Abstract

This DSS, OSCAR, was designed to provide comprehensive spatio-temporal analysis and simulation services in the context of public health emergency management. At baseline, the rate of outbreak prediction accuracy is not specified. The goal of the DSS is to optimize the prediction of disease outbreaks and support emergency management among researchers, medical staff, and policy makers. The DSS is designed so that the user will conduct spatial analysis and simulation in the Workflow of public health emergency management, specifically in the step of data aggregation and modeling, although others are involved as well: epidemiologists, data scientists, and IT specialists. The DSS "lives" in the context of a web-based integrated visualization portal, and employs the specific "widget" of spatio-temporal cube representation. Under the covers, it deploys a hybrid model integration approach using service-oriented cloud architecture. The DSS will be monitored by continuous system performance evaluations, with special attention to the adverse event of system downtime or inaccurate predictions. More generally, the system will be evaluated by its effectiveness in real-time emergency scenarios. The knowledge for the DSS will be acquired and maintained by automated data crawlers and manual updates by domain experts.

Name of the project

An Open Spatial Computing and Data Resource

Objectives of the Solution

- Maximize the accuracy of disease outbreak predictions: Ensuring that the predictions are highly accurate is critical for timely and effective emergency responses.
- Minimize the time required for data processing and analysis: Rapid data processing allows for quicker decision-making, which is crucial in emergency situations.

Justification:

Accurate predictions enable public health officials to allocate resources more efficiently and implement control measures more effectively. Minimizing the processing time is essential because delays in data analysis can lead to slower response times, potentially worsening the impact of a health emergency.

Context

Location: Government agency offices and public health departments.

Narrative: The problem is the difficulty in obtaining and analyzing diverse and dispersed spatio-temporal data quickly during public health emergencies. This delay hampers timely decision-making and effective response. Currently, there is no integrated system capable of aggregating, processing, and analyzing this data in real-time. Decision support systems can offer a solution by providing a centralized platform for data aggregation, real-time analysis, and simulation to aid in rapid and informed decision-making.

Target Actions

- Issue public health alerts: Promptly notify the public and relevant authorities about potential disease outbreaks to initiate preventive measures.
- Call up records of outlier patients: Identify and analyze cases that deviate from the norm to understand the dynamics of an outbreak.
- Implement control measures: Deploy targeted interventions, such as vaccinations or quarantine measures, based on the analysis.
- Conduct spatial analysis: Map and analyze the geographical spread of the disease to identify hotspots and patterns.

Justification:

These actions are critical for timely and effective response to public health emergencies. Issuing alerts can prevent the spread of diseases, analyzing outlier cases can provide insights into the nature of an outbreak, implementing control measures can directly reduce the impact of the disease, and spatial analysis helps in understanding and predicting disease spread.

Baseline Performance

The current baseline performance involves limited predictive accuracy and slow response times, leading to higher morbidity and mortality rates. For evaluation, the number of lives saved and adverse events averted per year will be compared against historical data where such a decision support system was not in place. For instance, if historically, 100 lives were lost annually due to delayed responses, the system's effectiveness will be compared against this figure.

Desired Outcome

- Fewer disease-related deaths and adverse events: Directly measure the effectiveness of timely interventions and accurate predictions.
- Improved response times: Faster decision-making and action implementation.
- Enhanced resource allocation: More efficient use of public health resources based on accurate data and predictions.

Justification:

Fewer deaths and adverse events directly correlate with the primary objective of maximizing prediction accuracy and minimizing response times. Improved response times demonstrate the system's efficiency in processing and analyzing data quickly. Enhanced resource allocation ensures that public health efforts are focused where they are most needed, maximizing their impact and effectiveness.

Target population

Intentional (Above-the-Line): Public health officials, medical staff, researchers, and policy makers involved in managing and responding to public health emergencies and disease outbreaks.

Extensional (Below-the-Line):

- Public Health Officials: Individuals working in government health agencies and departments responsible for public health and emergency response.

- Medical Staff: Healthcare providers, including doctors, nurses, and epidemiologists, who are involved in diagnosing, treating, and managing disease cases.
- Researchers: Scientists and analysts specializing in infectious diseases, epidemiology, and public health who use data to study and predict disease patterns.
- Policy Makers: Government officials and decision-makers who develop and implement public health policies and emergency response strategies.

For evaluation metrics, this target population can be defined using specific roles and job titles within public health and healthcare institutions, such as:

- ICD-10 Codes for Disease Outbreaks: A00-B99 (Certain infectious and parasitic diseases), U07.1 (COVID-19), and other relevant codes.
- Job Titles/Roles: Epidemiologist, Infectious Disease Specialist, Public Health Officer, Emergency Response Coordinator, Data Scientist in Public Health.

Possible Solutions:

1. Preemptive Public Health Campaigns:

Description: Initiate widespread public health education and awareness campaigns to inform the public about preventive measures, vaccination drives, and hygiene practices.

Effectiveness: This solution works well at a societal level by reducing the overall incidence of disease, but it may not be as effective in responding to an ongoing outbreak due to the slower dissemination of information.

2. Enhanced Surveillance and Early Detection Systems:

Description: Implement advanced surveillance systems using IoT and AI to detect early signs of disease outbreaks through environmental monitoring, social media analysis, and health record examination.

Effectiveness: These systems are very effective in early detection and can work synergistically with the decision support system (DSS). However, they require significant investment in technology and infrastructure.

3. Home-Based Monitoring and Telehealth Services:

Description: Equip homes with monitoring devices to track health indicators (e.g., temperature, respiratory rate) and provide telehealth services for remote consultation and early diagnosis.

Effectiveness: This approach helps in early identification and management of diseases at an individual level, potentially reducing the burden on healthcare facilities. However, its effectiveness is limited by the adoption rate and the technology available in households.

4. Decision Support System (DSS) – OSCAR:

Description: A comprehensive spatio-temporal analysis and simulation DSS designed to optimize outbreak prediction and emergency response.

Effectiveness: The DSS provides a robust and real-time analysis, integrating various data sources to offer timely and accurate predictions and recommendations. This intervention is highly effective within the context of emergency management, allowing for quick, informed decision-making and resource allocation.

5. Community Health Worker Programs:

Description: Deploy community health workers to educate, monitor, and report on local health conditions, providing a direct link between the community and healthcare providers.

Effectiveness: These programs are effective in providing grassroots-level health support and data collection but may lack the technological support and real-time data processing capabilities of a DSS.

6. Enhanced Hospital and Clinic Protocols:

Description: Develop and implement stricter protocols in hospitals and clinics for infection control, patient screening, and outbreak response.

Effectiveness: While this intervention can significantly reduce the spread of diseases within healthcare settings, it is reactive rather than proactive and may not address community-wide outbreaks effectively.

Intervention Comparison:

Preemptive Public Health Campaigns work well in preventing diseases but are less effective in immediate outbreak responses.

Enhanced Surveillance Systems provide crucial early detection but need substantial initial investment.

Home-Based Monitoring is excellent for individual health management but lacks community-wide impact.

Community Health Worker Programs offer valuable community-level intervention but may not be as comprehensive as technological solutions.

Enhanced Hospital Protocols are critical for controlling infection spread within healthcare facilities but do not address the broader community spread.

Why OSCAR (DSS) Works Best:

The DSS, OSCAR, should work the best among these interventions in the context of public health emergency management. It provides real-time, data-driven insights that enable quick decision-making and targeted responses. By integrating various data sources and employing advanced simulation models, OSCAR enhances the ability to predict and manage disease outbreaks effectively, making it superior to interventions that are either too slow or too localized in their impact.

Primary Stakeholders

1. Public Health Officials

Motivation: Emphasize the potential to save lives, improve public health outcomes, and enhance their capacity to manage crises effectively.

2. Epidemiologists

Motivation: Highlight the advanced analytical tools and data accuracy that will improve their research and outbreak prediction capabilities.

3. Healthcare Providers (Doctors, Nurses)

Motivation: Stress the importance of timely and accurate data in improving patient outcomes and managing resources during outbreaks.

4. Data Scientists

Motivation: Offer the opportunity to work with cutting-edge technology and sophisticated data models that can drive impactful results.

5. Policy Makers

Motivation: Demonstrate how the system can provide actionable insights for policy development and resource allocation.

6. IT Specialists

Motivation: Present the technical challenges and innovations involved, which can enhance their skills and career growth.

7. Community Health Workers

Motivation: Show how the system can streamline their work and improve community health management.

8. Government Health Agencies

Motivation: Focus on the potential for enhanced coordination and efficiency in managing public health emergencies.

9. Emergency Response Coordinators

Motivation: Emphasize the system’s role in improving the speed and effectiveness of emergency response operations.

10. Academic Researchers

Motivation: Highlight the access to extensive data sets and the potential for groundbreaking research.

Champion

Role: Public Health Official or Senior Epidemiologist

Pros:

- Deep understanding of public health challenges and needs.
- Credibility and influence within the health sector.
- Ability to advocate effectively for the system's implementation and adoption.

Cons:

- May face resistance from stakeholders resistant to change.
- Potential bias towards public health priorities, potentially overlooking technical or operational challenges.

User

Role: Epidemiologist

Justification: Epidemiologists are directly involved in disease surveillance, analysis, and prediction. Their work relies heavily on accurate data and robust analytical tools, making them primary beneficiaries of the DSS.

Specific Needs:

- Access to real-time, high-quality data.
- Advanced analytical and simulation tools.
- User-friendly interface for efficient data manipulation and interpretation.

Barriers:

- Potential resistance to adopting new technologies.
- Need for training and familiarization with the system.
- Data privacy and security concerns.

Other Roles Involved

1. Healthcare Providers (Doctors, Nurses):

 - Provide patient data and implement recommendations based on DSS outputs.

2. Data Scientists:

 - Develop and refine analytical models and algorithms.

3. IT Specialists:

 - Ensure the technical infrastructure and system security.

4. Community Health Workers:

- Collect and report field data, implement community interventions.

5. Policy Makers:

- Use data insights to shape health policies and allocate resources.

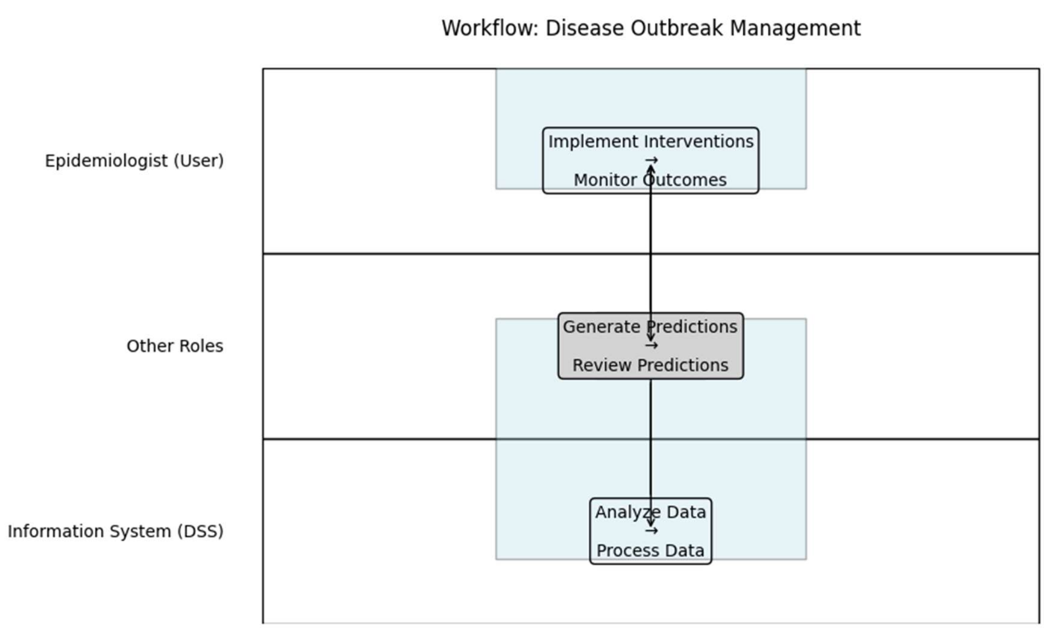
6. Emergency Response Coordinators:

- Coordinate on-the-ground response efforts based on DSS guidance.

7. Government Health Agencies:

- Oversee system integration and use at a national or regional level.

Workflow



Workflow: Disease Outbreak Management

Swimlane-Activity Diagram:

Below is a simplified swimlane-activity diagram for the workflow "Disease Outbreak Management," showing the roles of the Epidemiologist (User), Other Roles, and the Information System (DSS). The steps where the DSS is mostly involved are shaded in blue.

Swimlane Diagram Explanation:

- **Epidemiologist (User):**
  - **Collect Data**
  - **Analyze Data**
  - **Monitor Outcomes**
- **Other Roles:**
  - **Provide Data**
  - **Review Predictions**
  - **Implement Interventions**
- **Information System (DSS):**
  - **Process Data**
  - **Generate Predictions** (Shaded step)

Workflow Step:

- **Step: Generate Predictions**
  - **Justification in Terms of the 5 Rights:**
    - **Right Information:** The DSS processes diverse data sources to generate accurate outbreak predictions.
    - **Right Person:** Predictions are provided to epidemiologists and public health officials who are best positioned to act on them.
    - **Right Time:** Real-time predictions allow for immediate action, crucial for outbreak management.
    - **Right Format:** Visual and analytical representations are user-friendly and actionable.
    - **Right Channel:** Integrated into the DSS, ensuring seamless access within the existing information system.

Information System:

- **Type: Biosurveillance System**
  - **Justification:** A biosurveillance system is designed to monitor and analyze public health data to detect and predict disease outbreaks. It integrates various data sources, employs advanced analytical tools, and provides real-time insights, aligning perfectly with the needs of the DSS to support public health emergency management.

Design

Interactive Component (Widget):

- Widget Name: Outbreak Prediction Dashboard
- Design Approach**:**
    - **Synchronous or Asynchronous:** The dashboard would be synchronous to provide real-time updates and predictions, which is crucial for timely decision-making in public health emergencies.
    - **Soft Stop or Hard Stop:** A soft stop approach will be implemented. This means users will receive alerts and recommendations, but they will have the flexibility to override these suggestions based on their professional judgment.
    - **Preventing Alert Fatigue:** To prevent alert fatigue, the system will prioritize alerts based on severity and relevance, use tiered alert levels, and allow users to customize alert settings. Additionally, integrating context-aware logic can reduce unnecessary alerts.

User Interface/Widget

Mockup of the "Outbreak Prediction Dashboard":

Features:

1. **Real-Time Map Visualization:**
    - Interactive map showing current outbreak hotspots.
    - Color-coded regions based on risk levels (green, yellow, red).
2. **Prediction Analytics:**
    - Graphs and charts displaying predicted outbreak trends.
    - Filters to view data by region, disease type, and time period.
3. **Alert Panel:**
    - Notifications about new outbreaks, high-risk areas, and recommended actions.
    - Customizable alert settings to manage alert frequency.
4. **Data Input Section:**
    - Fields for inputting new data and updates.
    - Integration with external data sources for automatic updates.
5. **Decision Support Recommendations:**
    - Suggested interventions based on current data and predictions.
    - Links to detailed reports and resources.

Knowledge Representation in Use

- Chosen Representation: Hybrid Model Integration (Combining Rule-Based and Machine Learning Models)
    - Justification**:**
        - **Rule-Based Systems:** Effective for well-defined, deterministic knowledge such as standard outbreak response protocols.
        - **Machine Learning Models:** Excellent for pattern recognition and predictive analytics based on large datasets.
        - Combining these approaches allows for both structured decision-making and adaptive learning from real-world data.
- Why Not Others**:**
    - **Ontologies:** Although useful for structured representation of domain knowledge, they can be complex and less flexible in real-time predictive scenarios.
    - **Case-Based Reasoning:** While beneficial for learning from past cases, it may not be as effective for predicting novel outbreaks with no historical precedent.

Rule Logic

- Key Rules for DSS:
    - **If** the reported incidence rate of a disease in a region exceeds the predefined threshold **and** the model predicts an upward trend, **then** issue a high-risk alert and recommend immediate intervention.
    - **If** an area shows a sudden spike in related symptoms reported through various data sources (e.g., social media, health records), **then** trigger an investigation alert for potential emerging outbreaks.

Adverse Events

- Potential Issues:
    - **False Positives:** Over-predicting outbreaks leading to unnecessary resource allocation and public panic.
    - **False Negatives:** Failing to predict an outbreak, resulting in delayed response and higher impact.
    - **User Overload:** Excessive or irrelevant alerts causing users to ignore important notifications.
    - **Technical Failures:** System downtime or data inaccuracies impacting the quality of predictions.

Monitoring

- Metrics to Monitor:
    - **Alert Accuracy:** Track the rate of false positives and false negatives in predictions.

- **User Feedback:** Regular surveys and feedback forms to assess the usability and effectiveness of alerts and recommendations.
- **System Performance:** Monitor uptime, response times, and data processing speeds.
- **Outcome Measures:** Evaluate the impact of DSS recommendations on outbreak management outcomes, such as reduced spread and lower mortality rates.

Beyond HIMSS

Evaluation

Evaluation Approach:

To evaluate that the DSS has accomplished its purpose, the following methods and metrics will be used:

1. **Outcome Metrics:**
    - **Reduction in Outbreak Impact:** Compare the number and severity of outbreaks before and after DSS implementation. Metrics include the number of cases, hospitalizations, and mortality rates.
    - **Response Time:** Measure the time taken from detection to intervention. Faster response times indicate a successful DSS.
    - **Resource Allocation Efficiency:** Assess how effectively resources (e.g., medical supplies, personnel) are allocated during outbreaks based on DSS recommendations.
2. **Process Metrics:**
    - **Accuracy of Predictions:** Track the precision and recall of the system's outbreak predictions. This includes the rate of true positives, false positives, true negatives, and false negatives.
    - **User Engagement:** Monitor how frequently and effectively users (epidemiologists, public health officials) interact with the DSS. Higher engagement and adherence to DSS recommendations are positive indicators.
    - **Alert Fatigue:** Measure the incidence of ignored alerts and user feedback on alert relevance and frequency. Reduced alert fatigue suggests better system tuning.
3. **User Satisfaction:**
    - **Surveys and Interviews:** Conduct regular surveys and interviews with users to gather qualitative feedback on the DSS's usability, usefulness, and impact on their work.
    - **Usability Testing:** Perform usability testing sessions to identify any interface issues and areas for improvement.
4. **Comparative Analysis:**
    - **Before-and-After Studies:** Conduct studies comparing public health outcomes in regions using the DSS versus those not using it.

- **Pilot Programs:** Implement the DSS in pilot programs before a full-scale rollout, and compare results to control groups.

Knowledge Acquisition

System 1 vs. System 2 Knowledge:

- **System 1 Knowledge:** This involves intuitive, fast, and automatic knowledge, such as recognizing patterns or making quick decisions based on historical data.
- **System 2 Knowledge:** This involves analytical, deliberate, and logical thinking, such as understanding complex relationships in data and making strategic decisions based on in-depth analysis.

Knowledge Needed for the DSS:

The DSS requires a combination of System 1 and System 2 knowledge:

1. **System 1 Knowledge:**
   - **Pattern Recognition:** Using machine learning models to identify patterns in data that indicate potential outbreaks.
   - **Historical Data Analysis:** Leveraging historical data to make quick, initial assessments of current situations.
2. **System 2 Knowledge:**
   - **Epidemiological Analysis:** Detailed analysis of disease spread, transmission dynamics, and intervention strategies.
   - **Policy and Protocol Development:** Understanding and applying public health policies and outbreak management protocols.

Knowledge Acquisition and Maintenance:

1. **Sources of Knowledge:**
   - **Scientific Literature:** Regularly review and incorporate the latest research findings in epidemiology, public health, and data science.
   - **Expert Consultation:** Collaborate with epidemiologists, public health experts, and data scientists to refine the system's knowledge base.
   - **Data Feeds:** Integrate real-time data feeds from health information systems, social media, environmental sensors, and other relevant sources.
2. **Updating Frequency:**
   - **Continuous Updates:** Implement automated data pipelines to ensure real-time data integration and analysis.
   - **Periodic Reviews:** Conduct quarterly reviews of the DSS's performance and update algorithms, models, and knowledge bases accordingly.
   - **Annual Overhauls:** Perform comprehensive annual reviews to incorporate major advancements in public health research and technology.

How to Keep Knowledge Up to Date:

- **Automated Data Integration:** Set up automated systems to continuously collect and process new data from multiple sources.
- **Regular Expert Reviews:** Schedule regular meetings with a panel of experts to review the DSS's performance and make necessary adjustments.
- **User Feedback Loops:** Establish mechanisms for users to provide feedback on system recommendations, which can then be used to fine-tune the DSS.
- **Training and Retraining Models:** Periodically retrain machine learning models with new data to ensure they remain accurate and relevant.