Investigating Information Loss in Collaborative Design: A Case Study with Capstone Design Project

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This paper discusses a case-study for investigating the loss of design information in collaborative design projects. The case-study was conducted with senior mechanical engineering students at Clemson University working collaboratively on a semester long Senior Design Capstone project. The case study findings indicate that there is a potential loss of design information in collaborative groups. The design information, if archived systematically, can help future designers to review the past design and build upon the existing ideas to come with better or new solutions.

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Motivation for Investigating Information Loss

Engineering design problems and projects are increasingly becoming more complex with the advancement of technology and rising global economy. Thus, design of complex engineering systems is increasingly becoming a collaborative task[1]. In most cases, designers and the design teams are not located in same organization but collaborate from different organizations or even different parts of the world[2]. The type of data exchanged by the modern day designers includes Computer Aided Design (CAD) models, general knowledge about the design and design process, including design specifications, design rules, constraints, and design rationale[1].

In most collaborative design projects the information that is generated during the design process is not archived in a formalized manner that can be made available to all for current or future use[3]. There is, therefore, a potential loss of valuable information. This information includes not only the CAD drawings generated during the design process but includes everything from the requirements list to the design rationale that went into revising and modifying the design before it took its final form. This information, if archived in a formalized manner, could be of potential use for future projects and could prevent "reinventing the wheel"[4]. This issue is the motivation for investigating information loss.

Design process and type of information

The systematic design process describes the basic process for designing technical artifacts[5]. The design process consists mainly of four design phases: Planning and Clarification of Task, Conceptual Design, Embodiment Design and Detailed Design[5]. The activities that occur and the type of information that is generated under each design phase are as shown in Table 1.

DESIGN PHASE	STEPS IN DESIGN PROCESS	TYPE OF INFORMATION
Planning and clarifying the task	1. Analyze the market and company situation 2. Find and select product ideas 3. Formulate the product proposal 4. Clarify the task 5. Elaborate the requirement list	1. Product proposals 2. List of product ideas 3. Requirement list
Conceptual Design Stage	1. Identify essential problems 2. Establish function structures 3. Search for working principles and working structures 4. Combine and firm up into concept variants 5. Evaluate against technical and economic criteria	1. Problem statement 2. Constraints and criteria 3. Function structures 4. Working principles 5. Different concepts 6. Sketches for concepts 7. Design rationale for selecting a concept
Embodiment Design Stage	1. Develop construction structure 2. Preliminary form design, material selection and calculation 3. Selecting best preliminary layout 4. Refine and improve layout 5. Evaluate against technical and economic criteria 6. Eliminate weak spots 7. Check for errors, disturbing influences and minimum costs 8. Prepare preliminary part lists, and production and assembly documents	1. Construction structure 2. Preliminary designs 3. Preliminary layouts 4. Rationale for selecting the best layout 5. Refinement and revisions 6. Evaluation results 7. Preliminary parts lists 8. Production and assembly documents
Detail Design Stage	1. Elaborate detail drawings and part list 2. Complete production, assembly, transport and operating instructions 3. Check all documents	1. Detail drawings 2. Detailed parts lists 3. Complete production documents

Table 1: Information generated in each design phase[5]

Additionally, the information generated during the iterations in different design phases is also important and must be considered.

Apart from the activities of the design process, the concept generation and selection activity is supported by design synthesis and analysis tools. Alternative concepts are generated during synthesis. These alternative concepts are compared and chosen as per design requirements based on analysis results[6]. The activities involved in synthesis and analysis of design and type of information generated is as shown in Table 2.

	ACTIVITIES	TYPE OF INFORMATION
Design Synthesis	1. Formal ideation techniques, for conceptual phase, like brain storming, literature search, analyzing current technical systems 2. CAD, in embodiment phase, enabling the realization of shape, structure and form of solution concepts	1. Sketches of various concepts 2. Preliminary description of various concepts 3. Design rationale for selecting one concept over the other 4. CAD drawings
Design Analysis	1.Formal analysis tools and methodologies like Computer Aided Engineering, Computational Fluid Dynamics, Finite Element Analysis for analysis of various phases of design	1. Analysis results

Table 2: Information in synthesis and analysis of design[4].

From Tables 1 and 2, it is evident that a large volume of information of different types and purposes is generated in the design process.

Importance of information in engineering design

As a result of the increasing product complexity, a single designer or design team cannot manage complete product development[1]. Having the design teams collaborate will support the use of the expertise of other designers which may be located at different geographic locations. However, this will make sharing and exchanging information more challenging[1].

This information includes not only the CAD models generated during the design process but includes everything from the requirements list to the design rationale that went into revising and modifying the design before it took its final form. Large amount of information is generated at each stage in the design process. Additionally, generation of product information may not be on the same platform, and the information may be required to be exchanged across heterogeneous systems[3].

At present, there is no model which will allow capturing different type of product information and also facilitating the sharing of information seamlessly. It can prove to be expensive to recreate lost information or unused data and it may also require extensive manual efforts[7].

Studies have shown that reusing design information can reduce as much as 50% of the product development time and in addition helping the companies to save millions of dollars[8,9].

Case study protocol

Description of ME 402 Class at Clemson

ME 402, a senior Mechanical Engineering Capstone Design class in the Mechanical Engineering Department of Clemson University, is a 3 credit semester long (15 weeks) course. As a part of this course, the students work on industry sponsored design projects in teams of four or five students. A graduate student coach is assigned to one of the teams as part of this case study. The role of the graduate student coach is to coach the students at various stages of design process.

As a part of the design project, the students are required to define the problem statement. After defining the problem, the students develop a requirements list. From the requirements list, the students conceive, embody, and give detail design solutions. The final deliverable for the project is a written proposal for different concepts, engineering drawings, and physical prototypes used to demonstrate satisfaction of the requirements. The students have weekly design review with the advisory committee of evaluating faculty and midterm and final design reviews with the industry clients. Apart from this, the students are required to maintain design journals to write down the ideas, solutions and sketches as they think and work throughout design project.

Description of students and projects

The case-study was conducted with a team of four senior design students, three male and one female, working on a fifteen week long design project for ME 402 class. Two of the four students wish to pursue industry careers while one student will be joining graduate school and one is not sure of his plans upon graduation.

The students worked on a company sponsored design project addressing the defects observed in a packaging system used for producing individual packets of condiments or sauces such as those frequently seen in fast food restaurants. The packaging machines are manufactured by an automation company in Greenville, South Carolina. The defects consisted of misalignment issues in the packaging film at high operational speeds and the packets inaccurately filled.

The students underwent many iterations and design changes in the process of obtaining design solution and generated three major design solutions at the end of the project along with a mathematical model of the system.

Hypothesis and research questions

This case study was conducted to validate the hypothesis that in collaborative design, there is a potential loss of "design information" during the design process. The research questions considered are:

1. How do the designers archive/share information formally?
2. What "type of information" is generally lost?

Data Collection

For the purpose of this case study, different documents generated by student designers were considered for analysis. The documents collected mainly included minutes of meeting, weekly executive summaries, weekly presentation slides, midterm and final reports, and design journals. The details of these documents are as shown in Table 3.

Sr. No.	Document Name	Document Type	Size/Number of Pages
1.	Design Journals	Note book	Variable pages
2.	Minutes of meeting	Word document	A4/1-2 pages
3.	Weekly Executive summary	Word document	A4/1page
4.	Weekly presentation	Microsoft power point slides	-
5.	Midterm report	Word document	Variable pages
6.	Final report	Word document	Variable pages

Table 3: Documents collected for analysis

Data analysis

The data collected was analyzed to validate the hypothesis and to answer the research questions.

Formal means of sharing and archiving information

In order to find a formal means for which the designers archive and share information, the documents generated by the students were collected. The documents shared amongst the team members were:

- Minutes of meeting – Word document
- Weekly executive summaries – Word document
- Weekly presentations – Microsoft Power Point slides
- Midterm and final reports – Word documents

The documents that the students shared with the advisors and industry client were:

- Weekly executive summaries – Word document
- Weekly presentations – Microsoft Power Point slides
- Midterm and final reports – Word documents

This observation revealed that most documents were formally shared by the designers consisted of word documents and power point slides.

Investigating "type of information" lost

In order to investigate the loss of information, the documents were sorted week wise and were read thoroughly. The information in the design journals was compared with the information in other documents which were formally archived and shared with other team members as well as the advisory committee and industry clients. The information recorded in design journals but not reflected in any other documents is potentially considered as lost because the design journals are not shared or archived.

The following observations were found upon analyzing the collected documents and comparing the information in formalized and archived documents with the information recorded in design journals:

1. In the design process, the students worked on many concepts. The students used their design journals to write down the ideas and discuss them with other team members. However, all the ideas were not formally shared or archived. For instance, one of the student's design journal states "Putting the entire feeding system on a hinge may allow easier access for cleaning/maintenance," this design suggestion is not archived formally in any other document.

The same journal also states "Magnetic actuators with grippers could be used to pull the web off the spool," yet this solution is neither archived nor shared.

The above observations show there is potential loss of information at the conceptual stage, specially the information regarding the design solutions that do not materialize into final design solutions.

2. The initial design solutions proposed by the students consisted of a slide design and actuator design. These solutions were not the final design solutions. After the midterm presentations, the students started working on a friction plate, edge guide sensor blocks and fluidic muscle as their design solutions for the design problem.

The rationale for making design changes was not recorded in any form. The rationale that went behind making the design changes can be an important piece of information for future designers working on the similar problems. As a result, this observation shows that there is a loss of design rationale.

Future work

The observations made in the case study show that there is a potential loss of design information in collaborative design such as that in the Design Capstone Project. The literature survey indicates appropriate archival of design information is important for future retrieval and reuse. Future study needs to be carried out to answer the following questions:

- Of the information generated in the design process, which type of information is of utmost importance to engineers for current and future usage?
- How frequent is the archived design information revisited or reused by other design engineers?

- Does archived design information help in saving time and resources of company and design engineer?
- What could be the best way of archiving design information in its completeness without consuming much of the designers' time and resources?

Conclusion

The paper describes a case study performed with senior design students at Mechanical Engineering Department of Clemson University. The case study results show there is a potential loss of design information in collaborative design. The design information, if archived, can help future designers to review the past design and build upon the existing ideas to come with better or new solutions. The paper also discusses the future questions that need to be addressed.

References

1. Szykman S., Sriram R., Regli W., (2001) "The Role of Knowledge in next-generation product development systems." ASME, Journal of Computation and Information Science in Engineering.
2. Urban S., Shah J., Rogers M., (1993), "Engineering Data management: achieving integration through database technology." IEEE, Computing and Control engineering Journal.
3. Szykman S., Fenves S., Shooter S., Keirouz W., (2001), "A foundation for interoperability in Next-generation Product Development system", Computer-Aided Design, Vol 33, No 7, pp. 545-559.
4. Murdock J., Szykman S., Sriram R., (1997), "An information modeling framework to support design databases and repositories." ASME, Proceedings of DETC "97.
5. Pahl G., W. Beitz, Feldhusen J., Grote J.(2007), "Engineering design- A systematic approach", Third edition, Springer London.
6. Mocko G., Fenves S., (2003), "A Survey of Design – Analysis and Integration Issues", NISTIR 6996.
7. Murdock J., Donahoo M., Navathe S., (2001), "A Framework for method-specific Knowledge compilation from databases", Journal of intelligent information systems, Vol. 17, pp 5-21.
8. Allied Signals Inc., (1995) " Design History Archival and Retrieval based on Uniform Complex Electromechanical Vocabulary for Design History and Product Data," Technical Proposal submitted to DARPA, September.
9. Baya, Vinod and Liefer, L., (1995) "Understanding Design Information Handling behavior using time and information measure," ASME, Design Engineering Technical Conference, Volume 2.
10. Bilgic T., Rock D., (1997), "Product data management system-state-of-the-art and the future", ASME, Proceedings of DETC "97.
11. Kurtoglu T., Campbell M., Gonzales J., Bryant C., Stone R., (2005), "Capturing empirically derived design knowledge for creating conceptual design configurations," ASME Proceedings of DETC"05.