Applied Mathematics and Nonlinear Sciences

<https://www.sciendo.com>

Dichotomy model based on the finite element differential equation in the educational informatisation teaching reform model

Wei Yin^{1†}, Madini O. Alassafi², Hafnida Hasan³¹ Department of Training Service, Nanjing Institute of Tourism and Hospitality, Nanjing 211100, China² Department of Information Technology, Faculty of Computing and Information Technology, King Abdulaziz University, Jeddah, Saudi Arabia³ Applied Science University, Al Eker, Kingdom of Bahrain

Submission Info

Communicated by Juan Luis García Guirao

Received June 17th 2021

Accepted September 24th 2021

Available online November 22th 2021

Abstract

The dichotomy model of education informatisation is essential, which means the measurement of education informatisation construction and development. Finite element differential equations play an essential role in signal and information teaching. To improve teaching information, the paper applies the dichotomy model of finite element differential equations to the reform of physics education information teaching. This article fully introduces the basic principles of the dichotomy model in finite element differential equations and introduces several analysis methods of the inverse Laplace transform of differential equations. At last, the method is applied to the informatisation of physics education to improve the quality of teaching.

Keywords: finite element differential equation, dichotomy model, educational informatisation, circuit teaching, Laplace transform, circuit analysis

AMS 2010 codes: 44A10

1 Introduction

In 2010, the ‘Outline of the National Medium and Long-term Educational Reform and Development Plan (2010–2020)’ for the first time specifically put ‘accelerating the process of education informatisation’ as a chapter and proposed that information technology has a revolutionary impact on education development. Therefore, we must attach great importance to it and improve the quality of education through education informatisation. Subsequently, the Ministry of Education formulated the ‘Ten-Year Development Plan for Education Informatisation (2010–2020)’. As mentioned above, the formulation of the plans pointed out a direction for the reform

[†]Corresponding author.

Email address: hudsonyin@aliyun.com

of mathematics teaching, and at the same time, made mathematics classroom teaching ushered in realistic challenges [1]. For example, how to make information technology scientifically, rationally, efficiently and thoroughly applied to mathematics classroom teaching. As a result, information technology becomes a powerful tool for students to learn mathematical knowledge and solve mathematical problems. In this way, the quality of mathematics classroom teaching is comprehensively improved, and students' innovative spirit and practical ability are cultivated.

The Laplace transform method is one of the essential methods for analysing continuous-time systems and it is also the basis of some other new transform methods. The origin of the Laplace transform method should be attributed to the British engineer Heaviside at the end of the 19th century. The 'operator method' he invented can solve some fundamental problems encountered in power engineering calculations, but it lacks rigorous mathematical arguments. Later, people were able to find a mathematical basis for this method by applying the works of French mathematician Laplace and re-given a strict mathematical definition. As a result, scholars named it Laplace Transformation (Pull Transformation for short) method [2]. Pull transform is used more in signal teaching and more convenient when dealing with circuit teaching problems.

2 The definition and nature of pull transformation

We know that if the function satisfies the Dirichlet condition, the Fourier transform can be formed. But the requirement of absolute integrability in the Dirichlet condition restricts FT of specific growth signals [3]. For example, some signals continue to increase over time. Such signals cannot have FT, so a pull transformation needs to be introduced.

Let $f(t)$ be the original function and $F(s)$ the image function. They form a pair of pull transformations, usually denoted as $f(t) \Leftrightarrow F(s)$, $F(s) \Leftrightarrow f(t)$, and they satisfy the relationship:

$$L[f(t)] = F(s) = \int_0^{\infty} f(t)e^{-st} dt \quad (1)$$

$$L^{-1}[F(s)] = f(t) = \frac{1}{2\pi j} \int_{\sigma-j\infty}^{\sigma+j\infty} F(s)e^{st} dt \quad (2)$$

Unlike the FT transformation, the independent variable s here is a complex number. For the sake of distinction, we call it complex frequency. The set of all its values is called the complex frequency domain (s domain). The image function is a function whose independent variable is complex and so it is a complex variable function [4]. It is already learned that the independent variable will be an actual number in an actual variable function. Therefore, the LT method is a complex frequency domain transform method. We also often call it s -domain analysis.

LT is integrated from 0, so the value of the function in the interval $t < 0$ has nothing to do with the LT result. When seeking ILT, we can only give the value of the function within the time range $t \geq 0$. This feature of LT does not bring inconvenience to its application. Because when analysing the system actually, only the system response of $t \geq 0$ is often required, and the situation of $t < 0$ the system state determines 0 before the excitation access [5]. The fundamental nature of the pull transformation is the basis of the complete transformation and it plays a more critical role in solving problems. Its properties are as follows:

1. Linearity:

$$L\left[\sum_{n=1}^N a_n f_n(t)\right] = \sum_{n=1}^N a_n L[f_n(t)] \quad (3)$$

2. Time-domain translation:

$$L[f(t-t_0)u(t-t_0)] = e^{-st_0} L[f(t)u(t)] \quad (4)$$

3. s domain translation:

$$L[f(t)e^{s_0 t}] = F(s - s_0) \quad (5)$$

4. Scale transformation:

$$L[f(at)] = \frac{1}{a} F\left(\frac{s}{a}\right) \quad (6)$$

5. Time-domain differentiation:

$$L\left[\frac{d^n f(t)}{dt^n}\right] = s^n L[f(t)] \quad (7)$$

6. Complex frequency domain integration:

$$L\left[\frac{f(t)}{dt}\right] = \int_0^\infty F(s) ds \quad (8)$$

7. Convolution theorem:

$$L[f_1 f_2(t)] = F_1(s) F_2(s) \quad (9)$$

3 Solving method of inverse transformation of pull transformation

When we are teaching circuits, we often fail to explain the meaning of the problem due to too many unknown parameters or maybe because of the complicated steps in solving the problem, which prevents students from clearly understanding the idea of solving the problem [6]. But, now, we need to quote/explain a new transformation-the inverse transformation of the pull transformation. Its problem-solving ideas are as follows: 1) Use partial fraction method in which rational fractions are decomposed into partial fractions and an image function in the form of rational fractions is decomposed into partial fraction sums to solve them with the help of commonly used pairs of pull transformations; 2) Solve the properties of LT; 3) Solve by long division where we use the numerator as the dividend and the denominator as the divisor to find the result; and 4) Solve by the residue method. The partial fraction method is commonly used in the circuit teaching process. Because this method is not only the most basic in signal teaching, it is also the easiest for students to understand when teaching circuits.

4 Application of pull transformation in circuit teaching

In the circuit, what we think of for the first time is often to use the circuit analysis method to solve the circuit, such as the node current method and loop voltage method. But these methods are not suitable when solving more complicated circuits. In this case, we need to introduce a pull transformation [7]. First, understand several basic models of circuit operations. The resistance element calculation model is shown in Figure 1.

Fig. 1 Resistance model.

$$U = Ri \Rightarrow RI(s) \quad (10)$$

$$I = Gu \Rightarrow I(s) = GU(s)$$

The calculation model of the capacitive element is shown in Figure 2.

$$i_c = c \frac{du_c}{dt} \Rightarrow I_c(s) = sC U_c(s) - c u_c(0_-) \quad (11)$$

$$u_c = u_c(0_-) + \frac{1}{c} \int_{0_-}^t i_c dt \Rightarrow U_c(s) = \frac{1}{sC} I_c(s) + \frac{u_c(0_-)}{s} \quad (12)$$

Fig. 2 Capacitance model.

The inductance calculation model is shown in Figure 3.

Fig. 3 Inductance model.

$$u = L \frac{di}{dt} \Rightarrow U(s) = sL I(s) - Li(0_-) \quad (13)$$

We use the pull transform to solve the problem in the circuit to make the circuit calculation simple. The specific steps are as follows: 1) Find the initial state; 2) We express the power supply, resistance, reactance and capacitance in the frequency domain and make an operation diagram corresponding to the circuit diagram; 3) List the equations; 4) Solve the equation to obtain the image function of the unknown quantity; 5) Time-domain expression obtained by inverse pull transform; and 6) Substitute the initial value. The following example illustrates how to solve a circuit diagram using a pull transformation.

Case study 1: Figure 4(a) shows the RL series circuit and voltage source $u_s(t) = \delta(t)$, find the unit impulse response $i(t)$ and the current flowing through the circuit when $t = 1s$.

Solution: The arithmetic circuit is shown in Figure 4(b). The image function of the voltage source is $U_s(s) = 1v$. Find the s domain of the circuit to represent the equation. $I(s) = \frac{U_s(s)}{R+sL} = \frac{1}{L} \frac{1}{s+R/L}$, the inverse transformation $i(t) = \frac{1}{L} e^{-\frac{R}{L}t} \varepsilon(t)$ of the pull transform. When $t = 1s$, $i(t) = \frac{1}{L} e^{-\frac{R}{L}}$.

Through example 1, it can be seen that the pull transformation can be applied to the problem-solving of circuit teaching and is more conducive to the understanding of circuit problems.

Case study 2: Considering that s is closed when $t = 0$, find the voltage and current flowing through the inductor when $t = 1$.

Solution: Find the initial state of the circuit when the switch is on,

$$i_L(0_-)5A, u_c(0_-) = 100V \quad (14)$$

Fig. 4 RL series circuit.

After the switch is closed, the frequency domain representation of the inductance, capacitance and resistance in the circuit is obtained. We draw circuit diagram 5(b).

Fig. 5 Hybrid circuit with inductance.

$sL = 0.1s \frac{1}{sC} = \frac{1000}{s}$, $u_L(0_+) = 0.5A$. We use the loop current method to list the equations:

$$\begin{cases} I_1(s)(40 + 0.1s) - 10I_2(s) = \frac{200}{s} + 0.5 \\ -10I_1(s) + (10 + \frac{1000}{s})I_2(s) = \frac{100}{s} \\ I_1(s) = I_L(s) \end{cases} \quad (15)$$

and finally we obtain

$$I_1(s) = I_L(s) = \frac{5(s^2 + 700s + 40000)}{s(s + 200)^2} \quad (16)$$

Use the partial fraction decomposition method to get:

$$I_L(s) = \frac{1500}{(s + 200)^2} + \frac{5}{s} \quad (17)$$

Then use the inverse transformation property of the pull transformation to obtain:

$$I_L(t) = (5 + 1500te^{-200t}) \varepsilon(t) \quad (18)$$

$$U_L(s) = I_1(s) \bullet sL - 0.5 = \frac{150}{s + 200} + \frac{-30000}{(s + 200)^2} \quad (19)$$

$$u_L(t) = 150e^{-200t} - 30000te^{-200t} \quad (20)$$

When $t = 1s$ and $I_L(1) = (5 + 1500e^{-200})A$, $u_L(1) = -29850e^{-200}V$.

From this point of view, the pull conversion is a necessary means for processing signals and for circuit teaching [8]. Therefore, it is imperative to use and be able to use the pull transform. Furthermore, it has a greater potential for improving learners' independent innovation ability.

Case study 3: To achieve rapid and effective grid division, we took the following discriminating steps. Assuming that the region's boundary is composed of line segments, the endpoints of the detected dividing lines are i and j , as shown in Figure 6.

Fig. 6 Schematic diagram of area dividing line.

First, determine whether the number of nodes in the boundary of the two sub-regions formed by the segmentation of the measured line segment is less than 4. If it is less than 4, it indicates that the line segment ij under test is excluded [9]. This is because the line segment ij divides the region into two sub-regions, but one of the sub-regions has only 3 boundary points, so the line segment ij cannot be used as the dividing line of the region.

Then, determine the positional relationship between all points and line segments on the boundary except for points i and j . Starting from a certain point on the boundary, determine the positional relationship between each point (except points $i(x_i, y_i)$ and $j(x_j, y_j)$) and the line segment ij in turn. Suppose any point on the boundary of k except for points i and j has coordinates (x_k, y_k) . Take the determinant of a matrix $\begin{bmatrix} x_i - x_k & y_i - y_k \\ x_j - x_k & y_j - y_k \end{bmatrix}$ as the discriminant. If the value of the determinant is less than zero, the point arrangement $k-i-j$ is clockwise. If the value of the determinant is higher than zero, the point arrangement $k-i-j$ is counterclockwise. If the value of the determinant is equal to zero, the arrangement of points $k-i-j$ is on a straight line [10]. For any two adjacent points $e(x_e, y_e)$ and $f(x_f, y_f)$ on the boundary contour except i and j , there are the following two cases:

1. The product of the matrix determinants of any two adjacent points e and f is equal to zero, indicating that points e and f are on the line segment ij or its extension. Assuming that the determinant of point e is zero, it is necessary further to determine the relationship between point e and line segment ij . If $(y_e, y_i)(y_e, y_j) < 0$ or $(x_e, x_i)(x_e, x_j) < 0$, line segment ij passes through point e .
2. The matrix determinant product of any two adjacent points e and f is not equal to zero. If the product is less than zero, it means that the points e and f are on both sides of the line segment ij . The line segment formed by two adjacent points, e , and f , may intersect the extension line of the line segment, so the third step of judgement is needed [11]. If the product is higher than zero, it means that the points e and f are on the same side of the line segment ij . The line segment ij may be a possible dividing line of the area, so it is necessary to calculate the matrix determinants of all points except i and j on the boundary contour.

Suppose the product of the matrix determinants of all points except j and i on the boundary contour is higher than zero. In that case, the line segment ij is located outside the divided area.

3. Calculate the distance r between the midpoint $C(x_c, y_c)$ of the line segment ij and the point C to point i , calculate the intersection $P(x_p, y_p)$ between the line segment formed by two adjacent points e and f and the line segment ij , if $(x_c - x_p)^2 + (y_c - y_p)^2 < r^2$ is true. The line segment ij cannot be a division of the area line.

There are many dividing lines that meet the above requirements. Selecting the best dividing line from these possible dividing lines is the key technology of the algorithm. It directly affects the quality and efficiency of

meshing [12]. In the previous papers, the optimal dividing line was determined using two non-dimensional parameters, namely the linear combination of the deviation of the angle and the length S . The specific formula is:

$$S = c_1 \frac{\sum_{k=1}^4 |\theta_k - 90|}{360} + c_2 \frac{l}{d} \quad (21)$$

The formula c_1, c_2 represents the weighting factor, which is a constant. $\theta_k - (k = 1, 2, 3, 4)$ represents the angle formed by the possible dividing line and the ring. l represents the length of the possible dividing line. d represents the length of the diagonal of the rectangle that can completely close the ring.

The possible dividing line corresponding to the minimum value of S calculated by the above formula is the optimal dividing line of the ring. This criterion is very effective when the regional boundary is not complicated [13]. Usually, the first case a is more conducive to improving the quality of the mesh. For this reason, we propose a new method for determining the optimal dividing line. The specific formula is as follows:

$$S = c_1 \frac{\sum_{k=1}^4 |\theta_k - (\pi/2)|}{2\pi} + c_2 \frac{\sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}}{d} + c_3 \left(\left| 0.5 - \frac{\theta_1}{\theta_i} \right| + \left| 0.5 - \frac{\theta_3}{\theta_j} \right| \right) + c_4 \left(\frac{\theta_{\min}}{\theta_i} + \frac{\theta_{\min}}{\theta_j} \right) \quad (22)$$

$$S = c_1 \sum_{k=1}^4 \phi(\theta_k) + c_2 \frac{\sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}}{d} + c_3 \left(\left| 0.5 - \frac{\theta_1}{\theta_i} \right| + \left| 0.5 - \frac{\theta_3}{\theta_j} \right| \right) + c_4 \left(\frac{\theta_{\min}}{\theta_i} + \frac{\theta_{\min}}{\theta_j} \right) \quad (23)$$

When the divided area is a convex polygon, equation (22) is applied. When the divided area is a concave polygon, equation (23) is applied. In equations (21) and (22), c_3 and c_4 are weighting factors. $\theta_{\min}$ represents the minimum internal angle of the boundary node of the divided subregion. θ_i and θ_j indicate that the internal angles of nodes i and j are $\varphi(\theta)$ as:

$$\varphi(\theta) = \begin{cases} \frac{2}{\pi}(-\theta + \frac{\pi}{2}) & 0 < \theta < \frac{\pi}{2} \\ |\sin 2\theta| & \theta \geq \frac{\pi}{2} \end{cases} \quad (24)$$

In the above formula, the values of the weight factors c_1, c_2, c_3 and c_4 will directly affect the quality of meshing. After many trials, the weight factor c_1 can be taken as 0.5, the weight factor c_2 can be taken as 0.2, the weight factor c_3 can be taken as 0.15 and the weight factor c_4 can be taken as 0.15.

5 Conclusion

In this paper, through the study of finite element differential dichotomous farad transformation, students can understand the meaning and nature of pull transformation. In addition to playing a significant role in signal processing, pull transformation can also be applied in the information teaching of circuit education. The introduction of other methods of teaching broadens the students' thinking and inspires their thinking. Informatisation teaching mode has improved students' interest and efficiency in learning and further improved their self-learning ability and innovation ability.

Acknowledgements.

The key project of Jiangsu Education Science '13th five year plan' in 2020 is 'Research on the training mode of top notch innovative talents with technical skills in Higher Vocational Colleges' (BB/2020/03/31); Jiangsu University 'Blue Project' young and middle-aged academic leaders training funding project.

References

- [1] Kornilov, V. S., & Rusinov, A. S. Development of information culture of students when teaching equations of mathematical physics in the conditions of informatization of education. *RUDN Journal of Informatization in Education*., 2021. 18(1): 81-87.
- [2] Wang, W., & Mandal, D. Research on the construction of teaching platform of drama film and television literature based on IoT. *Journal of Intelligent & Fuzzy Systems*, 37(3): 3417-3424.
- [3] Lv, S., & Pan, Y. Research on the Spatial Distribution Difference of Compulsory Education between China and Australia. *International Journal of Emerging Technologies in Learning (iJET)*., 2020. 15(4): 129-141.
- [4] Vlasenko, K. V., Grudkina, N. S., Chumak, O. O., & Sitak, I. V. Methodology of computer-oriented teaching of differential equations to the students of a higher technical school. *Information Technologies and Learning Tools*., 2019. 74(6): 127-137.
- [5] Yue, C., & Xu, X. Review of Quantitative Methods Used in Chinese Educational Research, 1978–2018. *ECNU Review of Education*., 2019. 2(4): 515-543.
- [6] Yi, S., Yun, R., Duan, X., & Lu, Y. Similar or Different? A Comparison of Traditional Classroom and Smart Classroom's Teaching Behavior in China. *Journal of Educational Technology Systems*., 2021. 49(4): 461-486.
- [7] Zhou, P., Fan, Q. & Zhu, J. Empirical Analysis on Environmental Regulation Performance Measurement in Manufacturing Industry: A Case Study of Chongqing, China. *Applied Mathematics and Nonlinear Sciences*., 2020. 5(1): 25-34.
- [8] Xie, T., Liu, R. & Wei, Z. Improvement of the Fast Clustering Algorithm Improved by K-Means in the Big Data. *Applied Mathematics and Nonlinear Sciences*., 2020. 5(1): 1-10.
- [9] Kravtsov, Y., Bogomaz, K., & Sorokina, L. Features of informatization of sociological knowledge. *Scientific and Theoretical Almanac Grani*., 2020. 23(8): 70-77.
- [10] Jin, D., & Li, Y. A Teaching Model for College Learners of Japanese Based on Online Learning. *International Journal of Emerging Technologies in Learning (iJET)*., 2020. 15(15): 162-175.
- [11] Hu, X. The Current Situation Analysis And Countermeasures Of The Balanced Development Of Teacher Resources in My Country's Basic Education. *Journal of Frontiers in Educational Research*., 2021. 1(4): 62-69.
- [12] Hua, S., & Liu, F. A New Hybrid Teaching Model for a Psychology Course. *International Journal of Emerging Technologies in Learning (iJET)*., 2021. 16(3): 206-219.
- [13] Cao, Q. The Influence of Wisdom Platform Teaching on Students' Learning Effectiveness in Higher Vocational Colleges. *Turkish Journal of Computer and Mathematics Education (TURCOMAT)*., 2021. 12(11): 4270-4278.