International Journal of Electronics Communication and Computer Engineering
Volume 5, Issue (4) July, Technovision-2014, ISSN 2249–071X

Technovision-2014: 1st International Conference at SITS, Narhe, Pune on April 5-6, 2014

# Artificial Neural Network based Temperature Controllers for Incubators

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***Abstract* – Body temperature measurement and its maintenance for a premature baby is an important task in Bio-medical field and is required in NICU. In the commercially available radiant heat warmers to maintain the temperature at the required level, the PI (proportional integral) control is used. This work aims the use of Artificial Neural Network (ANN) based control mechanism to simulate the temperature controlling action in infants and thus starts trying to maintain the body temperature according to environment. This topic also includes centrally Monitoring of Baby temperature of such 8 warmers. The measurement of the baby's body temperatures could be done with the help of a linear semiconductor temperature sensor. The amplified output of the sensor will then be converted into digital format and will be given to the microcontroller for processing. The required set point could be set with the help of external membrane keypad. The PWM output from the microcontroller will be used to drive the heater. The measured temperature of the body and the required set point along with percentage power given to the heater will be displayed on the LCD, and transmitted to the central station through RS485 protocol. ANN determines the power applied to the heater. This central monitoring station is remotely located from the bed. Thus one can monitor set temperature and actual temperature of baby remotely.**

***Keywords* – Artificial Neural Network (ANN), Temperature Controllers.**

## I. INTRODUCTION

An artificial neural network (ANN), usually called neural network (NN), is a mathematical model or computational model that is inspired by the structure and/or functional aspects of biological neural networks. A neural network consists of an interconnected group of artificial neurons, and it processes information using a connectionist approach to computation. In most cases an ANN is an adaptive system that changes its structure based on external or internal information that flows through the network during the learning phase. Modern neural networks are non-linear statistical data modeling tools. They are usually used to model complex relationships between inputs and outputs or to find patterns in data the utility of artificial neural network models lies in the fact that they can be used to infer a function from observations. This is particularly useful in applications where the complexity of the data or task makes the design of such a function by hand impractical.

Neural network models in artificial intelligence are usually referred to as artificial neural networks (ANNs); these are essentially simple mathematical models defining a function $f:X\dashrightarrow Y$ or a distribution over X or both X and Y, but sometimes models are also intimately associated with a particular learning algorithm or learning rule. A common use of the phrase ANN model really means the definition of a *class* of such functions (where members of the class are obtained by varying parameters, connection weights, or specifics of the architecture such as the number of neurons or their connectivity)

The word network in the term 'artificial neural network' refers to the inter–connections between the neurons in the different layers of each system. An example system has three layers. The first layer has input neurons, which send data via synapses to the second layer of neurons, and then via more synapses to the third layer of output neurons. More complex systems will have more layers of neurons with some having increased layers of input neurons and output neurons. The synapses store parameters called "weights" that manipulate the data in the calculations.

An ANN is typically defined by three types of parameters

1. The interconnection pattern between different layers of neurons
2. The learning process for updating the weights of the interconnections
3. The activation function that converts a neuron's weighted input to its output activation.

Mathematically, a neuron's network function F(x) is defined as a composition of other functions g(x), which can further be defined as a composition of other functions. This can be conveniently represented as a network structure, with arrows depicting the dependencies between variables. A widely used type of composition is the nonlinear weighted sum, where f(x) =K(Σiwigi(x)), where K (commonly referred to as the activation function) is some predefined function, such as the hyperbolic tangent. It will be convenient for the following to refer to a collection of functions g1 as simply a vector g= (g1,g2,…..,gn).

This figure depicts such a decomposition of f, with dependencies between variables indicated by arrows. These can be interpreted in two ways.

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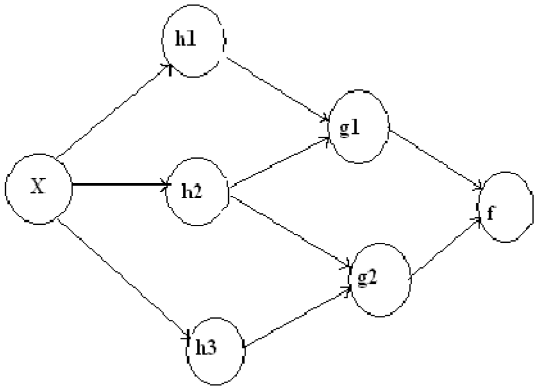

Fig.1.1. ANN Dependency Graph [2]

The first view is the functional view: the input is transformed into a 3-dimensional vector h, which is then transformed into a 2-dimensional vector g, which is finally transformed into f. This view is most commonly encountered in the context of optimization .The second view is the probabilistic view: the random variable F=f(G) depends upon the random variable G=g(H), which depends upon H= h(X), which depends upon the random variable X. This view is most commonly encountered in the context of graphical models.

The two views are largely equivalent. In either case, for this particular network architecture, the components of individual layers are independent of each other (e.g., the components of g are independent of each other given their input h). This naturally enables a degree of parallelism in the implementation.

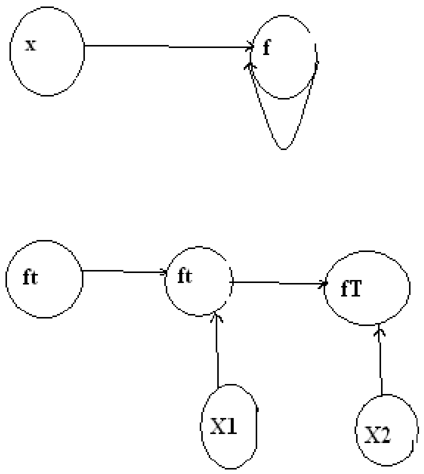

Fig.1.2. Recurrent ANN Dependency Graph [2]

Networks such as the previous one are commonly called feed forward, because their graph is a directed acyclic graph. Networks with cycles are commonly called recurrent. Such networks are commonly depicted in the manner shown at the top of the figure, where f is shown as being dependent upon itself. However, an implied temporal dependence is not shown.

## II. Hardware Implementation

As per the newborn infant or premature baby is concerned, it is not in a position to sense and go loosing the body temperature below minimum limit of required value and fails to survive. So, the necessary control action should be taken before baby fails to survive. Air temperature and infant body temperature is compared and control as per requirement. For this purpose we require two temperature sensors (LM35) which takes temperature as input parameter from surrounding and infant body temperature. For LM 35 output varies linearly and proportional to Celsius temperature. The analog form of temperature using analog to digital converter, which manipulates the analog signals in such way that meets requirement of further processing A/D conversion.

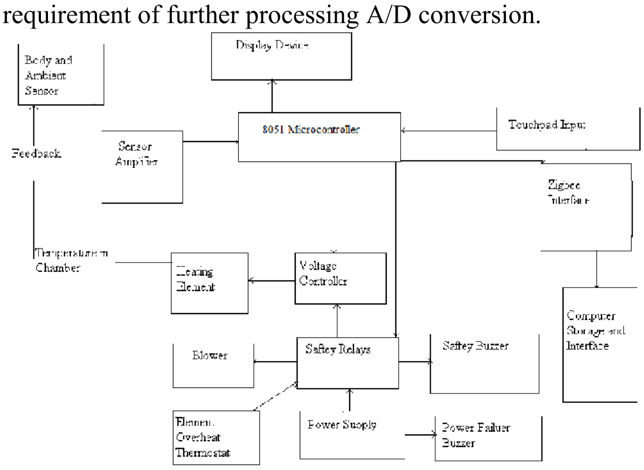

Fig.2.1. Block diagram for temperature controller

The set temperature is considered as air temperature whose value can be set through the external keypad membrane. If the control action is taken for first day of born baby then the required temperature for it's body is decided by doctor by providing the table which gives information about what weight and day the baby require the temperature. With the help of ANN logic in assembly language and required algorithm and software like LINK 31 , X31. The output PWM wave produced from controller 89S51.The main reason behind producing PWM wave is to drive heater through Opto isolator driver circuit. In this case ANN logic gives signal to generated PWM wave , that decides at what time slot the heater should be on/off that all makes possible due to setting of duty cycle. One advantage of ANN is the overshoot and undershoot can be handled properly with continuation.

The baby recovery is given in terms of percentage power that will be displayed on 16*2 LCD display. If 90% power is displayed means the baby is required 10% and 90% of power is contributed by heater. The set temperature range for working is stated as 27°c to 38°c. the same temperature is followed until the baby is in safe condition.

If in NICU more than two babies are kept in warmer /incubator for temperature , the information of each baby like set temperature, body temperature, % power will be displayed combinely bed wise on the system which may monitored by doctor in his department through Zigbee module.

A neonatal incubator is a device consisting of a rigid box-like enclosure in which an infant may be kept in a controlled environment for medical care. The device may include an AC-powered heater, a fan to circulate the warmed air, a container for water to add humidity, a control valve through which oxygen may be added, and access ports for nursing care. It may also contain a servo control to help regulate incubator air temperature.

The servo control uses a temperature sensing thermistor, which is taped to the child's abdomen.In infants born before 31 weeks gestation, evaporative water loss is the single most important channel of heat loss. This is due to inadequate keratinisation of the skin, which allows a high permeability of water to the skin. The permeability drops rapidly in the first 7 to 10 days after birth unless the skin becomes traumatized or secondarily infected. In that 7 to 10 day period, the absolute humidity must be monitored so that evaporative heat loss is kept to a minimum as well as water loss through the skin.

Premature babies are not always put in incubators. If a baby is in danger of going into respiratory arrest or other significant problems, they are put in an overhead radiant cradle so that they are easily accessible to nurses and doctors. The radiation from overhead puts the heat back into the baby while the baby is losing heat by other means. Heat losses and gains are difficult to monitor. The only way to monitor the baby's temperature is with a thermistor and servo controlled heating unit. The overhead radiator can account for the heat lost by other means, but cannot account for the water lost through the skin, which is critical to maintain for the first 7 to 10 days after birth to prevent dehydration. There have been significant advances in thermoregulation since the 1960s. These advances have reduced mortality in small babies by 25%. Although this is a great accomplishment, research continues so that the mortality in small babies is reduced even more. Conditions to be maintained for the radiant warmer is as follows

- Clean the mattress and platform, and cover the mattress with clean linen sheet
- When it is known beforehand that a baby is to arrive in the newborn unit, turn on the warmer for at least 20 minutes prior to pre-warm the linen and mattress so that the baby does not lie on a cold surface initially
- Read temperature on display. Adjust heater output to High : If baby temperature is below 36º C Medium : If baby temperature is between 36ºC-36.5ºC and to Low : If baby temperature is between 36.5ºC-37.5ºC
- Lonce the baby's temperature is between 36.5-37.5ºC, switch on to servo mode/skin mode
- If baby is in supine position place the skin probe on the right hypochondrium. When in prone position, place the probe on the loin area. To prevent skin injury, place tegaderm and fix the probe on it with an adhesive
- Ensure that the baby's head is covered with cap and feet secured in socks and the baby is clothed or covered unless it is necessary for the baby to be naked or partially undressed for observation or for a procedure
- Place only one baby under each radiant warmer
- Turn the baby frequently while under the warmer , if possible
- Check the temperature of the warmer and of the room every hour and adjust the temperature setting accordingly. Record the heater output in each shift (every 6 hours). Any sudden increase in heater output is an early indicator of sickness
- Move the baby to be with the mother as soon as the baby no longer requires frequent procedures and treatment. If the heater output is <20% in servo mode, it is safe to shift the baby to mother's side

## III. Results

| Birth weight | Median | +range |
|---|---|---|
| 500 | 35.5 | 0.5 |
| 1000 | 34.9 | 0.5 |
| 1500 | 34.0 | 0.5 |
| 2000 | 33.5 | 0.5 |
| 2500 | 33.2 | 0.8 |
| 3000 | 33.0 | 1.0 |
| 3500 | 32.8 | 1.2 |

## IV. Conclusion

We have reached to conclude that with the help of ANN logic the continuous generation of PWM wave is obtained, which helps in driving of heater which plays very important role for infants and make possible to compare with air temperature. Stable temperature control is achieved within the range of 0.1°C in 20 mins. Whereas the PI and other control action requires around 30 to 40 mins. ANN control action reduces overshoots and undershoots and this reflects in better efficiency. Thus as compared to the presently available controllers this controller gives early recovery of the infant

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