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OS	COLOŞI, Tiberiu, ABRUDEAN, Mihail, DULF, Eva Henrietta, and UNGUREŞAN, Mihaela Ligia. *Numerical modelling and simulation method for lumped and distributed parameters processes with Taylor series and local iterative linearizarion.* Ref.şt.: FEŞTILĂ, Clement, LAZEA, Gheorghe, VÂNĂTORU, Matei. Cluj-Napoca: Mediamira, 2008.
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p.3:01-p.06:16 (cuprins)	p.03:01 – p.06:19 (cuprins)
p.7:01 – p.11:09	p.7:01 – p.11:11
p.12:01 – p.21:15	p.12:01 – p.21:10
p.17:Fig.1.1	p.17:Fig.1.1
p.22:01 – p.27:20	p.22:01 – p.27:20
p.28:01 – p.29:14	p.28:01 – p.29:14
p.34:01 – p.55:06	p.34:01 – p.55:13
p.56:01 – p.61:12	p.56:01 – p.61:12
p.62:01 – p.77:18	p.62:01 – p.77:12
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Notă: La pag.10 a ambelor cărți există mențiunea că întreaga lucrare a fost elaborată de autorul Coloşi Tiberiu.

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I.3, pde I.4, pde II.2, pde II.3, pde II.4, pde III.2, pde III.3, pde IV.2, pde IV.3 and pde IV.4. All these (pde) have been considered with constant coefficients.

Further more we illustrate a non linear pde II.2 for modelling a column of isotopic separation N^{15}, then two control systems of some processes defined by pde II.2 and pde II.3, and finally a systems made of two (pde), each one of the second order. The chapter ends with two examples containing a ode II, as well as a pde II.2, solved with the methods Taylor series and the Taylor series-L.I.L., underlining some comparative aspects that practically certify the same results.

Chapter 9: "Cases for establishing the M_{pdx} matrix" refers to a usually and simple control system, with a PID controller for three distributed parameters processes, defined by pde II·4, then pde II·3 and pde II·2. The systemized and unitary character is being underlined for the stages of establishing the M_{pdx} matrix.

It needs to be noted that all (ode) and (pde) have proved either general solutions, or particular solutions, and the singular solutions have not been taken into consideration. The particular solutions have been considered in exponential or polynomial variants, used in technique. With these solutions we were able to establish the initial conditions and the final conditions. Also we were able to establish the performances of numerical integration, using the indicator called "cumulative relative error in perçent" (crep), which in most examples was between the limits $(10^{-6} \div 10^{-2})\%$, a fact that certifies the accuracy of the method and the programs.

The entire paper has been elaborated by Tiberiu Coloşi. This paper could not be published without the qualified and collegiate support of all authors.

Some examples and programs have been elaborated and included in year the projects and diploma papers of the students of the Faculty of Automation and Computer Science within the Technical University of Cluj-Napoca.

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The authors

IInd PART

PROCESSES WITH DISTRIBUTED PARAMETERS

Chapter 4

LINEAR PROCESSES WITH DISTRIBUTED PARAMETERS

4.1. Introduction

It is known that the usual analytical modelling of linear processes with distributed parameters can be expresses using equations or equation systems with linear partial derivatives, homogeneous (without a free component) or non homogeneous (with free component). The category of equations with linear partial derivatives (pde), to which this chapter refers to, is presented in the following examples:

$$a_{00}y + a_{10}\frac{\partial y}{\partial t} + a_{01}\frac{\partial y}{\partial p} = \varphi(t,p) \quad (4.1)$$

$$a_{000}y + a_{100}\frac{\partial y}{\partial t} + a_{010}\frac{\partial y}{\partial p} + a_{001}\frac{\partial y}{\partial q} = \varphi(t,p,q) \quad (4.2)$$

$$a_{00}y + a_{10} + \frac{\partial y}{\partial t} + a_{01}\frac{\partial y}{\partial p} + a_{20}\frac{\partial^2 y}{\partial t^2} + a_{11}\frac{\partial^2 y}{\partial t\partial p} + a_{02}\frac{\partial^2 y}{\partial p^2} = \varphi(t,p) \quad (4.3)$$

$$a_{000}y + a_{200}\frac{\partial^2 y}{\partial t^2} + a_{020}\frac{\partial^2 y}{\partial p^2} + a_{002}\frac{\partial^2 y}{\partial q^2} = \varphi(t,p,q) \quad (4.4)$$

$$a_{000}y + a_{100}\frac{\partial y}{\partial t} + a_{010}\frac{\partial y}{\partial p} + a_{001}\frac{\partial y}{\partial q} + a_{200}\frac{\partial^2 y}{\partial t^2} + a_{110}\frac{\partial^2 y}{\partial t\partial p} +$$
$$+ a_{020}\frac{\partial^2 y}{\partial p^2} + a_{011}\frac{\partial^2 y}{\partial p\partial q} + a_{002}\frac{\partial^2 y}{\partial q^2} + a_{101}\frac{\partial^2 y}{\partial t\partial q} = \varphi(t,p,q) \quad (4.4')$$

$$a_{0000}y + a_{1000}\frac{\partial y}{\partial t} + a_{0100}\frac{\partial y}{\partial p} + a_{0010}\frac{\partial y}{\partial q} + a_{0001}\frac{\partial y}{\partial r} + a_{2000}\frac{\partial^2 y}{\partial t^2} +$$

$$+ a_{1100}\frac{\partial^2 y}{\partial t \partial p} + a_{0200}\frac{\partial^2 y}{\partial p^2} + a_{0110}\frac{\partial^2 y}{\partial p \partial q} + a_{0020}\frac{\partial^2 y}{\partial q^2} + a_{0011}\frac{\partial^2 y}{\partial q \partial r} + \quad (4.4")$$

$$+ a_{0002}\frac{\partial^2 y}{\partial r^2} + a_{1001}\frac{\partial^2 y}{\partial t \partial r} + a_{0101}\frac{\partial^2 y}{\partial p \partial r} + a_{1010}\frac{\partial^2 y}{\partial t \partial q} = \varphi(t,p,q,r)$$

$$a_{00}y + a_{30}\frac{\partial^3 y}{\partial t^3} + a_{03}\frac{\partial^3 y}{\partial p^3} = \varphi(t,p) \quad (4.5)$$

$$a_{000}y + a_{300}\frac{\partial^3 y}{\partial t^3} + a_{030}\frac{\partial^3 y}{\partial p^3} + a_{003}\frac{\partial^3 y}{\partial q^3} = \varphi(t,p,q) \quad (4.6)$$

$$a_{00}y + a_{40} + \frac{\partial^4 y}{\partial t^4} + a_{04}\frac{\partial^4 y}{\partial p^4} = \varphi(t,p) \quad (4.7)$$

$$a_{000}y + a_{400}\frac{\partial^4 y}{\partial t^4} + a_{040}\frac{\partial^4 y}{\partial p^4} + a_{004}\frac{\partial^4 y}{\partial q^4} = \varphi(t,p,q) \quad (4.8)$$

All coefficients (a…) are considered to be constant or variable, and φ(t, p), y(t, p), φ(t, p, q), y(t, p, q), φ(t, p, q, r) and y(t, p, q, r), fulfil the continuity conditions in the Cauchy sense. The independent variables (t), (p), and (q) could represent the time (t), respectively the spatial abscise (p), and (q) defined, for instance, in Cartesian coordinates.

The initial conditions (IC) are considered to be known, and other explanations could be added, from case to case, for boundary conditions (BC) and final conditions (FC).

4.2. State variables, initial conditions and final conditions

Introducing the notations:

$$x_{TP} = \frac{\partial^{T+P} y}{\partial t^T \partial p^P} \quad (4.9)$$

$$x_{TPQ} = \frac{\partial^{T+P+Q} y}{\partial t^T \partial p^P \partial q^Q} \quad \text{or} \quad x_{TPQR} = \frac{\partial^{T+P+Q+R} y}{\partial t^T \partial p^P \partial q^Q \partial r^R} \tag{4.10}$$

(for T = 0, 1, 2, ...; P = 0, 1, 2, ...; Q = 0, 1, 2, ...; R = 0,1, 2, ...) the ten pde, that is (4.1), (4.2), ..., (4.8) can be rewritten as:

$$a_{00}x_{00} + a_{10}x_{10} + a_{01}x_{01} = \varphi_{00} \tag{4.11}$$

$$a_{000}x_{000} + a_{100}x_{100} + a_{010}x_{010} + a_{001}x_{001} = \varphi_{000} \tag{4.12}$$

$$a_{00}x_{00} + a_{10}x_{10} + a_{01}x_{01} + a_{20}x_{20} + a_{11}x_{11} + a_{02}x_{02} = \varphi_{00} \tag{4.13}$$

$$a_{000}x_{000} + a_{200}x_{200} + a_{020}x_{020} + a_{002}x_{002} = \varphi_{000} \tag{4.14}$$

$$\begin{aligned} &a_{000}x_{000} + a_{100}x_{100} + a_{010}x_{010} + a_{001}x_{001} + a_{200}x_{200} + a_{110}x_{110} + \\ &+ a_{020}x_{020} + a_{011}x_{011} + a_{002}x_{002} + a_{101}x_{101} = \varphi_{000} \end{aligned} \tag{4.14'}$$

$$\begin{aligned} &a_{0000}x_{0000} + a_{1000}x_{1000} + a_{0100}x_{0100} + a_{0010}x_{0010} + a_{0001}x_{0001} + \\ &+ a_{2000}x_{2000} + a_{1100}x_{1100} + a_{0200}x_{0200} + a_{0110}x_{0110} + a_{0020}x_{0020} + \\ &+ a_{0011}x_{0011} + a_{0002}x_{0002} + a_{1001}x_{1001} + a_{0101}x_{0101} + a_{1010}x_{1010} = \varphi_{0000} \end{aligned} \tag{4.14''}$$

$$a_{00}x_{00} + a_{30}x_{30} + a_{03}x_{03} = \varphi_{00} \tag{4.15}$$

$$a_{000}x_{000} + a_{300}x_{300} + a_{030}x_{030} + a_{003}x_{003} = \varphi_{000} \tag{4.16}$$

$$a_{00}x_{00} + a_{40}x_{40} + a_{04}x_{04} = \varphi_{00} \tag{4.17}$$

$$a_{000}x_{000} + a_{400}x_{400} + a_{040}x_{040} + a_{004}x_{004} = \varphi_{000} \tag{4.18}$$

In the hypothesis of integration with respect to the time (t), the elements of the state vector (**x**), which correspond to the pde (1), (2), ...(8) are presented in Table 4.1.

Table 4.1

pde	4.1	4.2	4.3	4.4	4.4'	4.4"	4.5	4.6	4.7	4.8
Notation	I·2	I·3	II·2	II·3	II·3	II·4	III·2	III·3	IV·2	IV·3
x STATE VECTOR	x_{00}	x_{000}	x_{00} x_{10}	x_{000} x_{100}	x_{000} x_{100}	x_{0000} x_{1000}	x_{00} x_{10} x_{20}	x_{000} x_{100} x_{200}	x_{00} x_{10} x_{20} x_{30}	x_{000} x_{100} x_{200} x_{300}

The notation (n · υ) in line 2, Table 4.1, underline by n = I, II, III and IV the order of pde, and by υ = 2, 3 and 4 the number of variables, respectively 2 for (t, p), 3 for (t, p, q) and 4 for (t, p, q, r).

The state vector is presented in Table 4.2 for the initial conditions ($\mathbf{x}_{IC}$) and for some possible boundary conditions ($\mathbf{x}_{BC}$), respectively the final conditions ($\mathbf{x}_{FC}$), where (0) and (f) underline the initial and final values.

Table 4.2

$\mathbf{x}_{IC}$	$\mathbf{x}_{BC}$		$\mathbf{x}_{FC}$
$\mathbf{x}(t_0, p)$	$\mathbf{x}(t, p_0)$;	$\mathbf{x}(t, p_f)$	$\mathbf{x}(t_f, p)$
$\mathbf{x}(t_0, p, q)$	$\mathbf{x}(t, p_0, q)$ $\mathbf{x}(t, p_f, q)$	$\mathbf{x}(t, p, q_0)$ $\mathbf{x}(t, p, q_f)$	$\mathbf{x}(t_f, p, q)$
$\mathbf{x}(t_0, p, q, r)$	$\mathbf{x}(t, p_0, q, r)$ $\mathbf{x}(t, p_f, q, r)$	$\mathbf{x}(t, p, q_0, r)$ $\mathbf{x}(t, p, q_f, r)$	$\mathbf{x}(t_f, p, q, r)$

4.3. The complete method of the Taylor series for the approximation of the vector ($\mathbf{x}_k$). The definition of the matrix $\mathbf{M}_{pdx}$

It is based on the iterative use of the Taylor series, included in a table structure, dependent on the form pde.