Fault Tolerance Temperature in the Infant Incubator Using Fuzzy Logic

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ABSTRACT

Temperature is an important parameter that needs to be controlled in any infant incubator design. This paper improved a multisensory system to provide high levels of accuracy and assurance. Four temperature sensors were used to adjust the incubator temperature. The proposed system is not only concerned with the air temperature control but it also extended to monitor the skin temperature. The results prove the ability of using a multisensory system with advanced control such as fuzzy control to provide a smooth operation.

Keywords—Infant incubators, Fuzzy logic, Fuzzy Logic Controller (FLC), Multisensory system, Fault tolerant control.

1. INTRODUCTION

A simple fault in Infant incubators operation will cause many health problems to those born prematurely. By placing an infant in an incubator making it easier for doctors and nurses to monitor the different aspects of the environment of the child to reduce the risk of infection and protect the womb (ideal conditions) from pollutants[1]. Fuzzy techniques have been successfully used in control in several fields, and engineers and researchers are today considering fuzzy logic algorithms in order to implement intelligent functions in embedded systems[2]. Fault tolerant control has the ability to increase the reliability of complex systems and performance requirements in the events of faults which led to the routing used used me in the last few years. Fault tolerant control with different types of defects such as motors, sensors, and system errors. Each of which requires a different approach from the other to work with. Fault tolerant control system has the ability to detect and isolate errors in addition to fault diagnosis [3]

2. PREVIOUS WORKS

A lot of research & development are going on over temperature air control using fuzzy logic. The implementation of temperature air control in the infant incubator was reported in [4] which specified two sensors to control the air inside the incubator.

3. METHODOLOGY

Development of the Fuzzy Logic Control Using Air Temperature The fuzzy logic system was developed to incorporate both the skin temperature and the air temperature to control the flow of hot air into the incubator. The temperature was sensed and used as inputs to the fuzzy logic system. The fuzzy logic system as shown in Fig [1] consists of two input sensors (Air Temp and Skin Temp) parameters and one output parameter corresponding to the flow rate of hot air [3].

Figure [1] Naming the input variable (flow)
The temperature is usually obtained by measuring the temperature by a sensor placed in the incubator. These sensors can be hung at different positions in the air and skin.[4] In the present investigation, changed automatically in each time step, Flow rate was expressed as a fraction of maximum flow of hot air from the blower into the incubator. Therefore, the output varied from a minimum value of zero to a maximum of 1[5]

In the Classical logic, a parameter belongs to only one sub domain. However, in the fuzzy logic system, a parameter can partially belong to several overlapping subsets at the same time. Since there is an overlap on some parts of the fuzzy subsets, values in those parts belong partially to both the overlapping subsets. Fuzzy membership functions were first defined for both of the input parameters (Air temp and Skin temp) with five overlapping subsets. The output membership functions were also defined. A set of rules (shows the table [1]) were developed to map the input to output membership values.

![Figure 2: Block diagram of fuzzy logic controller](image)

The dynamic input parameters (Air temp and Skin temp) were first fuzzified to obtain a set of membership values using the predefined membership functions. The membership values were then input to a rule based system. These rules decide the fuzzy output based on the fuzzy input variables. After the fuzzy output was computed, the centroid defuzzification technique was used to convert the fuzzy output into a crisp output.

This crisp output was used to control the flow rate of hot air into the incubator. The block diagram of the procedure is shown in Fig [2].

4. IMPLEMENTATION PRINCIPLE

Temperature control system shown in fig [1] is works on the basic principle of fuzzy logic.

The steps of Fuzzy logic algorithm summarized by:

1. Define linguistic variables and terms
2. Construct the membership function
3. Construct rule base
4. Convert crisp data to fuzzy values using the membership function
5. Evaluate rule in the rule base
6. Combine the result of each rule
7. Convert output data to non-fuzzy values

4.1 MEMBERSHIP FUNCTIONS

Fuzzy subsets were defined for the two input variables: temperature of incubator air space, Skin temperature of infant’s skin, and the output variable flow rate of hot air into the incubator. The domain of each input parameter was divided into five subsets: very low (VL), Low (L), medium (M), High (H), Very high (VH) and correspondingly five membership functions were formed (Fig. 3). Membership functions map an input parameter into five membership values. These membership values actually define the extent to which Air temp and Skin temp belong to each of the five subsets. Similarly, the output domain was divided into five sub-
domains: very slow (VS), slow (S), medium (M), Fast (F), and very Fast (VF). Triangular membership functions were used for all the input and output subdomains. (6)

4.2 FUZZY RULES

In a Fuzzy Logic, a rule base is constructed to control the output variable. A fuzzy rule is a simple IF-THEN rule with a condition and a conclusion. In Table 1 and 2, sample fuzzy rules for the temperature control system in Figure are listed.

<table>
<thead>
<tr>
<th>No</th>
<th>Fuzzy rules</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>If (ta₁ is VL and ta₂ is VL and ts₁ is VL and ts₂ is VL) then the Flow is VS</td>
</tr>
<tr>
<td>2</td>
<td>If (ta₁ is VL and ta₂ is VL and ts₁ is VL and ts₂ is L) then the Flow is VS</td>
</tr>
<tr>
<td>3</td>
<td>If (ta₁ is VL and ta₂ is L and ts₁ is VL and ts₂ is L) then the Flow is VS</td>
</tr>
<tr>
<td>4</td>
<td>If (ta₁ is VL and ta₂ is L and ts₁ is L and ts₂ is L) then the Flow is VS</td>
</tr>
<tr>
<td>5</td>
<td>If (ta₁ is L and ta₂ is L and ts₁ is L and ts₂ is L) then the Flow is S</td>
</tr>
<tr>
<td>6</td>
<td>If (ta₁ is L and ta₂ is L and ts₁ is L and ts₂ is M) then the Flow is S</td>
</tr>
<tr>
<td>7</td>
<td>If (ta₁ is L and ta₂ is M and ts₁ is L and ts₂ is M) then the Flow is M</td>
</tr>
<tr>
<td>8</td>
<td>If (ta₁ is M and ta₂ is M and ts₁ is M and ts₂ is M) then the Flow is M</td>
</tr>
<tr>
<td>9</td>
<td>If (ta₁ is M and ta₂ is M and ts₁ is M and ts₂ is H) then the Flow is M</td>
</tr>
</tbody>
</table>

In fuzzy logic system, a temperature control system controlled by a fuzzy logic controller. The temperature of the incubator can be adjusted by details like current temperature of the incubator and the target value by defined system. The comparison between the incubator temperature and the target temperature can be compared by fuzzy engine at certain period of time and produces a command of heating.

![Figure [3]: Membership Functions of the Air temp1](image1)

![Figure [3]: Membership Functions of the Air temp2](image2)
Figure [4]: Membership Functions of Skin temperature

Figure [4]: Membership Functions of Skin temperature

1. if (air-temp1 is VL) and (air-temp2 is VL) and (Skin-temp1 is VL) and (Skin-temp2 is VL) then (flow is VS)
2. if (air-temp1 is VL) and (air-temp2 is VL) and (Skin-temp1 is VL) and (Skin-temp2 is L) then (flow is VS)
3. if (air-temp1 is VL) and (air-temp2 is VL) and (Skin-temp1 is VL) and (Skin-temp2 is M) then (flow is VS)
4. if (air-temp1 is VL) and (air-temp2 is VL) and (Skin-temp1 is VL) and (Skin-temp2 is H) then (flow is VS)
5. if (air-temp1 is VL) and (air-temp2 is VL) and (Skin-temp1 is VL) and (Skin-temp2 is VH) then (flow is VS)
6. if (air-temp1 is VL) and (air-temp2 is VL) and (Skin-temp1 is M) and (Skin-temp2 is VL) then (flow is S)
7. if (air-temp1 is VL) and (air-temp2 is M) and (Skin-temp1 is M) and (Skin-temp2 is VL) then (flow is S)
8. if (air-temp1 is M) and (air-temp2 is M) and (Skin-temp1 is M) and (Skin-temp2 is VL) then (flow is S)
9. if (air-temp1 is M) and (air-temp2 is M) and (Skin-temp1 is M) and (Skin-temp2 is M) then (flow is S)

Fig[5]: Fuzzy Mamdani-Rule Editor
Figure [6]: Rule View

Figure [7]: Output Flow Membership Function

Figure [8]: Fuzzy Rule Viewer-3D Surface
5. DISCUSSION

The present investigation represents the first application of fuzzy logic to the control of infant incubators. Current incubator devices use either air servo control or skin servo control to control the incubator temperature. Air servo control uses the incubator air temperature and the skin servo control uses infant’s skin temperature to control the hot air flow into the incubator. The present study demonstrated the application of fuzzy logic expert systems to control the incubator heating using both the infant skin temperature and the incubator air temperature. The application of fuzzy logic control reduced the temperature fluctuations and provided a comparatively smooth response. The main objective of the present system is to maintain a specific core temperature without significant fluctuations in the air temperature, and without reaching the steady state too fast or too slow. The accuracy of the fuzzy model is very reasonable as shown in MATLAB FIS Editor. These results demonstrate that the fuzzy logic is a very useful method for assessing and not enforced to evaluate with a crisp number. The shape of the membership functions used in this fuzzy logic control system was straight lines which form triangular shapes. Figure [4] shows the membership functions for the input variable Air temp, and Fig [5] shows the membership functions for the input variable Skin temp. Fig [6] shows the Fuzzy Mamdani-Rule Editor and Fig [7] shows the Rule View and Fig [8] shows the membership functions for the output variable flow rate. Each of the membership values for both input and output parameters varies from 0 to 1 and indicates the degree of membership to the corresponding subdomain. and Figure [9] shows the Fuzzy Rule.

6. CONCLUSIONS

A fuzzy logic control system was developed successfully in order to control the incubator air temperature. A control system was evaluated using of four sensor temperature model. The advantage of this paper come the use of two skin temperature sensor and two Air temperature sensor using fuzzy logic provides a smooth control. The results show that the system with two different sensors to measure temperature is more reliable and gives more accuracy.

REFERENCES


