University of Waterloo
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Enhancing Clinical Task Management Efficiency with Natural Language Processing

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Honours Mathematics
1B

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Dear PD evaluators,

I am thrilled to present this report, “Enhancing Clinical Task Management Efficiency with Natural Language Processing”, for my 1B work term report. This report was written entirely by me and has not received any previous academic credit at this or any other institution.

HosTalky Corporation is a pioneering company in the healthtech industry, dedicated to enhancing patient care and streamline healthcare processes with cutting-edge technology. As a Software Engineer at HosTalky Corporation, I conducted research and assisted in the integration of Artificial Intelligence (AI) software on the beta version of the HosTalky app. This involved early research into cost-effective AI solutions, prototyping AI models with speech-to-text and text-to-text functionalities, implementing standard security measures for data privacy, and fine-tuning our models using healthcare training data. This report examines the utility and efficacy of intelligent automation (focused on text summarization and speech recognition systems) for healthcare communication apps, and provides solutions to workflow inefficiencies in a clinical setting.

Throughout the writing of this report, and thereafter, I have diligently checked for grammatical errors to the best of my ability. I present to you, the culmination of my research in a relatively recent but fast-growing industry.

Sincerely,

B. Yang

Brooke Yang
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Executive Summary

This report provides insights into the integration of AI-powered applications in healthcare, emphasizing an innovative approach to streamline clinical processes for healthcare workers. Firstly, the integration of AI into healthcare is primarily driven by patient data. Unlike traditional applications that focus solely on patient treatment and diagnosis, this approach aims to optimize inefficient clinical processes, such as health-related documentation and repetitive tasks, thereby enhancing overall workflow efficiency.

Leveraging network and routing models on a communication platform significantly improves response times, task delegation optimization, and information summarization and retrieval. By utilizing AI-driven triaging, which computes priority queues based on healthcare records and patient outcomes, the optimization of task delegation considers scheduling conflicts, user preferences, and areas of specialty to assign duties efficiently. Ensuring the structural soundness and permanence of the organizational network is imperative for healthcare systems. Finally, integrating AI as a task management assistant involves stringent specifications but can enhance the transfer and retrieval of information by introducing mediaries into the network system.

By focusing on streamlining inefficient tasks and leveraging advanced AI-driven models, the aim is to enhance the quality of patient care while reducing the burden on healthcare workers. Through strategic integration of AI technologies, organizations remain at the forefront of revolutionizing healthcare workflow management.

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1. Introduction

A long standing problem in the healthcare industry concerns the efficacy of clinical workflows. Current healthcare institutions are not connected by a common platform for task management, making it more difficult than necessary for workers to navigate and efficiently complete their duties. This issue is in part due to technological obstacles, but also because of the lack of reliable platforms complying with HIPAA.

The functional issue at hand involves limiting the amount of human intervention with clinical tasks. Today, there is an immediate application for Artificial Intelligence (AI) in healthcare processes such as predictive analytics, electronic health records (EHR) management, administrative workflow automation, and clinical decision support systems (CDSS). This field of healthcare technology, concerned with automated decision-making, demands a medium for which managerial duties can be performed. For instance, by leveraging AI-driven automated diagnostics, healthcare specialists can quickly permit and further examine complex diagnoses, and free up staff time for better-impact paintings (Logeshwaran et al., 2023, p. 1).

At HosTalky, a speech recognition system is being developed to support workflow, limit human errors, and improve the wellbeing of healthcare professionals. The current objective involves medical transcription for documenting clinical notes, medical reports, and EHR. The result of automating these processes will improve clinical documentation, both in time and accuracy as speech recognizers become exposed to training data. Leveraging Natural Language Processing (NLP) for clinical narratives is a topic of interest, namely for its applications in compiling “medical admission notes, discharge summaries, progress [and pathology] reports” (Raghavan and Lai, 2023, p. 1) to extract insights.

The ideal outcome involves combining NLP capabilities and speech recognition systems to analyze healthcare data. One such use case entails unsupervised clinical language translation, which would control the degree of professionalism in clinical transcriptions based on the knowledge of the audience (Weng et al., 2019, p. 1). Ultimately, the findings in this report will provide insight on the efficacy of AI-driven solutions in a clinical setting, and identify areas of workplace inefficiencies.

2. Literature Review / Background Information

The field of AI and machine learning applications has always been data-intensive, requiring vast amounts of training data to achieve practical levels of model accuracy. Specifically, the development of Large Language Models (LLMs) has accelerated significantly since 2020 (Brown et al., 2020). This surge has led to the emergence of a subfield known as "generative AI." This type of artificial intelligence utilizes billions of text data points, converting tokens into vector embeddings in a high-dimensional space. As a result, LLMs are trained to identify and cluster similar tokens based on their vector representations.

Recently, LLMs have become adapted to handle more than just text-to-text generation; training data now includes video, image, audio, and proprioception among other modalities (Radford et al., 2021). This multimodal approach has significantly broadened the capabilities and applications of LLMs, enabling them to perform complex tasks such as image captioning, video summarization, and cross-modal retrieval (Ramesh et al., 2021).

From a clinical standpoint, AI has proven particularly effective in medical aid management (CRM), providing real-time evaluation of a patient's condition by considering contextual data and resource availability (Logeshwaran et al., 2023). Additionally, recent research into AI-driven text summarization is opening new avenues for more efficient and convenient methods of delivering information to readers. Efforts are underway to develop effective notification systems that reduce information overload and highlight the most important parts of messages (Peng-Jui et al., 2023).

Amid these advancements, a significant clinical challenge remains in the initial transcription of healthcare data. Granted, recent progress in natural language processing (NLP)

and text mining has led researchers at the Chongqing Institute of Green and Intelligent Technology to propose a method for extracting linguistic features to enhance semantic content (Wang et al., 2018). This method could potentially involve using patient audio recordings, which are pre-analyzed by a speech recognition system. Healthcare workers would then receive a text-summarized document containing factually accurate and semantically enriched data to assist in their diagnoses.

On a final note, there is ongoing concern regarding data privacy and personally identifiable information (PII). Specifically, handling patient data during media transfers between large language models (LLMs) requires secure channels (HTTP endpoints) and trust in how the LLMs utilize such data. This issue can be addressed by redaction software, which temporarily censors patient data during this process. Once the LLM returns the updated media, the patient data may be restored, minimizing the risks associated with data transfer. However, it is important to note that redaction tools are less effective with speech-to-text models because these models often have lower accuracy when transcribing names.

3. Analysis / Results and Analysis

The specific use case of AI automated systems in a clinical setting involves annotating health documents and modularizing speech based on healthcare related data and user-specific instructions. This proves to be a difficult task for general purpose large language models (LLMs) due to the architectural design of its neural network. By adding training data, displaying the intended use case of the ASR, the model can be fine-tuned to more accurately perform its intended operations: summarizing and parsing dialogue, noting conversational dynamics between patients and healthcare workers, and recording documents according to specified formats.

Task-driven information flow

Consider the task-driven information flow, particularly in a clinical institution that operates with real-time data. This so-called collaborative network, possesses a “truncated power-law node degree distributions” (Miao et al., 2012), indicating that while most nodes (such as healthcare providers or data points) have a few connections, a small number of nodes have many connections, facilitating critical communication pathways. The truncation aspect suggests a limit to the number of connections any single node can have, which may be due to resource constraints or the need to prevent information overload. Understanding this distribution helps in designing more efficient information flow systems and optimizing the network for better performance and reliability, ensuring that essential data reaches the right people without unnecessary delays.

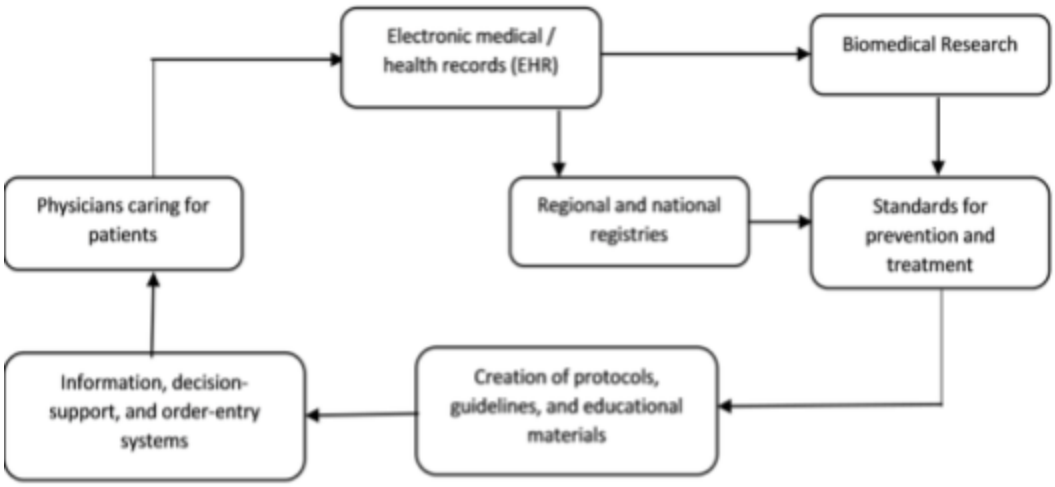

Figure 1 - Healthcare Task-Driven Information Network (Miao et al., 2012)

The figure above illustrates a simple collaborative network involving a directed flow of data. This is largely relevant in the design of clinical-specific ASR, where certain automated tasks leverage specific domains of data to provide a more secure and accurate performance. It is important to note that such networks are distinctively different from public social networks, where data is sourced through members' activities and connections (Miao et al., 2012).

In the context of healthcare systems, studying the information flow network within its user base can highlight areas of high traffic. These paths (i.e., healthcare teams) may require larger portions of training data dedicated to their sector-specific roles.

According to Miao, a collaborative network is defined by two main characteristics that enhance one's understanding of it.

1. Structure of the network

    a. A **network model** that captures key characteristics of collaborative networks and provides simulations with structural modifications.
2. Information routing driven by tasks
    a. A **routing model** to simulate human behavior in routing task-relevant data in a collaborative network.

The objective of their research was to answer: how can one modify a collaborative network to achieve higher efficiency (Miao et al., 2012). From the results, the following key observations were made:

1. The network model reliably simulated **static connectivity** of collaborative networks. On the other hand, the routing model was able to simulate **dynamic user behavior** in collaborative networks.
2. Combining these two models enables unprecedented means to improve the working efficiency of task execution, without structural modifications to the real-world network.

In the clinical perspective, the second point is highly valuable due to the stringent nature of healthcare systems, not being well-fitted to major changes. In the interests of a healthcare communication platform, it would be realistic to utilize user behavior in the task delegation process. This approach leverages existing network structures while dynamically optimizing task allocation based on real-time user interactions and behaviors, thus enhancing overall efficiency without disrupting established workflows. Consequently, healthcare institutions can improve their response times and coordination without the need for extensive overhauls, making it a practical and scalable solution for improving operational efficiency.

<u>AI-driven automated diagnostics</u>

With an understanding of typical clinical networks, the discussion shifts onto how AI can be leveraged in automating inefficient pathways in the task-driven network. Specifically, the clinical decision support systems (CDSS) involving task delegation can be trained on simulated networks for task inefficiency as well as user dynamics; levels of interaction between healthcare sectors, measured in volume and frequency over time intervals (Logeshwaran et al., 2023). Within the healthcare communication app, clinical professionals can assess health documents with the aid of CDSSs which would provide recommendations or insightful patterns into patient history, or a course of action involving medical operations and checkups (Logeshwaran et al., 2023).

Moreover, these applications build upon the potential of AI-driven text summarization, a common process involved in clinical settings with health documents. According to a group of researchers at the National Yang Ming Chiao Tung University, users of a AI-driven notification management app (NotiSummary) showed usage preferences in how they received information (Wang et al., 2023). Specifically, they highlighted behavioral patterns in the activity of the user interface, proposing that "summarized notifications may mitigate notification overload and enhance user engagement" (Wang et al., 2023). This is another aspect of improving operational efficiency in the clinical workplace, by improving the design of communication platforms with accessible and preferable features.

Among the several software features were user-customized summary generation and summary scheduling. It can be noted that the latter process involves compiling management data from the institutional database to figure out alignment with the user's schedule.

AI-driven triaging

A fundamental attribute in the healthcare workplace involves the priority queue of tasks to be completed. As part of the workflow process, institutions rely on computerized methods to prioritize, sort, and manage tasks on the basis of urgency, significance, or other special criteria. A real-world case study, conducted in Australia, focused their attention on optimizing clinical workflows for non-emergency scenarios. The study involved screening processes of tuberculosis (TB) in Australia, focused on "understanding radiologist perspectives of the effect of AI-driven triaging" (Hua et al., 2023). This process of AI-driven triaging utilizes an enhanced first-in-first-out (FIFO) queue to manage patient cases.

In the study, task productivity data was collected to quantify the benefits of AI-driven triaging. It involved processing timestamp data to arrive at two key metrics:

1. Turn-around time (TAT), covering the interval from when a patient's X-Ray results are sent to when a TB diagnosis report is submitted.
2. Reporting time, spanning the duration from the commencement of a TB diagnosis report to its submission.

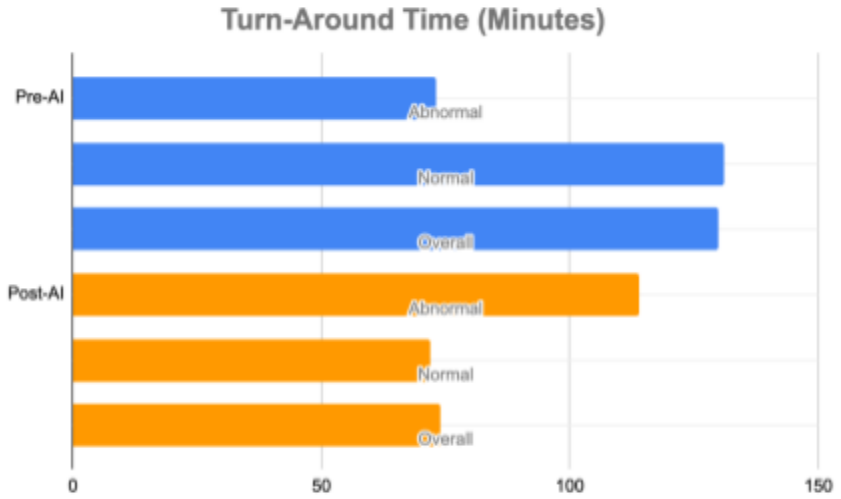

Figure 2 - Time between X-ray results and TB diagnosis report submission (Hua et al., 2023)

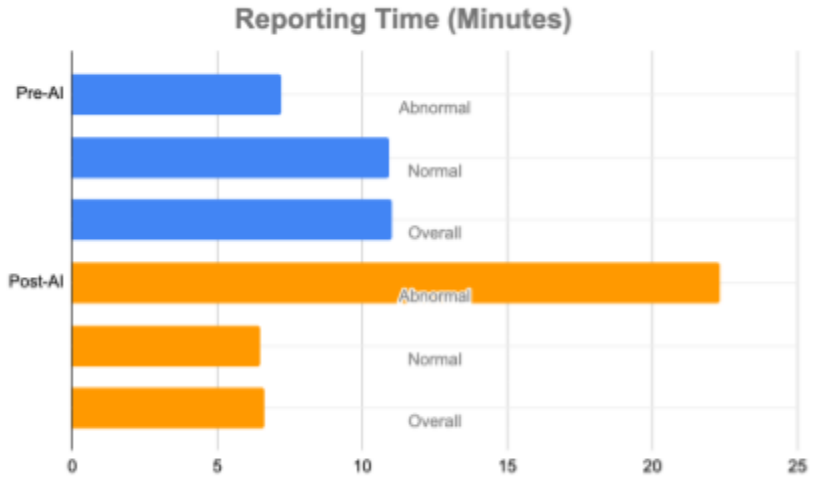

Figure 3 - Time between start to finish of TB diagnosis report (Hua et al., 2023)

Figures 2 and 3 display the results of these two metrics, comparing the effect of AI-driven triaging in the study. It effectively contributed to an "84.5% and 45% improvement for TAT and reporting time… in normal cases, and 60.56% and 214% time increase… for abnormal cases" (Hua et al., 2023). These metrics show a significant benefit for radiologists working with abnormal cases, leveraging AI to streamline their diagnoses in normal cases so that their greater attention is given to more complex patient issues.

4. Discussion

The integration of AI-powered applications in healthcare is driven by patient data, focused on treating and diagnosing patients using resource-intensive methods. At HosTalky, there is a different approach to improving healthcare, namely through streamlining inefficient clinical processes for the healthcare workers. These low-resource tasks involve health-related documentation as well as repetitive tasks where an intelligent automated system could aid in.

Leveraging both network and routing models on a communication platform can significantly improve the workflow efficiency in response times, task delegation optimization, and information summarization and retrieval. By allocating the correct portions of training data for task-specific purposes, speech-to-text models become more accurate at identifying and transcribing common speech dynamics and censoring patient sensitive data. Among these benefits, healthcare workers are alleviated of additional burdens concerning menial tasks (Wang et al., 2023). Additionally, the directed paths connecting clusters in the routing model can be reorganized based on the frequency of associated terms used in transcriptions between clusters.

An important step in analyzing task-driven information flows deals with how well terminology used from one department maps to another group. Given the vast amounts of healthcare terminology, large corpuses of medical words are required in training models to construct meaningful associations. This would be non-ideal for startup companies without the resources to fund such initiatives, requiring both experienced engineers and time to complete. A practical alternative involves the use of redaction software to accomplish two tasks; the first being to ensure HIPAA compliance with regards to using personal data, and the second goal is to categorize medically sensitive data into fewer groups for models to train on.

With the addition of AI-driven triaging, a method of computing priority queues based on healthcare records and patient outcomes, task delegation to healthcare workers factors in scheduling conflicts, user preferences, and areas of specialty to decide whom to assign duties in the workplace. An imperative feature of healthcare systems is the structural soundness and permanence of its organizational network. Integrating AI as a task management assistant involves stringent specifications, but can increase the transfer and retrieval of information by adding mediaries into the network system.

5. Conclusions and Recommendations

Key Takeaways & Recommendations:

This report underscores the critical role of AI-powered applications in healthcare, particularly in streamlining clinical processes for healthcare workers beyond patient treatment and diagnosis. HosTalky's innovative approach focuses on optimizing health-related documentation and repetitive tasks through intelligent automation, significantly enhancing workflow efficiency and relieving healthcare workers from additional burdens. Leveraging advanced network and routing models – on a communication platform – can fast track healthcare service delivery in a cost-effective and efficient manner. To advance these efforts, it is recommended that HosTalky enhance AI-driven task delegation, continuously refine network and routing models, and invest in robust AI infrastructure to facilitate the real-time demands of healthcare teams. Additionally, it is encouraged to integrate key insights from routing models to identify data transfer pathways with high volume.

Supporting Research & Future Activities:

The integration of AI in healthcare workflow management is supported by recent studies such as those by Wang et al. (2023), emphasizing the importance of streamlining clinical processes for healthcare workers. Additionally, Logeshwaran et al. (2023) demonstrate the effectiveness of AI in clinical resource management, providing real-time evaluation of patient conditions. Advances in AI-driven text summarization, as highlighted by Peng-Jui et al. (2023), indicate promising directions for improving information delivery methods in healthcare. Future activities that would benefit from this analysis include the implementation and testing of recommended enhancements, continuous monitoring and adaptation of AI-driven systems, and

collaborative research with institutions and industry partners to further explore innovative AI technologies and their applications in healthcare workflow management.

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