**OreSense**

PS ID : SIH1511

PS Title : Real time knowledge of ore body being mined out

Objective:

* Determine ore quality instantly
* Show real time position of miner and ore body estimation
* Enhance miner safety through efficient response mechanism

Introduction:

Our cutting-edge hardware device has been meticulously engineered to seamlessly capture data from an array of sensors, encompassing Vibration, GPS, BPM, IR, and Camera modules. This multifaceted sensor integration ensures a comprehensive and nuanced understanding of the mining environment. The heart of our data processing capability resides within the powerful Raspberry Pi, where state-of-the-art Machine Learning and Deep Learning algorithms meticulously transform raw sensor data into actionable insights.

The processing pipeline has been intricately designed to handle both Spectroscopy data and visual data with utmost precision. This dual-stream approach enables a thorough analysis, providing miners with a holistic understanding of the ore composition and quality. The integration of advanced algorithms ensures not only accuracy but also efficiency in deriving meaningful conclusions from the diverse datasets.

The culmination of this intricate data processing is presented to miners through a dedicated dashboard, designed with user-centricity in mind. The dashboard serves as a centralized hub, offering a comprehensive overview of sensor data while prioritizing the clear and concise presentation of meticulously processed results. This user-friendly interface empowers miners with real-time insights, allowing for informed decision-making and swift responsiveness to evolving mining conditions.

A key feature of the dashboard is the incorporation of an interactive map that not only accurately pinpoints the miner's location but also provides invaluable guidance through a concentration heatmap derived from the ore-body model. This dynamic map interface delivers real-time spatial intelligence, assisting miners in identifying optimal locations for resource extraction. The concentration heatmap, grounded in the sophisticated ore-body model, serves as a powerful tool for enhancing mining efficiency and maximizing resource utilization.

In summary, our integrated system represents a pinnacle of sophistication and efficiency in the realm of mining operations. With a meticulous focus on productivity enhancement and resource optimization, our solution stands as a testament to technological innovation in the mining industry. The seamless amalgamation of sensor data, advanced algorithms, and user-friendly interfaces positions our system as an indispensable asset for mining professionals seeking to elevate their operational efficiency and yield.

The hardware ensemble for our innovative mining solution comprises a strategic selection of components, each contributing to the system's robust functionality:

Breadboard:

Role: Fundamental for prototyping and circuit arrangement without soldering.

Significance: Facilitates rapid testing and modification of circuits, offering flexibility in design iterations.

Raspberry Pi:

Role: Central processing unit hosting advanced Machine Learning and Deep Learning algorithms.

Significance: Provides versatility and computational power for complex data processing, making it a pivotal element in our system.

ESP32:

Role: Microcontroller enabling communication between sensors, Raspberry Pi, and other components.

Significance: Incorporates wireless connectivity, low power consumption, and cost-effectiveness for seamless coordination within the system.

Jumper Wires:

Role: Establish electrical connections between components on the breadboard and other hardware.

Significance: Simplifies circuit setup, allows for quick adjustments, and offers reusability for diverse projects.

Vibration Module:

Role: Monitors vibrations in the mining environment.

Significance: Enhances safety by detecting idle periods, contributing to early warnings for potential hazards or equipment failures.

GPS Module:

Role: Tracks precise location, providing spatial data for mapping and guidance.

Significance: Ensures accurate positioning, real-time tracking, and supports emergency response in mining operations.

BPM (Barometric Pressure) Sensor:

Role: Measures barometric pressure for environmental data.

Significance: Contributes to atmospheric monitoring, safety indicators, and aids in predicting potential environmental hazards.

IR (Infrared) Module:

Role: Captures infrared data for spectroscopy analysis.

Significance: Facilitates material analysis, resource characterization, and supports exploration through spectral data insights.

Camera Module:

Role: Captures high-resolution images for quality measurement and visual assessment of ores.

Significance: Integrates visual data into the processing pipeline, enhancing overall analysis and reporting capabilities.

Technology q

In the domain of Machine Learning, our system leverages both spectroscopy data acquired from a real-life spectrometer and visual data captured by the camera feed, subjecting them to a comprehensive analytical process. The spectral data undergoes processing through a linear regression model to accurately determine ore impurity levels. Concurrently, both the processed spectral data and the visual data are input into a Convolutional Neural Network (CNN), featuring two convolutional layers and two dense layers. This CNN efficiently predicts the ore grade quality, showcasing the remarkable capabilities of edge computing on the Raspberry Pi.

The system's dashboard acts as a centralized hub with distinct sections, each serving a unique purpose. The "Home" section provides a visual representation of spectral data and the camera feed, highlighting the outcomes of the machine learning analysis. The "Data" section furnishes an in-depth analysis of sensor data through graphical representations and environmental information. The "Map" section presents the miner's location, overlaying a concentration heatmap of ore, and offers a pathway to the next optimal mining location. An essential safety feature includes a dedicated "SOS" button, allowing miners to promptly alert administrators in case of emergencies. On the administrator dashboard, a comprehensive overview displays the locations and data of all miners, alongside a log detailing received SOS signals.

The technology stack underpinning this system is as diverse as it is robust. For the front end, we employ React and Leaflet to ensure an interactive and visually appealing dashboard. On the backend, the system relies on Node.js and Express for server-side logic, MongoDB for database management, and Flask and Python for handling machine learning tasks, including pipeline construction and model training and prediction. This intricate integration of technologies enables the seamless functioning of our predictive model, combining spectroscopy data and diverse sensor inputs to deliver precise forecasts of ore impurities. The real-time processing of visual data further enhances the accuracy of our results, culminating in a powerful synergy that not only assesses but ensures the quality of the ore. These insights prove invaluable for optimizing mining and processing operations with unparalleled precision.

Implementation Report: Advanced Mining Safety System

1. Hardware Implementation:

The core of our innovative mining safety system is the ESP32 module, seamlessly collecting data from Vibration, GPS, IR, and BPM sensors. This data is transmitted to a Raspberry Pi through a local network connection. The Raspberry Pi, equipped with a camera module, captures visual data. The ESP32 and Raspberry Pi integration forms the backbone of our hardware system, ensuring real-time data acquisition and processing. The final processed information is displayed on a hardware device through an LCD screen, providing miners with crucial insights into ore quality and safety of miners.

2. Machine Learning Integration:

The collected data, including spectroscopy and visual data, undergoes a sophisticated machine learning (ML) and deep learning (DL) pipeline. Spectroscopy data is processed using a linear regression model to determine ore impurity levels. Simultaneously, the visual and spectral data are fed into a Convolutional Neural Network (CNN) with two convolutional layers and two dense layers. This CNN predicts ore grade quality. Importantly, this ML and DL processing occurs on the edge device, the Raspberry Pi, contributing to efficient edge computing. The models are implemented in PyTorch, orchestrated via a pipeline, and communicated using Flask. The linear regression model operates with a joblib file, while the neural network model utilizes a .pth file, producing precise ore quality predictions.

3. Dashboard Functionality:

The user interface comprises different sections for comprehensive monitoring and control. The Home section displays spectral data and visual feeds, presenting computed ML outputs. The Data section provides a detailed analysis of sensor data, presented through graphs, and offers environmental information. The Map section depicts the miner's exact location, overlaying a concentration heatmap of ore and mapping the optimal path to the next mining location. The SOS section features a dedicated button for miners to send emergency signals to the admin. On the Admin Dashboard, all miners' locations and data are displayed, alongside a log of received SOS signals.

4.Unified Frontend-Backend System:

Orchestrating Data Flow from Sensors to User Interface .This comprehensive system seamlessly integrates a frontend built with Next.js and React, providing an interactive user interface, with a robust backend powered by Node.js. The backend orchestrates data flow from various sensors, including Vibration, GPS, BPM, IR, and Camera modules, connected to Raspberry Pi and ESP32 hardware. The processed sensor data is communicated to the backend, where Node.js handles further analysis and storage in MongoDB. The Flask and PyTorch pipeline manages machine learning tasks, ensuring precise predictions.

This integrated approach enables efficient retrieval of processed data, which is then dynamically rendered on the frontend. Users can interact with the interface, gaining valuable insights into mining operations. The system's versatility is further augmented by Gunicorn facilitating a responsive REST API. Overall, this frontend-backend synergy offers a seamless and responsive experience, bridging the gap between sensor data and user interface in the mining solution.

5. Unique Selling Proposition (USP):

Our system stands out due to its paramount focus on miner safety. Vibration sensors send notifications to miners in case of inactivity. If there's no response after multiple notifications, the system identifies potential danger and broadcasts the miner's last captured location to nearby devices, creating a spider network. This critical data is then transmitted to the admin for immediate rescue or evacuation coordination. This innovative approach ensures a rapid and efficient response to emergencies, significantly enhancing miner safety.

6.Technical Flow:

The hardware, consisting of ESP32 and Raspberry Pi, collects data from sensors, including visual data from the camera, sent to the Raspberry Pi over a local network. The ML and DL algorithms, implemented in PyTorch, process the data on the edge device using Flask. Linear regression and CNN models provide insights into ore impurity and grade quality, respectively. The results are displayed on the LCD screen. Simultaneously, the Raspberry Pi, with Wi-Fi 6 capabilities, forms a network, sharing data with nearby devices. In case of inactivity, vibration sensors trigger notifications. If there's no response, the system initiates an emergency broadcast to the admin, creating a spider network for swift response.

Additional Information:

The network model employs Raspberry Pi at the edge, capable of sharing data via Wi-Fi 6. PyTorch is the chosen framework for building the ML and DL models. The implementation involves a pipeline structure, facilitated by Flask. The linear regression model relies on a joblib file, while the neural network model uses a .pth file. The seamless data flow is achieved through Flask, ensuring precise ore grade quality output.

In conclusion, our comprehensive implementation seamlessly integrates hardware, machine learning, and a user-friendly dashboard to create an advanced mining safety system. The emphasis on real-time data processing, innovative communication networks, and predictive analytics positions our solution at the forefront of ensuring miner safety and enhancing overall operational efficiency.

Assumptions

Due to the highly classified nature of mining data, a structured dataset tailored specifically to our requirements wasn't available. Consequently, we navigated this challenge by strategically amalgamating information from three distinct sources. These sources were chosen to mimic the real-world scenario as closely as possible, ensuring the robustness and efficacy of our predictive model.

IR Spectroscopy Data from Kaggle:

Source Explanation: We utilized an IR spectroscopy dataset available on Kaggle, a reputable platform for diverse datasets.

Significance: This dataset forms the foundation for the analysis of ore composition. While not directly sourced from our mining operations, it provides realistic spectral data, enabling the training and validation of our predictive model.

Images of Ore for Classification:

Source Explanation: To replicate the visual component, we engaged in web scraping to collect images of ores from online sources.

Significance: These images serve as crucial input for our Convolutional Neural Network (CNN). By employing web scraping, we mimicked the process of capturing real-world visual data to assess and classify ore grades accurately.

Simulated Map Analysis with Pre-defined Data:

Simulation Explanation: Recognizing the absence of real-time miner data, we simulated the map analysis by generating dummy data.

Significance: Although the miner locations and heatmap data are artificially generated, they adhere to the same principles that would be applied when using actual miner location data. This simulation allows us to showcase the system's capabilities, including the display of miner locations, concentration heatmaps, and optimal path suggestions.

It's essential to underscore that these data sources and simulations were meticulously chosen and crafted to align with the actual mining scenario. While the specifics may differ from a real-world dataset, our approach ensures that the machine learning and deep learning models are trained and tested on representative data, allowing them to generalize well when applied to actual mining operations.

Despite the unique challenges posed by the absence of a directly applicable dataset, our careful curation and simulation strategy uphold the integrity and functionality of our mining solution, demonstrating its adaptability and efficacy in situations where proprietary and classified data is the norm.

Future Scopes:

HYPERSPECTRAL IMAGING

hyperspectral imaging captures and processes information across a broad electromagnetic range beyond the visible spectrum. It provides detailed spectral data for each pixel in an image, enabling the identification and analysis of materials based on their unique spectral signatures. Hyperspectral imaging streamlines ore analysis in the mining industry by capturing spectral data across a wide range of wavelengths in a single device, eliminating the need for multiple instruments. This technology allows mining professionals to obtain comprehensive information about various ores in a single scan, enabling efficient and cost-effective mineral identification. Instead of employing separate devices for different mineral compositions, hyperspectral imaging provides a unified solution for capturing detailed spectral signatures of diverse ores.

Dynamic neural network adjustments of weights

In real-time ore quality prediction, our dual-model approach refines predictions continuously. Using spectral data, linear regression predicts ore impurity, focusing on silica percentage. Ongoing comparisons with chemical analysis, obtained an hour later, update the regression model's weights. Simultaneously, the CNN model, fed with results of spectral data and visual data, classifies ore in real time, refining its weights with the latest chemical analysis results. This integrated strategy ensures a perpetual improvement loop, allowing both models to adapt and evolve over time. The result is a progressively accurate prediction of ore quality, showcasing the efficacy of our iterative approach in leveraging real-time data for optimal performance.

L3 ROUTING

Layer 3 (L3) routing provides various advantages, including efficient network segmentation, scalability to accommodate growth without compromising performance, flexibility through dynamic routing protocols, and reduced latency for faster communication. In the proposed architecture, where nodes connect directly to an L3 switch and a router interfaces with the switch, the setup minimizes latency by reducing the number of hops required for communication. This design ensures increased reliability through redundancy and dynamic routing adaptation, along with enhanced efficiency achieved by segmenting the network into multiple subnets and utilizing Virtual LANs (VLANs). Overall, the system optimizes data paths, enhances security, and facilitates seamless network expansion while maintaining low-latency communication for improved performance.

Autonomous vehicles for mining

Autonomous driverless vehicles, forming a Vehicle-to-Vehicle (V2V) system, are proposed for underground mining, showcasing transformative potential. Leveraging microseismic monitoring, image recognition, AI algorithms, and IoT, these vehicles operate with precision in hazardous environments. Cloud computing centralizes data processing, optimizing vehicle control. Validation tests confirm the accuracy of the velocity-free localization method, vital for underground navigation. Equipped with smart sensors, these vehicles undertake complex tasks, enhancing efficiency and safety. A network of strategically deployed sensors, integrated with cloud-based processing, ensures real-time vehicle localization and environmental assessment. The integration of autonomous vehicles in underground mines emerges as a pivotal advancement, markedly improving safety and efficiency in challenging deep mining operations.

Citations and References  
  
<https://www.kaggle.com/datasets/edumagalhaes/quality-prediction-in-a-mining-process>

[https://www.sciencedirect.com/science/article/abs/pii/S0166361509001948?fr=RR-2&ref=pdf\_download&rr=83872d504fed4ae1#bib18](https://www.sciencedirect.com/science/article/abs/pii/S0166361509001948?fr=RR-2&ref=pdf_download&rr=83872d504fed4ae1" \l "bib18)

<https://ieeexplore.ieee.org/document/8977327/>

Repositories

<https://github.com/rajbeer1/nextjs-first/tree/main>

<https://github.com/rajbeer1/sih-backend/tree/main>

<https://github.com/okieLoki/admin-map>

<https://github.com/okieLoki/oresense-pipeline>