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Artifact "Metaphors": Gaining Capability Using "Wrong" Tools

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***Abstract*—In everyday life as well as in the asymmetric warfare domain, to achieve the intended goals, agents often don't exploit the designed and purpose-built tools but some other tools whose features simply fit for the purpose. Starting from the well established ideas carried out to build ontologies of functional concepts of artifacts, we propose to extend such ontologies with explicit recordings of physical features. A mechanism of similarity mapping between ontology classes, using feature-based similarity measures, will drive the research and retrieval of artifacts which are possible substitute for the proper tool.**

I. Introduction

Hostile *intent*, *capability* and *opportunity* are known to be the three components analysts should look for in detecting potential threats [1]. Given the huge amount of uncertain information to look into, formulating credible hypotheses about potential threats has become even more difficult or impossible in the case of asymmetric warfare where the means for carrying out an hostile plan are often of unconventional type, thus defying all knowledge available from military doctrines. While intents could be hypothesized based on current intelligence information, capability and opportunity might assume the aspect of normal patterns of life as in the case of recent terrorists attacks (where significant disruption was obtained through non-weapon objects possessing explosive characteristics such as fuel tanks). Since opportunity could be guessed once intent and capability are known, we turn here our attention to determining alternative solutions for assessing capability.

The urgent need for developing automated tools for intelligence analysis [2] should also push the development of alternative ways for encoding and exploiting knowledge in order to facilitate inexact and similarity-based matchings of hypothesized patterns in the knowledge-base. In particular, we propose to extend such ontologies with explicit recordings of physical features in order to capture the intrinsic characteristics that can match function-oriented queries. A mechanism of similarity mapping between ontology classes, using feature-based similarity measures, is discussed to drive the research and retrieval of artifacts which are possible substitute for the proper tool matching the sought after capability. Fusion methods and techniques, exploiting contextual data and informations, properly suit for such problems which also often involve soft data issues [3].

Our proposal starts from the analysis of the behaviour and of the ontological status of artifacs.

Let's consider the following situation, the so called "candle problem", a cognitive performance test, presented by Gestalt psychologist Karl Duncker in his thesis on problem-solving tasks, published posthumous in 1945 by the American Psychological Association. Test subjects are given the materials shown in Fig. 1a (a candle, a box of thumbtacks, and a box of matches on a table), and asked to fix the candle to the wall so that, once lit, it will not drip wax onto the table below.

The test challenges functional fixedness, a cognitive bias, which predicts that the participants will only see the box as a device to hold the thumbtacks and generally will not consider it as a functional component independent from the perceived context and therefore available to be used in solving the task. The solution consists in emptying the box of thumbtacks, putting the candle into the box, using the thumbtacks to nail the box (with the candle in it) to the wall, and lighting the candle with the match as in Fig. 1b.

As previously said, the test was created to assess problem-solving skills and the so called "lateral thinking", but we will not deal with its main evaluation purpose, rather we will focus on the mechanism of selection of the functional component, which we define "metaphorical".

II. Metahpors

The word "metaphor" derives from the greek word *metaphora*, whose meaning is "transfer" (from *metà* - "over" and *pherein* - "to carry"). A simple definition of the word can be found in Wordnet 3.0, one among the many other possible different definitions influenced by different theoretical backgrounds:

(1) [Metaphor is] a figure of speech in which an expression is used to refer to something that it does not literally denote in order to suggest a similarity.

George Lakoff and Mark Johnson in their 1980 study *Metaphors We Live By* [4] developed a novel view of metaphor, the Cognitive one, which coherently and systematically challenged all the aspects of the traditional theories, that only took under consideration the artistic and rhetorical functions, aimed at communicating eloquently, at impressing others with "beautiful", aesthetically pleasing words, or at expressing some deep emotion.

Lakoff and Johnson's claim was that metaphor is a property of concepts, and not of words, whose function is highlighting

(a) Given materials

(b) Solution

Fig. 1: Duncker's candle problem

certain concepts. Ordinary people usually take advantage of metaphors in everyday language and not just for aesthetic purposes and is an inevitable process of human thought and reasoning, essential in science as in everyday life, as thoroughly analysed in [5].

A linguistic metaphor consists of two elements. The first element is the "something" about which something else is said, the second one is the "something else" used to convey concepts pertaining to the first element. The two terms which are now commonly used to denote them are "target" and "source".

Target and source are part of a complex network of related meanings conveyed by words. For example, in the sentence

(2) THEORIES are BUILDINGS [4, p. 46]

"theories" is the target and "buildings" the source.

"Theories" is part of a conceptual network including, for example, "theorists", "construct (argument)", "foundation", "support", etc. but it can be infinitely extended. The source, "buildings", is part of a network of concepts as well. It includes "construction", "foundation", "ground", "demolition", "framework", "architecture", etc.

A structural relationship between elements found in a set of concepts (the source domain) and the corresponding elements in the other set of concepts (the target domain) must exist to enable the mapping from source to target (see Fig. 2), but also the context in which a metaphor appears must provide the interpreter with the details about which features are to be mapped. Usually only a few features or characteristics of a source are mappable and which features are to be mapped depends on many circumstances, namely on context.

Metaphors can also provide views of a given target domain creating links with an unexpected source domain, or by mapping unusual features from a familiar source domain to the target. This happens when the chosen source domain marks a similar latent structure in the target domain. This is what

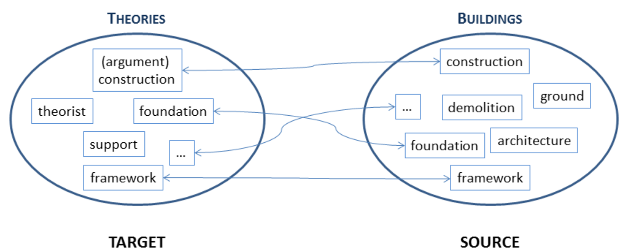

Fig. 2: Structure mapping in metaphor.

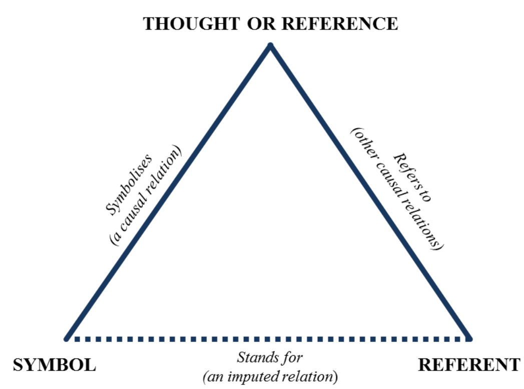

Fig. 3: Meaning triangle.

very interestingly happens in the use of metaphor in scientific theory-making.

Lakoff and Johnson, followed by other researchers, shifted the metaphor mechanism from the symbolic level (textual/linguistic) to the conceptual level. As we can see schematically represented in Fig. 3 (Ogden and Richard's *Meaning triangle* [6], used in several contexts, with different variations or terms at the nodes), *Symbols*, *Thoughts* (concepts), and *Referents* (objects) are related and interconnected. This is the reason why we will talk about "artifact metaphors", shifting the mechanism to the object level.

III. Artifacts

Dictionaries usually define an "artifact" as a simple object made by human art and workmanship, an artificial product (distinguished from a natural object) following the sense of the Latin words from which it derives *arte*, ablative of *ars* ("art, skill"), and *factum*, the past participle of *facere* ("to make").

The distinction between natural objects and artifacts dates back to the Greek philosophy. Aristotle divided existing things into those that "exist by nature" and those existing "from other causes." The former include "animals and their parts, [...] and the plants", while the latter include "a bed and a coat and anything of that sort, [...] in so far as they are products of art." [7, Book II, 192] The art of making something involves, and sometimes implies, intentional agency; thus an artifact may be defined as an object that has been intentionally produced for some purpose. It is worth noticing that not only humans but also animals show capacity to produce artifacts [8].

A. Artifact Ontologies

Human living environments have been populated by every kind of artifact since around 12,000 years ago and the technological evolution with its recurring revolutions, above all the three industrial revolutions, led to a massive increase in the complexity and diversification of the designed and built artifacts.

Together with complexity and purpose specialization the question arises on how to categorize them and how to incorporate them in ontologies, from the ones that deal with specific consumer products to the general ontologies for technical components and materials, and diverse answers can be foud in literature [9]–[11].

Researchers from three different domains, namely applied ontology, engineering design, and philosophy of technology, have been working on the problem with different perspectives and came to different definitions of "artifact", each one capturing and stressing diverse aspects of artifact's nature. We introduce here the three definitions, as reported in [12] and [13] by the researchers who are currently working on the creation of a common perspective.

D1. **(Ontological Artifact)** *A technical artifact $\mathcal{A}$ is a physical object which an agent (or group of agents) creates by two, possibly concurrent, intentional acts: the selection of a material entity (as the only constituent of $\mathcal{A}$) and the attribution to $\mathcal{A}$ of a technical quality or capacity.*

D2. **(Engineering Artifact)** *A technical artifact $\mathcal{A}$ is a physical object created by an intentionally performed production process. The process is intentionally performed by one or more agents with the goal of producing the object $\mathcal{A}$ which is expected to realize intended behavior in some given generic technical situation.*

D3. **(Technological Artifact)** *A technical artifact $\mathcal{A}$ is a physical object created by the carrying out by an agent (or by agents) of a make plan for an object with a physical description $\mathcal{D}$.*

According to definition **D1.** an artifact does not need to be the outcome of a production process and the same definition does not describe any creation event. The class of artifacts identified by definition **D1.** includes therefore all the produced artifacts as well as other artifacts obtained by intentionally collecting "natural objects". An artifact arises when the agent (the *artifex*) selects some material entity and attributes it some quality. For example in the process of selection of a pebble and the creation of a paperweight. The artifact is constituted by the selected material entity (the pebble) but is itself a new entity, with a new distinct property, namely the attributed capacity to perform as a paperweight.

Definition **D2.** stresses the concept of "intentionality": an agent intentionally performs a process which results in the production of objects $\mathcal{A}$ via physical changes. The goal consists in the realization of the specific desired behavior (the *essential function*) by the produced object. The same definition entails also that an object $\mathcal{A}$ is an artifact even if it does not have the capacity to realize the behavior intended by the agent at the beginning of the production process, both in the case that the resulting artifact $\mathcal{A}$ shows malfunctions and in case that the same gets used differently from how the creator intended it.

Definition **D3.** focuses on the concept of "make plan". A make plan for a physical object $\mathcal{A}$ can be defined as a use plan for a set of materials m_1, m_2,... and a set of tools t_1, t_2,... with the aim of creating an object that meets the predetermined physical description $\mathcal{D}$. The plan accomplishment coincides with the artifact production.

From the presented definitions follows that engineering artifacts (D2) belong to a subclass of technological artifacts (D3) since plans are intentionally carried out. Moreover an intentional selection of an object satisfying the physical description $\mathcal{D}$ cannot be taken as a make plan because the plan requires that one or more of the materials m_1, m_2,... be physically modified or assembled, or both. Such selection does not create a technical artifact, therefore pebbles used as paperweights are physical objects with use plans but not technological artifacts.

These three definitions condition the way we can introduce a general notion a "technical artifact" in formal ontologies. From each perspective, "technical artifact" constitute a disjoint category with respect to natural entities. This disjointness, nevertheless, is grounded on different principles, mainly on whether a natural object, modified or invested with additional intentional properties, becomes an artifact or not. And, as a consequence, perspectives differ on the weight given to the same intentional properties. For the sake of exploitation of artifact ontologies in the domain of fusion for threat assessment, crucial are the concepts of "intentional act" of creation or selection, "intended behavior" in a situation, "make plan" and "use plan" in a context.

B. Artifacts and Functions

As seen in the previous section (**D2.**) and following [14], artifacts can be characterized in terms of functions and goals.

Being $\mathcal{F}$ the function or purpose which an artifact has been created for, its properties as an $\mathcal{F}$*-object* can be divided into two classes:

(a) those relevant to the functioning of the object as an $\mathcal{F}$-*object*, and
(b) the properties irrelevant to the purpose $\mathcal{F}$.

The former properties can be considered the significant ones in relation to the object's purpose $\mathcal{F}$ (or $\mathcal{F}$*-significant* properties), thus in the context of a situation whose intent includes the object as a requisite to accomplish $\mathcal{F}$.

For example, the color of a hammer is not one of its significant features, whereas the weight always is, and the material of which it is made (steel, wood, plastic, rubber) is diversely significant only in the context of its use.

In general an artifact includes all the properties regarded as significant for the purpose $\mathcal{F}$ within the productive intention of its author(s), properties to be considered not simply a collection of predicates, but hierarchically structured. In many cases, therefore, an object is expected to serve many different purposes with different degrees of success and the production (or invention, or selection) activity can be evaluated along three dimensions [15]:

E1. the degree of fit or agreement between the *intended* character and the *actual* character of an artifact $\mathcal{A}$,
E2. the degree of fit between the *intended* character of an artifact $\mathcal{A}$ and the *purpose* $\mathcal{F}$, that is, the appropriateness of the artifact's "project" for the purpose $\mathcal{F}$,
E3. the degree of fit between the *actual* character of an artifact $\mathcal{A}$ and the *purpose* $\mathcal{F}$, that is, the suitability of the artifact $\mathcal{A}$ for $\mathcal{F}$.

E1. is a measure of how much an artifact successfully embodies of its author's intentions, **E2.** tells how much an artifact is suitable for the purpose $\mathcal{F}$ considering the character intended by its author, and **E3.** determines whether the author has succeeded in producing an artifact effectively suitable for the purpose $\mathcal{F}$ and its context of use.

In addition to the evaluation of an artifact and its design based on the purpose that its author had in mind, other evaluations can be made on the base of any other purpose for which the artifact might be used. For example, a user makes a new evaluation **E4.** in order to exploit (incidentally or on purpose) the artifact in new and diverse uses.

E4. the degree of fit between the character of an $\mathcal{F}_1$-artifact and the *purpose* $\mathcal{F}_2$, that is, the suitability of the artifact for an $\mathcal{F}$ different from the one it has been designed for.

Such an evaluation can be accomplished using a metric to compare vectors of weighted (W_n) $\mathcal{F}$*-significant* properties $P_n(\mathcal{F})$.

The capability of a tool $\mathcal{A}$ to fit the function (purpose, or intent) $\mathcal{F}$ can be expressed as:

$$C_{\mathcal{A}}(\mathcal{F}) = [P_1(\mathcal{F}) * W_1, \ldots, P_n(\mathcal{F}) * Wn] \tag{3}$$

The process of design and construction of the artifact or tool aims at maximizing the intended capacity but the same tool can be "metaphorically" changed with another artifact or tool with a sufficient capacity.

C. Artifacts and Context

The role of context in artifact selection and exploitation is crucial but in a different sense with respect to the role usually played in fusion problems. Context is recognized to be fundamental in achieving tasks by providing expectations, constraints and additional information for inference about the items of interest [16].

On the other hand, in the domain of artifact "metaphors", which involves problem-solving issues, context consolidates functional fixedness obstructing a possible solution as demonstrated by the candle problem.

Moreover, de-contextualization of objects is the first step of a process of "creative" production of substitute tools often deliberately accomplished to perform malicious actions, the most macroscopic among the accomplished ones being the metaphorical substitution "JET AIRPLANES are WEAPONS" in the 9/11 Twin Towers attack.

IV. EXAMPLE

In the present Section we propose an example of suggested metaphorical use of artifacts in the military domain, specifically in a sniper team mission scenario as published in the Sniper Trainig Field Manual [17], as a help in solving a radio antenna problem.

The team's portable radio antennas can be sometimes broken or damaged, causing either a communications failure or poor communications with the units involved in the mission. When there is no spare, the sniper team may have to construct an emergency antenna or, when possible fix the broken one. In the case of a wire antenna, emergency repairs may involve the wire used as the antenna or transmission line, or the assembly used to support the antenna.

> Antenna supports may also require repair or replacement. A substitute item may be used in place of a damaged support and, if properly insulated, can be of any material of adequate strength. If the radiating element is not properly insulated, field antennas may be shorted to ground and be ineffective. Many commonly found items can be used as field-expedient insulators. The best of these items are plastic or glass to include plastic spoons, buttons, bottle necks, and plastic bags. Though less effective than plastic or glass but still better than no insulator at all are wood and rope. The radiating element – the actual antenna wire – should touch only the antenna terminal and

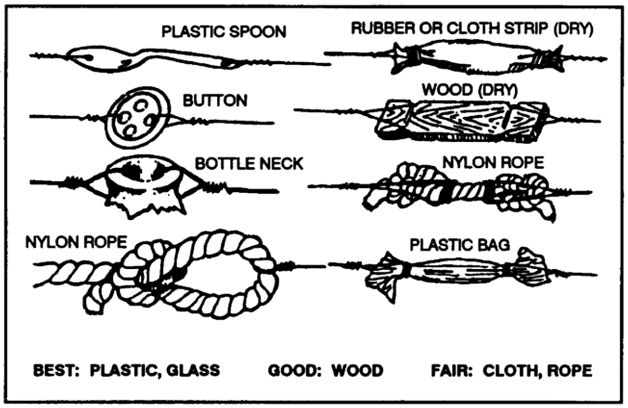

Fig. 4: Field-expedient insulators as suggested by the Sniper Training Manual [17].

> should be physically separated from all other objects, other than the supporting insulator. [17, p. 7-3]

Various methods of making emergency insulators are then prompted in a figure here reproduced as Fig. 4.

The objects depicted and suggested as substitutes of the designed original insulator, share with it some characteristics (features) which make them good for the purpose, namely

- electrical insulating power (conductivity)
- mechanical strength
- physical dimensions

together with task feasibility compliant, that is the capacity of being connected to metal wires, for example the property of having holes (like in button and bottle neck) or of getting drilled (like the plastic spoon).

Some of these features can change depending on secondary properties influenced by environmental conditions, for example the conductivity of a piece of wood depends on its grade of dryness which in turn depends on the location where it was found.

The last consideration focuses on the fact that the same substitute artifacts belong to different contexts. In our example we can roughly recognize the following contextual "domains":

- personal belongings
  - professional equipment (rope, ...)
  - clothing (button, cloth strips, ...)
  - food tools (spoon, bottle neck, ...)
- environment (wood, plastic bag, cloth strips, bottle neck, ...)

A discussion on the dynamic partitioning and clustering of available contextual information based on the relevance to the current focal element together with other partitioning strategies can be found in [16].

V. Capability in Intelligence

An interesting example for the application of metaphorical analysis and reasoning could be the field of military intelligence against asymmetric warfare activities. In general, in the military domain, there is often a more or less well defined "adversary" which could potentially carry on hostile plans. These can be considered a significant *threat* when they meet the threefold condition of: a) being driven by a clear hostile *intent*, b) being primed by a relevant *opportunity*, c) being supported by all the *capability* needed to bring them to completion [2].

Intelligence activities are therefore mainly concerned with assessing adversary intentions with the goal of detecting potential threats as they are being prepared. The task has shown to be particularly difficult in the case of asymmetric warfare where the adversary is purposely not following known military strategies and schemes in order to avoid early detection of own plans.

Given the huge amount of data and information that intelligence analysts have to continuously process from very different sources, there is a urgent need for reasoning methods that can provide automated support to integration and analysis. Shortcomings in the ability to make deductions about missing and conflicting information and the current inability to support automatic context based correlation and reasoning about vast amounts of information are drawbacks to providing a coherent overview of the unfolding events [2].

In the case of asymmetric adversaries, this is complicated by the fact that hostile plans are not only covert but also carried out by unconventional means. This is particularly true in the case of capability, where adversaries often don't exploit the designed and purpose-built tools, but some other tools whose features simply fit their hostile purposes.

Figure 5 shows on the left the three components of a threat as defined above, and on the right the main processing steps that would be required to assess the capability of a hypothesized threat. The process involves metaphorical reasoning in order to detect possible alternative tools for reaching the hypothesized intent $\mathcal{F}$. The process is iterative and involves:

1) For each hypothesized intent (purpose) $\mathcal{F}$
2) Abduce $\mathcal{F}$*-significant* properties
3) Check context for artifact which maximizes capacity (the $\mathcal{F}$-object)
4) If NOT present:
   Extract from KB next possible candidate with sufficient capacity
5) Loop to 3) until $\mathcal{F}$*-object* substitute is found or termination criterion is reached

The process explicitly looks for the $\mathcal{F}$-object that maximizes the capacity, but it could produce a ranking as well and evaluate alternative hypotheses involving tools that have not been explicitly designed for the purpose but that can be used by the adversary as unconventional means.

VI. Conclusions and Future Work

In the present paper we have shown how in everyday life as well as in asymmetric warfare domain, to achieve the intended goals, agents often don't exploit the designed and purpose-

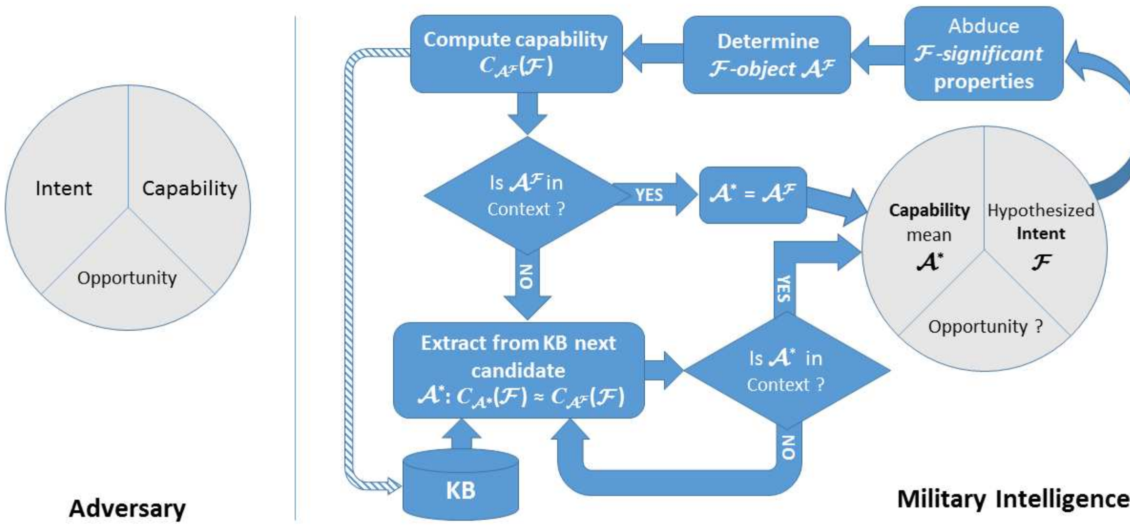

Fig. 5: Process of capability assessing.

built tools but some other tools whose features simply fit for the purpose.

Starting from the ideas carried out to engineer ontologies for functional concepts of artifacts, we propose to extend such ontologies with explicit weighted recordings of physical features.

A mechanism of similarity mapping, which will be object of our future research, between instances of property vectors, using feature-based similarity measures, will drive the retrieval of artifacts that are possible candidate substitutes for the proper designed tool.

Context plays a fundamental positive role in the tasks of achieving results from inference processes about the items of interest, namely regarding capabilities related to possible intents but, at the same time, de-contextualization of objects is a necessary step to achieve a successful selection of substitute candidates for tools that are unavailable or whose presence is undesired for example because of a malicious action plan.

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