Reverse Engineering Website Navigation Using an Information Architecture Approach (Case Study: Kanal Pengetahuan Universitas Gadjah Mada)

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Abstract. In its development, the website of Kanal Pengetahuan UGM is built through a practical approach, so there are many shortcomings in defining the need and strategy information for the needs of the service business. As for the current problem, i.e., poor navigation related to the definition of primary content and links in the navigation menu. This is causing the granularity of information that makes users difficult to understand and find the information they need. This research aims to do reverse engineering of website navigation using the information architecture method to investigate the way how users to find and interact with information content from the website. The main contribution of this research is the analysis of the result of card sorting has directed the research to gain insight into how the users in categorizing information on the website. As a result, in the current system, there are only 3 categories that have not yet represented all the information provided by the website, so that research conducted with 102 participants produced a new navigation proposal with 4 new categories that fit the user’s mental model.

1. Introduction

Kanal Pengetahuan UGM itself is a medium of dissemination of science, information, and education in the Universitas Gadjah Mada. Following its name, the Kanal Pengetahuan UGM is a channel that connects a variety of knowledge sources and actual and factual information in the scope of specific scientific fields with practitioners, policymakers, academics, and high school students as well as university students. So, if there is a problem when the user cannot find the desired content, then this becomes an important issue, where the flow of information provided between the content and the user is not running as it should.

Kanal Pengetahuan UGM is built through a practical approach so there are many shortcomings in defining the need and strategy information for the needs of the service business, as well as not yet referring to the good information architecture that makes the service of information generated by the system is not well organized. As for some problems encountered today namely poor navigation related to the definition of home content and links in the navigation menu, this is what causes the granularity of information that makes users difficult to understand and find the information they need, this is due to lack of standardization of websites and lack of maintenance done [1]. Unorganized site content is a real problem behind the low traffic that occurs nowadays in the Kanal Pengetahuan UGM. Readers certainly will not visit the site anymore if the content looks unorganized and messy. To solve this problem, the site needs to classify the information content that corresponds to the category provided. It will certainly
help the reader to search and read the information content. Newsreaders are usually looking for the latest news and events. However, the website today concentrates more on several categories of information from individual faculties that may not be related to the reader. So, to solve this problem, the site should post all the categories of information that can bring readers to the site of this problem certainly caused the low level of integration that exists in the system as a whole. These problems are what make users have trouble navigating websites, which then causes users to struggle to find the desired content.

This paper defines the website of Kanal Pengetahuan UGM as a complex organizational website and is designed to promote the brand and for dissemination of information with the following features 1) topics discussed and content provided heterogeneously; 2) content addressed to the target audience and heterogeneous user groups; and 3) content produced comes from various subunits within the organization, for that to fix existing system navigation required approaches where later can look into the system for being able to understand better how the flow of information architecture exists on the system today in delivering existing content to the user.

The study chose to use the reverse engineering approach to improve existing systems because reverse engineering is the process of analyzing components of a system with the intent to make a representation of the system into another form [2]. Reverse engineering is used because it can repair previously established systems as the subject. Reverse engineering can look into the system more thoroughly to find out how existing systems currently process existing business processes. Reverse engineering or commonly called back engineering, is a process of learning (extraction) knowledge, design, or anything that is made human, which then the extraction result (science) is reused by to reproduce knowledge/design and make something new based on the extraction of knowledge above. In this study, reverse engineering used to be able to understand how the flow of information architecture exists in the system. Currently in delivering content to users by looking into the system’s source code.

In this research conducted the reverse engineering approach of information architecture system on the website with the aim to see how navigation of existing systems currently running, after knowing how existing systems are set up the flow of business process architecture information, then doing improvements to the architecture of such information using the approach of information architecture to generate new navigation system that better suit the mental user model, approach information architecture used is a card sorting.

Card sorting is used to investigate how users find and interact with the content of information from the website. Thus, to improve the effectiveness of users’ interactions in the website of Kanal Pengetahuan UGM that is oriented to the topic of information dissemination, the session card sorting is done to collect information with the following purposes: 1) to Generate categories for the website of the Kanal Pengetahuan UGM with specific content, 2) to identify how the users compile the information, and 3) to get ideas about potential information architecture for website users. To accomplish this, it takes a better understanding of how the user organizes the information. After understanding this, it is hoped that it can help in developing the website so that it will be more beneficial to the general public.

To present the results of this study, the paper opened with an introduction explaining the background of research, a review of the literature that set a theoretical background for this study. Then explain the research methodology used. Then analyze the data and offer the results, lastly compare the results that are offered with the navigation of existing systems before giving conclusions.

2. Literature Review

The fact that nowadays many source code from legacy applications is designed and poorly documented creates complicated situations when wanting to perform system repairs [3]. Because it requires an expensive fee to replace all the source code on legacy applications, then the only sensible alternative is to maintain and develop existing source code. Much time is spent to understand a system before making improvements to the unfavorable improvement of the economic side because the development of software systems continues to grow, both in terms of size and also complexity. To that, to help reduce the cost of understanding the program, [3] suggests that "practicing with the reverse engineering technique increases the ability to understand the system rendered quickly and efficiently."

Reverse engineering is a broad term. Chikofsky and Cross formulated the most commonly used RE definition as follows: "Reverse engineering is the process of analyzing the subject system for..."
identifying system components and relating, and making system representations in other forms or on
Higher levels of abstraction "[2]. Recently, Tonella et al. expand the sense of reverse engineering to be: "Every method that aims to recover knowledge about software systems exists in supporting the execution of software engineering Tasks" [4].

Based on some previous literature that there has not been found the implementation of reverse engineering focusing on information architecture and also system usability. The existing literature only describes the implementation of reverse engineering to improve the existing system in a broader context. Tonella et al., [4] published in an exhausting overview of the popular methods that can be applied to support reverse engineering. One of these is the method of design recovery: This method aims to restore the design abstraction from the source of available information. Part of the restored design is the domain model. Design abstractions are recreated by combining informal information, existing documentation, and source code.

Design recovery is a vast field. Therefore, most of the research focuses on subareas. Concept assignment issues try to find human-oriented concepts and connect them to locations within the source code. Often this is further divided into concept recovery and concept location. Concept location is at a lower level, while concept recovery has become a very active field of research in the reverse engineering community especially in the area of system design recovery.

In this research uses the term IA to refer to the structural planning of information space of the website, consisting of three systems: 1) System organization, namely the system for organizing content to pages and managing the relationship between them, 2) Navigation System, which is the system to allow users to move from one page to another, and 3) the labeling system, namely the system for page naming and navigation functions [5].

Information Architecture (IA) refers to the arrangement of digital information space to provide users with simple and intuitive access to content and functionality [5]. IT on websites significantly affects usability and user experience during the navigation. Citing Malonery and Bracke (2004), "website design adds presentation and graphical elements to the information architecture to create a user experience" (p. 146). Thus, IT is a fundamental dimension that determines the ability to communicate effectively through a website [6].

Nowadays, much information comes through the website, so the importance of a website in communicating the information in the right way becomes very important. The website provides the advantage of being globally accessible through an Internet-connected computer network, as well as from information available Online to quickly answer user questions. The website is an information service that is accessed by many Internet users because it can handle the demand of many users with good quality (reliable).

According to Ding and Lin, information architecture involves several activities in order to remain maximally in making the right decision. First organizing and simplification of information, both design, third integration and aggregation of space or information systems, the four create ways for people to discover, understand, exchange, and manage information [7].

Information becomes very important because the right decision or does not rely on adequate information. Research conducted by several researchers such as Blake and Mangiameli [8], Collins et al. [9], Cao and Zhu [10]. Finding that is why many of the wrong decision makings occur is mostly due to the poor quality of the information provided, such as erroneous data or incomplete data. A website that has large-scale information and continues to grow in a fast-paced time can cause the possibility of people to fail to find more valuable information.

Organizing information is one of the most influential factors affecting the way users think of and interact with the interface [11]. Because of the Institute of Information, architecture is the art and science of organizing and labeling websites, intranets, online communities, and software to support usability [7]. Usability is very related to the extent to which the user's mental model matches and predicts system actions. The mental model has been used in human-computer interactions and improving usability. Users may not always have an optimal mental model. Designing a system based on an imperfect user's mental model can impede user performance. So, it is crucial to know the user's representative mental model with regards to the software structure, as it allows a designer to create content according to the user's expectation, thus making the resulting design as intuitive as possible for users [5].
Information Architecture can help increase usability aspects because the information users need will be displayed in such a way on institutional websites following their expectations. Card Sorting is one of the methods of Information Architecture, in which the respondent will be randomly assigned a collection of cards and asked to group the cards into a specific label. It is considered a design framework based on the information architecture that is used to recognize classified and structural website content. Card Sorting is used to understand users who think about website content [12]. It also helps to organize the content so that it matches the user's mental model rather than the product design standpoint. Card sorting chose as a way to give an understanding of how Users group, organize and label information [13].

3. Method

Reverse Engineering is the process of digging knowledge or useful information from a product. Reverse Engineering is usually used to design and modify a product based on an existing product [14]. Reverse engineering techniques can be used in the process of evaluating product quality or in the process of redesigning products that are not available for development documentation. Initially, the concept of reverse engineering has been used only for hardware projects, but now it is also very much used in software, although no one has implemented reverse engineering on the information architecture of a system. Reverse Engineering is used as a tool to acquire lost knowledge, ideas, and design philosophies, thereby collecting best practices from already developed applications.

![Reverse Engineering Process](image)

**Figure 1.** Reverse Engineering Process [15]

In this research, reverse engineering will be applied to improve the software on the system architecture part, especially in the website navigation section. The reverse engineering process can be divided into four phases: Context Parsing, Component Analyzing, Design Recovering, and Design Reconstructing [15]. However, this research will only end in the Design Recovering phase.

The reverse engineering process was done with the first phase, the context parsing to analyze the source code contained in the system and then parsed the source code and changed the source code to a more structured representation such as the conversion of source code of Machine language to a low-level language that is easier to understand. The second phase is to take the intermediate program structure to reveal component artifacts such as the current information architecture chart. Moreover, the third phase is the result of the extraction of design later in the analysis and concluded in the form of information at a higher level. In this phase also carried out the existing navigation improvements using the card sorting method. The card sorting method is done, which is hybrid card sorting.

Card Sorting is one of the methods of Information Architecture, where the respondent will be given a random collection of cards and then asked to classify the cards into a specific label [6]. On open card sorting where respondents were asked to sort and classify the cards that are available according to the views that they think are most reasonable according to them. Then they will then describe each group
created. This method is one of the generative methods done in the pre-design phase to help build the structure of information to be created. In the closed card sort, the respondent will be given a pile of cards along with the group category that has been specified. The respondent will then be asked to classify the cards into pre-defined categories according to their most sensible order. This method is an evaluative method done on post-design to evaluate and analyze the website created according to the previous research results. In addition, there is another category for the card sorting technique that is hybrid card sorting, wherein this technique is a combination of open method and closed card sorting. This study, hybrid card sorting techniques were used due to being more reproductive and also evaluative. It helps to generate ideas and also evaluations on how to re-engineer the information architecture of the website. Hybrid card Sorting is regarded as the most useful framework for designing and enhancing the information architecture of any website [12].

3.1. Materials

For research with a hybrid card sorting method, the data used is data obtained from online studies. Card Sorting Online is chosen because it is perfect in many ways, such as the number of participants who can take unlimited studies, get more participants in the study are very likely, and this is not in moderation. The resulting metric can be much more precise as more participants are earned at a lower cost and shorter time.

The Data obtained represents the need for user information that has or may not be fulfilled by the contents of Kanal Pengetahuan UGM. Samples were taken in the period of 9 July 2019 to 6 August 2019. In this period, the total data entered is 186 people who did the study until the completion of 102 people (54%) And who left 86 people (46%). Participants completed an average study took 5 minutes 38 seconds.

Before the actual card sorting starts, the candidate entity list is prepared. This is extracted from the results of analyzing the existing coding on the system by looking at how each existing navigation presents information to the end. A brief description of each of the existing subjects of the system is currently extracted and combined with the most frequently used categories in the organizational sub-unit. As a result, then generates a set of 24 cards, each with a brief description of the information loaded. The description includes what kind of information is displayed and the activities involved. The description of each item is embedded on the card to facilitate the participant in understanding the intent of the cards provided.

This research uses 24 cards with four categories of current navigation and data from the field of the most frequently used units in each sub-unit of the organizational Kanal Pengetahuan UGM. More than one method is used to visualize and understand the outcome of the study. It relies on various methods to perform analysis, including cluster analysis tools. The results of the research with different views highlight the different elements of grouping and associations that users create. Patterns of how users organize content in a site appears during the analysis process. The results of the analysis will be compared to existing systems.

3.2. Participants

When deciding which users to recruit for the study, it is known that most users of Kanal Pengetahuan UGM are regular users where most of the users prefer to go directly to the page of the Subunit site Faculty. For high turnover sites among users, how to display the interface is the most important part for novice users. To design a website for novice users, experts, or advanced users, then expect to be able to adapt and easily find what they need. Based on this, it is determined that the user in this research should have the characteristics of the first, general or novice user of website terminology and secondly, rarely or never use the website.

Participants were taken representing the four main target groups of the website. The sample has a total of 102 participants participating. Among these are 26 high school students, 26 students (Academic Community), 25 employees of the company (industry parties), and 25 people of the general public (entrepreneurial, alumni). These figures, in line with the number of participants mentioned, are required for the study of the card sorting type in the formative design phase. Participants are recruited through Online Media, which is then asked to fill the study. Before participating, each participant is instructed
about this study and fill in the personal data of names and types of work. Participants were also freed to withdraw from the study at any time.

3.3. Procedure
In individual sessions (averaged 5 minutes 38 seconds per person), the procedures that are done can be seen in Fig. 2.

![Figure 2. A Card Sorting Procedure](image)

3.4. Analysis
The result of the card sorting is analyzed based on the cluster analysis performed on the card stack (cluster) created by each participant. In this analysis, the card patterns associated with each other correspond to the participants’ mental models are identified by analyzing how often they are placed together in a single stack. From these results, the individual types compared and correlation items are computed. Based on the matrix correlation of the resulting item, analysis is done using optimal workshop software. For each sub-group of participants (high school students, university students, employees, general public) the number of existing clusters will be used for evaluation of what logic the participant follows in the created category, which cards are often paired in a group, what cards are never paired because they are considered to be conceptually different by the participants, and what types of labels are advised to represent the information.

Hybrid card sorting was made with a total of 102 people. The review is then done to get results. There are five methods used in the analysis process this time. Firstly, the cluster analysis method, each stack is analyzed and compared. Secondly, the standardization grid is to explore how high the actual match rate is. Third, the similarity matrix to show the percentage of a grouping of two cards together performed by the participant. Fourth, the Dendrogram gives another way to find a popular group of cards quickly and tells how similar or different the types of card participants are to each other. And fifth, participant-centric analysis (PCA) aims to find the most popular grouping strategies and then find two more popular alternatives among those who disagree with the first strategy.

4. Result and Discussion
Reverse engineering results by analyzing the coding in the system today generates some information, that is three main categories are present in the global navigation section of the websites that attached pages to several pages. Moreover, after further view that the three main categories of existing systems are not yet able to represent all the information provided by Kanal Pengetahuan UGM.
Information provided by the current website is just some of the information that is on the website. Existing Categories also still make visitors confused about the site.

To improve the flow of information, there is a card sorting study. From all the participants who took this study, a total of only 102 participants from 186 participants who completed the entire study process. Each session takes an average of 5 minutes to 38 seconds, although it may take 45 minutes to 52 seconds. The number of categories produced is 13 categories in which 4 of the categories are a standardized category, and nine other categories are the results made and by the participants themselves. Here are some analysis results from incoming data during the card sorting process.

4.1. Cluster Analysis

102 participants generated a total of 13 categories. Category distribution for all criteria. The results of standardization that is standardized and also made by participants in this study is a good entrance to see the results of hybrid card sorting, this is because it can facilitate in scanning the emerging categories and quickly form a 'mental model' impression of the participants on how participants view the overall theme or concept of the card provided. To explore the category results and filter the existing data, it is necessary to standardize the categories that have similar labels and cards, such as different words, spelling, uppercase, and so on. However, before looking at a group of labels that look similar and directly standardizing, it is worth seeing the similarities between the categories that have not been standardized in more depth-first. Exploration and statistical analysis approaches are conducted to do this.

When opening a study, it can quickly be seen groups that are popular through the highest agreement score to the low, depicted in fig. 3. The agreement score is an indication of the level of similarity of the category in the category of standardization. To ensure participants have the same conceptual approach, then done analysis closer to categories and cards. Of the 13 categories in which 4 of them are the category of standardization, whereas 9 is the category created by participants. Of the nine categories that are not standardized each made by 1 participant with a label that they think makes the most sense, it also shows that each person has a different mental model when viewing the card provided.

When viewing a standardized category, it has a low agreement score. Then be aware that the low agreement score is not the only reliable number to tell useful data. Something essential and useful can also be noted by looking at the number of participants placing the cards in each category. For example, from 102 people, there are a total of 96 people inserting a specific card into the same category. It is believed that most of the participants who make this category think that these cards are part of a particular category. As a solution, try to increase the result of the agreement score by removing the cards on the category that have the lowest selectable frequency of the other. After being tried on the category 'E-LEARNING' The result is now the agreement score to 71% from initially only 23%, see in Fig. 4. The high approval rate of more than approximately 60% of the deal will be useful to make this category Standards for residual analysis.

4.2. Standardization Grid

In addition to conducting card analysis and viewing of the agreement score assessment, the next method is to analyze by looking at the standardization grid to explore how high the actual match rate is in more detail. The boxes on the standardization grid only show how many times a given card appears.
in the standard category, look at fig. 5. In this section can be seen how often a card is placed on a particular category, e.g., 'Public lecture' card Placed by 82 participants into the standard category 'E-Learning'. It is, of course, beneficial for analysis.

### 4.3. Similarity Matrix

Similarity Matrix is used to show the percentage of participants that group the two most linked cards together and then group the two pairs in the rightmost corner. So, the darker the blue color and the larger the cluster number than the higher the agreement between the participants where the card is merged, look at Fig. 6.

### 4.4. Dendrogram

Dendrogram quickly finds popular card groups and knows in general how similar or different types of cards are grouped participants from each other. Dendrogram has two methods that can be used to explore, and more or less useful these two methods depend on the number of participants held. If we have more than 30 participants, then we should use the Actual Agreement Method (AAM) and conversely if we have fewer than 30 participants, then we should use the Best Merge Method (BMM). Because in this study of participants held as much as 102, The Actual Agreement Method (AAM) provides better data where "X% of participants agree with this exact grouping" and therefore allow to extract as much as possible from the data. The result of the level of approval of the Dendrogram which is the category 'BERITA' gained 85%, category 'E-LEARNING' and 'PENDIDIKAN' gained 33%, category 'SENI DAN GAYA HIDUP' gained 29%, and category 'RISET DAN PUBLIKASI' and 'E-LEARNING' gained 15%.

### 4.5. Participant-Centric Analysis (PCA)

The PCA shows three of the most popular information architectures that participants generate based on how often two cards are paired together in the same category during the entire survey. This information can be a useful starting place when it comes to compiling some of the potential website.
structures. PCA aims to find the most popular grouping strategies and then find two more popular alternatives among those who disagree with the first strategy. This works very well when it has a lot of results. In addition to the first option that hopefully is useful, it may later get useful ideas for the footer and sidebar aspects of options Two and three. This is called PCA because each participant's response is treated as a potential solution and is rated for similarity to all other responses. If it looks at the type with the agreement 89/102 score, it tells that there are 89 participants sorting their cards into groups similar to this one.

4.6. The Results of Analysis and Comparison with The Current System

Based on the analysis of hybrid card sorting that has been done, then we obtained the design of the information architecture of the website that corresponds to the user's mental model. It helps to decide the final structure of the design prototype interface. This information architecture navigation design includes four broad categories of groups, namely 'E-Learning', 'Riset dan Publikasi', 'Berita', and 'Seni dan Gaya Hidup'. Based on the analysis done, then the redesign of the information architecture with the existing updates, look at fig. 9.

![Figure 8. Current Information Architecture](image)

![Figure 9. Information Architecture Recommendation](image)

This research clarifies the benefits of engaging the target audience of users in a user-centered design process. When compared to existing navigation is a very noticeable difference where the proposed navigation based on the result of the card sorting is divided into four categories, where previously only three categories, see in Fig. 8. In the previous navigation, visitors will be confronted with three categories that have not yet represented all the information provided by the Kanal Pengetahuan UGM.

5. Conclusion

This paper reports the exploration of reverse engineering on the navigation of the information architecture on the website of Kanal Pengetahuan UGM using the approach of information architecture. The conclusion of this research is:

1. The results of card sorting analysis has directed this research to gain insight on how the 4 user's targets in categorizing information on the website of Kanal Pengetahuan UGM. Where in this study obtained participants of each of the high school students amounted to 26 participants, university students 26 participants, employees of the company (industry parties) 25 participants, and general public 25 participants. With a total of 102 participants, each participant has a different mental model in generating the grouping performed.

2. Many of the totals of 102 participants were not able to understand the meaning that would be delivered by 24 cards available, this can be seen in the standardization table where there are 15 cards that are not present in any category and also shown with a small number of cards made on
the new category is not labeled correctly. Of the 13 categories produced in which 4 of them are standard categories and 9 other categories are made by the participants obtained the data in which participants are more likely to use the standard Category that has been provided than to make a category with the new label.

3. Reverse Engineering and card sorting into useful techniques for specifications and verifying the credibility of this research work, this can be seen from the striking difference of the new information architecture results with previous architecture, where in the previous navigation there are only 3 categories that have not yet represented all existing information and also the categories provided still complicate users when searching for information content. So, with new navigation where there are 4 categories with each category contains the content of information that has been organized according to the mental model of the current user, expected later when the user visits the website, they will immediately obtain the required information. In other words, user involvement in defining the information architecture is a significant thing for website usability to be achieved.

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