A Semantic Framework for Monitoring Wheat Grain Warehouses

Djakhdjakha Lynda[1,*,†], Farou Brahim[1,†], Bouacida Imane[1,†] and Meguellatni Aya[2,†]

[1]LabSTIC Laboratory, Computer Science Department, 8 Mai 1945 Guelma University, Guelma, 24000, Algeria
[2]Computer Science Department, 8 Mai 1945 Guelma University, Guelma, 24000, Algeria

Abstract

The grain storage ecosystem involves multifaceted interactions among diverse elements responsible for preserving, managing, and utilizing stored grains. In recent years, there has been a notable upsurge in research focused on enhancing the management of grain warehouses. While existing approaches often relied on limited data sources or narrow information scopes, in this paper we diverge significantly by harnessing a broad spectrum of data streams to provide a more comprehensive understanding. Our research endeavors to develop a groundbreaking framework tailored for managing wheat grain warehouses, placing a significant emphasis on integrating heterogeneous data sources. This integration aims to achieve a thorough comprehension of grain historical data, grain storage conditions, insect behavior, and disease dynamics based on a new ontology that encapsulates domain-specific knowledge and offers a structured representation of essential concepts, relationships, and entities. Additionally, our framework implements image processing algorithms designed to detect disease symptoms based on the proposed ontology, thereby enhancing the capability of the system to identify and respond to potential threats to stored grain quality and safety.

Keywords

Domain ontology, IoT, Sensors, Storage Conditions, Warehouse, Warehouse management, Wheat disease, Wheat grain, Warehouse management

1. Introduction

Wheat is one of the most important staple crops globally, serving as a vital source of nutrition for millions of people [1]. To ensure a steady supply of high-quality wheat, efficient storage and management practices are crucial. Wheat grain warehouses play a pivotal role in preserving and safeguarding wheat crops, ensuring their availability throughout the year[2]. However, these warehouses face various challenges that impact the quality and quantity of stored wheat, necessitating innovative solutions to address these issues [3].

One of the significant problems encountered in wheat warehouses is the occurrence and spread of diseases and insects among stored wheat. These pests can lead to significant losses in yield, nutritional quality, and overall grain value. Furthermore, infected wheat can contaminate surrounding batches, exacerbating the problem and increasing the risk of economic losses for farmers and distributors.

Detecting and managing wheat grain in warehouses presents a multifaceted challenge [4]. Traditional manual inspection methods for disease detection suffer from limitations, such as time-consuming processes and labor-intensiveness, particularly in large storage facilities, leading to delays in disease detection and response. Visual inspection, the primary method utilized, is subjective and relies heavily on inspectors' expertise, resulting in inconsistencies and potential misdiagnosis [5]. Moreover, identifying diseases in stored wheat is complicated by various factors, including the wide variability in disease symptoms and their manifestation, making disease identification challenging and increasing the risk of misdiagnosis. Additionally, distinguishing disease symptoms from natural blemishes or storage-related issues can be difficult. The warehouse environment itself provides conducive conditions for

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*Corresponding author.
†These authors contributed equally.
djakhdjakha.lynda@univ-guelma.dz (D. Lynda); farou.brahim@univ-guelma.dz (F. Brahim); bouacida.imane@univ-guelma.dz (B. Imane); meguellatni.aya@univ-guelma.dz (M. Aya)
0000-0001-9596-3077 (D. Lynda); 0000-0002-1609-6006 (F. Brahim); 0000-0002-2189-1741 (B. Imane)

disease spread, with high-density storage facilitating pathogen transmission and warehouse conditions like temperature and humidity promoting pathogen growth. If left unchecked, these conditions can accelerate disease development and heighten the risk of widespread infections within the storage facility.

The advent of IoT data in agriculture offers immense opportunities for addressing these challenges. With the advancement of sensing technologies, warehouses can now collect vast amounts of data related to temperature [6], humidity, air quality, and other environmental factors [7]. Additionally, high-resolution imaging techniques allow for detailed monitoring of wheat grains, enabling the identification of pests symptoms and abnormalities [8].

In recent years, there has been a significant increase in research focusing on the control and management of grain warehouses. Existing works can be categorized based on their focus on different issues and the types of sensors used. Works such as the model proposed in [9] concentrate on environmental conditions, specifically temperature and humidity monitoring. This model efficiently acquires temperature and humidity measurements and triggers alarms if values exceed predefined limits, facilitating easy monitoring of stored items and preventing grain damage, thus enhancing their quality and longevity. Additionally, works like [2, 10, 11, 12] utilize IoT technologies for real-time monitoring of storage conditions. These systems employ various sensors such as temperature, humidity, CO2, vibration, and fire sensors to observe critical parameters for grain preservation. They collect sensor data, transmit it to centralized monitoring platforms, analyze it for deviations from optimal storage conditions, and generate alerts for prompt corrective actions. These systems offer benefits such as reduced stock losses due to inadequate storage conditions, rapid intervention in case of detected issues, continuous surveillance without human intervention, and cloud-based storage of warehouse data, thus improving efficiency and precision in monitoring and management practices. On the other hand, work [16] addresses intrusion detection and grain tracking within warehouses. Using sensors like PIR sensors for intrusion detection and RFID sensors for individual grain tracking, this IoT-based prototype aims to improve warehouse security and enable precise grain tracking within food reserve agencies. Moreover, recent studies like [6] introduce computer algorithms designed for remote monitoring and inspection of stored grain within large bulk storage facilities, focusing on analyzing the spatiotemporal distributions of the temperature field to detect changes in grain quantity and quality. Additionally, emerging technologies like deep learning, as demonstrated in [13, 8], are being employed for insect detection and monitoring within grain storage facilities, offering potential advancements in pest control and quality management practices.

The grain storage ecosystem encompasses the multifaceted interactions between various elements involved in the preservation, management, and utilization of stored grains [14]. It comprises physical infrastructure such as warehouses, environmental factors like temperature and humidity, biological aspects such as pests and microorganisms, and historical data of harvest and drying practices. Maintaining optimal environmental conditions, implementing effective pest management strategies, and adhering to best practices are crucial for preserving grain quality and preventing spoilage.

In contrast to existing approaches, this research focuses on the development of a new framework for wheat grain warehouses management places a strong emphasis on integrating heterogeneous data sources to provide a comprehensive understanding of grain storage conditions, insects and disease dynamics. While previous methods have often relied on singular data sources or limited types of information, our approach leverages a wide range of data streams to offer a more holistic perspective. Furthermore, the integration and analysis of heterogeneous data sources necessitate sophisticated techniques capable of managing diverse data formats and structures seamlessly. In this study, we introduce a novel ontology that serves as the cornerstone of our framework. This ontology encapsulates the knowledge pertaining to the grain warehouse domain, providing a structured representation of essential concepts, relationships, and entities. Furthermore, we will validate the efficacy of the proposed ontology by integrating image processing algorithms tailored to identify disease symptoms.

The paper is structured as follows: Section 2 provides a comprehensive background on the insects and diseases impacting wheat grain storage, elucidating their associated symptoms. Section 3 introduces the Semantic Framework for Monitoring Wheat Grain Warehouses, detailing the diverse data sources and presenting the framework's architecture and ontology model. Section 4 discusses the Implementation, describing the development process using Python and Owlready2. Finally, Section 5 concludes the paper by summarizing the key findings, addressing limitations, and presenting perspectives for future research and development.

2. Background

Wheat quality is a complex concept[15]. In warehouses, storage losses stem from both biotic and abiotic factors. Biotic factors encompass insects, pests, rodents, and fungi, while abiotic factors include temperature, humidity, and rainfall [16].

2.1. Insects Found in Wheat Grain Warehouses

Grain warehouses face the threat of various insects that can compromise the quality and quantity of stored grains [17]. Among these, wheat grain warehouses are particularly vulnerable to pests such as the Red Flour Beetle (Tribolium castaneum), Lesser Grain Borer (Rhyzopertha dominica), and Granary Weevil (Sitophilus granarius) [18, 19, 20]. These insects pose significant risks, leading to both quantitative and qualitative losses in stored wheat grains. Common signs of insect infestation in wheat grain warehouses include the presence of live insects or their larvae, damage to grains such as holes and tunnels, and the accumulation of insect frass and cast skins [19, 18]. Recognizing these symptoms is vital for early detection and prompt intervention to mitigate insect infestations and minimize losses.

2.2. Wheat Diseases in grain warehouses

The storage environments can provide favorable conditions for the development and spread of various diseases, posing significant threats to grain quality and quantity[18, 19, 20]. The common wheat grain diseases :

- `Fungal Diseases`: Fungal diseases are among the most prevalent and damaging pathogens affecting wheat grains during storage. Common fungal pathogens include species of Fusarium, Aspergillus, and Penicillium, which can cause grain discoloration, mold growth, and mycotoxin contamination. Fusarium species are notorious for causing Fusarium head blight (FHB), leading to grain shriveling, discoloration, and reduced quality.
- `Bacterial Diseases`: While less common than fungal diseases, bacterial pathogens such as Bacillus and Pseudomonas can also infect stored wheat grains. Bacterial infections typically result in soft rot, slimy grains, and foul odors. These diseases can accelerate grain deterioration and compromise storage quality.

3. A semantic Framework for Monitoring Wheat Grain Warehouses

This section introduces a semantic framework tailored for the monitoring of wheat grain warehouses. It outlines data sources, the conceptual foundation and methodology and the semantic model used in data representation.

3.1. Data Sources

One key aspect of our framework is the incorporation of diverse data gathered from several sources including: sensor technologies, datasets and analysis reports.

3.1.1. Remote Sensing Data

Integrating sensors in wheat grain warehouses for monitoring insects and diseases represents a significant advancement in our agricultural framework. These following sensors provide real-time data on environmental conditions, pest activity, insect and disease presence, enabling proactive pest management and disease control strategies [2, 10, 11, 12, 13, 8].

- `Temperature Sensors`: Temperature fluctuations can impact the growth of pathogens and pests in grain warehouses. Temperature sensors continuously monitor the temperature inside the warehouse to ensure it remains within optimal ranges for wheat storage. Deviations from these ranges can indicate potential issues such as fungal growth or pest activity.
- `Humidity Sensors`: Humidity levels can affect the development of fungal diseases. Humidity sensors measure the relative humidity inside the warehouse, helping to prevent conditions that promote mold growth and mycotoxin contamination.
- `Gas Sensors`: Gas sensors detect gases emitted by decaying organic matter or chemical reactions. Certain gases, such as carbon dioxide (CO_2) and ethylene, can indicate the presence of fungal or bacterial activity. Gas sensors help detect these gases early, allowing for timely intervention to prevent the spread of diseases.
- `Insect Monitoring Sensors`: Insect monitoring sensors detect the presence of insects or pests in grain storage facilities. These sensors can use various techniques, such as pheromone traps or acoustic monitoring, to detect pests early and prevent infestations.
- `Motion Sensors`: Motion sensors detect movement within the grain storage facility and can alert to the presence of rodents. By monitoring for unexpected movement, motion sensors help prevent vandalism, and tampering with stored wheat.
- `RGB Cameras`: Incorporating RGB cameras in grain warehouses introduces a novel dimension to monitoring and management practices. These cameras capture high-resolution images in red, green, and blue wavelengths, offering detailed visual data for assessing grain quality, detecting pests, and identifying disease symptoms. By deploying RGB cameras strategically throughout the warehouse, operators gain real-time visibility into grain storage conditions, facilitating early detection of insect infestations, fungal growth, and other anomalies.
- `Thermal camera`: The integration of thermal cameras in grain warehouses represents a significant advancement in monitoring and management technology. These specialized cameras detect and visualize temperature variations across the stored grain, offering insights into potential hotspots, moisture gradients, and signs of microbial activity.

3.1.2. Laboratory Analysis Reports

The quality of wheat grain in warehouses is characterized by a set of characteristics including [21] [15]: Moisture content, Total protein content, Wet gluten content and Starch content. Laboratory analysis plays a crucial role in wheat grain storage by providing valuable insights into the quality and safety of stored grains. These analyses involve comprehensive testing to assess various parameters such as :

- `Moisture Content`: Measurement of the moisture content in wheat grains is essential for determining their quality and susceptibility to spoilage. High moisture levels can lead to mold growth and grain degradation.
- `Protein Content`: The protein content of wheat grains is crucial for assessing their nutritional value and suitability for various end uses, such as baking and food processing.
- `Starch Content`: Starch is a major component of wheat grains and plays a significant role in determining their texture and cooking properties. Analyzing starch content helps evaluate grain quality and processing characteristics.
- `Gluten Content`: Gluten is a protein complex found in wheat grains that provides elasticity and structure to dough. Assessing gluten content is essential for determining the suitability of wheat grains for baking and producing gluten-containing products.

- `Ash Content`: Ash content indicates the mineral content present in wheat grains, which can influence their nutritional value and storage stability.
- `Fungal and Bacterial Contamination`: Laboratory analysis may include testing for the presence of fungi, bacteria, and other microbial contaminants in wheat grains. Identifying microbial contamination is critical for ensuring food safety and preventing spoilage.
- `Toxicological Analysis`: Laboratory reports may include toxicological analysis to detect the presence of mycotoxins, pesticides, and other harmful substances in wheat grains. Monitoring for toxins is essential for ensuring compliance with food safety regulations and protecting consumer health.
- `Physical Characteristics`: Analysis of physical characteristics such as grain size, shape, color, and texture can provide insights into grain quality and processing suitability.
- `Nutritional Composition`: Laboratory analysis may include determining the nutritional composition of wheat grains, including vitamins, minerals, and other essential nutrients.

By analyzing samples collected from stored wheat grains, laboratory tests can detect the presence of pathogens, fungi, molds, and other microorganisms that may compromise grain quality or pose health risks. Additionally, laboratory analysis reports provide data on grain characteristics and composition, helping to determine storage conditions and potential risks of spoilage or deterioration. This information guides storage management practices, including temperature and humidity control, pest management strategies, and appropriate handling and processing techniques.

3.1.3. Historical datasets

A historical dataset on harvest and drying stored grain refers to a collection of past records or data points detailing the processes and conditions involved in harvesting and drying grain before storage. This dataset typically includes information such as:

- `Harvest Dates`: Records of when the grain was harvested, including specific dates or time periods.
- `Harvest Conditions`: Information about weather conditions, moisture levels, and other factors affecting the harvest process.
- `Drying Methods`: Details on the methods used to dry the harvested grain, such as natural air drying, mechanical drying, or other techniques.
- `Drying Duration`: Duration of the drying process, including start and end times or total number of days.
- `Drying Conditions`: Conditions during the drying process, such as temperature, humidity, and airflow rates.
- `Grain Quality Parameters`: Assessments of grain quality before and after drying, including moisture content, uniformity, and potential damage.

Historical data about harvest and drying practices can greatly help predict and manage storage grain diseases and insects in several ways. Firstly, by looking at past records, we can spot patterns and connections between factors like moisture levels, temperature changes, and storage duration that may lead to grain diseases. Detecting any deviations from normal conditions early on can prompt quick action to prevent diseases from spreading.

By integrating data from these disparate sources, we gain a multi-dimensional view of the grain storage environment, encompassing physical parameters, chemical composition, and potential biological threats [14].

3.2. Overview of the Proposed Framework

In our context, laboratory analysis reports and historical datasets provide intricate meticulous grain quality assessments. These data, when combined with remote sensing data, afford macroscopic views

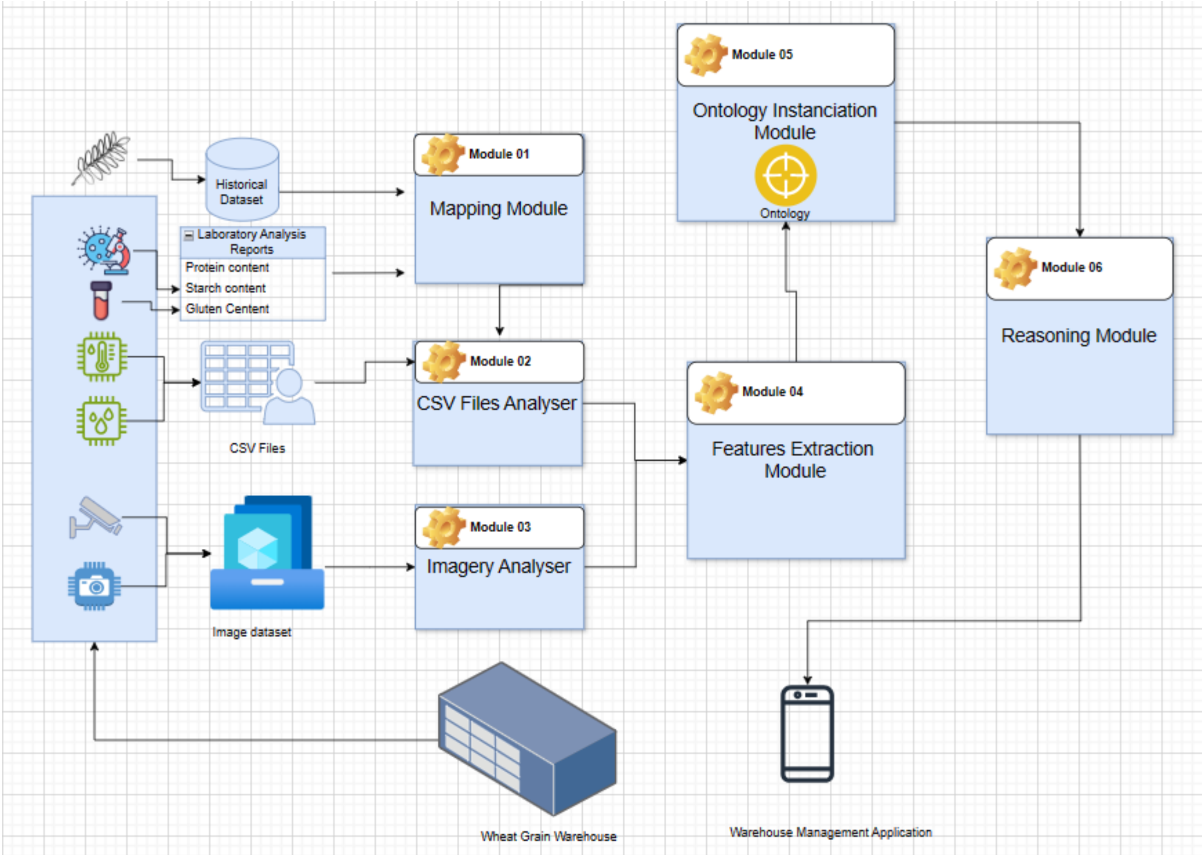

Figure 1: The Semantic Framework Architecture

of the warehouse environment, capturing trends in temperature, humidity, and other environmental conditions. Granular visual data from RGB cameras enable the detection of pests and anomalies, while thermal cameras unveil temperature differentials indicative of moisture content and pest activity.

To fully exploit the potential of these diverse datasets, a robust ontology is indispensable. The ontology serves as the cornerstone in our work, harmonizing disparate data formats and vocabularies into a cohesive semantic structure. It standardizes terminology and relationships, facilitating seamless data integration, query, and inference, thus forming a robust framework for collecting, organizing, and analyzing data related to wheat grain in warehouses.

Our semantic framework (Figure 01) is designed to gather data from various sources, including reports and warehouse environments. The data collected from analysis reports and historical datasets are structured and mapped to CSV files, ensuring compatibility and ease of processing.

Upon ingestion, the framework checks the dataset types to determine the appropriate analysis procedures. Different analyzers are employed for each dataset type, allowing for tailored processing and extraction of relevant information.

The framework systematically extracts useful insights from the datasets, leveraging its analyzers to identify patterns, trends, and anomalies. Subsequently, the extracted information is utilized to instantiate the ontology, enriching its knowledge base with real-world data.

After each instantiation, the framework employs inference mechanisms to derive additional insights and relationships within the ontology. This iterative process enhances the ontology's depth and breadth of knowledge, enabling more nuanced analysis and decision-making.

The semantic framework streamlines the integration of heterogeneous data sources, will facilitate automated analysis, and will empower users with actionable insights for efficient wheat grain management in warehouses.

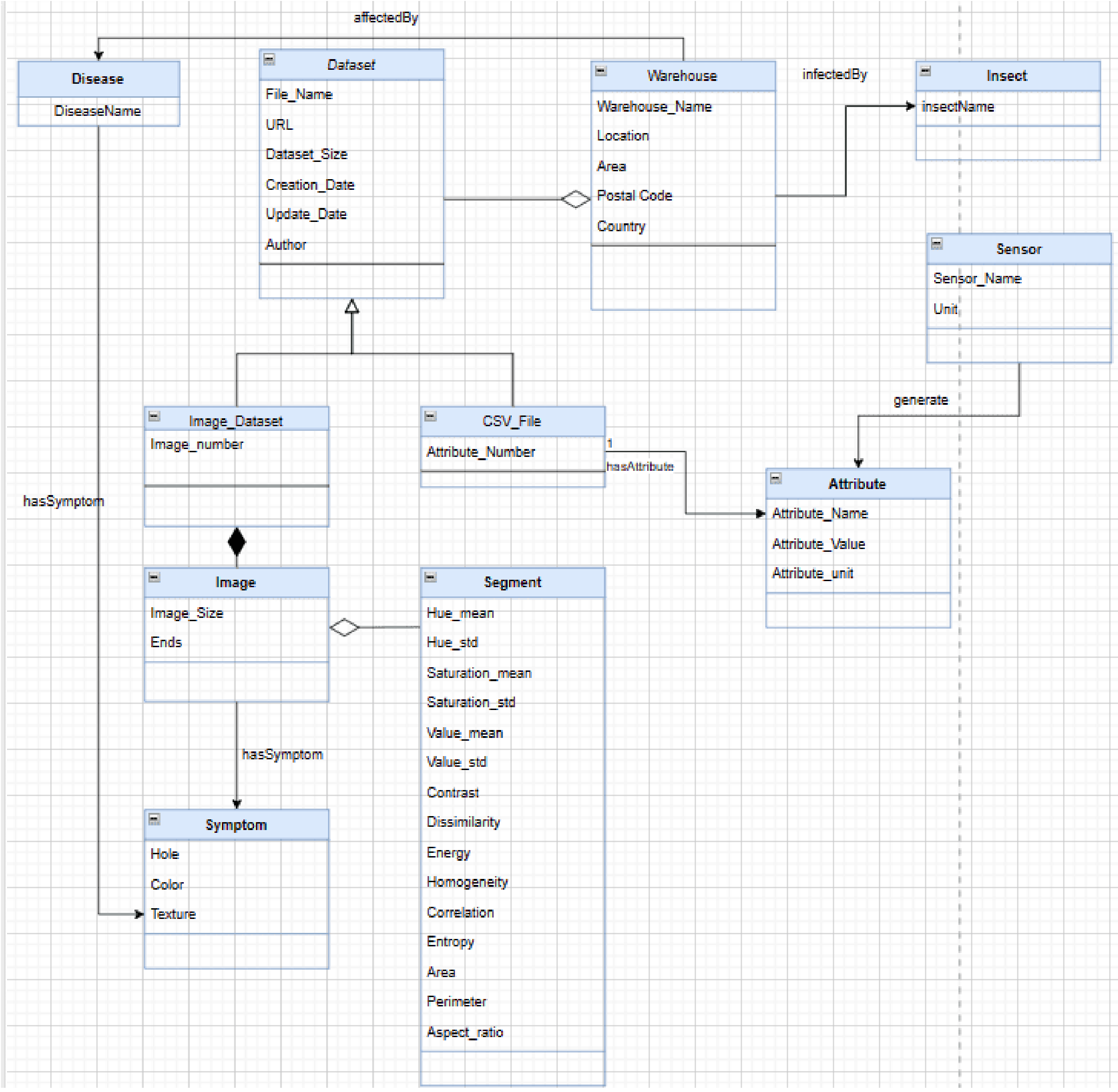

Figure 2: Meta-model of the Wheat Grain Warehouses Domain

3.3. Ontology Development and Data Representation

At the core of our framework lies the concept of ontology, serving as the foundational pillar that underpins the organization and interpretation of heterogeneous data sources in wheat grain management. We introduce a novel meta-model designed to encapsulate the intricate web of concepts, relationships, and entities pertinent to the domain of wheat grain warehouses (Figure 02). This meta-model not only delineates the fundamental elements within the domain but also establishes a structured framework for understanding the complex interplay between various data components. Based on this model and ontology definition, we develop a new domain ontology related to wheat grain warehouses. The new ontology facilitates the seamless integration and harmonization of disparate data streams, enabling comprehensive analysis and informed decision-making in wheat grain management practices.

4. Implementation

Through the establishment of a unified semantic structure encoded in OWL2, our goal is to enhance data interoperability, facilitate knowledge sharing, and enable advanced analytics. In our implementation, as

```python
def create_ontology(self):
    # Define the SWRL-like rule as a DL query
    onto = get_ontology("http://test.org/onto.owl")
    with onto:
        class Images(Thing):pass
        class Dataset(Thing):pass
        class symptome(Thing):pass
        class segment(Thing):pass
        class hole(Images >> bool, FunctionalProperty):pass
        class color(Images >> str, FunctionalProperty):pass
        class texture(Images >> str, FunctionalProperty):pass
        class hue_mean(segment >> float, FunctionalProperty):pass
        class hue_std(segment >> float, FunctionalProperty):pass
        class saturation_mean(segment >> float, FunctionalProperty):pass
        class saturation_std(segment >> float, FunctionalProperty):pass
        class value_mean(segment >> float, FunctionalProperty):pass
        class value_std(segment >> float, FunctionalProperty):pass
        class contrast(segment >> float, FunctionalProperty):pass
        class dissimilarity(segment >> float, FunctionalProperty):pass
        class energy(segment >> float, FunctionalProperty): pass
        class homogeneity(segment >> float, FunctionalProperty):pass
        class correlation(segment >> float, FunctionalProperty):pass
        class entropy(segment >> float, FunctionalProperty):pass
        class entropy(segment >> float, FunctionalProperty): pass
        class area(segment >> float, FunctionalProperty): pass
        class perimeter (segment >> float, FunctionalProperty): pass
        class aspect_ratio(segment >> float, FunctionalProperty): pass
        class holes(segment >> bool, FunctionalProperty): pass
        AllDisjoint([Images, Dataset,segment,symptome])
```

Figure 3: Implementation of the semantic structure

a first step, we have utilized the Python programming language along with the Owlready2 library to construct and manage the ontology (Figure 03). This ontology serves as a structured knowledge base, facilitating data integration.

Our goal is to effectively extract structured data from diverse sources and reformat it for seamless analysis. To accomplish this, we've implemented the methodology proposed by [22] for extracting attributes from CSV files. Additionally, for handling image datasets, we've integrated sophisticated image processing algorithms tailored to analyze uploaded images of wheat grains. These algorithms utilize advanced techniques including segmentation, feature extraction, and pattern recognition to discern symptoms indicative of grain diseases, such as color variations, texture anomalies, and the presence of holes (Figure 04).

5. Conclusion, Limitation and Perspectives

In this paper, we have proposed a new semantic framwork. Our framework represents a significant advancement in the monitoring and management of wheat grain warehouses. By leveraging semantic technologies, we have established a robust infrastructure capable of integrating heterogeneous data sources and providing valuable insights into grain storage conditions and disease dynamics. Through the implementation of ontology, we have achieved a structured representation of domain knowledge,

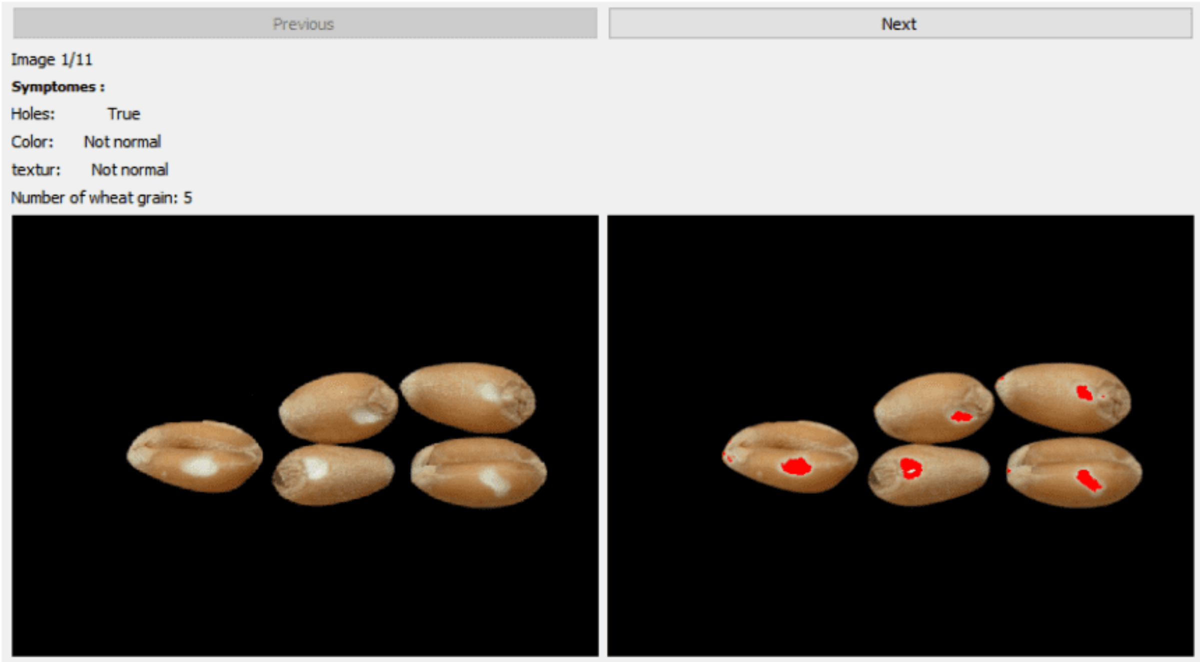

Figure 4: Extraction Symptoms from Image Datasets

facilitating the seamless organization and interpretation of complex data streams. Additionally, our framework incorporates sophisticated image processing algorithms to accurately identify symptoms indicative of grain diseases, further enhancing the precision and efficiency of our monitoring capabilities. Despite these advancements, it is important to acknowledge the limitations of our system, such as the absence of an implementation of the inference module and the need for additional data on insect infestations. Moving forward, we anticipate addressing these challenges and further refining our framework to meet the evolving needs of grain storage management. With continued research and development, our semantic framework holds the potential to revolutionize the monitoring and preservation of wheat grain.

Declaration on Generative AI

During the preparation of this work, the author(s) used GPT-4 in order to correct grammatical errors, typos, and other writing mistakes. After using this tool, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the publication's content.

References

[1] P. R. Shewry, S. J. Hey, The contribution of wheat to human diet and health, Food and energy security 4 (2015) 178–202.

[2] J. Lydia, R. Monisha, R. Murugan, et al., Automated food grain monitoring system for warehouse using iot, Measurement: Sensors 24 (2022) 100472.

[3] M. V. Petre, M. E. Popa, Effect of storage conditions on wheat quality parameters-a minireview. (2020).

[4] M. L. Flint, IPM in practice: principles and methods of integrated pest management, volume 3418, University of California Agriculture and Natural Resources, 2012.

[5] G. J. Daglish, M. K. Nayak, F. H. Arthur, C. G. Athanassiou, Insect pest management in stored grain, Recent advances in stored product protection (2018) 45–63.

[6] W. Wu, H. Cui, F. Han, Z. Liu, X. Wu, Z. Wu, Q. Zhang, Digital monitoring of grain conditions

in large-scale bulk storage facilities based on spatiotemporal distributions of grain temperature, Biosystems Engineering 210 (2021) 247–260.
[7] S. Shaik, L. R. M, M. K, P. M, K. B, H. Begum, Iot-enabled optimised sensor-based system for monitoring grain storage, in: 2023 4th International Conference on Electronics and Sustainable Communication Systems (ICESC), 2023, pp. 394–400. doi:10.1109/ICESC57686.2023.10193067.
[8] C. M. Badgujar, P. R. Armstrong, A. R. Gerken, L. O. Pordesimo, J. F. Campbell, Real-time stored product insect detection and identification using deep learning: System integration and extensibility to mobile platforms, Journal of Stored Products Research 104 (2023) 102196.
[9] B. K. Rai, S. A. H. Zaidi, D. Singh, Devops sensoring neuro cluster, in: ICCCE 2021: Proceedings of the 4th International Conference on Communications and Cyber Physical Engineering, Springer, 2022, pp. 69–77.
[10] K. Mohanraj, S. Vijayalakshmi, N. Balaji, R. Chithrakkannan, R. Karthikeyan, Smart warehouse monitoring using iot, International journal of engineering and advanced technology 8 (2019) 3597–3600.
[11] R. K. Kodali, J. John, L. Boppana, Iot monitoring system for grain storage, in: 2020 IEEE International Conference on Electronics, Computing and Communication Technologies (CONECCT), IEEE, 2020, pp. 1–6.
[12] Q. Wang, M. Xia, Y. Chen, Y. Yu, Design and implementation of wsn-based warehouse temperature sensor monitoring system, in: Journal of Physics: Conference Series, volume 2246, IOP Publishing, 2022, p. 012006.
[13] Q. A. Mendoza, L. Pordesimo, M. Neilsen, P. Armstrong, J. Campbell, P. T. Mendoza, Application of machine learning for insect monitoring in grain facilities, AI 4 (2023) 348–360.
[14] D. S. Jayas, Storing grains for food security and sustainability, Agricultural Research 1 (2012) 21–24.
[15] M. R. Simón, M. C. Fleitas, A. C. Castro, M. Schierenbeck, How foliar fungal diseases affect nitrogen dynamics, milling, and end-use quality of wheat, Frontiers in Plant Science 11 (2020) 569401.
[16] Á. Mesterházy, J. Oláh, J. Popp, Losses in the grain supply chain: Causes and solutions, Sustainability 12 (2020) 2342.
[17] M. Isbatullah, S. H. Amrullah, R. Harnita, Inventory of warehouse pests on grain samples at the plant quarantine laboratory of the makassar agricultural quarantine center, Journal Of Biology Education 6 (2023) 23–39.
[18] E. DEMIS, W. YENEWA, Review on major storage insect pests of cereals and pulses, Asian Journal of Advances in Research 5 (2022) 41–56.
[19] R. Ahmad, S. Hassan, S. Ahmad, S. Nighat, Y. K. Devi, K. Javeed, S. Usmani, M. J. Ansari, S. Erturk, M. Alkan, et al., Stored grain pests and current advances for their management, Postharvest technology-recent advances, new perspectives and applications (2021).
[20] L. Cai, S. Macfadyen, B. Hua, H. Zhang, W. Xu, Y. Ren, Identification of biomarker volatile organic compounds released by three stored-grain insect pests in wheat, Molecules 27 (2022) 1963.
[21] J. Belcar, J. Kaszuba, J. Gorzelany, Effect of wheat and barley malt addition on the quality of the baking blend and wheat bread, Polish Journal of Food and Nutrition Sciences 72 (2022) 129–139.
[22] D. Lynda, F. Brahim, S. Hamid, C. Hamadoun, Towards a semantic structure for classifying iot agriculture sensor datasets: An approach based on machine learning and web semantic technologies, Journal of King Saud University-Computer and Information Sciences 35 (2023) 101700.