Towards an Ontology-Based Approach for Enhancing Animal Sanitary Event Management

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Abstract: This study presents the development and integration of a contextual modeling approach for sanitary events, specifically focusing on outbreaks affecting animal populations. A specialized ontology for sanitary events was developed using Protégé and integrated into the PDSA-RS platform, which supports animal health regulation in Brazil. The platform aids in the certification of poultry and swine farming in Rio Grande do Sul, ensuring compliance with Brazilian animal health regulations. The system's effectiveness was demonstrated during FMD, avian influenza, and ND outbreak scenarios, where it significantly reduced analysis time and improved field team management through real-time task allocation and monitoring. The system's usability was evaluated using the System Usability Scale (SUS), resulting in a score of 75.52, reflecting positive feedback from users. Future developments will focus on refining the ontology and enhancing the embedded rules within the system to better align with real-world sanitary management processes and improve adaptability to various scenarios.

1 INTRODUCTION

Sanitary events involving animals have significant impacts both locally and globally. Diseases affecting animal populations, such as outbreaks of foot-and-mouth disease, African swine fever, or avian influenza, can compromise public health, directly affect food security, and result in billions of dollars in economic losses. For example, the foot-and-mouth disease outbreak in Germany in January 2025 underscored the rapid and far-reaching consequences of such events, including trade restrictions (BBC, 2025). The financial impact extends beyond the direct loss of animals, encompassing costs related to sanitary controls, trade restrictions, and reduced agricultural productivity (Rushton, 2009). In countries where the economy is heavily dependent on livestock, such as Brazil, the damages can be even more pronounced, disrupting entire production chains and jeopardizing exports.

The organization and management of sanitary events, such as farm inspections, the implementation of containment measures, and outbreak investigations, play a crucial role in mitigating these impacts. However, these tasks are complex and require efficient planning, team coordination, real-time data collection and analysis, and mechanisms to adapt to dynamic scenarios. Context-aware systems emerge as a promising solution to these challenges, enabling the capture, processing, and application of relevant information in a timely manner for decision making (Cook and Das, 2004).

In this context, ontologies become essential tools for formally representing knowledge related to sanitary events. They allow for the modeling of entities such as farms, inspection teams, vehicles, and field activities, as well as the relationships between these elements (Gruber, 1993).

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This paper focuses on the development of a contextual modeling approach for sanitary events (outbreaks), using ontology as the primary tool for describing and structuring the context. The main contribution is the creation of a specialized ontology for sanitary events, developed in Protégé (v5.6.4), which provides a structured framework for representing the complex relationships and data involved in outbreak management. This ontology was subsequently integrated into the PDSA-RS platform.

The Plataforma de Defesa Sanitária Animal do Rio Grande do Sul (PDSA-RS) is a platform designed to support animal health regulation in Brazil, integrating all stages of certification processes for poultry and swine farming in Rio Grande do Sul. It helps organize production activities while ensuring compliance with Brazilian animal health regulations. Veterinary certification processes depend on the model's ability to interpret complex Brazilian legislation on animal health (Descovi et al., 2021).

The first deployment of this integration occurred during the IAAP outbreak in Rio Pardo, RS, Brazil, in February 2024 (Secretaria da Agricultura, Pecuária e Desenvolvimento Rural, 2024), resulting in a significant reduction in analysis time from hours to minutes and improving field team management through real-time task allocation and monitoring. Its effectiveness was further validated during the containment of a Newcastle disease outbreak in Anta Gorda, RS, Brazil, in July 2024 (Rural, 2024), demonstrating the system's ability to provide rapid, cost-effective responses while maintaining rigorous biosafety protocols.

The paper is structured as follows. Section 2 presents the main concepts related to the proposal. Section 3 presents an analysis on the related work. Section 4 presents the definition of the proposed ontology and the integration of semantic definitions with an information system for response to events. Section 5 presents the evaluation process of the proposal and Section 6 presents the conclusions of this work and future directions.

2 BACKGROUND AND MOTIVATION

The increasing frequency and severity of animal health events, such as outbreaks of foot and mouth disease, African swine fever, and avian influenza, highlight the urgent need for advanced tools to support the management and mitigation of such crises. These events pose significant risks to public health, food security, and economies worldwide, requiring precise coordination, rapid decision-making, and effective allocation of resources. In this context, context-aware systems and ontologies have emerged as promising approaches to address these challenges.

2.1 The Animal Health Defense Platform (PDSA-RS)

Established in 2019, the *Plataforma de Defesa Sanitária Animal do Rio Grande do Sul (PDSA-RS)* is a specialized platform launched to support and regulate animal health and production within the state's poultry and broader livestock sectors. Developed with contributions from the *Federal University of Santa Maria (UFSM)* and the *Ministry of Agriculture (MAPA)*, and supported by the *Fundo de Desenvolvimento e Defesa Sanitária Animal (Fundesa)*, the PDSA-RS provides a real-time digital management solution for tracking health certifications and facilitating the export and movement of avian genetic material. This platform not only aims to improve traceability but also enhances biosecurity and compliance with sanitary regulations, an essential aspect in regions with high export volumes, such as Rio Grande do Sul.

The system's modules, such as the poultry health certification feature, streamline data collection and certification issuance, linking veterinary inspections, laboratories, and agricultural defense authorities. This interconnected system helps officials monitor disease control in flocks and facilitates efficient responses to health risks. The PDSA-RS allows inspectors and producers to follow up on health tests, sample processing, and the issuance of certificates required for both domestic and international movement of poultry, ensuring that health standards are met consistently.

As illustrated in Figure 1 ,the platform adopts a microservices-oriented architecture. The frontend comprises several specialized portals tailored for different stakeholders: the State Veterinary Service (*SVE*), technical managers (*RTs*), agricultural laboratories, and the *Ministry of Agriculture (MAPA)*. On the backend, the architecture differentiates between two distinct types of REST APIs. The business APIs manage the core logic and processes associated with the platform's regulatory functions, ensuring that workflows and data management align with specific legal and procedural requirements. In contrast, the service APIs provide more generic functionality, supporting integration and interoperability with the business APIs by delivering reusable services across the platform.

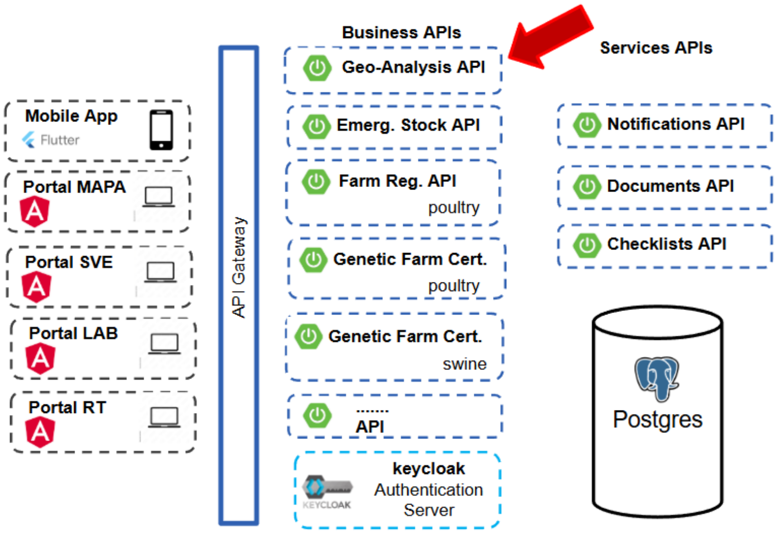

Figure 1: PDSA-RS Architecture.

The responsibility for animal sanitary control in Brazil is shared between federal and state official veterinary services, demanding close coordination and collaboration among multiple stakeholders. In Rio Grande do Sul state, the *Departamento de Vigilância e Defesa Sanitária Animal (DDA)*, which operates under the *Secretaria da Agricultura, Pecuária, Produção Sustentável e Irrigação do Rio Grande do Sul (SEAPI-RS)*, faced significant challenges in organizing fieldwork and collecting information during sanitary events, particularly in outbreaks of high-pathogenic. Multiple software systems were being used to compile data, manage activities, and geographically distribute information; while many were publicly available, they lacked integration. Additionally, the distinct sanitary status of each zone—contaminated or not—required field teams to be specifically assigned, further complicating the process.

Recognizing the need for a more efficient and streamlined system, the technical team at the *Universidade Federal de Santa Maria (UFSM)* and *SEAPI-RS* collaborated to develop a comprehensive module within the *Plataforma de Defesa Sanitária Animal (PDSA-RS)*. This module integrates registration data with geo-analysis tools to manage sanitary events effectively, without requiring specialized knowledge in information technology or geographic analysis. Motivated by this imperative, the Geo-analysis Module was created, featuring a suite of resources divided into four main areas: General Analysis (AG), Focus Analysis (AnF), Focus Response (RF), and Actions at Focus (AF).

2.2 Context-Aware Systems

Context-aware systems, also known as context-sensitive systems, are designed to capture and process environmental information and adapt their behavior accordingly (Dey et al., 2001). Their ability to operate effectively in dynamic environments makes them ideal for managing situations where conditions can change rapidly, such as during animal health crises.

Context, in the scope of context-aware systems, refers to any information that can characterize the situation of an entity, where an entity can be a person, a place, or an object that is relevant to the interaction between a user and the system, including the user and the system themselves (Dey et al., 2001). For example, in animal health management, context may include farms being inspected, current team status, geolocation of disease outbreaks, or weather conditions.

Key characteristics of context-aware systems include:

- **Context Capture.** Collecting and processing data from the environment, such as location, resource status, or user behavior. In the case of animal health events, this may involve tracking properties to be inspected, monitoring team status, and analyzing disease spread data (Perera et al., 2014).
- **Adaptation.** Adjusting system behavior based on the captured context. For instance, dynamically recalibrating an inspection team's route when a new disease outbreak is detected (Abowd and Mynatt, 2000).
- **Decision-Making.** Integrating information to determine optimal actions. For animal health man-

agement, this might involve prioritizing high-risk properties or optimizing resource allocation (Noy et al., 2001).

By leveraging these capabilities, context-aware systems reduce operational costs and improve efficiency, enabling more agile and effective responses during critical events.

2.2.1 Activities in Context-Aware Systems

In context-aware systems, an *activity* refers to a series of actions or tasks that are dynamically adjusted based on the captured context. These activities are adaptive, meaning they change in response to environmental or situational shifts. Here are a few examples:

- **Real-time Animal Health Monitoring.** In an animal health management system, monitoring activities may involve collecting data on animal health. If a system detects a behavioral change or signs of illness in an animal, it may automatically trigger an activity to alert the inspection team and direct them to specific areas (Terence et al., 2024). This context-driven activity helps detect disease outbreaks early and allows for a rapid response.
- **Disaster Response in Risk Zones.** In a disaster management system, evacuation activities can be adjusted in real-time based on weather conditions and population movements. The system adapts evacuation routes according to newly collected data on the severity of a hurricane or wildfire, ensuring that people are guided to the safest areas (Moreno et al., 2015).
- **Dynamic Inspection Tasks.** During disease outbreaks, such as avian influenza, context-aware systems may adjust the priority of inspection tasks based on outbreak location and risk severity. If a new high-risk area is identified, the system can prioritize inspections in that area, improving the efficiency of disease control efforts (Abowd and Mynatt, 2000).

2.3 Ontologies

Ontologies are formal structures that represent domain-specific knowledge by organizing concepts, properties, and relationships in a standardized and comprehensible manner (Guarino et al., 2009). Widely used in knowledge engineering, ontologies provide a robust foundation for modeling complex systems.

Ontologies typically consist of the following components:

- **Classes.** Representing entities or concepts within a domain, such as ”Farm,” ”Inspection Team,” or ”Activity” in the context of animal health (Bizer et al., 2023).
- **Relationships.** Connecting classes and defining interactions between them, such as an inspection team ”visiting” a property.
- **Properties.** Describing attributes of classes, such as a property having a “name” or a team being associated with a “trackable vehicle.”
- **Axioms.** Establishing logical rules and constraints to define relationships and system behavior.

In context-aware systems, ontologies facilitate semantic reasoning, enabling the extraction of actionable insights from diverse data sources. This structured representation enhances decision-making by standardizing and organizing critical information, such as inspection activities, resource allocation, and relationships between stakeholders (Chen et al., 2003).

2.4 Animal Health Events

Animal health events have significant impacts on both local and global scales, particularly in countries whose economies heavily depend on agriculture and livestock production, such as Brazil. Outbreaks of diseases like foot-and-mouth disease, avian influenza, and Newcastle disease are prime examples of threats that can compromise public health, directly affect food security, and result in billions of dollars in economic losses. These losses extend beyond the mortality of animals, encompassing costs associated with sanitary controls, trade restrictions, and reduced agricultural productivity (Cardenas et al., 2024).

Foot-and-mouth disease, for instance, affects cloven-hoofed animals such as cattle, sheep, and pigs. It is highly contagious and can spread rapidly among susceptible populations (Grubman and Baxt, 2004). The foot-and-mouth outbreak in Germany in January 2025 exemplified the swift and far-reaching consequences of such events, leading to significant trade restrictions and economic disruptions (BBC, 2025).

Avian influenza (AI) and Newcastle disease (ND) are critical threats to poultry production due to the high density of bird populations and the rapid transmission of infectious agents. AI is caused by influenza A viruses, with highly pathogenic strains (HPAI) resulting in high mortality rates among birds and posing zoonotic risks in certain cases. ND, caused by an avian paramyxovirus, is equally devastating, presenting symptoms such as respiratory distress, neurological manifestations, and decreased egg production. Both diseases underscore the importance of rapid surveillance, stringent biosecurity measures, and immediate response efforts to minimize their impacts (Swayne, 2009; Alexander, 2012).

Given the dynamic nature of animal health crises, where new disease outbreaks or environmental changes can emerge unexpectedly, effective coordination is necessary. The integration of ontologies within context-aware systems provides a structured representation of the elements involved, supporting decision-making and the execution of activities with increased efficiency. Rapid response is particularly important for poultry operations, as diseases can spread quickly through close contact, shared equipment, and transportation networks.

These outbreaks emphasize the importance of early detection systems and effective management strategies to minimize economic losses and prevent further complications. The use of digital tools and ontology-based approaches plays a key role in addressing the complexity and urgency of these events.

3 RELATED WORK

The integration of context-aware systems and ontologies has gained prominence as a means of improving efficiency and decision making in various domains, including animal health. Several studies highlight the potential and applications of these technologies in addressing challenges related to disease surveillance, data interoperability, and operational management.

One notable contribution is the Animal Health Surveillance Ontology (AHSO), which provides a framework designed to improve data interoperability and support surveillance activities in the domain of animal health. This ontology formalizes the representation of surveillance-related knowledge, enabling better integration and analysis of diverse data sources to inform decision-making processes (Dórea, 2019).

In the realm of syndromic surveillance, a systematic review of the literature on syndromic surveillance of animal health examines various systems used in veterinary medicine. The review evaluates innovative biosurveillance systems, particularly their effectiveness in monitoring equine health. These systems demonstrate the role of advanced technologies in the early detection and monitoring of health trends in animal populations, which is crucial for timely interventions (Dórea and Vial, 2016).

Although not exclusively focused on animal health, the study Context-Aware Systems: A Case Study provides valuable insights into the application of context-aware systems for facilitating daily activities. By focusing on the modeling of context-aware service platforms using ontologies, this work offers foundational knowledge that can be adapted for animal health monitoring and management systems (Chihani et al., 2011).

Additionally, the work on An Ontology-Based Context Model in Intelligent Environments proposes a formal context model based on ontology to address semantic representation, reasoning, and knowledge sharing. This model, applied within the Service-Oriented Context-Aware Middleware (SOCAM) architecture, presents a robust approach that can be tailored to meet the specific needs of animal health surveillance and management (Gu et al., 2020).

These studies collectively demonstrate the versatility and efficacy of ontologies and context-aware systems in improving the organization and management of data, enhancing operational efficiency, and supporting decision-making processes. By building on these advancements, this work aims to develop a specialized ontology for sanitary events involving animals, integrated into a context-aware system, to further contribute to the field.

4 ONTOLOGY DEFINITION AND INTEGRATION

In this study, we designed an ontology to model and manage the complexity of sanitary events in the context of animal health management. The ontology captures the essential entities and their relationships, providing a foundation for implementing context-aware systems capable of enhancing decision-making and operational efficiency during such events. Additionally, we have integrated the ontology with a Java Spring API to streamline system operations and improve real-time data handling.

To develop the ontology, we used the Ontology 101 methodology (Noy et al., 2001) with the analysis of Brazilian official Avian Influenza and Newcastle disease Surveillance Plan (Rauber, 2023).

4.1 Key Concepts and Relationships

The main concepts of the proposed ontology are presented in Figure 2. The core classes are presented below:

- **SanitaryEvent.** Represents the overarching event, connecting all associated activities and risk zones.

- **Activity.** Describes specific actions taken during the event, such as inspections, disease monitoring, or control measures.
  - **Collection.** Refers to the collection of data during the sanitary event, such as biological samples or environmental data.
    * **SampleCollection.** A subclass of **Collection** that represents the collection of biological samples, such as blood, tissue, or swabs, from animals at farms for diagnostic purposes.
    * **DataCollection.** A subclass of **Collection** representing the collection of general data, including environmental conditions, animal health metrics, and other relevant information.
- **Team.** Represents groups of personnel tasked with performing activities. Typically, a team consists of multiple members, such as veterinary or investigation teams.
  - **BarrierRoadTeam.** A subclass of **Team** responsible for setting up road barriers to control and monitor the movement of vehicles and individuals during sanitary events. These teams ensure compliance with containment protocols.
  - **SurveillanceTeam.** A subclass of **Team** that performs surveillance activities, including inspections, monitoring disease spread, and collecting relevant data at farms or other designated locations.
- **Device.** Represents technological tools used during sanitary events. Devices assist teams by providing data collection and communication capabilities.
  - **MobileDevice.** A subclass of **Device** that includes smartphones, tablets, and other portable communication devices used by teams for recording data and maintaining communication.
- **Sensor.** Represents equipment capable of detecting and measuring environmental or positional data to assist in decision-making.
  - **GPS.** A subclass of **Sensor** used for tracking the location of vehicles, teams, and other assets during sanitary events.
- **RiskZone.** Represents areas categorized based on their level of risk during a sanitary event. These zones help prioritize actions and allocate resources effectively.
  - **BufferZone.** A subclass of **RiskZone** representing areas surrounding infected or surveillance zones to prevent the spread of disease.
  - **SurveillanceZone.** A subclass of **RiskZone** representing areas under observation for potential disease outbreaks.
  - **InfectedZone.** A subclass of **RiskZone** representing areas confirmed to have disease presence, requiring immediate attention and containment measures.
- **Person.** Represents individuals involved in the sanitary event, such as team members or stakeholders. This class provides a foundation for capturing attributes like roles, skills, and responsibilities.
  - **Veterinary.** A subclass of **Person** representing veterinary professionals responsible for animal health assessments, diagnoses, and treatments during sanitary events.
  - **AgriculturalTechnician.** A subclass of **Person** representing agricultural technicians assisting in data collection, field inspections, and disease monitoring during sanitary events.
- **Farm.** Denotes locations assigned to teams for investigation and data collection. Farms are often the focal point for sanitary events and activities.
  - **IndexSite.** A subclass of **Farm** representing a central site for the sanitary event. It serves as a reference point for related activities or interventions.
  - **SecondarySite.** A subclass of **Farm** representing farms or locations identified as secondary sites in relation to an IndexSite. These sites are monitored to assess the spread of disease or risk factors.
  - **PotentialSite.** A subclass of **SecondarySite** representing a farm that has been identified as a potential site for intervention, based on data and other conditions.
- **Vehicle.** Represents the transportation resources used by teams for field operations. Vehicles are typically equipped with tracking capabilities to monitor team movements during investigations.

Key relationships between these entities include:

- **assignedTo.** Links a **Team** to the **Farm** they are assigned to, indicating the geographical area under investigation.
- **collects.** Relates a **Team** to the **Collection** they are responsible for, representing the data or samples collected during the sanitary event.
- **hasActivity.** Connects a **SanitaryEvent** to the specific **Activity** performed as part of the event.
- **hasRiskZone.** Connects a **SanitaryEvent** to the specific **RiskZone** associated with the event.

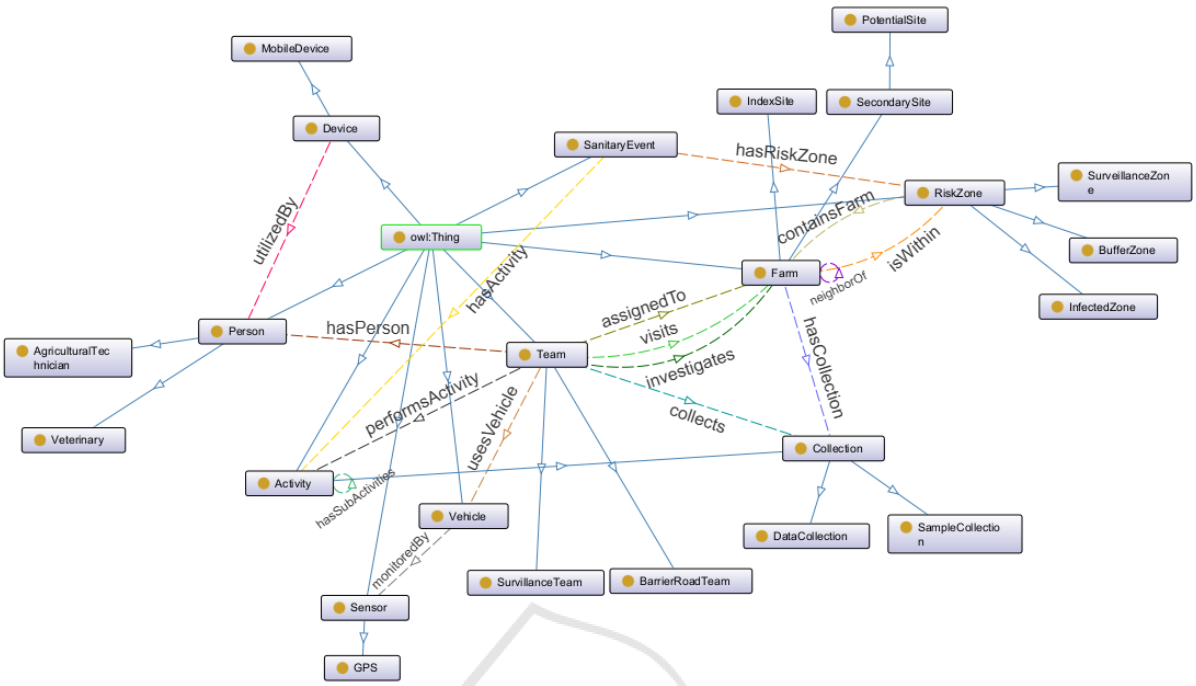

Figure 2: Main classes of the ontology for Context-Aware Response of Sanitary Event.

- **hasCollection.** Links a **Farm** to the **Collection** performed at that location, such as data collection or biological sampling.
- **investigates.** Describes the investigative actions performed by a **Team** at a **Farm**, such as health inspections or disease monitoring.
- **neighborOf.** Represents the spatial relationship between two **Farm** instances, indicating their proximity, useful for tracking disease spread.
- **performsActivity.** Relates a **Team** to a specific **Activity**, such as performing field visits or data gathering during a sanitary event.
- **usesVehicle.** Connects a **Team** to the **Vehicle** used during their field activities for transportation and logistics.
- **visits.** Links a **Team** to the **Farm** they visit during an investigation or intervention as part of a sanitary event.
- **hasSubActivities.** Relates an **Activity** to its sub-activities, representing a hierarchical structure of actions within a **SanitaryEvent**.
- **isWithin.** Links a **Farm** to a **RiskZone**, indicating that the farm is geographically located within a specific zone.
- **containsFarm.** Relates a **RiskZone** to the **Farm** instances it encompasses, identifying farms within the zone.
- **hasPerson.** Links a **Team** to a **Person**, representing team membership and roles within the sanitary event.
- **monitoredBy.** Links a **Vehicle** to a **Sensor**, such as a GPS, indicating that the vehicle's movements and activities are tracked through this sensor.
- **utilizedBy.** Links a **Device** to a **Person**, indicating the individual responsible for using the device during a sanitary event.

4.2 Rules for Operational Logic

The ontology integrates **SWRL (Semantic Web Rule Language)** rules to automate reasoning and ensure consistency within the model. These rules are processed via the Spring API, allowing for dynamic validation of operational constraints and automation of certain decision-making processes.

Example Rule. One example of a rule in the ontology ensures that if a **Farm** is assigned to a **Team** and the farm has a **SampleCollection**, the farm is considered a **PotentialSite** for further investigation. This can be represented in SWRL as:

```
Farm(?f) ˆ Team(?t)
ˆ assignedTo(?t, ?f)
ˆ hasCollection(?f, ?c)
ˆ SampleCollection(?c)
-> PotentialSite(?f)
```

Explanation

- **Antecedent (Left-Hand Side)**
  - `Farm(?f)`: Identifies an individual `?f` of type **Farm**.
  - `Team(?t)`: Identifies an individual `?t` of type **Team**.
  - `assignedTo(?t, ?f)`: States that the **Team** `?t` is assigned to the **Farm** `?f`.
  - `hasCollection(?f, ?c)`: Specifies that the **Farm** `?f` has a **Collection** `?c` associated with it.
  - `SampleCollection(?c)`: Ensures that the collection `?c` is a **SampleCollection**, typically biological samples from the farm.
- **Consequent (Right-Hand Side)**
  - `PotentialSite(?f)`: Infers that the **Farm** `?f` is considered a **PotentialSite** for further investigation due to the collection of samples.

This rule ensures that farms with specific collections, such as sample collections, are identified as potential sites for deeper investigation, helping prioritize areas requiring more attention.

Implementation Notes.

- **Practical Application**
  - If a **Farm** has sample collections, it will automatically be marked as a **PotentialSite** for further action, facilitating decision-making.
  - If the **Farm** does not have the required collection, it will not be considered a **PotentialSite**, thus reducing unnecessary investigation in non-critical areas.

By defining such rules, the ontology helps automate decision-making processes and enhances operational efficiency in managing sanitary events.

4.3 Integration with PDSA-RS Throught a Java Spring API

The developed ontology was integrated into a Java Spring API (Geo-Analysis API) as illustrated in Figure 1, enabling seamless interaction with the PDSA-RS platform. The developed API facilitates:

- **Data Storage and Retrieval.** The ontology's entities and relationships are stored in a database and are accessible through RESTful APIs for real-time data retrieval and updates;
- **Automated Reasoning.** SWRL (Semantic Web Rule Language) rules are executed via the API to ensure operational logic is maintained, such as ensuring teams are assigned to appropriate properties and activities are carried out according to specified constraints;
- **Real-Time Updates.** Integration with dynamic data sources, such as vehicle tracking and team assignments, allows the system to adapt in real-time based on operational conditions.

4.4 Applications and Benefits

This ontology and its integration with the Java Spring API facilitate the development of context-aware systems by enabling:

- **Context Capture.** Accurate representation of spatial and operational data, including property locations and team assignments, retrieved in real-time via the API.
- **Decision Support.** Automated reasoning via the API to optimize team assignments, route planning, and decision-making processes.
- **Adaptability.** Integration with dynamic data sources, such as real-time vehicle tracking, which are processed and delivered through the Spring API to adjust to evolving conditions during sanitary events.

By leveraging this ontology and integrating it with a Java Spring API, organizations can improve the efficiency and effectiveness of sanitary event management, ensuring more responsive and adaptable operations during animal disease outbreaks. This integration also facilitates better communication and coordination between field teams and central command, leading to reduced economic impacts during such events.

5 EVALUATION AND DISCUSSION

The proposed ontology and the API that supports the use of this ontology was integrated in the PDSA-RS platform. We prototyped a module called Geo-analysis. To validate the proposed ontology, the Geo-analysis was initially validated during the management of an avian influenza outbreak in February 2024 in Rio Grande do Sul state (RS, Brazil) (Secretaria da Agricultura, Pecuária e Desenvolvimento Rural, 2024).

The results demonstrated the effectiveness of the module, drastically reducing the time spent on data analysis from 3 to 4 hours per day with other tools to just a few minutes when using the platform. This allowed for faster and more efficient decision-making, optimizing the management of resources and reducing the workload on field teams.

5.1 The Geo-Analysis Module

The system provides various capabilities to manage the response to sanitary events. Below are the main areas of functionality:

5.1.1 General Analysis (AG) and Focus Analysis (AnF)

The **General Analysis (AG)** and **Focus Analysis (AnF)** areas provide a comprehensive view of the sanitary event management. The **General Analysis (AG)** area allows the visualization of registered rural properties on a map, along with the ability to insert the Rural Environmental Registry (CAR) shapes for area evaluation. An example of the visualization of an infected farm an the animal movement in Geo-Analysis module is presented in Figure 3.

The **Focus Analysis (AnF)** area allows for the identification of sanitary focus points, which could be a rural property or a specific geographical location, with the ability to create up to three zones (perifocus, surveillance, and protection). Additionally, animal movement history is available for analysis.

5.1.2 Focus Response (RF)

The **Focus Response (RF)** area manages the containment efforts of the sanitary event, linking Official Veterinary Service teams to the focus, assigning tasks, and monitoring the progress of information collection through checklists. An example of the planning of teams to visit the farms is presented in Figure 4.

5.1.3 Actions at Focus (AF)

The **Actions at Focus (AF)** area offers a real-time dashboard to track activities, pending tasks, existing focus points, and involved teams, allowing for better management of fieldwork and providing feedback for continuous improvement. An example of monitoring visits in AF is presented in Figure 5.

The platform's success lies in its simplicity and adaptability, allowing field teams to work effectively without needing advanced technological expertise. Additionally, real-time updates ensure that the management of the sanitary event adapts to changing conditions, improving overall effectiveness.

By utilizing the platform, the response to the sanitary event was rapid and efficient, with a rational use of human and financial resources while maintaining satisfactory levels of biosafety, as prescribed by best practices in emergency management.

5.2 First Evaluation - IAAP - Rio Pardo - RS

The tool was first used in the response to the IAAP outbreak in Rio Pardo, RS, Brazil, in February 2024, demonstrating its effectiveness in managing the sanitary event. It significantly reduced the analysis time from 3 to 4 hours daily with other tools to just minutes using the Platform. In addition to information analysis, the tool enabled better management of the teams involved across various control areas, allowing for more accurate estimation of team sizes and better task distribution. As a result, the response to the outbreak in Rio Pardo was both quick and effective, with a rational use of human and financial resources, ensuring activities remained at a satisfactory level of biosafety, in accordance with best practices for emergency management (Secretaria da Agricultura, Pecuária e Desenvolvimento Rural, 2024).

5.3 Second Evaluation - NewCastle Disease - Anta Gorda - RS

The tool was used during the Newcastle disease outbreak in Anta Gorda, RS, Brazil, in July 2024, demonstrating its functionality in managing sanitary events. The platform supported containment efforts and facilitated the coordination of involved teams. Its capability to process information and manage tasks contributed to an organized and efficient response to the outbreak. This included structuring field team operations and supporting decision-making regarding resource allocation, ensuring timely actions aligned with sanitary event management protocols (Ala'a et al., 2024; Rural, 2024).

The System Usability Scale (SUS) was used to evaluate the usability of the system. A total of **29 participants** completed the SUS survey, answering a series of 10 questions designed to assess the ease of use, complexity, and confidence in using the system.

5.4 Survey Results

The SUS survey consisted of 10 questions, each rated on a scale from 1 to 5. For the calculation of the SUS score, the responses to the odd-numbered questions (1, 3, 5, 7, 9) were adjusted by subtracting 1 from the given score, while the responses to the even-numbered questions (2, 4, 6, 8, 10) were adjusted by

Figure 3: General Analysis (AG) and Focus Analysis (AnF) - Visualization of rural properties, CAR shapes, sanitary focus points, and animal movement history.

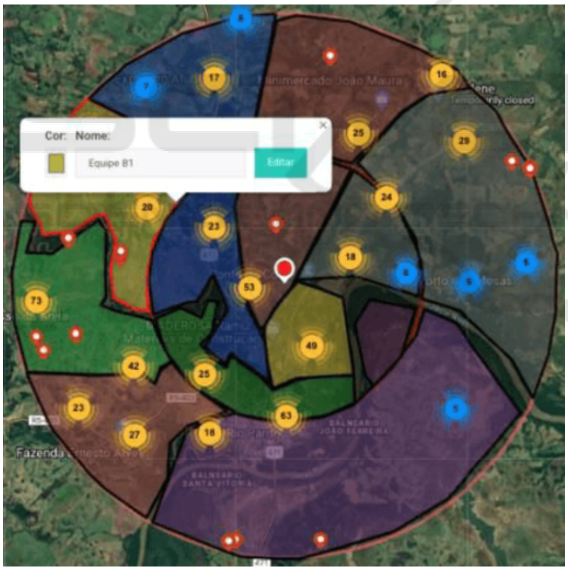

Figure 4: Focus Response (RF) - Management of containment efforts and team assignments.

subtracting the score from 5. The adjusted scores were then summed for each participant, and the average score was calculated.

The SUS scores were calculated using the adjusted ratings for each participant. The table (Table 1) shows the responses for all 29 participants, including their ratings for each of the 10 questions.

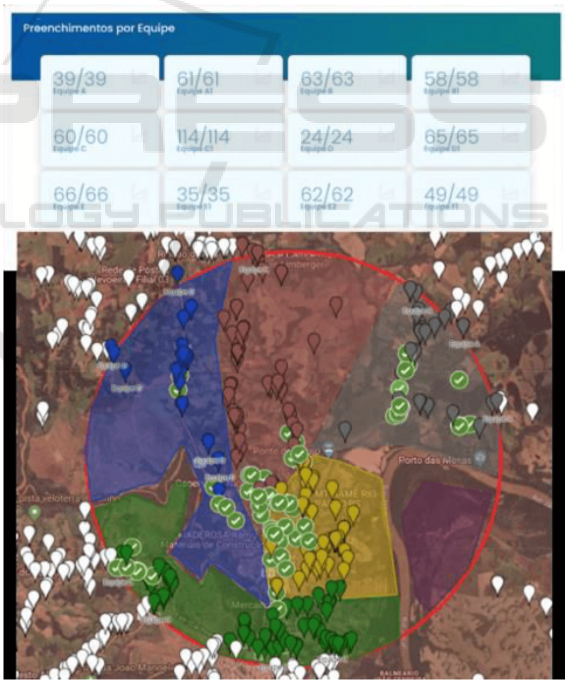

Figure 5: Actions at Focus (AF) - Real-time dashboard for activity tracking and team management.

5.5 SUS Score Calculation

To calculate the overall SUS score, the adjusted responses for each participant were summed and averaged. The formula for calculating the SUS score is as follows:

Table 1: SUS Questionnaire Results.

Participant	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
P1	5	1	5	1	5	1	5	1	5	1
P2	5	1	5	4	5	2	5	2	4	2
P3	5	2	5	4	4	2	5	1	4	1
P4	5	1	5	2	4	2	4	1	4	1
P5	4	2	4	2	4	2	4	1	4	1
P6	4	1	5	1	4	1	5	1	4	1
P7	5	2	4	3	3	2	5	1	4	1
P8	4	1	5	3	4	1	5	1	4	1
P9	5	3	4	4	4	3	5	3	4	4
P10	5	2	4	4	4	3	3	2	3	2
P11	5	1	1	1	5	1	5	1	5	1
P12	4	1	5	1	4	1	5	2	4	1
P13	4	1	3	2	2	3	3	1	3	4
P14	5	1	4	3	5	1	5	1	5	1
P15	5	1	5	3	5	1	4	1	5	2
P16	5	1	5	1	4	1	5	1	5	2
P17	5	2	4	2	4	2	4	1	5	1
P18	4	2	4	2	3	2	4	2	4	2
P19	5	1	5	1	5	1	5	1	5	1
P20	4	1	5	1	4	1	5	1	5	1
P21	4	1	5	1	4	2	5	1	4	1
P22	5	1	5	1	4	1	5	1	4	1
P23	5	1	5	1	5	1	5	1	5	1
P24	5	2	4	2	5	1	5	1	4	4
P25	5	1	5	1	5	1	5	1	5	2
P26	5	5	4	3	3	2	5	2	3	1
P27	5	1	5	1	4	1	4	1	4	1
P28	3	3	3	4	3	3	3	3	3	3
P29	5	5	5	4	5	4	5	1	5	4

$$\text{SUS Score} = \left(\frac{\sum \text{Adjusted Scores}}{\text{Number of Respondents}} \right) \times 2.5$$

Where the adjusted score for each item is calculated as:

$$\text{Adjusted Score} = \begin{cases} \text{Score} - 1 & \text{for odd-numbered items} \\ 5 - \text{Score} & \text{for even-numbered items} \end{cases}$$

For example, for a participant who answers: - Question 1 with a score of 5, the adjusted score would be $5 - 1 = 4$. - Question 2 with a score of 1, the adjusted score would be $5 - 1 = 4$.

After calculating the adjusted scores for all the questions, the total score for each participant is calculated, and then the average score across all participants is determined.

The higher the SUS score, the more usable the system is considered to be. A typical range for a SUS score is between 0 and 100, with scores above 68 generally considered above average and those below 68 considered below average.

Based on the SUS score, we can infer that the system received **a positive evaluation** from the participants, with a calculated SUS score of **75.52**, indicating that the system is considered **easy to use** and **well-integrated** overall. Most users expressed confidence in using the system, though there were some areas where improvement could be made, especially in reducing complexity and increasing ease of use for new users.

6 CONCLUSION

This study evaluated the usability of the system through the System Usability Scale (SUS), with the results indicating a positive response from the participants. The calculated SUS score of 75.52 suggests that the system is considered easy to use and well-integrated. Most users reported confidence in using the system, though there are areas that could be improved, particularly in simplifying the user interface and increasing the ease of use for new users. The evaluation provides insights into the system's current performance and areas for further refinement.

Moving forward, we plan to further enhance the system by refining its contextual modeling to better reflect real-world sanitary management processes. This includes improving the ontology to more accurately represent the dynamics of disease control and agricultural management. Additionally, we will develop and implement new adaptive rules within the system, allowing it to respond more effectively to diverse outbreak scenarios. These improvements aim to streamline the user experience while ensuring the system remains practical, responsive, and aligned with the needs of its users in managing sanitary events.

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REFERENCES

Abowd, G. D. and Mynatt, E. D. (2000). Charting past, present, and future research in ubiquitous computing. *ACM Transactions on Computer-Human Interaction (TOCHI)*, 7(1):29–58.

Ala'a, B. et al. (2024). Newcastle disease outbreak in the state of rio grande do sul, brazil 2024: Is there any impact on jordan as one of the major importers of brazilian poultry?

Alexander, D. J. (2012). *Newcastle disease*, volume 8. Springer Science & Business Media.

BBC (2025). Uk bans cattle, pigs, and sheep imports from germany after foot-and-mouth case. Accessed: 2025-01-16.

Bizer, C., Heath, T., and Berners-Lee, T. (2023). Linked data-the story so far. In *Linking the World's Information: Essays on Tim Berners-Lee's Invention of the World Wide Web*, pages 115–143.

Cardenas, N. C., Lopes, F. P., Machado, A., Maran, V., Trois, C., Machado, F. A., and Machado, G. (2024). Modeling foot-and-mouth disease dissemination in rio grande do sul, brazil and evaluating the effectiveness of control measures. *Frontiers in Veterinary Science*, 11:1468864.

Chen, H., Finin, T., and Joshi, A. (2003). An ontology for context-aware pervasive computing environments. *The knowledge engineering review*, 18(3):197–207.

Chihani, B., Bertin, E., Jeanne, F., and Crespi, N. (2011). Context-aware systems: a case study. In *DICTAP 2011, Dijon, France, June 21-23, 2011, Proceedings, Part II*, pages 718–732. Springer.

Cook, D. and Das, S. K. (2004). *Smart environments: technology, protocols, and applications*, volume 43. John Wiley & Sons.

Descovi, G., Maran, V., Ebling, D., and Machado, A. (2021). Towards a blockchain architecture for animal sanitary control. In *ICEIS (1)*, pages 305–312.

Dey, A. K., Kortuem, G., Morse, D. R., and Schmidt, A. (2001). Situated interaction and context-aware computing. *Personal and Ubiquitous Computing*, 5:1–3.

Dórea, F. C. and Vial, F. (2016). Animal health syndromic surveillance: a systematic literature review of the progress in the last 5 years (2011–2016). *Veterinary Medicine: Research and Reports*, pages 157–170.

Dórea, F. C. e. a. (2019). Drivers for the development of an animal health surveillance ontology (ahso). *Preventive veterinary medicine*, 166:39–48.

Gruber, T. R. (1993). A translation approach to portable ontology specifications. *Knowledge acquisition*, 5(2):199–220.

Grubman, M. J. and Baxt, B. (2004). Foot-and-mouth disease. *Clinical microbiology reviews*, 17(2):465–493.

Gu, T., Wang, X. H., Pung, H. K., and Zhang, D. Q. (2020). An ontology-based context model in intelligent environments. *arXiv preprint arXiv:2003.05055*.

Guarino, N., Oberle, D., and Staab, S. (2009). What is an ontology? *Handbook on ontologies*, pages 1–17.

Moreno, D., Ochoa, S. F., and Meseguer, R. (2015). A context-aware model to provide positioning in disaster relief scenarios. *Sensors*, 15(10):25176–25207.

Noy, N. F., McGuinness, D. L., et al. (2001). Ontology development 101: A guide to creating your first ontology.

Perera, C., Zaslavsky, A., Christen, P., and Georgakopoulos, D. (2014). Context aware computing for the internet of things. ieee communication survey and tutorials. 16 (1): 414–454.

Rauber, R. H. (2023). Avian influenza and the brazilian poultry production: Current situation and prevention strategies. *Ger J Vet Res [Internet]*, 3(4):13–9.

Rural, G. (2024). Governo vai informar fim do foco de doença de newcastle a órgão internacional de saúde animal. Accessed: 2025-01-16.

Rushton, J. (2009). *The economics of animal health and production*. Cabi.

Secretaria da Agricultura, Pecuária e Desenvolvimento Rural (2024). Agricultura conclui vigilância a propriedades num raio de 5 km do foco de gripe aviária em rio pardo. Accessed: 2024-12-17.

Swayne, D. E. (2009). *Avian influenza*. John Wiley & Sons.

Terence, S., Immaculate, J., Raj, A., and Nadarajan, J. (2024). Systematic review on internet of things in smart livestock management systems. *Sustainability*, 16(10):4073.