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Novel Artificial Intelligence-Dynamic Programming on Infrared Thermometer Based on Internet of Things (IoT)

Abstract*. According to the COVID-19 epidemic, the world has completely changed to new norm life. However, until 2022, people are still facing COVID-19 and its spreading and fast infection to the human body. Healthcare workers are on the front lines and are at higher risk of contracting COVID-19 than other occupations because they must be in close contact with the patient who risks virus diseases. The paper proposes the novel artificial intelligence (AI)-dynamic programming algorithm on infrared Thermometer based on the Internet of things (IoT) to support the medical personnel. The proposed novel thermometer is divided into three main sections, which are 1) Temperature sensing device, 2) Embedded dynamic programming algorithm, and 3) IoT communication platform. The innovation was designed using dynamic programming algorithm embedment, reducing complex and repetitive processing errors and fast computation. Moreover, it was tested according to the research methodology way. The temperatures were collected within the controlled condition test of time, environment condition, and same body organ of volunteer according to the various distances. The experimental results came out with three classified zones: best, moderate, and ineffective spaces. In addition, the discussions were also included about the complication factors about sensor's accuracy detection, such as angle detection, target distance, and focusing of wireless infrared Thermometer.*

*Streszczenie. Według epidemii COVID-19 świat całkowicie zmienił się w nowe, normalne życie. Jednak do 2022 r. ludzie nadal stoją w obliczu COVID-19 oraz jego rozprzestrzeniania się i szybkiej infekcji w ludzkim ciele. Pracownicy służby zdrowia znajdują się na pierwszej linii frontu i są bardziej narażeni na zarażenie się COVID-19 niż w innych zawodach, ponieważ muszą być w bliskim kontakcie z pacjentem zagrożonym chorobami wirusowymi. W artykule zaproponowano nowatorski algorytm sztucznej inteligencji (AI)-dynamicznego programowania termometru na podczerwień w oparciu o Internet rzeczy (IoT) w celu wsparcia personelu medycznego. Proponowany nowatorski termometr jest podzielony na trzy główne sekcje, którymi są 1) urządzenie do pomiaru temperatury, 2) wbudowany algorytm programowania dynamicznego oraz 3) platforma komunikacyjna IoT. Innowacja została zaprojektowana z wykorzystaniem dynamicznego osadzenia algorytmu programowania, redukującego złożone i powtarzalne błędy przetwarzania oraz szybkie obliczenia. Ponadto został przetestowany zgodnie z metodologią badawczą. Temperatury zbierano w ramach kontrolowanego testu warunków czasu, warunków środowiska i tego samego organu ciała ochotnika w zależności od różnych odległości. Wyniki eksperymentalne przyniosły trzy sklasyfikowane strefy: najlepsze, umiarkowane i nieefektywne przestrzenie. Ponadto dyskutowano również na temat czynników komplikacji związanych z wykrywaniem dokładności czujnika, takich jak wykrywanie kąta, odległość celu i ogniskowanie bezprzewodowego termometru na podczerwień. (**Nowatorskie programowanie sztucznej inteligencji — dynamiczne programowanie termometru na podczerwień w oparciu o Internet rzeczy (IoT)***

Keywords: COVID-19, AI, IoT, Thermometer, Dynamic Programming
Słowa kluczowe: COVID, sztucz\na inteligencja, popdczerwień, pomiar tempewratury

Introduction

The COVID-19 pandemic has accelerated the demand and innovations in touchless technology from touchpoint to touchless. The last few years have seen an incredible rise in touch-based technology, with many consumers embracing touch-activated devices and innovations for their convenience and aesthetic appeal [1]. Investing in touchless technology to protect employees and customers may likely determine an organization's success or struggle during this global health crisis. The Coronavirus may remain viable on glass, plastic, and steel surfaces for two or three days. This incident makes it even more critical to implement touchless in the workplace, retail, and hospital. Rightfully, the fewer times people touch possibly contaminated surfaces, the less our chances of catching a disease that has infected more than nine million people worldwide. As a COVID-19 changes the way we live, move and work, it has also accelerated the need for innovations in touchless technology [2, 3].

Artificial intelligence (AI) is the science of instilling intelligence in machines to do tasks that traditionally require the human mind. AI-based power IoT for innovative thermometer systems rapidly involves application, adaptation, processing speed, and capabilities [4]. The intelligent Thermometer can elegantly reduce the repetition of human efforts and could give results in a comparatively low time. Moreover, the system can do specific tasks enhanced by computerized technology. Various domains like philosophy, computer science, mathematics, statistics, biology, physics, sociology, psychology, and many more have come up together to boost the interdisciplinary nature of AI intelligence, which comes from the data generated in each of these domains.

Internet of Things (IoT) is a recent technology paradigm that creates a global network of machines and devices capable of communicating with each other. IoT is recognized as one of the most important future technologies and is gaining vast recognition in a wide range of applications and fields related to smart homes and cities, the military, education, hospitals, autonomous, connected cars, and other modern technologies [5]. Besides, the industrial Internet of things (IIoT) automates manufacturing and innovative machine communications, but there are still times when humans must interact with machines. For example, people need touchless alternatives to the traditional push-button or touchscreen controls to reduce germ and virus transmission.

In addition, wireless local area network technology is an ever-growing technology mainly in the quality of service (QoS) and high-speed wireless techniques. WLAN mesh networks feature a higher data transmission rate due to shortened communication distance, expanded network capacity through spatial frequency reuse, automatic network configuration, and improved robustness regarding a route recovery mechanism [6]. Namely, the intelligent WiFi technology-wireless mesh is the latest and most advanced technology that combines the features of the 802.11 predecessor family that prevents the shortcomings of the two technologies cloud mesh, WiFi, and mesh WiFi. This network includes innovative features in transmitting and routing data. Hybrid Wicell fully satisfies and contains exceptional features which do not exist in other technologies. Thus, it was applied in this system to make highly effective data communication without losing in a blind corner of a large building.

To achieve a more efficient wireless communication network based on IoT platforms, the mesh-networking for WiFi applications has become a choice for users. It has become universal in recent years, with the growth of cord-cutters and streaming media services. Thus, users have demanded higher performance with their home networks. The IoT promises to offer more connected devices and will only add to better networks. Hence, WiFi routers and networking devices have evolved dramatically, but today have reached commodity status. New technology and products are currently offered with the promise of addressing many of these performance issues. This IoT runs on "mesh networking" in the case of complicated areas in which signals cannot enter the internet network connection.

Proposed AI Infrared Thermometer Based on IoT Platform

The proposed AI infrared thermometer based on an IoT communication platform was designed to apply in a hospital. The proposed system can work effectively in smart data monitoring with programming algorithm design and transferring information through IoT network platforms. The structures of the proposed AI infrared thermometer are organized according to the following subsections.

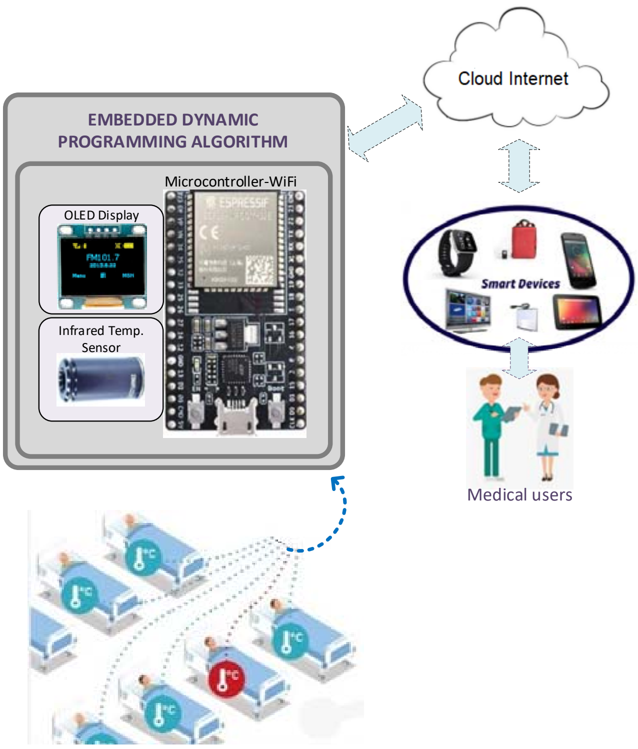

Fig.1 Structure of the proposed novel AI infrared thermometer

Figure 1 presents the structure of the proposed novel AI infrared thermometer. There are three important sections in the contribution: wireless AI infrared thermometer device, embedded dynamic programming algorithm design, and IoT network communication. More details have organized the information as follows.

1. Wireless AI-Infrared Thermometer Base-IoT Device

The wireless AI-infrared thermometer-based-IoT device is the front-end device that contacts the patient's body temperature. It was included the following components:

Infrared MLX90614 Temperature Sensor: The author mentions the noncontact infrared sensor using the IoT-Thermometer concept. The sensing device's priority in this circuit prototype is the medical infrared MLX90614 DCI sensor with a temperature of 0-50 °C [7]. The MLX90614 DCI is applied because it has high precision with noncontact temperature measurements. Moreover, it suits temperature sensing elements for residential and movement detection, and it has a sleep mode to reduce power consumption.

WiFi-Microcontroller Module: The wireless IoT-Thermometer applied NodeMCU ESP32, comfortable prototyping is possible with ease programming via Lua script or the Arduino IDE and the test breadboard-compatible design. The WiFi-Microcontroller module work with 2.4 GHz dual-mode WiFi and a BT wireless connection. In addition, a 512 KB SRAM and a 16 MB memory are integrated on the microcontroller development board. The ESP32 is adopted because it is much more potent than the ESP8266, comes with more GPIOs with multiple functions, faster WiFi, and supports Bluetooth.

Display Unit: The organic light-emitting diodes (OLED) is adopted in the implementation because it compact and uses a flat light emitting technology, which is made by placing a series of organic thin films between two conductors. OLEDs are emissive displays that do not require a backlight, and so are more delicate and more efficient than LCDs. The OLED is summarized for the following reasons; 1) improved image quality-better contrast, higher brightness, fuller viewing angle, a more comprehensive color range, and much faster refresh rates, 2) lower power consumption, 3) more straightforward design that enables ultra-thin, flexible, foldable, and transparent displays, and 4) Better durability – OLEDs are very durable and can operate in a broader temperature range [8].

The AI-infrared Thermometer used for monitoring-based temperature measurement on principle illustrated by Stefan Boltzmann's law. Namely, the human body emits radiation in the form of infrared waves. The quantity of radiation emitted and the Stefan Boltzmann's law gives its radiation with a temperature of the emitting body [9]:

(1) $$P = As\sigma T^4$$

Where: P = Power emitted by the object emitting the radiation; (in Watts) ; A = Surface area of the object emitting the radiation (meter); S = Emissivity of the object emitting the radiation (constant unique to the object properties, no units) ; σ = 5.670373 × 10^{-8} (W.m.) ; T = Temperature of the object emitting the radiation (in Kelvin)

2. Embedded Dynamic Programming Algorithm

This Section presents the programming algorithm, which produces the formula for processing and solving a problem. It conducted a sequence of specified actions describing how to do the touchless AI-powered IoT for an intelligent thermometer using a WiFi-mesh network. Namely, an algorithm was designed according to the following procedures, made up of inputs. Once it has followed all the information, the results will have appeared as output.

The dynamic programming algorithm is proposed into the microcontroller's processing. Thus, dynamic programming is both a mathematical optimization and a computer programming method.

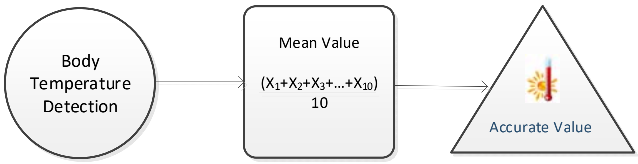

Fig.2 Proposed a programming algorithm concept

It is a technique that breaks the problems into sub-problems and saves the results for future purposes so that the software programming does not need to compute the mark again. The subproblems optimize the overall solution, known as optimal substructure property. The primary use of dynamic programming is to solve optimization problems. Namely, dynamic programming is a technique for solving the problem by breaking into a collection of simpler subproblems, solving each subproblem just once, and then storing their solutions to avoid repetitive computations.

The proposed dynamic programming algorithm solution to sense the body temperature has advantages as the following characteristics.

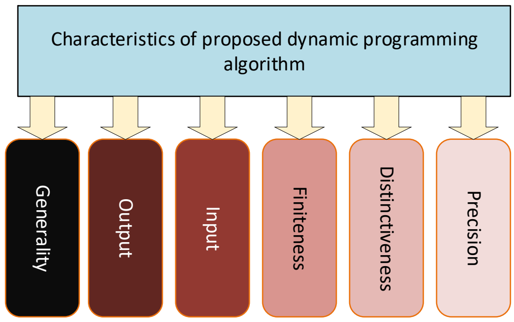

Fig.3 Proposed dynamic programming algorithm solution

Figure 3 presents the advantages of dynamic programming algorithms on touchless AI-powered IoT intelligent thermometers. The accuracy and reliability are highlighted in this article. The multiple of 10 sensed data will be computed using the methodology of dynamic programming algorithm. Dynamic programming is mainly an optimization over plain recursion. Wherever, a recursive solution that has repeatedly called for same inputs, so that the output can be optimized using. Namely, the results will be stored into subproblems. Thus, the results do not have to be re-computed when needed later. This simple optimization reduces time complexities from exponential time complexity, and if the results are optimized by storing solutions of subproblems, time complexity will reduce to linear [10].

Therefore, dynamic programming is designed as a method implementation to produce the optimized results, which achieve an accurate compilation. The divide and conquer methods will be causing the rate of growth of the function to be significantly reduced to satisfactory. The dynamic programming is planned to compute in this work to protect the optimal sub-problem and overlapping sub-problem. In this work, the AI touchless smart thermometer can work faster by doing it once and remembering quickly. Fibonacci's recurrence relation is given by [11]:

(2) $$F(N) = F(N-1) + F(N-2)$$

The discrete mathematic, the Fibonacci function is given by:

(3) $$F_{(n)} = \frac{\varphi^n - (1-\varphi)^n}{\sqrt{5}}$$

Thus, the function's execution time is $\Theta(\varphi^n)$, w

The memoization is applied by using an array to store a calculated result that has already been done. Every time the data results are called recursive, the answer can use immediately. If the results have not been done, it usually computes and stores them in an array until the repeat results appear, then the solution will use the same method.

The dynamic programming algorithm method design has many advantages as follows:

- Precision – the methodologies have precisely stated the formula.
- Distinctiveness – results of each stage is uniquely defined and only depend on the sensed input and the results of the proceeding steps.
- Finiteness – the algorithm will be stopped after a finite number of instructions are executed.
- Input – the algorithm receives feedback.
- Output – the algorithm produces accurate output.
- Generality – the algorithm applies to a computed set of inputs.

3. Internet of Things Network

The IoT network platform communicates between the sensing thermometer prototype on the patient's body temperature data and the medical personnel through the clever devices wirelessly. The cloud platform application is still in the initial stage, which can store is no complication. Therefore, the system adopts the public cloud to attach to the network layer. However, the cloud internet platform can be divided into three layers: Infrastructure as a Service (IaaS), Platform as a Service (Paas): and Software as a Service (SaaS). The main service object of the proposed system are patients, medical personnel such as nurses, and doctors. Moreover, users also can get services through mobile terminals [12, 13].

Experimental Results and Discussions

This Section demonstrates the experimental results on the body temperature measurement according to various distances. The prototype is a compact design to apply in an in-patient department ward, which is attached beside the patient's bed, and the sensor will detect the forehead's Temperature.

Fig.4 The model of a wireless AI-thermometer in a medical ward

The IoT thermometer is positioned according to Figure 6 according to the Light of Sight (LOS) direction. It can be placed away from the patient within the maximum distance of 1 cm to 50 cm, and it detects the patient's around the forehead area, including of the patient's head side. The temperature data will be sensed and sent, and recorded on the internet cloud system after ultimately transferring.

The novel prototype is tested several times to reach the user's requirement of the accuracy point. The measurement tested are arranged into three distance zones, which are 1) best distance, 2) moderate distance, and 3) ineffective distance. Namely, the applied thermometer sensor is limited according to its specifications. The best distance is good condition to detect the body's Temperature within 15 cm, moderate distance can detect the ranges of 30 cm to 45 cm, and lastly, uneffective distance is the distance rages of over 45 cm.

Based on the individual results, the body's temperature measurement tests with the various distances within the distance between 2 cm to 50 cm. Each length was done ten times. Finally, the information data is in the plotted form, as shown in Figure 5.

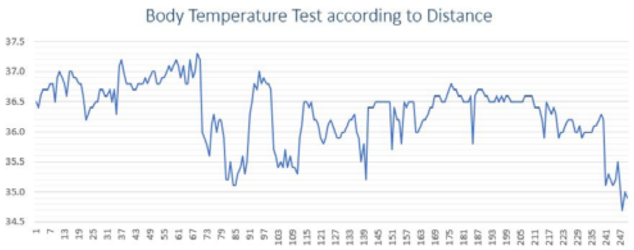

Fig.5 Body temperature test according to various distances

Several factors involved in the experiment's operator can affect the body temperature measurement accuracy due to the procedure, such as the measurement's angle of incidence and the data processing. A further complication of the measure is that the emission angle of the IR radiation for all-natural bodies is not perfect. Therefore, the accurate measurements, the essential body temperature detection, should be kept at a grade lower than 60-70° [14]. In addition, the target distance and focusing also impact the infrared Thermometer's effectiveness. The target or spot dimension needs to coincide with the surface intended to be measured. This issue affects the infrared thermometer measurement. Thus, it can only detect an average of the temperature target and the surrounding surfaces. Furthermore, the dimensions of the measurement target are closely related to the distance of the Thermometer from the target itself. Thus, the higher the space, the larger the spot size should be kept close to the target [15, 16].

Conclusions

The AI-power infrared thermometer based on IoT has created an idea to apply in the COVID-19 epidemic situation. It assists the medical personnel to work effectively, which can be concluded as follows; 1) to reduce the risk of spreading disease between people being evaluated, 2) easy to use, 3) easy to clean and disinfect, 4) measures Temperature and displays a reading rapidly, moreover 5) it provides the ability to retake a temperature quickly 6) the information data of the patients are recorded and stored into the database cloud systematic. In the future work, the author would like to improve more functions to support the medial work, such as experiment design and more options that users can use the prototype as much as possible.

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