Uniscript: A Model for Emergent Memory

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Abstract. In this paper we argue that mind is emerging. We first present a Knowledge Representation Model whose aim is to record in a clever way the 'facts and events' of a user. The main features of our model are: (1) Personal knowledge: no bottleneck, responsibility for validity. (2) Persistent storage: forces to record truths that are not supposed to change. (3) Instance-driven: knowledge units may exist even without classification or explicit rules to handle them. (4) Unicity-oriented: knowledge is composed by atomic pieces the existence of which is not supposed to be debatable. We show in what way it can be considered as an emergent organisation of memory, and then briefly its application to training in the ELeGI[1] EEC project (European Learning Grid Infrastructure).

1 Introduction

Representing human knowledge in generic representation formats such as semantic networks has been appealing in computer science since its very early ages [Qui67]. Even if tractability of computing processes handling such representations posed difficult problems, they seduced by their expressiveness: extending the content of such knowledge bases, as well as reusing them in unforeseen scenarios seemed more easy. Finding a tradeoff between expressiveness and tractability of the applied reasoning processes became a concern that implicitly guided most system designs, and that later became the object of explicit studies as well [LB85]. Accepting such a compromise would inevitably lead to rigidity of a knowledge-based system: it cannot keep up with the evolution of knowledge on the long term. In our opinion, one of the main reasons for this rigidity is that they are structure-driven. That is, they rely on *atemporal truths* such as rules and classifications, that are taken for granted and that govern the whole existence of the system. If the soundness or formulation of such a classification or rule needs to be revisited, it may seriously impair the consistence of the knowledge base.

We propose in this paper a quite challenging point of view: that of a spatio-temporally situated instance-driven representation of knowledge. In this model, the atomic knowledge bricks are individual objects and events that have had an existence in the real world. These individuals are persistently memorised, thus their existence is no longer dependent of the task at hand. All other structures are defined in function of these individuals. And not the other way around!

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The problem with these individuals is that there are too many of them. Fortunately, storage space at hand today is available in huge quantities, orders of magnitude the sizes available at the time when most of the founding work in KR was carried out. Even though, indiscriminate and persistent recording of individual instances looks foolish to any reasonable person.

It exists one scenario in which such an approach may be possible, that of a personal knowledge archival. Here, a person, master of his own knowledge base, is left the task of filtering the instances that are worth being stored. Doing this, his concern would be first of all the most faithful description of reality, which should prime over adequacy of the represented information to some particular purpose.

Our model intends to provide a basis for primarily personal knowledge representation. Beside the advantage of a person who selects what to record and is responsible for the content of the knowledge base, this approach could offer some other advantages:

- Since knowledge is not shared by default, there is no acquisition bottleneck: the owner is alone to decide how to model a new piece of knowledge in function of his perception of reality. He is not forced to seek for a consensus.
- Second, he can connect his knowledge to an acquisition source. Thus, in case of an inconsistence, he will be able to trace back the sources finding the origin, then eventually check what else may also be affected.

2 Previous works and context of the Uniscript project

We start in this work from the idea of emerging mind [Gla89], which states that " any implementation of humanlike intelligence in a machine will have to include lower levels, and that the mechanism of that implementation will have to be emergence rather than construction". This idea of emerging mind has been further developed in the framework of autopoietic systems [Rie92].

Boosted by the ubiquity of personal computing, new researches orient to decoupling knowledge from expected usage. Among these, there are projects that defend the idea of lifetime storage [GBL+02]. However, this orientation raises specific problems. Maintaining the consistence of stored knowledge, access to it, and above all correct interpretation of the stored content must be projected to an undefined future.

Our work started in a joint European research project, CoMMA (Corporate Memory Management through Agents) [PKD+00], dedicated to corporate memory management. The main objective of the project was to implement and test a Corporate Memory management framework integrating several emerging technologies in order to optimize its maintenance and ease the search inside it and the use of its content by the members of the organization.

The Multi-Agent architecture of the CoMMA system consists of a society of coarse-grained agents, that fulfill in general multiple roles, and are organized in a small number of functional sub-societies. The agents from user dedicated sub-society are concerned with the interface, monitoring, assistance and adaptation to the user, which involves Machine Learning abilities [KQ02].

The knowledge representation system was based upon semantic information processing and retrieval engine called Corese [CDH00].

New organizing possibilities are being proposed by projects as Placeless Documents [DEa00], Haystack [HKQ02], Lifesteams [FG96], trying to free the users from the unnatural constraints of classical file and hierarchy-oriented methods, focusing on semi-structured data in the form of annotations upon the raw information stored in documents.

The ELeGI project, in which this work takes place is dedicated to training environments on the Grid. The motivation of this project is to overcome some lacks of existing e-Learning practices and environments:

- they are based on the information transfer paradigm with focus on the content and the “teacher”: find the best way for presenting content in order to transmit information to learners.
- they are basically Technology driven approaches:
  - Missing specific didactical models,
  - no individual support of the students’ learning process
  - finds its perfect technical mirror in the page oriented approach to the Web
  - e-Learning becomes an activity in which teachers produce, and students consume, multimedia books on the Web

The ELeGI project proposes a Learning Paradigm Shift:

- In the new approach, knowledge construction, rather than information transfer, is the key.
- the focus is on the learner and on the learning strategies that better satisfy the learner characteristics
- It occurs through new forms of learning based on:
  - Experiential and Contextualised Learning: the understanding of concepts through direct experience of their manifestation in realistic contexts (e.g. providing access to real world data)
  - Social Learning: active collaboration with other students, teachers, tutors, experts or, in general, available human peers
  - Personalised Learning: guarantee the learner will reach a cognitive excellence through different learning paths tailored on learners characteristics and preferences

3 Basic concepts of the Uniscript system

3.1 The observer

We call observer the reference person who contemplates the world and whose attention is caught by some facts and events.

3.2 Stance

We named *stance* a personal view of the observer of an entity or phenomenon from his reality, which is situated (has a limited extension) in space and time. It is supposed to be observable during a time interval. From the observer’s point of view, it can be seen as a cutout of the space-time continuum surrounding him, which he chooses to regard as a whole (in its uniqueness).

Stance is the central notion in our model, which we felt useful to well distinguish from other notions that already bear heavy connotations, like object (too restrictive), concept or entity (that do not reflect situatedness). The word stance (originated from pp. of Latin *stare*) suggests that a phenomenon must have a set of stable features in order to be individualized.

3.3 Memorization

It is the decision of the observer to represent a stance in a unit of a memory, an abstract space containing set of addressable units. Its consequence is to modify persistently the memory. That is, an allocation cannot be undone.

3.4 Connection

We call *connection* an oriented relation, in the observer's mind, between two stances. As stances, connections are supposed to be persistent. They can be represented in the memory by altering the content of the units of the connected stances. Thus, a relation, once identified, remains always valid.

4 Specificities of the semantic net

Knowledge organised with the conventions just stated, can naturally be associated with semantic networks. Having described what stances are, we already drew a sharp delimitation of its scope.

4.1 Role of the natural language

Natural language has traditionally been considered at the core of the semantic nets. A characterization of their ”semanticness”, as lying in their being used in attempts to represent the semantics of English words [Bra79] was not really challenged in time. With our approach we shift somewhat away from this view, considering that natural language words constitute merely an important but not indispensable means facilitating retrieval of knowledge and evocation of possibly forgotten meaning. Words are then not represented as such in the base.

4.2 Role of space and time

Logics-based models suppose that knowledge is only useful when reasoning is applied upon it, and the type of inference is explicit (deductive inference, mostly). VB assumes that knowledge is useful when the user has an intuition that it could affect his future decisions. He should not be obliged to make explicit what those decisions will be, or in what manner they will be taken.

The field of *Interval Temporal Logics* [All83] gave the inspiration for the basis of the temporal aspect of our model. On the other hand, temporal logics are a well established field, and comport a number of extensions, in particular those dealing with events and actions [AF94]. Nevertheless, most of the terminology and examples reveal the inference mechanism from the background. For instance, a classical example of event representation, from the block-world scenario, describing that a block x is stacked upon block y during a time t. This example suggests an inference like: if we stack a block x upon a block y during a time t, then there exists a time (interval) t', immediately following t during which x overlaps y.

Such rules are designed to validate the information in the base and are inherently considered eternal. Thus, the hypothesis that everything has duration in time (which gives the power of the Allens model) is not applicable to rules. Moreover, it is not possible (at least we are not required) to reify rules, neither to create rules that manipulate rules.

5 Architecture of the model

5.1 Stance types

Primitive stances Presented as delimitations of the space-time continuum, one would think of stances first of all as objects. In this case, the stance represents the trajectory of an object through its lifetime. That is, from the moment it became that object until it transformed into something else. Both limits being considered from the point of view of the observer.

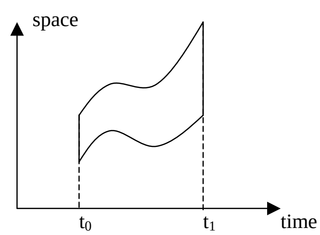

Fig. 1. A primitive stance seen as a cutout of space-time

If we were to imagine the space compressed into only one dimension, we could see an object as in the diagram: t_0 is the moment at which the observer considers the object came into being, t_1 is when it ceased to exist. (It is suggested that the object could have changed place and shape/size during its lifetime).

States and parts of objects that the observer can distinguish can also be considered primitive stances. As an example, a tree can be seen as a stance, its root can be a stance, and the tree in blossom (during last spring) another stance. Note that, as with most natural stances, there is no clear-cut delimitation between a stance and its environment: these are all approximate limits that are drawn in the mind of the observer. As are the

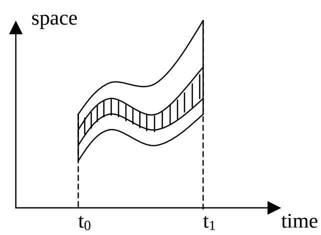

Fig. 2. Part or feature of a stance distinguishable throughout its whole lifetime

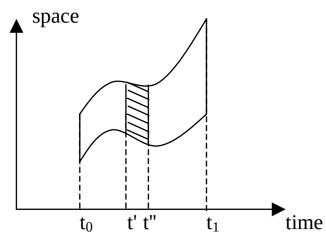

Fig. 3. Delimitable state of a stance

exact spatial and temporal extent of the tree, the limit between its root and the rest, and the exact moments between which it is considered in blossom.

Groups: capturing similarity Sometimes the observer can be concerned more with similarities he observes between different stances than with the individual aspect of each stance. He can than consider a group of such stances as a whole, a distinct entity. Since the group, as the sum of its elements, has a limited extent in space and time, it can be seen as a stance.

Classes For certain stances the observer may retain a set of distinguishing criteria that represent a particular importance for him. If he considers them well memorized, and he counts on his ability to apply them on stances he eventually encounters in the future, he can then consider the group of all stances on which he applied those criteria during his lifetime. Again, this will also be a finite set, thus matches the definition of a stance.

5.2 Link types

With the notion of stance we have managed to gather both objects and states of objects or events under a single concept. Thus we could naturally describe all possible relations between stances through two main types of connections reflecting the structure of the space and time, plus a third link providing the flexibility for evolution of the observer's viewpoint.

Composition or aggregation A composition relation can be drawn from a stance with a smaller space-time extent to another one with greater extent, that a-priori contains the first one. In the example above, the space-time extent of the tree contains the extent of its root, as well as that of its state when it was in blossom. That is, links can be drawn from the root stance to the tree stance, and from the tree-in-blossom to the tree. Remark again, that the observer is not concerned here with the possibility that the root could be separated from the tree, and both keep their identities as such afterwards. Cases where this is not acceptable could be described by intermediate states, as shown in an example later. The same way, if the class of trees was identified (as explained above), the tree could be linked to the class through the same type of link. At this point, many would fear a case of unclear mix of part-of, instance-of, and subclass-of relationships, as it often happened in the early ages of semantic nets [Woo75]. We hope to show further on, that a disambiguation is possible, at least in what concerns the goals of the observer.

Transformation A transformation relation is used to reflect an irreversible modification that affects the identity of a stance. For example, the tree in the above example may have finished its life (identity) being transformed into a table. Once again, it depends on the observer where it places the moments of change of identity: one may consider that the tree stopped existing at the moment it died (transformed in a piece of wood), while someone else may consider that the death was merely a change of state, it kept its identity while it kept its form, until the moment it was cut into pieces.

Revision When an observer realizes that there are important stances that were delimited in a way that no longer suits his changed reality, he can use revision links to make the necessary corrections. For example, one can suddenly realize that two different stances, Dr Jekyll and Mr. Hyde, each having its own history, are in fact one and the same stance. It is then possible to revise the situation through revision links, with or without introducing new stances.

Formal properties The 3 link types form 3 subgraphs of the main memory.

An agregation link implies that the space-time situation of the aggregated stance contains those of its component stances. Then, no circuit can occur in the aggregation graph, except between stances with the same space-time situation. More precisely, two stances are *equivalent* if they have the same space-time situation. Then, the aggregation relation is a *preorder* (reflexive and transitive relation). This point is illustrated in the twins example.

The transformation graph and the revision graph are also acyclic: this hypothesis states the *non reversibility* of the world evolution.

Let S be the current set of stances, $G_a = (S, A)$ be the graph of the agregation relation, $G_t = (S, T)$ of the transformation relation and $G_r = (S, R)$ of the revision relation.

If $(x, y) \in A$, $(y, z) \in T$, then $(x, z) \notin A$: x cannot outline its parent y. If a stance transforms (loose its identity), it is supposed that all its descendants disappear or transform as well.

6 Use as personal KB

6.1 Reinterpretation of memory content

One first task of a personal knowledge base should be to provide clues for the user to help him retrieve the meaning of possibly forgotten stances. It is even more important in the context of a memory in constant expansion, where it is critical to keep the redundancy as low as the perceived uniqueness of the represented natural phenomena.

A subset of our stances referred to as *restorable stances*, can have associated data structures that can be rendered by a computer in order to re-evoke the meaning of that stance. This data can be of different formats, including textual description, audio samples, images or other multimedia types, etc. Access to the data to be rendered could be materialized by libraries organized by the different formats, indexed by the unique ids of the restorable stances.

6.2 Retrieval of stances

Next task of the system should be to afford quick access facilities to the stances. A part of the stances can have some natural representation that can be organized in a way that permits quick retrieval. Such representations could be short text labels (terms), uniform descriptions of date and space coordinates, etc. We call these *reference stances*.

It may be found that most of these stances overlap with restorable stances of the same type. Yet it is preferable to keep them separate, as they serve different purposes, which can affect the way they are constructed: the representation for restorable stances should be the most suggestive possible, while for reference stances it shouldnt allow several different formulations.

Finally, decoupling content rendering data, and retrieval indexes from the main knowledge base makes it possible to change the associations of these data structures while keeping the stances underneath unmodified, as needed by the persistence requirement of the model. That is, stances describing real phenomena stay the same, no matter how we refer to them, or what techniques we use to remember them.

6.3 Knowledge Acquisition

We distinguished two main methods for knowledge acquisition:

– Non ambiguous capitalization (direct acquisition) and
– Progressive and incremental synthesizing of the knowledge (indirect acquisition), through intermediate knowledge sources.

Non ambiguous capitalization happens when observers stancify directly their perceptions or information.

Incremental Synthetization is useful when knowledge is already represented in existing information systems under the form of data. Some of the data, as well as references to the actual storage, can be stancified, and stored in the memory. Thus, the extracted knowledge can be seen as annotation of the original data. Keeping reference to the original storage can be useful until all relevant knowledge was extracted. Note that this point (capturing the complete semantics) can be reached for certain type of data (such as database records) and cannot be reached for other type of data (like multimedia records).

6.4 Stancification

There exist today several KR models, which could pretend fulfilling the requirements to become the kernel of a universal KR model. Most of these models (inference logics, frames, etc.) only care about how to represent without giving suggestions about what to represent [DSS93]. They oblige the user to see the world through a (more or less minimal) set of terms representing its basic perceptions, suggesting that anything, which is not easy to see through those terms, may be ignored.

Both acquisition methods begin with the identification of interesting objects and phenomena of reality, that have the smallest chances to be revised later; a process we refer to as stancification. Stances should be chosen such that overlaps with existing stances is minimized. We found that this search demands virtually no effort, as it corresponds to intuition; people do it naturally when describing their reality.

Second step is the identification of most significant permanent links, which connect new stances to other important ones in order to best describe the context.

Finally, it must be taken care to well identify the new stances. If possible associating them with individual rendering data, or else connecting with key restorable stances. Classification, when key restorable stances represent classes, should be only concerned with best identification. Looking for balanced, or elegant classification from the perspective of the class hierarchy is not the issue. If a stance is to be connected to a class, the observer should simply look for the most obvious answer to the question ”what is it?” That is, he should build on his most deeply memorized identification criteria.

6.5 Some examples

A simple situation like: ”Today I went swimming after work”, could be described as shown in figure 4: In the figure, numbers in parentheses may be internal ids of stances. We chose to show them to emphasize the uniqueness of each stance. Dotted arrows represent composition links and solid arrows represent transformations. Stances shown with a label outside the parentheses have textual data associated (stored externally) that should help restoring their meaning (restorable stances). If classes are thought of as compound stances with finite extent, the interpretation of this example is straightforward, posing no ambiguity problem. For instance, stance #32 is to be seen as the collection of all situations that the observer ever knew about, that he recognised as ”swimming”. The second example shows how knowledge can be augmented without affecting the existing links. Adding for instance the information ”I was driving from work to swimming” can look like in figure 5: Space and time intervals delimited by abstract limits, such as dates, or geographic coordinates can be also viewed as collections of events (stances) with their situations entirely included between those limits. For example, the date represented by stance #152 is the set of all stances whose lifetime is entirely included between the limits of the date.

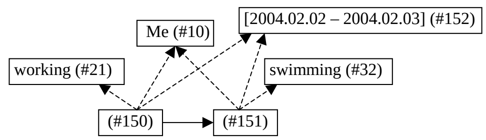

Fig. 4. Representing a simple situation

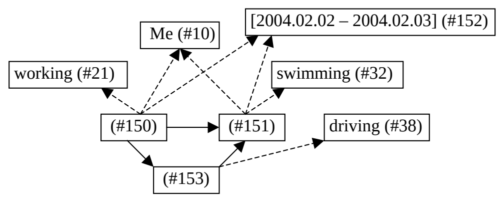

Fig. 5. Incrementally augmenting the knowledge

Remark that we gave this definition of the date as such, for the sake of simplicity of the example. In fact this definition does not offer any flexibility to treat such abstract limits from the point of view of different observers. In other studies (not presented in this paper) about representation of knowledge sources such as perception and communication we found a clearer and much more flexible representation of abstract coordinates.

Another set of examples show a case where an ambiguity can be cleared by adding extra information. If we were to record that ”John and Jack are twins”, we could use a construct like in figure 6.

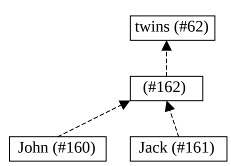

Fig. 6. Example of a possible ambiguity

It is not explicit until now that John and Jack are only twins, and there is not by chance an unknown third person, with whom John and Jack are in fact triplets. (Forget for the moment, that the English language limits the word ”twins” only to couples.) To add that extra information one could state that the group of twins contains exactly 2 persons. If we suppose that a stance representing all couples (two individuals sharing a similarity) already exists, we may add a construct as in figure 7.

Here, stance #163 is linked through double inclusion to stance #162, meaning that they are equivalent (two perspectives of the same cutout of space-time). It should be precised that stances representing groups of fixed number of individuals, as the group

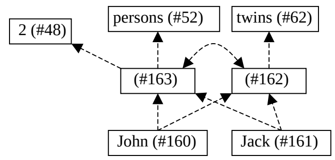

Fig. 7. Ambiguity solved by an additional information

of couples in this example, are always relative to a primary classification. Thus we couldn't have simply linked stance #162 to the stance of couples (#48): that would have been interpreted as two groups of twins.

Finally, a third example shows a very common situation: that of interactions between objects. Let's consider the event ”I was holding an apple”. Since the relationship between me and the apple can't be directly expressed, we need an intermediate stance, to make the bridge between the two objects: figure 8.

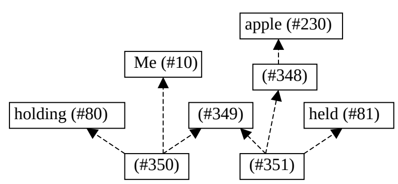

Fig. 8. Example showing a case of interacting objects

The intermediate stance represents the cutout of space-time with Me together with the apple. Now it is clear that it includes stance #350, ”me holding” and stance #351, ”the apple being held”. It is interesting to compare how such cases were described in different models in the history of semantic nets. This kind of relations were the most often the main argument explaining the need for different types of links [Woo75], or different types of nodes (like roles in Conceptual Graphs) [Sow84].

7 Conclusion

We have presented in this paper a knowledge representation model for persistent knowledge storage having the person of an observer as its central reference point. We describe a framework for capturing and integrating knowledge into a generic knowledge base materialized as an associative memory.

Two main ideas could be separated: First, representation of the world through situated entities; second, an application to personal knowledge archival. It could be tempting to consider the first part independently, and test its applicability to other domains as well. We have a strong conviction, that it would be the wrong way, as one cannot consider a KR model as a closed theory, that could live still, without evolution, as the foundation for knowledge based applications. Such a model should be alive, evolve and adapt in permanence, within a supporting community and can never reach a final state. We pointed out that the model needs flexibility to adapt to the users' subjectivity. Beside that, we hope that the personal perspective could start emerging the supporting community, thus bootstrapping the evolution process.

As a conclusion, we can say that we made in this work an attempt to modelize the "subconscious" mind of an intelligent agent, and pointed out 3 aspects:

- Psychology-based collective behavior
- Collective emergence of language and knowledge
- Application to collaborative learning (in the ELeGI project)

This also means that the final judgment criteria of a representation model would ultimately be its acceptance by the world, which will be directly influenced by its openness: it should permit the natural selection of its constructs, piece by piece. A theory of such developing knowledge pieces is upheld by the Memetics, a branch of Epistemology, first introduced by [Daw76].

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