DISCIPLINES
GA Group

Computing

1. GA-009 - Databases

The discipline covers the following topics: Conceptual Modeling, Entity Relationship Model, Unified Modeling Language, Mapping Techniques between Entity Relationship Model and Relational Model, The Relational Model, Operations on the Relational Model using Relational Algebra and Relational Calculus, Relational Database Design, Data Dependency, Normalization Theory, other Data Models: Graph, Multidimensional, Columnar, Structure Query Language, Database Physical Project, Data Layout, Data Partition, Views and Materialized Views, Index Structures, Database System Services, Database System Architecture, Database Query Processing, Transaction Management and Concurrency Control

Bibliography:

Systems Databases - A. Silberschatz et al, Terceira Edição, Pearson, 2005.

2. GA-017 - Introduction to Computer Programming

Basics of how compilers and computers work. Programming Fundamentals: data types, operators and expressions; control flow and loop structures; arrays and pointers; functions and abstract data types. The course is mostly taught in ANSI C, but other languages, such as FORTRAN, JAVA and PERL, can be used by the students at the laboratory as well.

Bibliography:

Schildt, H. (1997) C Completo e Total, Makron Books, ISBN: 8534605955
Kernighan, B. W.; Ritchie, D. M. (1989) C A Linguagem de programação Padrão ANSI, Campus, ISBN: 8570015860.
Rangel Netto, J. L. M.; Cerqueira, R. F. de G.; Celes Filho, W. (2004) Introdução à Estruturas de Dados, Campus, ISBN: 8535212280.

3. GA-022 – Introduction to Multimedia Systems and Virtual Reality

Media representation, Digitization: text, audio, Image and video. Data compression: text, audio, image, vid- eo; Data compression standards; Multimedia communication; Network protocols; Local and wireless net- works; Bluetooth. Media synchronization; Quality of service; Advanced Topics: Cryptography, Watermarking, Virtual Reality, Multimedia Services, On-Demand Video, Videoconferencing, Advanced multimedia systems, Collaborative Virtual Environments.

Bibliography:

Halsall, F. (2000) Multimedia Communications: Applications, Networks, Protocols, and Standards, Addison-Wesley Publishing, ISBN: 0201398184.
Bojkovic, Z. S.; Milovanovic, D. A.; Rao, K. R. & Milovanovic, D. A. (2002) Multimedia Communication Systems: Techniques, Standards, and Networks, Prentice Hall, ISBN: 013031398X.
Steinmetz, R. & Nahrstedt, K. (2002) Multimedia Fundamentals, Volume 1: Media Coding and Content Processing, 2a. Edição, Prentice Hall, ISBN 0130313998.
Effelsberg, W. & Steinmetz, R. (1999) Video Compression Techniques, dpunkt Verlag/Morgan Kaufmann Publishers, ISBN: 3920993136.
Packer, R.; Jordan, K. & Gibson, W. (2001) Multimedia: From Wagner to Virtual Reality, W.W. Norton & Company, ISBN: 0393049795.
Sayood, K. (2000) Introduction to Data Compression, 2a. Edição, Morgan Kaufmann Publishers; ISBN: 1558605584.
Jain, A. K. (1988) Fundamentals of Digital Image Processing, Prentice Hall, ISBN: 0133361659. Chapman, N. P. & Chapman, J. (2000) Digital Multimedia, John Wiley & Sons, ISBN: 0471983861. Soares, L.F.G.; Tucherman, L.; Casanova, M.A. & Nunes, P.R.R.L. (1992) Fundamentos de Sistemas Multimídia, VIII Escola de Computação da SBC, UFRGS.

4. GA-023 – Elements of Image Processing

Topics:Introduction, 2D Graphics Devices, Digital Image Representation. Linear Systems and Fourier Transform, Random Signals, Stochastic Models for Images, Estimation Theory, Entropy and Data Compression. Color Theory.

Sampling and Quantization: Nyquist Frequency e Aliasing, Sampling Theorem and Reconstruction, Image Quantization. Discrete Image Transforms: Discrete Fourier Transform, Cosine and KL Transforms. Image Enhancement and Filtering. Image Observation Models and Restoration: Inverse and Wiener Filtering. Segmentation and Image Analysis

Bibliography:

Jain, A.K. - Fundamentals of Digital Image Processing, Prentice Hall Inf. and Sciences Series, 1989. Rogers, D. F.- Procedural Elements for Computer Graphics, McGraw-Hill Int. Editions, 1985.
Rogers, D.F. e Adams, J. A. - Mathematical Elements for Computer Graphics, McGraw-Hill International Editions , 2ed, 1990.
Foley, J.D.; Dam, A.; Feiner, S.K. e Hughes, J.F. - Computer Graphics, Principles and Practice, 2ed, Addison Wesley, 1990.
[Rosenblum at al.(1994)] Scientific Visualization: Advances and Challenges, L. Rosenblum at al. (eds.), Academic Press (1994).
[Schroeder at al. (1998)] W. Schroeder, K. Martin e B. Lorensen, The Visualization Toolkit, 2ed, Prentice Hall[Schroeder at al. (2000)] W. Schroeder, K. Martin, L.S. Avila and C. C. Law, The Visualization Toolkit- User's Guide, 2000, Kitware, Inc

5. GA-024 - Computer Science: Data Structures and Applications

Elementary Data Structures: matrices, sparse matrices and their computational implementation, stacks and queues, linked lists, trees, implementation using recursive techniques; Hash Tables: direct access tables, hash functions, computational implementation and applications; Binary Search Trees: binary trees, methods for node searching, insertion and removal, computational implementation and applications; Spatial Data Structures and Graphs: octrees, k-d trees, graph concepts, depth- and breadth-first search in graphs, computational implementation; Applications: mesh generation, solution of systems of linear equations, out-of- core techniques for data analysis, graph otimization.

Bibliography:

Introduction to Algorithms - T. H. Cormen, C. E. Leiserson, R. L. Rivest, C. Stein, MIT Press, 2009 Estruturas de dados e seus algoritmos - J. L. Szwarcfiter, L. Markenzon, Livros tecnicos e científicos, Rio de Janeiro, 1994 (Portuguese only)
External Algorithms, DIMACS: Series in Discrete Mathematics and Theoretical Computer Science - J. M. Abello, J. S. Vitter, American Mathematical Society, 1998.
The Art of Computer Programming - Fundamental Algorithms - D. E. Knuth, Third Edition, Addisson Wesley, vol. 1, 1997
The Design and analysis of spatial data structures - H. Samet, Reading Addison- Wesley, 1990.

6. GA-025 – Computer Science: Foundations

Computing models. Logic. Recursion and computability. Mathematical, models of computation; Finite representation of infinite objects; Symbolic and "numerical" computing. Turing machines, automatons, grammars and formal languages. Decision tables; Predicate calculus and classical and non-classical; Well-ordered and induction. Total and partial recursion; Recursive and recursively enumerable logic sets; Computability, intractability and completeness. Computational complexity and algorithmic complexity; Exponential and polynomial algorithms. Parallel computing models and non-deterministic automata; PRAM's and SharedRAM's, interconnection networks, communication complexity; Models based on the orientation of objects.

Bibliography:

Dewdney, A.K. - The Turing Omnibus: 61 excursions in Computer Science, Computer Science press, Rockville, 1989.
Korfhage, R.R. - Discrete Computational Structures, 2ed, Academic Press, Orlando, 1984. Minsky, M. - Computation: Finite Infinite Machines, Prentice-Hall, 1967.

7. GA-026 - Computer Science: Algorithms I

Mathematical foundations: Induction, recursion. asymptotic analysis; Ordering: insertion, selection, quicksort,

mergesort, heapsort, radix sort; Search: Sequential, binary, hashing, binary tree search, balanced trees; Graphs: Minimum paths, Dijkstra's algorithm, Greedy Algorithm; Dynamic programming; Linear Algebra Equations Systems; Random Numbers.

Bibliography:

Computability, An Introduction to Recursive Function Theory - Cutland, N., Cambridge University Press, 1983
Foundations of Computer Science - Aho, A.V., Computer Science Press, 1992
Introduction to Algorithms - Cormen, T.H.; Leiserson, C.E. & Rivest, R.L., 2nd, MIT Press, ISBN: 0262032937, 2001.

8. GA-031 – Architecture, Design and Implementation of Software-Intensive Systems

Ementa:

Introduction: historic; basic definitions; relationship between architecture, design, and implementation of software-intensive systems; Software Architecture: notations for software architecture; architecture view models; architecture styles/patterns; Software Design: notations for software design; design patterns; Software Implementation: object-oriented programming, software components, aspect-oriented programming, concurrency-oriented programming; Examples of architecture and design application for software-intensive systems that model/simulate complex natural and artificial phenomena.

Bibliography:

Shaw, M.; Garlan, D. Software Architecture Perspectives on an Emerging Discipline. Prentice-Hall, 1996.
Hofmeister, C.; Nord, R.; Soni, D. Applied Software Architecture. Addison-Wesley, 2000.
Bass, L.; Clements, P.; Kazman, R. Software Architecture in Practice, second edition. Addison-Wesley, 2003.
Clements, P.; Bachmann, F.; Bass, L.; Garlan, D.; Ivers, J.; Little, R.; Nord, R.; Stafford, J. Documenting Software Architecture Views and Beyond. Addison-Wesley, 2002.
Buschmann, F.; Meunier, R.; Rohnert, H.; Sommerlad, P. Pattern-Oriented Software Architecture, volume 1 A System of Patterns. Willey, 1996.
Schmidt, D.; Stal, M.; Rohnert, H.; Buschmann, F. Pattern-Oriented Software Architecture, volume 2
Patterns for Concurrent and Networked Objects. Willey, 2000.
Kircher, M.; Jain P. Pattern-Oriented Software Architecture, volume 3 Patterns for Resource Management. Willey, 2004.
Jacobson, I.; Booch, G.; Rumbaugh, J. The Unified Software Development Process. Addison-Wesley, 1999.
Gamma, E.; Helm, R.; Johnson, R.; Vlissides, J. Design Patterns Elements of Reusable Object-Oriented Software. Addison-Wesley, 1995.
Heineman, G.; Councill, W. Component-Based Software Engineering Putting the Pieces Together. Addison-Wesley, 2001.
Szyperski, C. Component Software Beyond Object-Oriented Programming. Addison-Wesley, 2002.
Artigos recentes na área.

9. GA-035 – Artificial intelligence

Introduction: definition, basic concepts and foundations, including Dartmouth seminar, Turing machine and test; reasoning, language, speech and vision tasks; knowledge bottleneck, feature engineering bottleneck, and Moore's law; AI winters and the common task method; "AI effect". 2. Search: search space and complexity; games and heuristic strategies; case study (The Logic Theorist, The General Problem Solver, etc.). 3. Knowledge: representation and inference in first-order logic; rules; automatic planning; expert systems; case study (e.g., DENDRAL, MYCIN, etc.); 4. Uncertainty: uncertainty quantification, uncertain and probabilistic reasoning, d-separation and Bayesian networks, probabilistic graphical models, case study. 5. Learning: by examples, knowledge learning, graphical models, deep and reinforcement learning, case study (DeepBlue, NELL, etc.); 6. Deep Learning: origins and inspiration in nature, perceptron critique, representation learning, backpropagation, case study (AlexNet/ImageNet, AlphaGo, etc.); 7. Language: natural language processing, distributional hypothesis, transformer architecture, language models, scaling laws, case study (GPT, LLaMA, etc.).

Bibliografia:

Russell, S., Norvig, P. *Artificial Intelligence: A Modern Approach.* Pearson, 4th ed., 2022. (Tradução *Inteligência Artificial: Uma Abordagem Moderna*, editora LTC, 2022.)

Bishop, C. *Deep Learning: Foundations and Concepts*. Springer, 2024.
Jurafsky, D.; Martin, J. H. *Speech and Language Processing: An Introduction to Natural Language Processing, Computational Linguistics, and Speech Recognition with Language Models,* 3rd edition. Online manuscript released January 12, 2025. https://web.stanford.edu/~jurafsky/slp3
Haigh, T. *Artificial Intelligence: The History of a Brand.* MIT Press, (previsto para 2026 - estudantes interessados poderão receber uma cópia digital preliminar)
Nilsson, N. J. *The Quest for Artificial Intelligence: A History of Ideas and Achievements*. Cambridge University Press, 2009.
Bibliografia secundária:
Goodfellow, I., Bengio, Y., Courville, A. *Deep Learning*. MIT Press, 2016.
Nilsson, N. J. *Artificial Intelligence: A New Synthesis*. Morgan Kauffman, 2009.
Carvalho, A.C.P. de L. F. et al.. *Inteligência Artificial: Uma Abordagem de Aprendizado de Máquina*. LTC, 2a ed., 2021.
Wooldridge, M. *A Brief History of Artificial Intelligence: What It Is, Where We Are, and Where We Are Going*. Macmillan, 2021.
Caseli, H.M.; Nunes, M.G.V. (org.) *Processamento de Linguagem Natural: Conceitos, Técnicas e Aplicações em Português*. 3 ed. BPLN, 2024. Disponível em: https://brasileiraspln.com/livro-pln/3a-edicao.

10. GA-036– Introduction to Machine Learning

Introduction and definitions: machine learning, artificial intelligence, etc.; Types and sources of datasets; Data representation: vectors, tables, matrices, images, time series; Exploratory data visualization; Data cleaning: handling missing values and outliers; Data transformations: normalization, variable encoding, feature selection, discretization; Evaluation metrics: Accuracy, Precision, Recall, F1-score, ROC curve, AUC, MSE, RMSE, MAE, R^2, Silhouette Index, Davies-Bouldin Index; Cross-validation and hyperparameter tuning; Definitions and examples of supervised, unsupervised, semi-supervised, self-supervised, reinforcement, few-shot learning, transfer learning, etc.; Classification algorithms: KNN, Naive Bayes, Neural Networks, etc; Regression algorithms: Linear Regression, etc; Clustering algorithms: K-Means, etc; Association rules; Applications and advanced topics in machine learning.; Aplicações e tópicos avançados em aprendizado de máquina.

Bibliografia:

Gareth James, Daniela Witten, Trevor Hastie, Robert Tibshirani; An Introduction to Statistical Learning (https://www.statlearning.com/); Springer; 2023rd;
Yaser S. Abu-Mostafa; Learning from Data: A Short Course; AMLbook, 2012
Kevin P. Murphy; Probabilistic Machine Learning: An Introduction (https://probml.github.io/pml-book/book1.html#toc); MIT Press, 2022.

11. GA-053 – Distributed Computing

Architecture; Operating Systems; Distributed Systems; Networks; Clusters; Paradigms: Symmetric and Asymmetric; Synchronous and Asynchronous; Parallel and Distributed; Mobility; Collaboration; Distributed Algorithms: Election and Mutual Exclusion; Deadlock Detection and Resolution; Termination Detection; Protocols; Data Management; Achieving Consensus in the Presence of Uncertainty; Distributed Object Computing: Architecture; Middleware Concepts (Grid, ORBs, Agents); Languages; Access; Scheduling; Security; Task Management; Design and Implementation of Distributed Systems: Name Resolution; Event Notification; Timing; Mobility Support; Components; Fault Tolerance; Other Support Features; Evaluation Criteria: Two projects and Seminar with written work.

Bibliografia:

Silberschatz A ., Galvin P. e Gagne G.; " Applied Operating System Concepts" ,1st Edition, John Wiley & Sons, Inc.,2000, ISBN 0-471-36508-4, www.bell-labs.com/topic/boks/aos-book/
Raynal, M., "Distributed Algorithms and Protocols", John Wiley & Sons, 1988. Bertsekas D.P. e Tsitsklis J.N. , "Parallel and Distributed Computations Numeriacal Methods", Printice-Hall, 1989. Barbosa V.C., "A n Introduction to Distributed Algorithms", The MIT Press,Cambridge, MA, 1996, ISBN 0-262-02412-8. Lynch Nancy, "Distributed Algorithms", Morgan Kaufmann Publishers, San Mateo, CA, 1996.

Puder A . e Roemer K., "MICO: A n Open Source CORBA Implementation", Morgan Kaufmann Publishers, 2000 , ISBN 3-932588-72-X. Mahmoud Qusay H. ,"Distributed Programming with Java", Manning Publications Co. 1999,ISBN 188477765. Stevens, R. " Unix Network Programming - Networking APIs: Sockets and XTI "- Vol.1, Second Edition, Prentice-Hall, 1998. Stevens, R. " Unix Network Programming - Interprocess Communications" - Vol.2, Second Edition, Prentice-Hall,1999. Couloris, G. ; Dollimore J. e Kindberg, T. - " Distributed Operating System - Concepts and Desing" - Addison Wesley, 1994. ITU-T X901 - ISSO/IEC 10746-1 - "ODP Reference Model - Part 1: Overview; Part 2: Foundations; Part 3: Architecture" - 1996. OMG-"The Common Object Request Broker: Architecture and Specification" -ver.2.4, outubro 2000. OMG- " CORBA services: Common Object Services Scpecification" 2000. Orfalli, R. ; Harkey D. e Edwards, J. - " Instant CORBA" - John Wiley & Sons, 1997.

12. GA-055 – Introduction to Computational Biology and Bioinformatics

Introduction to Bioinformatics; Basic Concepts in Linux; Architecture and Management of Directories and Files; Text Editors and Text Processing; Programming Logic; Relational, Logical, and Arithmetic Operators; Algorithms: Natural Language, Flowcharts, Pseudocode, and Programming Language; Selection, Repetition, Sorting, and Recursion Structures; Introduction to Regular Expressions; Introduction to Programming; Version Control; Workflow managers; Task Automation and Scripts; Programming Paradigms; Databases and Web Tools;

Bibliografia:

CASTILHO, M. A. *Algoritmos e estruturas de dados 1*. ISBN: 978-65-86233-62-9. 2020.
HADDOCK S.H.D., DUNN C.W. *Practical computing for biologists.* ISBN 97,8-0-87893-391-4. 2010.
MOUNT D.W. *Bioinformatic: Sequence and Genome Analysis*. Revised ed. Cold Spring Harbor Laboratory Press. ISBN-13978-0879697129. 2004.
PROGRAMA DE EDUCAÇÃO TUTORIAL TELECOMUNICAÇÕES. *Introdução ao LINUX e Programação em Script-Shell*. Universidade Federal Fluminense. 2004.

13. GA-057 – Introduction to Data Analysis in Bioinformatics

Introduction to Bioinformatics and Biological Data Analysis; Introduction to Programming Languages for Bioinformatics; Fundamental Concepts: Variables and Numeric Types, Data Input and Output. Operations, Native Functions, and Modules; Data Structures: Strings, Lists, Tuples, Sets, and Dictionaries; Control Structures: Conditionals and Loops; File Manipulation; Functions: Definition and Usage; Regular Expressions; Libraries for Sequence Analysis in Bioinformatics; Libraries for Tabular Data Analysis in Bioinformatics; Libraries for Data Visualization in Bioinformatics; Applications to Real Biological Problems.

Bibliografia:

MARIANO, DIEGO. Python para Bioinformática: Fundamentos de Programação para Bioinformática e Biologia Computacional. Novatec, 2025.
ISMAIL, HAMID D. Bioinformatics: A Practical Guide to Next Generation Sequencing Data Analysis. CRC Press/Chapman & Hall, 2023.
STEVENS, TIM, e WAYNE BOUCHER. Python programming for biology, bioinformatics, and beyond. Cambridge University Press, 2014.
YOUENS-CLARK, KEN. Mastering Python for bioinformatics: how to write flexible, documented, tested python code for research computing. First edition, O'Reilly, 2021.
MACLEAN, DAN. R Bioinformatics Cookbook, Second Edition. Packt, 2023.
MATHUR, SUNIL K. Statistical Bioinformatics with R. Academic Press, 2010.

Mathematics

1. GA-001 - Linear Algebra

Vector spaces; Finite-dimensional vector spaces; Linear transformations; Eigenvalues and eigenvectors; Inner-product spaces; Normal matrices

Bibliography:

Álgebra Linear com Aplicações - H. Anton & C. Rorres, Décima Edição, Bookman, 2012 Álgebra Linear - E. L. Lima, Terceira Edição, IMPA, 1999
Álgebra Linear - Exercícios e Soluções - R. C. Teixeira, Terceira Edição, IMPA, 2014 Linear Algebra and Its Applications - G. Strang, Fourth Edition, Brooks Cole, 2006 Linear Algebra Done Right - S. Axler, 2 ed, Springer,

1997

2. GA-005 - Real Analysis
Enumerability: Concepts of Infimum and Supremum; Construction of the Real Numbers. Sequences and Infinity Series: Limit Theorems; Cauchy Theorem; Bolzano Weierstrass Theorem; Convergence Criteria. Topology in R: Characterization of Compact Subsets; Limits and Continuity of Real Functions and their relations with the Topology in R; Heine and Weirestrass Theorems. Differentiation: The Derivative; The Mean Value Theorem; Taylor's Theorem. The Riemann Integral: Riemann Integrability; Properties of The Riemann Integral; The Fundamental Theorem of Calculus; The Mean Theorem for Integrals.
Bibliography:
Introduction to Real Analysis – Robert G. Bartle, Donald R. Sherbert Curso de Análise - Elon Lages Lima , Volume
The Elements of Real Analysis – Robert G. Bartle

3. GA-007 - Functional Analysis
Banach spaces, the Hanh-Banach theorem. Strong, weak and weak start topologies. The Alaougu - Bourbaki Theorem, Reflexive Spaces. Hilbert spaces: The Lions-Stampacchia's theorem, the Lax - Milgram's Lemma. Compact operators, Riesz Fredholm theory, the Fredholm alternative. The L^p Spaces. Sobolev's Spaces. Approximations by smooth functions, the Trace Theorem.
Bibliography
Functional Analysis, Haim Brezis

4. GA-015 - Introduction to the Calculus of Variations
Variarional Methods, Weighted Residual Methods, Collocation Methods, Galerkin Method, Non- Homogeneous Boundary Conditions, Ritz Method, Minimum of a Functional, Minimizing Sequences, Variational Basis for the Finite Element Method, Least Square Method
Bibliography:
Calculus of Variation - Gelfand, I.M. e Fomin, S.V., Prentice-Hall, Englewood, 1963
Direct Methods in the Calculus of Variations - Dacorogna, B., Springer Verlag, Berlin, 1989 Variational Methods in Mathematical Physics - Mikhlin, S.G., Pergamon Press, NY, 1964

5. GA-018 - Numerical Methods
Mathematical preliminaries: errors, floating-point numbers, convergence. Polynomial interpolation and approximation. Solution of nonlinear equations. Numerical integration and differentiation. Solving systems of linear equations: direct and iterative methods. Numerical solution of ordinary differential equations. Numerical solution of partial differential equations: finite-differences.
Bibliography:
Introduction to Numerical Methods - Stark, P., Macmillan, 1970
Matrix Computations - Golub, G. e Van Loan, C., The John Hopkins University Press, 1993
Scientific Computing: An Introduction to Parallel Computing - Golub, G. e Ortega, J., Academic Press, 1993

6. GA-020 – Numerical Solution of Differential Equations
Ordinary differential equations. Euler's method. Multi steps methods and Runge-Kutta; Finite difference schemes: Difference operatord; Application to the Poisson equation; Finite element methods: Variational formulations; Weak forms; Ritz's Method; Galerkin method; Discretization; Approximation spaces; Kinematic formulations and Mixed methods; Discrete model for elliptic equations; Semi-discrete models for parabolic equations.
Bibliography:
Carey, G. and Oden, J., "Finite Elements" vol.I-An Introduction; vol.II-A Second Course; vol.III- Computational Aspects; vol.IV-Mathematical Aspects, Printice Hall, 1981.
Hughes, T., "The Finite Element Method: Linear Static and Dynamic Finite Element Analysis", Printice Hall, 1987.
Iserles, A., "A First Course in the Numerical Analysis of Differential Equations", Cambridge University Press, 1966.

7. GA-021 – Finite Element Method: Basic Theory

Continuous formulation: Variational Formulation of PDE: The Poisson Equation, Existence and Uniqueness: Lax-Milgram Theorem, Recalling the Sobolev Spaces, other Examples of Variational Formulations, Discrete Formulation: Variational Approximation, Galerkin Method, Best approach: Céa's lemma, Finite Element Method: Motivation, Definition and an 1D Example, Lagrangian Finite Element (Triangles), Notions of Refer- ence Element, Local and Global Approximations: Interpolation, Error Estimation: Aubin-Nitsche Lemma, Other Examples of Finite Element.

Bibliography:

Basic: Class notes,
Numerical Solution of Partial Differential Equations by the Finite Element Method, Claes Johnson, Dover Publication, 2009.
The Finite Element Method for Elliptic Problems, Philippe Ciarlet, Classics in Applied Mathematics, SIAM, 2002.
Aide-Mémoire Eléments Finis, Alexandre Ern, Dunod, 2005. (e Francês) Advanced:The Mathematical Theory of Finite Element Methods, Susanne Brenner and L. Ridgway Scott, Springer, 2002.
Theory and Practice of Finite Elements, Alexandre Ern and Jean-Luc Guermond, Springer, 2004

8. GA-032 - Linear Systems

Linear spaces; mathematical models; dynamic equations; norms of signals and systems; responses of linear systems; controllability; stabilizability; observability; detectability; duality; Kalman decomposition; realizations: minimal and canonical; stability: input-output and in the sense of Lyapunov.

Bibliography:

Linear System Theory - Rugh, W.J., 2ed., Prentice-Hall.
Linear System Theory - Chen, C.T., Holt, Rinehart and Winston, 1984

9. GA-033- Finite Element Method: Computational Implementation

Brief review of basic programming concepts, programming languages and their characteristics;
Variational formulations of Differential Equations, Galerkin Method and Finite Element Method; Data structures associated with the Finite Element Method; Review of mesh formats and implementation of mesh reading; Review of storage formats and resolution of linear systems; Assembling the 1D finite element matrix for an elliptical problem (using Lagrange polynomials of arbitrary order); Obtaining and processing the 1D element approximation; Assembling the 2D finite element matrix for an elliptical problem (using Lagrange polynomials of arbitrary order); Obtaining and processing the 2D element approximation; Extensions: stabilization, parabolic problems and nonlinear problems

Bibliografia:

Lecture notes made available during the course
Gockenbach M. (2006). Understanding and Implementing the Finite Element Method. SIAM
Johnson C. (1988). Numerical solution of partial differential equations by the finite element method. Dover Publications
Quarteroni A. (1994). Numerical Approximation of Partial Differential Equations.

10. GA-034- Optimization Methods

Definition of the general problem of nonlinear programming; Optimality conditions for problems with and without constraints; Convexity; Fundamental properties of algorithms and solutions; Linear search algo- rithms; Classic descent methods; Penalty and barrier methods; and Direct search methods (derivative-free methods).

Bibliography:

Nonlinear Programming, Theory and Algorithms. Bazaraa, M.S. e Shetty, C.M.. John Wiley and Sons, New York, 3th edition, 2006.
Linear and Nonlinear Programming. David G. Luenberger & Yinyu Ye. Springer, 3th edition, 2008.
Numerical Optimization. Jorge Nocedal & Stephen J. Wright. Springer, 2sd edition, 2006.
The Mathematics of Nonlinear Programming. Anthony L. Peressini, Francis E. Sullivan, J.J Uhj, Jr. Springer, 1993

Modeling

1. GA-028 – Probability and Stochastic Processes

Set theory: sequences; liminf; limsup; set functions and measurability; random phenomenon; sampling space; events and probability measure; conditional probability and Bayes formula; discrete and continuous random variables and induced probability law, joint and marginal; distribution function; normal and binomial distribution; change of variables; expectation; variance; covariance and moments; independency; conditional expectation; geometry of the linear estimation problem: Kalman filter and applications to data transmission; Jensen's inequality and application to finance; Bernoulli and Poisson processes; Markov chains; Chapman-Kolmogorov formula and stationarity; law of large numbers; central-limit theorem; Chebychev's inequality; Borel-Cantelli lemma.

Bibliography:

A Second Course on Stochastic Processes - Karlin, S. e Taylor, H.M., Academic Press, New York, 1981. Introduction to Probability Models - Ross, S.M., , 10ª, Associated Press , 2009
Introduction to Stochastic Processes - Çinlar, E, , Prentice-Hall Inc, 1975 Medida e Integração, Projeto Euclides - Fernandez, P. J, IMPA, 2002.
Probabilidade: Um Curso em Nível Intermediário, Projeto Euclides, IMPA - James, B.R., 1979. Probability & Measure Theory - Ash, R.B. and Doléans-Dade, C., , 2ª, 2000.

2. GA-030 – Statistics

Probability Theory for one Random Variable; Bayes' Theorem; Discrete and Continuous Probability Distributions; Expectation, Variance and Moments; Conditional Probability; Probability theory for a Set of Random Variables; Independent variables; Law of Large Numbers; Central Limit Theorem; Covariance and correla- tion; Marginal Distribution and Conditional distribution; Expected value; Statistical inference; Classic and Bayesian Estimation Methods; Confidence intervals; Hypotheses Null and Alternative; Error Type I and II .; Hypothesis Tests (Parametric and Non Parametric); Parametric Estimation; Maximum Likelihood method; Method of Moments; Least Squares Method; Stochastic Processes; Poisson process; Markov chains.

Bibliography:

Statistical Methods in Bioinformatics: An Introduction (Statistics for Biology and Health) - , 2a edição, Ed. SpringeP. L. Meyer. Probabilidade: Aplicações à Estatística. Livros Técnicos e Científicos
Editora, Rio de Janeiro, 2o edição, 1983

3. GA-037 – Continuous Mechanics

Signal sampling; z-transform; Discrete Fourier analysis; Fast Fourier transform (FFT) algorithms; Digital filter design methods; Power spectrum estimation; Kalman filter; Digital signal processing applications.

Bibliography:

Digital Signal Processing - Oppenheim, A.V. e Schafer, R.W., Prentice-Hall, 1975Digital Signal Processing: Principles, Algorithms and Applications - Proakis, J.G. e Manolakis, D.G., 3rd edition, Prentice-Hall, 1987.
Discrete-time Signal Processing - Oppenheim, A.V. e Schafer, R.W., Prentice-Hall, 1989Processamento Digital de Sinais - Projeto e Análise de Sistemas Paulo S. R. Diniz et al. Editora Bookman. ISBN 85-363-0418-9

4. GA-038 – Digital Signal Processing

Signal sampling; z-Transform; discrete Fourier analysis; Fast Fourier Transform (FFT) algorithms; digital filter design; power spectrum estimation; Kalman filter; applications of digital signal processing.

Bibliography:

Digital Signal Processing - Oppenheim, A.V. e Schafer, R.W., Prentice-Hall, 1975
Digital Signal Processing: Principles, Algorithms and Applications - Proakis, J.G. e Manolakis, D.G., 3rd edition, Prentice-Hall, 1987.
Discrete-time Signal Processing - Oppenheim, A.V. e Schafer, R.W., Prentice-Hall, 1989

5. GA-040 - Modeling of Continuum Systems

Short introduction to vectorial and tensorial calculus, Physical meaning of grad, div, curl an Laplacian operators. Characterization of properties associated to continuum systems and length scales. Motion and Kinematics Lagrangian and Eulerian descriptions. Conservation Laws. Mass, Momentum, Energy and Electric Charge. Unified

representation of the conservation laws. Applications to transport phenomena. mass, heat, electric charge and fluid percolation in porous media; Extension to multiphase systems, Appications to multiphase flows in porous media, extraction of hydrocarbons from petroleum reservoirs, population dynamics, drug transport in the human body Stationary and equilibrium processes. Constitutive laws. diffusive motion of solutes in fluids. Constitutive Laws of Fourier, Darcy and Ohm. Potential flows, Electrostatics, Linear Elasticity, convection-diffusion equations, Wave equation in solids and fluids, Electromagnetism, Maxwell equations.

Bibliography:

A Concrete Approach to Matthematical Modelling - Masterton,M., Gibhons, J. Wiley, NY, 1995 Advanced Transport - Slattery, J.
Introduction to Continuum Mechanics - Gurtin, M., Academic Press, 1981 Introduction to Fluid Dynamics – Batchelov
Mechanics ot Continuos Media – Hunter
Thinking With Models - Saaty , Thomas and Alexander, Joyce
Transport Phenomena and Materials Processing - Landau, L. and Listshitz

6. GA-041 - Modeling Fundamentals

Basic principles and methodology of modeling; qualitative and quantitative models; Lagrangean and Eulerian reference systems; physical (phenomenological) properties; continuous and discrete systems, scale concepts. Interpretation of mathematical operators; conservation/equilibrium principles; constitutive and state equations; deterministic, probabilistic and empirical models; evolution and adequacy analysis of mathematical models. Applications: Selected problems of general physical modeling (engineering), bio- systems, social-economic systems, ecosystems, etc.

Bibliography:

A Concrete Approach to Mathematical Modelling – Masterton, M., Gibhons, J. Wiley, NY, 1995; Mathematical Modelling Techniques – Aris, R., Dover, NY, 1978;
Advanced Transport Phenomena – Slattery, J.;Introduction to Continuum Mechanics – Gurtin, M., Academic Press, 1981;
Introdução à Modelagem Matemática – Karam F., J. e Almeida, R. C., 2003; Mathematical Biology – Murray, J. D., 2ed., Springer, 1993.
Thinking with Models – Saaty, Thomas and Alexander, Joyce.

7. GA-043 – Introduction to DNA and Proteins

DNA structure. Replication. Transcription and processing. Proteins structure; Translation and the genetic code; Organization of the coding regions of DNA; DNA / RNA, prokaryotes and eukaryotes, transcription and translation; Organization of non coding DNA regions (repeats), CpG islands, genomic techniques, PCR, ESTs, BAC / YAC, cosmid, genomic libraries, DNA chips, physical maps and genetic maps; Bioinformatics techniques; brief genome sequencing history; Acquisition and preliminary data analysis, DNA sequence as- sembly and analysis of DNA sequences; proteins; primary, secondary, tertiary and quaternary protein struc
tures; Protein classes and functions; DNA / protein interaction; Bioinformatics application in proteomics (analysis of primary sequence, secondary and tertiary structures); Proteomic techniques; Interactions pro- teins / proteins.

Bibliography:

An Introduction to Genetic Analysis - Anthony J. F. Griffiths, Jeffrey H.Miller, David T. Suzuki, 7th edition, W H Freeman & Co, 2000.
Genes VII - Benjamin Lewin Hardcover, Oxford Univ Press, 1999.
Lehninger Principles of Biochemistry - David L. Nelson, Michael M.Cox Hardcover, Third Edition Worth Publishing, 2000.
Molecular Biology of the Cell - Bruce Alberts (Editor), Bray Alberts, 3rd Bk&cdr edition Garland Pub, 1999.
Molecular Cell Biology - Harvey Lodish, Arnold Berk, S. Lawrence Zipursky, Paul Matsudaira, David Baltimore, James Darnell, 4th edition W H Freeman & Co, 1999.

8. GA-044 - Introduction do Evolution and Biology

Biological systems. What is life? Patterns and Processes in Biology. Evolutionary processes. Natural selection as an emergent property of life. Mutation. Genetic drift. Biological standards. Origin of life. Animal diversity. Historic: Darwin, Wallace, Mendel, Wright, Fisher and Haldane. Taxonomy: goal, past classifications, Linnaean classification and phylogeny. Hennig and phylogenetic systematics. New trends (monophyletic groups, bar code). Phylogenetic analysis. UPGMA and Maximum Parsimony. Phylogenetic systematics. Three axes of comparative analysis: space, time and form (biogeography, fossil record and morphology/molecular).

Bibliography:

Evolution - Monroe Strickberger, 3ª edição, Jones & Bartlett, Londres.

9. GA-046 - Modeling Techniques

Phenomena; Objects and their interactions; Change; Models; Observation methods, experiments; Observations, measures and scales; Precision and accuracy; Populations, recurrence, replication and repetition; Models, context and environment; Systems; General Systems; Attributes, Variables and Parameters; Systems as scientific framing method; State of a system; Systems perspective; Organizations; Mathematical and computational contexts; R. Rosen modeling relation; Building models; Adapting, extending and combining models; Dispersion, Dissipation and Transformation; Selected modeling problems: physico-chemical, biological, socio-economic, ecological and environmental.

Bibliography:

A Concrete Approach to Matthematical Modelling - Masterton,M., Gibhons, J. Wiley, NY, 1995. Mathematical Modelling Techniques - Aris, R., Dover, NY, 1978.

10. GA-047 - Bioinformatics I - Biological databases

Brief history: from *Atlas* of *Protein* Sequence and Structure (*Dayhoff,* 1968) to the web servers. The variety of current information sources, types, formats, methods, sizes and distributions. The databases of DNA and RNA sequences; History of GenBank, EMBL, DDBJ, study and format of GenBank / DDBJ and EMBL; Phi- losophy of databases and their redundancy; Problems of quality and heterogeneity of gene/protein annota- tions; complete genomes; Databases of protein sequences; Definition and description; Study of some pro- teins databases: RIP, MIPS, SWISS-PROT, TrEMBL etc., non-redundant sequences databases; Brief dis- cussion of other proteins databases; The databases of domains and protein families. Definition and descrip- tion; Detailed study of some databases: PROSITE, Pfam, PRINTS, PIRSF and BLOCKS. Automatically gen- erated protein domain databases: PRODOM, DOMO; InterPro. Proteomic database; Definition and descrip- tion; Detailed study of the SWISS-2DPAGE. The databases of three-dimensional structures; The PDB data- base: History and a brief description of its content; The derived database PDB (Swiss-3DImage, HSSP, DSSP, FSSP, etc.); The NDB database; The metabolic databases; Definition and description; Study EcoCyc, KEGG, etc. The databases of functional categories; Definition and description; APIASTER, IntAct, PhosSuit, GlycoSiteDB, etc .; The biological image databases; BioImage, Global Image Database; The databases of genomes; Definition, description; Ecoli, FlyBase, DGS, etc. AceDB etc. The database of mutations and polymorphisms; Definition and description; SNP (Single Nucleotide Polymorphisms); Bibliographic databa- ses; Detailed study of the MEDLINE / ENTREZ.

Bibliography:

Bioinformatics : A Practical Guide to the Analysis of Genes and Proteins - Andreas D. Baxevanis, B. F. Francis Ouellette, John Wiley & Sons, 2001
Bioinformatics : Databases and Systems - Stanley Letovsky (Editor), Kluwer Academic publishers, 1999
Bioinformatics : Sequence, Structure, and Databanks : A Practical Approach - Des Higgins (Editor), Willie Taylor (Editor), 1st edition, Oxford Univ Press, 2000
Introduction to Bioinformatics - Teresa K.Attwood and David J.Parry-Smith, Addison Wesley Longman, 1999.

11. GA-050 – Introduction to the Modeling and Simulation of Physiological Systems

Historical Review, Basic Physiological Aspects of Blood Circulation: Structure of Circulatory System; Basic Characteristics of Arterial Walls; Basic Notions of Solid Mechanics: Arterial Wall Behavior (Constitutive Equations); Basic Notions of Fluid Mechanics: Blood Behavior (Constitutive Equations); Preliminary Concepts of Modeling; Introduction to Numerical Simulations: Lumped (0D) Models for the Cardiovascular System: Models of Systemic Arteries and Coupling to Left Ventricle; Closed-Loop Model; Models for Cardiac Valves;

Computational Simulation using MatLab; Distributed (1D) Models for the Cardiovascular System: Conservation Laws; Pressure Pulse; Arterial Structure; Boundary Conditions; Computational Simulation using HeMoLab System.

Bibliography:

F.C. Hoppensteadt and C. S. Peskin. Modeling and Simulation in Medicine and the Life Sciences. Texts in Applied Mathematics, Springer, Second Edition, 2002

Y.C. Fung. Biomechanics. Mechanical Properties of Living Tissues. Springer-Verlag, N.Y., 1981.

Y.C. Fung. Biodynamics Circulation. Springer Verlag, 1984.

12. GA-056 – Genome Assembly

History and contextualization; Biological sequence generation technologies; Sequence file formats and alignments; Basic alignment concepts; Dynamic programming algorithms; Distance metrics; Scoring matrices; Pairwise alignment; Multiple sequence alignment; Alignment editing tools; Homology search tools (BLAST); Sequence preprocessing for assembly; Family of indexing algorithms; Read mapping programs; Genome assembly programs; Genome alignment and ordering programs; Scaffolding and gap closure.

Bibliography:

ALSER, M., ROTMAN, J., DESHPANDE, D. et al. *Technology dictates algorithms: recent developments in read alignment*. Genome Biol 22, 249 (2021). https://doi.org/10.1186/s13059-021-02443-7

GAGNIUC, P. A. *Algorithms in bioinformatics : theory and implementation*. Polytechnic University of Bucharest, Bucharest, Romania. First edition. Hoboken, NJ : Wiley, 2021. ISBN 9781119697954 (adobe pdf).

MÄKINEN V., BELAZZOUGUI D., CUNIAL F., TOMESCU A. G*enome-Scale Algorithm Design: Biological Sequence Analysis in the Era of High-Throughput Sequencing* (2023). ISBN-10 : 1107078539. ISBN-13 : 978-1107078536.

MOUNT D.W. *Bioinformatic: Sequence and Genome Analysis*. Revised ed. Cold Spring Harbor Laboratory Press. ISBN-13978-0879697129. 2004.

Data da atualização: 26/05/2025