ENGINEERING
W Booth School of Engineering
Practice and Technology

McMaster University

SEP 769 – Cyber Physical Systems

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Group 1

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Introduction

This initiative represents a pioneering amalgamation of cutting-edge IoT (Internet of Things) and machine learning technologies. Its core objective is to harness room environmental variables, encompassing temperature, humidity levels, ambient noise levels, and sleep quality collection, for the purpose of enhancing sleep quality through the strategic control on/off of humidifiers.

This project undertakes a meticulous exploration of these multifaceted factors, seeking to establish a nuanced comprehension of their individual and collective influence on sleep patterns within the context of room environments.

To address the challenges associated with sleep quality, the initiative adopts a proactive approach. It leverages advanced machine learning models to autonomously adapt and optimize bedroom conditions. This adaptive process involves precise adjustments to various room parameters, such as temperature and humidity, in direct response to feedback generated by the machine learning algorithms.

In essence, the project aspires to provide a personalized, data-driven solution tailored to individuals seeking to elevate their sleep quality. By harnessing the potential of IoT and machine learning, it aims to forge an intelligent and self-regulating sleep environment that not only enhances the quality of sleep but also contributes to overall well-being.

Main Architecture

The architectural framework of this application comprises several integral components, each serving a distinct purpose in orchestrating its functionality:

Edge Computing: At the forefront of data collection and local control, a Raspberry Pi device assumes the role of an edge computer. It diligently gathers pertinent data points, including humidity, temperature, and noise levels, and orchestrates the operation of the humidifier switch, managing its on/off functionality. Concurrently, iPhones are employed to assist in capturing data on sleep quality.

Cloud Computing: The application leverages cloud computing infrastructure, with a focus on utilizing renowned cloud platforms like Google Cloud Platform (GCP). This facet serves as the backbone for data transmission and secure storage, ensuring that valuable information is reliably processed.

Data ETL Pipeline Techniques: The essential data processing tasks - extraction, transformation, and loading (ETL) - are seamlessly carried out with the aid of MQTT, Kafka, Pub/Sub, Dataflow, and Apache Beam. These technologies facilitate the smooth flow of data within the system. Additionally, the project considers various storage solutions, including GCP Cloud Storage, GCP Bigtable, and BigQuery, to accommodate the diverse data needs.

Machine Learning: Central to the project's intelligence and adaptability is the integration of machine learning. VertexAI serves as the cornerstone for model development, with a strong emphasis on continuous integration, continuous deployment, and continuous testing (CI/CD/CT). The choice of modeling techniques, spanning supervised learning, clustering, and reinforcement learning, hinges upon the volume and diversity of available data, ensuring the most effective and relevant insights are derived.

Project Roadmap

The project will follow a structured progression divided into three distinct phases:

Phase One: In this initial phase, the primary objective is to develop a Minimum Viable Product (MVP) with essential backend functionalities. These functionalities encompass real-time monitoring of environmental variables such as temperature, humidity, and noise levels within the bedroom environment. Additionally, an Extract, Transform, Load (ETL) pipeline will be established to facilitate seamless data transmission to the cloud environment. The system will also allow for remote activation and deactivation of switches based on predefined humidity thresholds. Users will play a pivotal role in this phase by manually labeling the dataset, indicating the quality of sleep experienced. This labeled data will be utilized to predict and assess the quality of sleep based on the bedroom environment.

Phase Two: In the subsequent phase, denoted as Phase Two, the project will introduce more advanced machine learning approaches. A/B testing methods will be used to test multiple machine learning models trained using the dataset from Phase One. Those trained models will assume the role of an intelligent system, providing feedback to regulate and control humidifiers. This feedback mechanism will optimize the room's temperature, humidity, and noise levels, thereby enhancing the quality of the user's sleep.

Phase Three: The final phase, Phase Three, will witness an expansion of the capabilities of the application's backend. It will be seamlessly integrated with iOS applications, facilitating access to user sleep quality measurements. Simultaneously, the application's frontend will undergo development to create an informative and user-friendly dashboard reporting system. This dashboard will provide users with comprehensive metrics and insights into their sleep quality, enhancing their overall experience with the application.

Project Timeline and Deliverables

In light of timeline constraints, our foremost priority is the completion of Phase One. Upon the successful conclusion of Phase One, we will proceed to tackle Phase Two and Phase Three in succession. Please see the task distributions and timeline below

Task Number	Main Task	Time Line	Responsible Team Member
1	Hardware connections and testing	Sep 30	Angel, Yuanlai
2	Data Engineering	Oct 7	Wei, Yuanlai
3	Machine Learning Adoption	Oct 14	Wei
4	Project Paper	Oct 15	Angel