

Subject Group I. (Compulsory)

I.1. Continuous and discrete time linear time-invariant systems: input-output and state space representations. Sampling. State transformations, realizations, realization properties. Canonical forms.

- Continuous- and discrete-time linear time-invariant dynamical systems, their input-output, and state-space representations.
- Equidistant sampling.
- State transformations and their properties, state space realizations, realization properties. Canonical forms, normal forms (controllability, observability, diagonal form).

Recommended literature:

- Hangos-Bokor-Szederkényi: Computer Controlled Systems (Egyetemi kiadó)

I.2. Continuous time time-invariant linear and nonlinear systems. Stability notions (BIBO and asymptotic and conditions, Lyapunov theorem.

- State-space model of continuous-time, linear, time-invariant dynamical systems.
- Stability notions (Bounded-Input-Bounded-Output and asymptotic stability) and stability conditions for the linear case, local stability in the nonlinear case.
- Lyapunov function and its properties, Lyapunov stability theorem.

Recommended literature:

- Hangos-Bokor-Szederkényi: Computer Controlled Systems (Egyetemi kiadó)

I.3. Deterministic automata: definitions, relationship with languages. Unary and binary operations on automata.

- Deterministic finite automata: definitions, relationship with languages, languages represented by automata.
- Generalization of automata, nondeterministic automata.
- Unary and binary operations on automata, product of automata and parallel composition of automata.

Recommended literature:

- Cassandras, Lafortune: Introduction to Discrete Event Systems, Springer
- Lecture presentation – subject homepage: <https://virt.uni-pannon.hu/index.php/en/education/courses/190-discrete-and-continuous-dynamic-systems-vemivim254e>

I.4. Discrete event systems as nonlinear discrete time systems. Relationships between automata models and state space models of discrete time nonlinear systems. Petri net description of discrete event systems, relationship with automata models.

- Discrete event systems as special nonlinear discrete-time systems, correspondence between signals and functions of the models.
- Formal model of automata as nonlinear discrete-time nonlinear state-space model Petri-net description of discrete event systems, relationship with automata models.

Recommended literature:

- Cassandras, Lafortune: Introduction to Discrete Event Systems, Springer
- Lecture presentation – subject homepage: <https://virt.uni-pannon.hu/index.php/en/education/courses/190-discrete-and-continuous-dynamic-systems-vevivi254e>

I.5. Observability and nondeterminism of automata. Observer automaton. Diagnosability, diagnose automaton. Timed automata.

- Observability and nondeterminism of automata. Observer automata, algorithmic construction of observer automata (nondeterministic finite automata) for deterministic automata. Diagnosability, diagnose automaton. Timed automata.

Recommended literature:

- Cassandras, Lafortune: Introduction to Discrete Event Systems, Springer
- Lecture presentation – subject homepage: <https://virt.uni-pannon.hu/index.php/en/education/courses/190-discrete-and-continuous-dynamic-systems-vevivi254e>

I.6. Recursive functions. Primitive recursive functions, Primitive recursive relations, the limits of primitive recursive functions.

- Topics: basic functions (zero function, identity function, successor function),
- operation with function (composition, recursion, minimization),
- primitive recursive function, μ -recursive functions,
- implementation of functions (plus(m, n), mult(m, n), exp(m, n), pred(m), m~n, isZero(m), sgn(m), greater-than-or-equal(m, n), less-than(m, n), equals(m, n)),
- a function is μ -recursive \leftrightarrow Turing computable.

Literature:

- The download materials of the subject: <https://oktatas.mik.uni-pannon.hu/>
- Literature: Harry R. Lewis, Christos H. Papadimitriou: Elements of the Theory of Computation, Prentice Hall, Inc., 1998. (second edition), chapter 4.7.

I.7. Turing machines. Turing machines, Construction of Turing machines, Extensions of Turing machines.

- Topics: Definition of Turing machines,
- Turing machine vs. Pushdown automata,
- final state vs. halting state,
- the output of Turing machines,
- basic machine schemas, the copying machine, conversion of machine schema to Turing machine, shifting, machine deciding anbn, machine with two way infinite tape, machine with multiple tape, machine with multiple head, machine with multidimensional tape, random access TM, non-deterministic TM.

Literature:

- The download materials of the subject: <https://oktatas.mik.uni-pannon.hu/>

- Literature: Harry R. Lewis, Christos H. Papadimitriou: Elements of the Theory of Computation, Prentice Hall, Inc., 1998. (second edition), chapter 4.1-4.5.

I.8. Turing computable. Turing computable, recursively enumerable languages, undecidable problems.

- Topics: Definition of Turing computable, characteristic function,
- Turing decidable and acceptable languages, the connection between Turing decidable and acceptable languages,
- Church Turing thesis, halting problem, tiling problem, other unsolvable problems.

Literature:

- The download materials of the subject: <https://oktatas.mik.uni-pannon.hu/>
- Literature: Harry R. Lewis, Christos H. Papadimitriou: Elements of the Theory of Computation, Prentice Hall, Inc., 1998. (second edition), chapter 4.6., 5.1-5.4.

I.9. Technologies and considerations related to database server side business logic implementation

- Technology of server side stored procedures, user defined functions and DML triggers, and their application in the implementation of business logic
- Transactional requirements, transaction related technologies in OLTP databases, control and error handling for transactions
- The concept of jobs and their application to support business processes
- Loose coupling case study using jobs and triggers

Related literature

- DML Triggers <https://docs.microsoft.com/en-us/sql/relational-databases/triggers/dml-triggers?view=sql-server-ver15>
- Stored Procedures <https://docs.microsoft.com/en-us/sql/relational-databases/stored-procedures/stored-procedures-database-engine?view=sql-server-ver15>
- User-Defined Functions <https://docs.microsoft.com/en-us/sql/relational-databases/user-defined-functions/user-defined-functions?view=sql-server-ver15>
- SQL Server Transaction Log Architecture and Management Guide <https://docs.microsoft.com/en-us/sql/relational-databases/sql-server-transaction-log-architecture-and-management-guide?view=sql-server-ver15>
- Create a job <https://docs.microsoft.com/en-us/sql/ssms/agent/create-a-job?view=sql-server-ver15>

I.10. Database replication technologies

- The objectives of replication, the replication metaphor
- Key components of the replication architecture
- Overview of the main replication types and their application scenarios in MS SQL Server
- Role of the software agents used for the implementation of the various replication types
- The use of replication to support business processes
- The architecture and application fields of log shipping

Related literature

- Log Shipping and Replication concepts <https://docs.microsoft.com/en-us/sql/database-engine/log-shipping/log-shipping-and-replication-sql-server?view=sql-server-ver15>
- Replication tutorials <https://docs.microsoft.com/en-us/sql/relational-databases/replication/replication-tutorials?view=sql-server-ver15>
- SQL Server Replication <https://docs.microsoft.com/en-us/sql/relational-databases/replication/sql-server-replication?view=sql-server-ver15>
- Implement log shipping
<https://www.microsoftpressstore.com/articles/article.aspx?p=2832586&seqNum=3>

I.11. Cloud database technologies

- Overview of cloud database technologies, specific data security, administration and performance challenges related to cloud based data storage
- Migration of relational OLTP databases to cloud based database technologies
- Standard cloud data modeling methods
- Administration of cloud databases
- Connecting cloud databases to cloud services, a case study

Related literature

- Cloud-Based Database Workloads: An Introduction
<https://cloud.netapp.com/blog/cloud-based-database-challenges-and-advantages>
- Relational vs NoSQL and RDBMS to NoSQL Migration
<https://dzone.com/articles/relational-vs-nosql-databases-and-rdbms-db-to-nosq>
- GCP Database migration <https://cloud.google.com/solutions/database-migration/technical-resources>
- GCP Firestore database administration
<https://firebase.google.com/docs/database/admin/start>
- Choose a Database: Cloud Firestore or Realtime Database
<https://firebase.google.com/docs/database/rtdb-vs-firestore>

Subject Group II. (Elective)

Subject Group II.1. Software Systems

II.1.1. Definition, characteristics and role of the various cloud abstraction layers

- Cloud layers (such as IAAS, PAAS, SAAS, etc), their definition, the role of each layer and their key components, expected level of user involvement at each level, the typical application areas of each levels.
- Choose one of the main cloud providers (Google, Amazon, Microsoft) and using their technology/service stack, describe the interoperation of these layers.

Recommended literature

- Juhász Zoltán: Cloud Programming lecture notes (in preparation)
- Google, Amazon and Microsoft Azure online documentation

II.1.2. Fundamental programming steps of cloud application development

- Describe the key programming steps of a cloud application from the system functionality perspective (data transport, server-side business logic, data storage, scalability considerations, security issues, fault tolerance, etc.).
- What level of support is given to developers and in what form by the major cloud service providers for implementing these tasks?

Recommended literature

- Juhász Zoltán: Cloud Programming lecture notes (in preparation)
- Google, Amazon and Microsoft Azure online documentation

II.1.3. Fundamentals and use of stream data processing

- The concept of stream-oriented data processing.
- Benefits and disadvantages in terms of resource consumption, application constraints and code complexity.
- Describe few application scenarios where stream processing is advantageous and how the application benefits from stream processing.
- Describe and evaluate the basic functionality of a cloud stream-oriented data processing software framework.

Recommended literature

- Juhász Zoltán: Cloud Programming lecture notes (in preparation)
- Google, Amazon and Microsoft Azure online documentation

II.1.4. The relationship of cloud programming with various well-known, large-scale system architecture/programming abstraction paradigms

- Compare the following technologies with cloud programming: service-oriented systems, grid computing, peer-to-peer systems, web services, message-passing based distributed systems.
- Which technology is similar and to what extent to current cloud computing technologies and how do they appear (if applicable) in cloud programming models?

Recommended literature

- Juhász Zoltán: Cloud Programming lecture notes (in preparation)
- Google, Amazon and Microsoft Azure online documentation

II.1.5. Threats to IT systems: physical, logical and human security

- Physical threats (data loss, data theft, data leakage, device destruction)
- Prevention methods (data backup, endpoint protection, security incident reporting, investigation, prevention)
- Physical protection (access control, closed rooms, guard)
- Logical threats (malware, denial of service, (DoS, DDoS, unauthorized access)
- Main elements of logical protection (firewalls, IDS / IPS systems, authorization management)
- User threats (lack of knowledge, social engineering)
- User protection (security awareness, segregation of duties, principle of minimum authorization)

Literature:

- Teaching aids of the subject in the Moodle system: <https://oktatas.mik.uni-pannon.hu/>
- Charles J. Brooks, Cristopher Grow, Philip Craig, Donals Short: Cybersecurity Essentials, Sybex 2018, ISBN: 978-1119362395

II.1.6. Business continuity planning: process assessment, planning, strategy and action plan development

- Mapping operational processes
- IT system and service catalog, data asset inventory
- Impact Assessment of Operational Process Failures (BIA)
- Analysis of risks to critical processes
- Business continuity strategy and framework
- Activation manuals
- Action plans

Literature:

- Teaching aids of the subject in the Moodle system: <https://oktatas.mik.uni-pannon.hu/>
- Charles J. Brooks, Cristopher Grow, Philip Craig, Donals Short: Cybersecurity Essentials, Sybex 2018, ISBN: 978-1119362395

II.1.7. IT security regulation: data security and data protection, OCP, DRP, BCP

- Information risk management and compliance
- Security policy and control system
- Security monitoring, incident management
- Data administrator role, data security classification
- IT audit and consulting
- CMM graduation levels
- Information, development of internal organizational culture
- The concept, role and relationship of BCP, DRP and OCP

Literature:

- Teaching aids of the subject in the Moodle system: <https://oktatas.mik.uni-pannon.hu/>
- Charles J. Brooks, Cristopher Grow, Philip Craig, Donals Short: Cybersecurity Essentials, Sybex 2018, ISBN: 978-1119362395

II.1.8. Business Process Modelling (BPM): In BPMN 2.0, notation of processes, roles, and interactions between them.

- Participants and roles, using pools and lanes.
- Interactions among process steps, sequences, gateways.
- Interactions among processes, messages.
- Events, message, timer, error, escalation.

Suggested sources materials:

- Tankönyvtár: Budai Imre – System Analysis and System Design. <https://dtk.tankonyvtar.hu/xmlui/handle/123456789/2846>

- Alan Dennis, Barbara Haley Wixom, Roberta M. Roth: Systems Analysis and Design, 6th Edition, Wiley, 2015. ISBN-10: 1118897846, ISBN-13: 978-1118897843
- Scott Tilley, Harry J. Rosenblatt: Systems Analysis and Design (Shelly Cashman Series) 11th Edition, Course Technology, 2016. ISBN-10: 1305494601, ISBN-13: 978-1305494602

II.1.9. Lexical analysis

- Defining regular languages: defining a regular expression, specifying a regular definition, the concept of regular grammar, illustrative examples
- Acceptance of regular languages: definition of a non-deterministic finite state automaton, definition of a deterministic finite state automaton, list of steps by which a nondeterministic finite automaton can be created for regular expressions, list of steps by which an deterministic finite automaton equivalent to a nondeterministic finite automaton can be created

Suggested sources materials:

- Electronic teaching materials of subject Compilers: <https://oktatas.mik.uni-pannon.hu/course/view.php?id=2931>
- Stephen Chong: Compilers, Lecture 3: Lexical Analysis, <https://www.seas.harvard.edu/courses/cs153/2018fa/lectures/Lec03-Lexing.pdf>

II.1.10. Syntactic analysis

- Defining context-free languages: Definition of context-free grammar, illustrative example
- Accepting context-free languages by a pushdown automaton: definition of non-deterministic pushdown automata, creating a non-deterministic pushdown automaton for accepting a context-free grammar (example), the concept of LL (k) languages, presenting an LL (k) derivation table in an example

Suggested sources materials:

- Electronic teaching materials of subject Compilers: <https://oktatas.mik.uni-pannon.hu/course/view.php?id=2931>
- Stephen Chong: Compilers, Lecture 5: LL Parsing, <https://www.seas.harvard.edu/courses/cs153/2018fa/lectures/Lec05-LL-Parsing.pdf>

Subject Group II.2. Computer Networks

II.2.1. Basic routing concepts:

- role of static and dynamic routing protocols, convergence, route summary,
- VPN,
- IPsec, RIP,
- RIPv2,
- RIPng,
- routing protocol authentication

Literature:

- Teaching aids of the subject in the Moodle system: <https://oktatas.mik.uni-pannon.hu/>
- Diane Teare, Bob Vachon, Rick Graziani: Implementing Cisco IP Routing (ROUTE) Foundation Learning Guide, Cisco Press, 2015, ISBN-10: 1-58720-456-8, ISBN-13: 978-1-58720-456-2
- Andrew S. Tanenbaum - David J. Wetherall: Computer networks, Pearson 2012, ISBN: 978-0132553179

II.2.2. EIGRP:

- basic operation, topology table,
- best route selection, metrics, stub control,
- symmetric and asymmetric load balancing,
- EIGRP for IPv6

Literature:

- Teaching aids of the subject in the Moodle system: <https://oktatas.mik.uni-pannon.hu/>
- Diane Teare, Bob Vachon, Rick Graziani: Implementing Cisco IP Routing (ROUTE) Foundation Learning Guide, Cisco Press, 2015, ISBN-10: 1-58720-456-8, ISBN-13: 978-1-58720-456-2
- Andrew S. Tanenbaum - David J. Wetherall: Computer networks, Pearson 2012, ISBN: 978-0132553179

II.2.3. OSPF:

- Hierarchical structure and basic operation of OSPF, message types,
- DR / BDR selection, passive interfaces,
- ABR / ASBR routers, virtual links, stub and totally stubby areas,
- OSPFv3

Literature:

- Teaching aids of the subject in the Moodle system: <https://oktatas.mik.uni-pannon.hu/>
- Diane Teare, Bob Vachon, Rick Graziani: Implementing Cisco IP Routing (ROUTE) Foundation Learning Guide, Cisco Press, 2015, ISBN-10: 1-58720-456-8, ISBN-13: 978-1-58720-456-2
- Andrew S. Tanenbaum - David J. Wetherall: Computer networks, Pearson 2012, ISBN: 978-0132553179

II.2.4. BGP:

- Basic concepts and basic operation, routing between autonomous systems,
- BGP route vector, BGP tables and message types when worthwhile or not worth using, neighborhood,
- eBGP and iBGP, routing process, attributes (Next-Hop, Local-Preference, MED, Weight),
- BGP filtering

Literature:

- Teaching aids of the subject in the Moodle system: <https://oktatas.mik.uni-pannon.hu/>

- Diane Teare, Bob Vachon, Rick Graziani: Implementing Cisco IP Routing (ROUTE) Foundation Learning Guide, Cisco Press, 2015, ISBN-10: 1-58720-456-8, ISBN-13: 978-1-58720-456-2
- Andrew S. Tanenbaum - David J. Wetherall: Computer networks, Pearson 2012, ISBN: 978-0132553179

II.2.5. SpanningTree:

- standards, basic operation,
- BPDU, RootBridge selection,
- PVST +,
- RSTP,
- PortFast,
- BPDU and RootGuard,
- MST

Literature:

- Teaching aids of the subject in the Moodle system: <https://oktatas.mik.uni-pannon.hu/>
- Diane Teare, Bob Vachon, Rick Graziani: Implementing Cisco IP Routing (ROUTE) Foundation Learning Guide, Cisco Press, 2015, ISBN-10: 1-58720-456-8, ISBN-13: 978-1-58720-456-2
- Andrew S. Tanenbaum - David J. Wetherall: Computer networks, Pearson 2012, ISBN: 978-0132553179

II.2.6. VLANs:

- end-to-end and local comparison,
- role of native VLANs, trunk connections,
- DTP,
- VTP,
- routing between VLANs,
- SVI, EtherChannel

Literature:

- Teaching aids of the subject in the Moodle system: <https://oktatas.mik.uni-pannon.hu/>
- Richard Froom, Erum Frahim: Implementing Cisco IP Switched Networks (SWITCH) Foundation Learning Guide, Cisco Press, 2015, ISBN-10: 1-58720-664-1, ISBN-13: 978-1-58720-664-1
- Andrew S. Tanenbaum - David J. Wetherall: Computer networks, Pearson 2012, ISBN: 978-0132553179

II.2.7. High availability

- FHRP,
- HSRP,
- VRRP,
- GLBP

Literature:

- Teaching aids of the subject in the Moodle system: <https://oktatas.mik.uni-pannon.hu/>

- Richard Froom, Erum Frahim: Implementing Cisco IP Switched Networks (SWITCH) Foundation Learning Guide, Cisco Press, 2015, ISBN-10: 1-58720-664-1, ISBN-13: 978-1-58720-664-1
- Andrew S. Tanenbaum - David J. Wetherall: Computer networks, Pearson 2012, ISBN: 978-0132553179

II.2.8. Connected Network Security:

- RADIUS,
- TACACS +,
- Vulnerabilities,
- MAC Flood Attacks,
- Port Security,
- StormControl,
- DHCP and ARP Spoofing,
- IP SourceGuard,
- VLAN Hopping,
- PVLAN

Literature:

- Teaching aids of the subject in the Moodle system: <https://oktatas.mik.uni-pannon.hu/>
- Richard Froom, Erum Frahim: Implementing Cisco IP Switched Networks (SWITCH) Foundation Learning Guide, Cisco Press, 2015, ISBN-10: 1-58720-664-1, ISBN-13: 978-1-58720-664-1
- Andrew S. Tanenbaum - David J. Wetherall: Computer networks, Pearson 2012, ISBN: 978-0132553179

II.2.9. Messaging Systems

- The structure and elements of messaging systems, the importance of tightly coupling, examples
- The types and properties of message channels
- The different types of messages and their characterization
- The concept of pipes and filters and its application
- Possibilities of routing the messages, types of message routers and their properties
- The levels of message translation with examples
- Properties of message endpoints and their connection to the message channel

Suggested sources materials:

- Electronic teaching materials of subject Enterprise integration patterns: <https://oktatas.mik.uni-pannon.hu/course/view.php?id=3633>
- Tibor Dulai: Enterprise Integration Patterns (slides) <https://dtk.tankonyvtar.hu/xmlui/handle/123456789/2886>
- Enterprise integration patterns, Home page <https://www.enterpriseintegrationpatterns.com/>
- Gregor Hohpe, Bobby Woolf: Enterprise Integration Patterns – Designing, Building and Deploying Messaging Solutions, Addison Wesley, 2003, ISBN 0321200683

II.2.10. Messaging Channels

- Characterization of point-to-point channels, examples for their application
- The properties of publish-subscribe channels and the advantages and disadvantages of their use
- The importance of datatype channels
- The role of invalid message channel
- How to realize guaranteed delivery?
- Types and properties of channel adapters
- A complex example for a tightly coupled messaging system with the application of different types of channels

Suggested sources materials:

- Electronic teaching materials of subject Enterprise integration patterns: <https://oktatas.mik.uni-pannon.hu/course/view.php?id=3633>
- Tibor Dulai: Enterprise Integration Patterns (slides) <https://dtk.tankonyvtar.hu/xmlui/handle/123456789/2886>
- Enterprise integration patterns, Home page <https://www.enterpriseintegrationpatterns.com/>
- Gregor Hohpe, Bobby Woolf: Enterprise Integration Patterns – Designing, Building and Deploying Messaging Solutions, Addison Wesley, 2003, ISBN 0321200683

Subject Group II.3. Engineering Applications

II.3.1. Time-domain and frequency-domain representation of signals. Fourier series, Fourier Transform, Discrete Time Fourier Transform (DTFT), Discrete Fourier Transform (DFT), Fast Fourier Transform (FFT) and their properties. The z-transform and its properties.

- Time-domain and frequency-domain representation of signals.
- Fourier series, Fourier Transform, Discrete Time Fourier Transform, Discrete Fourier Transform, Fast Fourier Transform and their properties.
- The z-transform and its properties.

Recommended literature:

- Oppenheim, Schafer, Buck: Discrete-Time Signal Processing, Prentice Hall
- Orphanidis: Introduction to Signal Processing, Rutgers University, <http://www.ece.rutgers.edu/~orfanidi/intro2sp>
- Moodle course

II.3.2. Digital filters. Finite impulse response (FIR) and infinite impulse response (IIR) filters. IIR filter realizations (direct, canonical, cascade). FIR design principles. Decimation and interpolation filters.

- Basic notions of digital filters.
- Basic properties of finite impulse response and infinite impulse response filters.
- Infinite impulse response filter realizations (direct, cascade, canonical).
- Design principles for finite impulse response filters.
- Decimation and interpolation filters.

Recommended literature:

- Oppenheim, Schafer, Buck: Discrete-Time Signal Processing, Prentice Hall
- Orphanidis: Introduction to Signal Processing, Rutgers University, <http://www.ece.rutgers.edu/~orfanidi/intro2sp>
- Moodle course

II.3.3. The pinhole camera model. Calibration of the projective camera. Stereo imaging.

- The geometric model of the pinhole camera.
- Geometric transformations with homogenous coordinates.
- Intrinsic and extrinsic camera parameters.
- Transforming from world coordinates to image pixel coordinates.
- The steps of camera calibration and the role of calibration patterns, lens distortion.
- Stereo image geometry: the epipolar plane, point correspondence, rectification, estimation of the depth map.

Recommended literature:

- Kató, Czúni: Számítógépes látás, 1-3. Fejezet
- Richard Szeliski: Computer Vision, Algorithms and Applications, Chapter 11.
- Lecture slides: keplab.mik.uni-pannon.hu

II.3.4. The optical projection of motion. The elementary methods for the estimation of optical flow.

- Change detection, motion detection, motion analysis, motion field, optical flow.
- The intensity preservation principle.
- Methods for motion estimation: block-, gradient-, and feature point based methods.
- The description of motion in case of moving cameras. The aperture problem.

Recommended literature:

- Kató, Czúni: Számítógépes látás, II. Rész: Dinamikus látás
- Fortun, D., Bouthemy, P., & Kervrann, C. (2015). Optical flow modeling and computation: a survey. Computer Vision and Image Understanding, 134, 1-21.
- Lecture slides: keplab.mik.uni-pannon.hu

II.3.5. Parameter estimation based on least squares and its properties. Least squares parameter estimation for static and dynamic linear models. The unbiasedness of the estimate, the covariance matrix of the estimate. The execution of the parameter estimation: experiment design, the evaluation of the measured data, the evaluation of the quality of the estimate.

- Parameter estimation based on least squares and its properties.
- Least squares parameter estimation for static and dynamic linear models.
- The unbiasedness of the estimate, the covariance matrix of the estimate.
- The execution of the parameter estimation: experiment design, the evaluation of the measured data, the evaluation of the quality of the estimate.

Recommended literature:

- Lecture presentation: subject homepage: <https://virt.uni-pannon.hu/index.php/en/education/courses/160-parameterbecsles-vemivim133p>

II.3.6. Dynamic analysis of continuous and discrete time linear time-invariant systems: the notion and conditions of stability, observability, controllability and reachability.

- Dynamical properties of continuous and discrete-time linear time-invariant state space models: controllability, reachability, observability, stability.
- State space realizations, realization properties.
- Canonical forms, i.e. normal forms (controllability, observability and diagonal normal forms).

Recommended literature:

- Hangos-Bokor-Szederkényi: Computer Controlled Systems (Egyetemi kiadó)

II.3.7. Machine Learning: inductive learning, decision tree learning, neural networks in machine learning, back-propagation, reinforcement learning.

- Machine Learning: inductive learning, decision tree learning.
- Neural networks, perceptron, training of neural networks, error back-propagation, basics of reinforcement learning.

Recommended literature:

- Moodle course
- Stuart J. Russel –Peter Norvig: Artificial Intelligence: A Modern Approach, Prentice Hall, <http://aima.cs.berkeley.edu/>

II.3.8. Formal and graphical description of Petri nets and their operation. Solution of Petri net models, the reachability graph. Dynamic analysis of Petri net models: behavioural and structural properties.

- Formal and graphical description of Petri nets and their operation.
- Solution of Petri net models, the reachability graph and its construction algorithm.
- Dynamic analysis of Petri net models: behavioural and structural properties.

Recommended literature:

- Lecture presentation – subject homepage: <https://virt.uni-pannon.hu/index.php/en/education/courses/190-discrete-and-continuous-dynamic-systems-vemivim254e>

Subject Group II.4. Healthcare Applications

II.4.1. Noise entry points in amplifiers

- Distinction of electric and magnetic noises
- Common-mode rejection in amplifiers
- Applying negative and positive feedback in noise rejection

Suggested sources materials:

- Bronzino JD (ed) The Handbook of Biomedical Engineering, 3rd ed, CRC Press and IEEE Press, Boca Raton, FL, 2000.

- Webster JG (ed): Medical Instrumentation: Application and Design, 3rd ed. J Wiley & Sons Inc., New York, 1998.
- Gulrajani MR: Bioelectricity and Biomagnetism. J Wiley, New York, 1998.

II.4.2. Principles of indicator measurements

- Theoretical limits of determining bolus response
- The applicability of invasive blood flow measuring methods
- The applicability of non-invasive blood flow measuring methods

Suggested sources materials:

- Bronzino JD (ed) The Handbook of Biomedical Engineering, 3rd ed, CRC Press and IEEE Press, Boca Raton, FL, 2000.
- Webster JG (ed): Medical Instrumentation: Application and Design, 3rd ed. J Wiley & Sons Inc., New York, 1998.
- Hwang NHC, Norman NH (ed): Cardiovascular Flow Dynamics and Measurements, University Park Press, 1977.

II.4.3. Interpretation of measured data in computed tomography (CT)

- The definition of “projections” in image reconstruction
- The importance of one-variable Fourier transforms in image reconstruction based on Radon transform

Suggested sources materials:

- Bronzino JD (ed) The Handbook of Biomedical Engineering, 3rd ed, CRC Press and IEEE Press, Boca Raton, FL, 2000.
- Webster JG (ed): Medical Instrumentation: Application and Design, 3rd ed. J Wiley & Sons Inc., New York, 1998.
- Macowski A: Medical Imaging Systems, Prentice-Hall, Inc. Englewood Cliffs, N.J., 1983.
- Oppenheim AV, Schater RW: Digital Signal processing. Prentice-Hall Inc, Englewood Cliffs, NJ, 1975.
- Tarján I (ed): An introduction to biophysics with medical orientation, Akadémia, Budapest, 1989.

II.4.4. Positron emission tomography (PET)

- Nuclear magnetic resonance (NMR) imaging
- Differences in measuring the projections
- Applicability in the exploration of certain properties

Suggested sources materials:

- Bronzino JD (ed) The Handbook of Biomedical Engineering, 3rd ed, CRC Press and IEEE Press, Boca Raton, FL, 2000.
- Webster JG (ed): Medical Instrumentation: Application and Design, 3rd ed. J Wiley & Sons Inc., New York, 1998.
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II.4.5 Recent technologies for modeling and exchanging healthcare data

- Specific characteristics of health care related data, legal requirements and their effects on the logical database model for health care applications
- Design and application of record oriented and time series data models
- The concept of archetype based, two level healthcare messaging standards
- Overview of the reference information model of the ISO 13606 and MSZ22800 messaging standards
- The concept and structure of the ICD11 coding system, relationships between ICD11, ICD10 and BNO10, code conversion procedures

Related literature

- The ISO 13606 standard <http://www.en13606.org/information.html>
- Archetype Definition Language <https://specifications.openehr.org/releases/AM/latest/ADL1.4.html>
- ICD-11 for Mortality and Morbidity Statistics <https://icd.who.int/browse11/l-m/en>
- Catalina Martínez Costa. Clinical data interoperability based on archetype transformation <https://doi.org/10.1016/j.jbi.2011.05.006>

II.4.6 Security and anonymity of health data, auditing databases

- Specific characteristics of health care related data, legal requirements and their effects on the data security design for health care applications
- Challenges related to data anonymization, overview of widely used methods for data anonymization
- A data anonymization case study
- MS SQL Server audit architecture, the objective, definition and monitoring of an audit

Related literature

- Z. Alexin. Does fair anonymization exist? <http://dx.doi.org/10.1080/13600869.2013.869909>
- Understanding the SQL Server Audit <https://www.sqlshack.com/understanding-sql-server-audit/>
- SQL Server Audit (Database Engine) <https://docs.microsoft.com/en-us/sql/relational-databases/security/auditing/sql-server-audit-database-engine?view=sql-server-ver15>
- SQL Server Audit Records <https://docs.microsoft.com/en-us/sql/relational-databases/security/auditing/sql-server-audit-records?view=sql-server-ver15>