Revista de Sistemas de Informação da FSMA
n. 9 (2012) pp. 24-44

SISTEMAS DE INFORMAÇÃO
http://www.fsma.edu.br/si/sistemas.html

TRILHA PRINCIPAL

Essential Requirements for Digital Annotation Systems

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***Abstract* — Digital annotation systems are usually based on partial scenarios and arbitrary requirements. Accidental and essential characteristics are usually mixed in non explicit models. Documents and annotations are linked together accidentally according to the current technology, allowing for the development of disposable prototypes, but not to the support of non-functional requirements such as extensibility, robustness and interactivity. In this paper we perform a careful analysis on the concept of annotation, studying the scenarios supported by digital annotation tools. We also derived essential requirements based on a classification of annotation systems applied to existing tools. The analysis performed and the proposed classification can be applied and extended to other type of collaborative systems.**

***Keywords*—Requirement analysis; System classification; Conceptual modeling; Collaborative Systems; Digital Annotation Systems; Electronic Texts.**

I. INTRODUCTION

Given the newfound popularity of digital documents and content, digital annotation systems have also become popular. Nevertheless, annotation systems and prototypes are created accidentally, with no essential conceptualization for reuse. Hence, the solutions become a mix of accidental (*ad hoc*) and essential aspects dependent on the editors and browsers technologies and on the available documents.

Therefore, the research issue at hand consists on demonstrating the essential requirements for a digital annotation system. The hypothesis we rely on intends to characterize the autonomy between annotations and documents as independent artifacts, as well as to circumscribe the requirements for annotation access..

This paper is organized as follows. In section II, we present the fundamental concepts that will allow the reader to clearly understand what a digital annotation is. In section III we present the different annotation scenarios, from which we extracted the characteristics which were used to create a classification system that was applied to existing systems (as described in Section IV). From the set of such analyses and with the application of criteria to recognize the fundamental principles, we derived a set of essential requirements for digital annotation systems. The inclusion of such requirements will allow for digital annotation systems to be more general and robust.

Final manuscript received in June 6th, 2012. This work was partially funded by FAPESP, graduate scholarship 98/00083-1.

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II. ANNOTATION: BASIC CONCEPTS

Based on current studies on annotations on paper, it is possible to isolate the definition from the object “annotation” from interference from technological artifacts, circumscribing and differentiating it from other concepts, what takes us to the following definition.

Annotation is a byproduct of the interaction with the text or any other annotation-prone object. They are made with tacit (Marshall studies, section II.A) or explicit intentions (National Library Manuscript studies, section II.E). Nevertheless, in both intentions, annotations depend on the context for their meaning (Microsoft Research Studies, section II.D). They are the result of cognitive non automatic activities, not being a consequence of translation between languages (oral to written) as is the case of note taking. They are also not semi-automatic markings, as in the case of meta-information ontologies.

From this definition, we can arrive at two transversal aspects that create a correlation between the act of creating annotations and the act of editing documents:

Autonomy of the annotations: annotations must exist separately, both physically and time-wise from their respective documents. The elimination of a document must not eliminate its annotations.

Interdependency between annotation and document: the document's writing may be able to use the annotations as a resource, but annotate must be a different act from edit.

The term "digital annotation" is found in many different research areas, such as semantic web, digital library, human-computer interact and computer mediated collaborative work. Hence, it is critical do define the study object not only conceptually, but also as related to the usage and technological support that are valid to the research problem at hand. Therefore, we define the concept of annotation considering first the human factor research, second, the evolution of the digital annotation support systems and last, its usage scenarios as approached in scientific literature.

At the W3C-Annotation Working Group [1], there is the following definition: "in general, an annotation is defined as an object associated with another through a relationship. The annotation object and the relationship may be of any kind." This is a quite generic definition, which may become a problem, for it does not allow differentiating between annotations of objects such as anchors, links, and messages in discussion groups or even combinations of those, as in chat environments.

In order to improve this definition, we performed an investigation on how annotations were conceived, both in its digital and manuscript formats.

A. *Annotation as a result of reading*

Anthropologist Michel de Certeau interprets reading as a hunting operation, in which the annotator's role is:

> "In effect, reading is like a peregrination on an imposed system (the text's, analogous to the order built in a city or a supermarket). Therefore, if the book is an effect (a construct) from the reader, one must consider the latter's operation as a *lectio*, a production that came from the reader. He doesn't switch places with the author, but invents in the text something other that its original intention. He detaches it from its origin (lost or accessory), combines its fragments and creates something unknown in the space organized by his capacity to allow an indefinite plurality of meaning." [2, p.264]

Hence, for de Certeau, when the reader annotates he does not produce authorship, but yet a tangle of interpretations, questions, addendums and highlights. On the other hand, Marshall's ethnographic research defends annotations as an intelligible and researchable byproduct of reading [3,4]. In order to create this idea, Marshall studies student's annotations in library textbooks and, since he did not have access to the students themselves, he relied solely on the characteristics of the annotations for the classification task, such as markings for emphasis, references, interpretations and associations. The annotations as byproducts of the reading process present tacit and idiosyncratic intentions, for they lose their meaning as time elapses, even for their original author. Therefore, to Marshall, the reader is not the author of the text, but the author of the annotations. This conclusion seems to conciliate the diverging opinions of de Certeau and Marshall.

B. *Annotation as note taking*

The activity of note taking has been extensively studied by researchers in educational psychology, which concentrated in the issues of effectiveness of annotations as a process and as a product [5,6]. Ladas suggests that the activity of note taking should be guided by tips given by the professor, so that the students are informed on the correct time and subjects of their notes [7]. Kiewra et al. have studied techniques and impacts on the learning in three scenarios of note taking – coding (taking notes and not reviewing), coding and storing (that also includes the review) and external storage (abstain from taking notes and review the ones taken by another student) [8,9]. In a digital scenario, Armel and Shrock returned to the issue of when a student must be asked to take notes [10].

C. *Annotation for discussion and to help recollection*

In an ethnographic study comparing reading on paper and online, O'Hara and Sellen observed the usage of annotations to help understand the text and to highlight elements that might be reused [11]. Ovsiannikov, Arbib and McNeill investigated the form and the object of annotations on paper and discovered that they are used during and after the reading [12], therefore in agreement with the conclusions of O'Hara & Sellen. According to both research, annotations are used to help recollection, by means of marks of interpretation (questions, reflection, and opinion), as well as complementation or rewriting in the annotator words.

The interviewees also declared to use annotations as a way to discuss passages with other students. Shared annotations work as an instrument of communication and, Therefore, the characteristics which were implicit in the paper paradigm become explicit, such as intention (or motive), relation between annotations, meta-information (author, date) and place in the text (in-line, pop-up, margins).

D. *Annotation as Contextualized Writing*

The role of context is determinant to the meaning of annotations, especially if we are discussing the concept of authorship. Usability experiments made by Microsoft Research [13,14] demonstrated the impact of the lack of context (due to the loss of annotation position). From the theoretical point of view and based on text organization theories, Botoni, Levialdi and Rizzo declared the lack of autonomy of annotations in relation to the context [15].

E. *Annotation as a review*

For this study, we sought out examples of explicit intentions of annotations. For that, we studied two manuscripts of the

National Library at Rio de Janeiro, "Namoros com a Medicina" by Mário de Andrade, from 1935, and "Numa e Nympha" by Afonso Henrique de Lima Barreto, from 1914.

Mário de Andrade's manuscript is a series of annotations performed on the text of an article that the writer published on the Journal of Medical Publications. This article was a study by Mário de Andrade on beliefs about the therapeutic use of excrements.

Lima Barreto's manuscript is a series of annotations made on an edition of his own book "Numa e Nympha". Lima Barreto uses annotations to correct grammar mistakes and to add new content to his opus.

We can identify in these manuscripts two basic options in the annotations: choice of place in the text and of the appearance of the annotation.

The choice of place is made according to the best way to associate the annotation to the text. For instance, corrections are made over the letters of the original text while idea complementation is made at the margins.

The choice of appearance shows the intention of the author. Mário de Andrade uses pencils and different color pens according to a pre-establish intention. Annotations in pen serve to correct typographic errors and to add new discussions to the text. Red pen characterizes the annotations of the most recent version, while black pen corresponds to an initial analysis made by the author. Penciled annotations serve to group the paragraphs by subjects (in this case, diseases). There are also examples of annotations on annotations. The annotations made by the writers follow self defined patterns of symbols and colors in order to define specific review actions (for themselves or for the editors).

III. Usage Scenarios for Digital Annotations

Scenarios represent different contexts for the concept of annotation. The intention is to provide an interpretation framework for the already defined annotation concept. We will describe the scenarios based on some categories such as the relation of the annotations with the documents, collaborative use and the motivations behind them. As factual support, we will list for each scenario evidences of use in literature and the available tools.

The scenario exposition is in growing order of collaborative use, the first ones describing individual use and tacit motives, while the last ones describe collaborative use and explicit motives. We also list the activities performed and the products generated in each scenario.

A. *Reading*

Owning a text and given the permission to intervene with a pen or digital instrument, the reader writes down her annotations or takes notes in a notebook. She will take note of her impressions, doubts and opinions, and also mark the text, underlining it, writing symbols and scribe over lines.

Annotations and notes made this way are not intended for sharing. This way, many of these interventions are idiosyncratic and have tacit meaning. Some frequent readers tend to develop a personal catalog of symbols and their annotations are made for themselves, not for the original authors and therefore there is no relation between annotation and text authorship. Consequently, it is a premise not to have more than one version of the text.

1) *Environmental Evidences*

Mayer demonstrates that the practice of creating annotations improves markedly the reading [16]. Adler et al. reported that the reading takes about 70% of the time spent in document manipulation activities [17]. For these readers, 18% performed writing activities in the document itself. Meanwhile, note taking and annotations during reading took about 48% of the time.

Reading accompanied by writing, note taking and discussion was observed by many researchers. In the reference "Reading – a hunting operation", Michel de Certeau states that the reader, in spite of the resemblance, does not become an author. Marshall points out that in spite of the tacit and often idiosyncratic character of the annotations, the reader uses several different ways of annotation to help his reading [9]. Schilit, Golovschinsky and Price have created the term "active reading" [18] for this situation. Kaplan and Chisik evaluated the exchange of annotations in a digital book [19] and observed impact in the reading practices both at the individual and at the group level. In posterior studies, Brahier took the discussion beyond cognitive effects and focused on the social effects, such as making explicit the students' reading impressions which were initially tacit [20]. Such information could be used to improve the teaching of reading practices.

2) *Tools*

Prototypes such as Alph [19] and commercial tools such as HyLighter™ [21] and RepliGo (http://www.cerience.com) were used in this scenario, as well as text editors that support annotations such as Microsoft Word® and Adobe Acrobat® Reading devices such as the Amazon Kindle™ also contemplate annotation during reading. There are also prototypes that work in a similar way as in paper annotations, as presented by Schilit, Golovschinsky and Price [18] and Bargeron and Moscovich [22].

B. *Note taking Scenario*

Students write comments on slides, video or audio that is shown in classroom using some device (blackboard, screen project or even a TV). The notes are taken for personal use, even though it is common practice for students to photocopy notebooks from their classmates that are more organized or come to class more often.

During school years, it is common for teachers to gather their students' notebooks in order to evaluate the quality of the notes taken. The annotations do not influence the content authorship, in spite of the facts that the teacher is the author

and that the teacher has access to the students' comments. In this case, the content version is also unique.

1) Environmental Evidences

Educational research on note taking is quite old, starting from the beginning of the last century, with Crawford [23].

Carter and van Matre discussed the process of taking notes and its byproducts [3]. The authors showed that there is no marked improvement in the student's understanding when she takes notes herself or when she uses her colleagues'. In this line, Ladas recommends that the teachers give the students some clues on when take notes and what to annotate, in order to maximize the amount and the quality of the notes taken [4]. Kiewra corroborates those results showing that the activity of note taking is more justified by their use to study and review the subject rather than by the cognitive process [2,5]. As such, educational psychology turned itself to the investigation on the use of memory, as in the mentioned three configurations treated by Kiewra et al. [6]. Armel and Shrock developed experiments on note taking in a computerized environment [7] and found evidences similar to those of Kiewra.

2) Tools

Research in this scenario still attracts a large industrial and academic production. There are tools for the association of written notes and audio recorded in meetings, such as the Filochat [24] and Dynomite [25] systems. In this same line, the AWS system [26] allows for the association of text on slides and its respective audio. Pimentel et al. [27] and Goularte et al. [28] also demonstrated systems that allow for the annotation of videos with digital ink in a note taking scenario. In those systems, annotations on the audio media serve to search the audio spot annotated, as well as to aggregate content. uAnnotate [29], Classroom 2000 [30] and BSCW [31] support note taking and the creation of new content.

3) Incompatible Systems

We found systems that are not compatible with this scenario, for they do not allow for annotations on content (whether it is slide, audio or associated video). Examples of those are the systems NotePals [32], WandaML [33] e NoteTaker [34], which deal with ergonomic and character recognition issues. Collaborative authorship systems on the Web such as Wiki are also not compatible with this scenario. This is the case of educational environments such as Moodle (www.moddle.org), TeleEduc (www.teleduc.org.br/), WebCT (www.blackboard.com), ATutor (www.atutor.ca/) and OLAT (http://www.olat.org). The same applies to collaboration environments such as Curio (www.zengobi.com/curio) and Google Notebook (www.google.com/notebook).

C. Digital Libraries and Ontologies Scenario

This scenario is characterized by two different usage moments. First, people annotate parts of a page with personal interpretations or with labels from a specialized catalog called an ontology, which consists of a formal representation of concepts in a domain and the relation between those concepts [35].

In a second moment, users navigate among pages searching for information that might have received a specific ontology label. This way, it is possible to retrieve all pages that received classification notes such as "good practices". Based on the searches and the annotations made, a librarian evaluates the use of annotations and suggests new items to improve the ontology. Based on the annotation density in some pages, the librarian may suggest new related content. This way, the digital library is continuously improved and adheres to a community of readers.

This collaborative style is similar to Wikipedia, but with the structure and the organization of a library. In spite of the evolution of the annotated material, no versioning is kept with the respective annotations.

1) Environmental Evidences

Smith tested annotations as instruments for reflection and interpretation, whose final results created ontologies [36]. For that, he organized experiments in which students created annotations as labels over images. Smith demonstrated the possibility of collaborative building knowledge made explicit as new ontologies.

Arko experimented with annotations in a digital library in order to foster collaboration among readers through an exchange of labels and text interpretations [37].

2) Tools

At first, hypermedia systems with capacity for annotation exchange such as Knowledge Weasel were used in this scenario [38]. More recently, we have seen semantic annotation tools based on Web browsers such as Amaya [39]. Specific uses for digital libraries are exemplified by the WebCobalt system [40] and, for image databases by VideoAnnex (www.research.ibm.com/VideoAnnEx) and EVA systems [41]. Prototypes have been proposed, such as the one described by Rigo et al. [42], by Fogli, Fresta and Mussio [43], the M-OntoMat-Annotatizer [44] and the Vannotea [45].

D. Discussion Scenario

This scenario starts with the distribution of a text in digital format for debate. The debaters annotate on the text, request their peers' annotations and annotate those annotations.

The annotations on annotations are a dialog among annotators that may give birth to new subjects. In this case the moderator may decide to add a new topic to the text. Even with those changes, the text version is unique – in other words, there are no different versions of the text being debated.

Next, new annotations can be made on the new topic. The debate can have a finish date or remain open until the moderator decides to end it. At the end of the debate, the moderator summarizes the discussion using a compilation of notes and text.

1) Environmental Evidences

In a seminal work, Davis and Huttenlocher implemented this scenario on classes at Cornell University using a proprietary tool called CoNote [46]. Swan and Meskill reported on students annotating on their colleagues annotations in a hypermedia system for literature teaching [47]. In a web based course, Nokelainen et al. reported that study habits were undergoing positive change after students annotated the supplied material [48]. Lauer and Busl demonstrated the use of voice annotations to discuss educational materials in textual format [49]. A similar scenario can be found in discussions forums (for instance http://ifets.ieee.org/). The difference is that the text does not receive the annotation directly, because it does not perform the function of organizing the discussion, but only of introducing the issue. According to Hermann and Kienle, the discussion through annotations must follow the underlying structure of the text [50].

2) Tools

Examples with demonstrated use for this scenario are in their majority prototypes, such as CoNote [46], WebAnn [51], Vannotea [45], Educosm [52], SholionWB [53] and uAnnotate [29] systems.

E. Colaborative Writing Scenario

This scenario intends to allow many authors to create a text by using several suggested texts and to annotate them. . The annotations serve to question, interpret, illustrate, synthesize and add content or references. The annotations also serve to highlight important parts. In a certain moment, all authors define the general structure of the new text. The material for the new text will come from the exchange of annotations already written and from discussions coming through annotations on the final text. For that, the annotations are transformed into text that may become the foundation for new annotations. At this point, a new version of the document is generated and all participants use the same version. Hence, there is no collaborative writing on different versions.

1) Environmental Evidences

In a research on collaborative learning, Jackson demonstrates that it is not enough for the students to read and summarize texts– it is also necessary for them to debate and to reorganize arguments [54]. The scenario described illustrates this situation through the support for contextualized discussion and the consolidation of annotations as parts of the text.

Using a proprietary tool called PREP, Neuwirth et al. investigated collaborative writing using annotations [55]. In another study, Neuwirth et al. reported that in-line annotations generate higher volume of revision, problem solving and discussion interactions when compared to annotations separated from the text [56].

2) Tools

Text editors that support revisions are the main tools used in this scenario. Seminal examples were the prototypes QUILT [57] and PREP [55]. Commercial tools such as Microsoft Word were tested in this scenario by Cadiz, Gupta and Grudin [11]. As a complementary act to the revision activity, Weng and Gennari suggested an annotation tool that supports versioning and planning of collaborative text writing [58]. GoogleDocs (www.google.com/documents) has resources to exchange files and to perform annotation in the text itself.

F. Revision Scenario

This scenario is based on the exchange of annotations between reviewers and a team that is responsible for the digital material, which can be either text or source code.

Each reviewer has a goal – for example, if the material is a source code, reviewers may verify security rules, architecture patterns or algorithm complexity.

The reviewers not necessarily annotate on the same version of the material. Hence, there are annotations in different versions.

The review annotations are made in order to require clarifications or adjustments on a text. Team annotations are explanatory and corrective, indicating that a detected problem was or will be solved in the code in a certain way. Therefore, annotations induce change in the material and, therefore, the creation of new versions.

In order to organize the review, annotations are made in pre-established points, such as methods and variable declarations. Annotation exchange can involve annotations on annotations. The reviewer can also request that another reviewer write down new annotations.

As soon as the new points are all taken, the review will perform the last annotations which will become an evaluation of the material and of the team's annotations. Notice that the collaborative review does not contemplate orthographic or style corrections because such activities are more adequate to the collaborative writing scenario.

1) Environmental Evidences

This scenario can be a support for formative evaluation. According to Black and William, an evaluation can be considered formative if the result of the learning activities is used to adapt the teaching approach [59]. Cowie and Bell stress that it is fundamental the bi-directional character of the formative evaluation [60].

Crooks defends the need for the evaluation to include a self-reflection of the student [61]. Using students' digital annotations as an input for formative evaluation is analyzed and recommended by Brahier, who performed experiments on reading education with commercial tools [20].

Nokelainen et al. reported the use of a tool within an approach similar to formative evaluation [48], which contemplated analysis of the annotation and e-mail exchange logs. Moreover, a questionnaire on the personal learning

strategies and perceptions (self-reflection) was applied, demonstrating gain in both aspects.

2) Tools

We did not find specific support for annotations in this scenario, but there are reports of experiments with commercial tools such as Hylighter [21], Educosm [52] and RepliGO (http://www.cerience.com).

G. Scenario Analysis

Table 1maps all the activity types for the previous scenarios. We can see that is not possible to differentiate between scenarios based on the activities. This would also not be desirable, for it would lead to the conception of unrealistic and impoverished scenarios, such as ones that included only questioning activities, for example.

Nevertheless, based on the scenarios description, we can realize that there is a gradual transition from the individual to the collaborative use.

In reading and note taking scenarios, the annotations byproducts are vestigial from the activities. The focus in those scenarios is on the representation of cognitive processes that are tantamount for learning.

On the other hand, on collaborative scenarios (discussion, writing and review), the emphasis is on the communication media. Therefore, from the first described scenarios up to the last, there is a shift from the interest in the product (annotation-content) to the process (annotation exchange-communication). The ontology scenario is at a transition point.

The impact of annotations on documents (and vice-versa) corresponds to a transversal aspect declared in the definition of digital annotations – autonomy between annotations and documents. Table 2 illustrates two extreme situations. The first one (lines 1, 2 and 3) suggests that even if we increase the number of annotation there is no impact whatsoever on the document, while the second one (lines 4 and 5) suggests that the increase of changes in the document does not imply in an increase in the number of annotations.

The use case sought is the one that support both impacts. We choose, therefore, the review scenario and use as premise the idea that by supporting the most complex situation we will automatically support the simpler ones. In other words, through reductionism, from the review scenarios we can arrive at the other scenarios.

The scenarios identified were analyzed with the application of the theory of conceptual metaphors [62, 63]. From this analysis, we derived functional characteristics and metrics associated with each scenario, and the following attributes:

Author: person that edits an annotation or a document;

Content: information produced by the author of the annotation;

Position: point in the document referred by the annotation;

Date/time: temporal label that marks the moment when the annotation was created or modified;

Media: support media where the content was generated (sound, video, text);

Intention: reason that motivated the creation of the annotation (doubt, interpretation, reference);

Context: Temporal session that includes a set of activities. The context establishes a common goal for a group of collaborators. One single author can have different roles in different contexts.

Figure 1 summarized in a class diagram the attributes, metrics and behaviors extracted from the scenario analysis.

IV. Classification of Digital Annotation Systems

In order to perform the analysis presented in this paper, we considered 80 digital annotation systems proposed in the last 25 years. The analyzed systems may be defined in four technological cycles, as presented in Figure 2. Each cycle corresponds to the use of a specific technology in the development of annotation resources.

The first cycle represents the first stand-alone programs with annotation resources (beginning circa 1987). Cycle 2 represents the resources of annotation on Web pages (beginning in 1994). Cycle 3 gathers the resources for annotations based on XML technology (beginning in 2000) and cycle 4 represents the annotations made in Web 2.0 technology, Plugins and Cloud Computing (beginning in 2004).

Nevertheless, a classification solely based on time is not enough. The diversity of existing application types makes us pose another question: how can we classify those systems so that we can make better selections and comparisons?

Different classifications of annotation systems have been made with specific focus. Brush et al. classified systems according to the asynchronous change between documents and annotations. For that, they divided the annotation resources into two groups: frozen documents (systems that do not allow change after receiving annotations) and documents with pre-established annotation points (that allow for change as long as the annotation points are removed) [12].

In another classification made by Hori, Abe and Ono, the systems are organized according to the transforming function of the annotation versus the authorship system used [64]. According to those authors, transforming annotations are those which suggest some structure modification in the annotated passage, while assertive annotations merely declare attributes on that passage. As to the authorship method, in this category of classification, annotations can occur by selection or by example, the former representing the situation when the annotation is associated with a specific passage of the text and the latter representing the situation when the annotation becomes part of the passage itself. With this classification, the author identified three different annotation systems, because they did not find examples of assertive annotations.

Analyzing the scenarios, the main characteristic that demanded another form of classification was the autonomy of annotations and documents. The **annotation autonomy** consists on the dependency type from the annotations to the

documents. The dependency will be heteronomous if the annotations do not have a life cycle of themselves, that is, the actions of saving, moving and editing always happen together with the document. This is the case of the Wikis, GoogleDocs, Google Notes, Microsoft OneNote and locally installed editors. On the other hand, if the annotations have a life cycle of themselves, they may exist independently of the document. In this case, the annotations will be autonomous, even if the documents are centrally stored, as in the case of Web annotations.

On the other hand, **document autonomy** consists on the type of dependency from the document to the annotations. The document is stored centrally and all the annotations point to the same document instance, implying in a single document version. This is the case where the life cycle of the document is not controlled by the annotator, but by somebody else who has the role of editor. Tools that support this centralized document writing are the Wikis, GoogleDocs and Web page annotations.

In another case, the autonomous character of the document implies in having annotations in different version of the same document. This is the case where the document life cycle is controlled by the annotator, who also has the role of editor. We see this character in text, code or diagram editors that get their documents from a shared versioning system (CVS, Subversion, SourceSafe, etc.). Hence, both annotations and documents can be classified as **heteronomous** (stored in a single repository and in a single version) or **autonomous** (stored in many places and in independent versions).

In order to create a classification based on those characteristics, we sought in several sources for a classification method that supplied an adequate systematic analysis and found an adequate framework in the work of Dunnell from the field of archaeology [65].

Using a research from such a distant field of expertise may strike as odd, but there is a certain similarity between both areas: since archaeology is the study of objects modified by man, the classification of systems (some that are more than 30 years old) is not far from being a branch of that science.

We can make a small synthesis of the road we traveled so far: we defined the concept “annotation” based on the following elements: attributes, places of annotations and use scenarios. This approach has a parallel with Dunnell concepts such as intensive definition, extensive definition and description, respectively.

An intensive definition is found by the list of essential attributes. In our case, the annotation definition and the proposed model.

The extensive definition is obtained through the enumeration of all objects for which the concept is applicable. In our case, the forms of annotation (types of annotation places).

The description of a concept is the explanation that contemplates the variable attributes. Variable attributes are those that are not necessary to identify uniquely one concept, being non-essential or accidental. In our case, the usage scenarios and the derived functionalities correspond to the description of the annotation concept, for they are rich in variable attributes.

For the classification we will use all these concepts, which have already been adequately instantiated.

The second part of the method is to find the classes, what will be done using the concepts of paradigmatic and taxonomic classification. Both methods are called non-historic, because they build their classes based on time events.

Dunnell explains that the paradigmatic classification consists in creating classes through the intersection of dimensions, where a dimension is a set of attributes that cannot coexist, that is, they are mutually exclusive.

On the other hand, the taxonomy allows creating classes based on variable attributes. Using paradigmatic and taxonomic classes allows us to seek correlations between different types of attributes. This approach has a predictive and heuristic character, first because all the defined dimensions forecast new types (as happened in Mendeleiev periodic table) and second because the sorted criteria allow for the fast characterization of a new element according to its immutable (essential) and variable (accidental) attributes that matter to the model.

Based on the combination of the two dimensions of autonomy, we arrived at four different classes of annotation systems. We adopted the labels *N* and *D* for annotations and documents respectively and *h* and *a* for heteronomous and autonomous respectively (Figure 3). The class *NhDh* is the simpler, because annotations and documents share the same life cycle. It is not possible to separate annotations from documents, because we use a single tool to edit and annotate. This way, annotations are stored in the documents themselves.

The classes in the other quadrants are defined based on the transitions from the classes previously defined.

In the transition from *NhDh* to *NhDa* (labeled as 1 in Figure 3), the document property ceases to be unique. Each annotator will have a different version of the document. This is the case where persons need to cooperate, but will be evaluated individually on the final result of the annotated document. The annotation resource in commercial text editors is an instance of this class. Each person has a document with the same structure, but with different annotations, which remain heteronomous, while the document is now autonomous, for it can change together with the annotations.

In the transition from *NhDh* to *NaDh* (labeled as 2 in Figure 3), the annotations become private, so that they can be more easily controlled by the annotators. On the other hand the document is kept unique and centralized. The pre-collaborative scenarios require this type of system. Web annotation resources through browsers are an instance of this class. The same is valid for annotation resources in mobile devices, because due to its disconnection prone infrastructure a separation between annotation in local bases and centralized documents is necessary. Hence, this class of system implies in

documents with heteronomous life cycle and autonomous annotations.

With the transition from *NhDa* to *NaDa* (labeled as 3 in Figure 3), the collaboration on document versions starts to use annotations made locally through a mobile device or partially made available by the author.

Situations requiring this kind of flexibility correspond to collaboration groups organized under demand and temporarily. Persons can decide to annotate and afterwards make one or some of the group's annotations available. This can be the case of collaborative writing of a report from an extensive research project. Participants and observers share different document versions and decide do annotate it as the results are reported.

The reason for persons to keep annotations without sharing may be to wait for a better version of their own annotation or of the report itself. This way, one would make sure that the annotation will be a contribution instead of a distraction. This is patent in the observers because they did not participate intensively in the reported findings.

Systems in this class can evolve from *NhDa* through a resource that allows segregating annotations from the document, therefore allowing for the separate evolution of annotations and document. When we add resources to a *NhDa* system to make private annotations available to distributed collaborators, we get a *NaDa system type*.

With the transition from *NaDh* to *NaDa*, the collaboration through private annotation exchange ceases to be on a single document and takes place on different document versions. The autonomous annotations make reference to different document versions. This situation happens in collaborative writing of the manual of a family of equipments which share parts of the documentation and its respective annotations. This is also the case of software products documentation systems, in which deliveries (releases) require versioned and documented source code. The use of open patterns in the *NaDh* systems is the path of interoperability that leads to *NaDa* systems.

The application of this classification to the analyzed systems (Table 3) demonstrates that there is a lack of solutions for the quadrants *NhDh* and specially *NaDa*.

We also considered in this analysis the annotation places types used in these systems. We identified the following types: **anchor** (or bridge) type, in which the annotation is associated to an icon or hyperlink in the document; **post-it** (or in-line), in which the annotation is attached to the document in a minimized form; **in-place**, with the annotation visible and integrated to the document, similarly to an annotation on paper; **projection**, as the annotation made on a transparent layer overlaid to the document; and **notebook**, with the annotations stored in different documents.

The synthesis of the relation between types of annotation places according to the systems classification in presented in Figure 4. We realized that systems from quadrants *NhDh* and *NaDh* prioritize annotation of the anchor type, while the systems from quadrant *NaDa* presents a larger proportion of projection type annotation than the other quadrants. The reason for that is the facility offered by the projection type for the repositioning of annotations in the document, which is a requirement identified with this class of digital annotation systems. The list of all classified systems is in the appendix.

V. Essential Requirements

The choice of software frontiers is a difficult design decision that can have many consequences. The first architectural design restriction implies that aspects classified as essential must be inside the frontier while the accidental ones, outside. To be outside the frontier does not mean that they will not be included, but that they will require uncoupling solutions.

Bourque et al. [66] established eight criteria that have been used by Software Engineering specialists to reduce an initial list of 65 recommendations to 16 suggested as fundamentals for the field. Similarly, we can use these criteria to identify the essential requirements for digital annotations. The criteria are:

1. Fundamental principles are less specific than methodologies and techniques.
2. Fundamental principles last longer than methodologies and techniques.
3. Fundamental principles usually are discovered or abstracted from practice and must have some correspondence to good practices.
4. Fundamental principles of software engineering must not contradict more general fundamental principles.
5. Fundamental principles must not prioritize characteristics of a solution (the engineering process is responsible for that). Fundamental principles must identify and explain the importance of several characteristics which will be selected by the engineering process.
6. There can be compromises in the application of fundamental principles.
7. A fundamental principle must be precise enough to be able to guarantee confirmation or contradiction.
8. A fundamental principle must be related to one or more basic concepts.

Some of these criteria to identify fundamental principles in software engineering can be applied to the problem of selecting essential requirements in digital annotation software. Hence, four new criteria specific for this type of application were derived:

Technical Limitation (derived from do criterion-2): The essential requirement must not be justified solely as an answer to technical limitations.

Specificity (derived from criterion-1): The essential requirement must not exist in other systems that have different goals. In other words, the requirement must not be fulfilled by other systems.

Viability (derived from criterion-7): The essential requirement must resist to the confirmation or contradiction test: can we annotate without this resource?

Identity (derived from criteria 4 and 8): The essential requirement must be described in terms of annotation, position and annotation place. Therefore, it must not contradict those concepts either. In other words, is this activity considered as an annotation?

The application of these new criteria to requirements resulted in the classification of 21 requirements defined in this type of system into five groups (Table 4). The requirements that escape all four criteria are considered accidental.

VI. Implemented Prototype

We consider the coding a design step [67]. We did not performed usability tests. In order to demonstrate the requirements, we chose the review scenario and extended a plugin from the Java Eclipse framework called Jupiter (http://code.google.com/p/jupiter-eclipse-plugin/), which automatizes the review process into four phases: configuration, individual, team and rework.

The first phase (Figure 5) consists in choosing author, reviewers, files and review attributes (severity, type, resolution, status, etc.).

The second phase consists in the individual creation of occurrences by the reviewers ("Individual Phase" tab in Figure 6). An occurrence consists in a problem identified in the code and is shown as an annotation beside the source code. This exhibition mode and the access to content in a separate area correspond to the metaphor of the anchor place (Figure 7).

In the third phase, the team receives a list of occurrences filtered by a moderator ("Team Phase" tab in Figure 6), while the fourth phase corresponds to the action of the person to which the solution of the occurrence was delegated ("Rework" tab in Figure 6).

We adapted the plugin Jupiter in two aspects. First, we changed the occurrence visualization in order to have an annotation place adequate to the proposed review scenario. For that, we allowed for the visualization of comments exchanged between authors during review phases (Figure 8). Second, we forced the respect to authorship information. We also developed an authentication component in order to guarantee the integrity of the authorship information and another to allow the persistence of annotations in XML files.

VII. Conclusion

In this paper, we showed an extensive and analytical panorama of the digital annotation technology, from the analysis of 80 different systems available in the last 25 years. The analyzed systems and the resulting classification are shown in the appendix.

We also described six different use scenarios that were widely supported by scientific literature in the fields of educational technology and human-computer interaction. In other words, those scenarios were not a result from an arbitrary and imaginative exercise.

We created a classification of annotation systems with a matrix of paradigmatic classes that can be used to guide the project of new digital annotation systems. The viability of this proposal was verified with the implementation of an annotation system as a plugin for the Eclipse development framework, in which those requirements were contemplated [68].

The classification of those 80 systems, together with the separation on essential and accidental requirements, opens space to really reusable digital annotation models. Since this separation was based on objective and testable criteria, it is possible to reapply them for future new technological advancements.

Finally, we must highlight the fact that conceptual metaphors used in this work can also be applied to other collaborative scenarios, such as information seekers or collaborative editors. The selection criteria for essential requirements would support the analysis of other technology families, such as application frameworks. The paradigmatic classification based on autonomy and heteronomy categories can be applied to other distributed models, such as agent systems or network based systems. The classification can also be used as a criterion in the selection of essential requirements.

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Table 1 Activity types at each use scenario

Activities	Reading	Note taking	Ontologies	Collaborative Writing	Discussion	Review
Analyze	X				X	X
Sinthesize	X	X		X	X	
Memorize		X				
Copy		X		X		
Classify			X			X
Search		X	X			
Question	X				X	X
Mark	X				X	X

Table 2 Relation between annotations and document

	Scenario	Annotations cause impact on the document?	Document causes impact on the annotations?
1	Reading	No	Yes
2	Note taking	No	Yes
3	Ontologies	No	Yes
4	Collaborative writing	Yes	No
5	Discussion	Yes	No
6	Review	Yes	Yes

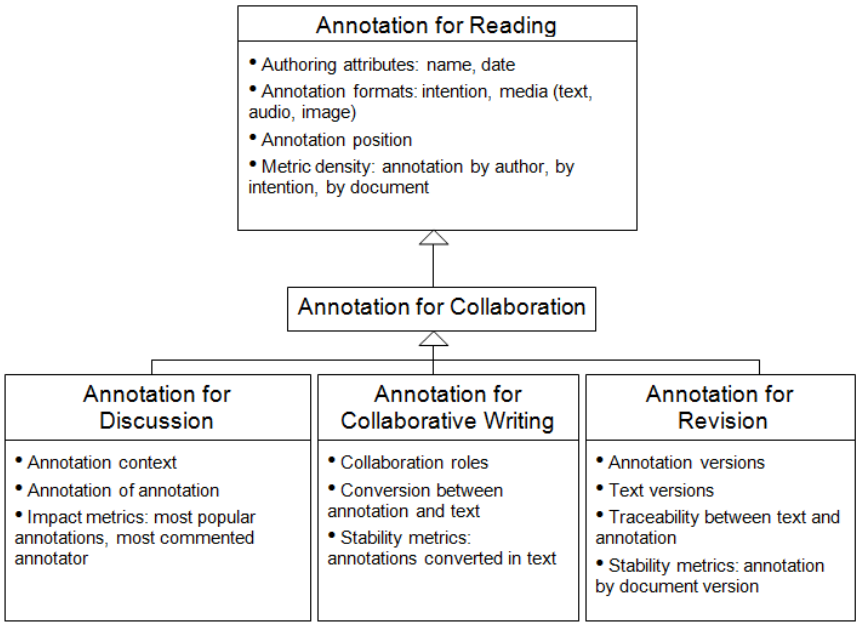

Figure 1 Summary of the extracted characteristics

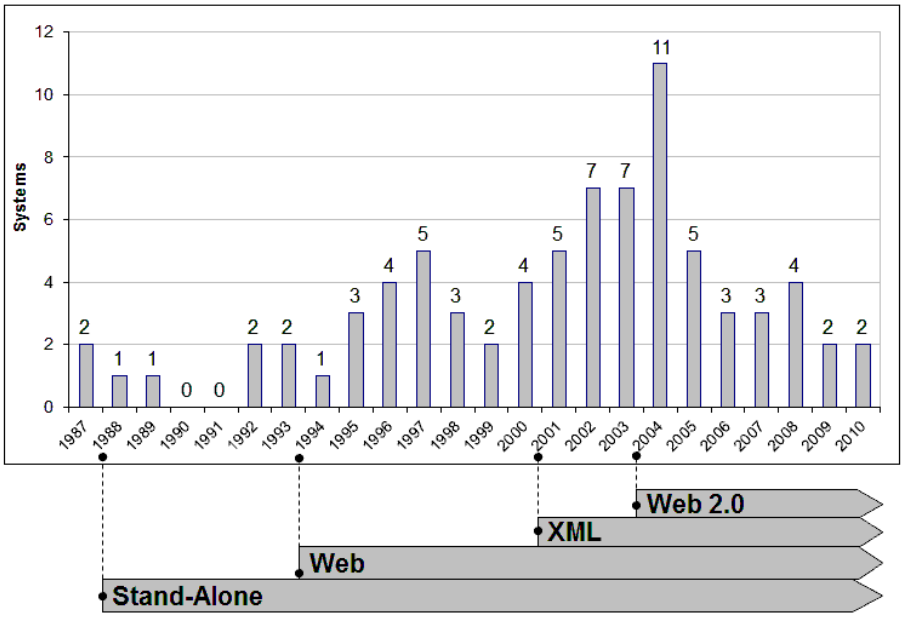

Figure 2 Published systems and technological cycles: cycle 1, Stand-alone; cycle 2, Web; cycle 3, XML; cycle 4, Web 2.0

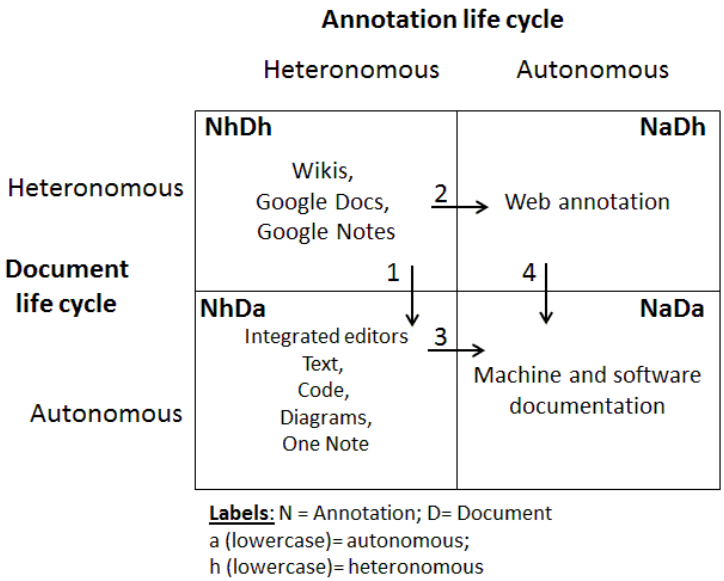

Figure 3 Autonomy quadrants

Table 3 Distribution of systems by quadrants

Quadrant	Amount of systems	%
NhDh	9	11%
NaDh	36	45%
NhDa	31	39%
NaDa	4	5%
Total	80	100%

Table 4 Application of the criteria to the requirements

	Matches the criterion?				
Requirements	**Identity**	**Viability**	**Specif icity**	**Technical Limitation**	**Justification**
FR1: Associate annotations to any part of the document or to predefined parts.	**Yes**	-	-	-	Is part of the annotation activity
FR2: Change the annotation position	**Yes**	-	-	-	Is part of the annotation activity
FR3: annotate on different media (sound, text, image, video)	**Yes**	-	-	-	Is part of the annotation activity
FR4: Keep authorship information and annotation justification	**Yes**	-	-	-	Is part of the annotation activity
FR5: Annotate over other annotations (annotation place)	**Yes**	-	-	-	Is part of the annotation activity
FR6: Keep annotations independent from the document	No	**Yes**	-	-	Its absence makes the scenario not viable
FR7: Share annotations among collaborators	No	**Yes**	-	-	Its absence makes the scenario not viable
FR8: Keep documents intact (copyright)	No	**Yes**	-	-	Its absence makes the scenario not viable
FR9: Annotate on different document versions	No	No	**Yes**	-	Cannot be supported by external components
FR10: Conciliate competing annotations and document versions.	No	No	**Yes**	-	Cannot be supported by external components
FR11: Preserve annotations whose position in the document was lost (annotation orphaning)	No	No	**Yes**	-	Cannot be supported by external components
FR12: Search on annotations	No	No	No	**Yes**	It is expected that in the future the environments will support this functionality
FR13: Visualize documents and annotations together	No	No	No	**Yes**	It is expected that in the future the environments will support this functionality
FR14: Render annotations	No	No	No	**Yes**	It is expected that in the future the environments will support this functionality
FR15: Print documents and annotations together	No	No	No	**Yes**	It is expected that in the future the environments will support this functionality
FR16: Control document versions.	No	No	No	No	Did not match the criteria
FR17: Control access by profile.	No	No	No	No	Did not match the criteria
FR18: Coordinate dialog	No	No	No	No	Did not match the criteria
FR19: Notify about change	No	No	No	No	Did not match the criteria
FR20: Manage publishing	No	No	No	No	Did not match the criteria
FR21: Work offline	No	No	No	No	Did not match the criteria

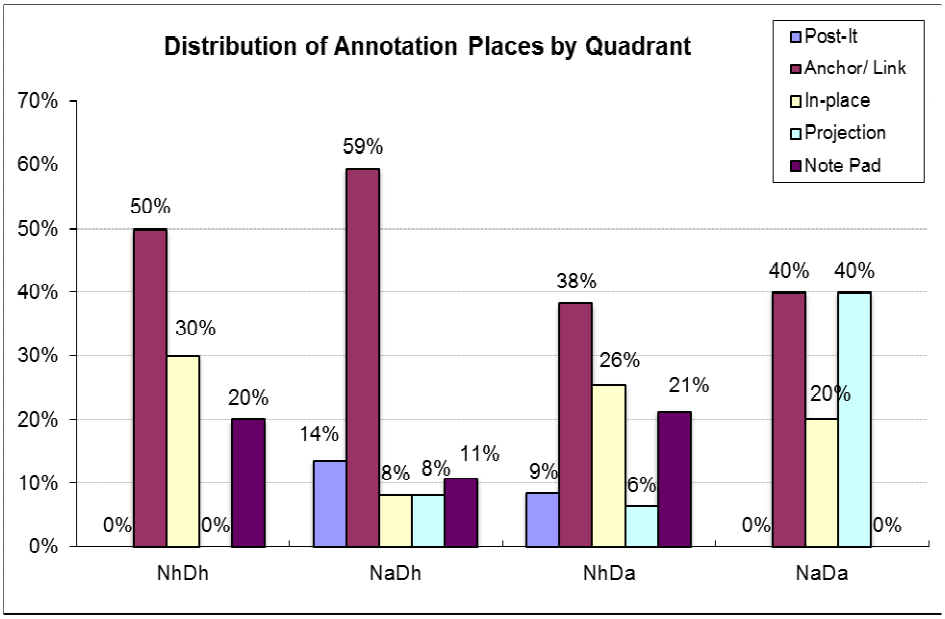

Figure 4 Distribution of annotation places by quadrant

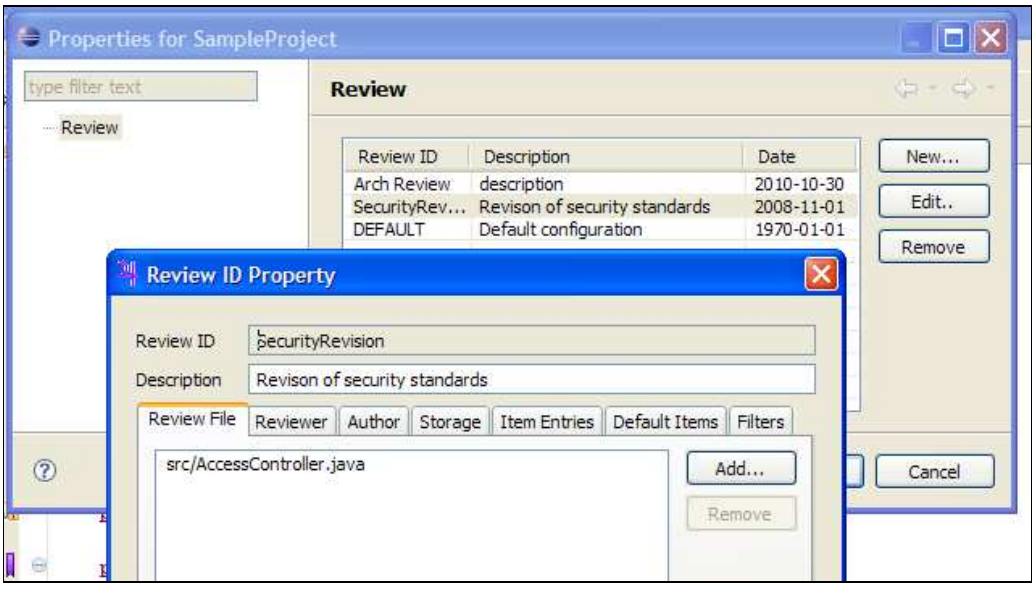

Figure 5 Review configuration in the implemented prototype.

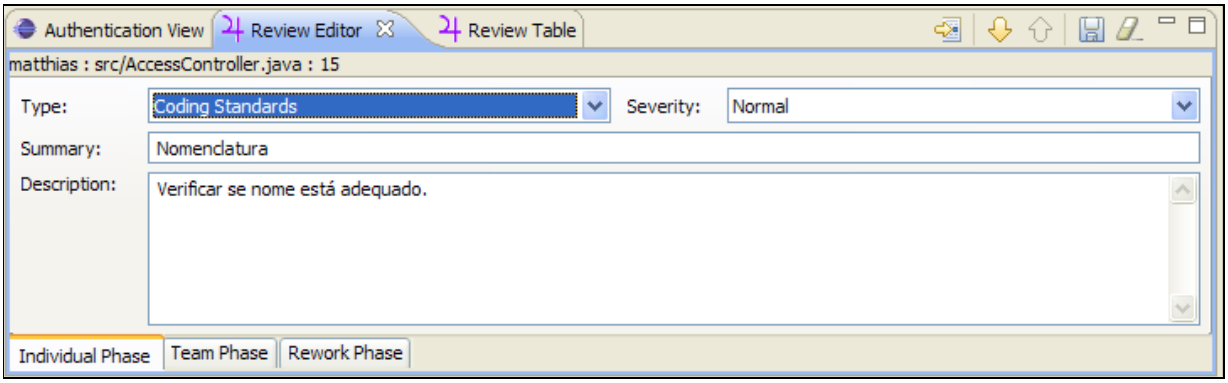

Figure 6 Review ocurrence creation in the implemented prototype.

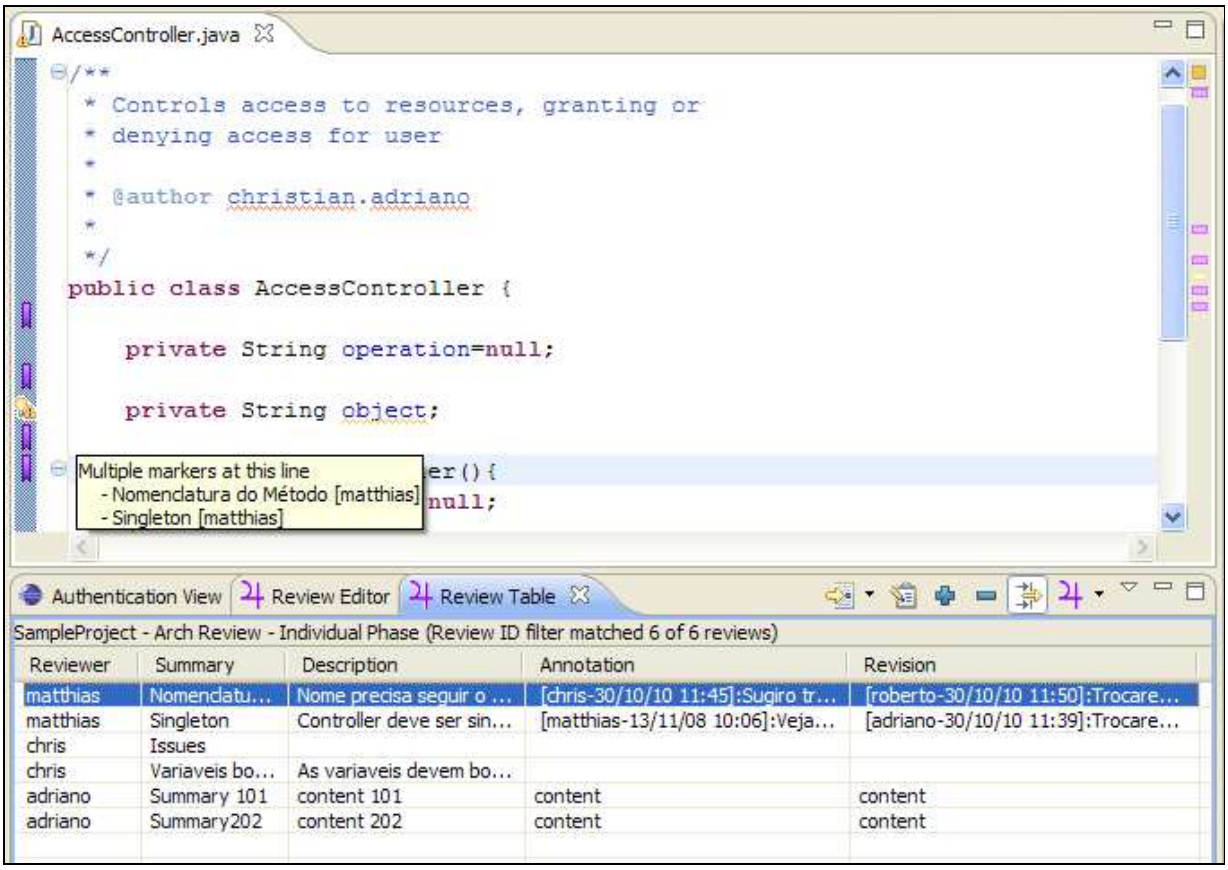

Figure 7 Implementation in the prototype of the anchor place with two occurrences in the same position.

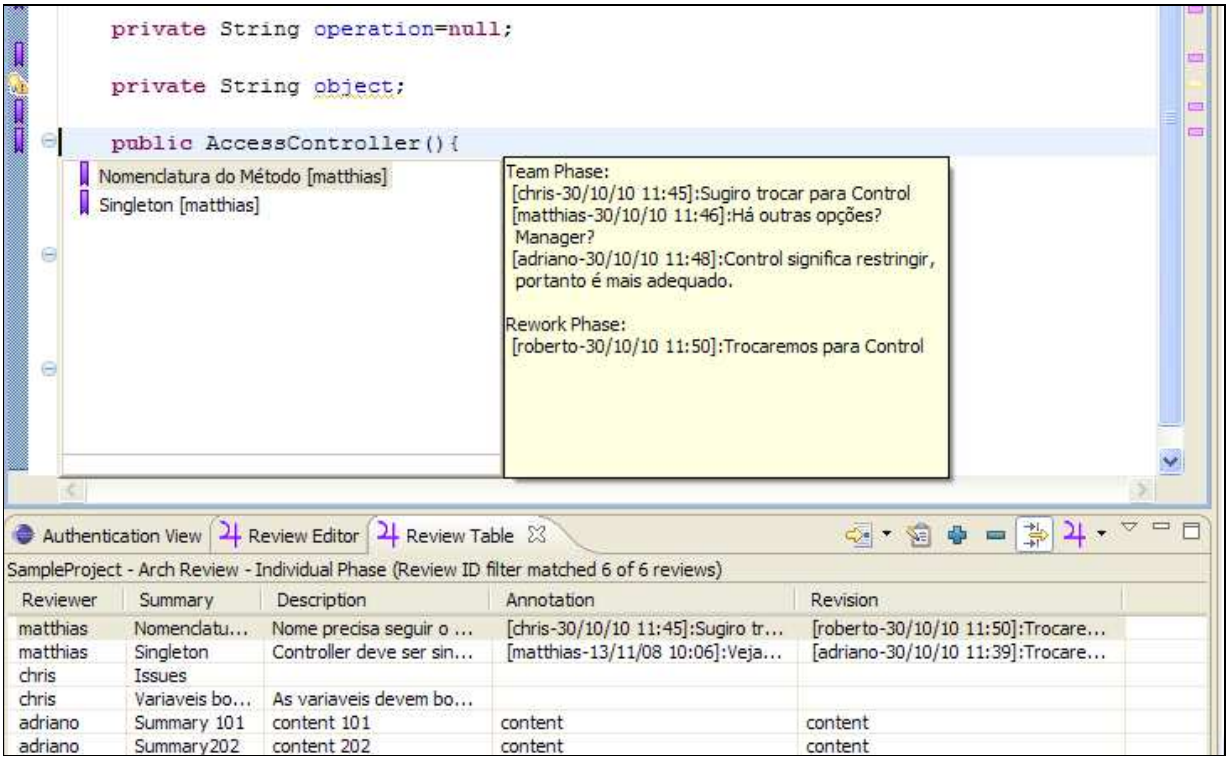

Figure 8 Annotation place for the discussion of the review process in the implemented prototype.

APPENDIX – CLASSIFICATION OF THE ANALYZED SYSTEMS

				Quadrants				Annotation Places				
System	**Reference**	**Year**	**Source**	**NhDh**	**NaDh**	**NhDa**	**NaDa**	**Post-It**	**Anchor/Link**	**In-place**	**Projection**	**Notebook**
HyperCard	[69]	1987	Product			X			X			X
Notecards	[70]	1987	Hypertext			X			X			X
Quilt	[57]	1988	CSCW			X						X
InterNote	[71]	1989	Hypertext			X			X			
Aquanet	[72]	1991	Hypertext			X						X
SEPIA	[73]	1992	Hypertext			X						X
Deckview	[74]	1993	UIST			X			X			
KnowledgeWeasel	[38]	1993	Hypertext		X				X			
Filochat	[24]	1994	CHI			X				X		X
GPA	[75]	1995	WWW		X				X			
CoNote	[76]	1995	CSCL		X				X			
Commentor	[77]	1995	CHI		X				X			
BSCW	[31]	1995	CSCW	X					X			
GroupWeb	[78]	1996	CHI		X				X			
Panbrowser	[79]	1996	WWW		X				X			
W4	[80]	1996	CHI		X				X			
Classroom 2000	[30]	1996	MM	X						X		X
WebKB	[81]	1997	ICCS	X					X			
Web4Groups	[82]	1997	DEXA	X					X			
Multivalent	[83]	1997	DL				X		X		X	
Dynomite	[25]	1997	CHI			X			X	X		X

				Quadrants				Annotation places				
System	**Reference**	**Year**	**Source**	**NhDh**	**NaDh**	**NhDa**	**NaDa**	**Post-It**	**Anchor/Link**	**In-place**	**Projection**	**Notebook**
Prep	[56]	1998	CHI			X						X
iMarkup	[84]	1998	Product		X			X	X	X		
Inote	[85]	1998	Product			X			X		X	
Notable	[86]	1999	CHI			X			X	X		
VirtualNotes	[87]	1999	AMCIS		X			X			X	
Ka	[88]	2000	COLING		X				X			
AnnotTool	[89]	2000	EDMedia		X			X	X			
WebDiscussion	[13]	2000	CSCW		X				X			
Amaya-Annotea	[39]	2001	Product		X				X			
A4SM	[90]	2001	MM			X			X			
Y-Notes	[91]	2001	Hypertext		X				X			
SMAT	[92]	2001	HICSS		X							X
Wispa	[93]	2001	ITVE		X				X			
Melita	[94]	2002	EKAW			X			X			
WebCobalt	[40]	2002	ICCE		X				X			
SpacePen	[95]	2002	IUI			X		X		X		
WebAnn/CAF	[51]	2002	CHI		X				X			X
AnchorConversation	[96]	2002	CHI				X		X			
Fluid	[97]	2002	WWW			X			X			
XLibris	[98]	2002	UIST				X			X		
Evol	[64]	2003	CHI				X				X	
Ambulant	[99]	2003	DocEng		X							X
WordFreak	[100]	2003	HLT			X				X		
Callisto	[22]	2003	CHI			X				X		
Vannotea	[45]	2003	KCAP		X				X			
UCAT	[15]	2003	DNIS			X			X			
Paper++	[101]	2003	CIKM			X					X	

				Quadrants				Annotation Places				
System	**Reference**	**Year**	**Source**	**NhDh**	**NaDh**	**NhDa**	**NaDa**	**Post-It**	**Anchor/Link**	**In-place**	**Projection**	**Notebook**
Layer	[102]	2003	ISWC			X				X		
Del.icio.us	[103]	2003	Product		X					X		
Swog	[58]	2004	CSCW		X			X				
VideoAnnEx	[104]	2004	Trecvid			X			X			
ESP	[105]	2004	CHI	X								X
Hats	[106]	2004	Hypertext		X				X			
Madcow	[107]	2004	AVI			X			X			
MemoryNet	[108]	2004	CHI	X					X			
Sholion	[53]	2004	ICALT		X						X	
eBook	[109]	2004	ITiCSE			X			X			
Crayon	[110]	2004	UIST			X				X		
DigitalGraffiti	[111]	2004	CHI		X					X		
Hylighter	[21]	2005	Product			X			X			
M-OntoMat-Annotatizer	[44]	2005	Product	X					X			
Annozilla-Annotea	[112]	2005	Product		X				X			
IBM-EVA	[41]	2005	Product		X				X			
Cronos	[113]	2005	LAWEB		X				X			X
3D-Book	[114]	2005	CHI			X				X		X
uAnnotate	[29]	2006	ICALT		X					X	X	
AWS	[115]	2006	ISM		X			X	X			
Stikis	www.stickis.com	2006	Product		X					X		
Acrobat	www.adobe.com	2007	Product			X		X	X	X		
MSWord	office.microsoft.com/msword	2007	Product			X		X	X	X		
OneNote	office.microsoft.com/onenote	2007	Product			X		X	X	X	X	
GoogleDocs	docs.google.com	2008	Product	X						X		
A.nnotate	http://a.nnotate.com	2008	Product	X						X		
MovieTool	www.ricoh.com	2008	Product			X						X
Reframeit	www.reframeit.com	2008	Product	X								X
Webnotes	www.webnotes.net	2008	Product	X				X				
LayerPad	www.layerpad.com	2009	Product	X							X	
Crocodoc	crocodoc.com	2010	Produto	X						X		
Blerp	www.blerp.com	2010	Product	X								X