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Visualizing Personalized Views in Virtual Museum Tours

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Abstract — We propose a multi-agent adaptive system to support tours of virtual museums. The system stores users' personalized views in *zz*-structures, particular data structures capable of representing both hypertext information and contextual interconnections among different information. We present an extension of the standard *zz*-structure model in terms of computational agents. These agents cooperate and collaborate in order to help users visualizing their personalized views. The power of this new model resides in the (partially limited) level of freedom users have for the dynamical choice, based on some present interest or necessity, of their navigational path inside the virtual museum.

Keywords — Software agents, adaptive hypermedia systems, personalized views, virtual museum tours.

I. INTRODUCTION

Over the past few years, the volume of information available through the World Wide Web has been expanding exponentially. Never has so much information been so readily available and shared among so many people. Unfortunately, the unstructured nature and huge volume of information accessible over the network has made it hard for users to sift through and find relevant information. To deal with this *information overloading* problem, the users' browsing space has to be limited.

Adaptive Hypermedia Systems (AHS) achieve this by knowing users' goals. More precisely, "by adaptive hypermedia systems we mean all hypertext and hypermedia systems which reflect some features of the user in the user model and apply this model to adapt various visible aspects of the system to the user" [1]. Different users may have different backgrounds, goals or tasks, preferences, hyperspace experiences, knowledges. Thus the system has to adapt to all the users and has to prevent them to get lost in the hyperspace, e.g., selecting a subset of interesting links for each of them.

Related Works. Personalized views [1, 2] consist of a set of links which the user often needs to access, i.e., a limited number of links to a restricted sub-portion of the entire hyperspace. Traditional web browsers implement this strategy through bookmarks or personalized site views (see, e.g., MyYahoo and MyNetscape). An extension to this are the adaptive bookmarking systems such as WebTagger [3], Site-seer [4], and PowerBookmarks [5]. In the Information Retrieval context, Web-based information services, typically supporting agent-based technology, have the aim of collecting information on different users (e.g., the pool of documents they retrieve), and to provide useful suggestions according to the users' needs (see, e.g., [6],[7]).

Guided tours inside virtual museums have strong similarities to standard information systems searches. Virtual museums can be divided in two categories, learning museums where users explore the information and learn something during the tour, and marketing museums, whose main aim is the publicity of real physical museums [8]. In learning museums, users want to explore a structured hyperspace with context-adapted narration. That is, the users would like to interact with a system that recreates a real life museum tour guided by a real museum guide [9]. Generally, museums have sites that assume standard figures of users and do not allow personalized visits, based on different interests, backgrounds, etc. Some work in this direction has been done, e.g., with the integration of a virtual guide with adaptive behavior within an already adaptable application [10], with software agents that interact using a human-computer interaction paradigm with the visitor [11], with the creation, using natural languages generation technology, of dynamic (i.e., different for each user) labels associated to the museum objects [12], and some others, see, e.g., [13], [14].

Contributions of this work. The general goal of this work is to propose a formal structure for the visualization of personalized views. The proposed visualization technique, supported by an agent-based technology, may give a certain level of freedom to the users by allowing them to interact with the system in order to (partially) choose the path to

follow during their navigation.

In order to achieve this, we consider zz-structures [16], particular data structures that store both hypertext data information and the contextual interconnections among different information. These structures are very flexible and have been used in different kind of applications, such as modeling, e.g., an information manager for mobile phones (zz-phones) [15], electronic Editions of electro-acoustic music [19], bioinformatics workspaces [17], e-learning environments [18], [21], data grid systems [20], etc.

Case study. This new general formal structure for the visualization of personalized views has been applied to the particular setting of guided tours inside virtual museums. Web-based guided tours enable users to access a wide quantity of information sources. In order to simplify the touring process it is important to offer users tools to: 1) identify the collection of “interesting” pages; 2) store the collection of items in adequate structures, and enable the system to display personalized user views; 3) create personalized and adaptive paths for the users.

In this paper, we presently leave to other techniques (e.g., applying semantic closeness [13]) the handling of point 1 (which is the topic of our on-going research). Starting from the presentation of a formal analytic graph-based description of zz-structures, and in particular of n-dimensional views, we show how to use these structures and views, in an agent-based model, for the creation of personalized user views in the context of virtual museum tours (point 2). Finally, concerning point 3, we show how to extend this concept of views in a dynamically changing setting. In particular, we show how the users may dynamically interact with the system in order to decide the path to be followed (limited to a restricted neighborhood of their actual position). The paper is organized as follows: in Section II we first give a brief description of zz-structures and we then define them in an agent-based model; in Section III, we show how to display personalized views and how to move to neighboring views, we also apply this to our case study. We conclude in Section IV.

II. CONCEPT SPACE AND MAP

In order to define the concept space and map, we need some preliminary definitions of zz-structures and related views.

A. Zz-structures

Zz-structures [16] introduce a new, graph-centric system of conventions for data and computing. A zz-structure can be thought of as a space filled with cells.

Cells are connected together with links of the same color into linear sequences called *dimensions*. A single series of

cells connected in the same dimension is called *rank*, i.e., a rank is in a particular dimension. Moreover, a dimension may contain many different ranks. The starting and an ending cell of a rank are called, *headcell* and *tailcell*, respectively, and the direction from the starting (ending) to the ending (starting) cell is called *posward* (respectively, *negward*). For any dimension, a cell can only have one connection in the posward direction, and one in the negward direction. This ensures that all paths are non-branching, and thus embodies the simplest possible mechanism for traversing links.

Formally a zz-structure is defined as follows (see, [20], [21]). Consider an *edge-colored multigraph* $ECMG = (MG, C, c)$ where: $MG = (V, E, f)$ is a multigraph composed of a set of *vertices* V , a set of *edges* E and a surjective function $f : E \rightarrow \{\{u, v\} \mid u, v \in V, u \neq v\}$. C is a set of colors, and $c : E \rightarrow C$ is an assignment of colors to edges of the multigraph. Finally, $deg(x)$ (respectively, $deg_k(x)$) denotes the number of edges incident to x , (respectively, of color c_k).

Definition 1 : Zz-structure - A zz-structure is an edge-colored multigraph $S = (MG, C, c)$, where $MG = (V, E, f)$, and $\forall x \in V, \forall k = 1, 2, \dots, |C|, deg_k(x) = 0, 1, 2$. Each vertex of a zz-structure is called *zz-cell* and each edge a *zz-link*. The set of isolated vertices is $V_0 = \{x \in V : deg(x) = 0\}$.

An example of a zz-structure related to an art museum is given in Fig. 1. Vertices are paintings, in particular self-portraits. Normal, dotted and thick lines represent different colors. Normal lines group operas of the same artist: in particular, $\{v_1, \dots, v_8\}$ and $\{v_9, \dots, v_{15}\}$ identify, respectively, Van Gogh’s and Gauguin’s self-portraits; dotted lines group operas of the same year (v_1 and v_2 have been painted in 1887, v_5, v_6, v_3, v_9 and v_{10} in 1888, v_4, v_7 and v_{11} in 1889, v_8 and v_{12} in 1890, v_{13} and v_{14} in 1893); finally, thick lines group operas of the same museum (v_6, v_1, v_3 and v_{10} are in the Van Gogh Museum of Amsterdam, while v_2, v_4, v_8, v_{12} and v_{14} are in Musée d’Orsay of Paris).

Dimensions. An alternative way of viewing a zz-structure is a union of subgraphs, each of which contains edges of a unique color.

Proposition 1 Consider a set of colors $C = \{c_1, c_2, \dots, c_{|C|}\}$ and a family of indirect edge-colored graphs $\{D^1, D^2, \dots, D^{|C|}\}$, where $D^k = (V, E^k, f, \{c_k\}, c)$, with $k = 1, \dots, |C|$, is a graph such that: 1) $E^k \neq \emptyset$; 2) $\forall x \in V, deg_k(x) = 0, 1, 2$. Then, $S = \bigcup_{k=1}^{|C|} D^k$ is a zz-structure.

Definition 2 : Dimension - Given a zz-structure $S = \bigcup_{k=1}^{|C|} D^k$, then each graph $D^k, k = 1, \dots, |C|$, is a distinct dimension of S .

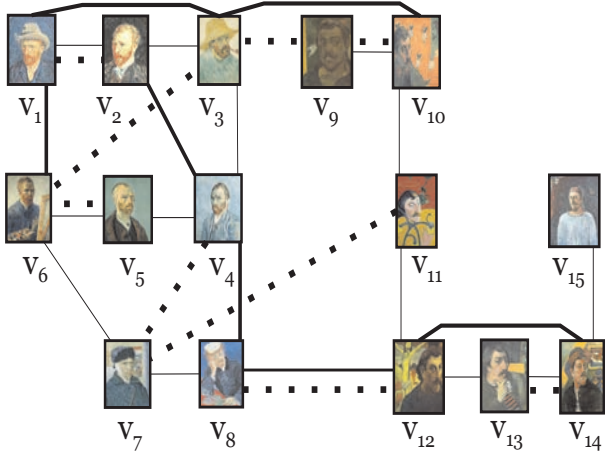


Fig. 1: Van Gogh - Gauguin: self-portraits.

In Fig. 1, we may identify three dimensions: *artist*, *museum* and *year*, respectively represented by normal, thick and dotted lines.

Ranks. A rank is in a particular dimension and it must be a *connected component*.

Definition 3 : Rank - Consider a dimension $D^k = (V, E^k, f, \{c_k\}, c)$, $k = 1, \dots, |C|$ of a *zz-structure* $S = \bigcup_{k=1}^{|C|} D^k$. Then, each of the l_k connected components of D^k is called a rank.

A dimension can contain one (if $l_k = 1$) or more ranks. Moreover, the number l_k of ranks differs in each dimension D^k . In Fig. 1, dimensions *artist* and *museum* contain only two ranks: respectively *van-gogh*, *gauguin* and *amsterdam-van-gogh*, *paris-orsay*, while dimension *year* contains five ranks 1887, 1888, 1889, 1890 and 1893.

Given a rank R_i^k , an alternative way of viewing a dimension is a union of ranks: $D^k = \bigcup_{i=1}^{l_k} R_i^k \cup V_0^k$.

Head and tail cells. If we focus on a vertex x , $R_i^k = \dots x^{-2}x^{-1}xx^{+1}x^{+2} \dots$ is expressed in terms of negward and posward cells of x : x^{-1} is the negward cell of x and x^{+1} the posward cell. We also assume $x^0 = x$. In general x^{-i} (x^{+i}) is a cell at distance i in the negward (posward) direction.

Definition 4 : Headcell and tailcell - Given a rank $R_i^k = (V_i^k, E_i^k, f, \{c_k\}, c)$, a cell x is the headcell of R_i^k iff \exists its posward cell x^{+1} and \nexists its negward cell x^{-1} . Analogously, a cell x is the tailcell of R_i^k iff \exists its negward cell x^{-1} and \nexists its posward cell x^{+1} .

Views. Personalized views are shown to the users, when they choose a vertex as a focus and a set of preferred topics, e.g., type of operas, artist and so on.

We now formally present the concept of a 2-dimensional

view. $x \in R_{(x)}^a$ denotes that $R_{(x)}^a$ is the rank related to x of color c_a .

Definition 5 : H-view - Given a *zz-structure* $S = \bigcup_{k=1}^{|C|} D^k$, where $D^k = \bigcup_{i=1}^{l_k} R_i^k \cup V_0^k$, and where $R_i^k = (V_i^k, E_i^k, f, \{c_k\}, c)$, the *H-view* of size $l = 2m + 1$ and of focus $x \in V = \bigcup_{i=0}^{l_k} V_i^k$, on main vertical dimension D^a and secondary horizontal dimension D^b ($a, b \in \{1, \dots, l_k\}$), is defined as a tree whose embedding in the plane is a partially connected colored $l \times l$ mesh in which:

- the central vertex, in position $((m + 1), (m + 1))$, is the focus x ;
- the horizontal central path (the $m+1$ -th row) from left to right, focussed in vertex $x \in R_{(x)}^b$ is:
 $x^{-g} \dots x^{-1}xx^{+1} \dots x^{+p}$ where $x^s \in R_{(x)}^b$, for $s = -g, \dots, +p$ ($g, p \leq m$).
- for each cell x^s , $s = -g, \dots, +p$, the related vertical path, from top to bottom, is:
 $(x^s)^{-g_s} \dots (x^s)^{-1}x^s(x^s)^{+1} \dots (x^s)^{+p_s}$, where $(x^s)^t \in R_{(x^s)}^a$, for $t = -g_s, \dots, +p_s$ ($g_s, p_s \leq m$).

Intuitively, the *H-view* extracts ranks along the two chosen dimensions. Note that, the name *H-view* comes from the fact that the columns remind the vertical bars in a capital letter H.

As example, consider Fig. 2 that refers to the *zz-structure* of Fig. 1. The chosen dimensions are *artist* and *museum*.

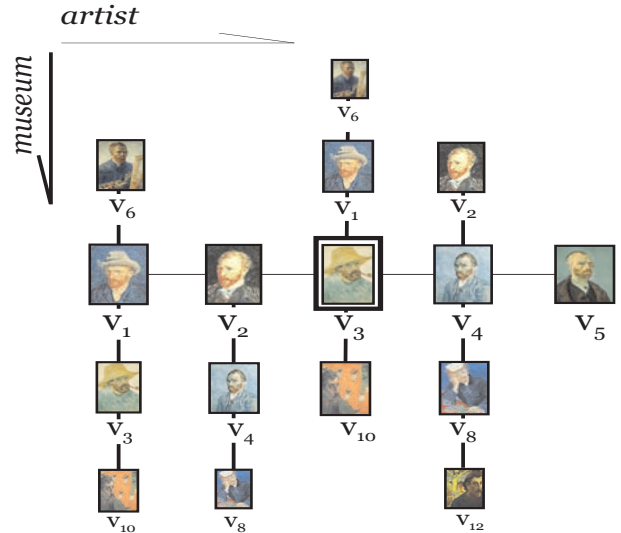


Fig. 2: An *H-view* related to Fig. 1.

The view has size $l = 2m + 1 = 5$, the focus is v_3 , the horizontal central path is $v_3^{-2}v_3^{-1}v_3v_3^{+1}v_3^{+2} = v_1v_2v_3v_4v_5$ ($g, p = 2$). The vertical path related to $v_3^{-1} = v_2$ is $(v_3^{-1})(v_3^{-1})^{+1}(v_3^{-1})^{+2} = v_2v_4v_8$ ($g_s = 0$ and $p_s = 2$), that is $v_3^{-1} = v_2$ is the headcell of the rank as $g_s = 0 < m = 2$.

We now extend the known definition of H to a number $n > 2$ of dimensions. Intuitively, we will build $n - 1$ different H -views, centered in the same focus, with a fixed main dimension and a secondary dimension chosen among the other $n - 1$ dimensions. Formally:

Definition 6 : N-dimensions H-view Given a zz -structure $S = \bigcup_{k=1}^{|C|} D^k$, where $D^k = \bigcup_{i=1}^{l_k} R_i^k \cup V_0^k$, and where $R_i^k = (V_i^k, E_i^k, f, \{c_k\}, c)$, the n -dimensions H -view of size $l = 2m + 1$ and of focus $x \in V = \bigcup_{i=0}^{l_k} V_i^k$, on dimensions D^1, D^2, \dots, D^n is composed of $n - 1$ rectangular H -views, of main dimension D^1 and secondary dimensions $D^i, i = 2, \dots, n$, all centered in the same focus x .

B.A-Space and a-Map

A concept space provides an ontology for a given knowledge domain.

Definition 7 : A-Space - An a -space a -CS is the representation of a concept space in terms of a multi-agent system composed of five types of agents: concept maps, dimensions, ranks, composite and atomic cells.

These five agent classes represent five abstraction levels of the concept space. Concept maps know and directly manipulate dimensions and isolated cells; they include concepts and relationships between concepts, that are organized in dimensions. Dimensions, uniquely identified by their colors, know and manipulate their connected components, i.e., their ranks. Ranks know and coordinate the cells and the links that connect them; composite cells contain concept maps related to more specific topics, and finally atomic cells are primary entities and directly referenced documents.

Agents can be used in order to model concurrent computations. They are organized as a universe of inherently autonomous computational entities, which interact with each other by sending messages and reacting to external stimuli by executing some predefined procedural skills. Various authors have proposed different definitions of agents. In our setting an agent is formally defined as follows:

Definition 8 : Agent - An agent is denoted $A = (Ts, En, Re, Ac)$ where

- Ts represents its **topological structure**;
- $En = \{\eta_1, \eta_2, \dots\}$ defines its **local environment**;
- $Re = \{\rho_1, \rho_2, \dots\}$ is the **finite set of incoming requests**;
- $Ac = \{\alpha_1, \alpha_2, \dots\}$ is the **discrete, finite set of possible actions**.

Ts and En represent the passive part of the agent, while Re and Ac its active part. To give an idea of our agent classes, we define the concept map agent.

Definition 9 : Concept map - An a -map is an concept map agent, denoted a -map = (Ts, En, Re, Ac) where

- $Ts = S$ (see Definition 1 and Proposition 1);
- $En = \{\text{dimensions, isolated-cells, colors, ranks, cells, links, } \dots\}$;
- $Re_S = \{\emptyset\}$, initially;
- $Ac_S = \{\text{return-colors, return-ranks, return-cells, return-links, check-global-orientation, delete}(cell_1, \dots, cell_n, \dots)\}$.

$dimensions, isolated - cells$ and the other data of En_S contain information on the structure. The first four actions of Ac_S are internal to the agent and enable it to derive the colors, ranks, cells and links of the zz -structure. These actions are performed by sending querying messages to $dimensions$ and $isolated-cells$; ranks and used colors are obtained sending a request to the dimension agents, while cells and links references are requested from the dimensions to the rank agents. Other scripts, such as *check-global-orientation* that checks whether local orientation of neighboring cells are consistent, and *delete}(cell_1, \dots, cells_j)*, that deletes a chosen set of cells, are used in dynamic operations illustrated in the next section.

III.DISPLAYING AND CHANGING VIEWS

In this section we will show how a session agent may interact with the users in order to first create and display H -views, and then neighbouring views, i.e., views where the focus is at distance one from the previous one. While displaying these personalized views, the users will also be able to personalize their paths, by deciding to what neighbouring view they will move, what dimension they would like to add/remove and so on. During this navigation process, the users can recreate a setting similar, e.g., to the one of [22], by storing the information they find interesting in an album, in order to create a personal, re-usable workspace.

More precisely, assume that A is the user-author, SA the session agent of Z , D^k is the dimension with color c_k , and for simplicity, $R_{(x)}^k$ is the rank cell x belongs to.

Whenever SA receives from A the message h -view(x, l, D^a, D^b), regarding the displaying of an H -view, centred at x , of size l , using main vertical dimension D^a and secondary horizontal dimension D^b , it sends to x the message $focus(h$ -view, l, D^a, D^b), asking x to assume the role of the focus in the visualization of the H -view. The visualization operation may be divided into two different steps.

Step 1. Wake-up of vertices in the horizontal $m + 1$ -th row, i.e., vertices $x^{-g}, \dots, x^{-1}, x^0 = x, x^{+1}, \dots, x^{+p}$. The focus activates rank $R_{(x)}^b$ that propagates the request to the vertices in the $m + 1$ -th row. These vertices are woken-up and are visualized horizontally, i.e., as *horiz* (see Fig. 3).

Step 2. Propagate the wake-up request from the vertices in the $m + 1$ -th row, to their rank of color c_a , and

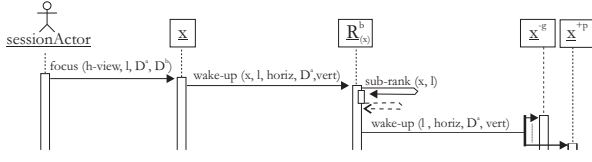


Fig. 3: Computation related to D^b .

from the rank to its vertices at distance at most m from $x^{-g}, \dots, x^{-1}, x^0 = x, x^{+1}, \dots, x^{+p}$, respectively. These vertices are visualized vertically, i.e., as vert (see Fig. 4).

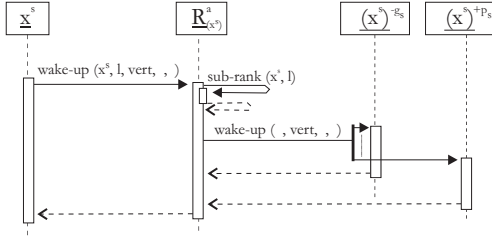


Fig. 4: Computation related to D^a .

Another interesting issue is the visualization of a neighbouring view, e.g., a view where the focus shifts by one position.

Agents may either apply the *sleep* procedure that turns off all the cells that have been woken up, and then start from scratch a new *wake-up* procedure, or try to optimize the computation and turn off only part of the cells and turn on part of others. E.g., whenever the focus moves vertically, the simplest procedure consists of turning off the whole old view and turning on the new one as it follows:

Posward-Vert-Shift-h-view($(x^0), (x^0)^{+1}, l, D^a, D^b$)

1. send-now (*sleep*($(x^0), l, horiz, D^a, vert$)) to $R_{(x^0)}^b$
2. send-now (*focus*($h\text{-view}, l, D^a, D^b$)) to $(x^0)^{+1}$

Note that the focus is shifted from x^0 to $(x^0)^{+1}$: the cells that do not change are the $(l - 1)$ placed vertically.

Now, we assume that the focus moves horizontally, i.e., from x to x^{+1} . Consider, e.g., Fig. 1 and move the focus from $x = v_3$ to $x^{+1} = v_4$. Fig. 5 shows the new view.

In this case, an optimized procedure, called Posward-Horiz-Shift-h-view(x, x^{+1}, l, D^a, D^b), is activated by *SA*. The procedure has to turn off the vertical column related to vertex $x^{-(l-1)/2}$ (lines 1-2), if it exists, and has to turn on the column related to vertex $x^{+(l-1)/2+1}$, given that vertex $x^{+(l-1)/2}$ exists (lines 3-4). The first operation is analogous to the one of Fig. 4 with vertex x^s substituted by vertex x^{-g} and the script *wake-up* with the script *sleep*, with the same arguments. The second operation (lines 3-4)

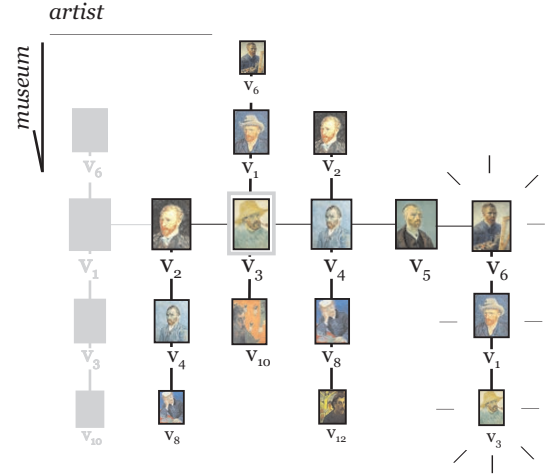


Fig. 5: Horizontal shift of focus.

Posward-Horiz-Shift-h-view(x, x^{+1}, l, D^a, D^b)

1. **if** $g = (l - 1)/2 < \text{vertex } x^{-(l-1)/2} \text{ exists} >$
2. **then** send-now (*sleep*($l, horiz, D^a, vert$)) to x^{-g}
< the $(l - 1)/2$ -th column on the left is turned off >
3. **if** $p = (l - 1)/2 < \text{vertex } x^{+(l-1)/2} \text{ exists} >$
4. **then** send-now (*wake-up*($l, horiz, D^a, vert$)) to $x^{+(p+1)}$
< the $((l - 1)/2) + 1$ -th column on the right is turned on >
5. *update - view*

is similar but it has to be applied to vertex $x^{+(p+1)}$ using the script *wake-up*. Finally, *SA* has to update its view (line 5).

Displaying n-dimensions H-views. In this section we will show how to extend the technique of the previous section and thus how the *SA* may display n-dimensions *H*-views.

The technique is very similar. For example, for the n -dimensions *H*-view the *SA* contacts the focus x with message *focus*($n\text{-dim-h-view}, l, D^1, \dots, D^n$). Since an n -dimensions *H*-view on main dimension D^1 and secondary dimensions D^2, \dots, D^n is composed of $n - 1$ different *H*-views on main dimension D^1 and secondary dimension D^i , for $i = 2, \dots, n$, the visualization operation is divided into two different steps.

Step 1. *Wake-up the vertices in the secondary dimensions of each H-view centered in x , i.e., of dimensions D^2, D^3, \dots, D^n . The focus x sends, in multicasting to ranks $R_{(x)}^i$ ($i = 2, \dots, n$), message *wake-up*($x, l, plane, D^1, vert$).*

*The output of this script is the computation of sub-ranks (x, l) , i.e., the sub-ranks of size l centered in x in dimension $D^i(x)$, for $i = 2, 3, \dots, n$. Then, each $R_{(x)}^i$, $i = 2, 3, \dots, n$ sends message *wake-up*($l, plane, D^1, vert$), to all its ver-*

tices.

Step 2. Similar to the one of the 2-dimensions case respectively applied to the vertices in ranks $R_{(x)}^i$, for $i = 2, 3, \dots, n$.

The technique for the n -dimensions I -view is very similar. In the case of the 3-dimensions extended H -view the SA contacts the focus x with message $focus(3-ext-h-view, l, D^1, D^2, D^3)$. The focus, as in a 2-dimensions H -view, activates rank $R_{(x)}^3$ in order to compute a 2-dimensions H -view with main dimension D^2 and secondary dimension D^3 . The activated vertices x^{-g}, \dots, x^{+p} of $R_{(x)}^3$, while executing the standard second step of the wake-up procedure for the H -view, will also act as focus and activate a new procedure for a new 2-dimensions H -view of size l on on main dimension D^1 and secondary dimension D^2 .

IV.CONCLUSION

In this paper we have proposed a multi-agent adaptive system to support tours of virtual museums. We have shown how this system, based on an extended zz-structure model, can be used to display personalized user views and to create personalized and adaptive paths for users. As future work we want to concentrate on the preliminary part of our work, i.e., on the study of good techniques to identify the collection of “interesting” pages for specific users, based on their preferences and characteristics.

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