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Object replacement and object composition in a creative cognitive system. Towards a computational solver of the Alternative Uses Test

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Abstract

In creative problem solving, humans perform object replacement and object composition to improvise tools in order to carry out tasks in everyday situations. In this paper, an approach to perform Object Replacement and Object Composition (*OROC*) inside a Creative Cognitive framework (*CreaCogs*) is proposed. Multi-feature correspondence is used to define similarity between objects in an everyday object domain. This enables the cognitive system *OROC* to perform creative replacement of objects and creative object composition. The generative properties of *OROC* are analysed and proof-of-concept experiments with *OROC* are reported. An evaluation of the results is carried out by human judges and compared to human performance in the Alternative Uses Test.

Keywords: Cognitive systems; Computational creativity; Creative object replacement; Creative object composition; Alternative uses test

1. Introduction

Imagine the following scenario. You are in a kitchen, you are really thirsty and want to drink some water. You have located the sink, however, they are no cups in sight on any kitchen surface, nor in the cupboards. You could, of course, drink directly from the water source, if your head can reach there. Or you could use your *cupped* hand to make your own little container. Now imagine you had to carry some water in a different part of the building, to bring it to your desk and store it next to you. And indeed, despite not seeing any cups or glasses, you have seen some ceramic bowls. You realize on the spot you could use those, despite it being socially uncouth. In fact, if your mind is in a higher creative state, you might not even need to *see* the bowls to realize you could use them as a cup replacement. Your friend may indeed find you searching deep in your desk drawers to find a DVD spindle case you remembered you own, which you *mentally realized* you could use if there was no bowl around. If your friend is very conservative, he might think you are searching in the wrong place (a place which couldn't contain a cup) for the wrong tool (a tool that is not a cup) to get the job done. Yet this atypical behaviour would prove to your advantage: your atypical solution will get the job done, enabling you to carry and store water. Your friend might indeed exclaim, seeing you use the DVD spindle case to drink from, half annoyed by your uncouthness and half amused by your resourcefulness: "what are you, a cat?". And indeed, the DVD spindle case would largely look more like a bowl, which is something we give our cats water in, than a cup.

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This level of resourcefulness indicates a general ability to creatively use objects in problem solving, which most people would deem intelligent. Humans are tool creators and tool wielders par excellence. Tool use and creativity are not restricted to the human domain (Bailey, McDaniel, & Thomas, 2007; Kaufman & Kaufman, 2004). However, humans are all expert object users, since they have acquired through experience many rules about what tools or objects should be used, where and when.

Generally, solving a problem involves goal oriented behaviour – knowing what you are searching for (i.e. a cup) and where you could find it (i.e. kitchen surfaces, cupboards, dishwasher, etc.). Knowing that you need a cup and that this cup can be in specific places may narrow your search. Yet, if this type of problem-solving fails to find a solution, creative problem-solving kicks into gear. Creative problem-solving sometimes involves ambiguity of goal, for example: (a) you do not know exactly what your are searching for, nor where to find it or (b) you might know the problem you need to solve, but not how it looks solved. Thus, such creative search is not fully constrained (but neither is it optimized) by goal clarity.

In many cases, creative problem solving involves looking at something we already know in a different way. Or an exercise of *seeing as* (Olteţeanu, 2015) – that is seeing a previously known object as something else. In the practical case, this is seeing a DVD spindle case as a cup or a bowl or seeing a thumbtacks box as a candle support (Duncker, 1945). In the abstract case, it can be seeing a molecular structure as an Ouroboros snake.[1] In both cases, this is called re-representation (Batchelder & Alexander, 2012). Yet, if we would re-represent all the objects and concepts we know all the time, the boundaries of our reality would be slim and fuzzy indeed. The streamlined processing we do when having specialized tools would be gone. Everything could potentially be considered to be anything else, and computational explosion would ensue in our processing. As we know, creativity is possible without such an explosion, therefore we need to wonder about the mechanisms that make it possible.

In the following, an approach is presented for enabling a cognitive computational system to solve similar tasks as the one presented above by creative object replacement and object composition (*CreaCogs-OROC*) using matching and correspondence between multiple features and object structure.

In this paper, object replacement, composition and decomposition are discussed in an everyday object domain. In this domain, the aims of the *CreaCogs-OROC* system are to organize and to process knowledge in a cognitively-inspired way which enables it to perform the following creative tasks:

i. Replace an unfound object needed for a task with other objects present in the environment. Let us consider tasks of the form: *If I do not have an object X, which I would normally use because of its affordance* Af_X*, what other object Y could I use, so that I can get a similar affordance,* $Af_X \approx Af_Y$*?*
ii. Compose objects. Let us consider tasks of the form: *If I do not have object X with affordance* Af_X*, which objects* $Y_1, Y_2, \ldots, Y_n$ *could I use to construct X or an object X′ with an equivalent or similar affordance,* $Af_X \approx Af_{X'}$*,* $Af_X \approx Af_{Y_1} + Af_{Y_2} + \cdots + Af_{Y_n}$*?*
iii. Decompose objects. Let us consider tasks of the form: *If I do not have object X with affordance* Af_X*, which objects* $Y_1, Y_2, \ldots, Y_n$ *which are components of object Y could I use to obtain an object* Y'_i *with an equivalent or similar affordance,* $Af_X \approx Af_{Y'_i}$*?*

The knowledge organization and processes of *CreaCogs-OROC* permit creative object replacement, object composition and decomposition. The properties of such knowledge organization are described in this paper, and the resulting creative object uses are compared to human creative responses in a similar domain.

The rest of this paper is organized as follows. First, related work regarding computational and human creativity, the use of structure in knowledge representation and re-representation is introduced in Section 2. The Creative Cognitive Solving (*CreaCogs*) framework is described in Section 3, together with the challenges of an everyday object domain and the approach to object replacement and object composition (*OROC*). Knowledge retrieval in *OROC* and the types of feature similarity used for creative inference are presented in Section 4. The experiments with *OROC* in object replacement and object composition are presented as a proof-of-concept in Section 5. An evaluation of *OROC* is presented in Section 6, using as methodology a test for evaluating human creativity – the Alternative Uses test. The *OROC* results and evaluation are discussed in Section 7. Finally, conclusions and future work are provided in Section 8.

2. Related work

The computational creativity field has grown in recent years, gaining its own conferences, associations and journals. It has also yielded systems that perform creative feats in various domains: mathematics (Colton, Bundy, & Walsh, 2000; Lenat, 1976), music (Pachet, 2012; Smith & Garnett, 2012), art (Cohen, 1995; Colton, 2012), poetry (Colton, Goodwin, & Veale, 2012), architecture and design (Schneider, Fischer, & König, 2011), discovery of physical laws (Langley, 1981), magic trick making (Williams & McOwan, 2014) and video games (Cook & Colton, 2014).

Other work has shed theoretical insights into the nature of human creativity (Boden, 2003; Fauconnier & Turner, 1998; Guilford, 1956; Koestler, 1964) and proposed evaluation

[1] Kekulé recounted a day-dream of an Ouroboros-like snake biting its tail or a tibetan knot before discovering the structure of benzene.