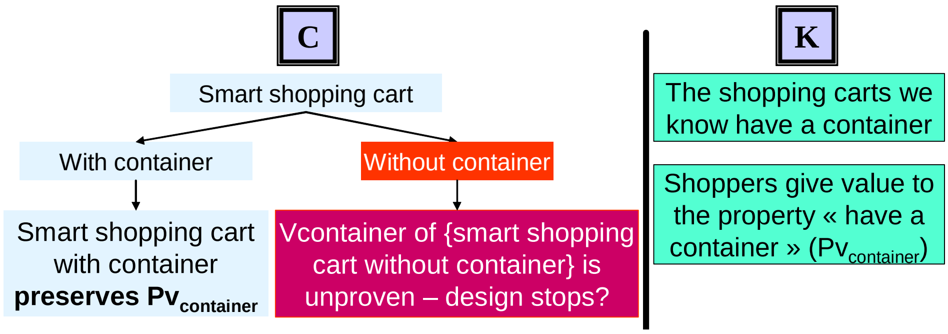

Figure 6. Bounded creativity ΔV=preserves $V_{container}$; $\Delta O=0$

4.2 Value-achievement creativity

A more balanced process consists in preserving value while being original. This is close to a systematic design process. A "functional" phase clarifies value initially: mobile, help to pick up, to transport, safe, robust, in a supermarket, for the user… Smart is interpreted as communicating. Then generative rules on communicating are activated, to build a number of alternative ways for the shopping cart to communicate with the shopper (communication = display + information). However when tested on price and reliability, few of them succeed. This learning provokes the hacking of the communication generative rules: a communication system without display (eg. no display provided by the supermarket but a display is provided by the shopper himself, using his own PDA…).
In this case, originality exists. But it doesn't apply to the value (which is preserved in the process). A counterexample would be: the communication system that increases the value for the supermarket (and not for the shopper), by enhancing cart management, department management or even by

providing new business opportunities to the supermarket (advertising space). Here originality applies not only to the communication systems but also to the functions and the value. In a classical systematic design process, these alternatives would be rejected.

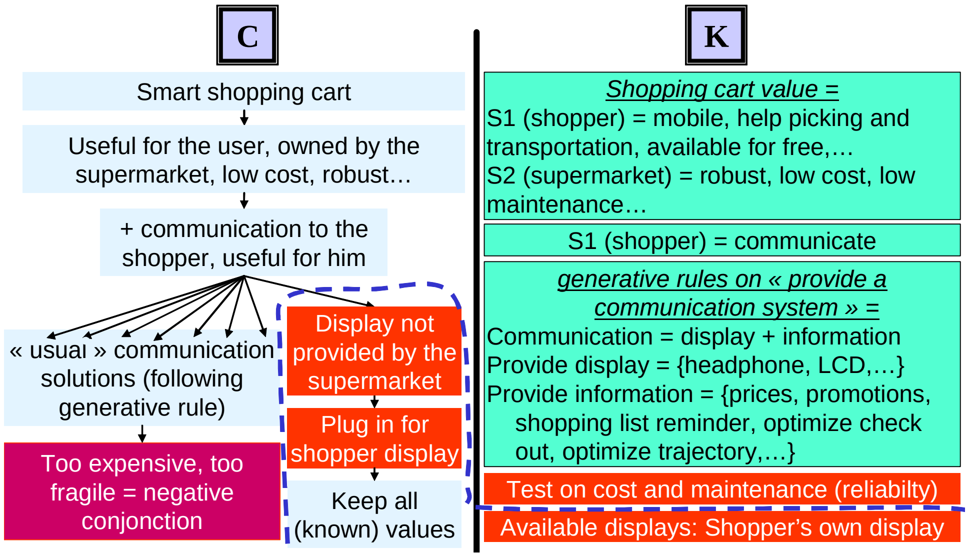

Figure 7. value-achievement creativity ΔV=preserves V potential on prices, reliability, communication; ΔO=revise "communication" generative rules

4.3 Value-generation creativity

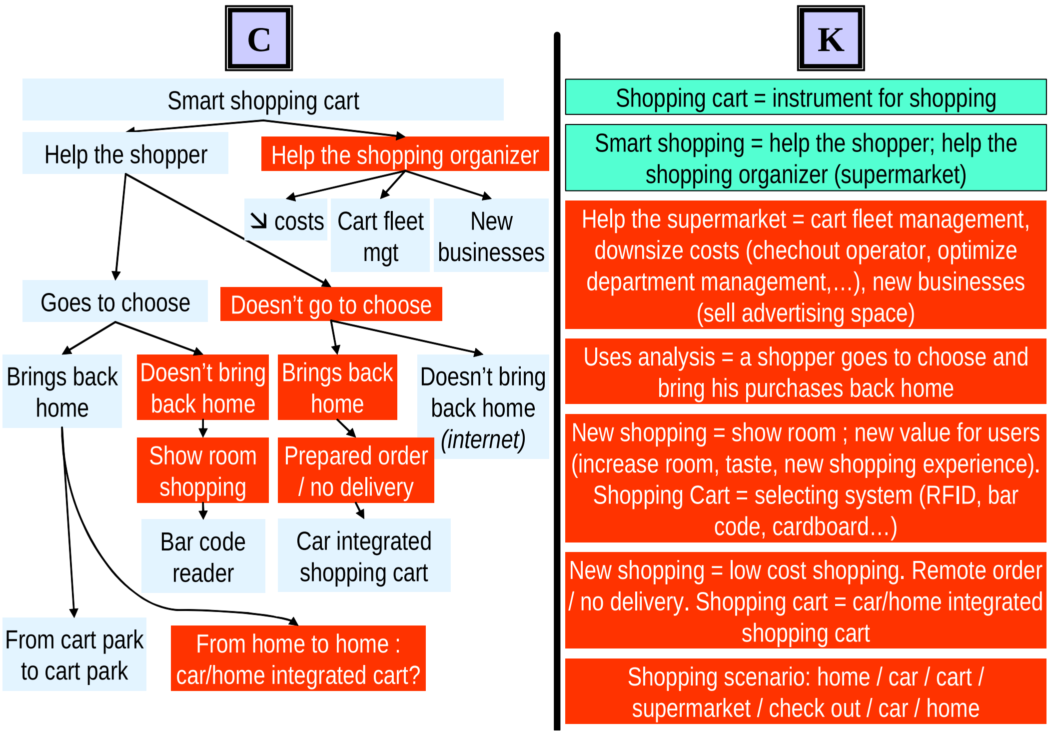

Figure 8. value-generation creativity ΔV=4 expanding partitions (value for supermarket; new shopping concepts; car/home integrated shopping cart); ΔO=revise value for whom; revise first definition (go to choose and bring back) and second definition (from cart park to cart park). Importance of learning.

The last illustration precisely addresses this kind of creativity, where originality is applied to value. The reasoning described in figure 8 unfolds as follows: C→K: states basic propositions on shopping cart and smart shopping. This provides a partition on who could be interested in smart shopping cart: shopper / supermarket (K→C). Regarding "smart for the supermarket", knowledge on supermarket help to identify several users and user needs (C→K, K→K and K→C). Regarding "smart for the

shopper", a usage analysis (K→K) provides a shopping scenario ("user goes to choose and bring his purchases back home") that can be hacked at two levels: "doesn't go to choose" and "doesn't bring back home". Resulting partitions (K→C) point in particular on "virtual shopping cart", eg the internet shopping cart. Two partitions are expanding. In bounded creativity these partitions would be considered as negative conjunction. In C-K theory, they lead back to K to ask "what is a shopping where shopper goes, looks and buys without bringing purchases back home?" In the knowledge base, some students found the show room. They hence worked further on the "show room shopping cart".
In this process, originality *and* value are both and simultaneously enhanced. This happens thanks to one striking element: regular learning on heterogeneous competences.

5 CONCLUSION: TOWARDS NEW CREATIVE DESIGN PROCESSES

In this paper we show that 1- creativity and design are not intrinsically incompatible when using the C-K theory of design reasoning. 2- design reasoning guided by the C-K framework can simultaneously increase variety, originality, value and robustness and it can do that in a rigorous, controllable way. 3- This C-K design reasoning enables to avoid the creative design traps like pseudocreativity or bounded creativity; it helps to orient creative design in two different ways, value achievement or value exploration. It provides monitoring capacity in both cases, based on the clarification of the relationship to knowledge and knowledge expansion (identify the relevant knowledge to be hacked in value achievement creativity; organize heterogeneous learning to revise and rebuild value generative rules in value exploration creativity).
The theoretical approach adopted in this paper paves the way to new organizational processes and new techniques adapted to creative design. We can identify a three step loop:

1- Establish an enriched knowledge base with clear generative rules for the main objects caught in the concept.
2- Target the generative rule to be revised: either by *first* fixing the value and then trying to realise it in a creative way (value achievement), *or* by hacking already identified value-related generative rules.
3- In value exploration: (re)build generative rules related to the new partitions emerging from the hacking process.

These organizational processes will be studied in coming experiments.

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