How Affordances can Rule the (Computational) World

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Abstract. In this paper we present an ontology representation which models the reality as not objective nor subjective. Relying on a Gibsonian vision of the world to represent, our assumption is that objects naturally give suggestions on how they can be used. From an ontological point of view, this leads to the problem of having different representations of identical objects depending on the context and the involved agents, creating a more realistic multi-dimensional object space to be formally defined. While avoiding to represent purely subjective views, the main issue that needs to be faced is how to manage the highest complexity with the minimum resource requirements. More in detail, we extend the idea of ontologies taking into account the subjectivity of the agents that are involved in the interaction. Instead of duplicating objects, according to the interaction, the ontology changes its aspect, fitting the specific situations that take place. We propose the centerpieces of the idea as well as suggestions of applications that such approach can have in several domains, ranging from Natural Language Processing techniques and Ontology Alignment to User Modeling and Social Networks.

1 Introduction and Research Questions

We usually refer to the term *ontology* with several meanings in mind. Generally speaking, it can be defined as an attempt to represent the world (or a part of it) in an objective way. This is usually reflected in a representation of objects with fixed properties, independently from the interaction schemes. From the other side, there can be a purely subjective vision that every single agent may have. Our idea regards an ontological modeling of the behavior of intelligent agents, built on top of the concept of affordance introduced by [1] to describe the process underlying the perception. Generally speaking, Gibson claimed that objects assume different meanings depending on the context, and more specifically, according to which animal species interacts with them. The verb "*to afford*", in fact, implies the complementarity of the animal with the environment. In this sense, it is a distributed property between the agent, the action, and the object (i.e., the one that receives the action). All these components contribute to the meaning of the whole situation. An important characteristic of an affordance is that it is not objective nor subjective: actually, it cuts across the dichotomy between objective and subjective. More in detail, it relies on both environmental and behavioral facts, turning in both directions: from the environment point of view and the observer's one. Still, an interesting Gibsonian point of analysis is that the body depends on its environment, but the existence of the latter does not depend on the body. At this point, we recall to the classic dichotomy of the two main types of knowledge: explicit (to know what) and implicit (to know how) [2]. As an example, let us consider a surface. A table can offer an affordance of walking to a fly but not to an elephant, due to their different sizes and weights with respect to its surface. Different species can perform different actions on the same object but also the same action can be performed differently by the two species. Let us now consider an apple: it can be eaten by a worm living inside it, while an elephant can chew it. This situation cannot be modeled in a hypothetically objective approach to ontologies, whereas, according to a subjective approach, it would result in a multiplicity of separated ontologies. The problem of having such a large and fine-grained object space is that every single species has to be duplicated for each pair of species/agent, conducting to misalignments and relative problematic management. However, the purpose of a computational ontology is not to specify what "exists" and what "does not exist", but to create a specific knowledge base, which is an artifact of men, containing concepts related to the domain of investigation and that it will be used to perform certain types of computation. In our view, according to the interaction, the ontology should change its aspect fitting the specific situations that the ontologists would want to represent. From this, some questions arise:

– How to change the primitive of ontology representation in order to take into account affordances?
– What kind of direct applications may be found, and how can they be implemented?

However, Gibson limits his approach only to objects, whereas we aim at considering also technological artifacts and institutional entities from the socially constructed reality, like schools, organizations, and so forth. The aim of this paper is not purely theoretical, since we want to apply the idea in several domains of Computer Science, from natural language understanding to user modelling.

With the introduction of an affordance level, we increase the flexibility of the world we are going to represent. More specifically, with an augmented representation of the interaction between agents and objects, we start representing the tacit and implicit knowledge to model the explicit one.

2 Cognitive-based Computational Ontologies

The idea of going towards cognitive approaches for the construction of ontologies has been already proposed in [3, 4]. Our starting point is to compare approaches to ontologies that represent purely objective rather than subjective views of the world. On the one hand, in the objective view, all objects have the same features and belong to fixed classes. The actions that can be performed on the objects are the same and have the same meaning regardless of the agent performing the action. On the other hand, in a purely subjective scenario, we have a plurality of possibly inconsistent ontologies, one for each agent or species. Besides being too broad and complex to represent, the main problem would be that the same concept would be unrelated to the corresponding ones in the ontologies of other agents. This leads to disalignments, to the impossibility to reuse part of the representations even if the concepts are similar, and to difficulties in maintaining the knowledge base.

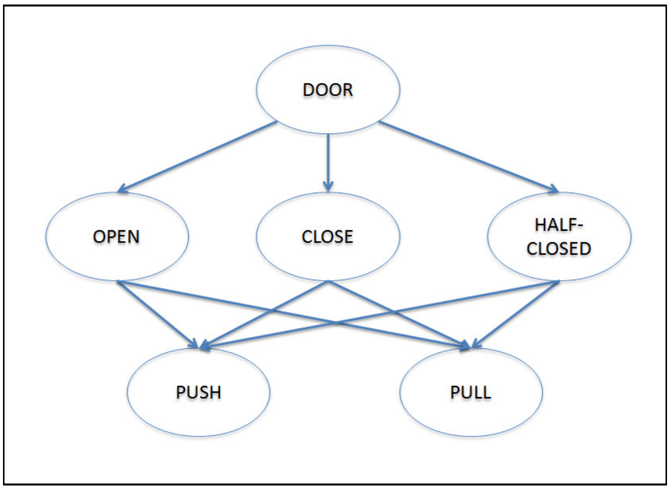

Fig. 1. The purely objective view of the world. The door can have different states like open, close (and other ones in the middle, like half-close). Then, there exist different actions that may change its status, like "push" and "pull".

To represent these issues, our starting point is to use formal ontologies. In general, formal ontologies are inspired to the basic principles of the First Order Logic [5], where the world is explained by the existence of defined objects and fixed relationships among them. This belongs to a physical and static view of the world. Figure 1 shows how this representation reduces to the existence of many objects and different behaviors associated with them. The same actions are offered to all agents interacting with the object, independently of the properties of these agents.

Let us now consider the action of opening a door, first performed by a person and then from a cat. In this case, depending on the subject and its physical capabilities, the action of opening the door is performed in different modalities. From our knowledge, we are able to distinguish a human from a cat from many things; for example, the human has fingers and hands. For this reason, we can easily imagine that such action will be completed by the use of a door handle. Switching the subject "person" with "cat", the action will be mentally visualized

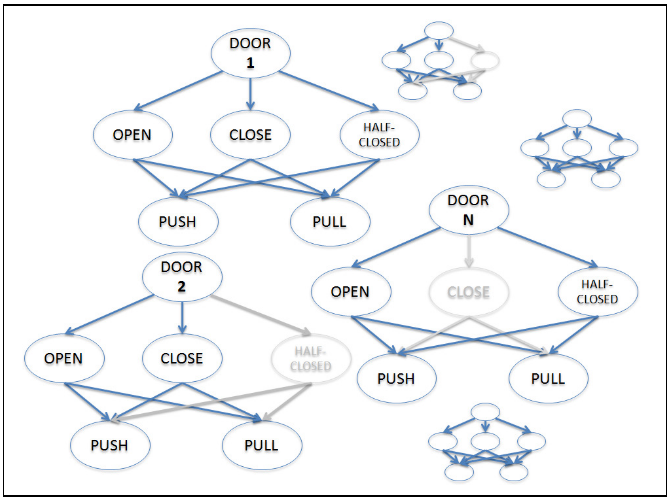

Fig. 2. The purely subjective view of the world. The enumeration of all instances and relationships without any ontology alignments produce a huge object space that turns out to be impossible to treat computationally.

in a different shape. The cat does not have fingers and it usually does not use any door handle[1]. This dependency between object and subject influences several activities: the mental image of the action by the subject or by another agent figuring out the situation, and the interpretation of a sentence describing it; then, in Computer Science scenarios, the implementation of the action on the object must be made differently depending on the subject interacting with the system. A completely subjective vision of how a situation can be would lead to an excessive chaos and a huge proliferation of instances, classes and relationships, as illustrated in Figure 2.

Our hypothesis is illustrated in Figure 3: we introduce concepts which have different perspectives depending on the kind of agent or species is interacting with them. Instead of having an object duplicated in different classes according to the different possible behaviors afforded to different agents (which would be reflected in an ontology with countless disjoint subclasses of the same object), we now have more inner classes depending on the agent who performs the action. The door provides two different ways to interact with it (the set of methods, if we want to use a programming language terminology): a way for a *human* user and on the other side the one for a *cat*. These two ways have some common actions with different ways to be performed (implementations), but they can also offer additional actions to their agents or players. For example a human can also lock a door with the key or shut it, while a cat can not. For example, the behavioral consequence of “how to interact with the door” can be “opened by the handle” rather than “pushed leaning on it”, and the way the action will

[1] Someone may argue with that.

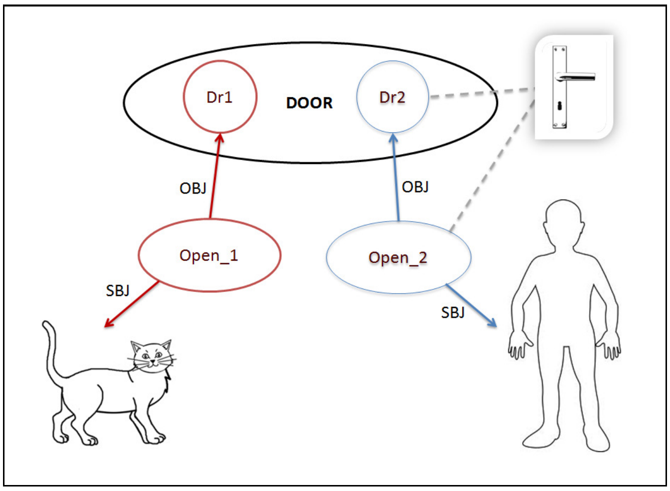

Fig. 3. From an ontological point of view, when the subject takes part to the meaning of the situation under definition, there is no need of concept duplication. Instead, the ontology has to provide mechanisms to contextualize the relationships according to the subject, eventually with the addition of specific properties or objects (as the door handle for the human subject).

be performed is determined by who is the subject of the action. The second example has a different character, since it refers to a technological artifact, i.e., a printer. As such, the object can have more complex behaviours and above all the behaviours do not depend only on the physical properties of the agents interacting with it but also with other properties, like the role they play and thus the authorizations they have. The printer provides two different roles to interact with it (the set of methods): the role of a *normal user*, and a role of *super user*. The two roles have some common methods (roles are classes) with different implementations, but they also offer other different methods to their agents. For example, normal users can print their documents and the number of printable pages is limited to a maximum determined (the number of pages is counted, and this is a role attribute associated with the agent). Each user must be associated with a different state of the interaction (the role has an instance with a state). Super users have the printing method with the same signature, but with a different implementation: they can print any number of pages; furthermore, they can reset the page counter (a role can access the status of another role, and, therefore, the roles coordinate the interaction). Note that the printer has also different properties for different roles and not only behaviours: for a normal user there is a number of remaining copies, for a super user that number is always infinite. A classical ontological view of the printer case is shown in Figure 4, while Figure 5 shows an example of how an intelligent system like a printer works depending on who is the user performing the action. The printer is divided into different “inner classes” (using a programming language terminology), depending on how many number of remaining copies are printable (marked as *nc* within the figure). The third example we consider is of a totally different kind. There is no more physical object, since the artifact is an institution, i.e., an object of the socially constructed reality [6]. Consider a university, where each person can have different roles like professor, student, guardian, and so forth. Each one of these will be associated to different behaviours and properties: the professors teach courses and give marks, have an income; the students give exams, have an id number, and so forth. Here the behaviour does not depend anymore on the physical properties but on the social role of the agent.

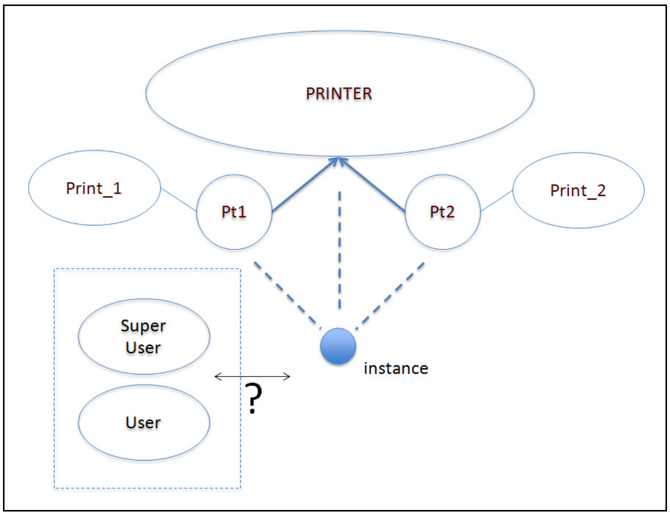

Fig. 4. A classic ontological view of the printer scenario. An instance has to belong to one of the three classes, but none of them captures the semantics associated to the interaction with the users. In case the new instance belongs to both printer pt1 and printer pt2, then it inherits all their methods, thus avoiding the differentiation at user-level.

The role of super user can safely access the state of other users and roles only if encapsulated in the printer. Hence the definition of the role should be given by the same programmer that defines the establishment (the class of the role belongs to the same class namespace, or, in Java terminology, it is included in that). In order to interact as user or super user, a particular behaviour is required. For example, in order to have the role of user, the user must have a certain type of account.

3 Applications

When we think at an object, what we perceive is not its qualities; rather, we get the affordances that it offers to the external world, in which the quality inhabits.

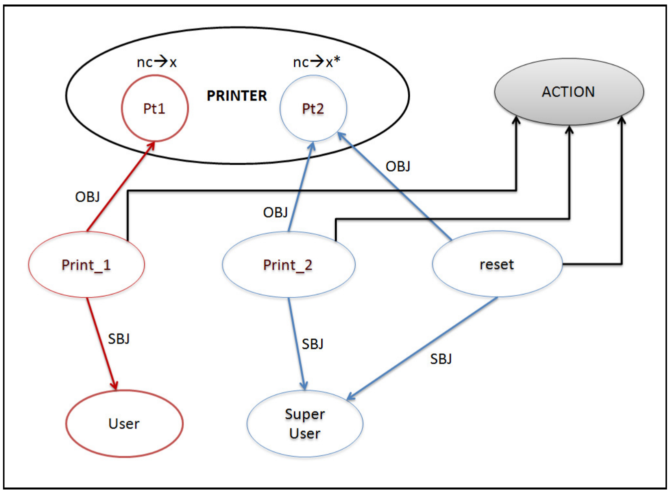

Fig. 5. An intelligent system where a printer works differently depending on who is the user performing the action.

Moreover, objects can be manufactured as well as manipulated. Some of them are transportable while others not; depending on the physical characteristics of an object, agents may perform distinct actions. In spite of this, however, it is not necessary (and possible) to distinguish all the features of an object. Perception combines the geometry of the world with behavioral goals and costs associated to them [7]. Still, positive and negative affordances are properties of things in reference to an observer, but not ownership of the experiences of the observer. [8] stated that all things, within themselves, have an enquiring nature that tell us what to do with them. In the end, we should not think about the existence or not of real things, but if the information is available to be perceived. If the information is not captured, the result is a misperception that may avoid the need of a tentative representation.

3.1 User Modeling

We discuss now the problem of modeling the ontology of different types of users and the ways they can interact one to each other. We can find a link between the User Modeling and the ontological theory of Von Uexküll [9], which can be expressed as follows: there is a circle which is a functional model of the agent who performs the action in its environment. The object of the action acquires a meaning if the action is implemented, thus through the concept of interaction. Von Uexküll theorized that each living organism was surrounded by a neighborhood perceived in a subjective manner, which he called umwelt. The environment is formed not by a single entity thet relates in the same way all living beings, but as an entity that changes its appearance depending on the species that perceives it. He reports, for example, the case of a "forest" that is seen differently from the hypothetical eyes of a forest (as a set of trees to be treated and cut), an agronomist (as an area to be tilled to make room for crops), or a child (as a magical place populated by strange creatures). Thus, affordances can be employed to fragment the subjective views of the same ontological concepts, related to users within a community. Instead of having multiple ontologies (with eventually minimal differences), there can be a single one together with some formally defined middle-layer interface that can entail the specificity of the users. For example, let us consider an ontology about beverages. If we take the concept "wine", it can be viewed under different perspective depending on the subjectivity of a wine expert rather than a wine consumer. The former may consider technical facets like taste, appearance and body that a standard wine consumer could not even have in mind.

3.2 Natural Language Processing

The concept of affordances can meet well-known tasks belonging to Computational Linguistics. In fact, if we consider the objects / agents / actions to be terms in text sentences, we can try to extract their meaning and semantic constraints by using the idea of affordances. For instance, let us think to the sentence "The squirrel climbs the tree". In this case, we need to know what kind of subject 'squirrel' is to figure out (and visually imagine) how the action will be performed. According to this, no particular issues come out from the reading of this sentence. Let us now consider the sentence "The elephant climbs the tree". Even if the grammatical structure of the sentence is the same as before, the agent of the action is different, and it obviously creates some semantic problems. In fact, from this case, some constraints arise; in order to climb a tree, the subject needs to fit to our mental model of "something that can climb a tree". In addition, this also depends on the mental model of "tree". Moreover, different agents can be both correct subjects of an action whilst they may produce different meanings in terms of how the action will be mentally performed. Consider the sentences "The cat opens the door" and "The man opens the door". In both cases, some implicit knowledge suggests the manner the action is done: while in the second case we may think at the cat that opens the door leaning to it, in the case of the man we probably imagine the use of a door handle. A study of these language dynamics can be of help for many NLP tasks like Part-Of-Speech tagging as well as more complex operations like dependency parsing and semantic relations extraction. Some of these concepts are latently studied in different disciplines related to statistics. Distributional Semantics (DS) [10] represents a class of statistical and linguistic analysis of text corpora that try to estimate the validity of connections between subjects, verbs, and objects by means of statistical sources of significance.

3.3 Social Networks

Social networks are a modern way people use to communicate and share information in general. Facebook[2], Twitter[3], Flickr[4] and others represent platforms to exchange personal data like opinions, pictures, thoughts on world wide facts, and related information. All these communities rely on the concept of user profile. A user profile is generally a set of personal information that regard the user in itself as well his activity within the community. Understanding the reference prototype of a user is central for many operations like information recommendation, user-aware information retrieval, and User Modeling-related tasks in general. In this context, the concept of affordance can be used in several scenarios. First, it can be a way to personalize the content to show to the user according to his interests and activity. This is massively done in today's web portals, where advertising is more and more adapted to the web consumers. Secondly, the whole content shared by 'user friends' can be filtered according to his profile, in the same way as in the advertising case. Notice that this does not have to do with privacy issues. In fact, a user may be not interested in all facts and activities coming from all his friends. Future social networking web sites may take into consideration such kind of personalization at user-context level.

3.4 Ontology Alignment

Ontology alignment, also called ontology matching, is the task of finding connections between concepts belonging to different ontologies. This is an important issue since usually identical domains are defined by using hand-crafted ontologies that differ in terms of vocabulary, granularity, and focus. [11] represents one of the most complete survey on the existing approaches. The concept of affordance can be thought as the conceptual bridge between the definition of a domain and the domain itself. In fact, the former is a view of the domain that takes into account the subjectivity and the context the concepts would fit with. Focusing on how to formalize such middle level can put the basis for a semantic-based ontology alignment that dodges most of the existing statistical techniques and their relative semantic blindness.

4 Related Work

In this section, we review the main works that are related to our contribution. For an exhaustive reading, it is worth to mention the ideas presented in [12–14] about the design of ontologies in Information Systems.

Mental models have been introduced by Johnson Laird [15], as an attempt to symbolic representations of knowledge to make it computable, i.e., executable by a computer. This concept is the basis of the most important human-computer

[2] https://www.facebook.com/
[3] https://twitter.com/
[4] http://www.flickr.com/

cognitive metaphor. A mental model is composed by tokens (elements) and relations which represent a specific state of things, structured in an appropriate manner to the processes that will have to operate on them. There is no a single mental model to which the answer is right and that corresponds to a certain state of things: a single statement can legitimately correspond to several models, although it is likely that one of these matches in the best way to describe the state of affairs. This allows to represent both the intension that the extension of a concept, namely the characteristic properties of the state described; the management procedures of the model are used to define the extension of the same concept, that is, the set of all possible states that describe the concept. Figures 6 and 7 show the case of an airplane and the resulting mental models that we create according to different types of action: recognize it or travel with it. Indeed, the action changes the type of perception we have of an object and the action takes different meanings depending on the interaction with the subject that performs it.

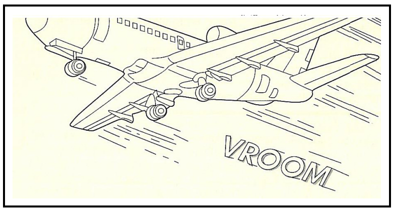

Fig. 6. A mental model of an airplane to recognize it. [15]

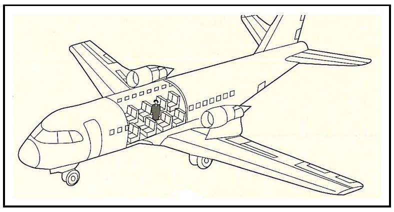

Fig. 7. A mental model of an airplane when travelling. [15]

From the mental models theory we then reach the mental images theory [16]. Mental images are not figures in a person's mind, but they are mental representations even in the absence of the corresponding visual stimuli. Unfortunately, the operation for defining how the images are built, formed, and transformed is still a controversial issue.

Another related work which can be considered as a starting point of our analysis is about the link between the Gestalt theory [17, 18] and the concept of affordance in the original way introduced by Gibson for the perception of objects. Wertheimer, Kohler and Koffka, the founders of the Gestalt movement, applied concepts to perception in different modalities. In particular, it is important to remind the principle of complementarity between "figure" and "ground". In this paper we intend the ground as the contextual basis of an action; for instance, we can not understand the whole meaning(s) of a sentence if we do not consider the ground which surrounds the interaction. The perception process, as we know, is immediate; however, to understand a figure, the input must be somehow recognized and trasformed within our brain. The final output is then mediated by contextual and environmental facts: it is a dynamic and cooperative process. Another point that we want to focus on within this contribution is to create a connection between the Gestalt theory and the Natural Language Processing applications that we explained in previous sections. Again, let us think at the sentence "The cat opens the door". In this case, our basic knowledge of what the cat is and how it moves can be our ground or contextual layout; this is useful to understand the whole figure and to imagine how this action will be performed. In simple words, the Gestalt theory helps us say that the tacit knowledge about something (in this case, how the cat uses its paws) is shaped on the explicit knowledge of "what the door is". Following this perspective, the concepts are not analyzed in a dyadic way, but in a triadic manner, similarly to the Pierce's semiotic triangle of reference, which underlies the relationship between meaning, reference and symbols [19].

Then, in Object-Oriented programming, an inner class is a type of class defined as part of a top-level class, from which its existence depends. An inner class could even define a distinct concept with respect to the outer class, and this makes it different from being a subclass. Powerjava [20] is an extension of the Java language and a simple object-oriented language, where an objective and static view of its components is modified and replaced on the basis of the functional role that objects have inside. The behavior of a particular object is studied in relation to the interaction with a particular user. In fact, when we think at an object, we do it in terms of attributes and methods, referring to the interaction among the objects according to public methods and public attributes. The approach is to consider Powerjava roles as affordances, that is, instances that assume different identities taking into account the agents.

5 Conclusions and Future Work

In this paper we proposed a Gibsonian view to ontology representation; objects of a domain offer affordances that help the involved agents make the correct actions. This approach can have several applications in different domains. For instance, it can be used to model some natural language dynamics like the attachment among subjects, verbs and objects in textual sentences. From the ontological point of view, the concept of affordance can be seen as the different ways the same objects can be seen by different people with specific interests and characteristics. Still, User Modeling tasks like information recommendation may be faced according to the definition of affordance. Social Networks like Facebook and Twitter play an important role in nowadays online information spreading, as they represent frameworks where subjective views of identical information come out naturally and from which it would be crucial some formal mechanisms of knowledge representation. To apply affordances to user-generated and shared data can be useful for a number of applications like user-aware content sharing, and targeted advertising. In future work, we aim at focusing on these applications in order to implement ways of building ontologies according to the concept of affordance while minimizing redundancy.

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