

A Computational Intelligence-Based System for Assessment of Severity Index of Contagious Disease

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Abstract

The impact of infectious diseases on public health is shaped by factors such as environment, cultural behaviour, transmission mode, and policy. This study proposes a computational approach to assess the Severity Index (SI) of contagious diseases, focusing on Tuberculosis. An Algorithm-Based Method (ABM) guides the evaluation process, supported by literature review to identify research gaps. Data was segmented quarterly (2019–2022) to compute Case Fatality Rate (CFR), including symptom-specific severity analysis. Exploratory Data Analysis (EDA) was used to explore variable relationships. Two computational intelligence techniques, Fuzzy Logic (FL) and Artificial Neural Network (ANN) were applied. FL used a Triangular Membership Function (TMF), showing progressive fuzzified outputs with increasing input ranges. The ANN model, trained with 10 inputs and 2 hidden layers, achieved 88% accuracy using Cross Entropy Error Function (CEEF).

Introduction

Contagious diseases spread from one person to another through various means, including close contact, airborne droplets, contaminated environments, or consumption of infected food or water (Edemekong & Huang, 2017). They affect vulnerable individuals via contact with infected persons, organisms, or objects (van & Hochberg, 2017). Caused by viruses, bacteria, fungi, or parasites, examples include Salmonella, measles, TB, HIV, and hepatitis. These diseases can lead to severe global consequences death, high societal costs, and economic burdens (Lindahl & Grace, 2015). Assessing disease severity is critical for effective prevention. The Severity Index quantifies a disease's impact on individuals and society (Rethlefsen & Livinski, 2013). Managing contagious diseases requires a comprehensive strategy that includes evaluating severity and implementing protective measures. As the disease intensifies computational intelligence including machine learning, and data analysis offers efficient tools for revealing complex patterns and ensuring the accuracy of severity assessments, which helps in health sector planning and distribution of resources.

Statement of Problem

Analysing the Severity Index is essential for the operation and avoidance of contagious diseases. Although, restricted medical resources and the

imprecision of conventional evaluation procedures present challenges (Li et al., 2021). Computational intelligence system is needed that can reliably dictate the severity index of contagious diseases, irrespective of whether concurrent illnesses are present.

Aim and Objectives

The aim of this research work is to utilise a Computational Intelligence System for Assessment of Severity Index of Contagious Disease with the following objectives;

1. To design an explicit technique using correlation Matrix.
2. To build and train a Computational Intelligence Models, which include Fuzzy Logic (FL) and Artificial Neural Networks (ANN).
3. To substantiate and Benchmark the System's implementation.

Literature Review

Contagious diseases can range in severity from minor to critical, and in some cases may be life threatening. Healthcare professionals must analyse the severity of contagious diseases in order to choose the suitable ways to contain and stop the spread of the infection. The rate at which an infection spreads comprise one of the most important elements in

ascertaining how severe a contagious disease is. Age, symptom status, environment(settings), and length of exposure or contact are only a few of the variables that have an effect on the extent to which transmission occurs (Thompson et al, 2021). The interrelation connecting the infectious agent, the host, and the environment is referred to as the agent-host-environment triad, which comprises of additional significant element. The existence of sterile carriers of infected people whose symptoms are asymptomatic but nonetheless able to spread a contagious agent can

provide serious difficulties for preventing infection (van & Hochberg, 2017).

Severity Assessment of Contagious Disease and its Impact on Public Health

Analyzing the severity of contagious diseases is efficient in healthcare execution. The Case Fatality Rate (CFR), the proportion of people who have been diagnosed with a certain disease and end up dying of it. It can be represented as a percentage and is calculated using the equation 1 and 2.

$$\text{Case Fatality Rate} = \frac{\text{Total number of new deaths due to a certain disease}}{\text{Total number of incident patient with the specific disease}} \quad 1$$

$$\text{Case Fatality Rate} = \frac{\text{Number of deaths due to a particular disease}}{\text{Total number of cases due to the same disease}} \times \frac{100}{1} \quad 2$$

Another index for determining severity is Hospitalization Rates (HR), calculated as the number of residents in a surveillance area who are hospitalized with laboratory-confirmed. The range of hospitalization rates is influenced by factors such as age, sex, location, socioeconomic standing, and the frequency of specific diseases.

Techniques for Contagious Disease Severity Assessment

Strategies for identifying the severity of contagious diseases includes the following:

1. **Symptom Severity Assessment:** refers to the intensity and impact of psychological or physical symptoms experienced by an individual. It is a crucial measure in clinical assessments, helping clinicians understand how symptoms affect a person's daily functioning and quality of life.
2. **Disease Severity Assessment:** Asymptomatic infections and acute respiratory failure are also examples of contagious diseases (DT et al, 2027). The presence of indicators, for being hospitalized, and the potential of prolonged influence can all be used to examine the disease's severity.
3. **Risk Severity Assessment:** A diverse way of ascertaining the gravity of an infectious disease is risk. Age, underlying health issues, and impaired status are signs of risk for critical challenges and transfer of transmissible diseases.

Current Computational Models for Contagious Disease Severity Assessment

Current contagious disease severity assessment computational techniques include:

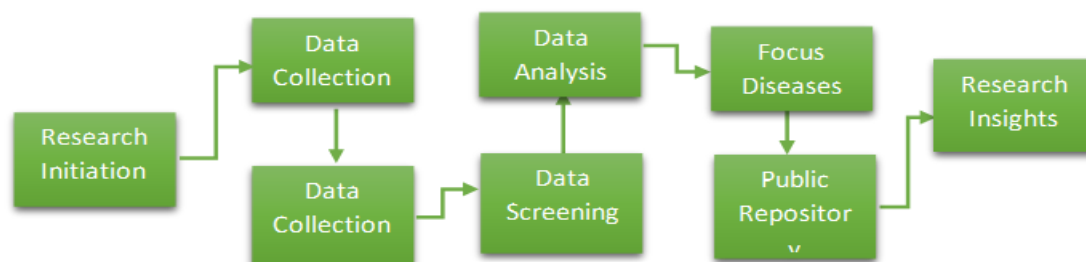
1. **Mathematical Models:** Integration of systematic knowledge into logical frameworks for predicting outcomes (Jenner et al., 2020).
2. **Multiscale Models:** Replication of disease at scales from cells to populations for transmission insight (Jenner et al., 2020).
3. **Stochastic Modeling:** Captures variability and unpredictability in disease patterns (Mikler et al., 2007).
4. **Game Theory:** Research shows strategic human interactions impacting disease distribution (Jenner et al., 2020).

System Analysis and Methodology

Systems analysis is the process of studying a procedure to identify its goal and purposes and create systems and procedures that will efficiently achieve them

Evaluation of The Existing Research Work

The research by Bhakar et al. (2023) examines the rising use of computational intelligence-based procedures for evaluating disease severity, focusing mainly on Parkinson's Disease and Diabetic Retinopathy. Following PRISMA guidelines, it reviews recent studies, analysing their methodologies, datasets, and performance metrics like accuracy and specificity. It also briefly covers severity assessment in conditions such as COVID-19, tuberculosis, breast cancer, sepsis, and Alzheimer's. The study highlights useful public repositories, offering insights to support and inspire researchers in this growing field.

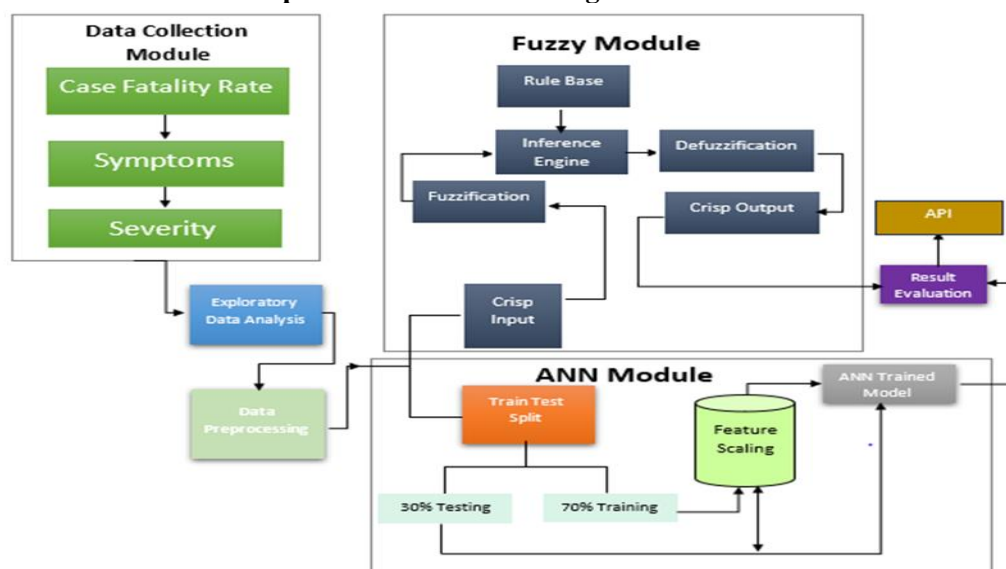


Architecture of the Existing Research Work (Bhakar et al,2023).

Limitation of the Existing Research Work

1. limitation of the Existing Research Work.
2. Data were mostly from systematic reviews.
3. Case Fatality Ratio was not considered as a method that could be used in severity assessment.

Architecture of the Proposed Model Based Design.



Conceptual Framework of the Severity Index Assessment

Justification for the Proposed Research Method

To the best of our knowledge, severity assessments of tuberculosis-based contagious diseases using computational intelligence techniques have not been deeply researched quarterly across multi-year intervals, especially in four-year spans. This study addresses key issues such as:

1. Variability in Severity Index Assessment – Tuberculosis cases show quarterly variability, which computational intelligence must accurately manage to meet the study’s goals.
2. Data Bias – Given the importance of unbiased data in health research, this study uses primary data collection from hospitals, guided by

medical professionals managing contagious disease cases.

Data Presentation and Analysis

A system is a collection of interconnected components deliberately constructed. Key elements in system design include formulating high-level technical requirements, creating system blueprints, and evaluating how well designs meet specific needs. Precise system specifications must guide implementation.

Data Collection

Data collection involves gathering measurements or observations for investigation and is foundational to research. This study collected clinical data from St. Luke's Hospital, Anua, Uyo, Akwa Ibom State, Nigeria, covering 2019 to 2022, on a quarterly

basis. The data includes confirmed tuberculosis cases and recorded deaths, used to compute the Case Fatality Rate (CFR). Hence, we calculate the case fatality ratio for each quarter and year respectively is presented in the table below.

Year 2019	(JAN - APRIL) Q1	(MAY-AUG) Q2	(SEP-DEC) Q3
Total no. deaths	3	1	2
Total no. of officially confirmed case	37	34	35
Case Fatality Ratio	8.11	2.94	5.71
Year 2020	(JAN - APRIL) Q1	(MAY-AUG) Q2	(SEP-DEC) Q3
Total no. of deaths	0	1	1
Total no. of officially confirmed case	33	30	28
Case Fatality Ratio	0.00	3.33	3.57
Year 2021	(JAN - APRIL) Q1	(MAY-AUG) Q2	(SEP-DEC) Q3
Total no. of deaths	3	1	4
Total no. of officially confirmed case	20	18	14
Case Fatality Ratio	15.00	5.56	28.57
Year 2022	(JAN - APRIL) Q1	(MAY-AUG) Q2	(SEP-DEC) Q3
Total no. of deaths	2	0	0
Total no. of officially confirmed case	18	16	18
Case Fatality Ratio	11.11	0.00	0.00

Furthermore, we present graphical visualization of different years recording showing the total number of confirm tuberculosis cases, total number of deaths and their respective case fatality rate. These are illustrated in fig 1 to 4, depicting their respective records.

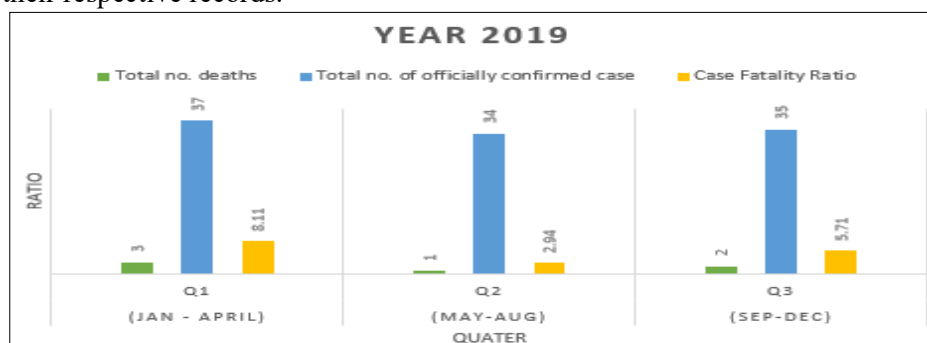


Fig 1: Tuberculosis records for 2019

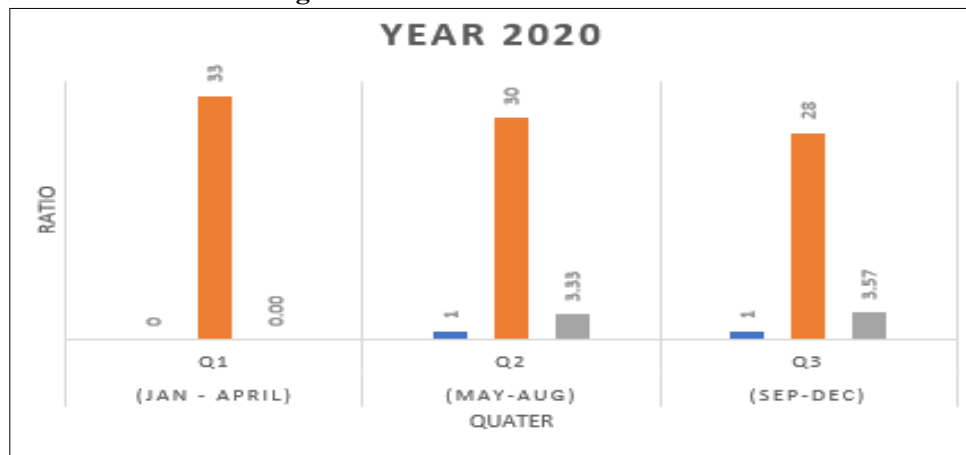


Fig 2: Tuberculosis records for 2020

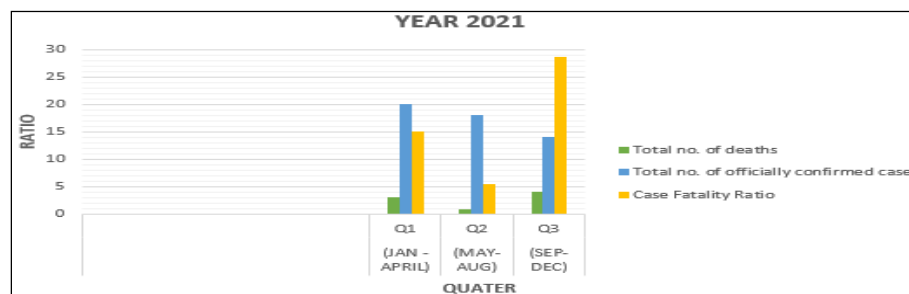


Fig 3: Tuberculosis records for 2021

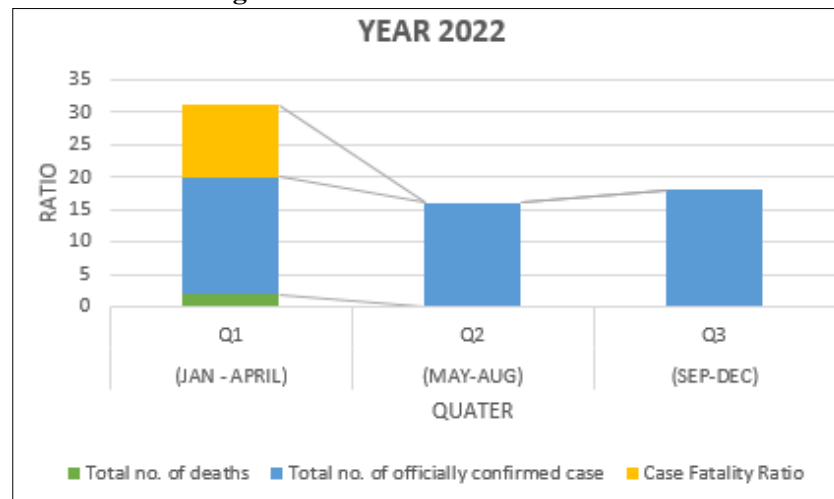


Fig 4: Tuberculosis records for 2022

Fuzzy Logic Model

A Type-1 Fuzzy Logic System (T1 FLS) model was selected to assess the severity of tuberculosis, a contagious disease. The model comprises the following modules:

1. Type 1 Fuzzifier Module: Converts crisp inputs using a triangular membership function for rule inference.
2. Inference Engine: Evaluates rules from the Fuzzification rule base.
3. Defuzzification Module: Computes output via Interval Type 1 Fuzzy Set Mamdani.

4. Knowledge Base: Stores expert-derived rules.
5. Membership Function: Transforms crisp input into a fuzzy set.

Artificial Neural Network

Artificial Neural Networks (ANNs) are intricate pattern prediction and forecasting algorithms inspired by biological neural networks in the human brain. Though not exact replicas, ANNs are designed to mimic brain functionality, handling only structured, numerical data. The core elements of ANNs are artificial neurons, simplified versions of biological neurons. Therefore, in this research, ANN was adopted for the second phase of the assessment of severity index of contagious disease, and the subsequent section outlines the processes followed in the development of the ANN for this purpose.

Conclusion

In this study, a computational intelligence system for assessment of severity index of contagious disease, specifically tuberculosis, was conducted. The research began with a detailed review of literature to identify research gaps in contagious disease severity. Recognizing these gaps led to the data collection phase, segmented quarterly from 2019 to 2022: Quarter 1 (JAN–APR), Quarter 2 (MAY–AUG), Quarter 3 (SEP–DEC). Data was collected for Case Fatality Rate (CFR) calculation using total number of deaths and confirmed cases, and for symptom-based severity assessment.

Recommendations

This study comes highly suggested for evaluating the severity index of contagious diseases. The research specifically highlights its efficacy in assessing the severity of Tuberculosis using sample text related to the disease. The combination of two Computational Intelligence models proposed in this research surpasses traditional approaches. Consequently, it is recommended for adoption by hospitals, health agencies, medical consultants, schools, and other institutions aiming to enhance the effectiveness of contagious disease assessment based on severity.

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