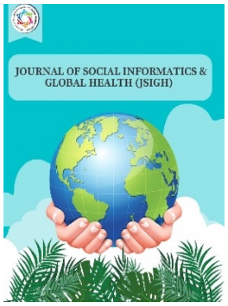
https://doi.org/10.62585/sigh.v1i1.61



Volume and Issues Obtainable at Centeriir.org
Journal of Social Informatics and Global Health
ISSN (Print): 3006-9424 ISSN (Online): 3006-9432

Volume 1, No.1, 2022
Journal Homepage: https://journals.centeriir.org/index.php/sigh

Building Robust Surveillance Systems: The Intersection of Data, Innovation, and Collaboration

Masoomeh Latifi[1] **Kalankesh KL**[2]

[1]Ph.D. Knowledge and Information Science, Hormozgan University of Medical Sciences, Iran. E-Mail: masoomehlatifiinf@gmail.com
[2]Lecturer of Medical Informatics at Tabriz University of Medical Sciences, Iran. E-Mail: kalankeshlr@tums.edu

ABSTRACT

Public health surveillance is indispensable for safeguarding population health, relying on systematic data collection and analysis to inform interventions. This article delineates its principles, emphasizing its dual purpose and systematic nature. It discusses the evolving scope, including novel data sources and analytical techniques crucial for adapting to modern health challenges. Global health surveillance's significance in detecting emerging threats is highlighted, necessitating timely information exchange for effective response. Moving forward, the author explores challenges and opportunities in global surveillance, proposing strategies for advancement. It underscores the transformative potential of emerging technologies like big data analytics and artificial intelligence (AI) in enhancing health equity and improving population health outcomes, especially in low-resource settings. To harness these technologies effectively, the article emphasizes the importance of regulatory frameworks, digital infrastructure investment, and training programs for healthcare personnel. It also advocates for reintroducing Health Informatics disciplines to develop individuals capable of utilizing big data analytics for informed decision-making in managing global health crises. Overall, the article underscores the critical role of collaboration, technological innovation, and data-driven approaches in shaping resilient surveillance systems for safeguarding global health.

Article History: Received: September 02, 2022: **Accepted**: October 02, 2022: **Published**: October 05, 2022
Keywords: Health , Digital Era, Big Data Analytics, ehealth, Global Health, Surveillance

Corresponding Author's E-Mail: masoomehlatifiinf@gmail.com

https://doi.org/10.62585/sigh.v1i1.61

1. Introduction

Public health surveillance plays a pivotal role in safeguarding population health by systematically collecting, analyzing, and interpreting health data to inform decision-making and guide public health interventions (World Health Organization, 2017). To comprehend the intricate framework of public health surveillance, it is imperative to delineate its fundamental principles and conceptual underpinnings.
As asserted by Casey et al., (2016), “Workgroup consultants have distilled two basic principles from the definition of public health surveillance, providing a foundational framework for understanding its essence. Firstly, public health surveillance serves a dual purpose: to address defined public health issues or questions and to utilize the collected data to devise strategies to safeguard and enhance population health.” Secondly, public health surveillance is characterized by its ongoing and systematic nature. It encompasses a series of interconnected processes, including planning, data collection, analysis, interpretation, dissemination, and application of information to public health programs and practices. These principles serve as guiding pillars for framing discussions on key concepts and terms within public health surveillance, thereby situating surveillance activities within the broader context of population health assessment and actionable public health knowledge. The traditional definition of public health surveillance encompasses various concepts that can be interpreted in diverse ways, leading to differing scopes of surveillance systems (Brownson et al., 2009). While a conventional interpretation restricts surveillance to morbidity and mortality of diseases or specific health events, a broader perspective expands the realm of surveillance to encompass new areas of public health inquiry utilizing innovative data sources, collection methods, and analytical techniques. Embracing this expansive interpretation is vital to adapt to evolving health information needs and advancements in public health surveillance in the 21st century (Dolley, 2018).
Central to public health surveillance is the ongoing systematic collection of health data, capturing the temporal occurrence of events and the reporting frequency of those events. The notion of "ongoing" implies the consistent capture of events over time, irrespective of their occurrence timing. In contrast, reporting frequency is tailored to the specific needs of public health programs, balancing the urgency of rapid reporting for high-hazard events with the longer time frames required for chronic disease surveillance (Nsubuga et al.,2011). In public health surveillance, health information goes beyond morbidity and mortality data to include diverse information such as environmental exposures, risk behaviors, and health policies. The various sources of health information and their connection to prevention and control measures highlight the complex nature of public health monitoring in meeting population health requirements and guiding evidence-based policies. The significance of global health surveillance is becoming more apparent due to the heightened shared vulnerability to infectious diseases and other public health hazards caused by global interconnection. As asserted by Morse (2012), “From the emergence of HIV/AIDS and novel influenza strains to bioterrorism incidents and pandemics like SARS and H1N1, global health surveillance serves as a critical tool for identifying and preventing emerging and reemerging diseases worldwide.” Providing timely health information to countries is essential to enable effective response and preparedness measures against epidemics and other health emergencies.
Moving forward, this research article aims to explore the current landscape of global health surveillance, identify challenges and opportunities, and propose strategies to advance surveillance efforts in the 21st century. By fostering dialogue and collaboration within the public health community, we strive to shape a collective vision for global health surveillance that promotes the well-being of populations worldwide. Through innovative approaches and shared commitment, we can build resilient surveillance systems capable of safeguarding global health in an increasingly interconnected world.

2. Understanding Big Data Analytics

Within business intelligence (BI), big data analytics combines two essential elements: huge data and sophisticated analytics. Understanding the importance of big data analytics requires defining advanced analytics and exploring the relationship between big data and advanced analytics. Advanced analytics uses complex analytical methods to uncover insights from large datasets, frequently compared to a discovery expedition (Belhadi et al., 2019). A 2009 survey conducted by TDWI revealed a growing adoption of advanced analytics, “with 38% of organizations already practicing it and 85% intending to do so within three years” (Russom, 2011). This surge in interest can be attributed to the ever-changing business landscape and the burgeoning opportunities that emerge in the wake of economic shifts. Advanced analytics serves as a compass, guiding organizations to identify new customer segments, optimize supply chains, discern sales patterns, and navigate other intricacies of the business terrain.

As organizations embark on their journey into advanced analytics, they encounter many challenges and complexities, particularly if they are venturing into this domain for the first time. While prior experience in data warehousing and reporting may provide a foundation, the nuances of advanced analytics necessitate a distinct approach to both business and technical requirements (Dremel et al., 2017). Hence, it is crucial to investigate new choices for sophisticated analytics and analytic databases designed for large data, enabling users to make well-informed decisions using analytics. "Advanced analytics" refers to various approaches and tools such as predictive analytics, data mining, statistical analysis, and complicated SQL. Furthermore, as Fortem (2020) asserted, “it includes data visualization, artificial intelligence, natural language processing, and database features that aid in analytics. Yet, a more fitting term for this combination of methods would be discovery analytics, emphasizing its main goal of revealing fresh business insights.” Within this context, big data analytics catalyzes exploration, enabling business analysts to delve into vast volumes of detailed data to unearth previously unknown phenomena

Big data, characterized by its voluminous nature, provides an extensive statistical sample that enhances the accuracy of analytic results. The data sample size directly correlates with the precision of statistical analyses, making big data particularly conducive to mining insights. Modern analytic tools and databases are adept at handling big data, executing complex queries, and parsing tables remarkably efficiently. Furthermore, the affordability of tools and platforms for big data analytics has democratized access to these capabilities, making them accessible to organizations of all sizes (Periasamy & Raj,2016). Big data analytics relies on diverse and detailed raw data, avoiding standard data cleaning methods that may remove key insights. In discovery and predictive analytics, even dubious or unconventional data can provide useful insights, particularly in areas like fraud detection. Preserving the integrity and richness of big data is crucial for fully utilizing its promise in advanced analytics.

3. Applications of Big Data Analytics in Healthcare

There has been a noticeable surge in demand for effective analytical tools in recent years, particularly in big data (BD) analysis. Organizations across sectors are increasingly seeking to harness the potential of big data to enhance decision-making, gain competitive advantage, and improve overall business performance (Fortem, 2020). However, despite its potential, the practical outcomes of implementing big data solutions in various organizations still need to be discovered. The healthcare sector, in particular, has witnessed a paradigm shift from a disease-centered to a patient-centered model, even transitioning towards value-based healthcare delivery. This shift underscores the importance of personalized care, preventive strategies, and improved health outcomes for individuals. To effectively meet the requirements of this evolving model and provide patient-centered care, it has become imperative to manage and analyze healthcare big data (Batko & Ślęzak, 2022).

One primary challenge in healthcare is the appropriate utilization of big data. With the advent of electronic medical records and the proliferation of data from various sensors and social media platforms, healthcare organizations grapple with ever-growing data streams (Farahani et al.,2018). The data cover various sources such as “clinical records, medical pictures, genomic data, and health behaviors.” Utilizing this data efficiently can enable healthcare organizations to bolster clinical decision-making, improve disease surveillance, and maximize public health management. The large amount and intricate nature of clinical data present substantial processing obstacles. Big data has developed over time, resulting in many definitions and understandings. Big data refers to large and constantly growing digital information that poses issues for traditional storage and analytical methods. It encompasses tools, technologies, and phenomena aimed at efficiently handling large volumes of data (Dremel et al., 2017).

From a practical standpoint, Wang et al. (2019) highlighted that “big data analytics in healthcare involves leveraging tools, processes, and procedures to create, manipulate, and manage vast datasets and storage facilities.” These technologies enable organizations to extract value from large volumes of diverse data types by facilitating high-velocity capture, discovery, and analysis. Big data analytics in healthcare is not merely about managing data; it represents a complex system that requires specialized expertise and resources. It involves databases for storing data, programs, and tools for data management, and personnel capable of retrieving valuable insights (Wang et al., 2019). Visualization also plays a crucial role in understanding and interpreting the vast amounts of data generated.

Big data analytics in healthcare holds immense potential for revolutionizing patient care, improving clinical outcomes, and driving healthcare innovation. By effectively harnessing the power of big data, healthcare organizations can unlock new insights, optimize processes, and ultimately deliver better patient outcomes.

Moreover, big data analytics applications in healthcare extend beyond clinical settings. Healthcare providers can leverage big data to enhance operational efficiency, streamline administrative processes, and identify cost-saving opportunities (Mohamed, 2021). Big data analytics can support population health management by pinpointing high-risk patient groups, forecasting disease outbreaks, and executing focused interventions. Big data analytics in healthcare allows enterprises to use predictive analytics to find trends and patterns in patient data, predict future healthcare requirements, and allocate resources accordingly. Being proactive enhances patient outcomes and lowers healthcare expenses by avoiding unnecessary hospitalizations and interventions. Big data analytics has great potential to revolutionize the healthcare industry. Healthcare organizations can utilize big data to innovate, enhance patient care, and progress toward providing high-quality, patient-centered healthcare services.

4. The Significance of Global Health Surveillance

Global health surveillance is crucial in today's globalized world where commerce and economic activity occur rapidly across countries and continents. Globalization has reduced travel times so much that it often takes less time to travel worldwide than for many infectious diseases to develop. This interconnection presents substantial problems and requires a strong global health surveillance system to detect and address public health issues efficiently.

Recognizing the pivotal role of health in human development, various international bodies, including the United Nations, have emphasized the importance of health as an essential component of global development. The establishment of organizations like the “United Nations' Global Commission on Macroeconomics and Health” and the “Global Commission on Social Determinants of Health” underscores the global recognition of health as a critical aspect of human welfare (Labonté & Schrecker, 2007).

The evolution of global health surveillance can be traced back to the latter part of the 19th century when weekly reports on diseases of critical health importance were disseminated. Over time, international bodies like the League of Nations and the Pan American Sanitary Bureau played crucial roles in global disease surveillance by publishing weekly health records and bulletins (Choi, 2012).

However, it was not until the “World Health Organization” (WHO) was created in 1945 that the responsibility for global disease reporting was consolidated under a single entity. The WHO's Weekly Epidemiological Record became the cornerstone of global health surveillance, incorporating reporting mechanisms from various international health organizations (Clift, 2013).

The “International Health Regulations” (IHR), originally established as the International Sanitary Regulations in 1951, underwent significant revisions in 2005 to address emerging challenges in global health security (Le Moli, 2023). The IHR-2005 expanded the scope of surveillance beyond specific diseases like cholera, yellow fever, and plague to encompass a broader range of public health risks, including bioterrorism and pandemics. Under the IHR-2005, countries must report any events that may constitute a public health emergency of international concern, thereby facilitating a coordinated global response to emerging threats (Wilder-Smith & Osman, 2020). The regulations also mandate the establishment of national IHR centers to ensure seamless communication with the WHO.

The importance of global health surveillance is further underscored by the constant emergence of new diseases and pathogens and the reemergence of previously controlled conditions (Nii-Trebi, 2017). The interconnectedness of human and animal populations and environmental and socioeconomic factors contribute to the spread of infectious diseases. In response to these challenges, initiatives like the US Agency for International Development's Emerging Pandemic Threats program aim to preemptively combat newly emerging diseases of animal origin. These initiatives enhance global preparedness and response capabilities by monitoring wildlife and identifying geographic hotspots of disease emergence (Foray et al., 2012).

5. Big Data Sources for Health Surveillance

The sheer size and availability of multidimensional data, coupled with rapid technological innovation, have the potential to significantly impact various disciplines, particularly the healthcare sector. This vast and rapidly growing data landscape has given rise to "big data," which refers to complex electronic healthcare datasets that are challenging to manage using traditional methods or tools. In the healthcare context, big data encompasses healthcare records (such as patient records, disease surveillance data, hospital records, medication data, and clinical decision support feedback) and clinical data, including imaging data, personal health records, financial records, genetic data, pharmaceutical data, and Electronic Medical Records (Mehta & Pandit, 2018).

As technology advances, big data analytics holds immense promise for predicting, preventing, managing, treating, and curing diseases. Additionally, it aids government agencies, policymakers, and hospitals in resource management, medical research, epidemic planning, and preventative measures (Dash et al., 2019). With the shift from hard copy medical data to Electronic Health Records (EHR) and Electronic Medical Records (EMR) systems, there has been an exponential growth in health data. This includes data collected from clinical records, telemonitoring, medical tests, and many healthcare apps, with millions of subscribers worldwide.

The advent of social media and internet usage has further contributed to the volume of health-related data, with billions of people accessing online platforms for various purposes, including health and well-being. Big data in healthcare exhibits five main characteristics: Volume, Variety, Velocity, Value, and Veracity. Volume refers to the vast amount of medical and clinical data generated, including personal data, clinical data, radiology images, genetics, and population information (Jony et al., 2016). Variety encompasses structured, unstructured, and semi-structured healthcare records, ranging from patient information to MRI images. Velocity describes the pace at which data is generated, whether at rest or in motion, with high-velocity data often crucial for real-time monitoring and decision-making in healthcare settings. Value assesses the usefulness of data, while Veracity refers to the reliability and accuracy of healthcare records. Overall, big data sources for health surveillance encompass diverse data types and sources, including electronic healthcare records, medical imaging data, genetic data, telemonitoring data, and information from healthcare apps and social media platforms. Leveraging these sources effectively can enhance health surveillance efforts, improving healthcare outcomes and decision-making.

6. Applications of Big Data Analytics in healthcare sector

Big data analytics is revolutionizing disease detection and monitoring in the healthcare sector. With the exponential growth of patient data, traditional methods are being replaced by sophisticated analytics tools that can handle large volumes of electronic healthcare records. Hospital strategic planning benefits from machine learning algorithms that predict patient flow and reduce waiting times, ensuring timely treatment (Mtonga et al.,2019). Fraud detection has become more effective with the analysis of vast datasets, helping organizations identify and prevent fraudulent activities before they occur, thus improving cost-efficiency and quality of care. Resource management is optimized through predictive models that identify patients at high risk of readmission, enabling targeted interventions and cost reduction. Personalized medicine is facilitated by analyzing individual patient data, including genomics, allowing for tailored treatment plans and better patient outcomes. Disease prediction and prevention are enhanced through big data analytics, enabling early detection and intervention. Medical image processing is another area where big data analytics plays a critical role, aiding in the detection, diagnosis, and decision-making in therapy based on various imaging modalities (Belle et al.,2015). Heart disease prediction benefits from early detection using biosensors and online systems, guiding treatment decisions and improving patient outcomes.

Similarly, brain disorder detection and diabetes analysis are improved through data mining and analytics tools, enabling early diagnosis and effective management of these conditions. Remote healthcare applications leverage big data analytics to facilitate appointment scheduling, patient diagnosis, and consultation, improving access and efficiency in healthcare delivery. Overall, big data analytics in healthcare transforms disease detection and monitoring, leading to more accurate diagnoses, better treatment outcomes, and improved patient care (Rehman et al., 2022).

Applications of Big Data Analytics in Healthcare are transforming conventional medical diagnosis and treatment paradigms. By integrating data from various medical records and real-time wearable sensors, big data analytics can revolutionize medical diagnosis, providing early warnings of potential health risks and enabling preventive measures during the early stages of disease development (Ali et al., 2016). This approach enhances efficiency and convenience by allowing patients to access personalized medical services through healthcare apps, right from the comfort of their homes. However, a significant challenge lies in the fragmentation of patient data across different databases, hindering a comprehensive understanding of each patient's health status. Integrating these fragmented data sets is key to democratizing health information and fostering collaboration between medical and data sciences. Such integration can pave the way for establishing Learning Health Systems (LHS), merging expertise from policymaking, medical care, engineering, and technology to analyze and combat diseases rapidly and accurately (Ali et al., 2016). The potential of LHS extends beyond individual countries, offering insights into global health trends and early detection of viral epidemics. Practical applications of big data technology have already been demonstrated in developing early warning systems for epidemic outbreaks. For instance, studies have utilized algorithms deployed on platforms like Google Flu Trends to detect signs of potential epidemics.
Furthermore, projects focusing on human genome sequencing play a crucial role in understanding the origins and dynamics of various diseases. The massive amounts of data generated from genome sequencing provide valuable insights that contribute to advancements in healthcare and disease management (García et al., 2020). Overall, the applications of big data analytics in healthcare are reshaping the landscape of medical diagnosis, treatment, and public health initiatives locally and globally.

7. Case Studies: Successful Implementation of Big Data Analytics in Global Health Surveillance

Various case studies have demonstrated the successful implementation of big data analytics in global health surveillance. One crucial application is contact tracing, which utilizes diverse data sources such as social media metadata, passenger lists, and credit card transactions. Although social media data may not always be accurate, it can aid in tracking individuals' movements for early detection of potential outbreaks. However, effective data architecture is vital for merging, sharing, and analyzing these diverse data streams. Additionally, case detection benefits from big data analytics, with studies utilizing social media search indexes to identify new COVID-19 cases based on relevant keywords like clinical symptoms (Agbehadji et al., 2020). Despite challenges in accuracy, social media posts can help identify at-risk locations, supporting response efforts. Real-time analytics platforms like Storm, Kafka, and Apache Spark enable rapid processing of streaming data, facilitating timely response to emerging threats.

Furthermore, artificial intelligence models, particularly machine learning and deep learning, are crucial in handling large and heterogeneous datasets. Deep learning, in particular, has significantly advanced applications in drug discovery, genomics, and medical image analysis by uncovering complex relationships within high-dimensional data. These case studies underscore the importance of data-driven approaches in enhancing disease surveillance and improving public health responses globally (Belle et al.,2015).

Several studies have delved into applying digital health technologies for integrated disease surveillance and response in sub-Saharan Africa (SSA). While some have shown improved early detection and response, others have highlighted weaknesses in surveillance systems. The COVID-19 pandemic underscored the need for resilient surveillance systems, especially in Africa, where challenges like data misrepresentation and late response strategies were evident (Rana, 2017). In one study, the Southern African Centre for Infectious Disease Surveillance (SACIDS) implemented a mobile technology-enabled surveillance system for animal diseases. This system utilized SMS and digital forms for data submission, enabling early detection of diseases like foot-and-mouth and facilitating prompt quarantine measures (Achieng & Ogundaini, 2024).

Another study examined Tanzania's Council Health Management Teams (CHMT) attitudes and practices regarding disease surveillance data analysis. Challenges such as incomplete data capture and limited accessibility hindered effective analysis and reporting. Capacity building across healthcare institutions is essential to leverage big data analytics for informed decision-making (Mremi et al., 2022).

Despite improvements in surveillance activities, data integration from multiple sources remains challenging in countries like Nigeria, Malawi, and Tanzania. Big data analytics is underutilized in implementing Integrated Disease Surveillance and Response (IDSR) strategy in SSA, hindering evidence-based decision-making. Improving disease surveillance in Africa includes initiatives like the Regional Integrated Surveillance and Laboratory Network (RISLNET), which focuses on pandemic preparedness through collaboration and capacity-building (Mremi et al., 2022).

In the Global North and South, big data analytics has been successfully used to develop efficient disease detection and forecasting models (Wang, Kung & Byrd, 2018). For example, predictive analytics frameworks have been employed to identify early warning signs, track infected individuals, and pinpoint at-risk locations. Lessons from these case studies highlight the importance of adapting context-specific technologies and big data analytics to achieve the goals of disease surveillance strategies like IDSR in SSA's health systems.

8. Challenges of Big Data Analytics

Implementing Big Data for Development (BD4D) brings a host of technical challenges that must be addressed to leverage its potential fully. These challenges span various aspects of data processing, storage, and analysis, hindering the widespread adoption of big data analytics. Here are some of the key technical challenges:

Crowdsourcing Coordination
Social media platforms provide useful crowdsourced data for humanitarian assistance, but the absence of a cohesive collaboration framework among aid organizations results in redundant efforts and ineffective crisis responses.

Bias and Polarization
Algorithms predicting personalized content based on user behavior can inadvertently create polarization by presenting different perspectives to different users. Advanced deep-learning techniques and context-aware computing aim to mitigate this issue.

Data Supply Chain
Policy analysis using big data faces challenges such as privacy concerns and data context and semantics alterations during the gathering process. Disparities in technology proliferation globally introduce statistical biases, impacting the efficacy of policies.

Technology Usage
Variations in individuals' attitudes towards technology usage pose challenges in data analysis, particularly in contexts like online learning analytics. Careful consideration must be given to avoid penalizing students with different usage patterns.

Spatial Problem
Users providing crisis-related information on social media may be geographically dispersed, posing challenges in pinpointing the actual location of a crisis. Ground-based surveys and aerial imagery must be corroborated for effective crisis response.

Interoperability and Fragmentation
Big data analytics combines diverse unstructured data sources such call detail records, satellite imaging, and survey data. Integrating these varied data sources for analysis is a major challenge. Healthcare fragmentation, involving patient interactions with several specialists and undergoing various testing, impedes comprehensive analysis. Integrating these scattered data sources is essential to ensure thorough diagnosis and tailored treatments.

Technology Scaling
While cloud computing and software-defined networking have been instrumental in implementing big data solutions, further work is needed to ensure that computing and networking infrastructure can scale to handle the ever-increasing volume of data.

Addressing these technical challenges requires ongoing research and development efforts to enhance data processing capabilities, improve stakeholder coordination, and develop robust frameworks for data analysis and interpretation in humanitarian development.

9. Emerging Trends in Big Data Analytics for Global Health Surveillance

The case studies of Taiwan and Estonia exemplify the transformative potential of blockchain technology in revolutionizing global health surveillance. External experts have confirmed the effectiveness and sustainability of real-time surveillance systems implemented in these regions, showcasing promising capabilities. Estonia, for instance, has fully integrated blockchain into its public health infrastructure, ensuring secure and accessible healthcare information for patients while maintaining confidentiality (Ali et al., 2022). Similar initiatives have been undertaken in countries like the UK, USA, and Canada, where real-time surveillance systems have been deployed across various departments and sectors, enhancing monitoring capabilities. Key characteristics essential for an ideal disease surveillance system include coverage, durability, consensus, selective privacy, uniqueness, and timing. Blockchain applications in disease surveillance offer a robust solution that meets these criteria effectively, surpassing traditional surveillance methods in terms of efficiency and promptness. Blockchain-based systems guarantee transparency, security, and cost-effectiveness, with the added advantage of easy integration into mobile applications at minimal cost (Khan & AbaOud, 2023). Moreover, these systems can operate without centralized supervision, making them scalable even in regions with limited connectivity.

The Global Health Security Agenda has worked diligently to establish real-time surveillance systems in several locations worldwide, such as South America, Central America, North America, Africa, Asia, and Europe. Countries can improve their ability to detect epidemic diseases early by utilizing blockchain technology, leading to decreased mortality, morbidity, and economic expenses. Timely data validation and accessibility facilitate quicker responses in health crises, enhancing global health security (Chattu et al., 2019). Blockchain-based surveillance systems have various advantages, but scalability, security, and cost-effectiveness require more research and development.

10. Future Directions and Emerging Trends in Big Data Analytics for Global Health Surveillance

Database technology landscape is evolving rapidly, especially with the emergence of big data and Web 2.0. Traditional relational databases struggle to efficiently store and access unstructured data like word documents, email, and multimedia content (Junaid et al.,2016). NoSQL databases have gained prominence to address this challenge, offering distributed and easily scalable solutions. Companies like Amazon and Google utilize NoSQL databases such as Dynamo and Bigtable for efficient data storage and retrieval. However, concerns arise regarding the lack of inherent support for ACID properties in NoSQL databases, necessitating manual programming of these functionalities (Corbellini et al., 2017). Predictive analytics, powered by data mining and machine learning techniques, holds immense potential for providing a competitive edge by predicting future occurrences or behaviors based on past data. Crowdsourcing, distinct from outsourcing, involves outsourcing tasks to the general public via open calls. This technique, particularly when leveraging social media data, has been instrumental in disaster relief efforts, such as during the 2010 Haiti earthquake (Kankanamge et al.,2019). By harnessing data from diverse sources like text messages and social media updates, crowdsourcing facilitates mapping disaster-stricken regions and coordinating search operations.

The Internet of Things (IoT) represents a burgeoning field driven by advancements in big data, network science, and digital communication. IoT's potential economic value is estimated to be in the trillions of dollars, contingent upon overcoming interoperability challenges. IoT facilitates real-time monitoring and diagnosis in healthcare through wearable body sensors and ML-powered analytics, revolutionizing disease management and industrial maintenance processes through predictive analytics and real-time data insights (Sinha & Dhanalakshmi, 2022).

As we look to the future, these trends in database technology, predictive analytics, crowdsourcing, and IoT offer promising avenues for enhancing global health surveillance. By leveraging these technologies, stakeholders can gain actionable insights from vast amounts of data, enabling more effective decision-making and proactive responses to emerging health challenges on a global scale.

11. Conclusion

Global health surveillance is critical in detecting and responding to emerging public health threats in an increasingly interconnected world. By fostering collaboration among nations and organizations and leveraging technological advancements, global surveillance efforts contribute to safeguarding public health and promoting global well-being.

The convergence of emerging technologies in healthcare, from information technology to artificial intelligence, presents a transformative opportunity to revolutionize healthcare delivery worldwide. These technologies hold immense promise in discovering novel medications, enhancing healthcare outcomes, and reducing costs and waste. Innovative approaches like ASBRU and theranostics offer personalized treatment plans. At the same time, value-based healthcare models prioritize patient health results and deliver coordinated, high-quality care through organizations like ACOs and PCMHs.
Big data analytics, artificial intelligence, and machine learning are crucial for enhancing health equity and population health. These technologies can improve healthcare delivery, especially in low-resource settings, by analyzing complex data and creating effective solutions. Successful integration of big data analytics in global health surveillance depends on overcoming contextual obstacles and difficulties. Delineating big data analytics requirements is crucial for operationalizing methods such as the Integrated Disease Surveillance and Response (IDSR) system, aiming to efficiently prevent, monitor, control, and respond to infectious disease outbreaks. Key requirements to create an enabling environment include implementing strong ICT regulatory and data governance frameworks, investing in digital health infrastructure, and providing healthcare personnel with specific digital skills. Training programs focused on analytics skills are essential for healthcare practitioners to proficiently gather, evaluate, and communicate disease surveillance data, thereby improving public health interventions. The growth of data-driven professions and related stakeholders is becoming more crucial as we transition to a digital economy. Reintroducing Health Informatics disciplines can help develop individuals who can utilize big data analytics for healthcare decision-making, essential in managing new and recurring disease outbreaks worldwide. The core of big data analytics is not the technology, but the profound insights it provides to businesses. Organizations can use big data and discovery analytics to adapt and succeed in a changing marketplace.

References

Achieng, M. S., & Ogundaini, O. O. (2024). Big Data Analytics for Integrated Infectious Disease Surveillance in sub-Saharan Africa. *South African Journal of Information Management*, *26*(1), 1668.

Agbehadji, I. E., Awuzie, B. O., Ngowi, A. B., & Millham, R. C. (2020). Review of big data analytics, artificial intelligence and nature-inspired computing models towards accurately detecting COVID-19 pandemic cases and contact tracing. *International journal of environmental research and public health*, *17*(15), 5330.

Ali, A., Qadir, J., Rasool, R. U., Sathiaseelan, A., Zwitter, A., & Crowcroft, J. (2016). Big data for development: applications and techniques. *Big Data Analytics*, *1*, 1-24.

Ali, O., Jaradat, A., Ally, M., & Rotabi, S. (2022). Blockchain technology enables healthcare data management and accessibility. *Blockchain Technologies for Sustainability*, 91-118.

Batko, K., & Ślęzak, A. (2022). The use of Big Data Analytics in healthcare. *Journal of big Data*, *9*(1), 3.

Belhadi, A., Zkik, K., Cherrafi, A., & Sha'ri, M. Y. (2019). Understanding big data analytics for manufacturing processes: insights from literature review and multiple case studies. *Computers & Industrial Engineering*, *137*, 106099.

Belle, A., Thiagarajan, R., Soroushmehr, S. M., Navidi, F., Beard, D. A., & Najarian, K. (2015). Big data analytics in healthcare. *BioMed research international*, *2015*.

Brownson, R. C., Fielding, J. E., & Maylahn, C. M. (2009). Evidence-based public health: a fundamental concept for public health practice. *Annual review of public health*, *30*, 175-201.

Casey, J. A., Schwartz, B. S., Stewart, W. F., & Adler, N. E. (2016). Using electronic health records for population health research: a review of methods and applications. *Annual review of public health*, *37*, 61-81.

Chattu, V. K., Nanda, A., Chattu, S. K., Kadri, S. M., & Knight, A. W. (2019). The emerging role of blockchain technology applications in routine disease surveillance systems to strengthen global health security. *Big Data and Cognitive Computing*, *3*(2), 25.

Choi, B. C. (2012). The past, present, and future of public health surveillance. *Scientifica*, *2012*.

Clift, C. (2013). The role of the World Health Organization in the international system.

Corbellini, A., Mateos, C., Zunino, A., Godoy, D., & Schiaffino, S. (2017). Persisting big-data: The NoSQL landscape. *Information Systems*, *63*, 1-23.

Dash, S., Shakyawar, S. K., Sharma, M., & Kaushik, S. (2019). Big data in healthcare: management, analysis and future prospects. *Journal of big data*, *6*(1), 1-25.

Dolley, S. (2018). Big data’s role in precision public health. *Frontiers in public health*, *6*, 68.

Dremel, C., Wulf, J., Herterich, M. M., Waizmann, J. C., & Brenner, W. (2017). How AUDI AG established big data analytics in its digital transformation. *MIS Quarterly Executive*, *16*(2).

Farahani, B., Firouzi, F., Chang, V., Badaroglu, M., Constant, N., & Mankodiya, K. (2018). Towards fog-driven IoT eHealth: Promises and challenges of IoT in medicine and healthcare. *Future generation computer systems*, *78*, 659-676.

Foray, D., Mowery, D. C., & Nelson, R. R. (2012). Public R&D and social challenges: What lessons from mission R&D programs?. *Research policy*, *41*(10), 1697-1702.

Fortem, M. J. (2020). *Exploring Strategies to Transition to Big Data Technologies From DW Technologies* (Doctoral dissertation, Walden University).

García, A., Palacio, A. L., Román, J. F. R., Casamayor, J. C., & Pastor, O. (2020). Towards the understanding of the human genome: a holistic conceptual modeling approach. *IEEE Access*, *8*, 197111-197123.

Jony, R. I., Rony, R. I., Rahman, M., & Rahat, A. (2016, May). Big data characteristics, Value chain and challenges. In *Proceedings of the 1st international conference on advanced information and communication technology. Bangladesh*.

Junaid, Q., Anwaar, A., Andrej, Z., Arjuna, S., & Crowcroft, J. (2016). Crisis analytics: Big data-driven crisis response. *Journal of International Humanitarian Action*, *1*(1).

Kankanamge, N., Yigitcanlar, T., Goonetilleke, A., & Kamruzzaman, M. (2019). Can volunteer crowdsourcing reduce disaster risk? A systematic review of the literature. *International journal of disaster risk reduction*, *35*, 101097.

Khan, M. F., & AbaOud, M. (2023). Blockchain-Integrated Security for Real-time Patient Monitoring in the Internet of Medical Things Using Federated Learning. *IEEE Access*.

Labonté, R., & Schrecker, T. (2007). Globalization and social determinants of health: Promoting health equity in global governance (part 3 of 3). *Globalization and health*, *3*, 1-15.

Le Moli, G. (2023). The Containment Bias of the WHO International Health Regulations. *British Yearbook of International Law*, brad001.

Mehta, N., & Pandit, A. (2018). Concurrence of big data analytics and healthcare: A systematic review. *International journal of medical informatics*, *114*, 57-65.

Mohamed, A. (2021). Framework of Big Data Analytics in Real Time for Healthcare Enterprise Performance Measurements.

Morse, S. S. (2012). Public health surveillance and infectious disease detection. *Biosecurity and bioterrorism: biodefense strategy, practice, and science*, *10*(1), 6-16.

Mremi, I. R., Sindato, C., Kishamawe, C., Rumisha, S. F., Kimera, S. I., & Mboera, L. E. (2022). Improving disease surveillance data analysis, interpretation, and use at the district level in

Tanzania. *Global Health Action*, *15*(1), 2090100.
Mtonga, K., Kumaran, S., Mikeka, C., Jayavel, K., & Nsenga, J. (2019). Machine learning-based patient load prediction and IoT integrated intelligent patient transfer systems. *future internet*, *11*(11), 236.

Nii-Trebi, N. I. (2017). Emerging and neglected infectious diseases: insights, advances, and challenges. *BioMed research international*, *2017*.

Nsubuga, P., White, M. E., Thacker, S. B., Anderson, M. A., Blount, S. B., Broome, C. V., ... & Trostle, M. (2011). Public health surveillance: a tool for targeting and monitoring interventions.

Periasamy, M., & Raj, P. (2016). Big Data Analytics: Enabling Technologies and Tools. *Data Science and Big Data Computing: Frameworks and Methodologies*, 221-243.

Rana, S. (2017). *Mobile phones for reproductive health care information: Reviewing mobile health (mHealth) from gender perspective in sub-Saharan Africa (SSA)* (Master's thesis).

Rehman, A., Naz, S., & Razzak, I. (2022). Leveraging big data analytics in healthcare enhancement: trends, challenges and opportunities. *Multimedia Systems*, *28*(4), 1339-1371.

Russom, P. (2011). Big data analytics. *TDWI best practices report, fourth quarter*, *19*(4), 1-34.
Sinha, B. B., & Dhanalakshmi, R. (2022). Recent advancements and challenges of Internet of Things in smart agriculture: A survey. *Future Generation Computer Systems*, *126*, 169-184.

Wang, Y., Kung, L., & Byrd, T. A. (2018). Big data analytics: Understanding its capabilities and potential benefits for healthcare organizations. *Technological forecasting and social change*, *126*, 3-13.

Wang, Y., Kung, L., Gupta, S., & Ozdemir, S. (2019). Leveraging big data analytics to improve quality of care in healthcare organizations: A configurational perspective. *British Journal of Management*, *30*(2), 362-388.

Wilder-Smith, A., & Osman, S. (2020). Public health emergencies of international concern: a historic overview. *Journal of travel medicine*, *27*(8), taaa227.

World Health Organization. (2017). WHO guidelines on ethical issues in public health surveillance.