Multisensors System for Real Time Detections of Length, Weight, and Heartbeat of Premature Baby in The Incubator

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***Abstract*— Premature babies inserted into the incubator will always be monitored progressively, especially the heart rate, body length, and body weight. The aims of this research are to design and to create an incubator that can detect the abnormalities of baby's heartbeat through the baby's fingers in continuous and real time by using pulse sensor. The incubator also able to measured baby's length and weight automatically by using ultrasonic sensor and load-cell sensor, respectively. The output of all sensors will be processed and calibrated by Arduino Microcontroller, then the results will be displayed on the liquid crystal display (LCD).The systems also able to allow some notifications if any abnormalities have been occur. As a result, the heartbeat detector has a precision of ± 95% when compared to a reference heartbeat detector. The system also can measure the length and weight of the infant with the measurement results are closer to the reference instrument, which the average error is not more than 5%. The results are most likely is a good preliminary results in order to build a smart incubator.**

Keywords—pulse sensor, ultrasonic sensor, load-cell sensor.

I. Introduction

Premature baby mortality is still the largest contributor to baby mortality rate in Indonesia. In 2010, Indonesia was in fifth rank of the most preterm birth rate in the world, with preterm birth rates reach 675,700 cases per year from about 4.5 million births per year [1].

Premature baby's care can be categorized as very complicated and complex because of the risk that can be occur. Organs of premature babies are generally unable to work perfectly yet so that it makes it difficult to adjust to life outside the womb. Therefore, babies are usually placed in incubators to overcome problems such as temperature differences [2]. In additionally, the incubator also serves as a protective baby from the danger of infection.

Several researches have been done to build a better incubator. Budiono [3] published incubator design that could distribute heat evenly. It is also done by Nurcahya [4], but coupled with the regulation of moisture using microcontroller. Incubators with remote monitoring systems have been made but only for temperature and humidity control [5].

Premature babies inserted into the incubator will always be monitored progressively, especially the heart rate, body length, and body weight [6]. Measurement of these parameters is usually done outside the incubator, then this will make the baby must be in and out of the incubator. To solve the problem, the availability of an incubator that has been equipped with a baby's heartbeat detector, body length detector, and body weight detector is very important. The measurement should be done real time and continuously.

Therefore, in this research, by using other studies related to infant and infant weight measurement tool [7-9], we try to build an incubator that more complete that other. The aims of this research are to design and to create an incubator that can detect the abnormalities of baby's heartbeat through the baby's fingers in a real time. The incubator also able to measured baby's length and weight automatically. The systems also able to allow some notifications if any abnormalities have been occur. This research is a preliminary research to build a smart incubator.

II. Method

In this research three types of sensors are needed, which is for measuring heart rate, body length, and body weight. Block diagram of the system is shown in Fig.1.

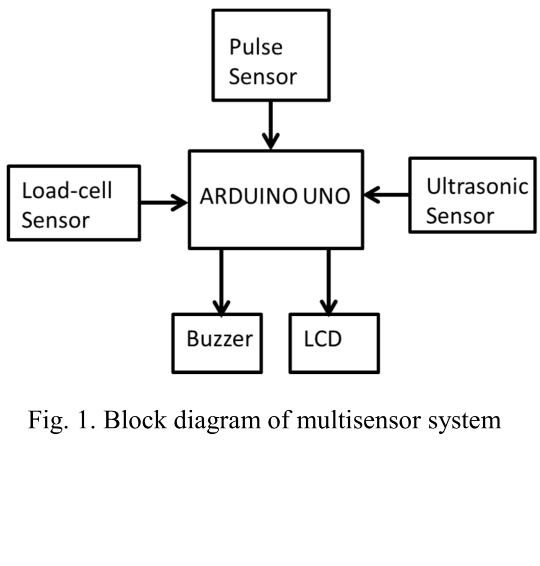

Fig. 1. Block diagram of multisensor system

For the measurements of the heart rate it used pulse sensor, then ultrasonic sensor for body length measurement, and load-cell sensor for body weight measurement. Pulse sensor has been used because it can measure heartbeat in the fingertip successfully based on some research [10-13].

Pulse sensor is a heart rate measurement sensor that can be connected to a microcontroller. Pulse sensor has a characteristic that has a heart shape and there is a green LED light in the middle. This sensor is very sensitive to vibration from the heartbeat. This sensor can be placed in all parts of the human body such as fingertips, chest or ears. The physical shape of the pulse sensor is shown in Fig. 2. On the front there is a small, optically plated hole, where the green LED will be visible. This light is generated by the ambient light sensor. When the LED rays are blocked by the fingertips, ears or other capillary networks then the sensors will read the amount of light that will be reflected back to the sensor.

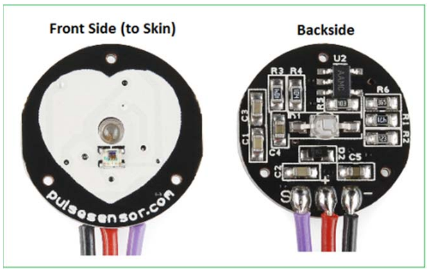

Fig.2 Pulse Sensor
[Source: http://www.theorycircuit.com/wp-content/uploads/2016/08/pulse-sensor-image]

Ping sensor is an ultrasonic sensor that can detect the distance of the object by emitting ultrasonic waves with a frequency of 40 KHz. This ultrasonic wave propagates through the air at a speed of 344 meters per second, and then the sensor will detect its reflection. The output of this sensor is the pulse, where the pulse width will represent the measured distance. The width of the high pulse will correspond to the ultrasonic wave length traveled between the measuring distances to the object [14].

Load Cell is a force sensor that is often used to measure weight. It contain of strain gauge, a component made of foil grid which is a long thin wire and arranged in zigzag. When the strain gauge gets loaded, it will cause a change in the length of the thin wire, causing an increase in the resulting resistance. The change in resistance will be equivalent to the measured load. The length of the strain gauge is about 0.20 Mm up to 102 Mm. The standard strain gauge values are 120 Ohm and 350 Ohm. Strain gauges are commonly used in the measurement of the force, weight, pressure, load, and displacement of objects [15].

The output of all sensors will be processed and calibrated by Arduino Microcontroller, then the reasults will be displayed on the liquid crystal display (LCD). The Arduino be equipped with normal data of heart rate, therefore if abnormality detected then it will activate the buzzer.

Reaserch steps with the outcomes for each stage are described in Fig. 3.

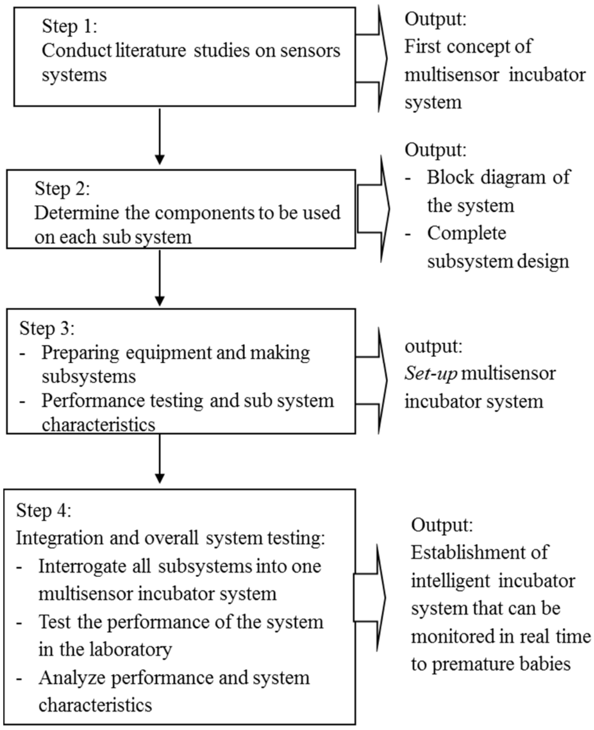

Fig. 3. Research Steps

Research steps are importance to ensure that the research is doing well. After literature studies, design process, and build the instrument system, next steps are doing some experiment to test the systems. We did several experiments to obtain instrument performance. Some of them will be explain in the next section.

III. RESULTS AND DISCUSSIONS

In this section it will discuss the results of tests that have been obtained and examined about the measurement of heart rate by pulse sensor, body length with ultrasonic sensors and weight with load-cell sensors. The purpose of this test is to know the level of precision and resistance of the system. However, in this research, it was unable to conduct a premature baby's heartbeat because the system is still in the preliminary studies so may be not secure yet for premature babies which is very sensitive to external interactions of physical as well as non-physical. In order to obtain the validation of data, every measurement has been repeated ten times in the same condition, however not all data is shown in this manuscript.

A. *Pulse Sensor Test*

The test on the pulse sensor is divided into two parts. First, in order to know output response of the pulse sensor (in the form of Bit Per Minute = BPM) when there are any beat and no beat detected, or the sensor does not touch the human skin. Second, in order to know output response of the pulse sensor in reading the heart beat humans with different ages. For all measurements, we used reference sensors, i.e. Xiaomi Mi Band 2, which has been equipped with heart rate measurment for checking the precission of the pulse sensor. Results of the first experiment have been shown in Fig. 4.

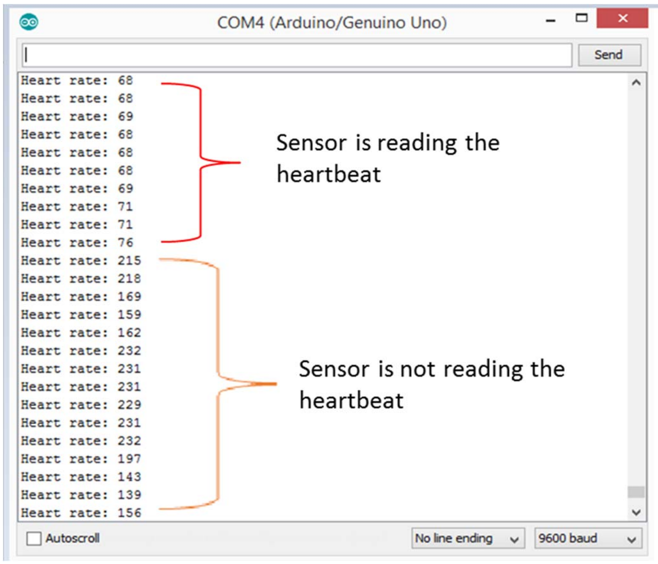

Fig.4 Pulse sensor's responses

Fig. 4 shows the sensor's responses when there is any beat and also no beat can be detected. Under no beat condition means the sensor doesn't touch human skin. The results show that the heart rate detected under no beat condition is faster comparing with under beat. It is reasonable because pulse sensor working by counting transmitted light that be reflected back to the sensor. If sensor touch human skin, light will be disturbing only by heartbeat. However, if it doesn't touch human skin, there is so many reflector of the light everywhere, which causing many light will be reflected back to the sensor.

Then, sensor's output is compared with reference sensor. Table 1 shows the measurement result of the pulse sensor and Xiaomi Mi Band 2 as a reference instrument. Both instruments have been use at the same time under same condition.

TABLE. 1 COMPARISON OF SENSORS'S RESPONSES

No.	Mi Band 2	Pulse Sensor	Error (%)
1	69	65	1,44
2	66	68	1,51
3	67	65	1,49
4	65	66	1,53
5	70	69	1,42
6	65	65	0
7	69	70	1,44
8	71	70	1,40
9	65	65	0
10	65	67	3,0
		Error	**1,32%**

As a result, it can be seen that there is difference results obtained between the pulse sensor and the comparator sensor, that it called by error. For 10 times measurement, it obtained error's mean of 1.32%. Error has been calculated by equation:

$$(\%)Error = \frac{Reference\ value - sensor\ value}{reference\ value} \times 100$$

In this case, reference value is measurement result using Mi Band 2 and sensor value is measurements results of pulse sensor

Second part was performed by measuring the heart rate of patients with different age. Although the system will be used for infants, but experiments on some types of human age are needed to know the performance of this instrument. As a sample, it used 5 different age variations. The first patient is a woman aged 50 years and above. The second patient is a man aged 50 years and above. The third patient is a man under 25 years old. The fourth patient is a 10 year old female and the last patient is a toddler. Testing is still done by comparing pulse sensors with comparator sensors for 10 times measurements for each patient. The test results will be shown in Fig. 5.

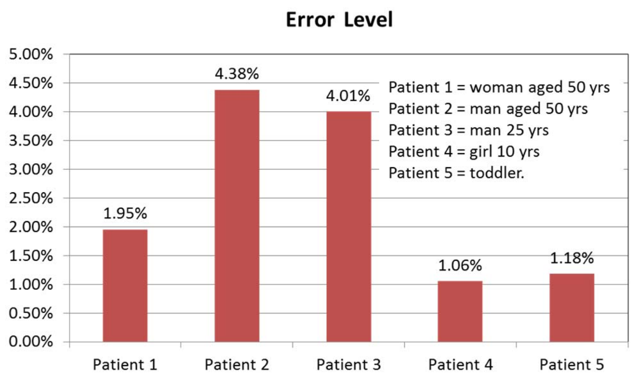

Fig. 5. Error level for several types of human

In the measurements performed for the three adult patients, the results obtained percentage error of 1.954% for the first patient, 4.384% for the second patient and 4,006% for the third patient. In the test of patients with the age of the category of children obtained results of 1.055% for patients 4 and 1.181% for patients 5. This indicates that there is no problem in making measurements using pulse sensors. With error percentage value less than 5% when compared with comparator sensors.

The results of heart rate readings also influenced by several factors such as the position of data retrieval or the laying of sensors in patients and the effects of movement when taking of heart rate data. Heartbeat sensor is very sensitive to movement, alike EKG, digital tension meter that has been equipped with heart rate detector and sensors used in this research, such as pulse sensor. So in this case it is advisable to take data in a minimum movement (stable) state. This research will be applied to premature babies in incubators that are usually wrapped with scarf, so the movement will be minimalized.

B. Ultrasonic sensor test

This test is performed to see the level of precision generated by Ultrasonic sensor. Ultrasonic sensor is a sensor that utilizes ultrasonic light as the reading medium. This test uses a ruler as a calibrator that serves as a comparator value for the value generated by the ultrasonic sensor. The results of ultrasonic sensor testing can be seen in Table 2.

TABLE. 2 RESPONSES OF THE ULTRASONIC SENSORS

No.	Distance	Measurement Result
1.	30 cm	30,3 cm
2.	35 cm	35,3 cm
3.	40 cm	40,4 cm
4.	45 cm	45,5 cm
5.	50 cm	50,3 cm

The results on five tests by ultrasonic sensors, obtained results that are not much different. By using the percentage error form then obtained error of 0.914% or under 1%. Because the error value generated only about 1%, then the measurement results by the sensor can be said almost close to the appropriate accuracy.

C. Load-cell sensor Test

Tests load cell sensor has been done to determine whether the sensor will be used to work properly. After connecting Arduino Uno on a computer, testing is done by uploading a pre-made program. Then open the Arduino IDE software and the monitor serial window in the software. Then we will see the measurement result of load in Kg. The results of this measurement are shown in the following Table 3.

TABLE. 3 RESPONSES OF THE LOAD-CELL SENSORS

No	Load	Load Cell Sensor
1	1000 gram	968 gram
2	1500 gram	1489 gram
3	2000 gram	1920 gram
4	2500 gram	2480 gram
5	3000 gram	2870 gram

The results obtained after five times of data collection, obtained results that are not much different from the desired value. In this test results obtained an error of 2.6%. With an error rate of only 2.6%, this sensor has a good precision to be used as a premature baby weight sensor.

IV. Conclusions

Based on the experimental results, it can be concluded that the multisensors system instrument for real time detection has been realized well by using pulse sensor that can read heartbeat, ultrasonic sensor as body length sensing, and load cell as body weight of sensor. As a result, the heartbeat detector has a precision of ± 95% when compared to a reference heartbeat detector. The system also can measure the length and weight of the infant with the measurement results are closer to the reference instrument, which average error is not more than 5%. Weak point of this research is the heart detector actually has been not yet used for premature baby caused by technical problem. However, the experiment results are most likely is a good preliminary result in order to build a smart incubator with internet of things method.

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