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IDENTIFYING USER EXPERIENCE ISSUES FOR COMPUTER AIDED DESIGN (CAD) SOFTWARE: A SURVEY AND EXPLORATORY FACTOR ANALYSIS TO IDENTIFY THE ISSUES TO IMPLEMENT ARTIFICIAL INTELLIGENCE FOR IMPROVING USER EXPERIENCE.

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Abstract

The work has been carried out for identifying User Experience issues currently acknowledged by the users of Computer Aided Design (CAD) software, especially those from a background in Mechanical Engineering. A survey is carried out with experts and users of CAD software, with a questionnaire consisting of 24 variables, addressing the current need of the user experience for CAD. The questionnaire consisted of variables categorized into two distinct forms to understand the need for Automation with CAD usability. The collected information is put forth to Exploratory Factor Analysis which has helped to identify 8 latent factors contributing to user experience requirements related to CAD. Further, an approach is suggested for improving user experience on the basis of Fatigue and Productivity measures. Also, the study has suggested the requirement for implementing Artificial Intelligence to integrate all the issues identified put forth for further research.

Keywords: User Experience; Computer Aided Design; Optimization; Artificial Intelligence

Introduction

The user experience is gaining importance in the last decade in all areas, especially product design. The paper highlights its importance in the area of software design, especially for Computer Aided Design Software. The first part on User Experience discusses about the development of User Experience in the last few decades and various approaches to it as depicted in various research. The primary objective of User Experience is discussed and its extension to software engineering is then elaborated with some reference to literature.
In the second part, some light on the User Experience situation with Computer Aided Design Software is shown. Various authors have tried to comment on the need for the study of User Experience issues with CAD. The discussion from those writings is collectively briefed.
The need for studying User Experience Issues is explained in detail in the next part of the article. The study is carried out in three distinct phases which have resulted in disclosing of 8

latent factors significant for the study of User Experience issues for CAD in the current scenario for Users.

In the fourth part, a discussion about the survey carried out for identifying important issues for study to improve User Experience for CAD with an application of Automated UI through Artificial Intelligence is explored. The survey was important as the literature has mentioned that there are 179 User interface issues identified for CAD. So through a systematic survey, an attempt is made to identify the current to be addressed latent (information) issues from the data collected with 104 CAD experts with the help of a questionnaire containing 24 variables through exploratory factor analysis technique.

In the fifth part Results of the survey from a pilot study to the final results are elaborated which is continued by a discussion and conclusion about the survey results.

The User Experience

User Experience has been a buzz word in last few decades. A lot of work and efforts have been taken by researchers, software developers and engineers to integrate the concept of User Experience into the Software Design Process itself. Various local, national and international standards have been developed to help the process of improving upon the User Experience. The concept of User Experience has been developed from initial stage of Software Ergonomics to Software Usability to User Experience Design. The concept has been widely applied in all parts of product design and development perhaps more efforts have been applied in regards to software development.

The User Experience has been a need to ensure higher productivity and lower discomfort to the user. Therefore, there are various local, national, international and various other standards that have been established to prepare products with better user experience which will meet the users expectations.

User Experience With CAD

The literature has addressed various needs of CAD users. The literature has addressed that the CAD user has to bear a cognitive load which can be of three types, Intrinsic, Germane and Extraneous Cognitive load. Intrinsic Cognitive load is the load which is the load the user has to withstand because of User Interface structure and pattern of CAD environment. This is similar to the load an aircraft has to carry while carrying the weight of aircraft itself. The Germane load is the load on cognitive memory which is because of need to understand design fundamentals and principles and apply them with CAD for the user. The Germane load is similar to the load an aircraft has to carry while carrying the load of passengers which is required for it to work. The extraneous load on a CAD user is his or her understanding and perspective vision of applying of design task along with design knowledge and CAD User Interface. This extraneous load is alike to the extra load of baggage and other materials the aircraft is supposed to carry while delivering its service.

Ghang Lee, et. al have discussed a comparative best practices that they have identified with User Experience Principles followed in 10 CAD software that they have used and recognized having better user experience. They have categorized the User Experience Issues into nine

topics namely modeling, dialogue box, terminology, drawing and report, help, menu items, toolbar, view and navigation. They have identified 179 UI issues with CAD which they propose to be because of Cognitive load that is significantly a cause for poor User Experience with CAD. They have analyzed a data collected from an online bug reporting system which was further put to a survey with the participants and proposed some measures to improve upon UX with CAD. They termed it Criticality and Complexity and based on it they have proposed a priority index for developers of CAD.

In line with Ghang Lee et al some other studies also have been done by researchers. One of them being by Zoe Kosmadoudi et al. They have suggested that the CAD User Experience is having many limitations because of Germane and Extraneous Cognitive load on the user. They have suggested that the concept of User Experience which is applied in designing Games can be satisfactorily applicable for CAD. They have proposed a concept of Serious Games which is being used in many applications. They suggest that the User Experience Design with Games is very much as per the need of the user which is required with CAD. They have also commented that even if UX with Games may not be exactly suitable for CAD but can satisfy some of the issues. Therefore, a study in this direction can be helpful.

Yujiang Li et al. have also evaluated usability of CADCAM software in their study in which they have mentioned that there is a need to evaluate and understand the usability concerns with CADCAM software and Automated Manufacturing. They have especially studied the need of usability concerns for CAD because of today's industry requirements like digital manufacturing, cyber-physical systems and Internet of Things, Industry 4.0, Cloud Manufacturing and Industrial Internet. According to them these all technologies are a future because of need for high flexibility in manufacturing domain. According to them the reason behind poor usability with CAD being because of small group of users associated. They have also commented that because of requirement to excel in complex engineering tasks with domain knowledge applications, it puts difficulty for novice users. Therefore it affects on various dimensions of usability like efficiency, learnability and engaging. This compromises User Experience and decreases productivity. Its also required that the Usability studies to be carried out with User Observations and Interface Inspections. Therefore accordingly the need to evaluate usability can be done with these two perspectives.

The Survey for Identification of User Experience Issues with CAD

The need to understand the user experience issues with CAD has motivated researchers and CAD developers to improve upon the complexity issues. Perhaps, still a need to ensure improvement in reducing cognitive load especially germane and extraneous exists. Therefore an attempt is made to identify issues with CAD user experience. Initially, a questionnaire with 45 questions surveyed with experts of CAD for review. The questionnaire was categorized mainly into two broad areas of Questions. The first one pertaining to CAD Users and their experience with CAD which was consisting of questions related to significance, need and opinions of CAD users. The second category of questions was for CAD developers and Importance of General User Interface Guidelines for both users and developers. The study highlighted that there is a need to work on User Experience issues and there is a confusion with CAD users and developers that both have different opinion regarding the complexity. Users

confused between complexity and usability whereas developers proposed to study this need with some interviews with users which complexity issues exist.

In the second phase, subjective questions were included in the questionnaire to integrate survey and interviews together. This called for online meetings with CAD developers, online questionnaire and offline discussions with CAD users. This resulted in more detailed understanding about current User Experience needs of CAD users today. In addition to complexity and usability issues, it was observed that, the need for better user experience is latently present in the data. This inference is drawn on the basis that the same results of usability needs existed in second phase of survey in addition to questions related to User Experience which is observed by CAD users during their CAD experience. The second phase consisted of a combination of questions related to User Experience for Users which were objective (on a 5 Point Likert's scale) and subjective (which is best tool/command that you used with CAD, etc). There were 48 questions with stage second questionnaire out of which 6 were personal information, 18 Objective and 24 Subjective. The subjective questions were discussed and then noted after comments from users. The questionnaire was categorized into 6 main categories, Personal Information, Need and Importance of study, Modeling, Selection, Toolbars and Menu Structure.

In the Third and Last phase of survey, a questionnaire with 24 questions was identified based on the observations and findings from first two phases. Also current CAD software User Experience issues were discussed with CAD developers and a need for automated User Interface for CAD was significantly identified as suggested from research findings of the literature. These 24 questions were mainly categorized into two main broad categories, Users Opinions for Experience Improvement and Need for study of User Experience Issues that are to be currently addressed with Automated Interfaces and similar criteria.

The following table briefs about the survey and its development for identifying user experience issues with CAD.

Table 1. Process of User Experience Issues Identified

Sr No	Survey carried out	The basis for the issues identified	Number of variables identified	Output obtained
1	Pilot Survey	Scholarly writings	45	Need to study and improve user experience for CAD
2	Interviews and Survey Phase 2	Basis of results obtained from the pilot survey	42	User Experience with CAD has developed which has been not addressed with literature but there is a need to improve upon it with more efforts

3	Final Phase of Survey	Literature gap identified, results of the survey in phase 2, interviews with CAD users and experts	24	8 significant factors contributing to user experience design with current CAD systems

During the last and final phase of survey, the data was collected from 104 CAD experts out of which a significant number of them being from industry and having an average experience of more than 5 years of using CAD systems. The experts from academia and private training centers of CAD have also contributed for the survey in all 3 phases perhaps a significant number being in the last phase. The next section discusses about the results obtained after analyzing the data for identifying the User Experience issues currently need to be studied for CAD.

Exploratory Factor Analysis for Identifying UX issues with CAD

As discussed earlier, the survey was completed in multiple phases to understand the variables that contribute to current needs of user experience with CAD. After completion of last phase, the data sample collected was put to tests for understanding its sufficiency for the results. Since the prime objective of the study was to extract the knowledge from the information phase of data collected, a thought was put to consider multiple methods of data analysis. Perhaps since the objective to identify significant user experience issues was to be attained, a method of factor analysis was suggested. Therefore, the data was put for sufficiency tests accordingly to complete the need for fruitful results with exploratory factor analysis method.
The sample was a mix of industry experts, academia, and private training institutes. The graph shown in Fig 1 gives an idea about the skill levels of sample data collected according the area of expertise. The data values are in percentage of total population.

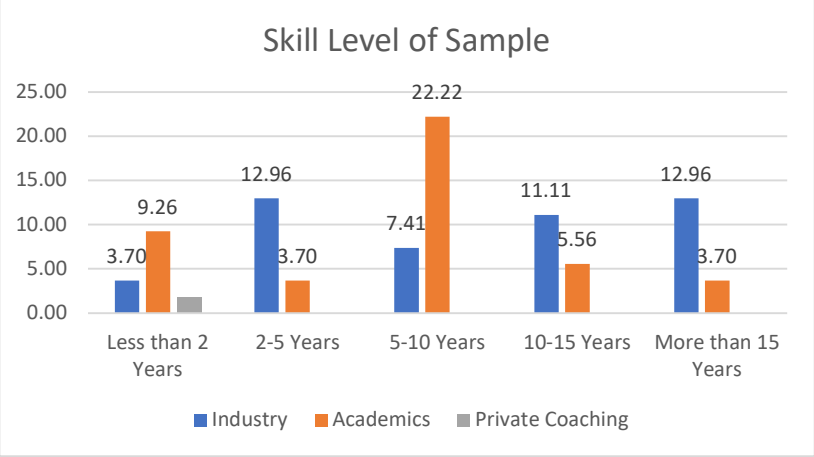


Fig 1 Skill Levels of Sample

A. Cronbach's Alpha: An assessment of how reliably survey or test items that are designed to measure the same construct actually do so. A construct is an underlying theme, characteristic, or skill. A high degree of internal consistency indicates that items meant to evaluate the same construct yield similar scores. To use internal consistency measures, items generally should be in a single measurement instrument and administered to a group of people on one occasion in order to avoid confounding variables.

Cronbach's Alpha is 0.7041.

A historical benchmark value of 0.7 is commonly used to suggest that at least some of the items measure the same construct. The Cronbach's Alpha is above the threshold 0.7.

B. Kaiser-Meyer-Olkin Measure of Sampling Adequacy: 0.558

The Kaiser-Meyer-Olkin Measure of Sampling Adequacy is a statistic that indicates the proportion of variance in your variables that might be caused by underlying factors. High values (close to 1.0) generally indicate that a factor analysis may be useful with your data. If the value is less than 0.50, the results of the factor analysis probably won't be very useful.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy: 0.558.
KMO is just adequate.

C. Bartlett's Test of Sphericity: Approx. Chi-Square - 1016.825, df- 276, P value – < 0.001

Bartlett's test of sphericity tests the hypothesis that your correlation matrix is an identity matrix, which would indicate that your variables are unrelated and therefore unsuitable for structure detection. Small values (less than 0.05) of the significance level indicate that a factor analysis may be useful.

Minitab is used for Cronbach's alpha and SPSS is used for KMO, Bartlett's test.

Results and Discussions

Extraction:

The factor extraction is based on principal components and correlation coefficients. Use correlation matrix to standardize variables when the variables are measured using different scales.

How many factors?

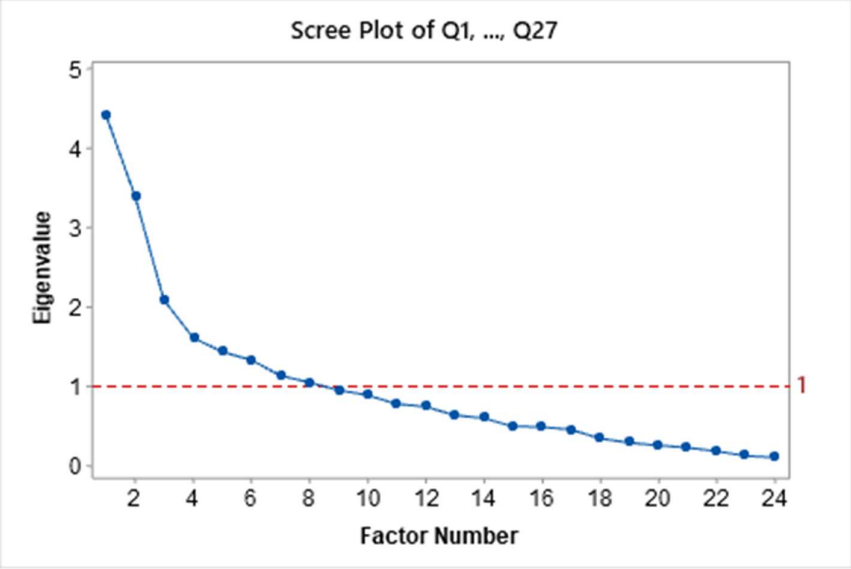
Kaiser's criterion: This approach is based on eigenvalue. Each component is associated with an eigenvalue of the correlation matrix. The eigenvalue of a factor represents the amount of total variance explained by the factor. Using this rule, only factors with an eigenvalue of 1 or more are retained for further investigation because Components with eigen values less than 1 explain less variance than contained in a single variable.

Fig 2 Scree Plot: Eigen Value plot for understanding important factors

Scree test: Another approach that can be used is Cattell scree test. In this test, the eigenvalues are plotted against their component numbers. Such plots will typically demonstrate a bend or elbow, and the components above this sharp break are retained.

In above scree plot the sharp bend is quite before so eigen values are considered to decide number of factors. The eigen values below 1 are not considered because the variance contribution is negligible. So, 8 factors can be extracted from this data.

After identifying the number of factors through scree plot, the identified factors were analyzed with Varimax Rotation for explored factor analysis. The identified 8 factors which have shown eigenvalue significance of more than 1 are shown in the table below which has factor loadings of more than 0.6 which shows that below 0.6 of the factor loading, the variable is not contributing to that factor. Loadings are correlation coefficients between the variables and the factors. Loadings can range from -1 to 1. Loadings close to -1 or 1 indicate that the factor strongly influences the variable. Loadings close to zero indicate that the factor has a weak influence on the variable. In factors extraction from corelation coefficient matrix, the



eigenvalues represent variance. The number of factors is decided by Kaiser criteria i.e., factors having with less than 1 eigenvalues are not considered

Rotation:

The original factor loadings are often difficult to interpret. Rotation usually creates a simpler factor structure and makes the factors more clearly distinguishable. Rotation also tends to remove general factors that load highly on all variables. Varimax rotation is used to extract factors.

Varimax: Maximize the squared factor loadings in each factor (gamma = 1). Varimax is the most widely used rotation method. This rotation simplifies the columns of the factor loading matrix. In each factor, the large loadings are increased and the small ones are decreased so that each factor has only a few variables with large loadings.

Other rotations:

Equimax: Rotate the loadings so that a variable loads high on one factor but low on others. This method is a compromise between the Varimax and Quartimax rotations.

Quartimax: Maximize the variance of the squared factor loadings in each variable (gamma = 0). This rotation simplifies the rows of the factor loading matrix. In each variable the large loadings are increased and the small ones are decreased so that each variable will only load on a few factors.

Orthomax with γ: Use loadings based on the value of gamma that you enter. Enter a gamma value between 0 and 1.

Communality

The communality is each variable's proportion of variability that is explained by the factors. The communality value is the same, regardless of whether you use unrotated factor loadings or rotated factor loadings for the analysis. Communalities are estimated by addition of square of loadings for that variable

Table 2 Gives results of consolidated results obtained with factor analysis carried out

Table 2: A simple way to present factor analysis Results.

	Variable	Loadings	Eigen Value	% Variance
Factor1	Q9	0.812	3.3265	0.1390
	Q20	0.785		
	Q16	0.704		
	Q10	0.623		
	Q15	-0.617		
Factor2	Q19	0.84	3.0079	0.1250
	Q1	0.676		
	Q25	0.661		
Factor3	Q2	-0.8	1.9299	0.0800
	Q11	-0.708		
Factor4	Q4	-0.77	1.8285	0.0760
	Q22	-0.673		
Factor5	Q24	-0.808	1.6737	0.0700
Factor 6	Q17	0.645	1.6023	0.0670
	Q13	0.637		
Factor7	Q7	887	1.5731	0.0660
Factor8	Q3	-0.693	1.5034	0.0630
	Q21	0.669		
Total			16.4453	0.6860

The important criteria is to identify the issues with CAD which contribute to User Experience. Therefore. The factors which were formulated with exploratory factor analysis were required

to be signified with suitable title. Table 3 gives an idea about the questions grouped into factors and the relevant title that can be associated with the factor. Factor 1 to Factor 8 is serially identified on the basis of percentage variance contributed in the analysis. This is the significance of these factors on the basis of their importance identified for application for the further study.

Table 3: Factor Definitions

Factor Number	Question	Factor Definitions (Issue Identified for UX for CAD)
Factor 1	It is better to provide Automated facility to place toolbar than customized	Automated Generation of UI for Standardization, History, Customization for Search of Commands in Toolbars and Menubars
	Providing Automated Suggestions through UI to the user for carrying out repeated or standardized work can be useful to user to carry out task with more efficiency (e. g. Providing a standard Hole or a Standard Fillet with a radius defined in history)	
	Changing the UI Automatically for a user as per the history, standards and need will help to improve the experience with the software use	
	An Automated generation of UI will benefit to deal with large number of commands with UI	
	Providing Self Adapting Menus with a combination from customized menu-bars will be helpful in making task more easy	
Factor 2	With Automatically Adapting UI, the complexity to carry out the task will be increased	Automation with UI for CAD may generate or increase complexity for users which needs to be addressed during Implementation
	There has been an increase in complexity with CAD with its evolution for the last few decades	
	If the problem which is faced mentioned in above question is resolved, may will create a problematic concern for other users	
Factor 3	Spending more money on improving User Experience of CAD software will make the design task more efficient	Providing Custom Views as per the requirements irrelevant of cost involved in UX Design are necessary
	Providing Custom Views in addition to standard view options available are required	
Factor 4	The Capability of CAD software today is more than its Usability	The Usability issues are still a

	The errors made during a task are more dependent on user experience than the experience of user	concern for CAD instead of improvement in its capabilities because of its need for all categories of users irrespective of expertise
Factor 5	A typical problem which a user faces with carrying out any typical task as experienced by you is frequently observed or the concerned errors are reduced over time	A typical problem specific for a user, faced during accomplishing a task, is frequently observed and errors are associated with it unless this UX issue is resolved
Factor 6	With Automatically Adapting UI, the time required to carry out the task will be reduced significantly and will improve the Productivity	Automating UI and providing tools with it like Wizards and Standardized Repetitive Commands will help improve Productivity and improve ease of working
	Providing a wizard for drafting of a frequently used models or commands will improve ease for modelling	
Factor 7	Modeling features are easy to search and identify with toolbars and menubars	Focusing on Providing ease in search for Menu and Toolbars will make the task easy
Factor 8	In-Depth Knowledge of the Design Engineering Concepts is essential to use CAD software effectively	To improve upon the search and decision time and make the design task easy which needs in depth knowledge of Design Engineering, a UI with different shape, Size and
	Providing different shape, size and color combinations with UI with the same software in different domains (like Sheet Metal, Piping, Mould Flow, Engineering Analysis, etc.) will help reduce search and decision times for user	

		Color combinations will be helpful

The study is intended to identify the user experience issues which are the need of currently available CAD packages. This has led to carry out a research design which can address these needs. Therefore, this work has identified a need to implement automated user experience, a need addressed in literature. The need addressed in literature is for Mobile and other applications perhaps, this study shows that, the CAD users are also in need of it. Automation required for CAD can be provided through customization and possibly through a dedicated Artificial Intelligence program. There have been few studies which address the use of Mouse Tracking for AI implementation for User Experience evaluations. Perhaps this study proposes use of two measures Fatigue and Productivity to be used to improve upon User Experience. An eye-tracking approach to be used for identifying Saccades as measures for evaluating Fatigue for the users of CAD. This study also addresses a need to understand the Mental Cognitive Load on the user which is required to be involved while designing task for AI implementation. All these measures were studied and were latent while surveying to identify the UX issues.

Conclusion

As discussed earlier, the three phases of survey which were intended to identify User Experience issues with CAD, were useful in identifying 8 important factors through exploratory factor analysis. As represented in table 3, out of 24 questions which were used in last phase of survey, the questions which have been significantly contributing in the User Experience are 18. So there are 6 questions which have been eliminated during the analysis which have factor loading below 0.6 in all the factors that have eigen values of more than 1.0 in scree plot. The table 4 gives a description of those questions and their factor loadings with rotated factor analysis.

Table 4: Eliminated Questions in Factor Analysis

Question	Question Number
A few interesting modeling features which are available with the CAD software you are working on make it more usable and appealing	Question 5
Instead of Custom Parametric modeling available, an Automatically generated UI will be more appropriate	Question 6
The errors associated with using modeling commands are less as compared to earlier versions of CAD which were used few decades ago	Question 8
Hot Keys available for few commonly used commands are more helpful than Input devices	Question 12
Providing Self Adapting toolbars which will change in its combinations with different modules and domains will benefit more to improve UI	Question 14
The solution that is stated for above question can be unclear or may not be possible	Question 24

So this study has identified the significant user experience issues which the literature couldn't address clearly with available CAD software. This study has also studied and analyzed the gap between literature and user opinion regarding user experience which CAD developers can utilize for further enhancements. The issues identified in this research are proposed to be useful for carrying out further research to improve upon CAD User Experience with a measure of User Fatigue and User Productivity which are interdependent and contribute to improve user experience. Since the work to apply Artificial Intelligence in various areas of research has become very widespread in this decade, and last few years for User Experience, the findings of this research has proved that the results are in line with the research requirements recently being applied by the researchers.

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