DESIGN AND IMPLEMENTATION OF AN ONLINE DISEASE MAPPING MODULE WITHIN AN ELECTRONIC EPIZOOTIC MONITORING SYSTEM

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ABSTRACT

The digital transformation of veterinary services has become a key strategic direction in strengthening animal health systems and improving the effectiveness of epizootic surveillance. Traditional paper-based reporting and fragmented information flows are no longer sufficient to ensure timely detection and response to infectious animal diseases, particularly under conditions of increasing livestock mobility and intensification of animal production systems. In this context, electronic epizootic monitoring platforms based on geospatial information technologies provide new opportunities for real-time or near-real-time situational awareness, spatial risk assessment, and evidence-based decision-making.

1. Introduction

The digital transformation of veterinary services has become a key strategic direction in strengthening animal health systems and improving the effectiveness of epizootic surveillance. Traditional paper-based reporting and fragmented information flows are no longer sufficient to ensure timely detection and response to infectious animal diseases, particularly under conditions of increasing livestock mobility and intensification of animal production systems. In this context, electronic epizootic monitoring platforms based on geospatial information technologies provide new opportunities for real-time or near-real-time situational awareness, spatial risk assessment, and evidence-based decision-making.

Geographic Information Systems (GIS) have been widely applied in public and animal health for mapping disease occurrence, analyzing spatial-temporal patterns, and identifying high-risk zones. The integration of GIS with electronic disease reporting systems allows veterinary authorities to visualize outbreaks, monitor disease spread, and optimize surveillance and control strategies. However, many existing systems remain limited in terms of interoperability, real-time visualization, and automated data integration from field and laboratory levels.

Within the framework of an electronic epizootic monitoring system, the “Online Map of Detected Diseases” module was developed to address these limitations. The module enables interactive visualization of confirmed and suspected infectious disease events at farm level, based on precise geographic coordinates. The system supports near-real-time display of outbreak locations, spatial clustering, temporal filtering, and access to extended epidemiological attributes, thereby facilitating rapid situational assessment and targeted response measures. This paper presents the design principles, technical architecture, and applied value of the online disease mapping module, highlighting its contribution to strengthening epizootic surveillance and decision support.

2. Materials and Methods

2.1. System architecture

The "Online Map of Detected Diseases" module was developed as an integrated component of a national electronic epizootic monitoring platform. The system architecture follows a modular, service-oriented design and consists of four core layers: (i) user interface (front-end), (ii) application server (back-end), (iii) centralized database, and (iv) cartographic and geospatial services.

2.2. Front-end and interactive mapping

The user interface was implemented using the Leaflet open-source web mapping library. This framework enables interactive visualization of disease events as spatial objects (point markers, polygons, and clusters) on a dynamic map interface. Each marker represents a farm or epidemiological unit where an infectious disease was detected or suspected. Upon user interaction (clicking a marker), a pop-up window displays extended epidemiological attributes, including disease type, date of detection, administrative location, and relevant case metadata.

The interface supports multiple analytical functions, including zooming and panning, layer management, temporal filtering, disease-type filtering, and marker clustering to enhance visualization performance in high-density areas. These tools enable users to explore spatial patterns, compare disease occurrence across time intervals, and identify emerging hotspots.

2.3. Cartographic base and spatial reference

OpenStreetMap was used as the base map provider, offering up-to-date, open-access cartographic coverage. All geographic coordinates were referenced using the WGS-84 coordinate reference system (EPSG:4326), ensuring compatibility with international geospatial standards and interoperability with external GIS tools.

2.4. Back-end services and data exchange

The back-end layer handles user requests, queries the centralized database, processes epidemiological records, and transmits geospatial data to the front-end. Data exchange between system components is implemented via RESTful APIs, ensuring scalability and interoperability. Spatial data are delivered in GeoJSON format, allowing seamless integration with the Leaflet visualization layer and efficient rendering in web browsers.

2.5. Database and data management

A centralized digital database stores detailed epidemiological records, including unique farm identifiers, disease type, date of detection, number of affected animals, laboratory status, and geographic coordinates. The database is continuously updated as new field reports and laboratory results are submitted. Once validated by system administrators, newly confirmed disease events are automatically propagated to the online map, ensuring that the visualization reflects the most recent epidemiological situation.

2.6. Data flow, validation, and access control

Primary epidemiological data are entered by district-level veterinary officers following field investigations. Biological samples are submitted to accredited laboratories, and diagnostic results are linked to the corresponding field records. Each case is assigned a status category, including "Under laboratory testing", "Sampling error", "Confirmed", or "Not confirmed".

The system operates within a closed information environment with role-based access control. Preliminary or unvalidated records are visible only to authorized administrators, while confirmed cases can be shared with a broader group of institutional users. Automated notification mechanisms inform neighboring administrative units about confirmed cases, supporting early warning and coordinated response.

3. Results and Discussion

The implementation of the online disease mapping module significantly enhanced the spatial and temporal resolution of epizootic surveillance. The near-real-time visualization of disease events allowed veterinary authorities to rapidly assess the geographic distribution of outbreaks and to identify spatial clustering patterns indicative of localized transmission or emerging hotspots. Compared to traditional tabular reporting, the interactive map provided a more intuitive and actionable representation of the epizootic situation.

The integration of laboratory information systems with the mapping module improved data reliability and reduced delays between field detection and confirmation. Automated synchronization ensured that changes in case status (e.g., confirmation or rejection) were immediately reflected on the map, thereby supporting dynamic risk assessment. The application of temporal filters enabled retrospective analysis of disease spread dynamics and facilitated the evaluation of control measures over defined time intervals.

Role-based access control and the closed-system architecture contributed to data security and prevented the dissemination of unverified information. At the same time, the internal sharing of validated data among regional veterinary units strengthened inter-institutional coordination and situational awareness. The automated notification functionality further supported early warning by alerting neighboring jurisdictions to confirmed disease events, enabling timely preventive and containment actions.

Overall, the results demonstrate that the online disease mapping module functions not only as a visualization tool but also as a decision-support component within the broader electronic epizootic monitoring system. Its application enhances the operational capacity of veterinary services to monitor, analyze, and respond to infectious disease threats in a spatially explicit and timely manner.

4. Conclusions

1.The online disease mapping module enables near-real-time spatial visualization of infectious animal disease events at farm level.

2.GIS-based visualization improves the detection of spatial patterns, clusters, and high-risk zones in epizootic surveillance.

3.Integration with laboratory information systems enhances data accuracy and timeliness.

4.Role-based access control ensures data security and prevents the dissemination of unverified information.

5.Automated notifications strengthen early warning and inter-regional coordination.

6.The system supports evidence-based planning of preventive and control measures.

7.Digital epizootic monitoring improves the overall efficiency and responsiveness of veterinary services.

The module provides a scalable and interoperable architecture for future expansion and integration with additional surveillance components.

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