Fuzzy adaptive resonance theory failure mode effect analysis non-healthcare setting for infectious disease: review

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ABSTRACT

Fuzzy adaptive resonance theory (ART) is an ART network that is developed as one of the alternative methods to evaluate risk priority number (RPN) in failure mode and effect analysis (FMEA). Not only is FMEA are common technique as an analysis tool in industrial sectors, but also, especially during the global emergency COVID-19 pandemic hits, FMEA is used in prevention and mitigation measures. Many alternative methods have been proposed. However, not many investigations use clustering models such as Fuzzy ART in FMEA. This paper aims to provide a comprehensive review and then propose a model for systematic risk analysis which implement the fuzzy ART model, named clustering- transmission causes and effects analysis (c-TCEA), for the prevention and mitigation of infectious diseases.

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1. INTRODUCTION

Illnesses brought on by pathogens or their toxic byproducts that are spread from an animal, contaminated things, or even an infected person to a vulnerable host are known as infectious diseases. They have a significant global burden of disease, disproportionately affecting vulnerable populations. Diarrheal diseases, lower respiratory tract infections, malaria, human immunodeficiency virus (HIV) or acquired immunodeficiency syndrome (AIDS), and tuberculosis (TB) are leading causes of mortality worldwide. Emerging infectious diseases like middle east respiratory syndrome, extensively drug-resistant tuberculosis (XDR TB), and Zika virus pose new threats. Preventing and controlling infectious diseases requires a thorough understanding of transmission factors, including agent, host, and environmental determinants.

Infectious diseases, such as coronavirus disease 2019 (COVID-19), still pose life-threatening risks. As of July 2023, there are over 836 million cases of COVID-19 around the world [1]. It is very advantageous to create interventions that will eliminate and stop the spread of a pandemic strain on the human population. However, the rapid spread of the disease gives significant challenges to designing and developing realistic risk assessments in order to contain the emergence of the disease.

According to Covello and Mumpower [2], risk analysis and management have a major role in human history when battling against pandemics or endemic diseases, which have been existing for a long time. Covello and Mumpower [2] also mentioned that interventions and measures from experts in handling infectious diseases had been placed for centuries. One example is the establishment of policies and laws for isolation and quarantine during emergency periods. These were mentioned as a crucial component for the mitigation and control of infectious diseases and as one of the societal risk management strategies [3], [4].

Modern risk management is seen in practice as a process of risk identification, assessment, and prioritizing, followed by a coordinated and cost-effective deployment of resources to reduce, manage, and control the likelihood or impact of unfavourable events. Therefore, the failure modes and effect analysis (FMEA) are introduced as a method to do risk analysis and management for a broad range of industries. For example, transport and automotive [5], [6], agriculture [7], [8], and medical and healthcare [9]–[11]. Many variations of the FMEA method are accessible in writing. The general FMEA methodology, however, takes into account root causes, failure modes, effect analysis and relationships, as well as corrective actions, when implementing FMEA. A straightforward scoring method that uses three indices; severity (S), occurrence (O), and detection (D) as inputs and a risk priority number (RPN) as output is used for risk analysis and prioritization.

Risk management in non-healthcare settings for COVID-19 has been the focus [12]. During the pandemic, FMEA is also being implemented in the healthcare setting as well. For example, transferring protocol in the management of COVID-19 patients [13], assessing the COVID-19 protocols of obstetric emergencies [14], and controlling the admission of asymptomatic COVID-19 patients to the emergency department [9]. Despite the numerous FMEA implementations in many application fields and various research on the risks of infectious disease in healthcare settings, a systematic method for regular risk management of infectious disease has not yet been developed. Besides, the transmission of infectious disease cannot be (fully) interrupted by using basic precautions of healthcare alone [15]. Therefore, transmission-based precautions can be adopted. An innovative method in this approach is the transmission-based risk analysis methodology, where fuzzy adaptive resonance theory (ART) will be used to rate and prioritize all the risks, which considers recent developments in risk research for the healthcare and non-healthcare environments.

Thus, fuzzy ART will be used as a tool to explore FMEA from a different approach. The main aim of this paper is to outline step-by-step transmission-based risk analysis and management, where the risk is all rated and prioritized. This paper is organized into several sections. A summary of duzzy ART will be in section 2. Section 3 describes the FMEA and the fuzzy ART algorithm applied to FMEA will be further explained. Section 4 presents the proposed Fuzzy ART-TCEA. Finally, section 5 concludes the review study purposes.

2. FUZZY ART (ADAPTIVE RESONANCE THEORY)

Carpenter *et al*. [16] created the algorithm known as fuzzy-ART. Any binary or analogue data can be clustered using this neural network model. One of the main causes for the development of fuzzy ART was ART 1's inability to classify analogue data, as well as the predictive ART architecture based on ART1 modules.

ART is a prime example of how developing artificial intelligence (AI) and comprehending 'the brain' can work together to benefit both fields. ART draws its inspiration from the cortex and deeper learning structures' recurrent organization of information processing. The difficulties of implementing ART on a computer should not be confused with the fact that it was inspired by recurrent brain structures [17]. A new set of principles that have been realized as quantitative systems and can be applied to problems involving prediction, category learning, and recognition have been added to the earlier theory. This has been done through a series of developing ART neural network models.

In order to address clustering and classification problems, ART networks are frequently used. A clustering algorithm takes a set of input vectors as input to generate a set of clusters, along with a mapping from each input vector to each cluster as output. A specific similarity measure should be used to determine which input vectors should be mapped to the same cluster. The interpretation of each input vector mapped to a cluster can be indicated by the labelling of the clusters [16].

There are several classical ART clustering algorithms, such as ART1, ART2, ART2A, ART3, and fuzzy ART [18]–[20].

- ART1: the basic ART network and its cluster binary inputs.
- ART2: clusters real-value input patterns.
- ART2A: a fast version of ART2.
- ART3: an extension of ART that controls the search process with "chemical transmitters" in a hierarchical ART structure.

Fuzzy ART architecture: fuzzy set theory computations are incorporated into ART1. Instead of the crisp operator, uses the fuzzy AND operator. ART adapts to input indefinitely. If the environment and the patterns are sufficiently related, new categories can emerge when the environment does not match any of the observed patterns [21]. An output and input layer make up the two layers of a typical ART network. There are no hidden layers. The dynamics of the network are controlled by an orienting subsystem and an attention