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Reducing Grain Loss During Storage

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Abstract: Efficient storage structures are crucial in minimizing global grain losses, aggravated by population growth, increased consumption, and natural disasters. Mechanized practices and engineering interventions are vital to curtail post-harvest losses, with 10-15% attributed to inadequate storage facilities, exacerbating grain deficits. To mitigate this, a solution integrates a Mobile App for remote grain monitoring and real-time assessment, alongside an automated inspection system to preemptively address pest or mold issues. This holistic approach, driven by advanced technologies (IOT), enhances storage efficiency, aligning with the demand for technologically-driven agricultural solutions. It becomes pivotal in establishing resilient and sustainable grain storage infrastructure, crucial for meeting rising global food demands and promoting hygienic, economical, and scientifically designed storage structures. In the future, we aim to fully automate operations with Machine Learning (ML), developing AI-driven inventory management systems to dynamically update warehouse status and optimize storage, facilitating efficient rentals between warehouse owners and farmers.

***Index Terms* -** Inventory management, Grain Monitoring, Temperature and Humidity Sensors, Real-time Alerts.

I. Introduction

The objective is to design and implement solutions for efficient grain storage, addressing challenges posed by diverse agricultural commodities. We aim to integrate advanced technologies, ensure environmental sustainability, and optimize operations to enhance the resilience of the global food supply chain while benefiting farmers, facility operators, and the entire supply network. Inefficient grain storage practices contribute to post-harvest losses, impacting food security and sustainability. The diverse range of agricultural commodities, each with unique storage requirements, poses challenges in loadings, flow patterns, and specialized handling. Balancing versatility and specialization in grain storage facilities, along with the integration of advanced technologies, becomes imperative. This project addresses these complexities to optimize the design and operations of grain storage facilities, ensuring minimum wastage, environmental sustainability, and a resilient global food supply chain. The origin of the problem lies in the intricate dynamics of the global agriculture and food supply chain. With a burgeoning global population, estimated at 9.1 billion by 2050, ensuring a stable and efficient food supply becomes paramount. Diverse agricultural commodities, each with unique characteristics, challenge traditional grain storage practices. The globalization of food markets and rapid technological advancements further complicate storage solutions. Environmental sustainability concerns and market fluctuations add layers of complexity. Adapting to changing agricultural practices necessitates a comprehensive examination of grain storage facilities, motivating this project to address the multifaceted challenges arising from a dynamic and interconnected global landscape**.** The motivation for this project is to optimize the grain storage for food security, minimizing the post-harvest losses, integrating advanced technologies, and promoting environmental sustainability. By enhancing the efficiency of grain storage facilities, we aim to empower farmers, improve supply chain resilience, and contribute to a sustainable and consistent food supply for the growing global population. The final product benefits farmers, grain storage facility operators, food distributors, consumers, and the global food supply chain. Optimized storage practices ensure increased profitability for farmers, efficient facility management, reliable grain availability for distributors, and a stable food supply for consumers. The entire supply chain gains resilience, contributing to global food security.

II. LITERATURE SURVEY:

Title: Thick Layer Drying and Storage Of Rice Grain Cultivars in Silo-Aerator : Quality Evaluation at Low Drying Temperature:

Author: ***Rosana Santos de Moraes, Paulo CarteriCoradi, Marcela TrojahnNunes, Marisa Menezes Leal, Edson Irineu Müller, Paulo Eduardo Teodoro, Erico Marlon Moraes Flores****Department of Agricultural Engineering, Rural Science Center, Federal University of Santa Maria, Santa Maria, RS 97105-900, Brazil.*

Findings: This study assessed the impact of single-layer drying of rice in a silo-dryer-aerator at low temperatures. Results indicated that this method preserved physicochemical properties, morphology, and starch characteristics, especially in the lower layers, with Guri INTA and BRS Pampeira cultivars exhibiting superior quality.

Disadvantages: may pose a logistical challenge, increased energy consumption and operational costs.

Title: Nanostructured antifouling coatings for galvanized steel food storage and container surfaces to enhance hygiene and corrosion resistance against bacterial, fungal, and mud contamination:

Author: ***Wentao Zhou, Shuhao Liu, William DeFlorio, Sang Ha Song, Hayoung Choi, Luis Cisneros-Zevallos, Jun Kyun Oh, Mustafa E.S. Akbulut*** Department of Food Science, Texas A&M University, College Station, TX, 77843, USA

Findings: The study introduces a super hydrophobic and antifouling coating for galvanized steel, inhibiting attachment of fungi, bacteria, and mud. This coating, with a 157° water contact angle, demonstrates substantial reduction in bacterial and fungal adherence, making it promising for diverse applications in food-related storage and processing.

Disadvantages: Scaling and cost challenges arise in the two-step silica coating process.

Title: Studies on the application of bio-carbon dioxide as controlled atmosphere on pest management in wheat grain storage:

Author: ***Himanshu Kumar, Virendra K. Vijay, Paruchuri M.V. Subbarao, Ram Chandra*** *Centre for Rural Development and Technology, Indian Institute of Technology Delhi, HauzKhas, New Delhi, 110016, India.*

Findings: The study investigated the efficacy of bio-CO2, a purified waste gas from a compressed biogas plant, for wheat grain storage. Bio-CO2 demonstrated superior insect mortality and maintained seed quality compared to pure CO2 over two and six months. The controlled atmosphere treatment showed no significant seed weight loss and minor impact on nutrient content. However, high CO2 concentration affects seed germination after six months.

Disadvantages: Bio-CO2 for wheat storage may impact seed germination at high concentrations, posing a disadvantage compared to pure CO2.

Title: Temperature forecasting of grain in storage: A multi-output and spatiotemporal approach based on deep learning:

Author:***Zhongke Q, Yang Zhang, Chao Hong, Changdong Zhang, Zhongwen Dai, Yanyan Zhao, Xiaodong Wu, Yuan gao, Xuemei Jiang, Jing Qian, ZhaolinGu****Xi'an Branch of China Grain Reserves Group Co. Ltd, Xi'an 710075, China.*

Findings: This paper addresses limitations in grain temperature forecasting models by proposing a multi-output spatiotemporal model using Graph Convolution Neural Networks and Transformer. The model outperforms existing ones, enabling continuous temperature field predictions in a granary. **DISADVANTAGES:** Existing models lack spatial awareness, hindering grain temperature forecast accuracy.

GUNNY BAGS: Approximately **41.5%** of farmers use gunny bags for grain storage.

Fig 1: Gunny Storage

BULK STORAGE IN ROOMS: About **18.1%** of farmers store grains in rooms. **Metallic Bins**: Around **11.1%** of farmers opt for metallic bins.

Fig 2: Bin Storage

Bulk (Open) Storage and Other Traditional Structures: The remaining **30.0%** of farmers use various local materials and structures, including: Storage baskets made from plant materials. Underground storage. **Post-Harvest Losses**: Unscientific storage practices contribute to post-harvest losses, estimated at **10%** of total food grains in India. **Economic Impact**: Annual storage losses amount to **14 million tons** of food grains worth **Rs. 7,000 crore** (approximately $950 million), with insects alone causing losses of nearly **Rs. 1,300 crores**.

TYPES OF LOSSES:

1) **Quantitative Loss**: Direct feeding insects reduce the weight of stored grains.
2) **Qualitative Loss**: Insects contaminate grains, cause chemical changes, and spread microorganisms.
3) **Loss of Seed Viability**: Insects affect seed viability.
4) **Damage to Storage Structures**: Some insects can destroy wooden structures and containers.

III. MATERIALS AND METHODS

Integration of advanced sensors: Incorporating state-of-the-art sensors capable of detecting minute changes in moisture content, temperature, and other environmental factors can provide more precise and real-time monitoring of grain storage conditions.

Table 1: IOT Materials Required

IOT SENSORS
1. Arduino 2. Temperature & Humidity sensor 3. Thermal cameras 4. Weight sensor

Fig 3 :Arduino

Fig 4 : Temp. and Humid. Sensor

Fig 5 : Thermal Camera

Implementation of predictive analytics: Utilizing data collected from automated inspections, predictive analytics algorithms can be developed to forecast potential mold and pest outbreaks. This proactive approach can help preemptively address issues before they escalate, further reducing grain loss.

Remote monitoring and control: Introducing remote monitoring capabilities will allow personnel to access real-time data on grain storage conditions and receive alerts or notifications regarding any anomalies or potential threats. Additionally, remote control functionalities can enable adjustments to storage parameters and intervention measures from a centralized location.

Integration of inventory management features: The automated inspection system can be augmented with inventory management capabilities, allowing warehouse owners to update the status of their storage facilities through a dedicated app portal.

Fig 6 : App

This feature enables warehouse owners to indicate the availability of storage space, providing real-time visibility into capacity utilization. By allowing warehouse owners to promptly update the app portal when a significant portion of their storage space becomes vacant (e.g., 3 out of 5 compartments), the system facilitates efficient allocation of resources and helps streamline grain storage logistics for both the company and its partners. **Customized warehouse options for farmers:** Farmers can choose warehouse features tailored to their needs (e.g., cold storage for perishables, bin storage for grains). Vacant spaces can be listed, facilitating efficient rentals and maximizing utilization.

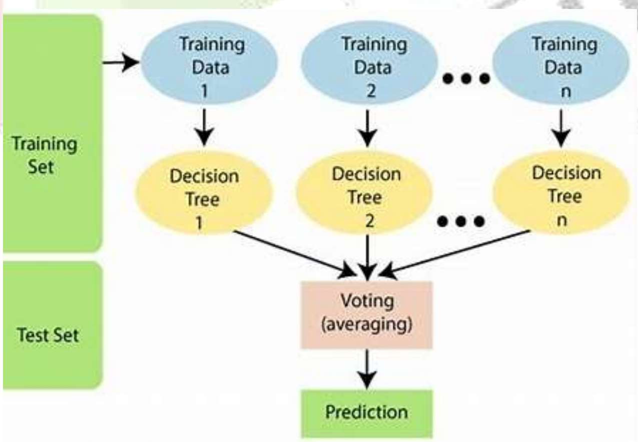

Fig 7: Random Forest

Data Collection and Integration: Gather data from sensors, historical records, and other sources to create a comprehensive dataset. This dataset should include information on environmental conditions, inventory status, pest and mold outbreaks, and warehouse occupancy.

Machine Learning Model Development: Utilize machine learning algorithms to analyze the collected data and develop models for predictive analytics. These models can forecast potential mold and pest outbreaks, predict optimal storage conditions, and identify patterns in warehouse occupancy and utilization.

Real-time Monitoring and Control System: Implement AI-powered algorithms to continuously monitor grain storage conditions in real-time. These algorithms can detect anomalies and potential threats, trigger alerts or notifications, and recommend appropriate intervention measures based on predefined rules or learned patterns.

Integration of Inventory Management: Develop AI-driven inventory management systems that can dynamically update warehouse status and availability based on real-time data. These systems should be capable of automatically adjusting inventory levels, optimizing storage allocations, and facilitating efficient rentals between warehouse owners and farmers.

Personalized Recommendations and Optimization: Leverage AI algorithms to provide personalized recommendations to warehouse owners and farmers based on their specific needs and preferences. These recommendations can include suggestions for optimal storage conditions, inventory management strategies, and rental opportunities that maximize efficiency and profitability. **Continuous Learning and Improvement:** Implement mechanisms for continuous learning and improvement within the AI system. This involves updating machine learning models with new data, refining algorithms based on feedback and performance metrics, and adapting to evolving trends and requirements in the agricultural industry.

IV.PROPOSED ARCHITECTURE

Fig 8 : Workflow

1. **Data Collection Layer:**
   - Sensors: Deploy advanced sensors (e.g., temperature, humidity, CO2 levels) within grain storage facilities. These sensors continuously collect environmental data.
   - Historical Records: Integrate existing historical data from grain storage records.
2. **Data Integration and Preprocessing Layer:**
   - Data Fusion: Combine data from sensors and historical records to create a comprehensive dataset.
   - Data Cleaning: Handle missing values, outliers, and noise.
   - Feature Engineering: Extract relevant features (e.g., average temperature, humidity trends).
3. **Machine Learning Model Development Layer:**
   - Predictive Analytics Models:
     - Develop ML models (e.g., regression, time series analysis) to predict grain spoilage, mold outbreaks, and optimal storage conditions.
     - Train models using historical data and real-time sensor data.
   - Convolutional Neural Networks (CNN):
     - Use CNNs for image-based quality assessment (e.g., grain images).
     - Detect anomalies (e.g., mold spots) in grain samples.
4. **Real-time Monitoring and Control Layer:**
   - IoT Gateway:
     - Collect real-time data from sensors.
     - Transmit data to the cloud or local server.
   - Alerts and Notifications:
     - Trigger alerts (via SMS, email, or app notifications) when anomalies are detected (e.g., sudden temperature rise).
     - Notify warehouse personnel and farmers.
   - Remote Control:
     - Allow remote adjustments of storage parameters (e.g., temperature, ventilation) based on ML recommendations.

        - Enable intervention measures (e.g., turning on fans, adjusting humidity levels).

5. **Inventory Management and Resource Allocation Layer:**
    - App Portal:
        - Develop a user-friendly mobile app for warehouse owners and farmers.
        - Warehouse owners can update storage status (e.g., vacant compartments) via the app.
    - Dynamic Inventory Updates:
        - Automatically adjust inventory levels based on real-time data.
        - Optimize storage allocations (e.g., allocate available space efficiently).
        - Facilitate rentals between warehouse owners and farmers.
6. **Personalized Recommendations Layer:**
    - AI-driven Suggestions:
        - Provide personalized recommendations to warehouse owners and farmers:
            - Optimal storage conditions (e.g., temperature range, humidity).
            - Inventory management strategies (e.g., prioritize perishables).
            - Rental opportunities (based on available space).
    - User Preferences:
        - Learn from user interactions and preferences to tailor recommendations.
7. **Continuous Learning and Improvement Layer:**
    - Feedback Loop:
        - Gather feedback from users (e.g., warehouse owners, farmers).
        - Update ML models with new data periodically.

V. CONCLUSION:

The proposed project aims to address grain storage losses by leveraging a robust technology stack. By combining hardware components like IoT devices, sensors, and cameras with a sophisticated software infrastructure, to maintain the data in cloud services, open source databases, and applications, the solution provides remote monitoring and automated grain inspection capabilities. This comprehensive approach considers both biotic and abiotic factors influencing storage losses. The system's features, such as real-time monitoring through mobile applications, coupled with a notification system for pest and mold alerts, empower users to proactively manage grain storage conditions. The automated grain inspection, powered by image processing and machine learning, enhances precision in identifying and mitigating potential threats to grain quality. Security measures, including authentication, authorization, and data encryption, ensure the integrity and confidentiality of sensitive information. The technology stack's scalability and performance enhancements, such as containerization and load balancing, contribute to a reliable and scalable solution. In essence, this project offers a comprehensive, technologically advanced solution to minimize grain storage losses, providing a valuable tool for farmers, storage facility managers, and stakeholders in the agricultural supply chain.

Reference:

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