ECE 5930 003 / ECE 6930 003

Fractional order models and fractional differential equations in science and engineering

Course Title:	Fractional order models and fractional differential equations in science and engineering
Instructor:	Igor Podlubny
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Office Hours:	M W F 10:00–11:30 Other hours by appointment.
Lecture Time:	Tu Th 12:30–14:50
Lecture Place:	ENGR 204
Pre-requisites:	standard calculus and basic numerical methods.
Texts:	Podlubny I. Fractional Differential Equations. San Diego: Academic Press; 1999. Magin R. Fractional Calculus in Bioengineering. Begell House Inc., Redding; 2006.
Final Exam:	12:30–14:00 on Tuesday, August 7. (subject to change)

Course Summary

The course is aimed on introducing the methods and tools of the fractional-order calculus into engineering education.

Course outline.

Special Functions of the Fractional Calculus. Gamma Function. Mittag-Leffler Function. Wright Function.

Fractional Derivatives and Integrals. Grünwald-Letnikov Fractional Derivatives. Riemann-Liouville Fractional Derivatives. Some Other Approaches. Geometric and Physical Interpretation of Fractional Integration and Fractional Differentiation. Sequential Fractional Derivatives. Left and Right Fractional Derivatives. Properties of Fractional Derivatives. Laplace Transforms of Fractional Derivatives. Fourier Transforms of Fractional Derivatives. Mellin Transforms of Fractional Derivatives.

Linear Fractional Differential Equations. Fractional Differential Equation of a General Form. Existence and Uniqueness Theorem as a Method of Solution. Dependence of a Solution on Initial Conditions. The Laplace Transform Method . Standard Fractional Differential Equations. Sequential Fractional Differential Equations.

Fractional Green's Function. Definition and Some Properties. One-Term Equation. Two-Term Equation. Three-Term Equation. Four-Term Equation. General Case: n-term Equation.

Other Methods for the Solution of Fractional-order Equations. The Mellin Transform Method. Power Series Method. Babenko's Symbolic Calculus Method. Method of Orthogonal Polynomials. Numerical Evaluation of Fractional Derivatives. Approximation of Fractional Derivatives. The "Short-Memory" Principle. Calculation of Heat Load Intensity Change in Blast Furnace Walls. Order of Approximation. Computation of Coefficients. Higher-order Approximations.

Numerical Solution of Fractional Differential Equations. Initial Conditions: Which Problem to Solve? Numerical Solution. Examples of Numerical Solutions. The "Short-Memory" Principle in Initial Value Problems for Fractional Differential Equations. Matrix approach to discrete fractional calculus. Numerical solution of nonlinear problems.

Applications.

SUPPLEMENTAL REFERENCES:

1. Podlubny, I., Heymans, N.: Physical interpretation of initial conditions for fractional differential equations with Riemann-Liouville fractional derivatives. Rheologica Acta. vol. 45, 2006, pp. 765–771.
2. Podlubny I.: Fractional-order systems and PIλDμ–controllers, IEEE Transactions on Automatic Control, vol. 44, no. 1, January 1999, pp. 208-213.
3. Podlubny, I., Petras, I., Vinagre, B.M., O'Leary P., Dorcak L.: Analogue realizations of fractional-order controllers. Nonlinear Dynamics, vol. 29, no. 1–4, 2002, pp. 281–296.
4. Podlubny, I.: Geometric and physical interpretation of fractional integration and fractional differentiation. Fractional Calculus and Applied Analysis, vol. 5, no. 4, 2002, pp. 367–386.
5. Podlubny, I.: Matrix approach to discrete fractional calculus. Fractional Calculus and Applied Analysis, vol. 3, no. 4, 2000, pp. 359–386.
6. Carpinteri A, Mainardi F, editors. Fractals and fractional calculus in continuum mechanics. CISM Courses and Lectures no. 378. International Center for Mechanical Sciences. New York: Springer-Verlag Wien; 1997.
7. Churchill RV. Operational mathematics. New York: McGraw- Hill; 1958.
8. Magin RL, Fractional Calculus in Bioengineering, Critical Reviews in Biomedical Engineering, Part I 32(1): 1-104, 2004, Part II 32(1) : 105-193, 2004, Part III 32(1)
9. Mandelbrot BB. The fractal geometry of nature. New York: W. H. Freeman; 2000.
10. Miller KS, Ross B. An introduction to the fractional calculus. New York: John Wiley; 1993.
11. Oldham KB, Spanier J. The fractional calculus. New York: Academic Press; 1974.
12. West BJ, Bologna M, Grigolini P. Physics of fractal operators. New York: Springer; 2003.

Web site:

http://people.tuke.sk/igor.podlubny/
http://people.tuke.sk/igor.podlubny/USU/
http://people.tuke.sk/igor.podlubny/fc.html

Homework

It is department pedagogical philosophy that students are responsible for their own learning. The instructor may not cover all of the material in each reading assignment in the lecture period. The student is therefore responsible for asking questions about reading material not covered in the lecture. Questions on exams may come from lectures, computer assignments, reading assignments, or supplementary materials given in class. Homework is due at the beginning of class on the due date. No late homework will be graded.

Grading

Scores will be weighted as follows:

Homework & computer assignments	40%
Midterm	20%
Final exam	40%
Total	100%

Grades will be computed according to the following scale:

A	> 93%
A-	> 90%
B+	> 87%
B	> 84%
B-	> 80%
C+	> 77%
C	> 74%
C-	> 70%
D+	> 67%
D	> 64%
D-	> 60%
F	< 60%