A Knowledge-based Framework for Developing Smart Interfaces for Smart Service Systems

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Abstract: Nowadays, smart service systems are value co-creating configurations of people, technologies, organisations, and information that are capable of in-dependent learning, adaptation, and decision-making. They are propelled by unprecedented advancements in connectivity, sensors, data storage, computation, and artificial intelligence. One of the key challenges faced by those systems is how to provide smart interfaces, which can assist business users with limited knowledge in business analytics in gaining business insights from business data. For this reason, this paper proposes a knowledge-based framework for developing smart interfaces for smart service systems, which will assist business users in exploring business data to gain business in-sights and subsequently make better business decisions to promote value co-creation. A prototype with simulation data has been developed and presented as a running example to illustrate how the proposed framework can be applied to create an effective smart interface for a typical smart service system: a customer intelligence system.

Keywords: *Smart interface design, smart service systems, customer intelligent systems, service-oriented approach.*

Tiêu đề: **Khung hỗ trợ dựa trên tri thức cho phép triển khai giao diện thông minh cho các hệ thống dịch vụ thông minh**

Tóm tắt: Hiện nay, các hệ thống dịch vụ thông minh nhằm tạo ra giá trị kinh tế bằng cách kết hợp con người, công nghệ, tổ chức và thông tin, có khả năng học, thích ứng và ra quyết định độc lập. Chúng được thúc đẩy bởi sự tiến bộ chưa từng có trong kết nối, cảm biến, lưu trữ dữ liệu, tính toán và trí tuệ nhân tạo. Một trong những thách thức quan trọng mà các hệ thống này đối mặt là cung cấp giao diện thông minh, giúp nhân sự trong các tổ chức doanh nghiệp có thể khai thác trí tuệ kinh doanh một cách phù hợp với vai trò và yêu cầu mà không cần hiểu biết quá sâu về kỹ thuật và các công nghệ. Vì lý do này, bài báo này đề xuất một khung hỗ trợ để phát triển giao diện người dùng thông minh cho các hệ thống dịch vụ thông minh, giúp người dùng kinh doanh khám phá dữ liệu kinh doanh để nhận thức thông tin kinh doanh và sau đó đưa ra quyết định kinh doanh tốt hơn để thúc đẩy sự tạo giá trị chung. Khung hỗ trợ sẽ cung cấp một kiến trúc tổng quát định nghĩa các thành phần thiết yếu của một hệ thống dịch vụ thông minh có hỗ trợ giao diện thông minh. Kiến trúc này bao gồm một số thành phần hệ thống đã được xây dựng sẵn và thuật toán dự đoán thành phần nào của giao diện phù hợp nhất với thông tin người dùng. Việc cung cấp các thành phần sẵn có này giúp các doanh nghiệp có thể tái sử dụng để triển khai giải pháp giao diện thông minh của chính họ với chi phí thấp nhất. Khung hỗ trợ cũng đã được tích hợp vào một hệ thống dịch vụ thông minh có sẵn nhằm minh hoạ khả năng có thể đưa vào sử dụng trong thực tế của khung hỗ trợ.

Từ khóa: *Thiết kế giao diện thông minh, hệ thống dịch vụ thông minh, hệ thống trí tuệ khách hàng, hướng tiếp cận hướng dịch vụ.*

I. INTRODUCTION

Nowadays, smart service systems are value co-creating configurations of people, technologies, organizations, and information that are capable of independent learning, adaptation, and decision-making. They are propelled by unprecedented advancements in connectivity, sensors, data storage, computation, and artificial intelligence [1–3].

One of the key challenges faced by those systems is how to provide smart interfaces, which can assist business users with limited knowledge in business analytics in gaining business insights from business data. The term “smart interface” or “intelligent interface” refers to both the design of user interfaces for smart systems and the design of user interfaces, which utilizes intelligent approaches [4].

For this reason, this paper addressed this challenge by proposing a knowledge-based framework for developing smart interfaces for smart service systems. Smart interfaces will assist business users with a limited knowledge in business analytics in exploring business data to gain business insights and subsequently make better business decisions to promote value co-creation. Furthermore, a prototype with simulation data has been developed and presented as a running example to illustrate how the proposed framework can be applied to create an effective smart interface for a typical smart service system: a customer intelligence system.

The rest of the paper will be structured as follows. The **Theoretical Background** section introduces fundamental concepts of customer intelligent systems and smart user interfaces. The **Research Motivation** section provides an explanation for the rationale behind this paper. The **Related Work** section provides an overview of previous research conducted in the domain of smart interfaces. The **Methodology** section outlines the processes and principles employed to conduct this study. The **Framework** section describes the knowledge-based framework for the design of smart interfaces for smart service systems, including the data, information, and knowledge modules. The evaluation activities of the proposed approach is presented in the **Validation** section, which is based on a running example extracted from a specific case of an effective smart interface for a customer intelligence system, which is as a typical and popular smart service system. Finally, the **Conclusion** section will summarize the contributions of the paper and outline potential directions for future research.

II. THEORETICAL BACKGROUND

1. Smart Service System

A smart service system (SSS) is a service system that can learn, adapt dynamically, and make decisions depending on information it receives, transmits, or processes to better handle a scenario in the future [1, 2]. An example of a smart service system is one that has smart devices installed to help people recognize, learn from, adapt to, monitor, and make decisions [3]. The area of smart service systems is indeed a multi-disciplinary research field that encompasses various disciplines, making it difficult to provide a comprehensive definition [1]. From the service-oriented and data-application perspective, a smart service system can be defined as a system that leverages data analytics and user interaction to assist business users in gaining valuable insights and then optimizing their service offerings [5].

In particular, customer intelligent systems (CIS) are a type of smart service systems that focus on gathering, processing, and analyzing large volumes of customer data (e.g., customer behaviors, preferences, profiles). Customers are a gold mine for valuable information and can aid in developing important business strategies [6]. By employing customer analytics, a CIS provides business users with precious insights related to their customers' needs and behaviors, that can aid them in improving customer satisfaction, increasing revenue, and achieving sustainable long-term growth.

2. Smart User Interface

Smart user interfaces (SUI), a sub-field of Human-Computer Interaction (HCI), focus on enhancing interaction between end-users and systems by proposing interface elements, along with relevant information to end-users intelligently [7]. Unlike traditional HCI, which focuses mainly on how to design interfaces to facilitate user actions, SUIs go further by assisting users in performing actions with incorporated knowledge.

SUIs not only enable users to perform "smart" actions but also facilitate intelligent and fashionable interaction between humans and computers by dealing with various input and output mechanisms. SUIs employ a variety of techniques and technologies, including machine learning, natural language processing, computer vision, and robotics, to create intelligent interfaces that can adapt to the user's needs and preferences. These interfaces can be found in various applications, including mobile devices, smart homes, wearable devices, and virtual and augmented reality environments.

III. RESEARCH MOTIVATION

The paper aims at proposing a knowledge-based framework for the design and implementation of smart interfaces for SSS that will assist business users with limited knowledge in business analytics in exploring business data to gain business insights to make better business decisions.

Studies about human-centered service systems are rapidly emerging as a highly promising approach for transforming service systems into smart service systems. A smart service system can act on data analysis results to develop insights related to human behaviors to support the actions of smart service systems [1]. Smart user interfaces (SUIs) aim at facilitating intelligent interaction between humans and computers [7]. Through the use of a variety of intelligent techniques and technologies, including machine learning, natural language processing, computer vision, and robotics. Consequent, smart interfaces can be created to adapt to the user's needs and preferences that can be found in various applications such as mobile devices [8, 9] and smart homes [10].

The topic of smart service systems and smart user interfaces has emerged in their respective domain in recent years. However, a unified approach that takes into account smart interfaces from the perspective of smart service systems is still lacking. In fact, a smart interface can assist business users in gaining business insights from business data to make better decisions and improve the service experience to promote value co-creation [1]. However, in an enterprise, business users in different roles may require varying levels of knowledge, as well as typical manners of knowledge consumption. A general interface might not be able to satisfy all the needs of different user roles. In addition, the emergence of big data has created both opportunities and challenges for exploring business data from large data sources [11, 12]. For instance, big data is a great source for promoting different types of customer intelligence, such as customer segmentation based on their characteristics, customer journey discovery, product/service recommendation, or customer value calculation [13, 14]. On the other hand, information overload may make it difficult for business users to benefit from smart service systems.

To respond to this issue, smart interfaces should be designed in such a way that they can learn about the context of a business user (e.g., needs, profiles, behaviors), and then present the user with appropriate interface elements and pertinent information to facilitate their decision-making process.

Consequently, this paper focuses on analyzing and then proposing a knowledge-based framework for answering the following research question:

"How to design and implement a smart user interface for a smart service system?".

IV. RELATED WORK

Various studies have explored the design and the implementation of intelligent user interfaces, while others emphasize the critical role that smart user interfaces plays in the success of business intelligence and recommendation systems [15]. The next paragraphs provide an overview of earlier studies done in the field of smart interfaces.

For example, there is a study that aimed to improve customer satisfaction through optimizing the user interface [16]. The study has developed a conceptual model that enables the classification of different levels of the user interface design in the field of business analytics (e.g., Visual Friendly UI for basic users, Advanced UI for experienced users, and Professional UI for pro-users).

Another study addressed the challenges of smart user interface design based on an analysis of the characteristics of users and their emotional state [17]. The system will create user groups with appropriate interface design based on this analysis.

Thus, a study based on a rule-based adaptation mechanism is proposed for the educational sector [18]. By using rules, it is possible to identify user interface components and educational content that are tailored to the individual needs of learners.

Finally, the SitAdapt system was presented that enables context-aware adaptations of the user interface during design and runtime [19]. The system is currently operational in the domains of e-business and travel and incorporates a variety of situation patterns to facilitate the adaptation process.

Although numerous studies have acknowledged the importance of smart user interfaces and focused on the smart interface design and implementation, none has yet proposed a comprehensive framework for developing such interfaces for a smart service system in the context of business analytics. Based on the knowledge-based perspective [2, 20], the proposed framework is one of the first that aims at assisting business users with limited knowledge in business analytics to transform business data into business information and explore that information to gain business insights.

V. METHODOLOGY

The exploratory research methodology is used to conduct the study (see Figure 1).

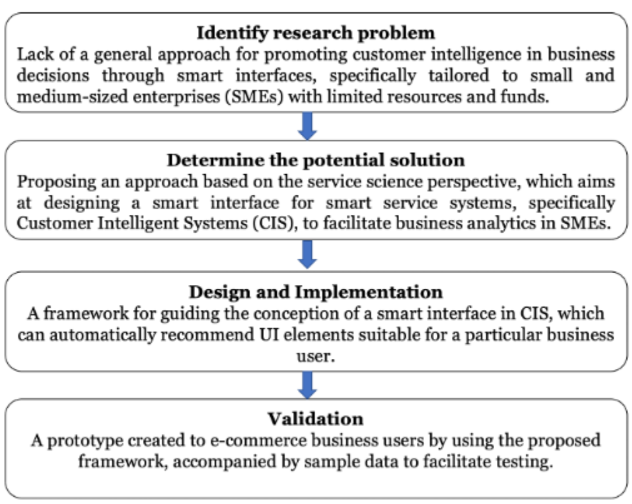

Figure 1. Adopted Methodology

The methodology includes a literature review to identify the research problem and determine the potential solution, experimentation to design and implement the proposed smart interface, and a validation to evaluate the proposed approach [21]. To demonstrate the design and implementation of the proposed framework, a running example extracted from a specific case of an effective smart interface for a typical smart service system: a customer intelligence system will be presented accordingly in the rest of the paper. Indeed, customer intelligence systems have been selected because those systems can help business users, especially marketers, to acquire knowledge and skills from big data through customer analytics and then apply them to the process of creating, communicating, delivering, and co-creating to promote customer intelligence [14].

VI. A KNOWLEDGE-BASED FRAMEWORK FOR SMART INTERFACE

This section presents a comprehensive knowledge-based framework for developing smart interfaces for smart service systems that considers the specific needs and preferences of business users, including essential elements of the framework. It can serve as a guide for the conception and implementation of future SSS projects that promote smart user interfaces. The overall architecture of the framework comprises a front-end layer, a backhand layer, and data sources (see Figure 2).

The **front end layer** serves as the interface between users and the SSS and is responsible for visualizing UI elements. In the fronted layer, the elements such as dash-boards, reports, or charts are designed and presented interactively to provide an intuitive user experience in order to be adaptable to a particular business user profile.

The **back end layer** handles data management, analytics, as well as UI recommendations. To structure the elements of the back end layer, the study has drawn inspiration from the DIKW model [20] and organized these elements hierarchically into three levels: Data management, Information management, and Knowledge management. The back end layer is the core of the framework and will be presented in more detail in the next paragraphs.

Concerning the **data sources**, the back end layer gathers, organizes, and conducts analytics on business data from a variety of data sources, including websites, enter-prise databases, and even the internet. For instance, related to customer intelligence systems, the collected data can be categorized into two types: customer data and business user data. The former contains information about customer's demographic, transactions, or customer interactions, which is examined to produce business insights. The latter, on the other hand, comprises business user profiles and business user history data, which is utilized to recommend UI elements.

In summary, the back end layer is designed in a manner that enables the smooth transition of data, information, and knowledge between different modules of the system. The primary focus of this paper is to utilize (business) user data to create intelligent user interfaces. Analyzing business data is beyond the scope of this paper and will not be explored. More information about the suggested architecture is shown in Figure 2, whereas the next subsections present the architecture in more detail.

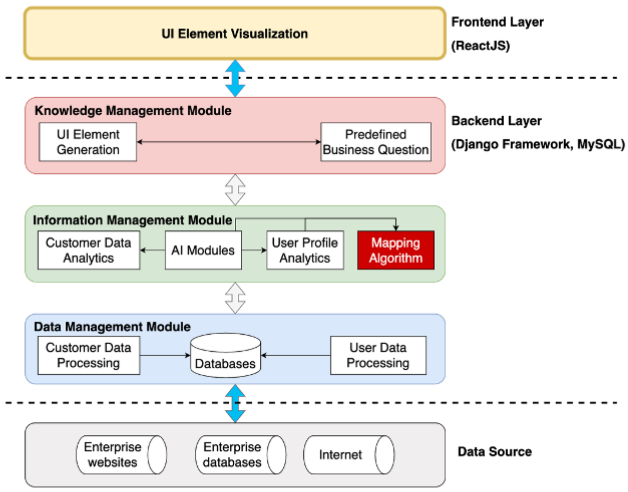

Figure 2. General architecture of the proposed framework

1. Data Management Module

The Data management module is composed of two key elements for the collection, processing, and transfer of customer data (**Customer data processing**) and business user data (**User data processing**) into the systems' databases. To structure the data, a tabular-based organization is used, which is suitable for the mapping algorithm in the superior layer. For UI element generation, (business) user profile and history are considered in this project. On one hand, user profiles describe specific characteristics of users, including their gender, location, level of management, industry, and any pertinent business questions or reports. These profiles are utilized to customize user interfaces based on characteristics. On the other hand, the user history comprises details about the user's previous interactions, preferences, and behavior over time. By tracking user history and analyzing previous behavior data, it is possible to enhance recommendations for UI elements, improving the user's experience.

2. Information Management Module

The Information management module consists of four elements, including artificial intelligence (AI) modules, Business data analytics, User profile analytics, and Mapping algorithm.

Firstly, the **AI modules** are pre-programmed with data mining and machine learning techniques such as linear regression, K-nearest neighbors (KNN), random forest, decision tree, and LightGBM, which are employed to discover relationships among data. Secondly, in the **customer data analytics**, AI modules are used for grouping similar customers, recommending products, and predicting profitable products/customers (a summary of those use cases can be found in [14]). Thirdly, in the user profile analytics, recommendation techniques, such as collaborative filtering, are applied to analyze the profiles and historical data of business users. These techniques are used to predict the most suitable user interface (UI) elements for a particular user profile.

Finally, the **mapping algorithm** is the key element for smart user interface recommendations. The algorithm receives a business user's profile specifying role (e.g., managers, staffs), domain (e.g., IT, marketing), and fields of interests (e.g., customer engagement and social media) as input data (see Figure 4)). Following that, the algorithm is used to calculate scores for UI elements based on each user's profile. These scores are used to identify the most suitable UI elements for a specific business user. The interaction between business users and UI elements is also collected each time they perform an action on a UI element to improve the scores. The output data of the algorithms consists of a collection of the most suitable UI elements, along with relevant data.

The mapping algorithm consists of the following main steps (see Figure 3):

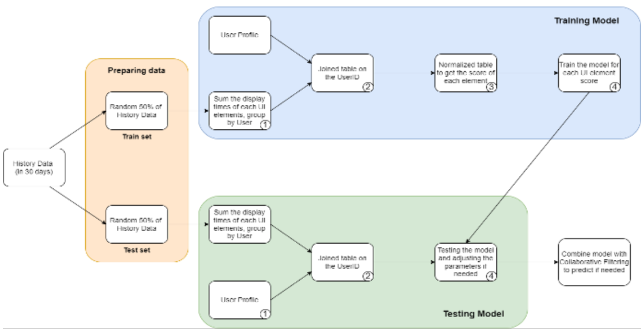

Figure 3. Mapping algorithm

- Firstly, the most recent data from the databases is extracted. In this study, data will be collected from the previous 30 days. This data was then divided into training (50%) and test datasets (50%) randomly to train and evaluate our model.
- In the next step, the usage frequency of each UI element for every user is summarized. This data will be combined with the user profiles through a jointure process, resulting in a complete dataset for analysis.
- The number of occurrences of each UI element for a specific user will be normalized before being sent to the training model.
- Several training models based on machine learning techniques, such as KNN, Random Forest, can be used to predict the score of each UI element for a new user profile.
- The last step (optional) based using the collaborative filtering algorithm (i.e., a very popular technique used to recommend similar products according to behaviors of similar users) can be performed to improve the accuracy of predicted scores.

3. Knowledge Management Module

The Knowledge Management module comprises two key components: UI element generation and a **predefined set of business questions**, which is a collaborative result of Dimalab, Canada, as proposed in 2022 (see Table I).

Table I
LINKING OF BUSINESS QUESTIONS,
UI ELEMENTS, AND PERTINENT DATA

Business questions	UI Elements	Pertinent Data
Which products can be sold together?	Top Products, Highlighted Products, Best Sales	productName, productDescription, productCategory
Which customers have relations to others?	Referred Customers, Best Referrals	visitNumber, sessionId, visitorId
Who are the most profitable customers?	Revenue from Top Customers	transactionRevenue, productId, customerId
How the website traffics?	Line chart of website traffics	visit, timeOnSite, hits, screenView, uniqueScreenViews
How attraction of website to new customers? What is the turn-back rate?	Bar chart of new user creation and visit back	lastVisitDate, createdAt
Where do visitors come from?	Pie chart of sources of the visitors	trafficSources

UI element generation utilizes the results of the mapping algorithm (scores as-signed to UI elements for each user) in the Information management module to generate a smart user interface consisting of the recommended UI elements. The generated interface includes relevant data, which is sent to the front end layer for visualization when the user logs into the system. The recommended UI elements will be arranged according to the scores assigned to each element. For example, the highest-scoring UI element will be displayed at the top of the page, indicating its importance and relevance. Returning to the running example about customer intelligence systems, *"What is the most profitable customers"* could be addressed through a bar chart associated with revenue from customers. Table 1 presents the relationships between predefined business queries, user interface (UI) components, and pertinent data.

VII. VALIDATION

The proposed approach was implemented and validated by developing the smart interface prototype for an open-source customer intelligence system for small and medium enterprises (SMEs), along with some sample datasets for testing the prototype. In-deed, business users in SMEs have a limited knowledge and expertise in information technology in general and business analytics, in particular [14] that are a real-world situation for validation of the framework.

In terms of tools and technologies for developing this test prototype, Django framework (www.djangoproject.com), which is a very well-known and powerful plat-form for data analytics and machine learning algorithms is selected for the back end. Furthermore, MySQL (www.mysql.com), which is a highly suitable database for storing a moderate amount of data for this test prototype is also selected for the back end layer implementation. Concerning the front end layer, ReactJS (reactjs.org) was selected because of its robust capabilities in creating dynamic and engaging interfaces.

A possible testing scenario could be outlined as follows:

1) A business user A creates a new account and provides their profile information (see Figure 4).
2) The mapping algorithm allows assigning a score to each UI element, such as the top product bar chart or website traffic line chart, based on the similarity of user A's profile data to existing data associated with those elements.
3) A predefined threshold value is used to determine which UI elements are suitable for the user A based on the UI element's score.
4) If a UI element has a score greater than the threshold value, it is considered suitable and will be automatically recommended to the user whenever they log in to the system (see Figure 5).
5) User A's interaction with UI elements is also used as feedback, which is stored in the history data to recalculate UI element scores. This will help improve the accuracy of the mapping algorithm over time.

Figure 4 depicts a piece of user profile data, including business roles (e.g., director, manager, staff), demographics (e.g., gender, location), and other relevant information, while Figure 5 expresses the UI elements that are dynamically generated based on the profile of User A.

user_id	gender	location	domain	seniority	interested_field_market_and_product	interested_field_business_and_revenue	interested_field_target_marketing	interested_field_positioning_and_differentation	interested_field_customer_engage_and_social_media
1	Male	RE	Industrial Ma	staff	0	0	1	1	0
2	Female	TH	n/a	manager	0	1	0	0	1
3	Male	CN	Auto Parts:O	staff	0	1	1	1	0
4	Male	JP	Auto Parts:O	manager	1	0	1	0	0
5	Female	CN	Semiconduct	director	0	1	1	1	1
6	Male	CN	Major Pharm	leader	0	0	0	1	0

Figure 4. User profile data sample

For example, tabular representations can list top products, while charts (bar charts, pie charts, and line charts) can illustrate website traffic (see Figure 5). The generated UI elements, reconfigured with relevant data, assist business users in obtaining valuable insights. This, in turn, can help them answer critical business questions, such as *"What are the most profitable products? How does the website traffic? Or where are visitors coming from? etc."*.

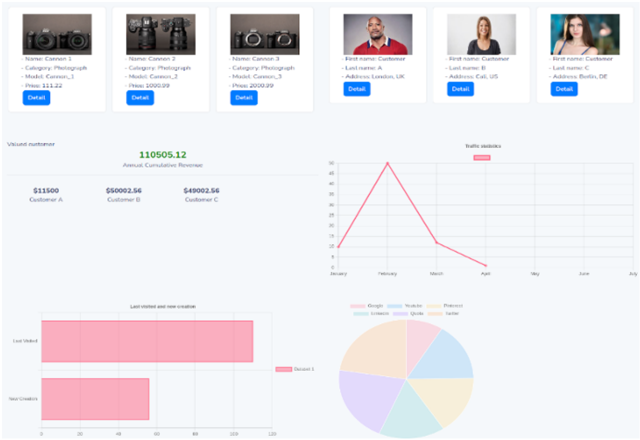

Figure 5. Example of UI elements generated for a manager

Table 2 provides a brief comparison of our framework to other relevant studies in the literature. Each paper will be evaluated based on 5 units of analysis (UA), or aspects to be investigated: *Data Management (UA1), Information Management (UA2), Knowledge Management (UA3), Transition between Data, Information, & Knowledge (UA4), and Integration into CIS (UA5)*. As shown in the table, our proposed framework covers all critical phases of data, information, and knowledge management, from initial handling to final integration into a CIS system. Furthermore, our framework places a strong emphasis on facilitating the smooth transition of data, information, and knowledge. This integration improves the framework's ability to function effectively in a variety of technological environments. SMEs can optimize and reuse the framework to create or integrate a new one into their existing system at a low cost.

Table II
COMPARISON TABLE

Paper	UA1	UA2	UA3	UA4	UA5
[16]	x	x			
[17]	x	x			
[18]	x	x			
[22]	x	x		x	
[23]	x	x			
This study	x	x	x	x	

VIII. CONCLUSION

The topics of smart user interfaces have been investigated in the field of human-computer interface (HCI) for many years. However, there has been limited research exploring smart interfaces from the perspective of smart service systems. This study is among the first to combine the principles of smart service systems and user inter-face design to create an interface that is user-friendly, intuitive, and customized to the specific needs of business users.

In terms of implication, by integrating these domains, the study aims at developing an interface that can effectively analyze business data, present it in a meaningful way, and provide insights to enhance the productivity and performance of business users, leading to improved business outcomes.

Since business users of those systems usually have limited capacity to use analytics tools, a smart interface is critical to provide an opportunity for business users with limited knowledge and experience to adopt analytics tools, which may help them to maintain the company's competitive position and generate positive results with minimal costs and efforts. In addition, the prototype implementation provided a practical example of how the suggested approach can be utilized to create an effective smart user interface for customer intelligence systems, which is a typical and popular smart service system.

In terms of future work, there are various potential research areas that can be explored to continue the study. Firstly, the algorithm used in the system is only suitable for a small amount of data, and it may require significant effort to process data when user data grows fast. Secondly, the current prototype is primarily concerned with recommending UI elements, but interesting future research could explore recommending data elements that align with the needs of specific business users. Finally, exploring the business aspects of smart interfaces to demonstrate how smart inter-faces can address specific business questions should be also a priority for future work.

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