

Translating text to SQL-Queries ensuring a privacy preserving AI

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Typically, when a user interacts with a website, such as searching for an item or filtering the search results, a SQL template is used for which the user input gets added. By using an AI that translates natural language into SQL queries, the initial search results based on the keywords passed will most likely be tailored to the user's wishes, providing better search results initially without the need to interact with filters. To ensure regulatory compliance, such as not being able to use passwords as a search criterion, we assert a privacy preserving AI that can easily be integrated into an existing code/database.

CCS Concepts: • **Human-centered computing** → *Web-based interaction*; Interaction design theory, concepts and paradigms.

Additional Key Words and Phrases: AI, Seq2Seq, SQL, UI, UX, Filters, Search, Transfer Learning, NLP

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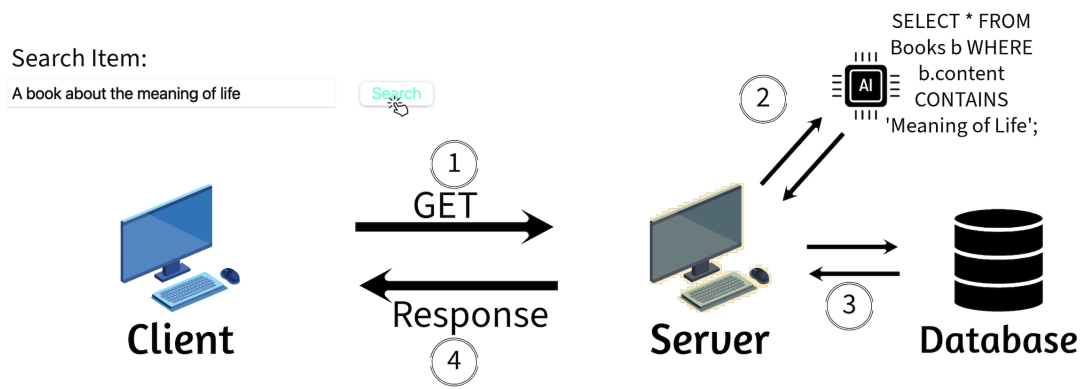


Fig. 1. Highlighting the interaction paradigm of the user with an AI. Instead of traditionally passing the users input to a static SQL-Template, it is passed to an AI-System that interpretes the users search request and dynamically generates a SQL-Query . The resulting query is then executed and displayed for the user in the Interface.

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1 Introduction

Online shopping platforms like Amazon and eBay have become the go-to sources for a vast range of products. However, users often face difficulties when searching for specific items, especially products with more complex or technical specifications, such as electronic devices, computer components, or specialized tools. These challenges can lead to frustration and even cause users to switch platforms in search of a better experience. The root of these difficulties lies in the individuality of search behavior, which varies between users. Some rely on generic search terms, such as "laptop," while others prefer highly specific queries, like "Dell XPS 15 9530 with Intel Core i7 and 32GB RAM." Our study found that search behavior is roughly evenly divided between these two approaches, making it essential for e-commerce platforms to optimize their search functionalities to accommodate diverse user needs. At the same time, this presents a challenge, as creating a platform that satisfies all users equally is difficult. In addition to search queries, filtering options play a crucial role in the online shopping experience. Filters help users refine their results based on criteria such as price, size, brand, technical specifications, or customer ratings. However, ineffective or overly complex filtering systems can hinder rather than enhance the search process. If filters do not align with user expectations, are difficult to use, or fail to narrow down results efficiently, users may become frustrated and abandon their search. Therefore, improving search functionalities is essential to enhance user experience, increase customer satisfaction, and ensure platform loyalty. Building upon these challenges, we propose an alternative approach to traditional search mechanisms. Instead of relying on predefined SQL templates, we suggest dynamically generating SQL queries using machine learning techniques. By leveraging AI to generate queries in real time, the system can automatically interpret the user's intent based on their input, providing more precise and relevant search results initially. If the AI performs at a high level, this approach could eventually eliminate the need for manual filtering mechanisms, as the AI would inherently incorporate these preferences into the generated query. This shift could significantly enhance human-computer interaction, making the search process more intuitive, efficient, and user-centric. To determine whether such a scenario is truly possible and to understand how users would interact with this approach, we conducted a study. To carry out this study, we implemented a prototype interface to evaluate user behavior and gather insights on the effectiveness of dynamically generated queries in direct comparison to traditional static templates.

1.1 old

In order for a user to interact with a website, an interactive element such as an input text is typically provided. Many of these input text-elements work by having a predefined SQL-Query-Template, for which the users input gets concatenated. This query then gets passed to the Database-Management-System (DBMS), which executes it and returns the result. Although this approach seems simple at first, it has some pitfalls which need to be addressed, as it is prone to attacks like SQL-Injections. According to the Open Worldwide Application Security Project (OWASP), which is a non-profit organization that aims to improve the security of software projects, SQL-Injections are still in the Top 10 Security Risks of 2021 and it is likely that they will remain in the Top 10 of 2025, taking into account that they were the number one attack in the Top 10 of 2017 [2].

1.2 Generating SQL-Queries dynamically

Instead of relying on predefined SQL-Templates, we would like to propose the idea of generating SQL-Queries dynamically using Machine-Learning-Techniques.

By generating SQL-Queries dynamically, the users wishes provided in the input text can be taken into account by the

AI automatically, providing more specific search results initially. Given that the AI performs well enough, this could lead to future websites dropping filtering mechanisms entirely, such as filtering by specific brands or other features, as the AI would reflect the users wishes automatically in the generated Query, further enhancing the Human-Computer Interaction. This new kind of interaction is highlighted in Fig. 1.

1.3 Why a privacy-preserving AI is necessary

Although the idea of generating SQL-Queries automatically sounds intriguing, there are some practical challenges that have to be taken into account, when deploying the AI into a software project. Under the assumption that the AI performs well and that it is unrestrained, nothing would prevent the user from requesting search results from the AI, that contain confidential information like passwords, email-addresses or other criteria, which poses a similar threat that are resembled by SQL-Injections. Arguably, this would make the threat of SQL like Injections even worse, as users with no technical background are now able to query for confidential data as well. To mitigate that issue, we enforce a privacy-preserving AI, with the goal to never output SQL-queries that could disclose confidential data.

1.4 Gathering Data

TODO

2 Background

The objective of this initiative is to enhance the effectiveness of the search function on websites, with a particular focus on enhancing the performance of the input box. As outlined in [3], 69% of users initiate a search for products directly via the search bar. However, 80% of these users subsequently depart from the webpage due to unsatisfactory experiences with the search functionality. In this study, 41% of respondents expressed frustration regarding the display of irrelevant content. A further issue that was identified as a point of frustration for 32% of users was the presentation of products that were no longer available. A further issue that 26% of users encounter with contemporary search systems on websites is the inability of these systems to accurately interpret user queries. To illustrate, when one seeks to procure a dresser and inaccurately enters "closet" as the search term, the websites encounter difficulties in locating the desired item.

A total of 69% of users have confirmed that they encounter irrelevant search results, and of those, 35% have indicated that this behavior prompts them to leave the webpage. A further 27% of users have confirmed that they have abandoned webpages due to the inability to restrict their searches. An additional 26% have done so due to out-of-stock status. A further notable issue is the absence of error tolerance in current websites, which results in the failure to display outcomes in instances of typographical inaccuracy.

2.1 Translation difficulties between text and SQL(A)

Achieving an accurate interpretation of the user's intent in the context of translating text into SQL poses a considerable challenge. This is due to the fact that some words could be ambiguous or the user might use synonyms. The system should also demonstrate fault-tolerance capabilities, as it is expected to generate a query in the event of typing errors. As previously stated in [1], it is imperative to exercise caution to ensure that the system does not generate erroneous queries. Otherwise, there is a risk of diminishing user trust in the website. As elaborated upon in [1], users demonstrate a reluctance to trade a user interface that is characterised by reliability and predictability for an intelligent system that is deemed unreliable.

2.2 Privacy concerns(A)

Furthermore, it must be considered that non-technical users can also exploit the system by requesting private data. This scenario poses significant privacy concerns, given that the users can bypass any need to understand SQL, and instead simply request the data they desire from the LLM. In such systems, the implementation of measures designed to restrict access to data is essential for ensuring the security of private data. According to the Open Worldwide Application Security Project (OWASP), which is a non-profit organization that aims to improve the security of software projects, SQL-Injections are still in the Top 10 Security Risks of 2021 and it is likely that they will remain in the Top 10 of 2025, taking into account that they were the number one attack in the Top 10 of 2017 [2].

2.3 Problem with existing text-to-sql(A)

The rule-based method for generating SQL queries was presented in the paper [1]. However, several issues were identified in the course of this approach, which were addressed to a limited extent. As previously mentioned, the system is confronted with ambiguous words. In [1], the recommendation was made to present the user with all possible variants that can be derived from the multi-word term. This enables the user to make an informed decision, ensuring an appropriate interpretation of their intention. A further challenge arises when a word is not present in the lexicon, as no query is generated in this instance. In such a scenario, it is imperative for the user to reformulate their query in a manner that is comprehensible to the system. However, this approach introduces a significant disadvantage, as the preliminary query may be processed by the system, but its execution is precluded due to the system's limited capabilities. The maintenance of synonyms poses a considerable challenge, as it is necessary to provide potential users with the opportunity to consult them. Consequently, a continuous adaptation of the system is required to ensure the quality of the results of the searches. As demonstrated in [1], a further issue is the considerable duration of user inquiry processing. In this study, a processing duration of six seconds was observed, which is regarded as relatively extensive when compared to the duration of a search in a web-based store. Nonetheless, a pivotal element was absent from the previously mentioned papers: the context of the values stored in the database. To illustrate, supplementary information becomes pertinent when storing the age of dogs. This necessity arises from the potential for storing the age of dogs in either months or years. Depending on the specific context, additional rules may be in place that must be taken into consideration.

Text-to-SQL systems that leverage LLMs have been developed; a notable example is SQLAI.AI¹. Despite its development for developers, SQLAI.AI is not suitable for practical application.

3 Methods

A user study was conducted to address the following research questions:

- RQ1: What characterizes typical natural language user queries to SQL systems?
- RQ2: What are the factors that influence the mismatch between user intent and displayed search results?
- RQ3: How do users prefer to fix SQL queries when they don't match their intentions?
- RQ4: What are effective ways to communicate system limitations and capabilities to users?
- RQ5: What mechanisms most influence user satisfaction with search results?
- RQ6: What are the potential drawbacks of deploying such a system in a real-world environment?
- RQ7: How necessary are filters when an intelligent system is involved?

¹<https://www.sqlai.ai/>

The optimization of SQL queries can be achieved through various methods. One such approach entails enhancing the initial query. However, this approach may present a challenge, as it requires that the user comprehend the erroneous interpretation of the query. To optimize the request, it is first necessary to develop a more profound comprehension of the underlying system. In this regard, the method for enhancing the user experience proposed in [1] may be applicable. This method enables the user to select from among various options (RQ3).

One of the objectives of the present study is to ascertain whether users find conventional search results satisfactory or whether they perceive the system with artificial intelligence as more advantageous. We hypothesize that users will evaluate the system employing artificial intelligence more effectively than they would a conventional system. The reason for this is that users will have more ease of use when filtering content, as opposed to the more difficult experience they face when using a conventional system(RQ5).

The hypothesis that was formulated posits that filters are only required when the system fails to comprehend the user's intention. It is hypothesized that both procedures will be utilized, as the prevailing Webshop practice involves the employment of filters, which is likely to be reflected in the user study (RQ7).

3.1 Participants

In the course of the user study, a group of 13 subjects was examined. The subjects included 12 males and one female. The majority of the subjects are currently enrolled in a Bachelor's or Master's program in Informatics. The majority of the subjects had prior experience with artificial intelligence. The subjects were aware of the objective of the study, which was to evaluate the performance of the AI system in comparison to conventional systems. The objective of the present study was to ascertain whether the artificial intelligence (AI) system is capable of producing superior results in the context of searching for products.

4 Results

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dolor. Nullam bibendum, turpis vitae tristisque gravida, quam sapien tempor lectus, quis pretium tellus purus ac quam. Nulla facilisi.

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Donec vel nibh ut felis consecetur laoreet. Donec pede. Sed id quam id wisi laoreet suscipit. Nulla lectus dolor, aliquam ac, fringilla eget, mollis ut, orci. In pellentesque justo in ligula. Maecenas turpis. Donec eleifend leo at felis tincidunt consequat. Aenean turpis metus, malesuada sed, condimentum sit amet, auctor a, wisi. Pellentesque sapien elit, bibendum ac, posuere et, congue eu, felis. Vestibulum mattis libero quis metus scelerisque ultrices. Sed purus.

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Cras dapibus, augue quis scelerisque ultricies, felis dolor placerat sem, id porta velit odio eu elit. Aenean interdum nibh sed wisi. Praesent sollicitudin vulputate dui. Praesent iaculis viverra augue. Quisque in libero. Aenean gravida lorem vitae sem ullamcorper cursus. Nunc adipiscing rutrum ante. Nunc ipsum massa, faucibus sit amet, viverra vel, elementum semper, orci. Cras eros sem, vulputate et, tincidunt id, ultrices eget, magna. Nulla varius ornare odio. Donec accumsan mauris sit amet augue. Sed ligula lacus, laoreet non, aliquam sit amet, iaculis tempor, lorem. Suspendisse eros. Nam porta, leo sed congue tempor, felis est ultrices eros, id mattis velit felis non metus. Curabitur vitae elit non mauris varius pretium. Aenean lacus sem, tincidunt ut, consequat quis, porta vitae, turpis. Nullam laoreet fermentum urna. Proin iaculis lectus.

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Sed consequat tellus et tortor. Ut tempor laoreet quam. Nullam id wisi a libero tristisque semper. Nullam nisl massa, rutrum ut, egestas semper, mollis id, leo. Nulla ac massa eu risus blandit mattis. Mauris ut nunc. In hac habitasse platea dictumst. Aliquam eget tortor. Quisque dapibus pede in erat. Nunc enim. In dui nulla, commodo at, consecetur nec, malesuada nec, elit. Aliquam ornare tellus eu urna. Sed nec metus. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Pellentesque habitant morbi tristisque senectus et netus et malesuada fames ac turpis egestas.

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Nullam eleifend justo in nisl. In hac habitasse platea dictumst. Morbi nonummy. Aliquam ut felis. In velit leo, dictum vitae, posuere id, vulputate nec, ante. Maecenas vitae pede nec dui dignissim suscipit. Morbi magna. Vestibulum id purus eget velit laoreet laoreet. Praesent sed leo vel nibh convallis blandit. Ut rutrum. Donec nibh. Donec interdum. Fusce sed pede sit amet elit rhoncus ultrices. Nullam at enim vitae pede vehicula iaculis.

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Nulla malesuada risus ut urna. Aenean pretium velit sit amet metus. Duis iaculis. In hac habitasse platea dictumst. Nullam molestie turpis eget nisl. Duis a massa id pede dapibus ultricies. Sed eu leo. In at mauris sit amet tortor bibendum varius. Phasellus justo risus, posuere in, sagittis ac, varius vel, tortor. Quisque id enim. Phasellus consequat, libero pretium nonummy fringilla, tortor lacus vestibulum nunc, ut rhoncus ligula neque id justo. Nullam accumsan euismod nunc. Proin vitae ipsum ac metus dictum tempus. Nam ut wisi. Quisque tortor felis, interdum ac, sodales a, semper a, sem. Curabitur in velit sit amet dui tristique sodales. Vivamus mauris pede, lacinia eget, pellentesque quis, scelerisque eu, est. Aliquam risus. Quisque bibendum pede eu dolor.

Donec tempus neque vitae est. Aenean egestas odio sed risus ullamcorper ullamcorper. Sed in nulla a tortor tincidunt egestas. Nam sapien tortor, elementum sit amet, aliquam in, porttitor faucibus, enim. Nullam congue suscipit nibh. Quisque convallis. Praesent arcu nibh, vehicula eget, accumsan eu, tincidunt a, nibh. Suspendisse vulputate, tortor quis adipiscing viverra, lacus nibh dignissim tellus, eu suscipit risus ante fringilla diam. Quisque a libero vel pede imperdiet aliquet. Pellentesque nunc nibh, eleifend a, consequat consequat, hendrerit nec, diam. Sed urna. Maecenas laoreet eleifend neque. Vivamus purus odio, eleifend non, iaculis a, ultrices sit amet, urna. Mauris faucibus odio vitae risus. In nisl. Praesent purus. Integer iaculis, sem eu egestas lacinia, lacus pede scelerisque augue, in ullamcorper dolor eros ac lacus. Nunc in libero.

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5 Discussion

5.1 Design Recommendations

5.2 Limitations

6 Conclusions

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