ISKRM
An Implicit Simple Knowledge Representation Model[1].

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Abstract

There exists a large amount of knowledge representation models. But most of them have significant limitations at the epistemic level. They do not have explanatory power. Most of them do not have means to represent some functional needs to work as valid "Languages of Thought" (LOT). Many actual models have restrictions on flexibility to handle new problems or expert systems with encyclopedic knowledge. Most of them require a semantic assessment to symbols made by the same developers of the expert systems and technicians who do knowledge elicitation. These limitations have implications on feasibility for autonomous cognitive agents, capable of generating new concepts elicited out of learning and environment interaction. A model of knowledge representation is introduced, which allows for functionalities of traditional models of representation and solves many of their restrictions.

Keywords: Knowledge Representation, Semantics, Agent Conceptualization, Artificial Reasoning, Autonomous Cognitive Agents.

Resumen

Existe gran número de modelos de representación de conocimiento. Pero la mayor parte de ellos tienen significativas limitaciones a nivel epistemológico. No tienen poder explicativo. Muchos de esos modelos no disponen de mecanismos necesarios para representar algunas de las funciones necesarias para actuar como "Lenguaje del Pensamiento" (LOT, Language of Thought). Muchos modelos actuales tienen limitaciones de flexibilidad para abarcar nuevos problemas o sistemas expertos de conocimiento enciclopédico. La mayoría de los modelos exige una asignación semántica a los símbolos elaborada por los propios desarrolladores de los sistemas expertos y los técnicos que realizan la educción del conocimiento. Esto tiene serias implicaciones para la factibilidad de agentes cognitivos autónomos capaces de generar nuevos conceptos aprendidos a partir de la interacción con el medio. Aquí se presenta un modelo de representación de conocimiento que permite disponer de las funcionalidades de los modelos tradicionales y resuelve muchas de sus limitaciones.

Palabras claves: Representación de Conocimiento, Semántica, Conceptualización por agentes, Razonamiento Artificial, Agentes Cognitivos Autónomos.

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ISKRM
An Implicit Simple Knowledge Representation Model

1 Introduction

The model ISKRM (Implicit Simple Knowledge Representation Model) is at the same time a language and a model of knowledge representation, free of semantic which allows to solve some of the problems of other knowledge representation models. We like to pronounce ISKRM like the name “ice-cream” or like the phrase “I Scream”. These two are oronyms, and show the idea behind ISKRM, as a model of symbols that can change their meaning according to the context where they are interpreted.

Based on a feasibility study about a model of semantic similarity pursuing restricted domain problems [**1**] we continued studying present models to solve the problem of semantic similarity and matching. In other papers we describe critics to knowledge representation models, about their insufficient epistemological capability to represent meaning of terms and be effective support to solve semantic similarity problems [**2**]. We introduced a model of semantics (in the linguistic sense) [**3**] and the basis for an architecture of autonomous cognitive agents [**4**] capable of overcoming most of the problems detected. In this work, we present a model of knowledge representation that gives support to the models suggested in previous works.

Some of the general objectives of the present model are as follows: Support context dependent interpretation; knowledge based interpretation; conceptual and classificatory polymorphism; support semantic similarity resolution; support situational dynamic and static conceptual representation; capable of including different models of reasoning as context based inductive, deductive and abductive reasoning; capable of multi-level representation and abstraction, introspection and meta-reasoning support, support to several models of logic, among others. Explanation of the reasons why this model supports the previous functionalities is a broad subject that runs beyond the limited space of this paper. Besides, several aspects described are still under development. But the study of these and other subjects requires the use of a flexible reasoning model that could allow the experimentation with these theories.

2 Basic Description of the Model

The model has a unique basic element named **Concept**. The idea behind this is that a concept is described by the knowledge related to it, either by the concepts it contains, and/or by concepts that relate it to some other knowledge.

The knowledge of the cognitive agent is also a set of concepts, and this set is a concept on itself [4]. Thus every piece of knowledge is a concept, just like an attribute, a property, class belonging or any other cognitive element. What differentiates a concept (referent) from any other is its identity, which is of course unique, but does not warranty the uniqueness of the referenced.

Each concept can contain other concepts that describe it, and can have other concepts that refer to it (or contain it). Each concept has a unique identifier. In order to easy human comprehension we will use descriptive names, although it is not necessary for a computational autonomous cognitive agent, and could be replaced by a number id.

3 Relations

A problem long time discussed in philosophy is how a relation has to be interpreted. Many taxonomies and hierarchies of relations have been developed and explained, either on computation, logics and philosophy [5][6][7]. But from a cognitive point of view, we can see a relation among two or more concepts as a concept (situation) that groups all involved elements, and there exist a set of other concepts or relations that explain the meaning of this relation.

<situation1> element1 element2 </situation1>
<a> element1 origin
 element2 destination
<c> element1 place </c> …

The models assumes that relations can have multiple properties, and may be impossible to foresee or classify them in an absolutely fixed and universally agreed taxonomy. So they will have to be explained by the tacit knowledge of the agent, with the explicit or implicit knowledge represented in the situation or context.

4 Concept, Situation and Context

If a concept John is to be represented, it can be expressed simply as 'john'. This does not mean that just by itself the symbol 'john' refers to the person of our acquaintance we call John. More than that is needed. The meaning must be enforced with other concepts or clauses that bind the previous symbol to the representation of all what is known about John by the agent [3].

If the cognitive agent knows that John is a person, using XML notation, there must be a concept in the knowledge base like the following: '<john_person> john person </john_person>'. This means that there is a concept with a descriptive name of 'john_person', and we assume that it is unique. This concept has two other concepts, one is the concept 'person' and the other is the concept 'john'. The concept 'john_person' makes explicit a known relation between concept 'john' and concept 'person'. This is what we call a "Situation", that makes explicit a relation among the concepts involved.

A situation like this, as a concept containing two or more other concepts, assumes the conjunction of these contained concepts. It expresses a situation where all these concepts occur or happen jointly. A concept is a "Context" when it includes several interrelated situations (that share some concepts) in such a way that interpretation of a situation can be derived from the other situations in the context that includes them. Notice that naming the symbols as Concept, Situation and Context is a matter of interpretation depending on how are those nested concept considered in a reasoning process.

The existence of a concept, is not enough to warranty that the meaning in the agent is the same that what the reader understands by "John is a person". There must be some knowledge that explains what can be understood by the fact that some referred entity is related to the concept 'person'. There must be patterns, with undefined concepts that are represented by names starting in capital letters. '<Y> X person </Y>'. In this way Y referes to any concept that in the first place has any arbitrary concept and in the second has the concept 'person'. For human reading, when the identifying name of the container is irrelevant, it can be suppressed: <X person>, but the system will hold its id. Basically it represents "For all person X". Notice that the concept is different from a universal quantifier in classical propositional logic, because it refers to all elements that satisfy a certain relation, while the former is a truth evaluation of the formula.

5 Focus

In many cases the order of concepts inside a situation is relevant. One of the elements in the situation has a focus of attention. It can be the start or the end of the list of concepts. In this document we will use de starting element of the list. Then <X person> stresses 'X' as an object over 'person' as attribute. There can be a way to change focus on concepts, through transformation rules like the ones described ahead.

Focus also allows for some kind of abbreviation and packing of knowledge for example <<A a> <B b>> as an abbreviation of the following: <<A B> <A a> <B b>>. Also this model allows for a twofold vision of relations an attributes as in the case <flower red> that could mean the flower that is red, against the representation of <red flower> as the red a flower has.

To describe a situation, all roles and actors have to be described. If an agent A takes an object B from source C to destination D, it can be represented as follows: <<A agent> <B object> <C source> <D destination>>. Since there are differences in focus when referring to situations, this can be shown in the phrase: "To destination D is where A takes object B from source C", which has from communication perspective a distinct but near synonym from the previous phrase [8] and changes the focus on the terms referred: <<D destination> <A agent> <B object> <C source>>. A reserved concept could also be used to represent the same thing of having focus like in <D attention_focus>.

6 Rules

The phrase "Andres has no dog", assumes a reference to an hypothetical dog belonging to Andres. To explain this, a concept to describe the situation is needed, in a way that a candidate to be possessed could be identified as element X. this element X has a relation to concept 'dog' in the context of the situation 'andres_has_a_dog'. There is somewhere in the knowledge base a tacit knowledge which describes what it is meant by a relation to concept 'dog' in '<X_dog> X dog </X_dog>'. In this case, the name X_dog is for easy human reader interpretation, although it could be a simple number id. In the same way the situation 'andres_has_a_dog' holds that concept X has a relation with concept 'dog', that Andres has relation to concept X, that X has relation to 'object', and Andres is related to 'agent_Have'. For each one of these situations there is tacit knowledge in the agent that explains what is meant by having such relations with the named concepts.

```
<andres_has_a_dog>
        <X_dog> X dog </X_dog>
        <andres_agent> andres agentHave </andres_agent>
        <X_object> X object </X_object>
        <andres_dog> andres X </Andres_dog>
</andres_has_a_dog >
<andres_has_no_dog>
        andres_has_a_dog
        <truth_assignment> andres_has_a_dog false </truth_assignment >
</andres_has_no_dog>
```

In the previous description it is not assumed that the 'dog' has to be a singleton (unique), but it is possible to be expressed in the language just like another concept.

As an example, it is assumed that the autonomous cognitive agent will have some tacit knowledge used to interpret the message. Andres is a person, so there must be an assertion as the following:

<andres_person> andres person </andres_person>. There is also the need of knowledge to explain why ‘andres_has_a_dog’ implies possetion of a concept on the other. It can be said explicitly that relation ‘andres_has_a_dog’ is of type ‘have’: <type_action> andres_has_a_dog have </type_action>. A more intelligent option is the use of some epistemological explanation about why this relation can be interpreted as possession. There could be some implication-like concept that the environment could interpret to produce new knowledge out of the existing one.

In case of ‘rewrite_rule’ there exist an antecedent and a consequent, where the antecedent identifies the conditions en which a rule can be applied to a context. These kind of rules can have variations to add, modify or delete knowledge from concepts in contexts, and also move concepts among situations an contexts. Concepts can be added to lead the reasoning engine to take one or other interpretation of rules. Notice this is an example, and the terms used do not imply that the situation will be interpreted as a rule, unless there is a knowledge that tells de reasoner to interpret it as such in the working context. This allows the model to interpret concepts as rules in some context, and as data in some other, allowing for easy and simple introspection. Describing models for this go beyond the objective of the present paper, and are in development.

```
<andres_person> andres person </andres_person>
<type_action> andres_dog have</type_action >
<rewrite_rule>
        <AntecedentRW>
                <Y> A O </Y>
                <A_agent> A agentHave </A_agent>
                <O_object> O object </O_object>
        </AntecedentRW>
        <ConsequentRW>
                <Type_action> Y have</Type_action >
        </ConsequentRW>
</RewriteRule>
```

The pattern ‘AntecedentRW’ is matched with any knowledge that satisfies the pattern. In case that for any context there is a relation between two elements, and in the same context the first concept has relation to ‘agentHave’, and the second to ‘object’, the rule can be applied and the relation is related to ‘have’.

But classificatory concepts have relations of complex causality, thus saying that such a concept belongs to such and such class, implies that there are a set of suppositions, such as if someone is a person is also a human: ‘<rule> <X person> <X human> </rule>’. There is a mechanism of rule evaluation, which applies to the elements represented by the left part to the explanations or transformations on the right. The model supports different ways to undertake transformations. In the same way that any other concept, the agent identifies a rule by associating knowledge to the reserved concept ‘→’. Them we say that something is a rule if there is a knowledge that explains it: <rule →>. Adding or deleting such a reference in a context, allows the agent to change interpretation of the concept, in a way that some meta-knowledge can evaluate and analyze them without applying them. With this feature introspection can be achieved with a simple change of context, by analyzing the objective context based on the same knowledge base but on a different context and abstraction. This helps end the infinite (loop) dependency on knowledge-meta-knowledge chain, since meta-knowledge evaluation is nothing but a new point of view or interpretation out of the same knowledge of the agent.

7 Truth Assignment

The assertion 'andres_has_no_dog' has an explanation. This assertion is composed by an undetermined element that is 'dog', and has a relation with Andres of the type 'have'. The phrase "Andres has a dog" can be described although 'dog' is undetermined. There is no element 'd' which conceptually refers to the named dog in the working context. When the undetermined concept X is referred, means a search for a concept that what would be matched to the pattern of the hypothetical concept 'd' if it existed on the knowledge base.

```
<andres_has_a_dog>
        <X_dog> X dog </X_dog>
        <andres_agent> andres agentHave </andres_agent>
        <X_object> X object </X_object>
        <andres_dog> andres X </andres_dog>
</andres_has_a_dog >
```

This expresses the phrase "Has Andres dogs?" in ISKRM. An evaluation would retrieve all of Andres's dogs in the context. But nothing is said about truth assignment on the concept 'andres_has_a_dog'. The concept must be matched to the knowledge of real world, so there must be rules that allow determining whether that phrase is true or false, or assume that there is not enough knowledge to answer that.

Based on the autonomous cognitive agent model [4] which has a limited and approximated representation of real World, it is impossible to assign a truth value to any conceivable assertion or any perceived message, and is certainly possible that the agent will lack information to determine whether something is true or not. Also some assertions can be true or not in relation to the context where they are evaluated, such as the case whether Unicorns and Pegasus exist, they do in the world of imagination and myth, but they do not exist on real world.

In fact, truth evaluation is no different from any other interpretation in ISKRM, and will be derived from reasoning out of the agents knowledge. It the case "Andres has a dog", if the agent knows that there is no dog that satisfies the pattern, then there must be some knowledge explicit or derived that says so. Then 'andres_has_a_dog' is evaluated as false. The next partial knowledge base expresses the concept that Andres has a dog. Maybe is a concept derived from idea exchange with Andres where he expressed his intention or wish of having a dog: '<wish_have> andres_has_a_dog wish </wish_have>'. But this can be far from truth in real world, and the agent could know that there is no dog 'd' of Andres, but anyhow there exists the concept to which to operate and reason about it.

```
<what_is_known_about_andres>
        <andres_has_a_dog>
                <d_dog> d dog </d_dog>
                <andres_agent> andres agentHave </andres_agent>
                <d_object> d object </d_object>
                <andres_dog> andres d </Andres_dog>
        </andres_has_a_dog >
        <doesn_exist_d> d doesn_exist</doesn_exist_d >
<what_is_known_about_andres>
```

About the previous knowledge, some common sense could show us how can be reasoned on this kind of situation, to make a truth assignment when there is knowledge that the object of possession does not exists in the working context.

```
<is_false_have>
        <Antecedent_is_false_have >
                <Z>
                        <Y> A O </Y>
                        <T> O object </T>
                        <U> A agentHave </U>
                </Z>
                <Doesn_exist_O> O doesn_exist</doesn_exist_O >
        </Antecedent_is_false_have >
        <Consequent_is_false_have >
                        <Truth_assignment_01> Z false </Truth_assignment_01>
        </Consequent_is_false_have >
</is_false_have >
```

Notice that is different to express that there is no dog ‘d’ possessed by Andres than there is no concept ‘d’ that is possessed by ‘andres’. The lack of information about such dog ‘d’ does not determine that a false assumption has to be taken. On the contrary, if the agent receives information that such a dog does exist, then it could reason some other truth assignment.

8 Patterns

In an environment with knowledge about many situations, there may exist several situations with the same pattern, for example all those about throwing an object from one place to another, stretch an object from one place to some other, draw a line or whatever. It is clear that this representation is insufficient, so there is need for further information to determine and differentiate the meaning of each concept.

An option is to add information about de action to achieve: <<V action> <A agent> <B object> <C source> <D destination>>. This allows explaining explicitly that some action is of the type expected even when it does not satisfy the expected pattern: e.g. <my_action>< take action > < john agent > < cup object > < table source > < dishwasher destination > </my_action>. It is possible to represent the action even when there is not enough information to match the pattern, for example when the source is ignored: <my_action2> <action take> <agent john> <object cup> <destination dishwasher> </my_action2>.

If the action is completely specified it is possible to add knowledge about the situation that explains its kind: ‘<T><D destination> <A agent> <B object> <C source></T>’, ‘<T take>’. In this case the first concept expresses the described pattern and the second describes all concepts with relation to ‘take’. Since both refer to undetermined concept T, while belonging to the same situation a conjunction is assumed, so it describes all concepts of the type ‘take’ that satisfy the described pattern. This can be expressed in a rule of a determined context and can be described as follows: ‘<<T> < D destination > < A agent > < B object > < C source > </T> < T take >>’. Any knowledge that satisfies the pattern of this rule, and it is being interpreted inside this context, will be assumed of type ‘take’.

This way of representing actions and other concepts has the advantage of allowing greater flexibility about how can be reasoned about different relations. Assuming that a situation has focus on the object that was moved from one place to another, but the way (troponymy) it was taken is irrelevant for the context of the reasoning process, this allows to reason without accessory information that will complicate the process. The reasoning process can filter attributes and other cognitive elements out of the context, according to the objective, abstracting it to a determined reasoning model [**9**][**10**]. The cognitive agent, can interpret a message like: ‘<<fact1> <predetermined_lake destination> < john agent > < generic_stone object> <floor source> </fact1> < fact1 trow>>’, by having knowledge that explains this message in the following example: <<T> <D destination> <A agent> <B object> <C source> </T> <T take> <take_trow> take throw </take_trow> <take_trow troponymy>…>.

9 Classification, Attributes, Properties and Others.

Any concept can be classified on varied ways [2]. To represent elements of the real world, for example a cup, it could be classified according to a set of categories because of its use. In some other cases they can be classified by proper attributes, like color, size, having or not a handle, and the shape of the horizontal plane intersection (round, square, hexagonal, etc.). But it could be classified as some other things, like a weapon if it is used as projectile, or any other situation where it could be used on unconventional ways. Through ISKRM it is possible to classify concepts according to different criteria on different situations and contexts.

Adding information about attributes and properties it is nothing more than applying again the presented model. To say something like “The cat is black” means to associate the concept ‘black’ with the concept ‘cat’ and with means of rules and other cognitive elements explain what is meant by ‘black’, ‘cat’ and the set of the named situation. In a similar fashion can be done for properties like being cylindrical for a can, or any other intrinsic, extrinsic or emerging property [**11**]. The model supports a language with an adequate support for compositionality of meaning [**12**], with knowledge based interpretation.

The model can also represent fuzzy, geographical and temporal information, also a model of theory of mind about what the agent believes other agents’ beliefs are.

10 Perceptive Elements

This model is a means to represent knowledge and mental status of an autonomous cognitive agent. But in order to be useful this autonomous cognitive agent must be able to communicate with other agents and perceive the real world [3]. Other agents may not have the same concepts than this agent in their cognitive structures, so some sort of interpretation may be needed to communicate to the agents of a different knowledge domain to require a service (problem resolution by expert systems) or return an answer (solution), or just synchronize beliefs about a domain. The received messages must be associated to the existing knowledge in order to assign meaning to them.

On the other hand, a perceptive/expressive (sub)system for an agent of this kind can be of varied architecture, and have information representations models of very different kind than ISKRM concepts. Taking ideas from theory of mind [**13**] and concept of modularity of human cognitive systems [**14**], based on the proposed model [4], we suggest specialized perceptive/expressive systems (image, voice, data, etc.) which do pre-processing decomposing information in cognitive elements (percepts) represented as ISKRM concepts. This representation would be adequate for knowledge based interpretation and conceptualization of the perceived elements. In the reverse other could be used by the agent to express itself on the environment (motor activation, agent communication, distributed problem solving, etc.).

In this way the cognitive agent could communicate with the environment “making calls” to the agent's expressive/perceptive systems' services. A simple example, but also another use, could be a numeric subsystem to easy numeric and formula processing in a way more efficient that ISKRM reasoning. In this case concepts are followed by ":" and the name of the perceptive/expressive system that process them or that identifies its kind. The reasoning engine could associate concepts to services to be requested to those systems. In this way the agent could operate with symbols like the following: <<< 1:numeric 2:numeric> +:numeric> evaluate:numeric>. In a similar way can operate on character strings, eventually separating words and organizing conceptual structures to easy Natural Language understanding. From this, agents can have plug-ins or modules that give specialized services for certain kind of data that is more efficiently processed by conventional imperative models. In order to be able to use them some knowledge about the systems has to be introduced.

Notice that it is also possible to consider a relation to a reserved concept to associate concepts to systems, but there is the limitation that many may not be easily represented in ISKRM but as a reference to the binary block. This use of a reserved concept may also allow for interpretation through multiple systems of the same data, in case that there exists some kind of synesthesia among them.

11 Conclusions

The model assumes that concept meaning is made explicit or explained by other agent's knowledge, to which the concept is bound through rules and references. In this way an autonomous cognitive agent could assign meaning to new symbols, never perceived or evaluated before, coming out of perceptions or conceptualizations from external source, by being bound to internal knowledge. This allows the agent to generate or apply rules that explain new concepts out of the knowledge available by the agent. Also notice that the grammar is implicit on the model of interpretation, and at the end, valid constructs are only those from which knowledge based conceptualization can be achieved.

It is necessary to develop adequate models of reasoning to solve problems efficiently, like conceptual semantic similarity and context based reasoning with ISKRM. It is possible to assign to this model an expressive power similar or superior in some case to conceptual graph model like Sowa's [**15**] either representing static and/or dynamic information. ISKRM is also an adequate model for the study of "Theories of Thought", either on psychology or intelligent autonomous cognitive agents.

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