Knowledge Representation in a Visual Typed Language: from Principles to Practice

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Knowledge Representation in a Visual Typed Language: from Principles to Practice

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Abstract—**This paper presents a set of principles that an intuitive and efficient visual representation language should satisfy. Then after a presentation of the visual typed language MOT, we show that MOT may be criticized which leads us to introduce an improvement of MOT called VTL. VTL is a Visual Typed Language satisfying most of the principles that we introduced.**

Index Terms—**Knowledge representation, visual language, MOT, Mind Maps**

I. Introduction

Nowadays the transmission of ideas mainly goes through writing. The written language must meet some syntactic and grammatical rules, with a reading direction of the words which are the building blocks of sentences that should be read in a sequential order. Even if it allows us to express complex and subtle ideas, some representations go beyond the linear mode by adding a spatial dimension to information, possibly on an interactive support, or an approach combining a comprehensive view and a detailed one.

In order to go beyond the use of texts, there is nearly one century, Otto Neurath [5] undertook researches to define a universal graphic language. This research led to Isotype (International System Of TYpographic Picture Education). The semiotics of the pictographs was also theorized in order to define a visual communication by pictographs understood by all. This idea of using pictures for representing and transmit information has already been largely exploited in different domains. Indeed, pictographs are very efficient communication vectors that are used in road signs for instance... According to Teboul [14], Human beings have the capacity to immediately translate a graphical form into a semantic element. Moreover, the human visual perception system is well adapted to comprehend a situation, a place and by extent a graphical representation, as a whole. Our brain is indeed particularly efficient to quickly process visual information (it is often admitted[1] that 90% of information which come to the brain is under this form). Today, it has been shown that the information on the Internet and the social networks that contain visual elements (animated or not) have much more chances to be understood, memorized and shared.

There exist a lot of visual representation frameworks that are more or less commonly used[2]: Mind maps introduced by Tony Buzan [2], Concept maps [6], Venn diagrams [15], Historical timelines, Programming flowcharts [3], Geographical maps...

They all have interesting aspects : Venn diagrams are easy to understand immediately. Historical timelines and Geographical maps have a strong cultural anchoring hence are also understood immediately. Flowcharts bring a temporal dimension and are not a mere static picture. Mind maps offer great freedom and creativity, are easy to implement, they facilitate memorization. Concept maps allow the user to describe a mechanism or a procedure, with no ambiguity.

However they all have some drawbacks: in mind maps there are ambiguities in the use of keywords and relations that the user can define without any constraint. Concept maps have poor graphics, and the focus point is rarely highlighted and not in the center which gives not a very natural readability. Venn diagrams have a very limited use they are maybe too simple. Historical time limes require to have a physical support of the right length, there is no possibility to zoom or to modify the linear scale. Flowcharts require the knowledge of basic forms, it does not use colors or drawings. Sometimes the projections done by geographical maps are distorting the reality.

In order to overcome these drawbacks, we have formalized four principles and expressed eight postulates based on cognitive psychology to certify whether a visual language is adapted or not to human perception and understanding. Moreover, we propose a new language called VTL, for visual typed representation language, able to satisfy these postulates. Thereby, VTL combines the use of keywords with icons, shemes, links, pictures, to quickly understand the matter of what is expressed. This combination is related to the dual coding theory [7] which states that coding a stimulus in two different ways increases the chance of remembering it compared to a coding in only one way. Our idea is to enrich the model of mind maps in order to obtain a model that admits a non-ambiguous automatic translation, together with a visual aspect able to represent the properties of the objects and their links. Our aim is that this translation could constitute a medium for understanding, reason and decide visually.

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[1]Unfortunately, as far as we know, this sentence is always used without any reference to a scientific study on this subject...

[2]Note that we do not mention the specific visual languages, mostly done for computer scientists, whose first aim is not to be easy to understand by humans but rather to be translated for the machines (see [12] for an overview).

II. PRINCIPLES FOR AN INTUITIVE VISUAL REPRESENTATION LANGUAGE

Let us consider that a visual language defines a set of possible expressions, these expressions should contain elementary pieces of information that are related together according to the formalism of the visual language.

More precisely, we consider a set S of visual symbols, a set W of english words (the elements of the set $S \cup W$ are called *items*), and a set C of connectors (with their arities). An expression e of a visual language L is a combination of items (i.e. elements of S and W) by means of some connectors of C. The items of the expression e are denoted $items(e)$. The particularity of a visual language is that any expression e is associated with visual features such as shape/color/position that are attached to each of its items and also to each of its connectors. We denote by $c(i, j) \in e$ the fact that the two items i and j are connected with the connector c in the expression e. The existence of a path[3] of length k from i to j in e is denoted by $path_k(i, j) \in e$.

Moreover any expression e of a visual language has at least one item that is considered as visible at start, this item is called an entry of e, the set of entries of e, is denoted $entrySet(e)$. In order to formalize Access efficiency we define the following measure:

Definition 1: The *inefficiency of access in an expression e* is the maximal length of a path from an entry of e divided by the total number of items in e. $\forall e \in L$,

$$\mathcal{I}(e) = \frac{\max_k \{x \in entrySet(e), y \in items(e), path_k(x, y) \in e\}}{\mid items(e) \mid}$$

The *measure of inefficiency of the access to items* in a representation language L is the maximum inefficiency that could appear in any of its expression.

$$\mathcal{I}(L) = \max_{e \in L} \mathcal{I}(e)$$

An example of a 100% inefficient language wrt to the access to information, is for instance a written text in which the words are the items and their connection is given by their sequence in the text, if we consider that the entry is the first word. Then the greatest path has the size of the text in the worse case when we want to access to the last word of the text from the first word.

In this section, we propose to list a set of postulates that a human-friendly and efficient visual language should satisfy. We first give 4 postulates that are easy to formulate within the notations that we have introduced.

- ***Accessibility***: $\forall e \in L$, $\forall i \in items(e)$, $\exists k \geq 0$, $\exists x \in entrySet(e)$ with $path_k(x, i) \in e$.
- ***Navigation***: $\forall e \in L$, $\forall i, j \in items(e)$ if $\exists k \geq 0$, $\exists x \in entrySet(e)$ with $path_k(x, i) \in e$ then $\exists k' \geq 0$ s.t. $path_{k'}(i, j) \in e$.
- ***Access efficiency***: $\mathcal{I}(L) < 100\%$.
- ***Entry***: $\forall e \in L$, $\quad |entrySet(e)| = 1$.

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[3]We use the classical definition of a path in a graph, here arcs are connections and vertices are items with the convention that a path of length 0 (called empty path) exists from any item to itself.

These four postulates have the following meanings. *Accessibility* states that any piece of information that is expressed should be accessible to the user. *Navigation* expresses that from any accessible piece of information the user can access to any expressed piece of information. *Access efficiency* imposes that any piece of information should be easy to reach, i.e., it should not require to read all the document in order to find it. *Entry* requires that there is a unique entry point.

The following properties are consequences of the postulates:

Proposition 1: If a language L satisfies *Accessibility* and *Entry* then the graph of the connections of any expression $e \in L$ is connected.

Navigation and *Accessibility* implies that from any position it should be possible to come back to a previous position:

Proposition 2: If a language L satisfies *Navigation* and *Accessibility* then the connection relation is symmetric.

Note that the distance of any item wrt to the entry point (when it is unique) is important wrt efficiency of access.

Proposition 3: Let L be a language satisfying *Entry* and *Accessibility* and *Navigation*, $\forall e \in L$, let us denote by x_e the only element of $entrySet(e)$, if x is a centroid of $items(e)$ (wrt to the distance given in terms of the length of the paths from x_e to the items) then $\mathcal{I}(e) < 100\%$.

The next postulates are written in natural language since more notations are required for the notions involved in them, this will be the subject of future research.

- ***Similarity matching***: Similarity of position/shapes/colors should have a correspondence in terms of closeness of some features of the represented knowledge.
- ***Meaningfulness***: the position/shapes/colors of the pieces of information have a clear meaning (the center is important, left and right may refer to some precedence constraint)
- ***3 Dimensions***: the language should use the 3D (most natural environment for human beings), hence the 2D dimension should be combined with a possibility to zoom/unzoom.
- ***Shortness, suggestive power and clarity of symbols***: each symbol should be short and simple. Short means less than seven elements, according to the properties of the working memory [4]. Suggestive power could be measured by the use of dual coding theory [7].
- ***Limitation of cognitive overload***: the number of items that should be presented to the user at once should be limited (according to Sweller's theory [13]).
- ***Easy to write***: user-friendly tools are available,
- ***Translatable***: any valid expression is translatable into a logical formalism.
- ***Consistency checking***: there are rules for checking if any expression has at least one valid translation

Note that all these axioms are related to other important and desirable principles. Indeed, we could define a ***Neighborhood*** principle saying that: Any pieces of information that have common properties should be close visually or wrt to the length of a path. This postulate implies the postulate *Similarity matching* in space.

The postulate *Shortness, suggestive power and clarity of symbols* implies that the language is ***Easy to read*** it means that the symbols are understandable without training and that expressions will be easy to understand and memorize [7]. The postulate *Meaningfulness* may imply that the center of the representation has an importance. *Translatable* implies that an expression as an unequivocal meaning and allows us to use inference mechanisms.

Our aim is to build a visual language that satisfies the greatest number of these postulates. We start by recalling the definition of the visual language MOT then we introduce the new language VTL, we end by showing the postulates that are satisfied by it.

III. THE VISUAL LANGUAGE "MOT"

A. Description

We base VTL on the method called MOT "Modélisation par objets typés" (*Modeling with typed objects*) [8], [9], [16]. This knowledge representation method is adapted to the needs of instructional designers who define learning systems and task support systems it is based on a graphical formalism.

According to its author, the goals of MOT are

- simplicity of use by persons untrained in knowledge modeling techniques,
- representational expressiveness suited for a large variety of situations and knowledge domains,
- transparent view of relationships between knowledge units, uncovering the semantics of a field.

The two main principles of MOT are:

1) Any piece of knowledge can be represented by an item whose shape depends on one of the three types of knowledge: declarative, performative or strategical. The shape border is either plain for an abstract item, or dashed when it is a factual one:

Knowledge type	Abstract knowledge	Factual knowledge
declarative	Concept	Example
performative	Process	Runtime
strategical	Principle	Statement

2) There are 6 kinds of links between pieces of knowledge, namely: instanciation (I), specialization (S), composition (C), precedence (P), input/output (I/O) and regulation (R). Any link which is not of this kind can be represented as an intern attribute of the scheme.

Here is a more precise description of the 6 links in MOT:

- I: any abstract piece of knoweledge (concept, process, principle) can be instanciated into a factual knowledge
- S: any abstract knowledge concept, process, principle can be organized in hierarchies
- C: any attribute if it is complex enough can be externalized in a new scheme linked to the first one by the composition link
- P: Any process can be decomposed into sub-processes related or not by precedence links

- I/O: The process notion can admit input/output links towards facts or concepts according to the generality level of the process.
- R: The pieces of knowledge can regulate or control other pieces of knowledge this is done with a regulation link.

Fig. 1 and Fig. 2 is an example taken from [16] that uses MOT to represent the process of "Waste Management".
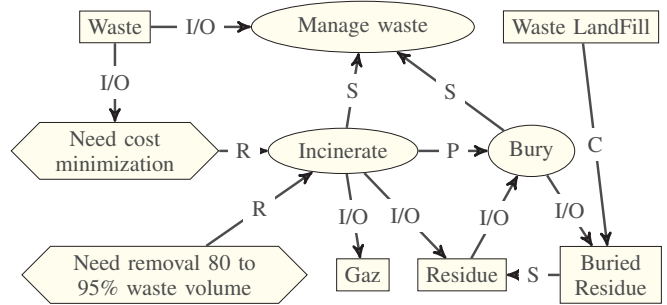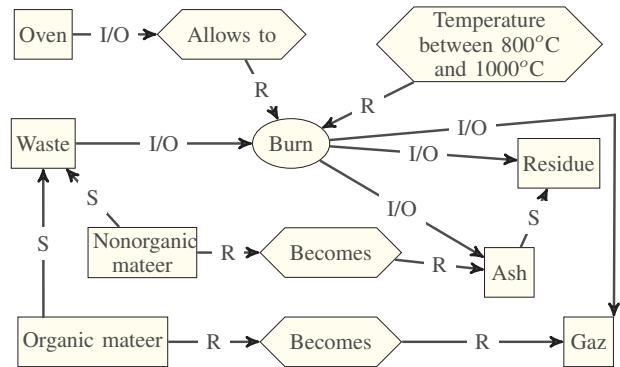

Fig. 1. Waste Management encoded in MOT

Fig. 2. Sub-model Incinerate in MOT

In the original work of Paquette, there are integrity constraints about links. Namely, a link cannot exist by itself, it should have an origin and a destination which should be a piece of abstract or factual knowledge. A link can relate a piece of knowledge to itself (being both origin and destination). A piece of knowledge can be related to none, one, or several pieces of knowledge. Between two types of knowledge, the only considered valid links are given in Table I. If there is a link between two pieces of knowledge then it is unique with a unique type. If there are several destinations for a link S, I/O or I then they should have the same type (which is not required for the other links).

Moreover Paquette [10] has imposed that Specialization (S), composition (C) and precedency (P) are strict partial orders (irreflexive, transitive, asymmetric and not total)[4] and that Input/output (I/O), regulation (R) and instanciation (I) are not transitive.

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[4]For sake of simplicity, transitive links are not expressed in the models.

TABLE I
VALID LINKS BETWEEN PIECES OF KNOWLEDGE

From \ To	Abstract knowledge			Factual knowledge		
	Concept	Process	Princip.	Ex.	Runtime	Stat.
Concept	S, I, C	I/O	R	I, C	I/O	R
Process	I/O	C, S, P, I	C, P, R	I/O	I, C, P	R, P, C
Principle	R	C, R, P	C, S, P, R, I	R	C, R, P	I, C, P
Example	C	I/O	R	C	I/O	R
Runtime	I/O	P, C	P, R, C	I/O	C, P	C, P, R
Statement	R	R	R	R	C,R,P	C,R,P

This MOT language is very interesting because it has brought the idea of typed objects and relations, however we are going to express some critics that justify the attempt to define a new language.

B. Critics

One goal of MOT was to be easy to learn and understand. In our opinion, this goal is not achieved. The letters used to differentiate the different types of links are not very friendly, it would be easier to use shapes, colors, words, symbols or emoticons... The standard shapes of MOT are not meaningful by themselves, for instance, concerning processes, there is a strong temporal/causal notion that could be captured by a gearwheel or an arrow... Moreover principles are not defined very sharply hence they are often complete sentences which goes against the idea to use a graphic models with simple and clear appearance. Hence the postulate of *Shortness, suggestive power and clarity of symbols* is not satisfied.

Regulation links seem to be used in an improper way: in the Example provided by the author, a regulation link is used to express the manner (e.g. "burn with an owen" in Fig 2) or to express links of precedence between concepts, this use is neither clear nor unequivocal violating the postulates of *Similarity matching* and *Meaningfulness*.

Complex diagrams may be difficult to apprehend, violating the *Access efficiency* and the *Limitation of cognitive overload* postulates. The method lacks the possibility to zoom/unzoom in order to make a projection according to some relations of interest or to some accurate attributes: geography, causality, specificity, etc. For instance composition and instances are relations that are changing the level of details hence could be associated to some zoom/unzoom operations. This violates the *3 Dimensions* postulate.

IV. OUR PROPOSAL: VTL

We propose to use also three kinds of items like in MOT: actions, entities and conditions. Our improvement is rather on the relations between those items.

A. The 3 main types of knowledge

The three types of knowledge may be in a generic (blue border and white background) or specific form (orange border and grey background), they can be associated with symbols.

The feature "instances" can describe particular example of a generic entity, e.g. "Oven n^oref F118" is an instance of "oven".

1) Entities:

Each entity is represented by a circle, with a blue label and an (optional) icon inside, this shape is always associated with five symbols that represent the features "composed of", "properties", "instances", "space", "time". It allows to associate the entity with some specific features and moreover to navigate by projection on a specific feature.

The feature "composed of" can describe a set of entities that compose the main entity. For instance a car is composed of a steering wheel, four wheels, one engine ...

The feature "properties" can describe specific characteristics of the entity. For instance a "waste" can be "macroscopic", or "yellow", or "food"...

The feature "space" is typically used to locate the entity in the world, in a room, etc. For instance, it is possible to specify absolute GPS coordinates, volumes and areas, and also relative positions (below/above/left/right of another entity).

The feature "time" allows to localize the entity w.r.t. time in an absolute or relative way (i.e., wrt other entities). For instance, a car can have a date of birth, and an average lifespan.

2) Actions:
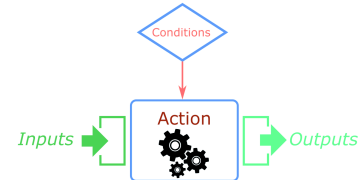
The actions are symbolized by a blue rectangle with a brown label associated with the drawing of a gear. Actions are related to inputs, outputs and conditions.

The inputs are the entities needed to execute the action, or the entities that are interesting to mention because of their properties before the action takes place. For example "waste" and "oven" are inputs for the action "burning waste".

The outputs are entities that result from an action or that have some interest to be mentioned after an action. For example the action "burning waste" is related to a set of output entities such as "residues", "gas" and the "oven".

The conditions are described in the next section.

3) Conditions:

Conditions are represented by blue diamonds with an orange label. Some actions require some conditions to hold. In our example Fig 4: the oven should be in working order. More generally conditions can be expressed about any entities

even if they are not related to actions. Several conditions can be connected by logical and/or operators. We use the *and-or tree* convention for representing and/or combinations of conditions. For instance, the global condition defined by ((condition n° 1) *and* (condition n°2)) *or* (condition n°3) is represented by:
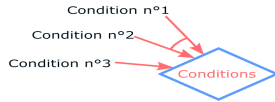
B. Relations

In VTL, relations between entities, actions and conditions, are represented by means of the 5 predefined features associated to entities, or the 3 features associated to actions or by combining conditions. This allows us to relate

- entities to entities: with the relations components/composed of, instance of/generic form of, localized before/after in time, localized at north/at south, etc.
- entities to actions: with the relation of input/output entities of actions
- conditions to entities: some conditions can be expressed on entities, they can be seen as filters of the possible entities
- conditions to actions: these relations are constraints on the possible executions of an action
- conditions to conditions: relations between conditions are symbolized by the and-or tree convention (as seen in Section IV-A3).

C. Navigation

VTL is associated with a navigation tool, in order to allow for a clearer representation. Hence instead of having a huge graph of entities, it is possible to represent a main topic with no detail and then to navigate in order to obtain a zoom/unzoom on one precise feature. Clicking on one entity or one feature allows the user to obtain a new view where this entity is the center. Navigation is hence a way to project according to some precise feature. Navigation is illustrated on Fig. 3.

D. Example

Fig. 4 shows a representation in VTL of the Waste Management example (Fig. 1 and Fig. 2) done with MOT. It represents the generic action of burning the waste, an instance of this action can be seen by clicking on the "Burn-278 action" of the field "instances" of the main action Burn Waste (Fig. 5).

V. Properties of VTL

It is possible to impose to any expression in VTL the fact that there is only one entry that is the center of a connected graph which would imply that *Accessibility*, *Navigation*, *Access Efficiency* and *Entry* principles hold.

In VTL the symbols that we propose are associated with short words and we recommend to add pictures with the items. Hence we use a dual encoding which implies that the *Shortness, Suggestive Power and Clarity* principle hold.

By construction, position/shapes/colors of the three types of items have been chosen in VTL in order to have a clear meaning hence *Similarity matching* is true for shapes and colors, as well as *Meaningfulness*. Concerning relative positions of items *Meaningfulness* holds only wrt actions (where inputs are on the left while outputs are on the right, and conditions are above).

The navigation in VTL is done in a way that gives the possibility to zoom/unzoom see Fig. 3. Hence the postulate 3 Dimensions holds. The *Limitation of cognitive overload* principle is a postulate that should be imposed to VTL writers, this condition can be imposed without loss of information by using the native features of VTL (navigation and zoom/unzoom).

For our purpose, we have used the XMind software that allowed us to create a complete example very easily. Hence the postulate *Easy to write* holds even if a dedicated tool would be more adapted. Concerning the *Translatable* postulate, the idea to use a typed language enables us to impose restrictions on the types of items that are allowed and also on their connections. An automatic translation of any expression will be the subject of our next study. *Consistency Checking* is not yet available in VTL, it will come together with the translation method.

VI. Conclusion

We have proposed some postulates and a new typed representation language VTL. In VTL information is accessed through navigation inside a tree structure. Indeed, at a given time point, the access to all the details about a given subject is either not mandatory for the user or implies a too heavy mental load. Nevertheless, navigation in VTL allows the user to access to the level of details that he wishes. The XMind software was used for creating some examples and for simulating the navigation but the development of a graphical user interface (GUI) specific for VTL is under study. Moreover our next step will be to study the automatic translation of VTL into a formal non visual language in order to propose inferences and consistency checks.

Another direction of work would be to study how VTL allows to encompass links that were not handle by MOT, namely RCC8 relations [11] or Allen intervals, or other relations between concepts (we could refer for instance to the *linking-words typology* written by Christian Barette [1]).

References

[1] C. Barette. L'analyse des relations. Technical report, Université de Sherbrooke, Québec, 2002.
[2] T. Buzan. *Use your head*. BBC Books, London, 1974.
[3] ISO. 5807: 1985 information processing-documentation symbols and conventions for data, program and system flowcharts, program network charts and system resources charts. *Geneva*, 1985.
[4] George A. Miller. The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review*, 63:81–97, 1956.
[5] Otto Neurath. International picture language. the first rules of isotype. *London: K. Paul, Trench, Trubner & Co*, 1936.
[6] Joseph D Novak and Alberto J Cañas. The theory underlying concept maps and how to construct and use them. Technical report, Institute for Human and Machine Cognition, 2008.
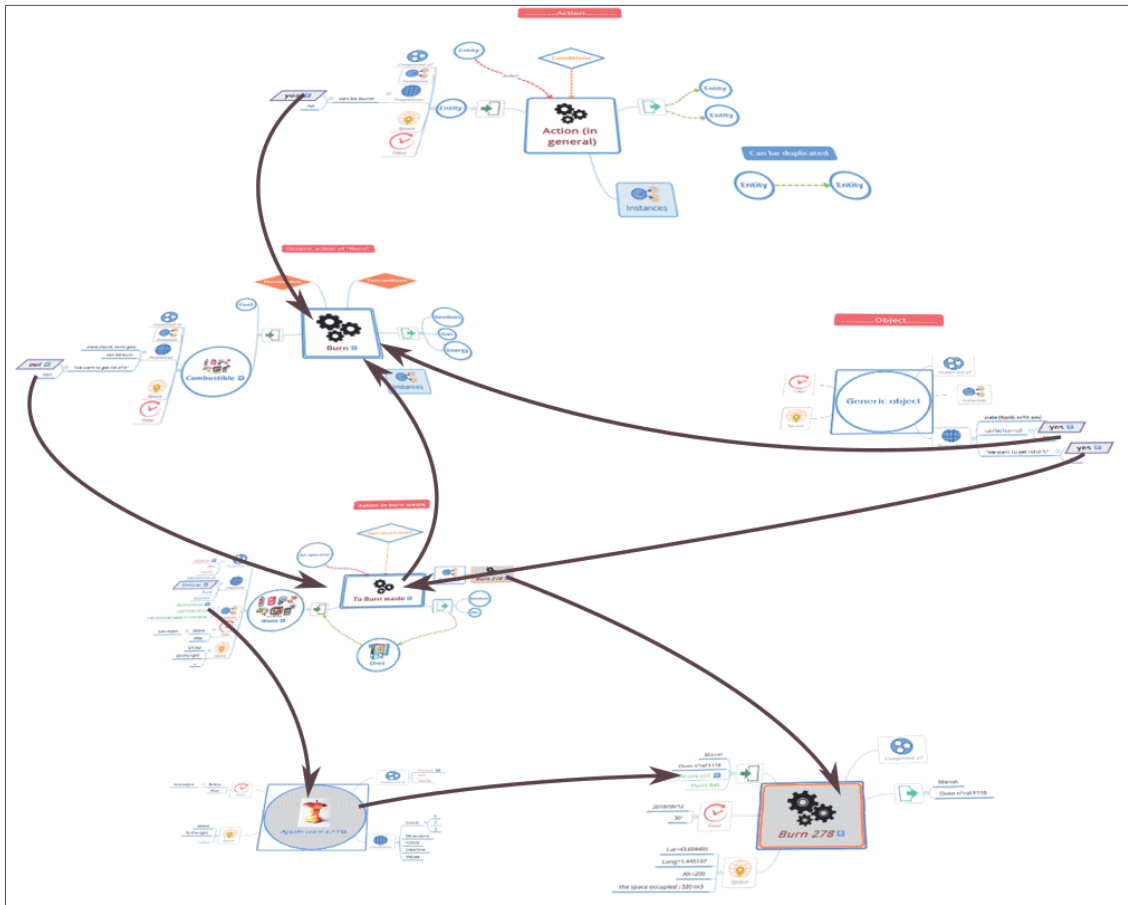
Fig. 3. Navigation in VTL
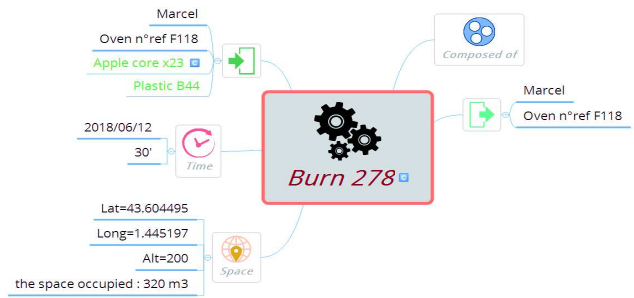

Fig. 4. Waste Management in VTL

Fig. 5. Waste Management in VTL

[7] Allan Paivio. *Mental representations: A dual coding approach*. Oxford University Press, 1990.

[8] Gilbert Paquette. La modélisation par objets typés - une méthode de représentation pour les systèmes d'apprentissage et d'aide à la tâche. *Sciences et Techniques Educatives*, 3(1):9–42, 1996.

[9] Gilbert Paquette. Visual knowledge and competency modeling-from informal learning models to semantic web ontologies. *Hershey, PA: IGI Global*, 2010.

[10] Gilbert Paquette, Michel Léonard, Karin Lundgren-Cayrol, Stefan Mihaila, and Denis Gareau. Learning design based on graphical knowledge-modelling. *J. Educational Technology & Society*, 9(1), 2006.

[11] David A Randell, Zhan Cui, and Anthony G Cohn. A spatial logic based on regions and connection. In *KR'92*, pages 165–176, 1992.

[12] John F Sowa. Semantic networks. *Encyclopedia of Cognitive Science*, 2006.

[13] J. Sweller. Cognitive load theory, learning difficulty, and instructional design. *Learning and Instruction*, 4(4):295–312, 1994.

[14] James Teboul and Philippe Damier. *Neuroleadership*. Odile Jacob, 2017.

[15] John Venn. On the employment of geometrical diagrams for the sensible representations of logical propositions. *vol*, 4:47–59, 1880.

[16] Wikipédia. Modélisation par objets typés, 2017.