Enhancing Collaboration through Idea-level Granularity: from Information Sharing Across Security Levels to Collaborative Learning

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Abstract. This paper proposes that idea-level granularity is an innovative design construct that has the potential to extend the boundaries of a range of human and organizational capabilities. Two examples are provided of how technology based on idea-level granularity versus document-level granularity can broadly transform collaborative work. Organizational success will depend on enabling sufficient information sharing across teams and organizations while preserving essential confidentiality and integrity. This paper explores the problems of producing and consuming information at different levels of classification and presents how technology based on idea-level granularity can overcome these problems.

Collaborative learning works; but, instructors are frustrated in assessing individual contributions, students complain about freeloading, and worst, freeloaders may fail to learn. Over two years, technology based on idea-level granularity was used to mitigate these flaws by allowing individual contributions within collaborative work to be identified, tracked, and analyzed. Students liked the ability of the instructor to monitor contributions; do not like overwriting other's work, nor other's overwriting their work; and most importantly, enjoyed a more positive group experience than in prior classes.

Keywords: Collaboration Technology · Architecture · Collaboration · Secure Knowledge Sharing · Collaborative Learning · Idea-level Granularity.

1 Introduction

This paper proposes that idea-level granularity is an innovative design construct that has the potential to extend the boundaries of a range of human and organizational capabilities and meet Hevner et al's requirements for design-science research [1].

Evidence of this potential is provided through two examples of how technology based on idea-level granularity versus document-level granularity could transform a broad spectrum of collaborative work. Computer Supported Collaborative Work (CSCW) "as a research area devoted to exploring and meeting the support requirements of cooperative work arrangements ... is basically a design oriented research area [2]." The first describes the problem of enabling collaborative work across security levels, within and among organizations. The second reports on the use of this technology to support collaborative learning.

In collaborating across security levels, knowledge management is expected to become more people-centric with the growing realization that it is the networking of competent and collaborating people that enable organizational success. Increasingly these teams are ad hoc, consist of people from multiple organizations who may work in different time zones and have dissimilar clearance levels. Organizational success will depend on how well organizations exploit synergies while minimizing risk in collaboration, i.e., enable sufficient information sharing while preserving essential confidentiality and integrity. This paper explores the problems of producing and consuming information at different levels of classification and presents how technology based on idea-level granularity could overcome these problems to enable successful collaboration across security levels at lower costs.

Collaborative learning works; but, instructors are frustrated in assessing individual contributions, students complain about freeloading, and worst, freeloaders may fail to learn. Two critical flaws of existing collaboration learning technologies are: (a) the inability to disassemble the unique contributions of each contributor from the work of the group as a whole; and (b) the inability to represent the instructor as a virtual presence in each group. Technology based on idea-level granularity allows individual contributions within collaborative work to be identified, tracked, and analyzed over time. In essence, the instructor and student become "visible to each other." This visibility provides an opportunity for the instructor to unobtrusively insert himself or herself into the group process to provide instructor value around identifiable contributions. This paper reports on the use of such technology for two years in advanced, year-long capstone classes in software development.

2 Idea-Level Granularity

Documents are made up of many ideas. Idea-level technology allows the dynamic segmentation of a document into idea-level granularity. It provides a means to tear apart a whole software object, such as a document, into parts; independently control, store, and work separately on the parts; and automatically reconstitute the whole as if never torn apart, but with any changes to the parts incorporated (see Fig. 1).

This technology is structured to be integrated within existing applications to add advanced collaboration functionality. In this way, it leverages existing participant knowledge and advances in the underlying application. For example, instead of requiring users to learn and use a separate, less-capable word processor, this idea-level enabled functionality is currently integrated within MS Word, the leading word processor of choice with superior capabilities.

It is useful to better understand how this idea-level granularity uniquely supports collaboration by comparing it to current technologies that support collaborative work: Sharepoint™ from Microsoft and Google Docs™.

MS Sharepoint™ and Google Docs™ support a document/file-centric view. MS Sharepoint™ provides two types of co-authoring. The first, described by MS as regu-

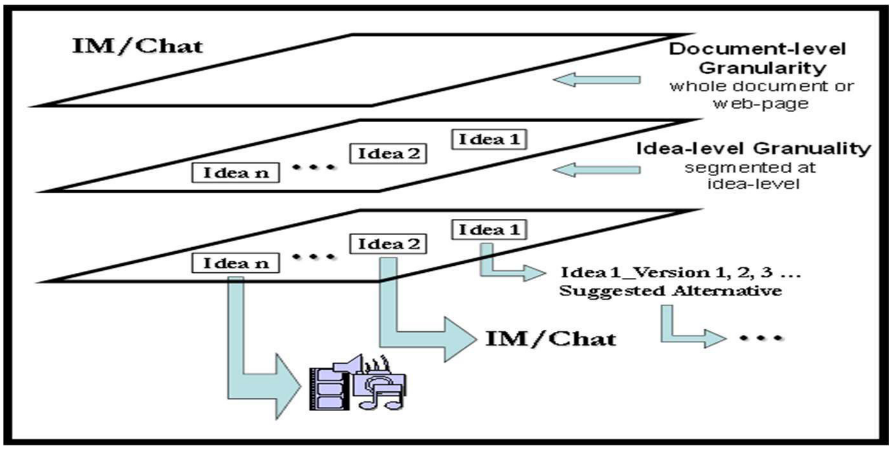

Fig. 1. Idea-level Granularity

lar co-authoring, temporarily locks a paragraph while being updated by others. The second, real-time co-authoring, is similar to Google Docs™. They use concurrency controls to allow users to simultaneously modify the same/document file, i.e., changes are allowed as long as they do not simultaneously conflict with other changes. In essence, they support "Last one in, wins", i.e., the last one to save the document/file has that version saved. Idea-level granularity enables ideas to be captured as separate nodes in a database. This provides some of the following benefits:

Participants can work in parallel in a controlled way. Ideas can be controlled so that others can not overwrite them. This concept is especially important and deserves more discussion. There is an erroneous, implicit assumption that collaboration is always egalitarian. Users may not like others to overwrite their work and like less overwriting the work of others. There could be multiple reasons for this. In one case, the idea may move in phases to the point where the group feels comfortable with a version of an idea and wants more control over the change, or perhaps someone with the most expertise or authority is given control as to what is acceptable. With idea-level granularity, similar to what we would do socially in other situations, if one does not have control or does not feel comfortable in overwriting, one can suggest an alternative version and provide rationale for this alternative, i.e., why this change is needed. The participant who controls the idea/section can evaluate the suggested alternative and its rationale and accept/reject as he/she sees fit - and even provide rationale for his/her decision.

There is an assumption that simultaneous collaborative work is preferred, however, idea-level granularity better supports the various phases of collaborative work and the preferred method of work for a given phase as identified by Salcedo and Decouchant [3]. They identified five phases: Planning - collaborators establish the objectives, structure, and divide up parts of the shared work product to be created. Creation - collaborators compose their portion of the joint work product. Although they may work alone, it is important that they are aware of what the other collaborators are doing. Evaluation - collaborators review, propose changes, and add comments to each other's work. Negotiation - collaborators discuss proposed changes with one another and decide on what changes should be made. Consolidation - collaborators resolve conflicts and merge changes into the shared work product. It should be stressed that these phases are normally not sequential. There is continuing cycling through these phases for different sections of the shared work product, e.g., while negotiation is occurring for one part, creation could be occurring for another part. Dealing with these social, intellectual, and procedural complexities, collaborators work asynchronously and synchronously as they navigate through these phases [4]. Collaborators prefer to work synchronously when planning, negotiating, and consolidating and asynchronously when creating and evaluating.

One can temporarily or permanently identify separate ideas/sections. One can create a segment/idea for control and discussion, but then merge the segment/idea and remove the discussion when agreement has been reached and there is no longer value in segmentation. However, one can also have permanent divisions at the idea-level - for example, the instructor can create a template with segmented divisions. Although control of these divisions can be assigned and further subdivided, as long as the instructor retains control of the section that contains these divisions, they will remain extant, i.e., no one else can remove them.

One can further segment any idea/section into as small a section as one character. This provides the ability for someone who is in control of some idea/section to further subdivide and assign control. This allows for the orderly segmentation of collaborative work.

Any idea/section can be separately opened and worked on independently of others. This can be especially valuable when documents become large. The ability to just open an idea/section saves time and reduces complexity.

Whenever you open up a section/idea that includes other subsections/ideas, the latest versions of these subsections/ideas are automatically incorporated. This eliminates consolidations and allows participants to maintain situational awareness of what others are doing without necessarily opening up the entire document. This is especially difficult, yet critical to effective joint development [5].

Because ideas can remain extant, participants can track versions of ideas not just track versions of the document/file over time. This also allows participants to: track who made the change and at what time; compare versions of ideas not just versions of the document/files; and replace current versions of ideas with earlier versions.

Notification can be targeted so that if one has interest in some ideas and not others, one can be notified when a specific idea changes and directed to that change, rather than be notified at the grosser level that the document has changed. This functionality is complementary and separate from physically segmenting a document into sections/ideas for control and deserves some further discussion. Participants will be able to place watches on regions of interests (ROIs)/ideas. Many times participants have an interest in only one or several parts of a large document when these areas are not under their control and changed by some participant. These ROIs may require their expertise or pertain to their area of responsibility. When an ROI/idea is changed, participants can choose to be notified, via a range of communication channels, and directed to the specific ROI.

It can be recorded when someone reads an idea and one participant can selectively direct comments to those participants based on who has read an idea. For example, in one case, the instructor can monitor those students who have not read an idea yet and direct attention just to those who have not done so. In another case, this ability to monitor who has read an idea can support the process of more effectively and efficiently correcting an error. For example, if there are 30 people in the class and the instructor needs to correct a mistake in a part of the document, the instructor can see that only 2 of 30 have seen the error on this part and direct the attention of those 2 to that item to view the correction, rather than send notices to 28 others who have not seen the error. The instructor can monitor the progress of these 2 students to view the correction without bothering all 30 students with a blanket notice that the document has changed.

One can have chats around ideas, rather than have chats parallel to document creation. With idea-level granularity these are associated with an idea, but not included within the document and the content can be of any format - audio, video, etc. The association is itself important information and there is value, especially to formative and summative evaluations, in associating such discussions/rationale with specific ideas/sections.

Database management tools can be built to analyze these interactions at the idea-level to support formative and summative evaluation.

3 Sharing Information Across Security Levels

This section explores the problems of producing and consuming information at different levels of classification and presents an architecture and strategy based on idea-level granularity to overcome these problems to enable successful collaboration across security levels.

Producers and consumers of classified information require secure access to essential information chunks that exist within documents. "With 14 million new documents stamped secret in 2003, the government created 60% more secrets in 2003 than in 2001 – the biggest jump in secrecy for at least a decade [6]". This trend has only accelerated. Government and non-government documents usually contain information of various classification levels, but are classified at the highest level. Serious problems include: collaboration across domains and security levels suffers; producers must classify too much information at higher levels; more people need higher security levels than warranted with concomitant increases in administrative costs to investigate; information is less secure while costs to manage escalate; producers restrict access to classified information because they fear leaks when non-essential consumers are granted access; consumers, who are denied access to essential information, fail.

Currently, multiple networks, file servers, and web servers are constructed for each sensitivity level, and individual documents are implicitly labeled by virtue of the network from which they each are accessible. Similarly, a user's workstation is attached to a network matching their clearance level. This separation-of-networks approach has many disadvantages. For example, many users have to use multiple workstations with consequent high hardware, space, weight, and power costs. In addition, the network infrastructure is inflexible in response to the formation of new coalitions.

Consumers of classified information greatly outnumber producers. Therefore, providing consumers the right access, at the right time will provide immediate benefits while development will be easier and risk of failure reduced. Initially one can build a One-way, Multi-level Secure Access System [7] (see Fig. 2). Data will be stored only at a single level. A One-way Multi-level Security component could be constructed to mediate with a Secure Data Storage System provided by existing companies in the marketplace. Separate instances of the component would run for each security level. The component would only retrieve information from lower security levels, never write to lower security levels (one-way), never collate and display data that is above its security level, and be small to make formal testing easier. Then one can build separate functionality to produce (write) unclassified and classified information. Build one or more separate components for producers of classified information. Ultimately, integrate functionality described above into a single, two-way, multi-level secure access system.

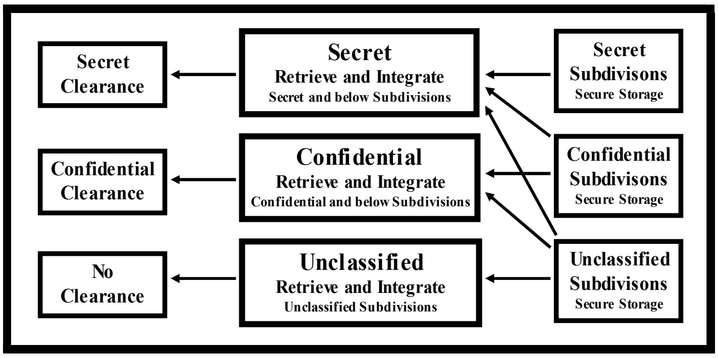

Fig. 2. Multi-level Secure Access System

In summary, idea-level granularity enables securing information to maximize benefits while minimizing costs: 1) Users may never view sections of documents for which they do not have clearance or approval. In fact since parts can be physically stored separately according to their classification, there is never a situation where a document contains classified information above the access level of the viewer. This is a major problem with redaction solutions. In redaction, the sensitive text does exist within the document and expensive, error-prone, and time-consuming actions must be taken to try and insure that it is blocked for certain levels of access before publishing. 2) Control is enhanced by controlling at the part-level what can be done; who can work on a part; when work can be performed; control from where work can be performed; control how work can be performed on a part, i.e., what procedures need to be followed, e.g., require two people at a certain access level, from authorized locations, to input unique codes before access to a part is allowed; and control work on a part based on why the work must be performed, e.g., viewing of a part is permitted in hot pursuit of terrorists in a homeland security emergency. 3) A statement within the shared document may be at a lower classified level, but there may be discussions and rationale associated with the statement that are at a higher level, e.g., the design requirement for some part, such as a satellite, is specified for manufacturing, but the discussion, or parts of the discussion, for the rationale of the specification may be at a more secure level and not available for consumption by all.

4 Supporting Collaborative Learning

Collaborative learning can improve learning outcomes [8, 9, 10] and engender positive attitudes towards group work while overcoming racial and gender biases [11, 12, 13, 14]. However, teachers are disinclined to use collaborative learning pedagogy because some students freeload and instructors can not identify individual contributions of group members [8]. Freeloaders may fail to learn, and those, who don't freeload, develop negative attitudes towards group work [8, 15].

Mitigating these problems will encourage instructors to incorporate more collaborative learning opportunities, which matches the preference for women and non-traditional students for collaborative strategies. This will result in learning environments that encourage all students, including women and under-represented minorities, to actively engage in and enjoy learning more and develop more positive attitudes towards teamwork.

Virtual Instructional Presence (VIP) encompasses, but extends beyond mere instructor and student social presence. VIP provides information to the instructor about the quality and quantity of student input within the learning process, thus facilitating formative and summative assessments. Idea-level granularity allows individual contributions within collaborative group work to be identified, tracked, and analyzed over time. In essence, the instructor and student become "visible to each other." This visibility provides an opportunity for the instructor to unobtrusively insert himself or herself into the group process to provide instructor value around identifiable contributions. Instructional value includes such things as assessment (evaluation), encouragement, guidance, answers to questions, suggestions, rationale, etc. Content can be provided in almost in any format, such as videos, spreadsheets, voice messages, etc. and can be associated with, but separately stored from, ideas.

Research Method. Technology that supports idea-level granularity was used in multiple sections of the year-long capstone experience taught by the same instructor. Students work with real-world clients over an academic year. Students work in teams of approximately five people to a team, although team size can vary between 4 and 10 people depending on the complexity of the project. In the first semester they learn analysis and design techniques and create detailed analysis and design documents. These documents can become quite large and some have grown to over 100 pages. In the second semester, teams program, test, and develop the user manuals for the application. Online, anonymous surveys were given after the end of the 2nd semester, after grades were assigned. Students were given extra credit before completing the survey based on their professed willingness to complete the survey.

Results & Discussion. Samples from first class (13) and the second (12) were tested for independence and found to be from the same population, so they were combined.

This was the most difficult project ever for most students. We were trying to understand if there is a cut-off point of difficulty where freeloading becomes more important, i.e., for more difficult, complex tasks is it much more important that participants contribute equally and not freeload, and therefore more important for technology to help mitigate freeloading in group work? However, students thought that it was similarly important in prior and current group work that team members needed to contribute equally. Students felt they experienced less freeloading in the current, very demanding group task (although not statistically significant (.18)). Most importantly, students were more satisfied with their group experience at a statistically significant level of .01. It seems reasonable that if higher performing students were more satisfied with more accurate assessment of their contributions and lower performing students freeloaded less, then these two factors can help to explain the greater satisfaction with this group experience.

Students liked the fact that the instructor could more accurately ascertain individual contributions within their group work. Pearson correlations did not show a relationship between grade point average and the desire of students to have instructors assess their contributions. Because of the limited data points, several correlations were run to identify if there was a cutoff point where students would not like this ability, i.e., we collapsed the data into two values based on grade point average. There was a break point at 3.0, i.e., students above 3.0 liked it, but those below did not. There were few grades below 3.0, so this is being reported as something interesting that should be studied more.

Students do not like others overwriting their work and they like capabilities that keep them from overwriting other people's work. These data make sense and require more research. Some examples where the issue of control and overwriting are important include: some may have more expertise on parts of a document than others and should control content; some idea in a document moves to an accepted stage and should not be changed afterwards; instructionally, teachers need to understand who has contributed to ideas within group work and not just be provided with marked up versions that chronicle document changes.

Students were positive about the value of the technology supporting collaborative learning pedagogy. Students were especially positive concerning: technology usefulness, enhanced sharing, virtual nodding, enabling give-and-take with the instructor, and chatting.

5 Summary

Documents are made up of many ideas. Many collaborative processes occur around ideas within a document, while much process support remains at the document/file-level and not at the idea-level. The main purpose of this paper was to challenge accepted practices and explore the effect of moving away from document-level granularity towards idea-level granularity. Idea-level granularity is proposed as a powerful, innovative design construct that can impact a range of human work and organizations.

Two very different applications were presented as examples of how broadly technology based on idea-level granularity can transform collaborative work. One discussed sharing information across security levels within and among organizations, while the other reported on its affect in collaborative learning.

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