Using the enaction paradigm as a basis for database exploration to favor users sensemaking

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Abstract.
This paper presents an interface between a user and a database inspired by the enactive field of cognitive science. This interface aims to favor the knowledge understanding for the user during his exploration of data. It proposes data progressively by estimating, in real time, the user centers of interest. Thus, a co-evolution between the user representations of the links between data and the navigation environment appears. To address the embodiment side of the cognition promoted by the enactive field, the user is immersed in a virtual museum that grows progressively, in real time. The data are embodied in 3D objects endowed with an interactive behavior. The structure of the data such as ontologies are also embodied in interactive graphical objects. Thanks to the co-evolution between the user and the environment, the resulting museum is specific for each user. The paper presents some arguments to raise this approach and provides some explanations about the links between the behavior of the user relative to the embodied data and the realtime evaluation of their respective relevances.

Keywords: data exploration, intelligent user interface, enaction, co-evolution, ontologies, embodiment, metaphor, sensemaking.

1 Positioning

In cognitive science, one paradigm that addresses the notion of human sensemaking is enaction which claims that cognition relies on the history of the interactions between an individual and his environment [5, 11]. Living beings modify their environment which, in return, impacts on the possibility of actions for them. After a while, this co-construction of the *agent* and his environment implies a strong interdependence between them. This coupling is inseparable to the explanation of the cognition and of the representations of individuals. The coupling lets emerge a specific understanding, individual to each person. Concept like affordances [2] is in line with these principles because it characterizes the influence of the environment in humans' actions. Enaction is also inspired by some phenomenologists, which considers that Humans find a stable representation of their own world from sensorimotor invariant [6, 7]. Eventually, enaction is also close to constructivism and embodied cognition because it highlights the role of the action in cognition and then, in sensemaking.

Our positioning is to take enaction as a basis of inspiration to develop awareness of users that should understand a huge amount of data. The challenge here, is to propose a user interface which favors the emergence of understanding. Currently, research engines only propose a list of suggestion to users according to some keywords but rarely address the embodied part of the cognition nor the real time behavior of the user relative to the propositions of the research engine. In our approach, we embody data in 3D objects which are introduced in a virtual environment. This last is used by the user to favor his embodiment relative to the data. We use also an on-line self-organization of the graphical representation of the data. Our claim is that it is more important to let the user actively discover links between information, making choice among these links, than giving to him a list of propositions without some cues.
In the literature, some works claim their links with enaction. For example, Kaipainen et al propose in [4] an enactive system allowing to study the co-influence between the human experience and the technologies. This system is based on the psycho-physiology of facial expressions and avatars that mirror them. Another enactive system is proposed in [8] which is implemented to design the bodily interaction with a virtual agent.

Our study can be considered as less embodied (even if it is one of our objective to immerse the user) than these previous works but more focused on the coevolution between humans and systems and moreover, more focused on the human sensemaking through his interaction and the subsequent evolution of his environment.

Indeed, our work aims to mix adaptive methods of information visualization and self-organization of data while introducing the user in the interactive loop. We also define an interactive intelligent system designed to guide the user to construct a representation of a problem. By this way, we transform the idea of artificial intelligence based of predefined knowledge (classical artificial intelligence) toward an evolving, not predefined and human coupled system that we design as an enaction-based artificial intelligence system [1]. This paper is structured as following, section 2 presents the theoretical principles of our proposition. This proposition implies a realtime evaluation of the user's center of interest according to some concepts. Section 3 is focused on the formalization of the concepts through ontologies as well as on the formalization of the evaluation of user's center of interest. Section 4 provides an illustration of the results obtained with this proposition.

2 Principles

We propose an interface for database exploration favoring the co-construction of the user sensemaking and his environment that we call *"enactive interface"* in reference to the inspiration that this research field gives to us for this study. The user is considered as the *agent* of the theoretical stance of enaction and his environment is a virtual *living* museum. It represents the database as well as the se-

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mantical relations between the data. Our virtual museum is considered as 'living' because it evolves in realtime according to the user's behavior.

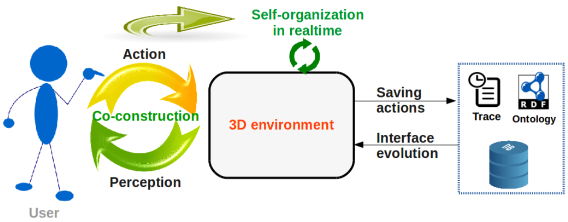

Figure 1. Enactive interface for database exploration

The figure 1 shows the functional principles of our proposition: the user interacts with a virtual environment and all his interactions are recorded. These are used to estimate the centers of interest of the user. The museum evolves and grows according to the estimation of the users interests. By *evolving*, we mean that the objects presented to the user are dynamically organized and by *growing* we mean that the topics of the next rooms are also defined dynamically. The evaluation of the user is provided from his actions in the virtual museum. For that, the user can use different interactive tools that are linked with some semantic concepts of the data (topic, space and time). This semantic concepts are defined by our research partners in cultural heritage and linguistics domains and formalized by three ontologies. For example, cultural topics are in an ontology that contains concepts like society, economy, mentality, natural cultural heritage, industrial cultural heritage, etc (dozens of concepts). The figure 2 illustrates the structure of these abstract concepts at a macro level and the figure 3 details the micro-level of one of the abstract concept *"Patrimoine industriel et artisanal"* (which means in English Industrial and artisanal heritage).

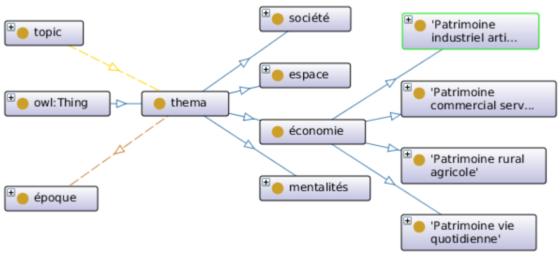

Figure 2. Structure of the concepts at macro level

The topos ontology can be described in the same manner. It defines places like towns, regions, geographical coordinates. Chronos ontology is divided in dates, years, century, ages, etc.. The cultural heritage objects of the database are connected to the concepts located at the leaf of the ontology.

Interactive tools are adapted to the meaning of these ontologies. For example, a map tool allows for the designation of places that represent the ontology structure (see Figure 4 on the bottom right). The use of this interactive tools as well as the behavior of the user

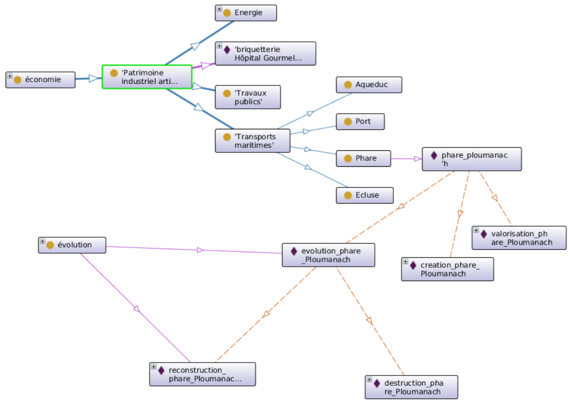

Figure 3. Structure of the concepts at micro level

can be interpreted in terms of concepts that interest him. Then, as the data are tagged with concepts, and as these concepts are linked together through ontologies, it is possible to choose data semantically close to the estimated user's center of interest. Moreover, as the concept are hierarchically organized, it is possible to choose more or less abstract concepts for the topics of the next rooms. Thanks to virtual environment, the user doesn't manipulate directly the concepts nor the ontologies. For example, if he stays a certain amount of time in front of an object, the system deduces that the concepts associated to this object are important. Some interactive tools are more explicitly linked with the ontology: for example, each object are linked with a place in the world (and are tagged with this place which is in the ontology). By this way, concepts that are easy to be represented *naturally* (as place in the world) and are explicitly represented with the tools while concepts that are more abstract, are just deduced from the behavior of the user. In short, the environment influences the user by suggesting objects that are linked semantically but not explicitly. It is their apparition during the visit and the distance that separate them, that express a semantical proximity. In the same time, the understanding of the user as well as its corresponding behavior evolves. It lets appear the co-evolutive loop between the agent and its environment.

3 Formalization

These section presents how the system estimates the center of interest of the user and how it will update the environment. For that, we specified a list of actions that the system can infer from the user's behavior his visit. The actions which are considered are the following:

- Enter in a room
- Display the information about an object
- Stay in front of an object
- Bypass an object
- Use a navigation tool
- Take an object

As each element of the museum is connected to at least one concept in the ontologies, we attribute a value to each concept that we call relevance and this last will be updated through the actions of the user. All user actions have a degree of interest, so, the updating of the relevance of one concept is different from an action to another. We suppose that:

- We have n types of possible actions and each type $type_i$ has a weight w_i which indicates the degree of interest of the user according to his actions. For example, when the user stays in front of an object, his center of interest on this object is lower compared to his center of interest when he takes this object with him. The more w is high, the more the user is supposed interested.
- An action a is defined by $a = \{type_a, \Gamma_a, t_a\}$ where Γ_a:a set of concepts involved in the action a, $type_a$: the type of the action a having a weight w_a, t_a: the time that the action a has been realized.

We consider now that the user do an action a of type $type_a$ at the moment t_a. So,

$$\forall c \in \Gamma_a, \tau_c(t) = \tau_c(t-dt) + [w_a * (\tau_{max} - \tau_c(t-dt))] * dt$$

where τ_c is the relevance of the concept c and τ_{max} the maximal relevance of all concepts.

As our objective is to favor the data discovery for helping understanding on a domain but not the research for data, we propose to the user not only the relevant concepts but also the concepts semantically close from the relevant concepts. For that, we introduce the measure of similarity distance between two concepts in a same ontology through the measure of distance proposed in [12].

It is based on the fact that concepts are hierarchically organized in trees of nodes. Each nodes represent one concept of the ontology. Thus, a concept has an upstream concept and some potential downstream node and there is a unique root concept which has no upstream concept.

The conceptual similarity between c_1 and c_2 is dependent on the least common superconcept of c_1 and c_2 designed as c_3 as well as on the root concept of the ontology :

$ConSim(c_1, c_2) = \frac{2*N_3}{N_1+N_2+2*N_3}$ where, if we consider that each concept is a node in the hierarchical tree of the ontology :

N_1 is the number of nodes on the path from c_1 to c_3. N_2 is the number of nodes on the path from c_2 to c_3 . N_3 is the number of nodes on the path from c_3 to $root$.

4 Example

We show through the following example how and when our system evolves according to the interactions of the user during his exploration.

Figure 4. Data exploration system using virtual museum as navigation metaphor

Figure 4 Shows the virtual museum. The data are embodied in photo frames and the interactive tools are accessible through the three icons in the top left.

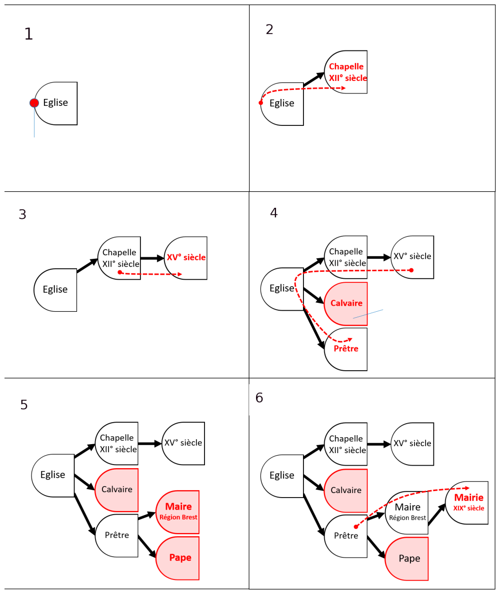

Figure 5. example of user's exploration path with dynamic creation of the museum's rooms: the red color rooms are the rooms which are not visited by the user. Legends: église: church, chapelle: chapel, prêtre: clergyman, calvaire: calvary, mairie: town hall, maire: mayor

Figure 5 illustrates the growing of the virtual museum during the user's navigation.

Each room is tagged by one or two concepts providing from the ontologies. Each object of each room is linked to concepts that are considered close to the room concepts. Moreover, the distance between the object is relative to the semantical distance defined in section 3. This grouping system is supposed to help the user to explore data that interest him. In the beginning of the interaction, the museum has just one room and a number of data is limited by the size of the room. For the example in the Figure 5, the system presents data related to the topic:*Eglise* (which means Church in English). We enumerate below the process of the dynamical creation of the other rooms and object selection :

1. The system proposes to the user a data extract about a given topic.
2. Referring with the user's interaction with the data proposed, the system creates another room close to the user. The topic of this new room is more or less close semantically to the room's topic where the user is. The topic is displayed on top of the room's door and there is a sound of door opening. It lets the system to influence the user to explore another data which may interest him (affordances). For this simulation, the user decided to enter in this new room (the course of the user is in red dotted lines).
3. At this step, the system creates a third room, the user entered in this room, but he was not interested by the data inside this room, so he went back to the second created room where he was.
4. The user continued his path in order to return to his initial position.
5. The system takes into account the displacement of the user in the environment and the time during which he has stayed in each room. After that, it creates new rooms with topics estimated close

to user's interest. For this step, the user ignores the room with a topic *Calvaire* but he visited the room with the topic *Prêtre*. When the user entered in one room, the system makes him aware of the impact of his interactions on his exploration by creating new rooms.

6. This last step shows that the user token his last path to return back.

This example shows that our system draws attention of the user during his exploration by proposing new information, and by indicating paths of navigation. It takes into account the user's interaction to propose the new information. So, the system could always propose new information even if the user did nothing.

5 Next stages

In the future, we plan to exploit the notion of affordances to improve the understanding knowledge for the user. For example, in the actual version, when new rooms are defined, a door opens and a sound that draw user's attention is emitted. We imagine also to improve the relationship between the user and the environment by inspiring of the models presented in [3]. In the future, we will work on the shapes of these doors and of other graphical representation. We will also work on the position of the objects relative to the user (below, above, small, big ...). Then, we plan to test immersive technologies like VR headset to address the effect of the embodiment on human understanding during data exploration. For this, we want to evaluate if the fact that the user walks physically into the data improve his ability to remember some information or links between these information. Finally, we also work on the mean to favor serendipity by the use of the structure of the ontology in parallel with some exploration policies to favor novelty during the exploration. The reader who needs more technical information about this study can refer to [10, 9].

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