Providing a heat-based treatment method based on fuzzy controller design to improve bed sore complications

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Abstract

Heat therapy is a cancer treatment that would supplement in combination with chemotherapy and radiotherapy used. Thermotherapy basis, providing a constant temperature in the range of 45-42 degrees and the temperature of the tumor tissue to keep the temperature evenly during treatment.
Thermotherapy nanoparticles are injected into the tissue in the process. Light from an external source such as laser light into the tissue contains nanoparticles, sharp increases in ambient temperature patient cells. But the important point is that the temperature is too high for healthy cells are very dangerous and can cause damage to them.In this article, in order to confront the serious challenge of heat treatment methods, appropriate control measures are provided, To the laser radiation can be adjusted during the time.More efficient control strategy for controlling the temperature of a tumor in the presence of nanoparticles and laser radiation is discussed.Simulation studies on appropriate physiological model in the presence of nanoparticles to tumors is done.
After obtaining the proper radiation profile, the efficiency of control measures were provided.
Controller parameters classical approach based on trial and error and once again was performed using an optimization algorithm.The performance of an intelligent controller based on artificial neural network with integral derivative controller performance compared. Training the neural network using data collected was used for open-loop.
To enhance control in order to overcome the uncertainties related to the dynamics of the system integral controller combination is used with the neural network. Artificial neural network (ANN) parameters set is integral controller, Then were compared with various controller performance.
The results showed that all controllers are investigated, a good performance to set the laser power control and temperature radiation of tumors.

Keyword:
Nanoparticles, Infrared , Laser input power, Proportional controller, Integral, Derivative, neural network

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List of Symbols

QD	Quantum-Dots
QD-QW	Quantum-Dot Quntum-Well
NPs	Nanoparticles
FEM	Finite Element Method
NIR	Near-Infrared
PID	Proportional Integral Derivative
ICA	Imperialism Competitive Algorithm
NN	Neural Networks

Symbolic naming

E	Total emitted radiance	(W/m^2)
H	Average convection coefficient	(W/m^2)
k	Thermal conductivity	$(W/m^{O}K)$
Q	Heat generation	(W/m^3)
T	Time	(s)
S	Sum of squares	
T	Temperature	(°C)
X	Sensitivity coefficient matrix	
σ	Stefan-Boltzmann constant	$(W/m^2\ K^4)$
GC	Blood perfusion term	$(W/m^{3o}C)$
c	Specific heat	$(J/Kg^{o}K)$
a	absorption	
s	scattering	

1.Introduction

Cancer in the United States is second and in the world the third most common cause of death.in recent years, new methods for prevention, treatment and diagnosis have been developed And efforts to improve efficiency and reduce the frequency of side effects of treatment has been done.One of the methods has improved, can be named thermotherapy. Heat treatment is a method of treating cancer in combination with chemotherapy Complementary used.All drugs used in chemotherapy are a common property that is destroying the cells of the body that have a high growth rate.Therefore, these drugs, in addition to destroying tumor cells, affect cells such as fast-growing hair cells. The goal of the heat treatment process is to increase the temperature of the tissue, including the tumor, to a constant temperature in the range of 42-45 degrees and to keep the temperature uniformly during the treatment (20-30 minutes). The cells of the body disappear at a temperature higher than 42 degrees, and the temperature increase will reduce the time it takes to kill the cells. But because the temperature might also affect healthy cells in regions generally applied to the body in the heat treatment temperature 43 or 44 degrees is considered.

Therotherapy is often created using techniques such as induction of radio frequency waves, infrared and ultrasound.

When releasing energy in heat therapy, the factors called photothermal agents with light absorption cause local warming of a cancerous tissue. When the light is absorbed by photothermal agents, the electrons travel from the base to the excited state. This excitation energy caused by the excitation of the electrons is further liberated through non-radiant transitions. In fact, the energy released by the transfer of kinetic energy to the surrounding environment and thus photothermal agents, warming the environment. Natural chromophores are not significant photothermal agents because of their low absorption coefficient. Therefore, we will use nanotechnology to eliminate the existing problems for photothermal agents. In nanotechnology, nanoparticles that are known as nanosensors are injected into cancer cells. These nanoparticles receive an external light source such as a laser and turn it on with its own emission. If nanoparticles are used to operate at infrared wavelengths, nanoparticles can be used as internal sources for heating. Generally, the amount of heat generated depends on the laser power, wavelength, and the design of the nanoparticles. With all the desirable properties of nanoparticles, their major problem is the significant increase in tissue temperature during light exposure of external sources such as laser to tissue in the presence of nanoparticles , Therefore, any laser power cannot be used, because by increasing the laser power, the heat produced by the nanoparticles increases and causes the saturation of the temperature of the place. Increasing the temperature of the tumor so that the temperature of the healthy tissues can be done in a very short time. Therefore, controlling the temperature in the presence of nanoparticles is very necessary because the high temperature for healthy cells is very dangerous and can cause them damage. In fact, conditions should be provided that by adjusting the laser power, increasing the temperature of the tumor tissue while preserving healthy tissues is possible. In this paper, the idea of using closed-loop control methods in a thermotherapy process has been proposed.

1-1. Goals and innovation project

-Using control strategies to control the radiation environment in the presence of nanoparticles, instead of extracting the radiation pattern using expert experience, is the most important idea in this paper. Because, due to changes in the physiological conditions of vital tissues over time, permanent radiation patterns lose their effectiveness during treatment.

-The provided control method should be capable of controlling the temperature of the cell's environment in order to follow a particular profile.

-Due to the significant increase in tumor tissue temperature in the presence of nanoparticles, the proposed control method should be able to control the proper localized leakage time due to laser radiation at an acceptable rate.

-One of the most important issues during the heat treatment process is the maintenance of healthy tissues while destroying tumor tissues. Therefore, the controller's performance should guarantee this.

1-2. Research hypotheses

-The wavelength of the laser is constant

-The type of nanoparticles (GaAs / AlGaAs) are because their emission wavelengths are in the infrared wavelength range.

-Emission wavelength range of 550 nm to 750 nm is assumed sensors.

-The absorption and dispersion coefficients of tissues are assumed to be due to the interaction of laser light with tissue.

-Numerical analysis methods are used to solve the problem of using FEM or FDM.

1-3. research method

In order to achieve the goals in the article, the following main steps for the implementation of the research were considered and implemented:

-In order to perform computer simulation studies, a suitable and valid model for virtual tissue including fat, glands and tumor cells was selected and implemented.

-The patient's profile of the patient's environment in the presence of nanoparticles with laser light irradiation (design and simulation) in open loop (without using control strategies) was evaluated and evaluated.

-Implementing and evaluating accurate and fast controllers designed to control ambient temperature is the next stage of this research. In the control process, the input has been controlled by the tumor tissue temperature error and has determined the output of the laser radiation control controller.

-Improving the efficiency of designed controllers according to the assumptions and objectives of the problem, as well as comparing the efficiency of the proposed control strategies along with the analysis of the results, is the final stage of the research.

2. The subject and the controller design

Similar projects have been carried out in this field, with the aim of sometimes designing and simulating nanosensors, providing accurate profiles of the thermal environment or the effect of nanoparticles on the heat produced by foreign sources, but the purpose of this project is to provide a control method that Can control the situation so that changes in the temperature of the patient's virtual cell environment follow a specific profile. On the other hand, due to the speed of the system and the performance of the temperature, the control panel should have a fast performance. Therefore, the main purpose of the thesis is to accurately control the temperature of the environment. In fact, we want to increase the temperature of the tumor tissue by adjusting the laser power to provide the necessary conditions for the destruction of the tumor while maintaining healthy tissues.

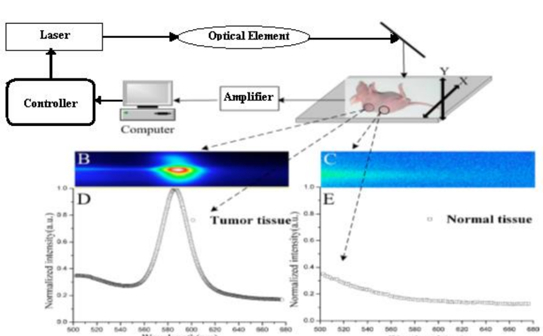

Fig 1. Preparation of the temperature profile from the target location with quantum

Of course, the designed controller must have properties such as leakage time and upward jump, and also the amount of sustainability error is one of the important parameters to be considered.

2-1. mathematical model of virtual tissue

So far, many mathematical models have been proposed for thermal therapy, but the best model for presenting is the Pens thermal equation. This model, which has greatly adapted to clinical data, was presented by Pens in 1946. In order to achieve this, a series of Y-shaped sensors, which include several thermocouples, are placed in different parts of the body, and by calculating the voltage of the thermocouples, the variation curve The temperature of different points of the text is plotted.

$$\rho c\frac{\partial T}{\partial t}=\nabla(k\nabla T)-w_b c_b (T-T_b)+Q \qquad (1)$$

The above equation $c(j/kgc^{\circ})$ is the specific heat and c_b specific heat tissue blood. $W_b=10(kg/m^3 \sec)$ rate of blood circulation and t_b Blood temperature is generally 37 to be considered , Q energy release function in the tissue , k Heat conduction rate and $\rho=1000$ density of tissue . study of the heat emission equation is complex, so try to align this equation along the axis of the body's depth X axis With an equation of one-dimensional equation (2) approximated, although closely approximated equation is less but due simply enormous and simple solution of this error negligible regardless and in the diffusion equation for (2) allocated Taken.

$$\rho c\frac{\partial T}{\partial t}=K\frac{\partial^2 T}{\partial x^2}-w_b c_b(T-T_b)+Q \qquad (2)$$

As mentioned above, in the above equation, x is the depth axis (the distance from the body surface of the disease that is horizontal) is considered on the body surface and the various points of the axis are named in accordance with Fig 2.

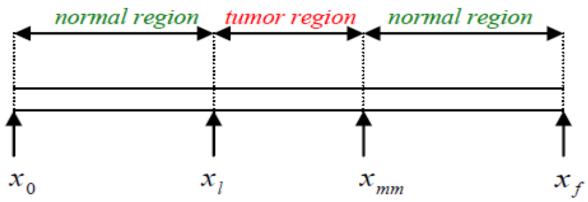

Fig 2. Showing the x-axis name in the patient

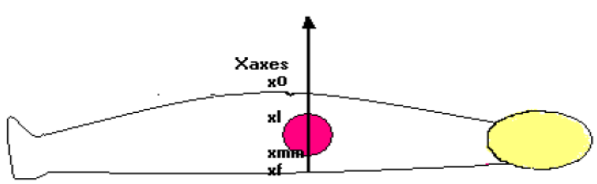

fig 3. Naming axis depth

x0 body surface and x small border of the tumor. xmm is the upper boundary of the tumor and xf is the upper bound of the healthy tissue.

Using the Pence equation, the equations describing the variation in the temperature of the virtual tissue that consists of three different tissue regions (endocrine, fat, and tumor) can be expressed as follows.

Gland tissue:

$$\rho_{Gland}c_{Gland}\frac{\partial T_{Gland}}{\partial t} = K_{Gland}\nabla^2 T_{Gland} + Q_{laser} + Q_{Metabolisim-Gland} + G_{Gland} \times C_{Gland}(T_{blood} - T_{Gland}) \qquad (3)$$

Tumor tissue:

$$\rho_{tumor}c_{tumor}\frac{\partial T_{tumor}}{\partial t} = K_{tumor}\nabla^2 T_{tumor} + Q_{laser\square QD} + Q_{Metabolisim-tumor} + G_{tumor} \times C_{tumor}(T_{Gland} - T_{tumor}) \qquad (5)$$

Fat tissue:

$$\rho_{fat}c_{fat}\frac{\partial T_{fat}}{\partial t} = K_{fat}\nabla^2 T_{fat} + Q_{laser} + Q_{Metabolisim-fat} + G_{fat} \times C_{fat}(T_{Gland} - T_{fat}) \qquad (4)$$

Ti: temperature of tissue
Ki: conductivity thermal conductivity
Gi: degree of blood transfusion
ci : heat of blood
QM-I : Metabolic tissue - Degree of temperature generator (energy release function in tissue)
Ci: Specific Heat of tissue
Qlaser :Heat source laser
QD: Thermal source
I: Indicator of the gland, temporis and adipose tissue

It is worth mentioning here that in the articles the values of the above parameters are considered constant and the researchers have been able to extract the average values of these parameters through numerous experiments. Table 1 shows the average values of these parameters. But in fact, in the issue of controlling heat therapy, since the main model is human-centered, it is expected that the biological parameters of the system, such as blood velocity, blood temperature and tissue density, vary according to the physical conditions for each human being, even in a human with a change in conditions The spirit of these values changes. According to the clinical study, the variation range of the variables of the distribution equation is as follows:

$3000 \leq c_i \leq 4500 \qquad 800 \leq \rho \leq 1600 \qquad 36 \leq T_i \leq 39$

$3000 \leq c \leq 4500 \qquad 9 \leq \omega \leq 13 \qquad 0{,}2 \leq k \leq 0{,}6$

As you can see, the above parameters are uncertain.

Table 1. Average value of the parameters of the Pence equation

Tumor	Tissue	Fat	Different areas
1050	1050	930	**Density** $(\rho)(kg/m^{3})$
3770	3770	2770	**(c) Specific Heat** $(J/Kg^{o}K)$
0.48	0.48	0.28	**Thermal conductivity** $(k)(W/m^{o}K)$
48000	2400	800	**Blood perfusion** $(GC)(W/m^{3o}C)$
42	720	400	**Heat metabolism** $(Q_m)(W/m^{3})$

2-2. Control measures

Integral derivative controller, for easy implementation and performance in relation to acceptable impossible in many cases, continue to be widely used as a controller known in the industry. In this thesis, the controller has been selected as the base controller. The controller parameters through trial and error and once again using an optimization algorithm was used as a colonial competitive algorithm. The efficiency of a smart controller based on artificial neural network with integrated-integral controller efficiency is compared. In order to improve the controller's ability to overcome the uncertainties associated with the system dynamics, a combination of integrally-integral controller and neural network is used. So that the artificial neural network has adjusted the integral-derivative controller parameters. Then, the performance of different controllers was compared.

2-2-1. Neural Controller

An artificial neural network is composed of a series of neurons. The most important factors that differentiate the species and applications of neural networks are the type of neuron used, the layout or network architecture, the input / output interval. In the architecture of a network, the number of layers and connections between them is important. A neural network consists of layers and weights components. The network behavior also depends on the relationship between the members.

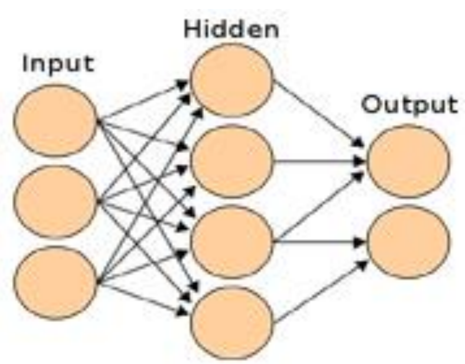

Fig. 4 General schematics of an artificial neural network

Today, neural networks are used in a variety of applications, such as pattern recognition problems, which include issues such as line recognition, speech recognition, image processing, and such issues as categorical issues, such as categorization of texts or images. In the control or modeling of systems that have an unknown or highly complex internal structure, artificial neural networks are increasingly used.

3. Implementing and evaluating control strategies

Prior to implementation and evaluation, the closed loop controller was used to determine the temperature of the tumor with the presence of nanoparticles. In order to emphasize the necessity of using control strategies in such a system, initial simulation studies were designed and implemented. These studies have been conducted as an open loop. In other words, studies were conducted without the presence of a closed loop controller. For this purpose, in the thermal-critical model used, the nanoparticle size between 15 and 40 nanometers and the size (diameter) of the trimening were considered to be 6 millimeters. Then, laser waves with a constant wavelength of 700 nm and power in the range of 10 to 3600 watts per square meter were exposed to the virtual tumor. It is noted that with increasing laser power from 10 to 3600 watts per square meter, the final temperature of the tumor center has increased sharply. This excessive increase in temperature is due to the presence of nanoparticles in the patient's cell. The results obtained at this stage indicate that the absence of a closed loop controller can lead to excessive tumor temperature, and thus a significant increase in the temperature of healthy tissues. This can cause serious damage to healthy tissues. On the other hand, the results indicate that the increase in tumor temperature, and thus the temperature of healthy tissues, can be done in a very short time. Therefore, it is necessary to design a precise and fast temperature controller for the texture environment. In fact, conditions should be provided that by adjusting the laser power, increasing the temperature of the tumor tissue while preserving healthy tissues is possible.

3-1. Neural Controller

The neural network used in this paper is a typical neural network with a hidden layer and an output layer that has a hidden layer (20 neurons). The hidden layer uses the sigmoid function and the output layer of the linear function. The Levenberg-Marquardt method has also been used to train this network. Training data was about 200 data. In the simulated neural network T (temperature difference between temperatures and 37), it is considered as the input of the neural network and the laser power as its output. The trained artificial neural network has an acceptable performance in controlling the patient's cell's environment. The neurological controller has not produced much improvement in transient and lasting behavior compared with the proportional-integral-derivative controller whose parameters are based on the colonial competition algorithm. In order to improve the neural control efficiency, a hidden layer with 20 neurons was added to the structure of the network. The simulation results showed that, with increasing number of hidden layers, network efficiency was not significantly changed.

3-2. Partial-integral-derivative controller and neural network

Accordingly, the thermal release model is as follows:

$$\rho c\frac{\partial T}{\partial t}=\nabla\left(k\nabla T\right)-w_b c_b\left(T-T_b\right)+Q \tag{6}$$

There are six biological parameters in this equation, although they are presented as problem constants, but their actual amount varies from person to person.

$3000 \le c_i \le 4500 \qquad 800 \le \rho \le 1600 \qquad 36 \le T_i \le 39$

$3000 \le c \le 4500 \qquad 9 \le \omega \le 13 \qquad 0{,}2 \le k \le 0{,}6$

In the above variables c, w_b, c_b function of the depth of the tissue (the tissue genus in that depth) and T function of the depth of the texture and time. And the variables k, ρ values are almost constant since the exact value of the parameters ρ , K , C It is possible to calculate the patient's image and determine the tissue around the tumor with a very good approximation; this section examines non-deterministic parameters C_b, T_b, W_b Will be discussed. These three parameters are blood-dependent and because of the continuous movement of blood, the exact amount of these parameters in the tumor and surrounding tissue can not be calculated and measured. Therefore, we are looking for a controller that can respond appropriately in the presence of model uncertainties. For this purpose, a combination of integral-integral-derivative and neural network controllers has been used. For this purpose, we first obtained the optimal values of kp, kd, ki in the defined intervals using the controller of the colonial competition algorithm. Then the trained neural network determines the values of kp, kd, ki (Partial-integral-derivative controlling parameters) set Is. Despite significant changes in blood perfusion, transient response to the system is not significantly altered, which means that the time of ascent, the time of deposition, did not have a significant increase in elevation. These results indicate that significant changes in the system's basic parameters over their nominal values have not reduced the performance of the controller.

Second, at this stage, in addition to changes in blood perfusion of tissue thermal conductivity values of the variables are taken into account. Despite significant changes in blood perfusion and thermal conductivity, it is also observed that the transient response of the system did not change significantly, meaning that the time of ascent, the time of deployment, did not have a significant change in elevation. These results indicate that significant changes in the system's basic parameters over their nominal values have not reduced the performance of the controller.

Step 3: At this stage, the optimal results obtained from the previous steps (colonial competition algorithm) are used in the training of the neural network, so that it can respond to uncertainty and change of parameters in a desirable manner. In the next step, in the presence of the neural network, the blood perfusion values were selected randomly and then, using the trained neural network, the optimal values of the parityintegral-derivative controller parameters were extracted. The composition of the trained neural network along with the proportional-integral-derivative controller has been able to control the ambient temperature with a suitable transient response and at the same acceptable durability error. As an example, it can be seen that the time of climb and deployment time are considerable due to the speed of system dynamics changes.

In the next step, in addition to changing the blood perfusion, the thermal conductivity values were also randomly selected and the efficiency of the neurological, proportional-integrative-derivative control was measured. In random selection mode, the parameters of the combined trained neural network together with the integral-derivative controller have been able to control the ambient temperature control with suitable transient response and at the same acceptable perceived error. Compared to conditions where only blood perfusion values change, controller performance has not been reduced. After reviewing the proper control of the out-of-line controller now, considering that in reality the parameters of the virtual texture model are constantly changing, we also look at these states:

Step One: We assume that only the values of blood perfusion are changing and that other parameters of the model have a nominal value, these changes are also applied to the system every 3 seconds and the system returns to its original state.

Step 2: In the next step, in addition to changes in blood perfusion values, the values of thermal conductivity of the tissue also changed every 3 seconds.

Step 3: Considering that in a real model of human-centered tissue, according to human conditions, the parameters of the model change, for example, the application of a stress or nervous pressure, so at this stage it is assumed that the model parameters in an instant Specific changes are made and these changes take about 3 seconds, and then the system returns to its original state.

Final stage: At this stage, the worst possible conditions are assumed to occur, that is, the parameters of the model are changing at random at each instant.

4. Conclusion

In this paper, we first used a classical controller (proportional-integral-derivative) whose parameters are based on a trial and error algorithm and an optimization algorithm for colonial competition. In the case of trial and error solutions, the following results were obtained: For the values of controller parameters **Kd** = 80, **KI** = 120 and **Kp** = 200, the system suffers from intense oscillatory behavior**.** On the other hand, the permanent state error has also been noticeable. Then, in order to improve the transient and lasting behavior of the system, all three parameters of the control were reduced for controlling parameter values: **Kd** = 10, **KI** = 100, **Kp** = 120, the maximum peak and the state of the error mode were significantly reduced Have found. But the time of ascent and the time of the meeting have increased. Therefore, in order to achieve a controller whose results are significant, in the next step, using an optimization optimization algorithm for colonial competition, the optimal proportional-integral-derivative controller values were obtained, which showed that the ambient temperature control was well done and the behavior of the transient The system is very suitable. In the next step, an artificial neural network based smart controller was evaluated. This intelligent controller also performs well control of the ambient temperature and has an appropriate transient response. It is worth considering that a proportional-integral-derivative controller whose parameters were determined using the colonial competition algorithm, has produced a better transient response compared to the neural controller.

In the next step, in order to enhance the proportional-integral-derivative controller function, in order to face variable dynamics with controlled system time, controlling parameters were determined by a neural network. The presence of uncertainty in blood perfusion shows that, while having The appropriate transient response is to increase the amount of laser power density by increasing the amount of perfusion in the blood. In the next step, by changing the thermal conductivity of the tissue, it was observed that the laser power density decreased by increasing the thermal conductivity in comparison with the results obtained from the nominal values of a maximum value of 10,000 W / m2 to 8000 W / m2. In the end, all model uncertainties were considered and controlled using the combination of neurological controllers-colonial algorithm controlling ambient temperature. The significant result showed that only changes in blood perfusion parameters and thermal conductivity were affected by laser power change and ambient temperature And changes to other parameters do not have a significant change in the system. In the next step, due to changing system conditions, for changing the parameters at different moments during the treatment process, parameters such as blood perfusion and thermal conductivity during the control process were changed randomly.
In addition to changing system parameters, the controller has been able to provide the appropriate transient response. Of course, the results indicate that the temporal temporal structure of the tissue has reached 46 degrees (unauthorized). Although this period has been short, it should not be seen to enhance the controller of such behaviors.
In sum, it can be argued that the controllers designed during the ambient temperature control were able to provide an appropriate transient and lasting response, and even in the presence of uncertainty and also the application of disturbances to the system, they would carry out appropriate control of the environment.

4-1. Offers

- The effectiveness of controllers for the use of CdSe / ZnS nanoparticles instead of GaAs / AlGaAs nanoparticles.
- Our methods are not based on system identification, so firstly the system is identified, then variable-control control methods should be used as a robust control strategy.

- In the case of the nominal values for the model, we can use a neuro-controller for the fuzzy or neural controller with other conditions, and in the presence of model instability, and compare the results with the results obtained in this paper.
- Providing a solution for online matching of neural network parameters while maintaining system stability
- An attempt to prepare a system of practical tests and practical evaluation of the control strategies provided on the phantom and tumor on the human body.
- One of the most important limitations of the evaluated controllers in this article was the lack of consideration of the effects of changes in parameters on each other. Therefore, the most important suggestions is that a new model for tumor tissue can be presented that effects the change of parameters on Each other and then design and review appropriate control strategies.

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