Current Trends in Incubator Control for Premature Infants with Artificial Intelligence Based on Fuzzy Logic Control: Systematic Literature Review

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Abstract—**Incubator Control for Premature Babies has benefited greatly from the development of creative methods and uses of artificial intelligence. Due to the immaturity of the epidermis, premature infants lose fluid and heat early in life, which causes hyperosmolar dehydration and hypothermia. Water loss through the epidermis. Therefore, in order to maintain the baby's healthy temperature, an incubator is required. As a result, it is anticipated that the baby will maintain the same temperature as in the mother's womb. A temperature regulation system with good measurement and regulation quality is necessary due to the necessity of Incubator Control for Premature Infants with Artificial Intelligence Based on Fuzzy Logic in treating premature infants. The purpose of this research is to assess current trends in artificial intelligence-based fuzzy logic incubator control for preterm infants. The Preferred Reporting Items for Systematic Review (PRISMA) were used in this study's systematic literature review. 188 suitable articles that fit the inclusion requirements were found after the articles were screened and chosen. The outcomes demonstrated that the Incubator Control for Premature Infants offered the best environment for newborns with growth or disease-related issues (premature babies). An incubator is a sealed space free of dust and bacteria with the ability to regulate temperature, humidity, and oxygen to maintain a stable environment.**

Keywords—component; incubator control; premature infant; artificial intelligence; fuzzy logic.

I. INTRODUCTION

In the 21st century, artificial intelligence (AI) has advanced quickly in all interdisciplinary scientific domains, including computer science, cybernetics, automation, mathematical logic, and fuzzy logic. Researchers in the fields of mathematics, engineering, and computer science has been investigating the potential of artificial brains and attempting to characterize machine intelligence since the 1940s and 1950s. With the ultimate goal of establishing a society in which people and machines reside in harmony, AI, in its most basic terms, aspires to expand and strengthen human capacity and efficiency in the work of recreating nature and regulating society through intelligent machines [1-3]. AI is a broad field that includes many information technology topics. Numerous ideas, including computing, developing software, and transmitting data, are based on AI. Machine learning, deep learning, speech recognition, biometric identification, and robots are examples of AI-based technologies. AI is applicable to a wide range of industries, including healthcare, business organizations, the assembly and manufacturing industry, and the automobile industry [4, 5]. AI is becoming more and more popular in a variety of sectors due to a number of additional benefits. AI machines are accurate and efficient, can perform numerous tasks at once, and are less expensive than humans. There are numerous issues with AI that make it difficult to deploy. AI systems are susceptible to technological issues, security obstacles, data issues, and mishaps if users don't understand them [6]. Particularly in the health industry, the growing application of AI has altered numerous industries by enhancing organizational performance and facilitating data security.

Artificial intelligence (AI) technology has made significant strides recently and is already a reality in many aspects of our daily lives [7, 8]. In the healthcare industry, efforts are being made to integrate AI technology into effective medical treatment. With the rapid advancements in hardware performance and machine learning algorithms, AI technology is anticipated to play a significant role in the analysis and efficient utilization of enormous amounts of health and medical data. However, compared to current health care technologies, AI technology has a number of distinctive qualities [9, 10]. For AI to be used more successfully and frequently in healthcare, a number of areas in the systems of today need to be complimented. Additionally, there are relatively few medical professionals and members of the general public that use AI in healthcare, and there are numerous worries about the security and dependability of AI technology. AI has made a significant contribution to the resolution of several biomedical issues, including [11]. Control of the incubator for premature babies. Deep learning, a highly adaptable branch of AI that facilitates automated feature extraction, is being used more frequently in both fundamental and clinical cancer research. Resources and datasets that can assist in utilizing AI for research on incubator control for premature infants [12] through [14]. Incubator Control for Premature Babies will benefit greatly from the development of novel methods and AI applications.

Due to the immaturity of the epidermis, premature infants lose fluid and heat early in life, which causes hyperosmolar dehydration and hypothermia. Trans-epidermal Water Loss (TEWL) is inversely correlated with gestational age at birth and is connected to the degree of epidermal maturation and barrier development in babies. as well as PNA [14-16]. The TEWL below 50% relative humidity (RH) on the first day after delivery for infants born between 24 and 25 weeks gestation was 58.4 g/m2/hr, and the insensible water loss from the skin (IWLs) was 164 mL/kg/day. A small layer of compact GW keratin is present at GW 21–22, while textured fabric keratin is found in the hair follicles and eventually spreads over the epidermis. The fetus is 22–23 weeks gestation. The stratum corneum, which makes up the epidermis, is composed of 1-2 layers and reaches morphological maturity in the late second trimester [16, 17]. In order to match the skin maturation process of newborns born at 22–23 weeks, the humidity and temperature of the incubator must be adjusted; however, there is currently no information available to guide this configuration. Because differences in TEWL values reflect differences in skin maturity, IWL of 22–23 GW infants is reported to be higher during the first few days of life than that of 24 GW infants [18, 19]. Warmwännaen, the first incubator, was created in 1857. Another account incubator, created by Etienne Stephane Tarnier for the use of a very large Paris Maternite called couveuse, was published by Pierre-Victor-Adolph in 1833. Alexander the Lion of Nice created a new incubator that was built in France, according to reports that first surfaced in 1891. Today, research is still being done to try to develop settings that are more akin to the womb; manage oxygen levels and other important systems with a variety of sensors, monitors, and alarms [20-22]. Therefore, in order to maintain the baby's healthy temperature, an incubator is required. As a result, it is anticipated that the baby will maintain the same temperature as in the mother's womb. A temperature control system with good measurement and regulation quality in the temperature range of 36-38°C is necessary for Incubator Control for Premature Infants with Artificial Intelligence Based on Fuzzy Logic in handling premature newborns [23, 24].

A control system that makes use of fuzzy set theory, fuzzy if-then rules, and fuzzy reasoning is known as fuzzy logic control (FLC), also referred to as a fuzzy inference system (FIS). Fundamentally, the input to the FIS can be either sharp or fuzzy, but the output is nearly always in the form of a fuzzy set. Sharp (firm) output is necessary when using FIS as a controller. The defuzzification method can be used to convert the fuzzy set into a crisp value. From fuzzification (fuzzification), fuzzy set membership function (used in fuzzy rules), rule base (rule base), decision-making unit (inference operation on fuzzy rules), and defuzzification (defuzzification) are the components of fuzzification control [25-27]. The benefit of fuzzy logic control is that a mathematical model of the plant is not strictly necessary. It is fairly simple to execute and is based on plant operator experience [28]. The goal of this research is to examine current developments in artificial intelligence-based fuzzy logic control for preterm newborn incubators.

II. Method

The Preferred Reporting Items for Systematic Review (PRISMA) are used in this study as part of a systematic review of the literature. The research was conducted methodically over the course of the necessary research stages. The information offered is thorough, impartial, and attempts to combine pertinent study findings. Developing research questions, searching for relevant literature, screening and choosing relevant articles, screening and choosing appropriate research articles, analyzing, synthesizing qualitative results, and producing research reports are all steps in a systematic literature review [29]. The steps taken in conducting a systematic literature review include developing a background and research objectives, gathering research questions, searching the literature, selecting and extracting relevant articles, evaluating the quality of fundamental studies, and synthesizing data [30].

III. Result and Discussion

One of the research techniques, systematic literature review, tries to locate, examine, and assess all the findings of earlier investigations. The stages of the research have been completed, and the findings are consistent with those stages.

A. *Formulating Research Question*

Table 1 displays the findings of the development of research questions connected to Current Trends in Artificial Intelligence-Based Fuzzy Logic Controlled Incubator Control for Premature Infants.

TABLE I. Research Question of Current Trends in Artificial Intelligence-Based Fuzzy Logic Controlled

Code	Research Question	Motivation
RQ1	How is the development of artificial intelligent control systems?	Identify articles related to the development of artificial intelligent control systems
RQ2	How is the development of fuzzy control?	Identify articles related to the development of fuzzy control
RQ3	How has the control system developed for the infant incubator?	Identify articles related to the development of control systems for infant incubators

B. *Literature Search*

Incubator control, premature newborn, artificial intelligence, and fuzzy logic were used as search terms to find relevant publications in the literature. The databases Scopus, Web of Science, and ResearchGate are among those from which articles are gathered. The inclusion and exclusion criteria that have been established in the past are the method utilized to search for articles. This is done to encourage perseverance in locating the article.

C. *Screening and Article Selection*

Articles with the following criteria were chosen: entire articles written in English, published in international journals between 2010 and 2022, indexed in databases, and with the theme Current Trends in Incubator Control for Premature Infants using Artificial Intelligence Based on Fuzzy Logic Control in Fig. 1.

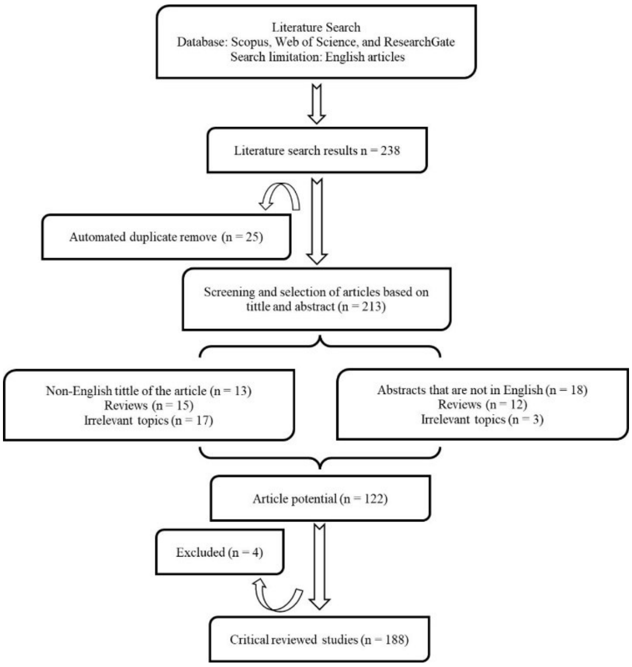

Fig. 1. PRISMA method in systematic literature

D. Data extraction, primary study quality test, and synthesis

In order to find the answers to the predetermined research questions, data extraction seeks to gather data. The interpretation of the synthesis of the findings and the formulation of the conclusions given are both influenced by the research quality test. The goal of data synthesis is to gather proof from a particular study to respond to research questions.

E. Discussion

It has been successful to do article searches across three databases, yielding 238 articles. Following the screening and selection of articles, 188 potential articles were discovered that satisfied the inclusion requirements. The meta-analysis of 188 papers utilized the theme "Current Trends in Incubator Control for Premature Infants using Artificial Intelligence Based on Fuzzy Logic Control" as its new statement theme. The author starts off this theme by talking about artificial intelligence. The term artificial intelligence (AI) describes the incorporation of human intelligence into machines. AI holds great potential for change in the healthcare industry. Indeed, healthcare companies face unheard-of difficulties caused by aging and labor shortages, shifting demographics, administrative demands, rising morbidity, and changes in information technology need [31-40]. Utilizing AI to provide accessible healthcare solutions with successful patient outcomes [31-33]. For instance, AI-assisted robotic surgery has shown to enhance surgical outcomes for surgeons. There have been reports of the application of AI to detect illnesses early, particularly chronic illnesses like cancer [4,10,34]. Due to the possibility of extensive automation, this rise in AI is anticipated to have an impact on the role of healthcare professionals, particularly those working with digital data, such as radiologists or pathologists. The domination of AI in the healthcare industry is anticipated to displace individuals who do not use technology or take over some of the tasks currently performed by doctors or healthcare administrators [35-37]. For instance, a recent study of Korean doctors found that only 6% of the respondents thought AI could replace them, although 35% of them believing it might. Although AI technology can be utilized to automate specific processes and enhance healthcare decision making, there is also assurance in this [38-41]. The majority of supervised learning applications in machine learning and precision medicine demand training datasets for which outcome factors (like illness onset) are known. Neural networks are a more advanced type of machine learning. This technology, which has been around since the 1960s and has been widely employed in medical research for decades, is used for categorizing applications like predicting whether a patient will contract a specific disease. The weights of the variables or "features" that connect inputs to outputs are taken into consideration while analyzing problems [42-44]. It has been compared to how neurons interpret signals, however that comparison focuses on very mediocre brain activity. Deep learning, or neural network models with several levels of features or variables that predict results, is one of the most complicated types of machine learning. The speedier processing of modern graphics processing units and cloud-building science may reveal thousands of hidden characteristics in the model. [41, 45-47]. Deep learning is frequently used in the healthcare industry to identify possibly malignant tumors in radiological images. Radiomics, or the discovery of clinically important patterns in imaging data beyond what the human eye can see, is a field in which deep learning is being used more and more. Oncology-focused image analysis is where radiomic and deep learning are most frequently used [48-50]. Compared to the previous generation of automated techniques for image analysis, known as computer-aided detection or CAD, their combination appears to promise improved accuracy in diagnosis.

The NHS and other organizations deploy AI implementations in many healthcare services; however, these systems lack the precision of more algorithmic systems based on machine learning [51-53]. These rule-based clinical decision support systems are challenging to keep up with as medical knowledge evolves and frequently are unable to handle the explosion of information and knowledge based on genetics, proteomics, metabolism and other "omics-based" approaches to care. Although it is largely prevalent in research labs and technology businesses, not in clinical practice, this scenario is beginning to change. According to research labs, methods for employing AI or big data to identify disease have been created [54-56]. It is a vital capability in this type of machine learning and is widely acknowledged as a crucial development in the field of precision medicine. Researchers anticipate that AI will eventually become proficient in this field as well, even though early attempts at making suggestions for diagnosis and therapy have been difficult [2, 9, 57, 58]. Given the quick development of AI for image processing, it appears plausible that robots will eventually review the majority of radiology and pathology images. For duties like patient communication and healthcare record keeping, speech and text recognition are already being employed, and this trend will continue. Assuring their adoption in routine clinical practice is the major barrier for AI in this healthcare area, not determining if the technologies will be capable enough to be beneficial [59, 60]. For AI systems to be widely adopted, they must be accepted by regulators, integrated with EHR systems, sufficiently standardized so that similar products function similarly, taught to physicians, supported by public or private pay groups, and periodically updated in the field [61-63]. These problems will eventually be resolved, but it will take longer so the technology may advance. As a result, applications of AI in the health sector, such the fuzzy logic controller, can be maximized (FLC).

Artificial intelligence (AI) and related technologies are increasingly prevalent in business and society and are beginning to be applied to healthcare. These technologies have the potential to transform many aspects of patient care, as well as administrative processes within providers, payers, and pharmaceutical organizations. There are already a number of research studies suggesting that AI can perform as well as or better than humans at key healthcare tasks, such as diagnosing diseases. Today, algorithms are already outperforming radiologists at spotting malignant tumors, and guiding researchers in how to construct cohorts for costly clinical trials. However, for a variety of reasons, we believe that it will be many years before AI replaces humans for broad medical process domains. Artificial intelligence is not one technology, but rather a collection of them. Most of these technologies have immediate relevance to the healthcare field, but the specific processes and tasks they support vary widely. Some particular AI technologies of high importance to healthcare are defined and described below.

1. Machine learning-neural networks and deep learning Machine learning is a statistical technique for fitting models to data and to 'learn' by training models with data. Machine learning is one of the most common forms of AI; in a 2018 Deloitte survey of 1,100 US managers whose organizations were already pursuing AI, 63% of companies surveyed were employing machine learning in their businesses [64]. It is a broad technique at the core of many approaches to AI and there are many versions of it. In healthcare, the most common application of traditional machine learning is precision medicine – predicting what treatment protocols are likely to succeed on a patient based on various patient attributes and the treatment context [65] The great majority of machine learning and precision medicine applications require a training dataset for which the outcome variable (eg onset of disease) is known; this is called supervised learning. A more complex form of machine learning is the neural network – a technology that has been available since the 1960s has been well established in healthcare research for several decades [66] and has been used for categorization applications like determining whether a patient will acquire a particular disease. It views problems in terms of inputs, outputs, and weights of variables or 'features' that associate inputs with outputs. It has been likened to the way that neurons process signals, but the analogy to the brain's function is relatively weak. The most complex forms of machine learning involve deep learning or neural network models with many levels of features or variables that predict outcomes. There may be thousands of hidden features in such models, which are uncovered by the faster processing of today's graphics processing units and cloud architectures. A common application of deep learning in healthcare is the recognition of potentially cancerous lesions in radiology images [67] Deep learning is increasingly being applied to radio mics, or the detection of clinically relevant features in imaging data beyond what can be perceived by the human eye [68] Both radio mics and deep learning are most commonly found in oncology-oriented image analysis. Their combination appears to promise greater accuracy in diagnosis than the previous generation of automated tools for image analysis, known as computer-aided detection or CAD. Deep learning is also increasingly used for speech recognition and, as such, is a form of natural language processing (NLP)

2. Rule-based expert systems

expert systems based on collections of 'if-then' rules were the dominant technology for AI in the 1980s and were widely used commercially in that and later periods. In healthcare, they were widely employed for 'clinical decision support' purposes over the last couple of decades 5 and are still in wide use today. Many electronic health records (EHR) providers furnish a set of rules with their systems today. Expert systems require human experts and knowledge engineers to construct a series of rules in a particular knowledge domain. They work well up to a point and are easy to understand. However, when the number of rules is large (usually over several thousand) and the rules begin to conflict with each other, they tend to break down. Moreover, if the knowledge domain changes, changing the rules can be difficult and time-consuming. They are slowly being replaced in healthcare by more approaches based on data and machine learning algorithms.

3. Physical robots

Physical robots are well known by this point, given that more than 200,000 industrial robots are installed each year around the world. They perform pre-defined tasks like lifting, repositioning, welding, or assembling objects in places like factories and warehouses and delivering supplies in hospitals. More recently, robots have become more collaborative with humans and are more easily trained by moving them through a desired task. They are also becoming more intelligent, as other AI capabilities are being embedded in their 'brains' (really their operating systems). Over time, it seems likely that the same improvements in intelligence that we've seen in other areas of AI would be incorporated into physical robots. Surgical robots initially approved in the USA in 2000, provide 'superpowers' to surgeons, improving their ability to see, create precise and minimally invasive incisions, stitch wounds, and so forth [69] Important decisions are still made by human surgeons, however. Common surgical procedures using robotic surgery include gynecologic surgery, prostate surgery, and head and neck surgery.

4. Robotic process automation

This technology performs structured digital tasks for administrative purposes, ie those involving information systems, as if they were a human user following a script or rules. Compared to other forms of AI they are inexpensive, easy to program, and transparent in their actions. Robotic process automation (RPA) doesn't really involve robots – only computer programs on servers. It relies on a combination of workflow, business rules, and 'presentation layer' integration with information systems to act like a semi-intelligent user of the systems. In healthcare, they are used for repetitive tasks like prior authorization, updating patient records or billing. When combined with other technologies like image recognition, they can be used to extract data from, for example, faxed images in order to input it into transactional systems [70].

Today, FLC is a growing study area that is still interesting. Additionally, FLC has been used in healthcare, complementing industrial control devices, and home appliances. Prof. Zadeh created fuzzy logic, followed by Mamdani and Assilian who introduced FLC. In systems where tolerance and response time are not crucial, or in circumstances where high accuracy FLC is not required, FLC response is slower than PID controller [64]. FLC is better suited for use in a hard-to-define system that the operator can control without being aware of the dynamic properties of the system. As opposed to the prior application, which relies on a personal computer and is therefore less effective and efficient, MATLAB software can be used to develop and model FLC [65]. Technology advancements have made it possible to implement the fuzzy current system in microcontrollers, particularly with regard to memory capacity. Several researchers implemented the fuzzy system on the microcontroller to increase the level of control over the hopper-conveyor plant [4, 66]. Fuzzy systems built on microcontrollers are capable of designing and constructing FLC in a modular fashion for use in a variety of systems. Once the fuzzy system has been successfully implemented in the microcontroller, it will be possible to design the FLC in a modular fashion. The module's input and output are DC voltages that can be created and used to control other processes.

Traditional controllers are modeled after the system or process being regulated and are created using a variety of methodologies for diverse control system applications. When the analytical behavior of the system to be controlled is known, traditional control theory can be used [67, 68]. Though full knowledge is frequently unavailable in many circumstances, such as space travel, control decisions must still be taken. Finding a capable human operator in this type of control and using his control expertise to create a suitable formula would be a reasonable approach in this case. Control experience, in accordance with, is typically expressed in the form of plain language norms, such as: if x is tiny, then the control action must also be little [69]. Human operator behavior is the foundation of fuzzy control. The methodology converts these regulations into a control method known as fuzzy control. Building an expert human control model that can execute control actions without requiring the use of intricate mathematical models is the major goal of fuzzy control [70]. These control rules are converted into a calculus that can mimic the actions of control professionals thanks to a fuzzy set theory framework. Numerous real-world issues have been effectively solved using fuzzy control systems. It has been demonstrated that these controllers can outperform traditional model-based controllers, particularly when used with challenging-to-model nonlinear systems. There are four main components that make up the FLC configuration at its core [71, 72]:

1) Fuzzification

The fuzzification procedure is denoted by the formula: x = fuzzifier (xo), where xo is the vector of the sharp values of one input variable, x is the vector of the defined fuzzy set, and fuzzifier is a fuzzification operator with a sharp mapping effect of data to fuzzy sets. The fuzzy logic controller needs two input parameters for process control applications: error and error change. The firm value of the error and the error change are then transformed into fuzzy terms like [NB, NM, NS, ZE, PS, PM, PB], which are understandable by fuzzy inference process.

2) Rule Base

Base Rules an "if-then" set of rules is used in a rule base to quantify the knowledge that human specialists could possess regarding how to address issues in their area of expertise. Every rule is expressed as an IF-THEN statement. One or more conditions, referred to as antecedents, that store the membership degree values computed during fuzzification can be found in the IF side of the rule.

3) Inference Mechanism

The inference mechanism's two primary objectives are to: (1) assess each rule's applicability to the current circumstance as described by input ui, where i=1, 2...., n and (2) make inferences based on the information in the base rule and the input ui. Multiple rules frequently apply to the same action (fuzzy output), in which case it is customary to use the rule that is most accurate or powerful.

4) Defuzzification

You can define defuzzification as you: defuzzifier (y), where y is the firm control action and defuzzifier is the defuzzification operator. Y stands for the fuzzy control action. The fuzzy inference engine generates a final conclusion or action in fuzzy words after adding up the logic of all the rules. It needs to be transformed into a deterministic control signal so that it can operate the actuator or plant. Defuzzification is the process of transforming a fuzzy phrase into a deterministic value.

Due to FLC's outstanding adaptability and flexibility, its practical applications have expanded quickly in recent years. A cutting-edge technology called fuzzy logic makes it possible to integrate "intelligent" features into embedded systems. Applications of FLC in industrial settings, particularly in telecommunications, environmental control, chemical process control, autonomous robots, and medical procedures, have incorporated FLC to better control engineering solutions [73,74]. FLC has made significant progress in the field of control systems and is frequently used to address issues with multi-variable and nonlinear systems that cannot be resolved by conventional control systems. Due to the presumption that the system is always stable, the fuzzy controller stability is, however, ignored during the design phase [75-77]. In order to operate, the designed system needs to be modified and optimized. Researchers have developed numerous methods and strategies that can be used to create fuzzy logic controllers. Some common methods include directly converting a classical control system's form into its fuzzy counterpart, using classical control systems to develop and test controllers, and finally altering the controller being tested to create the fuzzy controller [78, 79].

The development of the application of the fuzzy set theory is widely used in the health sector to diagnose various diseases. Harmful diseases usually require a quick and accurate diagnosis in treatment. But often the diagnosis of the disease is constrained because expert doctors have weaknesses in services such as limited working hours and have to wait in line to do the service. These obstacles can be fatal for sufferers of dangerous diseases. To overcome this, an expert system has been used as a result of the development of the fuzzy set theory. Expert systems are formed through the web, so they can be more easily accessed. Expert systems are built to facilitate the process of diagnosing diseases, so that diagnostic results can be obtained more quickly and precisely. Here are some application results from the use of Fuzzy set theory to diagnose diseases. The development of this expert system can use certain methods in the fuzzy set theory. Some diseases that can be diagnosed using an expert system include liver disease, diabetes mellitus, dengue fever (DHF) and typhoid fever, cardiovascular disease, umbilical cord blood analysis, heart disease, thyroid disease, dental and oral diseases [87]; [88]. The following will explain the development of fuzzy association theory application in the field of health.

1. Diagnosis of Liver Disease

One method of the fuzy set that can be used as a disease diagnosis tool is the Tsukamoto method. The Tsukamoto method was first introduced by Tsukamoto in 1979. The Tsukamoto method is a decision-making method that applies to the rules of monotonous reasoning. The point is to use a system with only one rule. The implications of each rule are in the form of "Cause and Effect" or "Input-Output" implications where the antecedents and their consequences must be correlated. Each rule is represented using a Fuzzy association, with a monotonous membership function. Tsukamoto's Fuzzy Method has a tolerance for data and is very flexible, intuitive and can provide responses based on information that is qualitative, inaccurate, and ambiguous. In the Tsukamoto method, each Rule is represented by a Fuzzy set with a monotonous membership function called fuzzyfication [89]. To facilitate the diagnosis, a fuzzy control model was designed that helps diagnose diseases related to the human heart. In addition to using the Tsukamoto method, a fuzzy design model was developed that has four input variables (leukocytes, hematocrit, hemoglobin, blood platelets) and three output variables (infection, anemia and thrombocytopenia). The fuzzy design model algorithm is divided into four stages, namely Fuzzyfication, Inference Engine, Rule selector and Defuzzyfication. Each input variable and output variable are represented by MF and regions graphically [90]. Some uses of the Fuzzy Tsukamoto method, namely, research on the Fuzzy Tsukamoto method with the system used as a diagnostic tool for liver disease with the use of Android, the conclusions of the research conducted are as follows: (1) Expert system as a diagnosis of liver disease can be designed and implemented for use with well, (2) an expert system for diagnosing liver disease can be implemented using the Fuzzy Tsukamoto method by going through five main processes, namely fuzzyfication, determining the alphapredicate for each Rule, calculating the z value of each Rule, multiplying the alpha predicate by z in each Rule, then defuzzification by dividing the number of alpha-predicate times z by the number of alpha-predicate, (3) this expert system can help diagnose liver disease or recognize common symptoms of liver disease, a system that is built can be used well by the user [91]; [92].

2. Diagnosis of Diabetes Mellitus

Furthermore, Fuzzy Tsukamoto method was developed to diagnose diabetes mellitus. Research on the application of Expert Systems in the diagnosis of Diabetes Mellitus. This application can be used as a tool for decision makers by inputting the results of laboratory examinations and based on the discussion in the previous section. The results of decisions produced by the application of this expert system produce the same decision with the medical record of the expert or doctor. Testing of this application by entering the values listed in the medical record into the application input and the resulting decision of the application is the same as the diagnosis stated in the medical record [23]. In addition to using the Tsukamoto Fuzzy method to diagnose diabetes mellitus, there is also the application of the Fuzzy set for the application of computational intelligence using Fuzzy hierarchical models that have the ability to detect early diabetes mellitus. The process of architectural acquisition of the method is designed based on how a doctor concludes that there are indications that someone has the potential for diabetes mellitus, whose model has been adjusted to the data obtained from the authorities in the laboratory. The results of the research using this method show that the proposed method has fulfilled the need for effectiveness and efficiency in conducting early detection of DM and can help the community in knowing the potential of DM early on [93].

3. Diagnosis of DHF and Typhoid Fever

Other diseases that can be diagnosed by using the Fuzzy Tsukamoto method are DHF and typhoid fever. There is an application built for early diagnosis of DHF (Dengue Hemorrhagic Fever) and Typhoid Fever by using the application of Fuzzy Tsukamoto logic. Based on the results of validation testing calculations by comparing the results of application calculations with manual calculations produced a valid level of application diagnosis of DHF (Dengue Hemorrhagic Fever) and Typhoid Fever by 96.875%. Thus this application can be used to limit deaths due to DHF and typhoid fever. This application is used as a tool to diagnose DHF and typhoid fever right [94].

4. Cardiovascular Disease

Furthermore there is an interval based classification system for Fuzzy rules which is used for medical diagnosis of cardiovascular disease. This system is developed for classifications that address the problem of determining the risk of patients suffering from cardiovascular disease in the next 10 years. The system provides a diagnosis and interpretation model that explains a decision. This classification system is based on Fuzzy rules, because it provides a good classification level and a model that is very easy to interpret. The ability of classifiers to correctly differentiate patients with different risk categories. This system is considered as a suitable tool for dealing with the diagnosis of cardiovascular disease, because it obtains a good level of classification and also provides an interpretable model that can be easily understood by doctors [95].

5. Premature babies

Premature babies are babies born in abnormal conditions, caused by insufficient gestational age or birth weight below the average normal baby. If this is left unchecked it will result in infant death [96]. Premature babies need exactly the same environment as in the womb to cope with external environmental factors. In fact mammals have the advantage of being homeothermic, i.e. they have a uniform body temperature, regulated independently of the ambient temperature [97]. The vital organs or enzymes of premature babies grow at a very low rate and thus require special attention to cope with external physical conditions such as temperature, humidity, light and oxygen levels. Babies have some disadvantages when it comes to thermal regulation. An infant has a relatively large surface area, poor thermal insulation and a small amount of mass to act as a heat sink [98]; [99]. Newborns have little ability to conserve heat by changing postures and no ability to adjust their own clothing in response to heat stress. Responses can also be hampered by disease or adverse conditions such as hypoxia (below normal oxygen levels) [100]; [101]. In order to provide the same environment as in the womb, the baby must be kept in a device known as an incubator. An infant incubator is a device consisting of a rigid, cage-like box in which a baby can be kept in a controlled environment for medical care. Infant incubators provide stable levels of temperature, relative humidity and oxygen concentration [28]; [102]. The air temperature should be maintained at around 37ºC. Relative humidity should follow the value set according to the incubation day number.

One of the places to put the baby is the baby incubator. The baby incubator is a closed container where the warmth of the environment can be adjusted by heating the air to a certain temperature, which functions to warm the baby [103]. Baby incubators need stable humidity so that conditions in the incubator are maintained according to the set point. In order to determine the temperature according to the needs of the baby in the incubator plant, a control logic that has no firm logic is needed. Uncertain logic is needed in determining whether the temperature and humidity levels are cold or hot, as well as humidity including damp or dry [104]; [86]; [105]. Determining the range of state level values cannot be determined with a value of 1 or 0, but can be determined by a value with a range of 0 to 1. Fuzzy logic was developed to deal with problems that cannot be handled by traditional logic (crisp logic), with traditional logic only known 0 and 1 or 'yes' and 'no'. Fuzzy logic accommodates values between 'yes' and 'no' [106]; [107]; [108]; [109]. Because the needs of babies who use these incubator plants are different. The size of the warm temperature between plant users is very different. The fuzzy logic method used is a logic that makes it possible to calculate dynamic complex values of temperature variables directly. In addition, the fuzzy logic control system has no dependence on the variables of the control process [106]; [110].

Premature births occur when a baby is delivered under unusual circumstances, such as an inadequate gestational age or a birth weight below the norm. if infant mortality is permitted to be an outcome [80]. To adapt to environmental stimuli outside the womb, premature newborns require exactly the same environment. Mammals actually benefit from being homoeothermic, which means that their body temperature is uniform and controlled separately from the surrounding environment [81]. Premature babies' important organs and enzymes develop at a very slow rate, necessitating extra care to help them adjust to changes in temperature, humidity, light, and oxygen levels. When it comes to temperature management, babies have some limitations. An infant has a modest amount of bulk that can serve as a heat sink, a relatively big surface area, and poor thermal insulation [17, 82]. Infants are unable to alter their own clothing in reaction to heat stress and have limited ability to conserve heat by shifting their posture. Disease or unfavorable circumstances, such as hypoxia (low oxygen levels), can also decrease response [83, 84]. The infant must be kept in an incubator in order to replicate the womb's environment. A device called an infant incubator is made out of a rigid box resembling a cage where infants can be maintained in a regulated environment for medical treatment. The temperature, relative humidity, and oxygen content are all kept constant in baby incubators [28, 85]. A constant air temperature of about 37 °C is recommended. The relative humidity must match the number of incubation days specified as the value.

The baby incubator is one of the areas where the infant can be placed. An infant incubator is a closed container where the temperature of the air may be controlled to keep the environment warm while also warming the infant [86]. In order to keep the environment in the incubator at the set point, baby incubators require consistent humidity. A control logic with unambiguous logic is required to set the temperature in the plant incubator in accordance with the baby's needs. When the temperature is chilly or hot, as well as when the humidity includes moist or dry, unclear logic is required to determine the level of temperature and humidity [79, 87, 88]. A value with a distance between 0 and 1 can be used to determine the distance value at the state level instead of a value between 1 and 0. Traditional logic, which can only be expressed as 0 and 1 or "yes" and "no," was developed to deal with difficulties that could not be resolved by traditional reasoning (crisp logic). Fuzzy logic accepts values that fall in the range of "yes" and "no" [89-92]. Because each baby using the plant's incubator has individual needs. Users of different plants measure warm temperatures in very diverse ways. The method of fuzzy logic employed allows for the direct calculation of the dynamic complex value of the temperature variable. Additionally, the fuzzy logic control system is independent of the control process variables [89, 93].

For premature babies or newborns with health issues, incubators are made to offer the best possible environment. An incubator is a sealed space free of dust and bacteria with the ability to regulate temperature, humidity, and oxygen to maintain a stable environment. Incubators are made to keep infants warm, monitor their several critical bodily processes, including heart rate, blood pressure, oxygen saturation, and, if necessary, assist with breathing [89]. The incubator should limit heat loss from the newborn and the eddies around it in order to control temperature and humidity. Temperature, humidity, oxygen saturation, and light are the key physical factors that influence the incubator's environment. The incubators are impacted by a number of factors.

1) Temperature

One of the most significant variables promoting preterm birth is temperature regulation, which is especially poor in babies. Not having sufficient thermoregulation is one of the key issues that causes the newborn's face. 38°C (100.4°F) is the temperature inside the mother's womb. The wet infant finds himself in a considerably colder environment when he is born after leaving the warmth of the womb, and he rapidly starts to lose heat. The infant will experience hypothermia and be more susceptible to developing health issues and passing away if heat loss is not stopped and allowed to continue [89, 94]. Because it increases morbidity and mortality, hypothermia (rectal temperature less than 36.5°C or 96.8°F) is significant for neonatal health outcomes. Even in an environment that is not extremely chilly, a newborn can lose one degree of body temperature per minute when wet. The infant must be dried, wrapped in a fresh, dry cloth, and have their head covered in order to avoid heat loss.

2) Humidity

The servo-controlled incubator's comparatively low humidity raises both its internal temperature and the premature babies' oxygen requirements. A considerable increase in water loss results from this. Additionally, premature newborns with low body weights or illnesses are more likely to develop adverse diseases like apnea. However, compared to traditional incubators, the unnoticeable water loss under radiant heating is greater [20, 95]. Evidently, minute differences in relative humidity within the servo-controlled skin incubator had no impact on the unseen water loss, but sizable variations will change the amount of imperceptible water loss. Numerous studies have demonstrated a negative correlation between body weight and insensible water loss. If the humidity in the shell environment is not at a healthy level, it may have a harmful effect on the patient. If the humidity is too low, babies can evaporate moisture and heat, while higher humidity levels increase the likelihood of bacteria and germs being present. Controlling or at least keeping track of humidity is advantageous [96-115].

3) Light

Good patient care depends heavily on the hospital's physical setting. High light exposure (such as phototherapy) and an irregular cycle of light and dark might also be harmful to the newborn sufferer. For day-night cycling to be possible, the ambient light level must be adaptable. Light treatment is another method for reducing jaundice in newborns. The most effective treatment for controlling jaundice in premature infants kept in newborn incubators is phototherapy. Jaundiced infants typically undergo phototherapy for 4 to 7 days. In an incubator, phototherapy considerably doubles or triples the insensible water loss of ill, low birth weight newborns. This has to do with the incubator's heat source, which is there for phototherapy purposes. It might also be linked to a delay in the time it takes for phototherapy to start working. The newborn experiences many alterations in a radiant heat warmer due to non-ionizing radiation energy exposure, necessitating phototherapy (e.g., changes in body temperature, higher water loss and fluid intake). While it might be required to treat premature infants with low birth weight without incubators, this leads to an unreasonably high rate of water loss. Because of this, the smaller the baby (smaller body weight), the more the water loss and hence the insensitive fluid intake.

4) Oxygen

In oxygenation, which is a therapeutic procedure, oxygen is given directly to help with breathing. The baby's breathing issues could result in major health issues if he or she is born more than two months early since other developing body organs might not be receiving enough oxygen. Ventilation is required to give the patient enough fresh air and oxygen. To ensure proper heat transfer from the heat source to the shell and patient environment, airflow is also necessary. Ventilation must be carefully controlled to ensure that there is enough fresh air and convective heat transfer through the heat exchanger, but that the flow is not too rapid that it disturbs the patient or increases heat loss from the incubator to the environment outside [26, 96]. Treatments using oxygen have been used to keep neonates from experiencing respiratory distress [97-120]. The partial pressure of arterial oxygen (PaO2) in the infant can occasionally reach extremely high and, in the worst circumstances, result in retrolental fibroplasia, whilst the inhaled oxygen concentration is regulated at a rather high level to alleviate discomfort and anoxia. Therefore, it is preferable that the incubator's oxygen pressure be properly adjusted in accordance with the PaO2 output being observed. The Control Temperature on Plant Baby Incubator with Fuzzy Logic has been successfully designed thanks to research findings [94]. Fig. 1 displays the project's block diagram. It mostly consists of a microcontroller, PID controller, carbon dioxide sensor, light sensor, humidity sensor, and temperature sensor. Fig. 2 illustrates a bit centigrade temperature monitoring device with an alert feature and non-volatile user-programmable up and down trigger points. The DS18B20 communicates with the central microprocessor via a 1-wire Bus, which by definition only needs one data line (and ground) for communication. It is accurate to 0.5°C in the 10°C to +85°C range and has a working temperature range of 55°C to +125°C. Additionally, the DS18B20 may obtain power directly from the data line (sometimes known as "parasitic power"), doing away with the requirement for an additional power source [6]. the final result. The DS18B20's direct-to-digital temperature sensor is what makes it functional. User-configurable resolution options for the temperature sensor include 9, 10, 11, or 12 bits, which, respectively, equate to increments of 0.5°C, 0.25°C, 0.125°C, and 0.0625°C. 12-bit resolution is the initial default setting. When idle, the DS18B20 starts up with little power. The master must send the Convert T command in order to begin temperature measurement and A-to-D conversion. After conversion, the DS18B20 goes back to being idle while the converted thermal data is saved in a 2-byte temperature register in the scratchboard memory. If the DS18B20 is powered by an external source, the master can send a Convert T command followed by a "read time slot" command (see section 1-Wire Bus System). The DS18B20 will respond by broadcasting 0 while the temperature conversion is in progress and 1 when the conversion is complete.

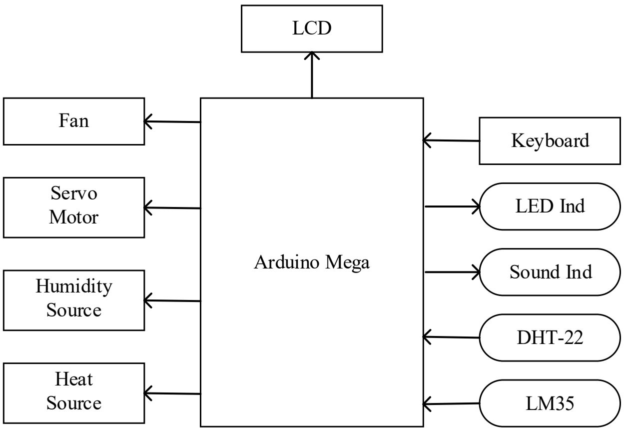

Fig. 2. Block diagram of the hardware design components temperature sensor ds18b20

This notification method cannot be used if the DS18B20 is powered by parasitic power since the bus must be pulled high by vigorous pulling throughout the full temperature conversion. The DS18B20 output temperature data is calibrated in degrees Celsius; therefore, a lookup or conversion method is required for applications that require Fahrenheit temperatures. The temperature register stores temperature information as a 16-bit sign that is extended by two complimentary numbers. We utilized a temperature sensor, the DS18B20, to create our incubator, and we connected it to a microcontroller (ARDUINOMEGA 2560).

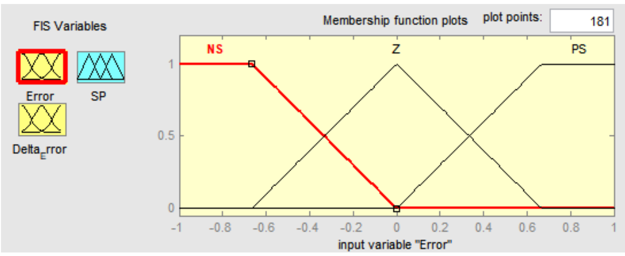

Fig. 3. Parameter Error

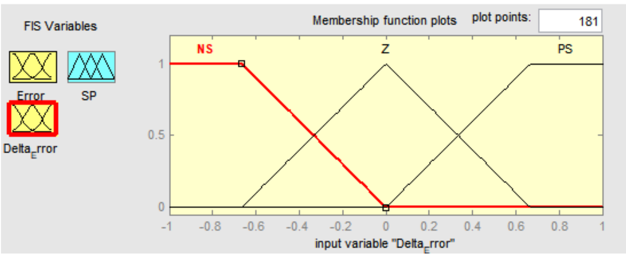

Fig. 4. Parameter delta error

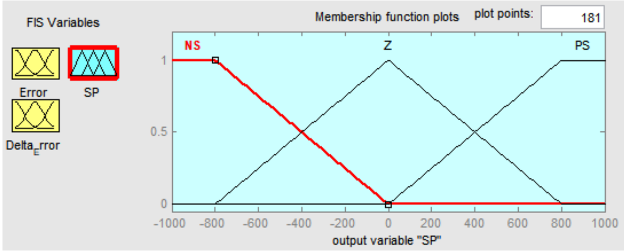

Fig. 5. Control signal parameter

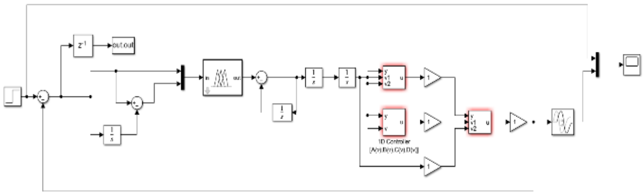

Fig. 6. Plant Temperature

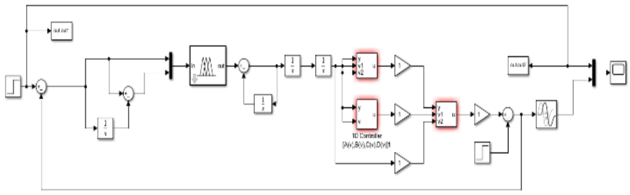

Fig. 7. Plant with more interference

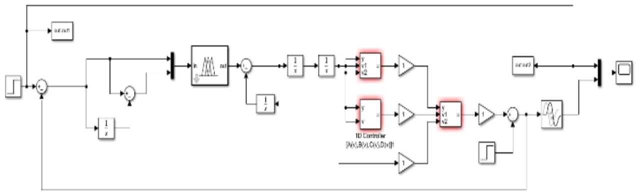

Fig. 8. Plant with less disturbance

Fig. 3 illustrates the design of the fuzzy logic control parameters used in this control system for the error parameters (X axis is the range value of system error parameters and Y axis is the value of the error parameter membership degree). Fig. 4 shows the range value of the delta-error parameter on the X-axis and the value of the delta-error parameter's membership degree on the Y-axis. Fig. 5 shows the control system parameters using MATLAB software (the X axis represents the range value of the system control signal parameters, and the Y axis represents the degree of membership of the control signal parameters).

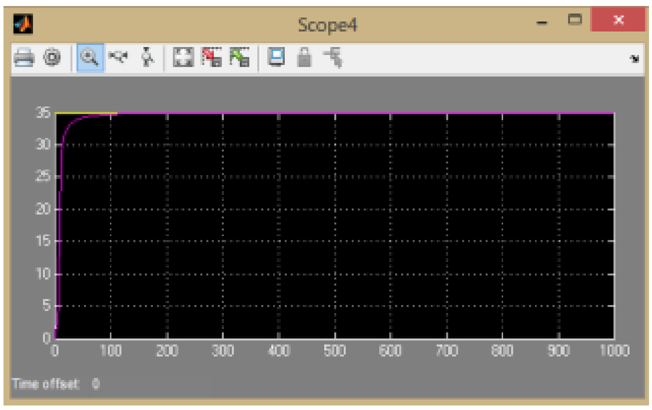

Fig. 9. Control results without interference

Fig. 6 shows the design of a temperature plant without disturbance; Fig. 7 shows the design for a system with a bigger disturbance; and Fig. 8 shows the design for a system with a lesser disturbance.

Fig. 9 displays the outcomes of maintaining the plant's temperature without causing any disruptions (X axis is the time of the system process, then the Y axis is the Setting Point data from the controlled temperature).

Similar research on the Temperature and Humidity Controlling System for Baby Incubator has also been done by [97]. The purpose of this project is to develop a newborn incubator with adjustable humidity and temperature. Its dimensions are 60 cm long, 40 cm wide, and 30 cm high. In accordance with the typical range of temperature and humidity in the incubator, the fan and/or heating will automatically turn on or off. 33°C to 35°C is the typical temperature range for application. While the incubator in use has a normal range of air humidity between 40% and 60%. The temperature and humidity sensors, the ATmega8535 microcontroller, the fan, the heater, and the LCD make up the data acquisition system. The results of temperature and humidity readings are shown on an LCD. The incubator's temperature is controlled by the heater. While the fan is utilized to control the incubator's humidity. According to the test findings, if the temperature falls below the threshold of 33°C, the heater will activate, and if the relative humidity rises to 60% or more, the fan will activate. Researchers [98-101] have created and developed an artificial intelligence-based fuzzy logic control system for incubators used to care for premature infants. For newborns with growth issues (premature babies) or with illness issues, Incubator Control for Premature Infants offers the ideal atmosphere. The environment in an incubator is sanitized, free of bacteria and dust, and it may be adjusted to keep the temperature, humidity, and oxygen at a comfortable level [102-104]. Infants are kept warm in incubators, which also monitor their numerous critical bodily processes like heart rate, blood pressure, oxygen saturation, and, if necessary, assist in breathing.

The incubator is designed to keep babies warm, to monitor many of their vital body parts functions such as heart rate, blood pressure, oxygen saturation and to support their breathing if necessary. Incubator Control for Premature Infants provides an optimal environment for newborns with growth problems (premature babies) or with disease problems. The incubator is an isolated environment without dust, bacteria, and has the ability to control temperature, humidity, and oxygen to keep it within acceptable levels [119]; [120]; [121]. Incubators are designed to keep babies warm, to monitor many of their vital body parts functions such as heart rate, blood pressure, oxygen saturation and to support their breathing if necessary. Development of Incubator Control for Premature Infants with Artificial Intelligence Based on Fuzzy Logic Control.

1.Prototyping a closed loop control system for a neonatal incubator has been developed by [115] through design and implement a closed loop control system to regulate the temperature inside a neonatal incubator. This closed loop control system has been designed using the software in the loop technique, which minimizes the hardware related work and concentrates all the decision making in the software. The closed loop implemented is a combination of sensing devices and actuators that operate synchronously to provide a stable thermal environment inside the incubator. The sensing devices are five resistance temperature detectors placed following the IEC-60601 standards, two current sensors, which give feedback information about the power consumption of the actuators, and two disturbance sensors that provide information about the opening of the incubator clappers. The actuators, which produce the stable environment inside the incubator, are the heater and the motor that propels the fan. Results confirm that the closed loop control system has been successfully implemented and the software designed is able to maintain a stable temperature inside the incubator. Moreover, the prototype implemented allows continuing the task started with this work, with further optimization and improvement of the controller.

2. Design of an enhanced temperature control system for neonatal incubator. An infant incubator provides stable levels of temperature, relative humidity and oxygen concentration. Temperature control system is the most important part of a baby incubator which has to be maintained around 37oC. In the present work we have designed and developed an enhanced temperature control system incorporating a combination of Pulse Width Modulation (PWM) and simple ON-OFF control system, where thermistors have been used as temperature sensors. The range of variation of temperature against the set temperature (37oC) has been found to be 1oC which is satisfactory. A temperature monitor has been designed through a circuit network incorporating a thermistor so that the voltage output is linearly related to the temperature. This allowed the use of a simple millivoltmeter to display the temperature directly through appropriate scaling. To ensure the safety of the baby an alarm circuit was designed which provides sound alarms for personnel attention if the temperature goes beyond a specified safe range, chosen here as 26oC – 38oC. In developing countries, like Bangladesh frequent power cuts demand an uninterrupted operation of incubator and a battery back up system, which could also be powered by a solar panel, has been suggested for this purpose [116].

3. Advanced control for incubator is rabidly increasing due to the significance of reducing the death ratio among the infant baby. In incubator, there are numbers of parameters need to be monitored. This paper presented an advance control system used to monitor some important parameter that affect the life of infant baby. This technique simultaneously monitored and controlled more than one parameter with advanced control and provides smooth operation helps to increase the accuracy of the system. The proposed system contained four temperature sensors which are used to adjust the incubator temperature and extended to monitor the skin temperature. The system also used two sensors to measure humidity. An application page was designed to ensure easy monitoring service for user. The systems based on Arduino and offer the ability to control incubator using the serial port [117].

4. Incubator must provide stable levels of temperature, relative humidity and oxygen concentration. Temperature on

infant incubator must be maintaned around 36°C-38°C. In order to control that, adaptive Fuzzy- PI controller is proposed and implemented on infant incubator's prototype. This research use DHT11 sensor as sensing element and the control method are actuated by lightbulbs. The controller used Microcontroller Atmega16 as processor which output determines the amount of power supplied to the lightbulb by employing pulse width modulation and MOSFET triggered circuit. Tests were carried out on temperature references that correspond to the standard incubator temperature range of 36°C to 38°C. References changes (fluctuatif reference) test and disturbances test were also carried out to prove system performance. The tests result on fixed reference temperatures were able to reach a stable setpoint with time rise (tr) around the 200 second with the highest overshoot maximum steady state error below 5%. References change tests and disturbances test successfully proved the controller was able to follow changes in references and overcome the disturbances [118].

5. The design and implementation of real time monitoring of an infant incubator, based on sensor fault tolerant control system, using a PIC microcontroller. Temperature and humidity are two parameters considered for the design infant incubator. The purpose of a Fault tolerant control systems (FTCS) scheme is to ensure that faults do not result in malfunctioning and system failure and to achieve the of best performance even with minimum number of sensors working. Fault tolerant control systems (FTCS) have ability to detect sensor fault automatically and to isolate faulty sensor which leads to system failure. The fault detection and the isolation (FDI) problem is an inherently complex one and for this reason the immediate goals are to preserve the stability of the process and, if is possible, to control and continue the process in a slightly degraded manner. The role of the FDI algorithms is that the control equipment must automatically isolate the faulted area, to adopt the correct attitude, to generate, to choose and to validate the correct decision. Prototype of infant incubator using FTCS was implemented by using redundant sensor with Build in self test (BIST) facility [119].

6. An Incu Analyzer comparison was used as a calibrator unit, a baby skin temperature thermistor sensor, and four LM35 sensors for baby incubator room temperature with one LM35 sensor as a PID control system carried out by trial-and-error method. Based on the results of measurements was made with the design, when the chamber is open, it produces an average error value of T1 4.083%, T2 6.06%, T3 3.78%, T4 4.88%, and T5 1.48%, while when the chamber is closed, it produces an average error value T1 0.75. %, T2 0.88%, T3 1.15%, T4 0.74%, and T5 0.87%. Measurement of skin temperature using a thermometer has an average error value of 1.1%. The results showed that uneven heat transfer, lack of air distribution, different sensor placements at each point, and non-standard chamber sizes were factors that were uneven at each point. Based on the results of the study, it was found that the use of a working system on this device can be implemented to control the temperature of the baby incubator by knowing the temperature distribution at each point [120].

In addition, the development of a solar-powered incubator for areas without electricity uses candles that are dried in a box as heat storage. Furthermore, the design of an effective incubator material for storing heat [121]. Modeling and using a fuzzy control system for neonatal incubators using a heat exchanger model between infants and dynamic environmental temperatures [122]. The application of indirect adaptive generalized predictive control (IAGPC) in neonatal incubators is more effective in regulating temperature than using on-off and PID, but the details of the incubator hardware and mechanics used are not spelled out [124]. Use of ANFIS control to control the temperature in the incubator. Several other incubator development studies added functions to the incubator [125]. Development of an automated incubator equipped with phototherapy, biometric fingerprint reader, remote monitoring, and heart rate control module for developing countries. Development of portable and wireless incubators using Wi-fi and infrared to measure heart rate, blood oxygen level, and temperature. Development of a smart incubator connected to a medical database server using LoRa. This incubator prototype uses a PID controller system with an optimum gain of Kp 1.501, Ki 0.016, and Kd -1.319 from the results of modeling and tuning in Matlab. The results of the bode plot stability analysis show that system stability is achieved with a gain margin value of 109 dB. Various control models and functions have been developed in incubators and a small number of incubator designs comply with the standard for medical electrical devices (IEC 60601-2-19). The development of the control system for infant incubators continues to be studied and developed to save premature babies.

IV. CONCLUSION

The Preferred Reporting Items for Systematic Review (PRISMA) were used in this study's systematic literature review. 188 suitable articles that fit the inclusion requirements were found after the articles were screened and chosen. The outcomes demonstrated that the Incubator Control for Premature Infants offered the best environment for newborns with growth or disease-related issues (premature babies). An incubator is a sealed space free of dust and bacteria with the ability to regulate temperature, humidity, and oxygen to maintain a stable environment.

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