AI Agency in Information Retrieval: Advancing Data Access Through Natural Language Interfaces
(Technical Paper)

Enhancing Global Accessibility and Information Flow: Bridging Language Divides with Natural Language Processing and Deep Learning
(STS Paper)

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

Vietnam faces an ongoing battle against natural disasters, with floods being a leading cause of devastation affecting millions of lives annually (Nguyen et al., 2021). Despite significant advances in machine learning (ML) and artificial intelligence (AI) that have enhanced our predictive capabilities, there exists a glaring disconnect between these solutions and their real-world applications for the average citizen. Addressing this challenge, our team, 'Floodwatch,' has developed an innovative web application designed to bridge this gap. Leveraging flood prediction algorithms, the application features an intuitive interface allowing anyone access to flood prediction information, at any time. My section of the project is focused on making this technology more accessible by adding Natural Language Processing (NLP), attempting to make our platform as user-friendly as popular voice-activated technologies like Amazon's Alexa.

This commitment to accessibility is about more than just user interface design; it's about a comprehensive approach that makes advanced flood predictions not only available but also understandable to everyone. Accessibility, in this context, is multifaceted. It involves designing systems that accommodate the needs of the elderly, who may benefit from simpler navigation, and the youth, who prefer quick and interactive experiences. This is particularly important for the elderly, who have been shown to be less confident and require more guidance with complex user interfaces, as described by Vaportzis et al. (2017). Additionally, it encompasses the creation of inclusive experiences for people with disabilities. This could include the visually impaired, those with motor challenges, or users with limited dexterity.

For example, the research by Suk and Kojima (2008) serves as a notable illustration of a commitment to accessibility. Their work demonstrates the effectiveness of voice-activated appliances in enhancing the independence of people with disabilities, particularly those with severe speech and motor impairments, such as those caused by cerebral palsy. This approach, which involves developing systems responsive to vocal commands, enables these individuals to control various aspects of their environment. In the context of disaster management technology, having control and access to information is crucial, making such innovations especially valuable.

This paper will not only delve into our technological innovations but also consider how the Social Construction of Technology (SCOT) theory applies to our efforts. SCOT suggests that technology is both shaped by and a shaper of the societal context in which it is developed and used. By offering a solution that is both technologically advanced and deeply accessible, we aim to redefine how the public engages with essential, life-saving flood information.

Technical Aspect

At the nexus of this project is the incorporation of Natural Language Processing (NLP) into our existing web application to enable voice-based interactions. This initiative is structured around a four-step technical pipeline: audio streaming, natural language processing, data querying, and data return via a language model. The first phase involves setting up a robust audio streaming interface within the application that can accurately capture user voice inputs even in varying conditions.

After transcribing voice input to text, it's crucial to accurately interpret the user's intent to formulate structured queries for data retrieval. This is where the significance of advanced NLP techniques and models, as discussed in Khan and Meenai (2021), becomes evident.

In their article "Pretrained Natural Language Processing Model for Intent Recognition (BERT-IR)" published in "Human-Centric Intelligent Systems" (Vol. 1(3-4); December 2021), Khan and Meenai explore the effectiveness of the BERT model in intent recognition, achieving an impressive 97.67% accuracy. Their work displays the potential of using pre-trained models like BERT for intent recognition tasks in NLP.

Incorporating advanced models could significantly enhance the NLP stage of the system. While libraries like Spacy provide robust foundational tools for NLP, integrating a pre-trained model like BERT could offer a more nuanced understanding of user intents. This is particularly relevant in complex domains like flood prediction, where the accuracy of intent interpretation directly impacts the relevance and precision of the data retrieved.

Furthermore, optimizing the intent recognition process not only improves the efficiency of data querying but also enhances the overall user experience by ensuring that responses are contextually relevant and accurate. The advanced capabilities of models like BERT, as demonstrated by Khan and Meenai, provide a compelling option for enhancing the interpretative accuracy of NLP systems in real-world applications.

The final step involves packaging the queried data into a coherent, easily understandable response in the returning data with a language model phase. Utilizing language models and Text to Speech (TTS) frameworks, the application will generate a vocal response to answer the user's query. Optimizing this step is crucial to ensure that the data retrieval is efficient and accurate, providing the most relevant information in response to the user's query, and also constructing the data into a digestible format. Research has shown that audio response is crucial to making information easily understandable by a wide range of users (Wood et al., 2017).

This technical venture not only poses challenges in real-time processing and accurate data retrieval but also explores interactive user interfaces in the realm of disaster management, setting a precedent for future innovations in this domain.

STS Topic: Bridging Socio-Technical Gaps in Disaster Management

Simplifying Complex Data

One of the primary objectives of this project is to make intricate flood data more digestible for the average citizen, a goal deeply rooted in the principles of the Social Construction of Technology (SCOT) theory. According to SCOT, technological development is not just a result of technical requirements but is also shaped by social factors (Klein & Kleinman, 2002). As Wachinger et al. (2012) noted, existing flood prediction systems often present information in forms that require specialized knowledge to interpret, such as complex graphs, jargon-filled reports, or abstract numerical values. This technical complexity reflects the traditional focus on expert users in the field of disaster management.

In response, our application leverages Natural Language Processing (NLP) to translate this data into a format that is understandable and actionable for the general public. This approach aligns with the SCOT perspective by recognizing and adapting to the diverse information needs and interpretative capacities of different social groups. For instance, our user interface presents critical flood information in a manner similar to weather forecasts, distilling high-level data into simple yet informative phrases such as “The flood risk in Danang is 10%” or "high flood risk in the next 48 hours." This simplification and translation of data are driven by the societal need for accessibility and ease of understanding, especially for those who may not have the background to interpret complex data. To address the question of whether NLP can make flood data more digestible, we refer to studies like those of (Bronfman et al., 2019), which find that simplified information leads to more actionable insights for the general public, thereby creating more prepared individuals.

Moreover, this transformation of data presentation leads to more actionable insights for the general public. By aligning the design of our NLP application with societal needs and preferences, we not only make flood data more accessible but also influence how society engages with and responds to this information. In essence, our application serves as both a product and a catalyst of the social context it operates within, embodying the iterative relationship between technology and society envisioned by SCOT theory.

Comparison to Existing Technology

While we draw inspiration from voice-activated NLP devices like Amazon's Alexa, our application serves a specialized function—disaster preparedness. Research highlights that

realtime distributed disaster information has a large effect on the damage of these events (Acosta-Coll et al., 2018). Our NLP component is tailored specifically to provide clear, timely flood warnings and suggestions for immediate action. This is created as an extension of the current application which allows us to make our specialized data and models usable by anyone in the world.

In considering the provision of actionable steps, our approach is cautious yet innovative. We understand the ethical implications of offering direct action plans in emergency situations. Therefore, our focus is on presenting users with information that can help inform their decisions, rather than dictating specific actions. For example, the application might suggest general safety measures or potential evacuation considerations based on the data, but it will also remind users to consult local news and official advisories for the most accurate and current guidance. This balanced approach highlights the importance of using our specialized data and models as tools for enhancing awareness and preparedness, rather than as sole sources of information. The goal is to make this critical information accessible to anyone in the world, while maintaining an ethical commitment to accuracy and reliability.

Technologies incorporating natural language as an interface to interact with users typically deliver instructions and suggestions with caution. For example, many LLM-based applications such as ChatGPT and Google's BARD seldom give direct answers when prompted for advice in potentially harmful situations. As stated in an OpenAI research paper, “In the context of foundation models, 'refusals' refer to instances where the AI system intentionally does not generate an output or refrains from providing a response to a user query due to safety or

ethical concerns. This may occur when the requested output could potentially lead to harmful consequences, promote misinformation, or violate the ethical guidelines and policies set by the AI developers" (Shoker et al., 2023). This is largely because the intent of this technology is positive, but when users interact with it in ways similar to human interaction, the information received appears more direct and may seem to come from a real person, perhaps even an expert. Therefore, providing direct responses can give the impression of ultimate validation, even when the outcome may not be ideal or the best option.

Identifying the Information Gap

The "information gap" we reference is complex: people may not be receiving the information necessary or may not be able to digest the information in its current form. The research by Acosta-Coll et al. (2018) also points out these issues, emphasizing that the information gap includes people not receiving timely flood alerts, finding existing alerts too complicated to interpret, or not knowing what actions to take. Our solution targets these specific gaps by not only delivering timely alerts but also ensuring these are readily understandable and actionable. With natural language, users don't need to be highly knowledgeable in flood data or have to digest all the information that can typically be displayed in the user interface. However, to foster trust, we go a step further. Our application integrates data from reliable and real time sources, ensuring that the flood predictions and warnings are based on the most current and valid information available. This integration is transparently communicated to the users, so they understand where the information is coming from.

Moreover, the use of natural language processing (NLP) in our application is a significant factor in building credibility. By presenting complex flood data in a format that is conversational and easy to understand, we reduce the likelihood of misinterpretation and confusion. Users do not need to be experts in flood data analysis; instead, they can receive and understand critical information in a way that is familiar and accessible to them.

Inclusivity and Accessibility

Inclusivity and accessibility are core principles of this project for several reasons. Natural disasters do not discriminate, affecting populations across various socio-economic statuses. Existing technologies often exclude marginalized communities due to language barriers, technological illiteracy, or lack of access to smartphones or computers (Sanders & Scanlon, 2021). Our project's NLP component aims to bridge these barriers by offering voice-activated functionalities that don't require textual interaction and by developing multilingual support. Users who are elderly will have to navigate a potentially complex user interface which can be challenging, and on the other end of the spectrum, younger users also may not be able to fully understand all of the information provided. The goal is to continuously work towards a solution that is as accessible as talking to a friend or family member in your native and natural language.

The impact of our inclusivity efforts is directly linked to enhanced action-taking by these diverse user groups during flood events. By simplifying the user interface and providing information in a conversational style, we enable elderly users, who might otherwise be overwhelmed by complex digital interactions, to quickly understand the flood risks and take necessary precautions. Similarly, for users with disabilities, such as those with visual

impairments or motor challenges, voice-activated and audio-responsive features ensure that they can access vital information without the barriers posed by traditional text-based interfaces.

Moreover, the multilingual support caters to non-native speakers and communities with language diversity, ensuring that crucial information is not lost. The inclusivity of our design thus plays a crucial role in ensuring that all segments of the population, regardless of their technical proficiency or language, are equipped with the necessary information to make informed decisions in the face of natural disasters. This is especially important as the Floodwatch application aims to become a global platform.

Building on the importance of inclusivity, the National Weather Service's Weather Ready Nation Strategic Plan (Henderson & Clark, 2015), underlines the value of integrating social sciences into meteorological research and disaster management. This plan recognizes the ways in which different communities receive, comprehend, and respond to warnings. It reinforces the need for our project to consider a wide range of social factors and human behaviors in its design, ensuring that the application is not only technologically advanced in prediction but also socially responsive and effective in guiding diverse populations to appropriate action during flood events.

Ethical Implications

As we leverage forms of AI technologies for disaster management, ethical considerations inevitably arise. One of the most pressing concerns is the risk of false positives or negatives in flood predictions. False positives could lead to unnecessary panic, resource wastage, and lower

public trust. On the other hand, false negatives could have even more dire consequences, including loss of life due to lack of adequate preparation.

Aligned with this, it is important to remain committed to ethical integrity and transparently disclose to users the limitations and uncertainties associated with our flood prediction system. It is necessary to make it clear that while our system is designed to be as accurate as possible, there is always a margin of error in predictive models. This transparency is intended to enable users to take our advisories as part of a larger decision-making process, rather than as absolute certainties. This is especially important when dealing with natural language interactions, as we humans expect some degree of variation with technology, it may be more difficult to convey the uncertainty when interacting with a user in natural language. ‘

This is especially important when dealing with natural language interactions. As the Stanford Encyclopedia of Philosophy's entry on Natural Language Ontology emphasizes, the interpretation of language involves complex ontological considerations, reflecting the multifaceted nature of human understanding and communication (Moltmann, 2022). In AI systems, this complexity can lead to challenges in accurately conveying uncertainties, especially given that natural language interactions inherently involve interpretative variability. As we humans expect some degree of variation with technology, it may be more difficult to convey the uncertainty when interacting with a user in natural language. Thus, it is vital for systems in disaster management not only to be technologically advanced but also to be designed with an awareness of the ontological intricacies of natural language, ensuring clarity and precision in communication.

It's crucial to acknowledge the significant role of technology, especially in the realm of disaster management, where its impact can be large. Therefore, our approach incorporates a multi-faceted ethical framework emphasizing transparent communication and a steadfast commitment to social responsibility. This aspect becomes increasingly vital considering the intended global reach of Floodwatch and our potential influence on society. Acknowledging the rapid and widespread propagation of misinformation on the internet, as detailed in the article by Muhammed and Mathew (2022), we are acutely aware of the need to handle information distribution with the utmost care. We recognize that in the digital age, misinformation can spread quickly and uncontrollably, potentially leading to harmful consequences especially during crises. Therefore, in our efforts, we prioritize not just the technical accuracy of our predictions and advisories but also the ethical responsibility to prevent the spread of misinformation, ensuring our users receive reliable and trustworthy information.

This requires clear communication to our users that while the data provided by Floodwatch is rooted in advanced predictive models, it should be considered as a guide for preparedness rather than the absolute truth. Users should complement the insights gained from our platform with local news updates and official advisories. It is essential to position Floodwatch as a valuable resource for planning and awareness, while also reinforcing the critical nature of staying informed through multiple channels for the most accurate and current information.

Comparative Analysis

Floodwatch distinguishes itself from general-purpose voice-activated services through its specialized focus on disaster management, specifically for flood scenarios. Unlike Alexa or Siri, which are designed to handle a broad range of tasks, Floodwatch will have more in-depth knowledge of flood information to understand the urgency and informational specificity that come with impending floods. It leverages specialized weather and water level data and to offer timely and more precise advisories, ensuring that critical, life-saving information is presented in an actionable manner. The primary value added by technologies like Alexa and Siri stems from their ease of use and the convenience they offer in simplifying daily tasks, helping to improve customer satisfaction (Brill et al., 2019). Similar chatbot-like technologies have been integrated into numerous customer service platforms used by companies such as DoorDash, as well as on the websites of many product-based companies. These technologies are valuable because of their robust understanding of context. Similarly, Floodwatch offers its own set of benefits, as our platform has a large amount of measured and predictive data, which can provide useful insights regarding floods.

The Floodwatch team is creating flood prediction which is not generally available to the public currently. Leveraging our own data and Machine Learning models we are able to zero in on the unique challenges of flood disaster management. Floodwatch aims to provide a more reliable and effective service compared to general-purpose voice assistants. To build public trust, our system will undergo multiple phases of testing and validation, with results made publicly available. Additionally, we are working on partnerships with established meteorological agencies for further validation.

Conclusion

The essence of our work with Floodwatch goes beyond mere technological innovation; it's a game-changer in disaster management. By incorporating Natural Language Processing, we aim to humanize the way people interact with critical flood information, making it accessible and actionable for everyone.

The project carries ethical weight, as the reliability of our system has real-world consequences. As we improve our models, our ultimate goal remains steadfast: to save lives and bridge the information gap that exists in disaster preparedness.

While our current focus is on Vietnam, the technology has global applications. Floods are a worldwide issue, and Floodwatch aims to be a worldwide solution. In essence, we're not just building a smarter tool; we're fostering a smarter, safer approach to handling disasters globally. And that's a mission worth pursuing.

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