OvERVIeW: Ownership Visualization Word Cloud

Ilenia Fronza and Stefano Trebeschi
Free University of Bozen-Bolzano, Piazza Domenicani, 3, 39100, Bolzano, Italy

Keywords: OvERVIeW, Word Cloud, Visualization, Code Ownership, SVN.

Abstract: In many situations, awareness about code ownership is important; for example, this awareness might allow to contact the responsible person(s) of a piece of code to get clarifications. Source versioning systems can provide information about code ownership. However, the considerable amount of data collected might prolong the time to retrieve the information needed. OvERVIeW addresses this issue: it collects data from a versioning system and visualizes developers' effort using a well-known and intuitive visualization, the word cloud. We applied pre-attentive processing principles in the designing phase, which use graphical properties (e.g., form and color) that are processed pre-attentively, i.e., they are understood faster. In our visualization, each word represents a class; the number of lines added and removed (during a given time period) is used as size metric, and the color represents the developer(s) working on the code. We show how OvERVIeW can be used to visualize three different cases of code ownership: collective, weak, and strong. We report a sample application of OvERVIeW in the context of a multi-developer OSS project.

1 INTRODUCTION

The work of many developers is required to create almost any non-trivial piece of code. Large teams face communication and coordination issues, and splitting software development across a distributed team make it even harder to achieve an integrated product (Herbsleb and Grinter, 1999). Open Source (OSS) projects represent the typical situation where coordination problems arise, since developers contribute from around the world, meet face-to-face infrequently, and need to coordinate virtually (Crowston et al., 2005). For example, the entry barrier is a problem that has been acknowledged by OSS developers (Cubranic and Booth, 1999): a newcomer needs to understand the existing code and read the available documentation. Usually, this is a very time consuming and tedious task. In this case, information about code ownership would allow contacting directly the responsible person(s) of a piece of code in order to get explanations. To this end, source versioning systems can provide information about code ownership. However, the considerable amount of data collected might prolong the time to retrieve the information needed.

The key to solve these issues, and to promote coordination in general, is increasing the level of awareness; in particular, information of *who* is changing *what* in the system (i.e., code ownership) has been proposed as a means to increase awareness in the team (Lanza et al., 2010). To this end, a large number of visualizations has been proposed in Software Engineering, mostly to show the evolution of software systems (Caudwell, 2010; Pinzger et al., 2005; Voinea et al., 2005; Wettel et al., 2011; Ciani et al., 2015), or development effort and authors (D'Ambros et al., 2005; Lanza et al., 2010; Ogawa and Ma, 2008; Vervloesem, 2010). Visualizations are often taken without any adjustments from other disciplines, for which they were specifically designed, and they do not convey information quickly and effectively. The problem is relevant as, if properly designed, visualizations can help people getting information effectively (Few, 2012; Fronza, 2013). On the contrary, bad-designed ones can be confusing.

In this paper, we propose a tool, OvERVIeW, that provides to the developer an overall understanding of code ownership in a project. OvERVIeW uses a well-known and intuitive visualization, the word cloud (Feinberg, 2010), where: a) each word represents a class; b) the number of lines added and removed (during a given time frame) is used as size metric; and c) the color represents the developer(s) working on the code. We used pre-attentive processing principles (Ware, 2012), so that the observer can get quickly the information needed. We propose three different code ownership cases (Fowler, 2006): a) collective, when each class has been developed by many developers;

Fronza, I. and Trebeschi, S.
OvERVIeW: Ownership Visualization Word Cloud.
In *Proceedings of the 18th International Conference on Enterprise Information Systems (ICEIS 2016) - Volume 1*, pages 405-412
ISBN: 978-989-758-187-8

b) weak, when some parts of the system are developed only by one developer; and c) strong, when each developer is responsible of a part of the system. A sample application of OvERVIeW, in the context of a OSS multi-developer project, shows concretely its potentials.

The paper is organised as follows: Section 2 discusses existing works in this area; Section 3 details the design rationale; Section 4 shows the usage of OvERVIeW in the context of a multi-developer OSS project; Section 5 draws conclusions and future work.

2 RELATED WORK

In this Section we provide an overview of the existing visualizations of development effort; then, we introduce the main principles of data visualization, word clouds, and their existing applications.

2.1 Visualizing Development Effort

Several visualizations have been proposed to show development effort. An overview is provided in (Tornhill, 2015), where effort visualizations are proposed in order to evaluate knowledge drain in a codebase, or to learn social pitfalls of team work. A spider chart is used in (Diehl, 2007) to show various software metrics, including effort. RUP hump charts are used in (Heijstek and Chaudron, 2008) to depict effort distribution through the development process. Fractal figures are used in (D'Ambros et al., 2005) to show whether many people contributed to the development of a class and the intensity of each contribution.

Many tools have been proposed to support the exploration of code structure, change histories, and social relationships, as well as to animate a projects history, such as:

- ProjectWatcher mines changes to the source code and provides a graph where the color of packages and classes indicates who edited the class most recently (Schneider et al., 2004);
- CVSscan shows, at the source code level, how code changes during the development process (Voinea et al., 2005);
- StatSVN uses SVN repositories to generate statistics regarding the development process, both for the overall project and for individual authors (Jason and Gunter, 2006);
- StarGate groups developers in clusters corresponding to the areas of the file repository they work on the most (Ogawa and Ma, 2008);
- Code Swarm shows the history of commits in a OSS project as a video (Ogawa and Ma, 2009);
- Gource displays the logs from a version control system as an animated tree (Caudwell, 2010);
- UrbanIt provides a visualization of software repositories together with evolutionary analyses (Ciani et al., 2015).

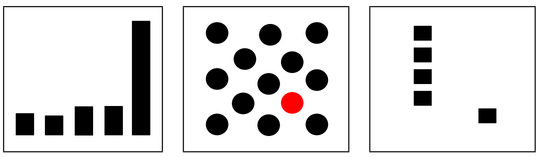
Still, many of the available visualizations are technical and some time is needed to understand them correctly, especially by non-experts in information visualization.

2.2 Principles of Data Visualization

Several studies have demonstrated the importance of pre-attentive processing, which is the unconscious accumulation of information from the environment. In other words, the brain can process the available information and filter the relevant message (Few, 2012). A visualization is *well-designed* when it is able to induce the viewer's brain to memorize only the information that should be communicated. According to (Ware, 2012) and (Few, 2013), information visualization should consider the following pre-attentive properties to maximize the understanding of the information, to guide attention, and to enhance learning:

- form (i.e., length, width, orientation, shape, size and enclosure), which is widely applied in data visualization. The bar chart, for example, preattentively shows data using the length;
- color (and intensity), which is applied to saturation and lightness;
- spatial position, which is the perception of the dimensional space, in terms of differences in vertical and in horizontal positions of elements.

Figure 1 shows some examples of these principles.



(a) Form (b) Color (c) Position

Figure 1: Examples of pre-attentive processing principles.

2.3 Word Clouds

Word clouds are graphical representations of word frequency that present a picture of the most common words used, with those used more often displayed larger. Words are placed in the playing field (i.e., the space that can be filled by words) which is often a cloud, although plenty of shapes are available. Word clouds are usually colorful, but colors are meaningless. The key point of this visualization is its understandability even by non-experts (Feinberg, 2010). For this reason, word clouds have been applied in a range of fields to provide a quick summary of texts pulled from, for example, websites and blogs for different purposes, including sentiment analysis and market research.

In Software Engineering, word clouds have been used, for example, for requirements engineering. In fact, since word clouds are understandable both by experts and non-experts, they are thought to be an excellent communication means between customers and developers. For example, (Delft et al., 2010) shows an application of word clouds that is built over an automatic analysis of spreadsheets and text documents. The user can split and organize concepts, which are represented by words, in entities. The resulting visualization is a set of word clouds which are graphically and semantically interconnected. Word clouds have been also applied to improve the development process; Lanza et al. (2010) propose the usage of word clouds to inform the developer if somebody else has recently changed one of the classes she/he is currently working on. The general purpose of this application of word clouds is to promote the coordination of developers working on the same piece of code. To the best of our knowledge, the usage of word clouds to visualize code ownership is novel in the field.

Despite their wide usage in many disciplines, the following aspects of word clouds are considered controversial: 1) colors are meaningless, 2) the context is lost, and 3) random orientation of words makes difficult to read the graph (Feinberg, 2010; Harris, 2010; Cui et al., 2010).

3 Designing OvERVIeW

This Section introduces a usage scenario and describes the design rationale.

3.1 Scenario

Sepp is a programmer and S is a OSS project that he has just joined. To start his activities, Sepp has been asked to fix some bugs in S. Now, suppose (not an off chance) S to be almost undocumented, unstructured, and poorly written. Sepp starts running the program, examining the source code, and reading any available documentation. Then, Sepp uses some tools, such as source code browsers and static analysers. Sepp is downhearted, and he decides to ask the developers for

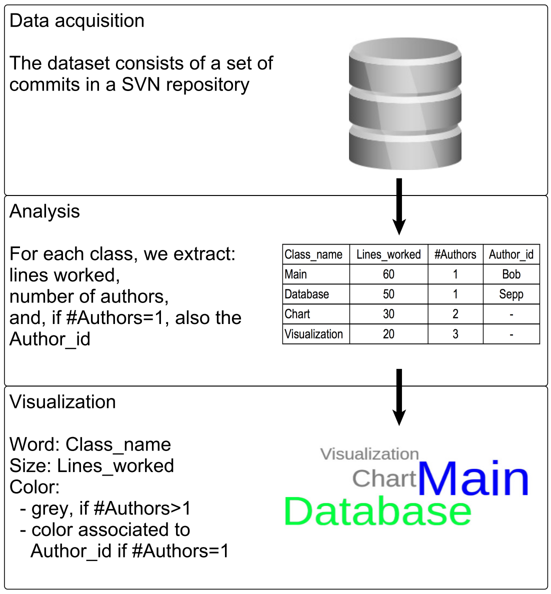


Figure 2: Schema of the proposed approach.

some explanations. To this end, he needs to know who is responsible of what. Sepp needs to get this information as quickly as possible, otherwise he will probably give up and leave the project.

3.2 Design Rationale

To overcome this or similar scenarios, we created OvERVIeW by addressing the three main steps of the visualization pipeline reported in (Diehl, 2007): data acquisition, analysis, and visualization. Figure 2 shows a schematic view of the proposed approach.

3.2.1 Data Acquisition

OvERVIeW extracts a set of commits from a SVN repository and, from each commit, one or more unique atomic changes. A change is composed of the fully qualified name of the class, authors of the commit, the number of lines added, the number of lines removed, and the timestamp of the commit.

3.2.2 Analysis

The set of changes is restricted to a particular time frame (e.g., one month) and grouped by class name. Afterwards, OvERVIeW extracts, for each class:

- *Class Name*, as the name of the class without its path;
- *Lines Worked* (L), as the sum of lines added and lines removed from the class in each change (Moser et al., 2008): $L = \sum L_{add} + \sum L_{del}$;

- *Number of Authors* (n_{auth}), as the number of distinct authors that have worked on the class;
- *Author IDs*, as the ID(s) of the author(s).

3.2.3 Visualization

OvERVIeW generates a word cloud, where each word is a class name and carries the properties of size and color. *Size* is defined as $size = f(L)$, where L are the lines worked, and f is a positive, discrete, monotonically increasing function. We tested for linear, logarithmic, exponential and square root functions (Feinberg, 2010). The latter provided the most appreciable results. *Color* is mapped to a categorical colormap T for a single-developer code, and to grey (i.e., (0.5, 0.5, 0.5) in RGB) otherwise. When a class is associated with multiple authors (i.e., it is represented by a grey color), OvERVIeW stores the list of authors. To visualize the names of the developers, the user can click on the class and a message box is superimposed (Figure 3). To be considered as an author of a class, a developer must satisfy a minimum threshold in terms of lines of code developed; this threshold depends on the type of project, the team and other environmental factors.

Figure 3: Message box showing the developers of a class.

The layout of a visualization influences its perception (Few, 2012; Lohmann et al., 2009). To obtain an effective design, we addressed the controversial aspects of word clouds (Section 2.3) as follows.

Context. Word clouds have been originally created for text analysis. Word size represents the frequency of words occurrences. This way, concepts and themes are completely lost (Harris, 2010; Cui et al., 2010). Moreover, stop words[1] are simply removed from the visualization, and the meaning of the text can be modified by this removal. In OvERVIeW, this problem is solved a priori, since there are no stop words to be removed, and no themes or context proper of a natural language.

Shape. In word clouds, words are placed in the playing field through a randomised greedy algorithm. Once the word is placed, its position does not change and the algorithm checks if that word overlaps another word or crosses the boundaries of the playing field. If the playing field is too small, most of the words will fall outside the field. If, on the contrary, the playing field is too large, the shape will be an incoherent blob, as every non-intersecting position will be acceptable. As a general rule, the playing field must be large enough to contain at least the largest word (Feinberg, 2010). In OvERVIeW, the size of the playing field is fixed. The vector of words sizes is scaled by a factor α to fit the largest word in the field. Thus, the proportion among sizes is maintained and the playing field is fitted. Words in the middle of the playing field attract more user attention than those near the borders (Lohmann et al., 2009; Bateman et al., 2008). In our case, the observer should focus on bigger words, as they might represent core classes. Therefore, OvERVIeW places bigger words in the center of the playing field.

Orientation. We choose for all the words an horizontal placement, which is the best choice in terms of readability (Few, 2012).

Colors. Usually, in word clouds colors are meaningless and are used for "aesthetic appeal" (Feinberg, 2010). In OvERVIeW, colors depend on the author(s) of the class in the given time frame.

To guide the design of OvERVIeW, we used graphical properties that are processed pre-attentively, meaning that they are understood faster (Ware, 2012). Pre-attentive elements have been grouped into: form, color, motion, spatial position. We decided to use the following properties in OvERVIeW:

- *Form:* classes that required more effort (i.e., having higher L) are bigger, as the observer should notice first the parts of the project absorbing most of the effort, and larger words have been shown to attract more attention than smaller ones (Lohmann et al., 2009);
- *Spatial Position:* larger words are in the center (Lohmann et al., 2009), as the observer needs to focus on the parts of the project absorbing most of the effort;
- *Color:* different types of code ownership can easily be recognized using the colors in the word cloud (Section 3.3).

The following Section explains how OvERVIeW can be used to show different types of code ownership.

3.3 OvERVIeW in Action

OvERVIeW allows to reason about code ownership in a software project. Figure 4 shows an example. The number of lines added and removed (during the given

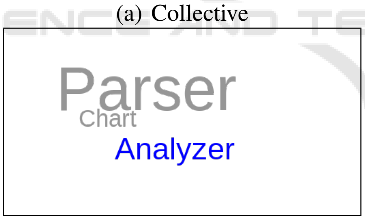
[1]Stop words are words that appear frequently in a natural language (e.g., "it", "do", "not"). They do not have a meaning themselves, but they assume a meaning when associated to another word.

time frame) is used as size metric; each color corresponds to a developer, and a word (i.e., a class) is grey when more than one developer has worked on it during the given time frame. Thus, Figure 4 shows that the distribution of effort among the classes does not change in the three cases, as the dimension of words does not change. The change of colors in the three cases, instead, allows to recognize the following three cases of code ownership:

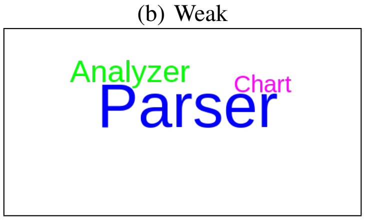
1. Collective. Figure 4(a) is completely grey, meaning that each class has been developed by many developers.
2. Weak. Figure 4(b) is mostly grey. Most of the system has been developed by multiple developers, but part of the code (i.e., "Analyzer") is *owned* only by developer 1, because it is blue;
3. Strong. In Figure 4(c) each developer is responsible of a part of the system: developer 1 works only on "Parser", developer 2 works only on "Analyzer", and developer 3 works only on "Chart".

The three types of code ownership are depicted in Figure 4.

(a) Collective



(b) Weak



(c) Strong

Figure 4: Sample application of OvERVIeW to show the three cases of code ownership. The distribution of effort among the classes does not change in the three cases. The change of colors allows to recognize three cases of code ownership.

4 CASE STUDY

In order to show concretely the potentials of OvERVIeW, we applied it to a OSS project, Epsilon (http://www.eclipse.org/epsilon/), a framework of the Eclipse project, which aims at providing consistent and interoperable languages for MDE tasks. We retrieved data from the SVN repository of the Epsilon project from December 2011 to December 2012. In December 2011 the project had 2340629 lines of code; in December 2012 it reached 2385455 lines of code. Therefore, 44826 lines were added in one year of activity. In the same period, 3 developers committed at least once.

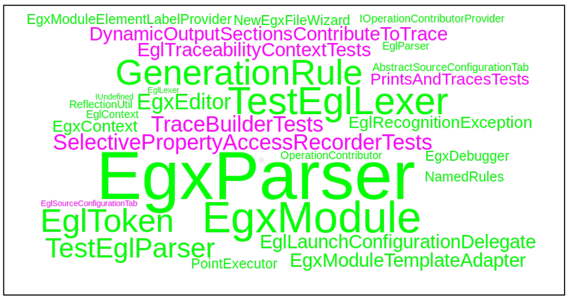
We applied OvERVIeW with time frames of 15 days. Figure 5 shows the OvERVIeW word clouds of different time periods during the analysed year. In particular, Figure 5(a) shows that only green-developer and pink-developer were working on the project during the first two weeks of December 2011. The names of the classes they are working on suggest their responsibilities. Words like "parser", "token", "lexer", and "generation" are green; therefore, we can suppose the green-developer to be responsible for compilation aspects. This seems to be confirmed in Figure 5(d) where "AbstractParser" is also green. Debug analysis and development seem to be done mostly by the blue-developer, as all the classes related to these activities are blue in Figure 5(c). Moreover, in all the word clouds, there are just a few grey classes, meaning that developers tend not to work on the same parts of code.

Overall, each developer in Epsilon seems to have a specific responsibility with respect to a subsystem. Therefore, this project seems to have a strong code ownership, in particular if we consider that the four word clouds have been selected from a time frame of one year. This excludes the possibility of finding the developers devoted to one particular task, thus working on a specific part of the code in that period.

4.1 Qualitative Evaluation

In order to be "useful", a visualization should convey information in an understandable, effective, easy-to-remember way. Evaluation is needed to assess the usefulness of a visualization. Two main types of evaluation exist (Diehl, 2007):

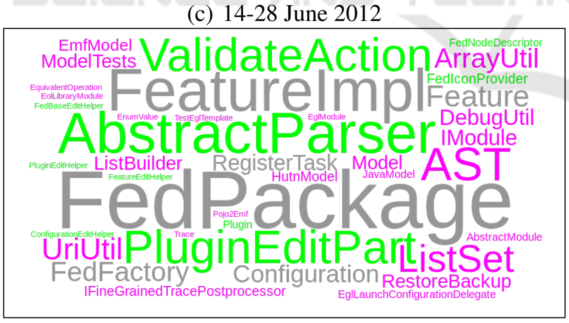
- *quantitative* methods measure properties of the visualization, of the algorithm, or of the human observer interacting with the visualization. Quantitative evaluation requires a statistical analysis of the results of a controlled experiment;
- *qualitative* methods gather data about the individual experience of human observers with the visualization. When it comes to the human perception of and interaction with a visualization, qualitative



(a) 1-15 December 2011

(b) 5-20 April 2012

(c) 14-28 June 2012



(d) 6-20 September 2012

Figure 5: Example using Epsilon.

evaluation methods are of the outmost importance for various reasons, including the fact that they cover more aspects of the visualization. In particular, "task-oriented" analysis is very popular, because it provides an answer to a key question from a user's point of view: "Does the system solve the user's problem?"

In this work we apply qualitative, task-oriented evaluation to answer the following question from a user's point of view: "Does OvERVIeW show effectively the information about code ownership?". To this end, we contacted the community of Epsilon to have a confirmation (or negation) of the information that we got by looking at the output of OvERVIeW; this means that we simulated to be a user in front of the word cloud generated by OvERVIeW. All the developers confirmed that each of them tends to focus on certain parts of the code, due to research interests at the time; anyway, they pretty much share some knowledge of the code. In particular, the green-developer is the founder of the project; he has written most of the code, and he has done improvements to ease the grammar building, and the other two members of the community have contributed to it in the past. The green-developer and the blue-developer did the first iteration of the debugging facilities; the latter has added some functionality, such as inspecting variables and doing step-by-step execution.

5 CONCLUSIONS AND FUTURE WORK

This paper describes OvERVIeW, a tool to collect data from a versioning system and to visualize code ownership using a well-known and intuitive visualization, the word cloud. We explained how OvERVIeW can be used to visualize three different cases of code ownership: 1) collective, 2) weak, and 3) strong. We described a sample application of OvERVIeW in the context of a multi-developer OSS project.

Altogether, we think that OvERVIeW is valuable and worth further investigation. Therefore, as future work we plan to improve the capabilities of OvERVIeW. For example, in this work the "owner" of a class is the developer who has been the only one working on it in the selected time frame. Our definition of "ownership" should be improved to consider possible collaborations and pair programming activities, which are suggested during knowledge transfer to improve productivity and quality (Fronza and Succi, 2009; Fronza et al., 2011b; di Bella et al., 2012). Moreover, we will deal with the scalability of our approach. To this end, we plan to improve OvERVIeW as follows:

- OvERVIeW should be able to deal with long and mostly meaningless class names, sometimes occurring in projects. Indeed, the current solution, which ignores the path name for class names, might not handle overloaded class names. Moreover, longer names might also receive more user attention than shorter ones with a similar size metric, because they occupy more space.

- In the case study shown in this paper, only a limited number of developers is participating to the project. Visualizing data of projects with large teams might result in too colorful graphs. We plan to consider bigger communities and to be able to focus on sub-communities in our visualization.
- The trade-offs between stability and visual clutter should be investigated more formally. In order to improve the readability of the word clouds, in the case study of this paper a short period (i.e., two weeks) was selected, as the team presented a high level of activity. OvERVIeW should be able to deal with high levels of activity of the teams.

The word cloud is generated at one point in time. This steady approach can be expanded by including time information. Time information can be represented, for example, by the time elapsed since the last commit, or the time during which a developer did not commit at all, or the time in which a code is handled only by a developer. This would require a multivariate facet approach, in which it is not sufficient to use a simple transfer function to map only intensity information. The combination of the resulting tool with a prediction algorithm (Abrahamsson et al., 2011; Fronza et al., 2011a) would enable to visualize, e.g., the evolution of effort distribution in the project.

Furthermore, interactive techniques for flexible word cloud navigation and manipulation should be considered. For example, the technique used in (Liu et al., 2014) supports multifaceted viewing of word clouds .

In this work we applied qualitative, task-oriented evaluation to understand if OvERVIeW shows information effectively and we received positive feedback; still, evaluation needs to be extended. In particular, we need to assess if the output of OvERVIeW is understandable and easy-to-remember. To this end, we plan to perform an experiment to evaluate OvERVIeW by asking developers to perform some tasks using different visualizations (including OvERVIeW) and to provide their feedback about OvERVIeW. Finally, we plan to perform case studies using more OSS projects. In this context, it would be useful to collect feedback from users that are living a scenario such as the one described in Section 3.1.

REFERENCES

Abrahamsson, P., Fronza, I., Moser, R., Vlasenko, J., and Pedrycz, W. (2011). Predicting development effort from user stories. In *Empirical Software Engineering and Measurement (ESEM), 2011 International Symposium on*, pages 400–403.

Bateman, S., Gutwin, C., and Nacenta, M. (2008). Seeing things in the clouds: the effect of visual features on tag cloud selections. In *Proceedings of the nineteenth ACM conference on Hypertext and hypermedia*, HT '08, pages 193–202, New York, NY, USA. ACM.

Caudwell, A. H. (2010). Gource: visualizing software version control history. In *Proceedings of the ACM international conference companion on Object oriented programming systems languages and applications companion*.

Ciani, A., Minelli, R., Mocci, A., and Lanza, M. (2015). Urbanit: Visualizing repositories everywhere. In *Software Maintenance and Evolution (ICSME), 2015 IEEE International Conference on*, pages 324–326.

Crowston, K., Wei, K., Li, Q., Eseryel, U. Y., and Howison, J. (2005). Coordination of free/libre open source software development. In *In Proceedings of the International Conference on Information Systems (ICIS 2005), Las Vegas*, pages 181–193.

Cubranic, D. and Booth, K. S. (1999). Coordinating open-source software development. In *Proceedings of the 8th Workshop on Enabling Technologies on Infrastructure for Collaborative Enterprises*, WETICE '99, pages 61–68, Washington, DC, USA. IEEE Computer Society.

Cui, W., Wu, Y., Liu, S., Wei, F., Zhou, M., and Qu, H. (2010). Context-preserving, dynamic word cloud visualization. *Computer Graphics and Applications, IEEE*, 30(6):42 –53.

D'Ambros, M., Lanza, M., and Gall, H. (2005). Fractal figures: Visualizing development effort for CVS entities. In *Proc. Int'l Workshop on Visualizing Software for Understanding (Vissoft)*, pages 46–51. IEEE Computer Society Press.

Delft, F., Delft, M., and van Deursen Delft, A. (2010). Improving the requirements process by visualizing end-user documents as tag clouds. In *Proc. of Flexitools 2010*.

di Bella, E., Fronza, I., Phaphoom, N., Sillitti, A., Succi, G., and Vlasenko, J. (2012). Pair programming and software defects - a large, industrial case study. *IEEE Transactions on Software Engineering*, 99(PrePrints):1.

Diehl, S. (2007). *Software Visualization: Visualizing the Structure, Behaviour, and Evolution of Software*. Springer-Verlag New York, Inc., Secaucus, NJ, USA.

Feinberg, J. (2010). Wordle. In Steele, J. and Iliinsky, N., editors, *Beautiful Visualization: Looking at Data through the Eyes of Experts*, chapter 3. O'Reilly Media.

Few, S. (2012). *Show me the numbers : designing tables and graphs to enlighten*. Analytics Press.

Few, S. (2013). *Information Dashboard Design: Displaying data for at-a-glance monitoring*. Analytics Press.

Fowler, M. (2006). Code ownership. Retrieved Feb. 10, 2016, from http://martinfowler.com/bliki/CodeOwnership.html.

Fronza, I. (2013). Opening statement. *Cutter IT Journal*, 26(1):3–5.

Fronza, I., Sillitti, A., Succi, G., and Vlasenko, J. (2011a). Failure prediction based on log files using the cox proportional hazard model. In *SEKE*, pages 456–461. Knowledge Systems Institute Graduate School.

Fronza, I., Sillitti, A., Succi, G., and Vlasenko, J. (2011b). Understanding how novices are integrated in a team analysing their tool usage. In *Proceedings of the 2011 International Conference on Software and Systems Process*, ICSSP '11, pages 204–207, New York, NY, USA. ACM.

Fronza, I. and Succi, G. (2009). Modeling spontaneous pair programming when new developers join a team. In Abrahamsson, P., Marchesi, M., and Maurer, F., editors, *Proceedings of XP2009, Pula, Sardinia, Italy, May 25-29, 2009.*, volume 31 of *Lecture Notes in Business Information Processing*, pages 242–244. Springer.

Harris, J. (2010). Word clouds considered harmful. Nieman Journalism Lab. Retrieved Feb. 10, 2016, from http://www.niemanlab.org/2011/10/word-clouds-considered-harmful/.

Heijstek, W. and Chaudron, M. (2008). Evaluating rup software development processes through visualization of effort distribution. In *Software Engineering and Advanced Applications, 2008. SEAA '08. 34th Euromicro Conference*, pages 266 –273.

Herbsleb, J. D. and Grinter, R. E. (1999). Splitting the organization and integrating the code: Conway's law revisited. In *Proceedings of the 21st international conference on Software engineering*, ICSE '99, pages 85–95, New York, NY, USA. ACM.

Jason, K. and Gunter, M. (2006). Statsvn: Statistics for svn repositories based on the open source project statcvs. in CSI5140, Winter 2006, Available from: http://www.statsvn.org/.

Lanza, M., Hattori, L., and Guzzi, A. (2010). Supporting collaboration awareness with real-time visualization of development activity. In *In Proceedings of CSMR 2010 (14th IEEE European Conference on Software Maintenance and Reengineering*. IEEE CS Press.

Liu, X., Shen, H.-W., and Hu, Y. (2014). Supporting multifaceted viewing of word clouds with focus+context display. *Information Visualization*.

Lohmann, S., Ziegler, J., and Tetzlaff, L. (2009). Comparison of tag cloud layouts: Task-related performance and visual exploration. In *Proceedings of the 12th IFIP TC 13 International Conference on Human-Computer Interaction: Part I*, INTERACT '09, pages 392–404, Berlin, Heidelberg. Springer-Verlag.

Moser, R., Pedrycz, W., and Succi, G. (2008). A comparative analysis of the efficiency of change metrics and static code attributes for defect prediction. In *Proceedings of the 30th international conference on Software engineering*, ICSE '08, pages 181–190, New York, NY, USA. ACM.

Ogawa, M. and Ma, K.-L. (2008). Stargate: A unified, interactive visualization of software projects. In *Visualization Symposium, 2008. PacificVIS '08. IEEE Pacific*, pages 191 –198.

Ogawa, M. and Ma, K.-L. (2009). code_swarm: A design study in organic software visualization. *IEEE Transactions on Visualization and Computer Graphics*, 15(6):1097–1104.

Pinzger, M., Gall, H., Fischer, M., and Lanza, M. (2005). Visualizing multiple evolution metrics. In *Proceedings of the 2005 ACM symposium on Software visualization*, SoftVis '05, pages 67–75, New York, NY, USA. ACM.

Schneider, K. A., Gutwin, C., Penner, R., and Paquette, D. (2004). Mining a software developers local interaction history. In *In Proceedings of the International Workshop on Mining Software Repositories*, pages 106–110.

Tornhill, A. (2015). *Your Code as a Crime Scene: Use Forensic Techniques to Arrest Defects, Bottlenecks, and Bad Design in Your Programs*. Pragmatic Bookshelf.

Vervloesem, K. (2010). Visualizing open source projects and communities. LWN.net. Linux info from the source. Retrieved Feb. 5, 2016, from https://lwn.net/Articles/382468/.

Voinea, L., Telea, A., and van Wijk, J. J. (2005). Cvsscan: visualization of code evolution. In *Proceedings of the 2005 ACM symposium on Software visualization*, SoftVis '05, pages 47–56, New York, NY, USA. ACM.

Ware, C. (2012). *Information Visualization: Perception for Design*. Interactive Technologies. Elsevier Science.

Wettel, R., Lanza, M., and Robbes, R. (2011). Software systems as cities: a controlled experiment. In *Proceedings of the 33rd International Conference on Software Engineering*, ICSE '11, pages 551–560, New York, NY, USA. ACM.