DYNAMIC VISUALIZATION OF CONCEPT MAPS: FIVE DIFFERENT MODELS

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Abstract. The importance of the conceptual maps' development and of the software instruments that set them up in phase of composition and utilization, in the context of e-learning, derives evidently from their connection with the thematic of the knowledge's ontologic structuring: the representation of the elements and relations that constitute an ontological frame has to be founded on the graphs' theory, linking the elements to the nodes and the relations to arcs, in relation to the rules defined from J.Novak (1984). The conceptual maps, however, are not configurable simply as products of the concept's evolution of contents' indexing, from which they differ structurally because they are not limited to the representation only of the hierarchical relations, since their role is dilated from the knowledge's organizational function to the transmissional function, assuming a specific task into the explicitness of the cognitive context that involves an intrinsic value about didactics, a various and ulterior task regarding the navigation support. In the relationship between knowledge's organized aggregation and representation, moreover, it's evident the requirement to automate the reconstruction of conceptual maps, using algorithmic models, owing to simplify the modalities of structural modification through a direct connection with information integrated in a database management system, and in the meantime to be able to use multiple shapes of representation and observation corners.

1 Introduction

CARID's research (Center of Athenaeum for Research, Didactic Innovation and Distance Instruction, University of Ferrara) has produced five models of automatic composition of conceptual maps, some of them rebuilding from each of the concepts that compose the cognitive contexts, other rebuilding from a predefined or randomized distribution of the concepts in the documental space, some characterized from a bidimensional graphic, other three-dimensional ones susceptible, as virtual objects, of rotations and variations of visualization corner. These models, working on the web, capture the data from a DBMS and compose images of maps visible in the browser and sensitive to the input events; therefore these maps can support navigation's functions or didactic interaction, both in SVG format, vectorial graphic standard deriving from XML and produced from Consortium W3C, and inside a Java applet. In the context of the formative processes managed from CARID, their use is connected particularly with the functionalities of structured forum and organized aggregation of documents and Learning Objects that support the didactic activity.

Inside e-learning environments, knowledge's representation of didactic domains using concept maps is an effective way to support context's navigation and documents' organisation: concept maps assume essentially the previous role of books' indexes, a role of domain's structural representation and guide to knowledge research and discovery for students. Therefore, the use of specific concept mapping tools, such as CmapTools (Cañas & Lott, 2003, Cañas et al. 2004), allows to link documents to the map's nodes, which become repositories of knowledge, and to point out relations (and to trace didactic paths) using map's arcs. A particular emphasis on the role of map's arcs proceed from the development of domains' ontologies and their representation: in order to explain and deepen a context's structure, relations' tissue becomes gradually more important than nodes' definition, and concept maps' potentiality becomes significantly more effective than other knowledge's representation methods or instruments, which don't define and don't label the arcs-relations, such as mind maps or indexes.

But the evolution toward domain's ontologic representation and structural deepening converts concept maps from enhanced and empowered indexes, which support structures, to documents, which can support both structures and contents: a concept map can be not only a well-organised structure which indexes repositories of documents, or a navigation guide among the context's arguments, but also a real knowledge support, a real learning object.

Carid experience demonstrates that the use of conceptual maps is placed in middle position between e-learning and knowledge management, it is indeed the conjunction ring, since it allows not only knowledge's structured aggregation, but also negotiation of meaning and relations between the customers of the map: in other words, the conceptual map is transformed from shared structure to shared document, that is object of knowledge, and it is shaped as reference instrument both for the didactic interaction and for the explicitness of tacit knowledge.
2 Conceptual maps' representation through dynamic rebuilding

The role of the conceptual maps in the e-learning, and in a more generalized manner in the knowledge management, is not limited to the macrostructure's representation of cognitive contexts (that is to the support, in more evolved shape, of the same function that previously was covered from the hierarchical index), but extends its role in other directions, and specifically:

1. the representation of large and complex structures (hundreds or thousands of nodes), that is characterized from many non-hierarchical interconnections;
2. the enrichment and the progressive deepening of the structures, and the negotiation of meaning, during the collaborative activity of the interlocutors of e-learning process, activity of knowledge's organized aggregation, from a constructivist point of view;
3. the unification, in the context of the same map, of both the aspects of context's representation and knowledge's explicitness, that is the use of the map like instrument both of structuring and of writing the contents.

In these multiple functions, an important improvement in the use of the conceptual maps comes from their transformation from dynamic to static documents, that is from documents produced through direct participation of the authors, facilitated from generic or specific instruments of graphic editing, to reconstructed documents capturing, from a database or a structured document, the information connected to the concepts and the relations to be represented, and reconstructing their graphical aspect using software procedures founded on particular algorithms.

The dynamisation of the concept map implies also the polymorphism, that is the transformation from single document, as a static one, to set of potential documents, whose differentiation derives from the options permitted from the software procedures, which for example:

- the possibility to implement in the algorithm of reconstruction the distribution's randomisation of the nodes, recreating to each request a different map's image;
- the possibility to reconstruct the map with rigorous procedures of a category that we can define "proximal development", i.e. characterized from the successive placement of the nodes in function of the position of the first one, procedures that always regenerate, starting from a specific node, the same design, but that generate various map's images based on the choice of the first node to place;
- the possibility to reconstruct the map according to "gravitational development" procedures, in which the first nodes' collocation, randomized or collected in document's center (nearly a simulation of "big bang"), balances and progressively stabilizes depending on the characteristics of connections that tie them (this modality obviously need the definition, inside the database, of intensity of every relation between two concepts);
- the possibility to implement, in the map visualization's instrument, functionalities of bidimensional or three-dimensional animation (mouse-driven animation), which permit its vision from different observation corners;
- the possibility to use in ergonomic way also maps extremely great for number of nodes and arcs, using functionalities as zoom or virtual magnifying lens;
- even the use of the background as third graphical element of the conceptual map, as not neutral but being able to support information using color or pattern's variations (Carid is still experimenting the use of background color in order to define intrinsic characters of the map, such as the interconnection's level of content's elements and the maps' tendency to be aleatory or scale-free, or extrinsic ones, such as separation of the map in zones based on contextualisation's concepts parameters).

In order to realize the potentialities of conceptual maps' dynamics reconstruction, the research carried out from Carid has originated the following models of map's representation:

1. “proximal development in concentric circles” graph
2. “proximal development in hierarchical circles” graph
3. “proximal development three-dimensional rotable conic structure” graph
4. “gravitational development three-dimensional initial random distribution rotable structure” graph
5. “gravitational development three-dimensional big-bang rebuilding rotable structure” graph

186
2.1 “Proximal development in concentric circles” graph

A procedure of rigorous construction of graph's figure is founded on the concentric circles, that permit nodes' distribution depending on their distance from an original node. The choice of the “root” node (in order to use a typical terminology of the tree structure) is the obliged step for this rigorous graphical reconstruction.

Determined the root node, the procedure continues with the distribution of the nodes connected on a circumference whose center is the same root node, afterwards reiterates the algorithm distributing, on a circumference concentric to the previous one, the nodes connected to the nodes situated on the first circumference, so that the links are dilated in radial matter (obviously, the nodes connected to a node situated north of the first...
The procedure tends to expand itself in relation to the number of concentric circles necessary to the representation of all the nodes: the detailed vision of this map needs therefore the functionalities of scrolling and paneling.

This method, that can also be used for the representation of a tree structure, offers a possibility that the index does not permit: in the case in which one of the nodes that would be placed on circumference x, owing to its connection to one of the nodes of the x-1, are already present in the circumference y, this node is not placed on x, but the connection between the two nodes, placed on the circumferences x-1 and y, is traced. In this way all the connections can be evidenced, moreover the concentric circumferences show the connection's distance (degree), as number of intermediate nodes, between each node and the root node, at least the procedure is rigorous, automatizable, and reproduceable starting from whichever node: it is possible therefore to generate as many various graphs as are the nodes, and this is a way in order to qualitatively improve the information's expression on the structure of a content.

The dynamic model realized by Carid has been developed in Java environment: the map is produced from a servlet that reconstructs an image in the structured markup language SVG, supporting vector graphic.

2.2 “Proximal development in hierarchical circles” graph

A second rigorous procedure for graphs' reconstruction, which supports an effective communication, is based on the reiteration of the context's scheme of each node.
The algorithm starts, analogous to the “concentric circles” procedure, from a root node around which locates, on a circumference, the nodes relative to arguments connected to the root, linking them to this using radial segments, and continues considering each node of the circumference as central node of its system, and constructing round it a second circumference, of smaller diameter than first, locating the connected nodes and tracing the radial segments.

Unlike the previous scheme (but both the options are possible in both the schemes), when a B node already present in the structure appears, among the nodes connected to the node A (that is when a link of not hierarchical type between two nodes is evidenced), algorithm doesn't trace a segment between A and B, but a second B node is designed on the circumference round to A, evidencing its nature of "alias" regarding the first B with a graphical characteristic, and connecting it to this: in this way, the transversal links connect always two different positions referred to the same argument, contributing to clarify the relations' structure.

In opposition to the concentric circles graph, the diameter of the hierarchical circles graph decreases at the increasing of the distance from the root node, consequently, this model does not tend to expand itself when the number of nodes and arcs increases, unlike the previous one, but it tends to increase the concentration of the nodes in the surface unit: therefore the detailed vision of this map is based on the zoom's functionality.

This representation permits to distinguish from the topic's concept, represented by the node, the area's concept, represented by the gray circle, that encircles the node, and which shows the child-nodes on its circumference: the area can be used like representation of a graph's part, composed from a node and its descendants (its sons, sons of sons etc), and this potentiality reveals its utility in the context of particular activities (for example, in e-learning, the vision of all the contributions, or all the participations, relative to a topic and to the group of topics that derive from that).

Also this dynamic model realized from Carid has been developed in Java environment, and the image is reconstructed in language SVG.

2.3 “Proximal development three-dimensional rotatable conic structure” graph

The algorithmic reconstruction of the conic graph is essentially an intermediate modality between the reconstructions of “hierarchical circles” and “concentric circles” graphs: subsequently to the development of the first circumference around the central node and to the location of the nodes connected to this, the image increases through the calculation of the circumferences of child-nodes' expansion, and the location of the derived nodes in the external semi-circumferences. The fundamental aspect of this reconstruction is the introduction of the third dimension: to each level of distance from the root node the depth of the image increases of a fixed largeness, generating the design of a conic shape.

This distribution implies, in the case of maps composed by many nodes and many relations, an increase of the complexity so fast as to get the image quickly unreadable, because of the superimpositions of nodes, arcs and labels. But the insertion of the tridimensionalisation is motivated from a functional issue, necessarily connected to this graphical model, that exceeds and eliminates the problem of readability: conic graph's vision has to be supported, using adapted software instruments, by the possibility to control the optical corner, that is to animate rotation in all the directions with mouse-driven events.

The structuring of the image of this map is realized inside a Java applet, optimal technology in order to permit the complex rendering software of the conic graph. In the sphere of usability, a similar instrument considerably expands the expressive potentialities of the conceptual map, conferring it also a ludic value, connected to the three-dimensional animation, that catalyzes the attention of the customers not only on the relations and topics' net that the map composes, but also on the shape of the same map. This consideration requests a deeper analysis, which in this paper we just point out, because the shape of a complex concept map can be interpreted like ulterior information relative to the cognitive context: about it, it is opportune to mention the theory of the scale-free nets (Barabasi, 2004), that analyzes the incidence between elements and relations on a net.
2.4 “Gravitational development three-dimensional initial random distribution rotable structure” graph

The structure of the conceptual maps to proximal development repeats constant outlines (concentric circles, hierarchical circles, cone) that tend to underline the net of relations according to a vision that confers to a single node the source's role, or root: the fact that this node is, in the previous models, interchanging with all the others, renders the maps polymorphic but it doesn't overcome the inability to prescind from "one" origin.
It's not simple to imagine an automatic distribution of the concept map's nodes that resolves the problem of the proximal development and the nodes' location in function of a first one "pivot", but this difficulty can effectively be overcome if a degree of intensity, or attraction, between the nodes connected by these relations, is associated to the same relations, using a value, a couple of values or with other requests of quantitative or qualitative character.

Starting from this consideration, and adding to the informative base for the dynamics reconstruction of the conceptual maps an indicative value, for every single relation, of the degree of attraction between two concepts, Carid's research has produced a software model, always in technology Java-applet, that distributes originally, in the document's space, the nodes according to an accidental disposition, and subsequently animates the movement up to an acceptable configuration.

The animation considers tendential distance between the connected nodes, calculated on the basis of attraction degree, and, using an algorithm based on multithreading, simulates an individual nodes' behavior, that move themselves contemporaly in the document's space, as function of resultant's calculation of a system of forces derived by the relations that each node has with the nodes connected to itself: synthetically, the algorithm simulates the application of a species of "gravitation" in the space occupied by the nodes.

The activity of the algorithmic threads that move the nodes finishes when the outline has got up to an equilibrium degree, judged sufficient and strongly improveable, that is when the differences between the distances among the connected nodes and the tendential reference's distances are inside a acceptability range.

The documents' space should be three-dimensionable, in order to permit a fast achievement of this point of equilibrium and a satisfying outcome of the algorithm's application, as for the cone maps: applying therefore the same functionality of a mouse-event interception, also the "gravitational development" map is rotatable.

In this map the division between the maps and the indices is concluded, because each reference to a possible hierarchy between the node-concepts disappears, and the characteristic of polymorphism get extreme, in function of the initial randomized nodes' disposition: it derives, however, the impossibility to reconstruct the identical configuration as a result of the repetition of the algorithmic procedure on the same base of data.

2.5 “Gravitational development three-dimensional big-bang rebuilding rotatable structure” graph

This model of map reconstruction, still in phase of development, does not differ, as far as final kind of representation and algorithm of gravitational equilibrium search, from the previous one, but on one side it reduces the polymorphic potentialities, on the other side it overcomes the impossibility of reconstruction's precise repetition, bypassing the randomisation's request of initial distribution of nodes.

The nodes, in this model, are originally placed in the center of the document's space, and the multithreaded algorithm, which reallocates each node in function of the resultant of the attractions with the connected nodes, simulates visually, in this case, the effect of the initial "big bang" of the universe. The distribution of the nodes to the achievement of the equilibrium point, because not subordinated to the casuality of initial location, is precisely rebuildable, repeating the algorithmic procedure, in the same shape.

3 Conclusions

The aspect of greater interest in the research inherent to the dynamic concept maps' reconstruction is represented from the possibility to operate a choice of the composition model, and consequently of the used algorithm, in function of the peculiarity of the cognitive sphere and the use's context of the realized communication's instrument.

The representation of a social network, characterized from a high number of nodes and arcs and presumably from a structure of "scale free" type (Barabasi, 1999), is better expressed therefore from a three-dimensional structure and gravitational development map, that does not privilege a “root” node and can offer uncountable angles of visualization and multiple levels of image's magnifying.
On the contrary, the representation of an ontological sphere not particularly complex, and finalized to support the exploration of a disciplinary cognitive context in a didactic environment, as for example a course distributed in e-learning modality, will find a better graphical release using a proximal development for concentric circles or hierarchical circles map, simpler and immediate to use even for users not enough bent to using these instruments.

But beyond these methodological and technological observations on the use of the concept maps, it is necessary also to emphasize the importance of their dynamic reconstruction for the representation of contexts that, even if characterized by imposing masses of data and by frequent updates, need a multidimensional, graphical representation, observable to various detail levels and constantly refreshable in real time: the use of the concept map like image that transmit contents is considerably permeating the communication, and therefore the culture, of the actual age, and is extending its use in extremely diversified sectors.

It derives, at least, the necessity of progressively improve and to share the modalities of concept maps' dynamic reconstruction from the point of view of the progressive differentiation of a kind of polymorphic, specific writing for digital technologies and the web, that, clearly separating the aspect of information conservation from the aspect of its representation, can be shaped in function of the expressed contents' characteristics and the users.

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