

Review of Visualization in User Behavior Analysis

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Abstract:

User behavior visualization as a powerful tool can help analysts better understand user behavior data. Previous research such as Information Architecture believes that a user journey map is the regular way to visualize user behavior patterns. The technique is a diagram that shows the steps, touch-points, and emotions that users go through when using their products or services. Current studies mainly focus on the procedure and framework of applying user behavior data into visualization tools and its benefit to business development. Studies also found that visualization in user behavior analysis has difficulty in dealing with complex data. However, few studies have discussed the possible solution for the current limitation of visualization in user behavior analysis. With the popularization of the Internet and mobile devices, the scale and scale of user behavior data and the complexity will continue to increase, and user behavior visualization will be an important tool for analyzing this data, helping to tap potential business opportunities and improve the efficiency of data analysis. Therefore, we would make the review on visualization in user behavior analysis. We will first provide the background of the user behavior and its visualization and then introduce the definition of user behavior. Afterward, we will discuss the current process of visualization in user behavior analysis and its current limitations. Next, we will propose the possible solution of introducing machine learning, deep learning, predicting the data with a sequence model, and using cluster analysis with usability analysis tools to contribute to the future development of visualization in user behavior analysis. We believe that with data amount and scale keep increasing, the visualization tools need to develop themselves in diversity and data processing speed.

Keywords: Visualization; user behavior; data analysis

1. Introduction

User behavior analysis is becoming more and more important in modern society, especially in the context of highly developed information technology. Jagat Saikia, the famous data analyst once confirmed that the effectiveness of data visualization is decided by its simplicity, relevancy, and its ability to hold the user's hand during their data discovery journey. With the popularity of the Internet and mobile devices, people's behavioral data is widely generated and recorded, and these data contain rich information, which can be used to understand user preferences, behavior patterns, and market trends. In this era, many industries such as IT, e-commerce, supply chain logistics, etc. are all applying visualization tools to have better insights into their users and customers. However, it is not easy to extract useful information from massive user behavior data, which requires the use of visualization technology to help analysts better understand and analyze data. Visualization technology can help analysts better understand the characteristics and patterns of user behavior

data. By displaying data in the form of charts or graphs, analysts can intuitively see the correlations and trends between data, thereby gaining a deeper understanding of the information behind the data. For example, by mapping users' browsing paths on a website, analysts can understand users' behavioral patterns on the website, thereby optimizing the website's layout and design and improving user experience. Current visualization techniques are mainly applied to four aspects, such as social interaction, travel, network communication, and financial transactions.

The technique enables those companies to be more efficient. Visualization techniques can help analysts better discover anomalies and problems in data. By visually presenting the data, analysts have chance to easily discover outliers or irregular parts in the data and make proper adjustments and optimizations. For example, by drawing a bar chart or a line chart, analysts can quickly detect a sudden drop in sales or an abnormal increase in user churn, so they can take timely measures to make adjustments. In addition, visualization technology can also help analysts better interact with data and conduct deeper analysis. The

trend can also be easily recognized. Data visualization could be a tool to tell a data story to the audience. The visualization can be applied to illustrate the data facts in an easy-to-understand form while telling a story and leading the audience to an inevitable conclusion. Interactive visualization tools allow analysts to sift, filter, and sort data based on their needs to find the most valuable information. For example, through interactive map visualization tools, analysts can filter data based on region, time, and other dimensions to better understand user behavior characteristics and trends in different regions. Therefore, we want to discuss and explore the application of user behavior visualization in analysis, and further explore the challenges and development direction of user behavior visualization in the analysis of complex user behavior data through the summary and analysis of existing methods. At the same time, we will also discuss how to use user behavior visualization technology to better understand users' preferences and behavior patterns, and how to apply them to marketing and user experience optimization.

2. The Definition of User Behavior and Its Relationship with Visualization

The definition of user behavior is critical in research, as it is the basis for understanding and predicting user behavior. In different fields and research categories, there may be some differences in the definition of user behavior [1]. In general, user behavior can be described as the behavioral behavior of individuals or groups in a particular environment, especially when using products, services, or systems. In the field of information science, user behavior usually involves the acquisition, processing, communication, and utilization of information, which involves information retrieval, information filtering, and information evaluation. In the field of social sciences, user behavior may involve wider social interactions, cultural expressions individual choices, etc., which reflects the diversity and complexity of user behavior [2]. In current society, user behavior has been applied to data visualization so the organization and manager can see the clear pattern and effect of their business strategy and performance. More specifically, in visualization analysis, user behavior data includes clicking, browsing, and searching on the website, which also includes interaction behavior on social media websites. These data can be visualized so the researcher can know better about users' preferences, behavior patterns, and decision-making processes [3]. In addition, when performing a visual analysis of user behavior, it is also necessary to consider the dynamic and timeliness of user behavior [4]. Over time, user behavior may change, so data needs to be collected and analyzed in time to ad-

just the analysis model and strategy promptly. At the same time, it is also necessary to consider the diversity and personalized characteristics of user behavior. Different users may have different behavioral preferences and behavior patterns. Therefore, it is necessary to comprehensively consider these factors when conducting visual analysis to obtain more comprehensive and accurate analysis results. To sum up, the definition of user behavior is of great significance in research, which can not only help researchers understand and predict user behavior but also provide important theoretical foundation and method guidance for visual analysis of user behavior.

3. The Visualization Process in User Behavior

User behavior visualization is a powerful tool to help analysts better understand user behavior data. By converting data into graphics or images, analysts can more intuitively observe patterns and trends in the data, thereby better understanding the user's preferences and behavior patterns. Specially speaking, analysts need to clearly define the main aspects of customer experience. By defining these aspects and making informed decisions according to the definition, companies can better increase customer engagement and make the customer journey more enjoyable. To define the main aspects of the customer experience, the enterprise needs to understand the steps of the customer experience in detail and the possible results of these steps. Second, companies need to choose the right data to visualize. In other words, among the many collected data, the analysts need to select those data that can provide insights and help them improve for visualization. Data visualization can use various visual formats, such as line charts, bar charts, pie charts, heat maps, word clouds, scatter charts, and infographics. Companies also need to choose the right data visualization tool to visualize the data most suitably and effectively. More importantly, the visualization could provide the pain points in the customer journey so the companies can make adjustments to the pain points to meet customers' satisfaction. Some tools can be very useful in building the right data visualization format to help understand data. For example, real-time customer data platforms such as BloomReach Engagement and external data visualization tools such as Visme can help enterprises manage customer data and customer analysis and create compelling and meaningful visualizations. They can use visualization tools to track the website visitor trend and create a funnel model. In this case, it is clear to show the customer journey and which step needs to be improved. In the end, all the data is integrated to obtain actionable insights, and the decision-making process of the enterprise

is perfect. Data is an important resource of an enterprise, and understanding the stories behind data is very important to the development of the enterprise.

Taking TianMao, the famous Chinese e-commerce, the platform intends to understand the behavior of users in the shopping process. They can use user behavior visualization technology to map the behavior path of the user in the shopping process [5]. This path map clearly shows the complete process of users from browsing items to adding to the shopping cart to the final purchase. By observing this path pattern, the analyst could find some valuable information such as the items with high views and low purchases. In this case, the analyst needs to optimize the commercial page and promotion strategy. In addition, if the analysts find an abnormal purchase rate in some commodities, they can try to increase the storage to satisfy the users' needs. Besides, the visualization of user behavior could help analysts find the time pattern of user behavior [6]. For example, by plotting the user's shopping behavior at different times of the day, the analyst can see the user's shopping peak and trough during the day. This information is very helpful in determining the timing and frequency of marketing campaigns and can help the platform to run advertising or promotional activities more accurately, attract users' attention, and improve conversion rates. Data visualization here is the language of decision-making. Therefore, user behavior visualization can not only help analysts better understand user behavior data, but also provide them with more operational suggestions, help them better optimize products and marketing strategies, and improve user experience and platform performance.

4. The Limitation of Current Visualization on User Behavior

Existing user behavior visualization methods are limited and need to be further improved and improved. The existing methods mainly focus on simple user behavior data. For complex user behavior data, such as the relationship between advertisement clicks and shopping behavior, the analysis effect of the existing methods is not ideal [7]. An online advertising platform wants to understand the shopping behavior of users after clicking on the advertisement. They might use traditional user behavior visualization methods, such as drawing time series diagrams of ad clicks and shopping behaviors. However, this simple time series diagram often fails to accurately reflect the relationship between ad clicks and shopping behavior. Because user behavior is often complex and changeable, it might be affected by various factors, including advertising content, user interests, shopping habits, etc. [8]. Traditional user behavior shows difficulty in extracting

meaningful information from massive data. This problem can be regarded as dimension exploration. With data dimension increases, the user behavior would involve many dimensions such as user ID, item ID, operation type, etc, depending on the specific business type. Those dimension combinations would cause information overload and cannot be displayed directly. Moreover, the massive data is diversified so it needs analysts to filter and choose the available data and show it. In this case, the visualization might not be very comprehensive. As for time effectiveness, user behavior analysis needs to have time effectiveness. Current visualization tools commonly show a certain period of the data. If the analysts want to know the updated one, they might need to adjust the timeline manually. Based on current visualization tools applications, we find that many websites pay attention to website usage data, user behavior data, and website structure information. Among all of them, the disk tree designed by Ed Chi has been widely used in combing website data and its structural information. The main performance is to map the usage data of the website to the structure diagram and apply the breadth-first search algorithm to represent the structure of the website as a "disk" [9]. That is, if multiple links can reach the web page, then the first searched link will be described. The technology has been applied to research areas such as visualizing website evolution, website usage trends over time, and evaluating information searches. In addition, Crowds Dynamics designed by Minar is a dynamic visualization system that regards the website as a social activity space and describes the process of user browsing the website. However, those visualization methods only can perform real-time user behavior and the methods are limited by the website scale. In this system, the website structure is established manually by analysts not automatically generated. In this case, we believe current visualization methods still have limitations. More importantly, these visualization tools do not only show the user behavior that already exists but also show the current user behavior. In other words, current visualization tools could not reflect previous user behavior which decreases the comprehensiveness of user behavior analysis.

Besides these limitations, data privacy protection is also one of the potential challenges for the current visualization of user behavior analysis [10]. Most countries would ask the user to consent to the online service to get their private data. However, users are more likely to consent without checking the consent rules carefully. Or, users have no idea about what the privacy policy is. In this case, when the data are dealt with and visualized, the users might feel offended that their data are used to be displayed to others. As for the visualization tool, it is possible that when they deal with the data, it cannot recognize which

are private and which are public, and leads to some safety risks. Therefore, the visualization user behavior analysis needs to secure the private data and deal with the data more cautiously.

5. The Possible Solution for Current Limitation

To solve this problem, the platform could introduce advanced data analysis techniques such as machine learning and deep learning. Machine learning is the computer learning from algorithms. On the other side, deep learning can imitate the human brain and solve the non-structural data. After applying them and making the outcomes visualized, the results would be clearer and helpful for providing decision-enabling insights. The analyst can use a sequence model to analyze the sequence relationship between advertising clicks and shopping behavior, to more accurately predict the user's shopping intent and behavior. In addition, technologies such as clustering analysis and association rule mining can also be used to discover potential patterns and laws in user behavior and provide more operable suggestions and strategies for advertising platforms. A previous study has found that a site usability analysis tool(SUAT) could be a useful visualization tool for reflecting user behavior. Drawing on the success and deficiencies of past application visualization technology, SUAT has adopted server log analysis data as a data source and developed interactive visualization tools that assist usability engineers to discover and analyze website availability problems [11]. The main function of this tool is to reflect user behavior on the website topology diagram and use graphic elements such as dots and lines to describe the problem. Each node represents a web page on the website and uses the title of the page as the node's label. The connection between nodes represents the hyperlink relationship between web pages, highlights the analysis of a web page, and simplifies the size of the elements in the diagram by scaling, hiding, strengthening fading, and opening specific web pages. Users can obtain the characteristics data of websites and web pages, such as web page status, download time, etc., by observing the topology diagram, to find the usability problems of the website. For example, through a case analysis study, it is found that the usability problems on the website include restricting the use of links in the webpage, links to the homepage, and the website level being too deep [12]. The webpage download time is too long, the link pointed to the landing page does not exist, the web page layout or style is suddenly changed, the link or button click is invalid, and the dead end is a problem. All those problems are shown in the SUAT and displayed as dots with different

colors and lines with different line thicknesses. The dot's color represents the frequency of users visiting pages. The line color represents the browsing path of users and the line thickness represents the time that the user has spent on viewing the website. The analyst could apply pattern algebra methods such as filter, plus, minus, outdegree, etc. to support the analysis and make the comparison of user behavior change when browsing the website.

6. The Future Development of Visualization User Behavior Analysis

User behavior visualization has broad application prospects in future development. "By compressing data from multiple reports into visuals, businesses can uncover data patterns and connections that matter in a timely fashion," said Cherinik, the expert. With the popularity of the Internet and mobile devices, the scale and complexity of user behavior data will continue to increase, and user behavior visualization will become an important tool for analyzing these data, which will help to tap potential business opportunities and improve the efficiency of data analysis. With the popularity of the Internet and mobile devices, the scale and complexity of user behavior data continue to increase [13]. More and more users are conducting various activities through the Internet and mobile devices, such as browsing the web, using mobile applications, online shopping, etc. The amount of data generated by these activities is huge and complex. Traditional data analysis normally cannot deal with large-scale and complicated data, which needs the visualization of user behavior to better understand and analyze the data [14]. As a powerful analysis tool, user behavior visualization will play an increasingly important role in future development. Through user behavior visualization, analysts can more intuitively observe patterns and trends in the data, thereby discovering potential business opportunities. For example, by analyzing the behavior data of users shopping online, they can discover users' shopping preferences and habits, provide personalized recommendation services for e-commerce platforms, and improve user satisfaction and purchase conversion rates. In addition, the visualization tools can be more dimensional by applying and combining different categories into one piece so that the company can make the comparison and find the clue. Currently, there is an exploratory visual analysis by using Tableau, and PowerBI to compare different data and dimensions to find clear analysis goals of user behavior. This analysis method could be used in combining multiple dimensions to analyze user behavior with a clearer goal.

7. Conclusion

To sum up, user behavior visualization is a powerful tool that can help analysts better understand user behavior data. However, current research mainly focuses on processes and frameworks for applying user behavior data into visualization tools and its benefits for business development, and few studies discuss possible solutions to current visualization limitations in user behavior analysis. With the popularity of the Internet and mobile devices, the scale and complexity of user behavior data will continue to increase. User behavior visualization will become an important tool for analyzing these data, helping to explore potential business opportunities and improve the efficiency of data analysis. Therefore, we have reviewed on visualization of user behavior by introducing the background and the definition of user behavior, the current procedure of user behavior visualization, the limitations of the current techniques, and the potential solutions such as introducing deep learning, machine learning, and so on. Lastly, we discussed future development. We believe that as the volume and size of data continue to increase, visualization tools need to continue to evolve in diversity and data processing speed.

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