Graphical representation of the web of knowledge. Analyzing the local hierarchies and the global network of connections in a specialized encyclopedia.

Daniele Besomi

Centre Recherches Interdisciplinaires Walras Pareto, University of Lausanne
E-mail: daniele.besomi@unil.ch

Abstract

Encyclopedias were originally intended to present knowledge in an organized way. Historically, this was often attempted by means of graphical metaphors, but strangely enough the advent of IT and the Internet seems to have hindered, rather than boosted, the original aspiration. This paper presents a tool that aims to visually place encyclopedic entries in their context. It takes the form of a working sample of a specialized 'En-cycle-pedia' concerned with the theories of economic cycles and crises, addressed to a learned readership. Its main feature is the representation of its articles as nodes of a directed graph, dynamically centred around the article under examination, linked by structural relationships representing different kinds of connections between articles (e.g., analytical or methodological), internal cross-references, and bibliographical references. The graph is customizable, as typologies of links and articles to be included can be selected by the user. Besides illustrating the relational structure of the encyclopedic contents, the graph also acts as a navigation tool. Moreover, users can experiment by editing both articles and the system of links, thereby turning the encyclopedia into an active analytical tool that permits the reader to compare different interpretations and their implications and premises.

Keywords: knowledge organization; Diderot & d'Alembert's *Encyclopédie*; connected graph as rendition of connections between encyclopedic articles; macrostructural graphical representation.

1. Introduction

This paper propounds an encyclopedic approach that descends from a long tradition of thought concerning the organization of knowledge, in particular with the aid of graphical metaphors and tools. Before describing the apparatus in section 3, I will briefly recall some relevant reflections on these issues by classical encyclopedists (especially Diderot and d'Alembert) and their recent reappraisal in an epistemological perspective.

2. Graphical metaphors for the organization of knowledge

The etymology of the word indicates that an encyclopedia is a 'circle of learning' or a 'chain of knowledge'. Thus, encyclopedias are meant not only to collect and present information, but to organize knowledge and order it in some way. Early encyclopedists often tackled this problem in graphical terms reflecting the epistemology that guides the chosen organization form. Medieval encyclopedias, such as Vincent de Bouvais's *Speculum Majus* (1240–1260), the 'great mirror' consisting

in a *Speculum naturale*, a *Speculum doctrinale* and a *Speculum historiale*, or Honorius Augustodunensis's *Imago Mundi* (12th century), referred to the image of the mirror: the book discovers and reflects the order of nature and human affairs as created by God (Clark, 1992: 99–101; Van Ewijk, 2011: 208). Later, stairways and ladders arranged bodies in order of increasing perfection, describing both a path of improvement for man and the structure of knowledge, as exemplified by Lull's *Liber de ascensu et decensu intellectus* (written in 1305 but published in 1512) and Carolus Bovillus's *Liber de sapiente* (Paris, 1510) (Quaggiotto, 2011: 5–7). With the Renaissance, and in particular with Francis Bacon's classification of all human knowledge, the image of the tree served as an organizing metaphor for knowledge, following the order of reason rather than the order of the world.[1] Chamber's *Cyclopædia*, for instance, incorporated a table showing how knowledge branches from a common stock, depicting how its several parts relate to each other (Chambers, 1728, vol. 1: ii); similarly, Diderot and d'Alembert's *Encyclopédie* portrayed a 'tree of knowledge' (1751, vol. 1: xlvii–liii), likewise represented as a table and later illustrated by means of a tree by Roth in 1769. The plan of the *encyclopédistes*, however, was more radical: while depicting the tree as a key for the organization of the sciences, they also rejected a systematic approach that fixed knowledge into an unchangeable scheme, and used the tree and the system of cross-referencing as a guideline capable of encompassing science in its dynamics (see Salsano, 1977; Zimmer, 2009; Yeo, 2001).

As a reaction to the form of 'reasoned dictionary' adopted by the *Encyclopédie*, with its revolutionary implications, there was for a while a return to a more systematic approach. In particular, the methodic (unfinished) *Encyclopaedia Metropolitana* and the early editions of the *Britannica*, which introduced within the alphabetic sequence long essays on about 45 principal subjects, each of which was supported by 30 more lengthy articles to which the shorter articles on specific subjects referred. During most of the nineteenth century, however, encyclopedias largely turned into repositories of knowledge. Only later in the twentieth century did the older encyclopedic spirit enjoy a revival. However, the problem of the organization of knowledge and of the relationship between different branches of science gave way to the related, but by no means identical, issue of reconstructing the unity of science fragmented by the breaking down of subjects into semi-monographic articles of manageable size arranged in alphabetical, rather than thematic, order. As summarized in the 'Encyclopedia' article of *Britannica* "Even a brief survey of encyclopaedia publishing during the second half of the 20th century is enough to make it clear that ... a number of modern encyclopaedists [are] concerned with the importance of making a restatement of the unity of knowledge and of the consequent interdependence of its parts. Though most encyclopaedists were willing to accept the

[1] Besides his stairway, Lullus also produced an *arbor scientiae*, which, however, identifed the order of knowledge with the order of creation (Salsano, 1977: p. 35).

essential reference-book function of encyclopaedias and the role of an alphabetical organization in carrying out that function, they became increasingly disturbed about the emphasis on the fragmentation of knowledge that such a function and such an organization encouraged. A number looked for ways of enhancing the educational function of encyclopaedias by reclaiming for them some of the values of the classified or topical organizations of earlier history" (Collson and Preece, 2013).

In its 15th edition (1974), *Britannica* carried a *Micropaedia*, with short definitions, a *Macropaedia*, or 'knowledge in depth', with longer entries, and a *Propaedia*, a topical guide to the opus, in its bid to be at once a reference work and an instrument of learning. The *Encyclopaedia Universalis* (1968–75) also focused more on science as a problem-solving activity than on the organized retrieval of results, and presented a series of *tableaux de relations* where it suggested by means of convoluted graphs different kinds of relationships (formal, methodological, ...) between concepts, some of which rather loose but evocative of connections worth exploring, beyond disciplinary boundaries. The *Enciclopedia Einaudi* explicitly declared its role as organizing knowledge rather than acting as a storehouse of notions, and decided to focus on a limited number of "concepts capable of organizing the knowledge and the life of mankind as a whole that ... revolve around very general problems" (Einaudi, 1977: xvi, xvii and xiii). It also offered in graphical form a grouping of entries representing 'reading areas', based on a logical reconstruction of the network of relationships between entries.

This was all very promising, but instead of being further elaborated by means of the possibilities offered by IT and the Internet, in the web versions of *Britannica* and *Universalis* all attempts to show the intricate relationships between branches of knowledge have been ditched altogether. In its most up-to-date entry on 'Encyclopaedia', *Britannica* is rather reticent on Internet encyclopedias and itself effaces any trace of the *Outline of knowledge* of the 15th edition. The omologous article in *Universalis* explicitly worries that "IT technologies and the internet are destructors of the encyclopedic spirit".[2] The Internet version of *Universalis*, however, offers at least a thematic tree-index categorized by discipline branching into three further sub-levels.

[2]"Il est évident que l'existence d'Internet, où d'autres encyclopédies se créent et se créeront, où celles du passé peuvent être consultées en ligne, va dans le sens du projet encyclopédique de l'humanité, entrée dans l'ère du clavier. Mais l'instantanéité de l'électron, rendant accessible une accumulation de données et de liens jamais atteinte, ne donne aucune garantie de valeur, d'ordre ni de hiérarchie. En cela, l'informatique et l'Internet sont destructeurs de l'esprit encyclopédique incarné par Aristote, saint Augustin, Bacon, Locke, Leibniz, Condillac, Hegel, Coleridge ou Auguste Comte (pour s'en tenir à l'Occident), ce qui est au moins préoccupant. Dans *encyclopédie*, le 'cycle', le cercle est devenu sans limite, son centre étant partout et sa circonférence nulle part, et la 'pédagogie' que suscite *paideia* relève du self-service le plus hâtif. En même temps, la diffusion du savoir encyclopédique s'est largement accrue. Le présent nous lègue ce paradoxe; l'avenir ne le résoudra pas facilement" (Rey, 2013).

Even the Internet encyclopedia *par excellence*, Wikipedia, is rather modest in its claims regarding the organization of its materials – which is not surprising, given its essentially anarchic format. In its article on 'Encyclopedia', it recalls that "Some systematic method of organization is essential to making an encyclopedia usable as a work of reference. There have historically been two main methods of organizing printed encyclopedias: the alphabetical method (consisting of a number of separate articles, organised in alphabetical order), or organization by hierarchical categories. The former method is today the most common by far, especially for general works. The epigraph from Horace on the title page of the 18th century Encyclopédie suggests the importance of the structure of an encyclopedia: 'What grace may be added to commonplace matters by the power of order and connection.'" The article continues by claiming that "The fluidity of electronic media, however, allows new possibilities for multiple methods of organization of the same content. Further, electronic media offer previously unimaginable capabilities for search, indexing and cross reference". However, in presenting the influence of the Internet on encyclopedias it only stresses its "ever-increasing effect on the collection, verification, summation, and presentation of information of all kinds" and that "On-line encyclopedias offer the additional advantage of being dynamic: new information can be presented almost immediately, rather than waiting for the next release of a static format, as with a disk- or paper-based publication. The 21st century has seen the dominance of wikis as popular encyclopedias, including Wikipedia among many others" (Wikipedia, 2013). In truth, Wikipedia offers a number of cladistic 'portals' aiming at systematizing some fields; but it is precisely in some of these portals (e.g., business and economics) that the absence of co-ordination by an encyclopedist is most notable.

2.1 Trees vs. networks

Meanwhile, however, some of the issues raised by Diderot and d'Alembert have been taken up in the literature in an epistemological perspective. Umberto Eco noted that the *Philosophes* themselves made the tree metaphor inadequate (Eco, 1984: 80–84; see also Cernuschi, 1996; Bates, 2002; Chauderlot, 2002; Zimmer, 2009: 104; and Weigel, 2013: §21). While their *Système figuré des connoissances humaines* summarized the "genealogy and the filiation of the parts of our knowledge"[3] and introduced the examination of "the causes that brought the various branches of our knowledge into being, and the characteristics that distinguish them" (d'Alembert, 1751, Eng. transl.: 5), they were fully aware that the image of the "encyclopedic tree" would be "disfigured, indeed utterly destroyed" if one were to take into account the actual intricacies, discontinuities, obstacles, U-turns and crossroads of thought processes. A more appropriate metaphor would be the labyrinth, to reflect the tortuous roads followed by the intellect, or the map (ibid.: 46–47). The encyclopedic

[3] D'Alembert described the *Encyclopédie*'s "genealogical or encyclopedic tree" as gathering "the various branches of knowledge together under a single point of view and [serving] to indicate their origin and their relationships to one another" (1751: 45–46).

tree provides no more than "a kind of world map", where only "the principal countries, their position and their mutual dependency, the road that leads directly from one to the other" are shown (ibid.: 47). Individual articles are placed on such a world map by means of a direct reference to the discipline(s) to which they pertain.[4] The intricacies are shown by means of cross-references to other articles. D'Alembert is anxious to stress that "such references in this Dictionary are unusual in that they serve principally to indicate the connections of the materials, whereas in other works of this type, they are intended only to elucidate one article by another" (ibid.: 57). Diderot goes further, explaining that there are four kinds of links: explanatory ('verbal') references; the 'material references' that indicate close and distant relationships between objects, establishing analogies and consequences or, on the contrary, denying them; the 'references of genius' that suggest "new speculative truths" by imagining "fanciful conjectures" and drawing suggestive connections between distant fields; and the 'satirical or epigrammatic references' that deride "certain kinds of foolishness" and prejudices (Diderot, 1755: 642–644; see Anderson, 1986: 922–926 and 1990: Ch. 3; Zimmer, 2009; and Le Ru, 2002). The graphical representation by means of the tree image, with its linear branching, is naturally unsuitable to map these cross-references, for which the encyclopedists' metaphor of the map is surely better fitted, as are the modern analogies of the rhizome (Eco) or the network.

A related issue discussed by the *philosophes* concerns the different understandings of phenomena or concepts according to the point of view from which they are examined. D'Alembert stressed that "as, in the case of the general maps of the globe we inhabit, objects will be near or far and will have different appearances according to the vantage point at which the eye is placed by the geographer constructing the map, likewise the form of the encyclopedic tree will depend on the vantage point one assumes in viewing the universe of letters. Thus one can create as many different systems of human knowledge as there are world maps having different projections, and each one of these systems might even have some particular advantage possessed by none of the others. There are hardly any scholars who do not readily assume that their own science is at the center of all the rest, somewhat in the way that the first men placed themselves at the center of the world, persuaded that the universe was made for them. Viewed with a philosophical eye, the claim of several of these scholars could perhaps be justified by rather good reasons, quite aside from self-esteem" (d'Alembert, 1751: 48).

Diderot similarly stated that "In general the description of a machine can begin with any part at all. The larger and more complicated the machine, the more connections there are between its parts, the less we know these connections, the more different perspectives for description there will be. What then if the machine is in every sense

[4] The article 'Eau' (Water), for instance, refers to various domains including physics, medicine, hydraulics, pharmacy and chemistry.

infinite; if we are speaking of the real universe and the intelligible universe, or a work which is like the imprint of both? Either the real or the intelligible universe has infinite points of view from which it can be represented, and the possible systems of human knowledge are as numerous as those points of view" (Diderot, 1755).

This multiplicity of paths concerns both the encyclopedists and the readers. The very 'world map' of the *Système figuré des connoissances humaines* is an arbitrary construction, for other systems of classification could have been devised (d'Alembert, 1751: 49–50), while every local map – that is, any individual article in the *Encyclopédie* – offers many cross references to other articles, thus building innumerable possible paths that cannot be followed simultaneously, so that different minds will chose different routes at each crossroad (ibid.: 47).

3. The En-cycle-pedia: Connections between entries as a dynamically constructed graph

Constrained by the paper medium, Diderot and d'Alembert could hardly explore in full the implications of the challenge they set themselves. As we have seen, the approach of the *encyclopédistes* has remained largely underinvestigated by later encyclopedists, notwithstanding the increased potential opened by electronic editing and the Internet.[5]It has, however, inspired the construction of the encyclopedic scheme presented here.

3.1 A graphical tool for organizing knowledge

This En-cycle-pedia [6] offers a tool for organizing knowledge, in the form of dynamically constructed graphs built around the article being read that places it in its context. Articles are represented as nodes, connected by directed arrows standing for various kinds of links between them. The graph, besides showing the paths branching off from each node, also acts as a navigation tool, each node being an active hyperlink redirecting to the corresponding article to which a new graph is associated. The tool is exemplified by means of a sample of a specialized encyclopedic dictionary concerned with the theories of economic cycles and crises, offering for the time being about 80 articles. The choice of the topic was determined by the fact that the subject is circumscribed and that the propounder of this project has sufficient expertise in the field to have formed an epistemological view as to its representation. The entries are drawn from his previously published writings, with the double purpose of illustrating the working of the encyclopedic structure and of (literally) connecting the dots between the various topics of his research: hence the name En-cycle-pedia,

[5] The system of cross-references in the *Encyclopédie*, however, has been studied and represented by a graph depicting the connections between categories of entries (but not article by article): Blanchard and Olsen, 2002.

[6] www.en-cycle-pedia.ch. Access is not yet public as the work is still in progress, but readers can test the tool by entering the following: ID: elex.user, password: elex.user.

emphasizing at once the focus on cycles and the encircling scope of the project. The chosen target audience consists of graduate students and researchers. Such an expert readership has been selected in order to experiment with a large number of variables in the graph, to which corresponds some complexity in the management of control parameters. The objective is to explore the possibilities opened by the tool; simplifications for a more generic audience can be introduced at any time.

3.2 Structure and cross-references

Like the *Encyclopédie*, the En-cycle-pedia starts from a general structure representing the 'big picture' resulting from the encyclopedist's understanding of the En-cycle-pedia's subject matter. This is constructed by dynamically linking together, one by one, the various articles in a hierarchical, or genealogical, order. The resulting graph thus shows how the encyclopedist orders knowledge on the basis of his interpretation of the connections between individual topics within the general scheme.

There are, however, a number of differences between such an arrangement and that of the *Encyclopédie*. Firstly, while the *philosophes* could only resort to the tree metaphor for their basic classification of knowledge, the En-cycle-pedia has no such constraint. Its graph is a complex network, constructed beginning from a meta-classificatory project[7] and implemented by linking each entry to 'genealogically' connected articles. Locally, therefore, the structure is hierarchically organized. Globally, however, the tree soon turns into a non-linear network because lines of descent and ascent can be multiple and intersecting.

Secondly, while the encyclopédistes' graphical representation in the *Système* could only envisage one kind of link, indicating the division of a topic into various sub-topics, links in the En-cycle-pedia can have various attributes. The first is strength (represented by lines of different thickness): some connections are more forceful than others, and it makes full sense to recognize this and to allow the user to decide whether to focus only on stronger links or also to examine less cogent connections—in the map metaphor, one can choose whether to depict only motorways or also national and local roads.

The second attribute is qualitative (represented by lines of different colours). Relationships between topics have different natures. In the En-cycle-pedia, which is concerned with the history of economic thought, one can distinguish relationships between entries based on the discipline's methodology, or the general way of thinking

[7] The En-cycle-pedia has a core article focusing on the "Classifications of crises and cycles theories", discussing ten or so modes of classification suggested in the literature since the 1840s. Each mode of classification is discussed in detail in specific articles. Different specific theories are, of course, treated in different ways by each classificatory scheme, and are therefore linked to several of these schemes at once. The result is of necessity a rather intricate network.

about the subject; some articles are related at the analytical level, others by factual connections, or yet other connections characterize worldviews. These may be the encyclopedist's broad understanding of the relationships between the subject matters of the encyclopedia, or how different interpretations of the nature of the subject reflect into theoretical schools, approaches, etc. Naturally, knowledge in different domains suggests to focus on different qualities: an encyclopedia of jazz musicians, for instance, is more likely to be concerned with connections of the kind "plays compositions by ...", "has played with ..." or "is inspired by ...".

Thirdly, links have a preferred direction reflecting the hierarchical ordering of topics, which translates in directed or bidirectional arrows (see Figures 2 and 3). Other attributes could be added, making of course the network even more convoluted, and one should balance the benefits of finer representation with the increasing difficulty in usage and interpretation. Links appearing in the En-cycle-pedia's graph carry information on the reasons why they are set as they are.

Again like the *Encyclopédie*, the En-cycle-pedia superimposes the connections represented by the cross-references inserted in each article onto the systemic, hierarchical links, distinguishing the references to 'further information' from those inviting to consult 'in depth treatment' (see Figure 4).[8] A finer division, such as Diderot's four categories described above, can naturally be envisaged, but again one should balance advantages, increased complexity and risk of overlapping, with the scope of the hierarchical links.

The En-cycle-pedia also treats the literature cited as 'bibliographic objects' connected to each article; such objects can be visualized as nodes in the graph, so that the mutual relationship between the references (alone, or in connection with the links between the En-cycle-pedia's articles) can also be explored, distinguishing, if desired, between primary and secondary sources. Each reference in the bibliographies directly offers the link to a graph representing the network of citations (Figure 5).

The information carried by the links can be visualized selectively in the graph: by link type (structural, cross-reference or bibliographic), and by selecting any of the attributes (quality and strength, type of cross-reference, primary or secondary literature); the depth (that is, the number of 'generations') can also be adjusted, showing longer or shorter chains of nodes, and the visualization can be further

[8] A graphical tool depicting the 'main' cross-references between an entry and other articles is offered by the online version of Gabler's *Wirtschaftslexikon*. It is built starting from the system of cross-references to and from the article under examination: an unspecified algorithm selects the five most important entries, and represents them in their connections to the central article by means of incoming, outgoing or bidirectional arrows, depending on whether the entry refers to, is referred from, or both refers to and is referred from, the central article. Any cross-references between these entries are also represented in a lighter colour. Each node in the graph is a link to the corresponding article. The reader can also examine second-order connections, resulting from the iterated application of the algorithm to each of the five entries, giving rise to a 26-nodes graph (at most).

restricted by relevant dates (Figure 1). The result both places articles in their context, selectively defined, and suggests reading paths, which naturally can be explored by navigating the graph itself (one can visualize the articles' abstracts directly from the graph by positioning the cursor on the articles' labels). In contrast with the *Encyclopédie*, where a reader could visualize the (unique) 'world map' but could only follow the cross-references one at the time, the En-cycle-pedia offers at a glance a global perspective at the desired depth, enabling the reader to see distant connections otherwise hidden—concealed perhaps to the encyclopedist him- or herself. Each new article visualized forces a recalculation and re-drawing of the graph, with the new entry at its center. The user can thus personalize his or her reading experience, and save graphs for later usage.

3.3 Points of view: the En-cycle-pedia as an analytical instrument

The En-cycle-pedia radically interprets the second issue raised by Diderot and d'Alembert – that of the different perspectives from which one examines a certain problem. The encyclopedist offers a personal (hopefully well-informed) interpretation of the connections between topics, which is visually translated into the graphs. There is no reason, however, why the reader should necessarily agree with the encyclopedist's view. Users are therefore allowed (and invited) to implement their own interpretation by changing as extensively as they wish the system of structural links, editing the cross-references, modifying articles (including creating and deleting any), or revising the links to references—naturally on a separate, personalized copy of the encyclopedia, the settings of which can be saved and retrieved, shared with others and publicly discussed in a forum.

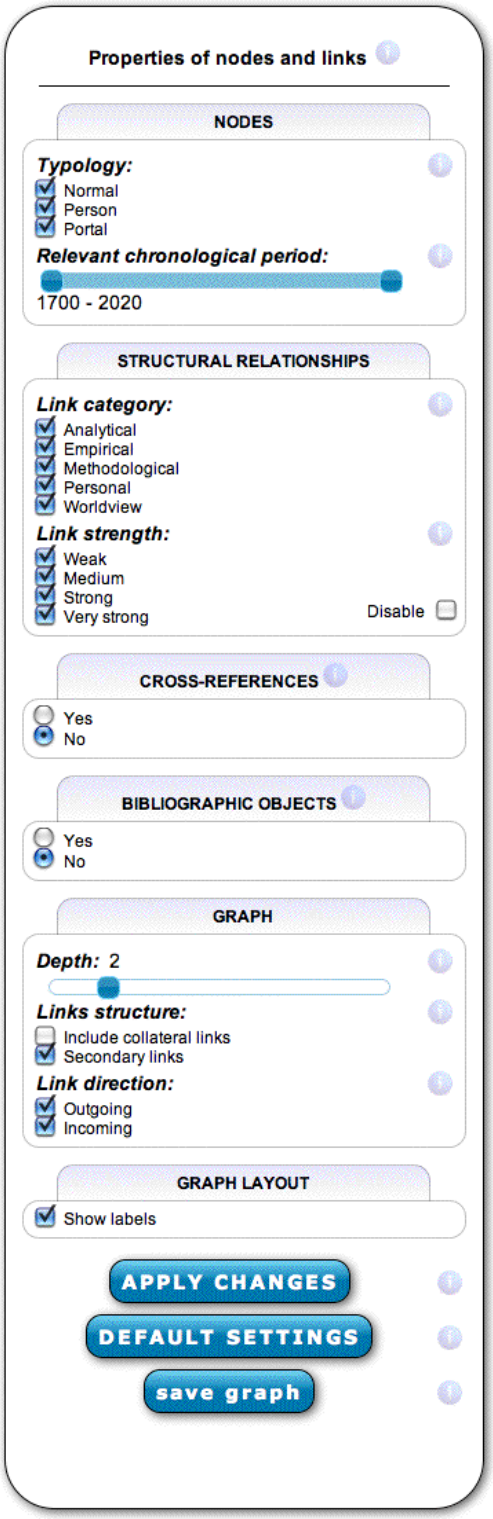
The purpose of this innovation is not only to allow for pluralism in the En-cycle-pedia, but to turn it into an active analytical instrument: the reader can compare the global consequences of switches to different epistemological views or changes of perspective on a point of detail; conversely, the reader can examine which fundamental assumptions have to be changed in order to build (or solidify) bridges between previously unconnected (or loosely linked) topics or, on the contrary, cutting existing connections that one feels should not be there. Again, if the reader thinks that some unconnected nodes should be linked, he or she can explore ways of building the necessary bridges and visualize the consequences of doing so.

By these means, the En-cycle-pedia is not a mere repository of notions or just a flexible organizer of knowledge, but becomes an analytical tool enabling the encyclopedist and readers to assess the implications of different interpretative schemes. Moreover, the tool helps to reveal gaps and inconsistencies in the planning of the list of entries, and is therefore of definite support to the work of the encyclopedist.

3.4 Searches

The graphical tool is also applied to search results. These are thus grouped in clusters of connected articles, thus forming islands of sense that can be explored separately (Figures 6 and 7).

Fig. 1: The filter system, enabling users to select the properties of nodes and links to be shown in the graphs.



The search page offers the possibility of finding the shortest directed path between two articles or any pair of items in the literature cited in the En-cycle-pedia, thereby enabling users to inquire into the connections between concepts, themes, people and the literature. It is also possible to find the common 'ancestors' and 'descendants' of any pair of articles, thereby examining whether there is a shared source or implication between concepts or people.

The filters illustrated in Fig. 1 can be applied to all these searches, thus restricting the query to specific domains, chronological periods or degree of significance.

3.5 Article attributes

The En-cycle-pedia's articles also have attributes that can be used to filter the elements appearing in the graph. Similar to the major articles in the old *Britannica*, some articles act as portals in providing general overviews of relatively large topics and redirecting the reader to more specific articles (which form a second category) or to other portals. A third category of articles are of a bio-bibliographical character, and also act as mini-portals redirecting to the various articles discussing that person's work. In the graph, one can select the kind of articles that should be shown.

Articles are also associated with a specific time frame where relevant, so that navigation and searches can be directed to the desired chronological period.

3.6 Limitations

While the graphical tool works as requested, and thus satisfies the purpose of exploring the features imagined for the En-cycle-pedia, it is not yet aesthetically very appealing and can be rather slow in representing large graphs. Although the logical engine determining the structural components of the graph works fairly fast and efficiently, the actual drawing of the graph takes too long to manage a large number of nodes and edges. The En-cycle-pedia's content is presently limited to about 80 articles, while one can imagine that the network's complexity would grow exponentially with the increase in the number of nodes. Nevertheless, in graphical terms the problem should affect mainly the 'central' articles, not the 'peripheral' ones (that is, those dealing with specific terms, concepts or facts); those more likely to be visited by users of an encyclopedia.

Generally, the tool is still under construction, as several details need to be sorted out,[9] and for this reason the En-cycle-pedia will remain, for some time, accessible only by invitation (see footnote 6).

4. Conclusion

For the time being, the En-cycle-pedia is intended as a proof of concept rather than an attempt at providing the contents of a full specialized dictionary. For that to be possible, the limitations of the graphical tools must be overcome—probably by choosing different graphical software to represent the structural matrix. Meanwhile, however, the tool offers the possibility of experimenting with a flexible organization of knowledge by enabling the reader to examine encyclopedic articles in their multiple mutual relationships: as interpreted by the encyclopedist with respect to their place in the construction of the discipline (pre-analytical, methodological, analytical, empirical, personal); as reconstructed by the article's author when cross-referring to other entries; and as emerging from the literature on which it is based. The En-cycle-pedia is also an analytical instrument, as users can modify any of the above connections and explore the consequences of such changes. These features are not limited to the academic field chosen for this example, but can be applied to any other domain, as the distinction of different numbers and kinds of nodes, links and other attributes, and their corresponding labelling, is fully customizable.[10]

[9] Among these, the search engine does not yet allow Boolean searches.

[10] Although the tool was developed to be applied to an encyclopedic project, its educational implications are rather straightforward, as the instrument is fully open to interaction when associated with appropriate management of access. Indeed I use a simplified version in my teaching.

5. Acknowledgements

The encyclopedic project is a creation of the author. The technical realization of the En-cycle-pedia is mainly due to the work of Stefano Pettorossi, with the collaboration of team Dedalos R&D, which is financing the project and is collaborating with the SSIG School in Bellinzona, Switzerland. Naturally, the original ideas co-evolve with the actual implementation of the tool, which makes apparent new potentialities. Stefano's role thus transcends mere technicalities. I am grateful to Cécile Dangel Hagnauer and two anonymous referees for comments and suggestions on the first draft, and to Roberto Baranzini, Giorgio Colacchio and Giorgio Rampa for discussions on the project; the usual caveats apply.

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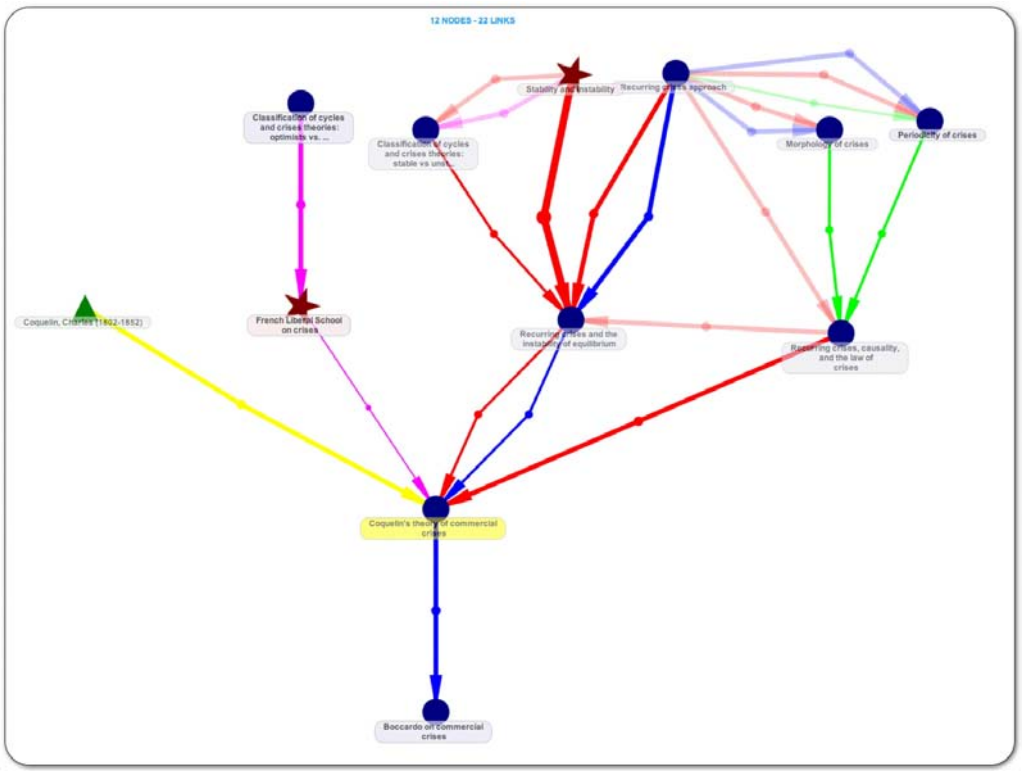

Figure 2: Graph relating to article on "Coquelin's theory of commercial crises", at depth = 2. Arrows of different colours represent various kinds of relationships (analytical, methodological, personal, etc.), while strength is represented by different thickness. Triangular nodes indicate bio-bibliographical entries, stars represent portal entries, while the ordinary articles are represented by circles.

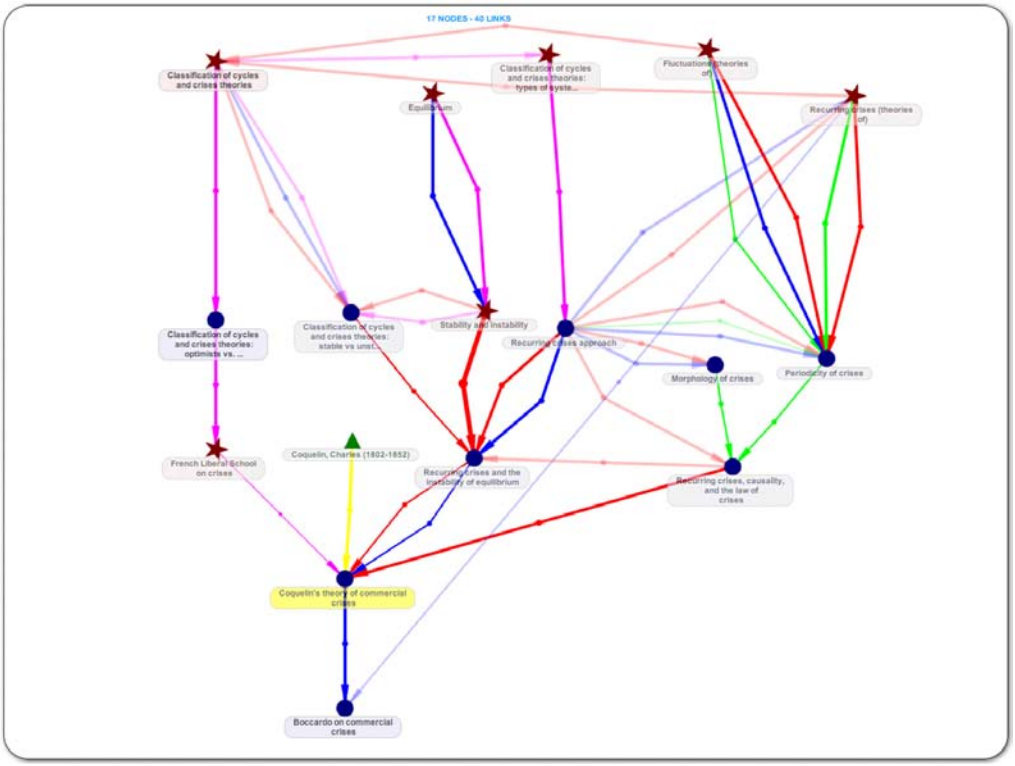

Figure 3: Third order structural links. Here, as in all graphs, any of the filters indicated in Figure 1 can be applied.

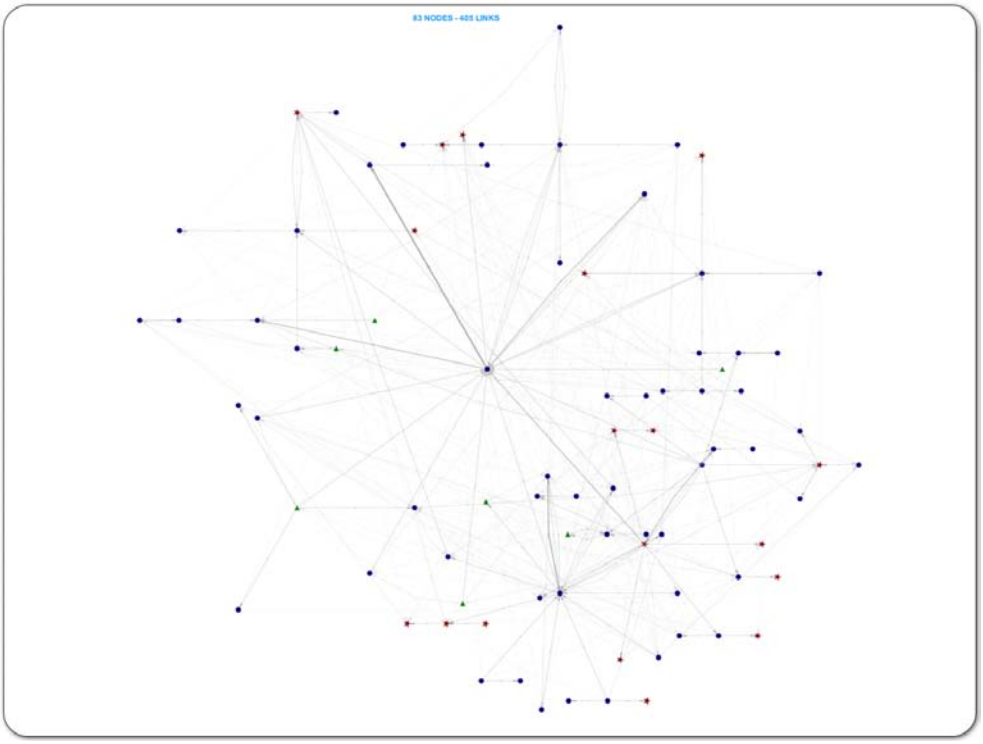

Figure 4: Graph representing the 3rd degree of cross-references relating to the same article on "Coquelin's theory of commercial crises". Line thickness is proportionate to the number of links to the same article.

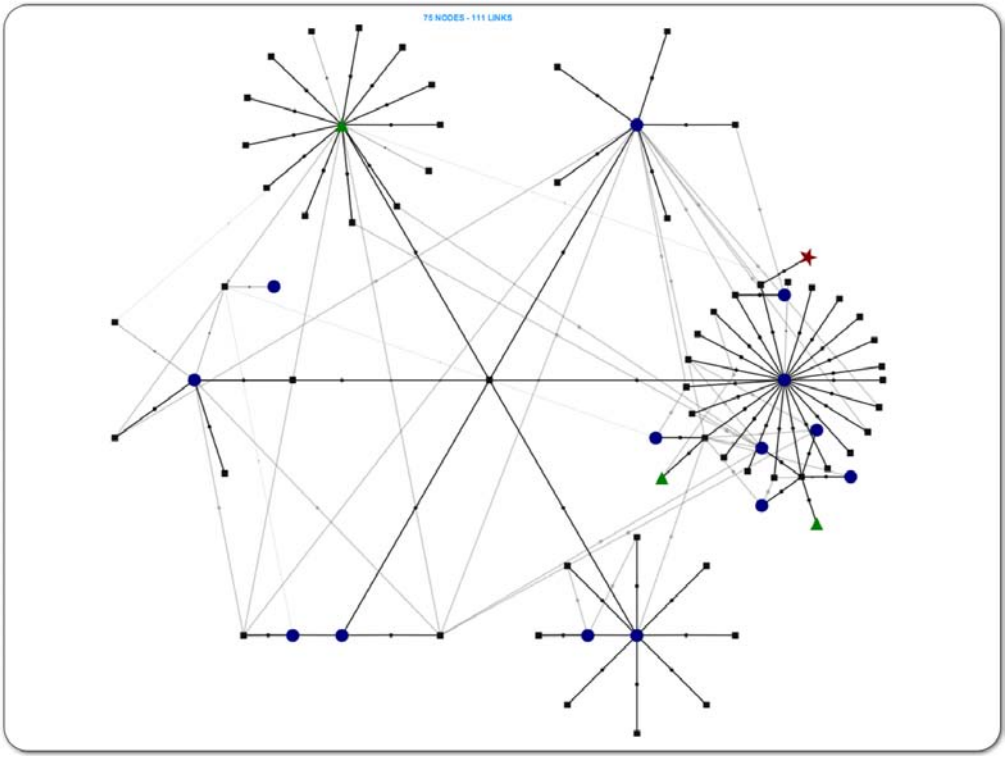

Figure 5: Graph showing the bibliographic relationships within the En-cycle-pedia: the literature item at the center of the graph is cited in the 6 articles connected with black lines; the remaining black square nodes represent the references cited by these articles, each of which is again connected to the articles citing it. The depth can be adjusted at will.

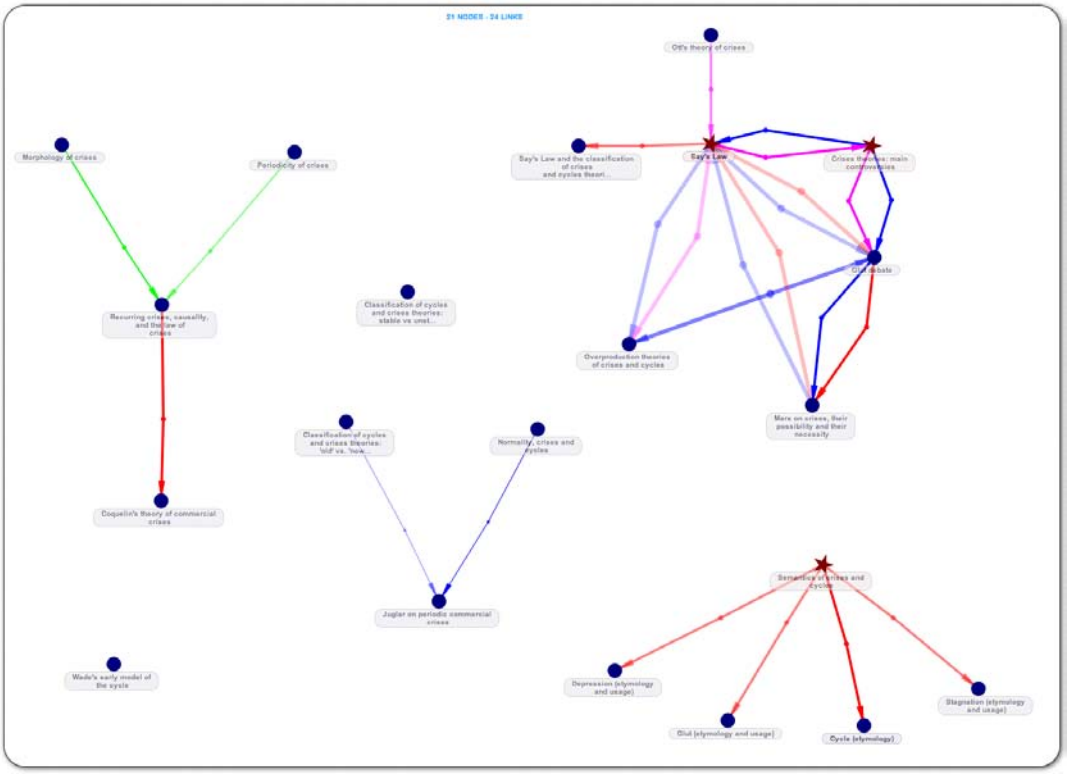

Figure 6: Graph representing a search result. Articles containing the term 'Glut' are clustered according to the existing structural links connecting them.

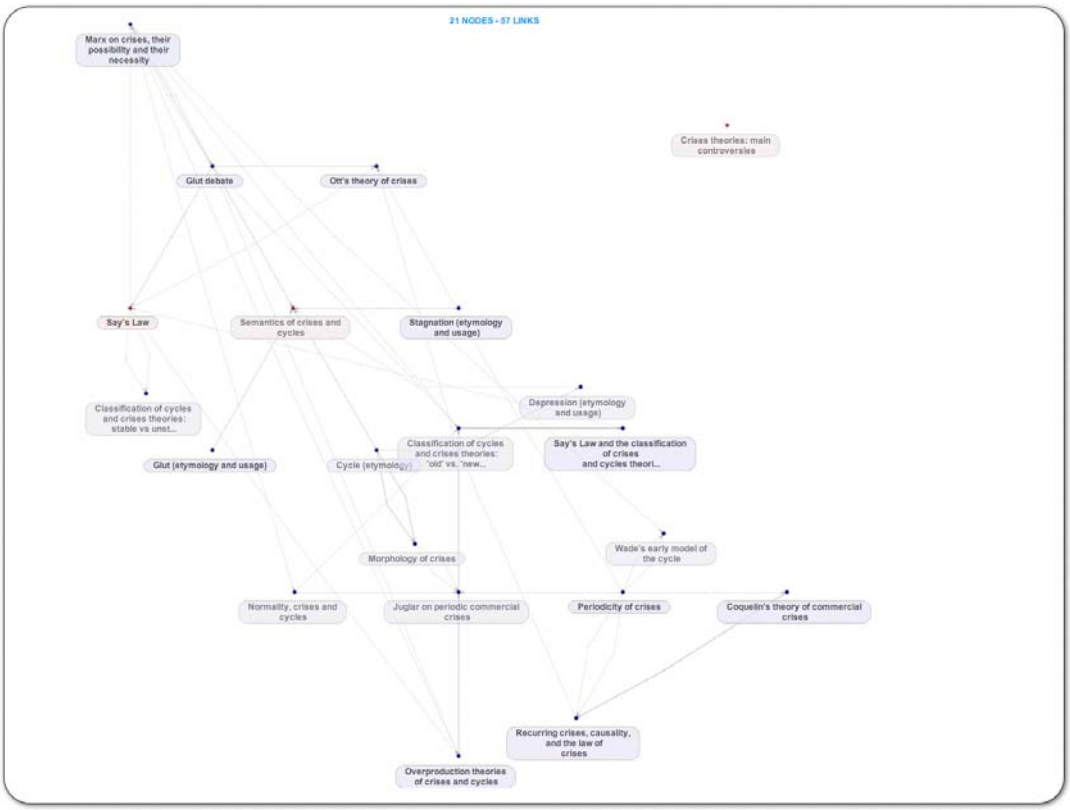

Figure 7: The same search results as in Figure 6, but clustered according to their mutual cross-references.