Wikis as Digital Ecosystems: An Analysis Based on Authorship

Robert P. Biuk-Aghai, Libby Veng-Sam Tang, Simon Fong and Yain-Whar Si

Department of Computer and Information Science, Faculty of Science and Technology, University of Macau, Macau
E-mail: {robertb,libbyt,ccfong,fstasp}@umac.mo

***Abstract*—Wikis, best represented by the popular and highly successful Wikipedia system, have established themselves as important components of a collaboration infrastructure. We suggest that the complex network of user-contributors in volunteer-contributed wikis constitutes a digital ecosystem that bears all the characteristics typical of such systems. This paper presents an analysis supporting this notion based on significance of authorship within the wiki. Our findings confirm the hypothesis that large volunteer-contributed wikis are digital ecosystems, and thus that the findings from the digital ecosystems research stream are applicable to this type of system.**

***Index Terms*—digital ecosystem, collaborative writing, co-authorship, wiki, analysis.**

I. Introduction

The concept of digital ecosystems dates back to the beginning of the decade [1] as a new way of perceiving the increasingly complex and interdependent systems being created today. The notion of digital ecosystems offers an approach to conceptualizing, managing and organizing loosely-coupled, interdependent, flexible and demand-driven interactive environments [2]. Main applications of digital ecosystems are in the business, health and education domains [3].

Traditionally digital ecosystems have been conceived of as systems of interacting systems, such as a supply chain business digital ecosystem in which the systems of each company in the supply chain interact with those of other companies in the supply chain. However, in this paper we argue that a single system may, through use, evolve to an extent of complexity that the volume of digital content as well as number of actors in the system leads to the emergence of behaviour characteristic of digital ecosystems, exhibiting their essential features. Specifically, we argue that this kind of emergent behaviour can be observed in large wiki systems whose contributors are volunteers (as opposed to staff authors).

Wikis are systems allowing large-scale collaborative knowledge creation and distillation [4]. The experience of the Wikipedia project, arguably the most visible and well-known wiki system, has demonstrated that large numbers of contributors can jointly create, review, revise, re-organize, edit and manage large amounts of high-quality digital content. As of this writing the Wikipedia project comprises 266 different language wikis totalling nearly 13 million articles co-authored by over 17 million users around the globe [5]. The largest language edition among these alone, the English Wikipedia, has 2.9 million articles authored by 9.6 million users. While the discussion about the quality of Wikipedia content during the early years of its existence was highly critical of its editorial model where basically anyone can edit anything at any time (with very few exceptions), to be immediately placed online without any review or approval, evidence of the high quality of a large number of Wikipedia articles has provided ample evidence suggesting that the basic editorial model does not stand at odds with a desire for quality. Thus wikis have become a proven and accepted collaboration tool used by increasing numbers of organizations to support their collaborative knowledge creation processes. Besides the well-known Wikipedia there are large numbers of other publicly accessible wikis, and an additional large number of private wikis used internally in organizations.

Wikis, however, are not only useful tools supporting joint knowledge creation in digital ecosystems, but as we have asserted above can also be regarded as digital ecosystems in their own right. They comprise large groups of users (in some cases counting several million members) who cluster together around common areas of activity, as well as interact with members of other clusters in ways characteristic of digital ecosystems. Thus we state our hypothesis:

Hypothesis: large volunteer-contributed wikis are digital ecosystems.

Our paper tests this hypothesis through a quantitative analysis, to demonstrate that such wikis indeed exhibit the features typical of digital ecosystems. The structure of the remainder of this paper is as follows: Section II briefly reviews related work on analysing wikis. In Section III we give an overview of our data analysis approach, and Section IV presents our analysis of wikis in terms of features of digital ecosystems. Finally, in Section V we give conclusions.

II. Related Work

The analysis of wikis has a relatively short history since the establishment of Wikipedia in January 2001. In general, the research trend evolved from direct statistical analysis such as counting the volume, size and contents of the archive of articles to more sophisticated analysis among the relations of authors who collaborate as communities. Table 1 summarizes a review of research contributions on different areas of analysis of wikis, which, while not exhaustive, highlights the diversity of analysis approaches employed. This list is divided into two parts that on the one hand represent analytic works centred on 'articles', and on the other hand lists works of implicit analysis oriented on 'authors' and their relations respectively.

Simple quantitative statistics measure the sizes of articles, the number of edits per article, the number of registered

Table 1 Literature review of wiki analysis

Article-oriented	**References**
Size and structure	[6],[7]
Edit count	[8],[9],[10]
Text count	[11]
Article quality	[12],[13],[14]
Accuracy of information	[15]
Evolution of article content	[16],[17]
Identification of controversial articles	[18]
Visualization of complex relationships among millions of topics	[19]
Author-oriented	**References**
Authors reputation and trustworthiness	[20]
Authorship attribution	[21]
Authorship verification	[22]
Disagreements among authors	[23]
Visualization of communities of authors	[24]
Visualization of co-authorship	[25],[26]
Co-authorship and expertise	[27]

users, and others. They serve as the foundations for more sophisticated analysis, such as on co-authorship. In particular, measures of author contribution have been used for estimating the nature of a wiki ecosystem whether it be a large group of novice users, or a small group of experienced authors who contribute most of the content of Wikipedia.

For author-oriented analysis many methods for detecting community structure by using complex social networks have been developed (c.f. Related Works in [24]). Our earlier work [25], [26] focused on visualizing authorship networks and interaction in collaborative writing, respectively. However, this paper applies our authorship analysis [27] to analysing wikis in terms of digital ecosystem aspects.

III. Analysis Approach

The data in a wiki system constitute the starting point for analysis. All wiki systems, regardless of the wiki engine they are based on, have three basic data entities in common: pages, revisions and authors. Pages are the jointly authored text, revisions are different versions of pages, and authors are the users who contribute revisions by editing pages. Many systems, such as the popular MediaWiki, also store categories and discussion in page objects. In addition, each specific wiki system usually has other data entities, but these are not of relevance to our analysis.

Our aim is to discover clusters of authors in the wiki that could be considered to be the equivalent of *species* of the wiki *ecosystem*. As we will explain in Section IV, we decided to cluster the author space by *expertise*. Authors who share the same area of expertise, regardless of their role in the content authoring process, are considered to belong to the same species. In order to determine expertise, we first determine co-authorship, and in a subsequent step use this information to determine expertise in a certain category area.

Our methods to determine co-authorship and expertise are documented in detail in [27] and we only outline the main principles here. Co-authorship refers to joint contribution by two or more authors to the same document. The co-authorship relationship between a pair of authors can be

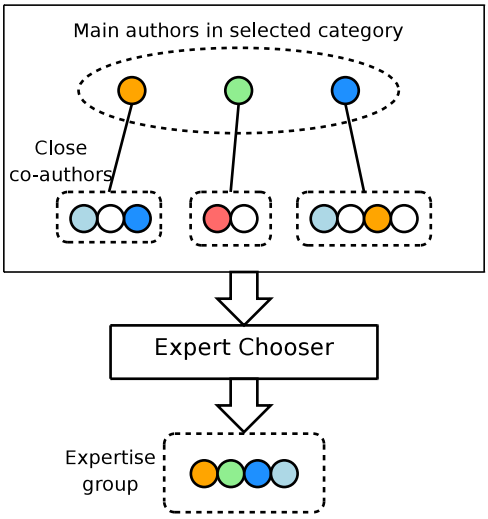

Figure 1 Finding an expert group

strong or weak, depending on the extent to which they have collaborated on the document, the amount and significance of contribution, and the length of time jointly involved. We have developed an algorithm for calculating the degree of co-authorship of a pair of authors. This algorithm uses the entire revision history of all wiki pages in a given wiki database.

Our calculation of degree of co-authorship initially filters author and page data to eliminate authors and pages that are irrelevant for our calculation. For a given author a, the selection of co-authors and pages, and the subsequent calculation of co-authorship degree, is made as follows:

1. Obtain the set of all pages edited by author a
2. Eliminate the pages from the set of all pages for which author a has only made minor edits
3. For each remaining page, obtain the set of other authors
4. For each set of other authors, eliminate those authors who have only made minor edits
5. For each page's set of other authors, calculate a *page degree*
6. Calculate the *co-authorship degree* from all page degrees

The page degree calculated in step 5 above is a measure of the strength of the co-authorship relation between a given pair of authors on a given page, and the co-authorship degree of step 6 is an aggregation of all page degrees of that pair of authors. Once we have calculated the degree of co-authorship for all pairs of authors we use it for finding expertise groups. When searching for experts on a certain topic, a search for co-authors of an article on the chosen topic provides a starting point. The process of finding expertise groups is outlined below, and illustrated in Fig. 1.

1. Select a category closely related to the required area of expertise
2. Find the main authors of the category
3. Find the close co-authors of those main authors, i.e. with strong degree of co-authorship
4. Apply pre-defined rules to include selected co-authors in the group of main authors
5. The resulting group of authors forms the expertise group of the selected page or category

Initially we define the main author of a page as the author who has made a number of revisions that constitute a significant portion of all revisions. Following the selection of main authors of a page, we define a similar rule for the category. That is, a user who is among the main authors of a significant portion of all pages belonging to that category is defined to be a main author of that category. For instance, a user who is main author of 10% or more of all pages of a category is a main author of that category, or an alternative could be to select the top n among the main authors of pages in that category, i.e. those users who are main authors of the largest number of pages of that category.

Then the close co-authors of main authors are found using the method described above, namely by calculating the degree of co-authorship between them. Only the co-authors who fulfil a defined condition (such as degree of co-authorship $> x$, or top n co-authors) are considered as close co-authors, i.e. having strong ties of co-authorship with the main author.

Finally, expert selection aims to determine the members of the expertise group. The main author group and the groups of close co-authors are analyzed and members chosen according to pre-defined rules. For instance, a member of the main authors group who is also a member of at least n of the other main authors' groups of close co-authors is considered a member of the expertise group. Authors who are not main authors but are members of at least m main authors' groups of close co-author groups may likewise be considered members of the expertise group. This process is illustrated in Fig. 1. The finally resulting set of category experts represents the main contributors of the entire wiki, classified by category. Using this set of category experts we conduct our analysis to test whether wikis display the characteristics of digital ecosystem.

IV. Analysis of Wikis as Digital Ecosystems

Following this description of our wiki analysis method we now apply this method to a specific wiki and analyse the set of category experts in order to test our hypothesis that large volunteer-contributed wikis are digital ecosystems. The wiki chosen for our analysis is the Simple English Wikipedia. Wikipedia has the advantage that its databases are available for free download, thus giving us access to the data needed for our analysis. Our choice of the Simple English edition of Wikipedia (which contains articles written in a simple form of English suited for non-native readers) is because its size is more manageable than the standard English edition of Wikipedia (gigabytes vs. terabytes).

We downloaded the Simple English Wikipedia database dump made on 30 March 2009 which contains 129,758 pages, of which 58,120 are content pages, and a total of 1,368,134 revisions made by 12,002 registered and 74,037 anonymous authors. We then applied our method outlined in Section IV above: finding main page contributors and main category contributors, calculating the degree of co-authorship for all pairs of authors involving at least one main contributor each, filtering to close co-authors, and finally filtering and merging the close co-author and main category contributor sets. As the category hierarchy in Wikipedia tends to be both very broad and deep we decided to focus our category expertise selection on top-level categories only. These are the most generic categories, which are first-level nodes in the category tree (which strictly speaking is not a single tree but is more similar to a set of partially overlapping trees). In the Simple English Wikipedia there are eight top-level categories: Everyday life, Geography, History, Knowledge, Literature, People, Religion, and Science.

We now come to the core of our analysis, the question whether large volunteer-contributed wikis can be considered to be digital ecosystems. Our hypothesis is that such wikis are digital ecosystems. To demonstrate that this is the case we test our hypothesis by evaluating our data in terms of a well-accepted definition of digital ecosystems by Boley and Chang [2] according to which a digital ecosystem has the following four essential aspects:

1. *Interaction and engagement* between different species for the overall good of the entire ecosystem.
2. *Balance*, through directing attention to where it is most needed, which is naturally maintained as individuals of each species perceive and attend to these needs.
3. *Domain clustered and loosely coupled*, as individuals of their own volition assume the roles and join the species they best identify with, without external pressure.
4. *Self-organisation*, as individuals are empowered to coordinate in order to take the necessary action demanded by a particular situation.

Our analysis seeks to determine whether each of these aspects applies to a large volunteer-contributed wiki system. Below we analyze each of these as they apply to the Simple English Wikipedia. As we will show, aspects 3 and 4 are implicit in volunteer-contributed wikis, so that the main focus of our analysis below is on aspects 1 and 2.

A. Interaction and engagement

The first aspect assumes that there are several distinct species. It is conceivable to distinguish the actors in a wiki system by the *role* they take on within the wiki, such as writers, editors or tinkerers. We suggest that a distinction by *topic area* is more in line with the characteristics of membership of a species: it is easier for the same person to take on different roles for different pages in the wiki, than to have substantial expertise in different topic areas. It is more likely, for example, that an expert on geography contributes text to some pages, edits other pages, and makes small improvements to yet others, but all related to geography, than that this same expert also makes similarly many and similarly significant expert contributions to pages about literature, religion or science. Thus we consider the topic area, or category, to be the primary distinguishing factor among authors. Role could, however, certainly be used as a secondary distinguishing factor, subordinate to a given topic area. Thus we consider "species" within the wiki site to be the expert contributors to different categories.

As mentioned above, we have applied our authorship analysis and expertise finder application to the eight main categories of the Simple English Wikipedia. Our selection of pages included all those pages belonging directly to the category, or to any of its sub-categories recursively descending the category tree. This analysis revealed the number of pages

Table 2 Main categories and number of pages and experts in Simple English Wikipedia

	Pages		Experts	
Category	**Num.**	**%**	**Num.**	**%**
Everyday life	23,926	18.8	1,852	19.6
Geography	31,494	24.8	1,737	18.3
History	10,923	8.6	1,235	13.0
Knowledge	270	0.2	48	0.5
Literature	2,015	1.6	527	5.6
People	8,449	6.6	1,228	13.0
Religion	1,767	1.4	441	4.7
Science	48,385	38.0	2,400	25.3
Total	127,229	100.0	9,468	100.0

Table 3 Number of category experts by number of expertise categories per expert in Simple English Wikipedia

Categories/Expert	**Num. Experts**	**%**
1	31	1.2
2	68	2.7
3	82	3.3
4	67	2.7
5	229	9.2
6	166	6.7
7	1,183	47.4
8	669	26.8
Total	2,495	100.0

and category experts per main category, as shown in Table 2: main category in the left column, number and percentage of pages in the next two columns, and number and percentage of category experts in the last two columns. As some authors have made contributions to more than one main category, however, the number of distinct category authors is lower than the total of 9,468 shown in Table 2. We have found that many authors have made contributions to two or more, even up to all eight main categories. The list of 9,468 category experts consists of totally 2,495 distinct authors, i.e. on average there are 9,468/2,495=3.8 categories/expert. However, as Table 3 shows the distribution is not normal: the majority of experts (74%) are experts in 7–8 main categories, and only 7% are experts in three or fewer main categories. Moreover, those authors who are classified as experts in multiple categories tend to have strong expertise in only one category, and a relatively smaller number of contributions to other categories.

This matches the characteristics of mutually interacting species: each group of category experts corresponds to a species in the wiki ecosystem, each member of which contributes to its own category, but also interacts strongly with other categories in what constitutes interaction and engagement with that species, for the overall good of the entire ecosystem. To enable visual analysis we entered our category expert data into the Pajek social network analysis application [28]. This data was then visualized with Pajek using a Fruchterman-Reingold 2D layout (vertex distance 2.5), producing the graph shown in Fig. 2. The eight green vertices represent the eight Simple English Wikipedia main categories, whereas the 2,495 red vertices correspond to the 2,495 category experts. Edges connect categories with experts and are colour-coded by category: “everyday life” in green, “geography” in red, “history” in blue, “knowledge” in gray, “literature” in maroon, “people” in orange, “religion” in cyan, and “science” in magenta. A visual analysis of this graph confirms the general structure mentioned above, namely several distinct category clusters with many connections between them. Clearly visible are the two clusters of vertices forming a curve at the top and at the left of the graph; these represent the experts who have only contributed to one category. The area of crossing lines in the centre consists of those experts who have also made contributions to other categories. Line thickness represents the number of contributions made by a particular expert to a particular category. It can be observed that those experts who have made a large number of contributions to one category also tend to have contributions to other categories, but that these generally are smaller in number. This confirms our earlier observation that experts in the wiki both have a main membership in one of the species of the wiki digital ecosystem and that lively contribution to other categories constitutes interaction and engagement with the corresponding species. We therefore conclude that the first aspect of digital ecosystems is given in this wiki.

B. Balance

This aspect means that members of the ecosystem direct attention to where it is needed. Exactly defining where attention is needed, however, is not easy as each wiki has its own purpose and may thus have different needs from others. Our initial approach, which we later discarded, was to compare the relative sizes (measured by number of articles) of the Simple English Wikipedia category distribution with that of other encyclopaedias. The challenge with this, however, is that main categories do not necessarily neatly align with each other. While some appear to do, such as the categories “geography” and “science” which are main categories in both the Simple English Wikipedia and a well-known traditional encyclopaedia, the Encyclopædia Britannica, other categories are harder to match, such as “social sciences” in the Britannica for which there is no clear equivalent in the Simple English Wikipedia. On the other hand, the Simple English Wikipedia has content that may be considered too trivial for a serious scholarly reference work such as the Britannica, grouped in its category “everyday life” with articles on topics such as “drinking straw”. Even when comparing with other online encyclopaedias such as Microsoft Encarta Encyclopaedia or even the regular English Wikipedia, similar problems of category alignment arise. We conclude that purpose and focus of each wiki are unique, which makes comparison with other wikis or traditional printed media difficult at best and questionable at worst. The purpose and focus of the wiki may in some cases be relatively well defined, such as to provide articles on all topics in a simple form of English as in the case of the Simple English Wikipedia, but in others is more open-ended and emerges over time.

Discarding external sources for determining balance, we instead consider attributes of the wiki itself. Balance should be given when contributions are made comparable to the amount of effort. In a wiki this means that the number of contributors, particularly main authors and experts, should be more or less proportional to the number of articles within

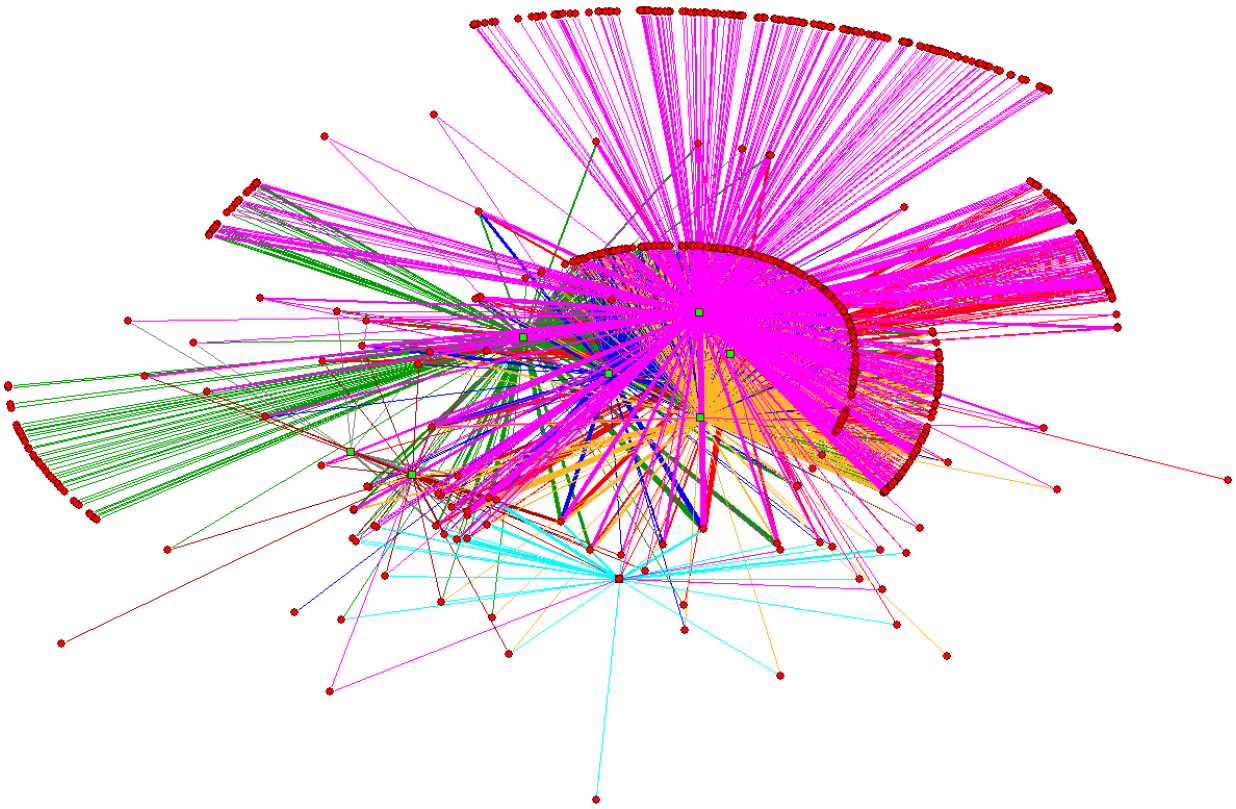

Figure 2 Network of category experts in Simple English Wikipedia

a given category. When the need for further contributions in a certain subject area is detected, some members of the overall wiki should attend to that need and make the required contributions. Conversely, in "crowded" subject areas with many expert contributors there is less demand for a given expert who may instead direct attention to a different subject area with greater need. In this way balance is naturally maintained. To evaluate whether this kind of balance is given in a wiki we consider the portion of expertise contribution to different categories: in a balanced wiki, each group of main authors and category experts should be of a size proportional to the size of that category, in terms of the number of pages this category contains. We have extracted the relevant statistics from the Simple English Wikipedia database, namely the number of pages, the number of main authors, and the number of experts, per main category. These are shown in the form of a line chart in Fig. 3: categories are plotted along the horizontal axis, normalized counts of pages, main authors and experts are plotted on the vertical axis. Each of the three lines shows the relative distribution of pages, main authors and experts across the eight categories. As can be seen, the shape of the lines, while not identical, is significantly similar to each other. From this we conclude that in this wiki the balance aspect is also given.

C. Domain clustered and loosely coupled

In a public wiki based on volunteer contributions, such as all the Wikipedia encyclopaedias, the domain clustered and loosely coupled property of digital ecosystems is given a priori. Being volunteers, users choose to contribute to the wiki of their own volition, they choose the categories and

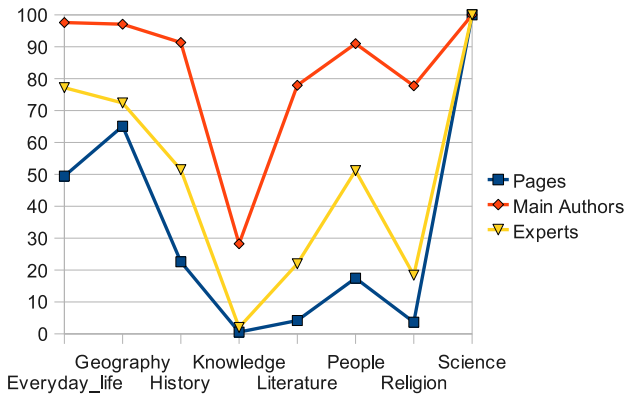

Figure 3 Relative numbers of pages, main authors and experts in Simple English Wikipedia

articles to which to contribute, and they choose the extent and nature of their contributions. They cluster together with others of similar expertise and interest, but are free at any time to change their association.

D. Self-organisation

As with the previous aspect, self-organisation is also given a priori in public wikis based on volunteer contributions. Wikipedia contributors pro-actively and independently take the actions they consider necessary, and self-organise to achieve goals as and when the need arises. One way in which this is done in the Wikipedia community is by assigning specific prerogatives and duties, such as the status of administrator, to individuals who have distinguished themselves

through their contributions. Another way is through votes that are being conducted from time to time in Wikipedia to obtain community consensus on a particular issue, such as an editorial decision that needs to be made.

Above we have presented an analysis of each of the essential aspects of digital ecosystems. This allows us to test our hypothesis that large volunteer-contributed wikis are digital ecosystems. We conclude that the characteristics of the particular wiki analysed by us, the Simple English Wikipedia, are congruent with those of digital ecosystems, thus confirming our hypothesis for this particular case. We presume, but have yet to confirm, that this is also true of other community-driven wikis, including other language editions of Wikipedia which share many of the characteristics of the Simple English language edition we analysed, as well as many of the other public open wikis that are volunteer-contributed.

Our hypothesis focused specifically on wikis that are both *large* and *volunteer-contributed*, as opposed to simply any kind of wiki. Two essential aspects of digital ecosystems, namely being domain clustered and loosely coupled as well as being self-organising, may be absent in non-volunteer wikis such as intra-organizational wikis in which contribution is an organizationally mandated part of the contributors' work. Moreover, our focus on large wikis did not provide a definition of what constitutes a large wiki. Testing of our hypothesis on different wikis, as well as on wikis of different size, remains as future work.

V. Conclusions

Digital ecosystems are becoming increasingly important in today's networked society. Current research on digital ecosystems has tended to focus on interconnected systems of systems. In this paper we have argued that a single system may exhibit the characteristics of a digital ecosystem, and have proposed the hypothesis that this applies to large volunteer-contributed wikis. We tested this hypothesis by taking an authorship approach: we identify wiki authors who are experts in some categories; the population of such category experts exhibits the characteristics of species in a digital ecosystem, namely interaction and engagement, balance, domain clustered and loosely coupled, and self-organisation. Thus a wiki system as a whole can be regarded as a digital ecosystem. We conclude that this hypothesis can be accepted for wikis that are both large and volunteer-driven. This allows insights from the digital ecosystems field to be applied to the modelling, organization and management of wikis.

VI. References

[1] Fiorina, C., *The Digital Ecosystem*, Speech at World Resources Institute Conference, Seattle, Washington, October 16, 2000, online at: `http://www.hp.com/hpinfo/execteam/speeches/fiorina/ceo_worldres_00.html` (accessed 4-May-2009).

[2] Boley, H. and Chang, E., "Digital Ecosystems: Principles and Semantics", in *Inaugural IEEE International Conference on Digital Ecosystems and Technologies*, Cairns, Australia, 21-23 Feb. 2007, pp. 398–403.

[3] Digital Ecosystems and Business Intelligence Institute, *Digital Ecosystems: Creating Value by Making Connections*, 2008, online at: `http://www.debii.curtin.edu.au/` (accessed 4-May-2009).

[4] Leuf, B. and Cunningham, W. *The Wiki Way: Quick Collaboration on the Web*, Addison-Wesley, 2001.

[5] Wikimedia Meta, *List of Wikipedias*, online at: `http://meta.wikimedia.org/wiki/List_of_Wikipedias` (accessed 4-May-2009).

[6] Vob, J., "Measuring Wikipedia", in *Proceedings of the 10th International Conference of the International Society for Scientometrics and Informetrics* (ISSI 2005), Stockholm, Sweden, July 2005.

[7] Zachte, E., *Wikipedia Statistics English*, `http://stats.wikimedia.org/EN/TablesWikipediaEN.htm` (accessed 4-May-2009).

[8] Wilkinson, D.M. and Huberman, B.A., "Cooperation and quality in Wikipedia", in *WikiSym '07: Proceedings of the 2007 International Symposium on Wikis*, 2007, pp. 157–164.

[9] Ortega, F. and Barahona, J.M.G., "Quantitative analysis of the Wikipedia community of users", in *WikiSym '07: Proceedings of the 2007 International Symposium on Wikis*, 2007, pp. 75–86.

[10] Stein, K. and Hess, C., "Does it matter who contributes: a study on featured articles in the German Wikipedia", in *HT '07: Proceedings of the 18th conference on Hypertext and Hypermedia*, 2007, pp. 171–174.

[11] Swartz, A., *Who writes Wikipedia?*, online at: `http://www.aaronsw.com/weblog/whowriteswikipedia`, September 2006 (accessed 4-May-2009).

[12] Hu, M., Lim, E-P., Sun, A., Lauw, H.W. and Vuong, B.Q., "Measuring Article Quality in Wikipedia: Models and Evaluation", in *Proceedings of CIKM'07*, Nov. 2007, pp. 243–252.

[13] Burke, M. and Kraut, R., "Taking up the mop: identifying future Wikipedia administrators", in *CHI '08: CHI '08 Extended Abstracts on Human Factors in Computing Systems*, 2008, pp. 3441–3446.

[14] Emigh, W. and Herring, S.C., "Collaborative Authoring on the Web: A Genre Analysis of Online Encyclopedias", in *Proceedings of the 38th Annual Hawaii International Conference on System Sciences* (HICSS-38), Big Island, HI, USA, Track 4, 2005, p. 99a.

[15] Giles, J., Internet encyclopaedias go head to head, *Nature*, vol. 438, Dec. 2005, pp. 900–901.

[16] Sabel, M., "Structuring Wiki Revision History", in *Proceedings of the 2007 International Symposium on Wikis*, Oct. 2007.

[17] Viegas, F.B., Wattenberg, M. and Dave, K., "Studying Cooperation and Conflict between Authors with History Flow Visualizations", in *Proceedings of CHI'04*, April 2004.

[18] Kittur, A., Suh, B., Pendleton, B.A. and Chi, E.H., "He Says, She Says: Conflict and Coordination in Wikipedia", in *Proceedings of CHI'07*, April 2007.

[19] Harrison, C., *Wikiviz: Visualizing Wikipedia*, online at: `http://www.chrisharrison.net/projects/wikiviz/` (accessed 4-May-2009).

[20] Adler, B.T. and de Alfaro, L., "A Content-Driven Reputation System for the Wikipedia", in *Proceedings of WWW2007*, May 2007.

[21] Bozkurt, I.N., Baghoglu, O. and Uyar, E., "Authorship attribution", in *Proceedings of 22nd International Symposium on Computer and Information Sciences*, Nov. 2007, pp. 1–5.

[22] Stein, B., Lipka, N and zu Eissen, S.M., "Meta Analysis within Authorship Verification", in *Proceedings of 19th International Conference on Database and Expert Systems Application*, Sept. 2008, pp. 34–39.

[23] Brandes, U. and Lerner, J., "Visual Analysis of Controversy in User-generated Encyclopedias", in *Proceedings of IEEE Symposium on Visual Analytics Science and Technology*, Oct. 2007, pp. 179–186.

[24] Kameyama, S., Uchida, M. and Shirayama, S., "A New Method for Identifying Detected Communities Based on Graph Substructure", in *Proceedings of 2007 IEEE/WIC/ACM International Conferences on Web Intelligence and Intelligent Agent Technology*, pp. 263–267.

[25] Biuk-Aghai, R.P., "Visualizing Co-Authorship Networks in Online Wikipedia", in *Proceedings of the International Symposium on Communications and Information Technologies*, Bangkok, Thailand, Oct. 2006.

[26] Biuk-Aghai, R.P., Kelen, C. and Venkatesan, H., "Visualization of Interactions in Collaborative Writing", in *Proceedings of the 2008 Second IEEE International Conference on Digital Ecosystems and Technologies*, Phitsanulok, Thailand, Feb. 2008, pp. 97–102.

[27] Tang, L.V.-S., Biuk-Aghai, R.P. and Fong, S., "A Method for Measuring Co-authorship Relationships in MediaWiki", in *Proceedings of the 2008 International Symposium on Wikis*, Porto, Portugal, Sep. 2008.

[28] de Nooy, W., Mrvar, A. and Batagelj, V., *Exploratory Social Network Analysis with Pajek*, Cambridge University Press, 2005.

[29] Wikipedia contributors, "Encyclopædia Britannica", *Wikipedia, The Free Encyclopedia*, `http://en.wikipedia.org/wiki/Encyclopaedia_Britannica` (accessed 4-May-2009).