PAKISTAN INSTITUTE OF ENGINEERING AND APPLIED SCIENCES
Department of Computer and Information Sciences (DCIS)

MS Program in Computer Science (CS)

Fields of Specialization

1	Computational Intelligence and Machine Vision
2	Scientific Computing
3	Information System Security

Semester-Wise Course Plan (Fellows)

FR: Fellowship Requirement, **IR:** Institutional Requirement, **C**: Core, **O**: Optional

No.	Course Title	Cr. Hrs.	Course Status	Credit Hours
SPRING SEMESTER – YEAR 1				
1	Communication Skills	1	IR	**13**
2	Algorithms Design	3	C	
3	**Optional-1**	3	O	
4	**Optional-2**	3	O	
5	**Optional-3**	3	O	
SUMMER SESSION – YEAR 1				
1	**Fellowship Requirement - I**	3	FR	**6**
2	**Fellowship Requirement - II**	3	FR	
FALL SEMESTER – YEAR 1				
1	Theory of Computation	3	C	**12**
2	**Optional-4**	3	O	
3	**Optional-5**	3	O	
4	**Optional-6**	3	O	
SPRING SEMESTER - YEAR 2				
1	Thesis Research	6	C	**6**
SUMMER SEMESTER - YEAR 2				
1	Thesis Research	6	C	**6**

*FR = Any repeated or specialized course based on basic degree, probable placement, future assignment, etc.

Total Credit Hours = 37+6

Semester-Wise Course Plan (Non-Fellows)

IR: Institutional Requirement, **C**: Core, **O**: Optional

No.	Course Title	Cr. Hrs.	Course Status	Credit Hours
SPRING SEMESTER – YEAR 1				
1	Communication Skills	1	IR	**13**
2	Algorithms Design	3	C	
3	**Optional-1**	3	O	
4	**Optional-2**	3	O	
5	**Optional-3**	3	O	
FALL SEMESTER – YEAR 1				
1	Theory of Computation	3	C	**12**
2	**Optional-4**	3	O	
3	**Optional-5**	3	O	
4	**Optional-6**	3	O	
SPRING SEMESTER - YEAR 2				
1	Thesis Research	6	C	**6**
SUMMER SEMESTER - YEAR 2				
1	Thesis Research	6	C	**6**

Total Credit Hours = 37

Semester-Wise Optional Courses

FR: Fellowship Requirement, **IR:** Institutional Requirement, **C**: Core, **O**: Optional

S. No.	Course Code	Course Title	Cr. Hrs.	Course Status	Pre-requisites *
SPRING SEMESTER – YEAR 1					
COMPUTATIONAL INTELLIGENCE AND MACHINE VISION					
1	CIS-525	Pattern Classification and Recognition	3	O	NIL
2	CIS-526	Digital Image Processing and Analysis	3	O	NIL
3	CIS-529	Bio Informatics	3	O	NIL
4	CIS-530	Artificial Intelligence	3	O	NIL
5	CIS-595	Special Topics in CIMV-I	3	O	
SCIENTIFIC COMPUTING					
6	CIS-542	Optimization Techniques	3	O	NIL
7	CIS-546	Parallel Computing	3	O	NIL
8	PAM-568	Numerical Solution of Differential Equations	3	O	NIL
9	CIS-596	Special Topics in SC-I	3	O	
INFORMATION SYSTEM SECURITY					
10	CIS-564	Computer System Security	3	O	NIL
11	CIS-567	Cryptography	3	O	NIL
12	CIS-568	Network Security	3+1	O	NIL
13	CIS-597	Special Topics in ISS-I	3	O	

SUMMER SESSION – YEAR 1					
14	-	Fellowship Requirement - I	3	FR	
15	-	Fellowship Requirement - II	3	FR	

FALL SEMESTER – YEAR 1					
COMMON COURSES					
16	CIS-502	Stochastic Processes	2	O	NIL
17	CIS-550	Advanced Computer Architecture	3	O	NIL
18	CIS-551	Advanced Operating Systems	3	O	NIL
19	NE-501	Fundamentals of Nuclear Engineering	3	IR	
COMPUTATIONAL INTELLIGENCE AND MACHINE VISION					
20	PAM-524	Linear Algebra	3	O	NIL
21	EE-508	Computational Intelligence	3	O	NIL
22	CIS-521	Soft Computing	3	O	NIL
23	CIS-522	Human Computer Interaction	3	O	NIL
24	CIS-523	Evolutionary Computing	3	O	NIL
25	CIS-524	Information Retrieval and Data Mining	3	O	NIL
26	CIS-527	Natural Language Processing	3	O	NIL
27	CIS-528	Knowledge Engineering	3	O	NIL
28	CIS-531	Medical Image Processing	3	O	NIL
29	CIS-532	Graphics and Visualization	3	O	NIL
30	CIS-534	Applied Bioinformatics	2+1	O	NIL
31	CIS-543	GPU Computing	3	O	NIL
32	CIS-621	Machine Learning	3	O	NIL
33	CIS-622	Machine Learning in Bioinformatics	3	O	CIS-525 or Equivalent, CIS-529
34	CIS-623	Biometrics Computing	3	O	NIL
35	CIS-624	Machine Vision	3+1	O	NIL
36	CIS-625	Computational Bio-molecular Design	3	O	NIL
37	CIS-627	Deep Neural Networks	3	O	CIS-521/525/526 or equivalent
38	CIS-630	Advanced Evolutionary Computing	3	O	CIS-523
39	CIS-631	Intelligent Watermarking Techniques	3	O	NIL
40	CIS-642	Virtual Reality	3	O	CIS-526/532

41	CIS-643	Mobile Vision	3	O	NIL
42	CIS-695	Special Topics in CIMV-II	3	O	
SCIENTIFIC COMPUTING					
43	PAM-524	Linear Algebra	3	O	NIL
44	CIS-532	Graphics and Visualization	3	O	NIL
45	CIS-541	Cloud Computing	3	O	NIL
46	CIS-544	Monte Carlo Simulations	3	O	NIL
47	CIS-548	Computer Animation	3	O	NIL
48	CIS-549	Finite Element Computations	3	O	PAM-568
49	CIS-555	Cluster System Management	2+1	O	NIL
50	PAM-585	Numerical Methods and Optimization Techniques	3	O	NIL
51	CIS-641	Grid Computing	3	O	NIL
52	CIS-645	Parallel Algorithms	3+1	O	CIS-546
53	CIS-646	Advanced Optimization Techniques	3	O	PAM-542
54	CIS-696	Special Topics in SC-II	3	O	
INFORMATION SYSTEM SECURITY					
55	CIS-552	Advanced Database Systems	3	O	NIL
56	CIS-562	Information Theory and Coding	3	O	NIL
57	CIS-563	Essential Mathematics for Cryptography	3	O	NIL
58	CIS-565	Information System Security Management	3	O	NIL
59	CIS-566	Auditing and Risk Management	3	O	NIL
60	CIS-569	Public Key Infrastructure	3	O	NIL
61	CIS-570	Digital Watermarking and Its Applications	3	O	NIL
62	CIS-571	Digital Forensics	3	O	NIL
63	CIS-661	Data Warehousing	3	O	NIL
64	CIS-662	Cryptanalysis	3	O	CIS-567
65	CIS-663	Secure Software Development	3	O	NIL
66	CIS-664	Mobile System Security	3	O	NIL
67	CIS-665	Embedded System Security	3	O	CIS-567
68	CIS-666	Formal Methods for Information Security	3	O	NIL
69	CIS-667	Network Security Monitoring	3	O	CIS-568
70	CIS-668	Security and Privacy in Cloud Computing	3	O	CIS-541
71	CIS-697	Special Topics in ISS-II	3	O	

SPRING SEMESTER - YEAR 2					
72	CIS-698	MS Thesis Research***	6	C	Relevant courses in previous semester

SUMMER SEMESTER - YEAR 2					
COMMON FOR THREE SPECIALIZATIONS					
73	CIS-698	MS Thesis Research***	6	C	Relevant courses in previous semester

* Condition of pre-requisites may be relaxed in special cases by the Head, DCIS, on the recommendation of instructor concerned.
** Fellowship requirement refer to any repeated or specialized course based on basic degree, probable placement, future assignment, etc.
*** MS thesis will be graded as Excellent, Very Good, Good, Fair or Unsatisfactory.

Note:

- Registered students of this program may register in courses offered by MS programs in other disciplines at PIEAS, if allowed by the Head, DCIS.

Course Contents

CMS-501: Communication Skills

Status	Institutional Requirement
Credits	1
Prerequisites	Nil

Writing module: Preparation of a project proposal or technical report, writing letters, mission statements, office memos etc; Speaking module: Presentation of the project proposal or technical report; Listening module: Simulations of interviews, lectures and question-answer sessions; Reading module: Reading of a suitable fiction novel (approximately 30-50 pages a week) with the use of vocabulary support, completion of assigned tasks and discussions.

References

1. Eric H. G., and Glendinning N., *English for Electrical and Mechanical Engineering*, Oxford University Press, 1995.
2. Huckin T. N., and Oslen L.A., *Technical Writing and Professional Communication for Nonnative Speakers of English*, 2nd Edition, McGraw Hill, 1991.
3. Swales J. M., and Feak C. B., *Academic Writing for Graduate Students, A Course for Nonnative Speakers of English*, 3rd Edition, Uni. of Michigan Press, 1994.

NE-501: Fundamentals of Nuclear Engineering

Status	Institutional Requirement
Credits	3
Prerequisites	Nil

Role and importance of nuclear energy; Nuclear cross-sections; Reaction rates; Nuclear fission and chain reaction; Criticality conditions; Conversion and breeding, Reactor components and their characteristics; Classification and design features of research, production, and power reactors, Introduction to fast and fusion reactor systems; Different types of fuel cycles; Core and feed-material preparations; Uranium enrichment; Fabrication of fuel; Reprocessing of irradiated fuel; Process waste disposal; Reactor fuel requirements; Burnup studies of nuclear fuels; Fuel cycle performance of commercially available reactors; In-core fuel management and fuel management strategies.

References:

1. Lamarsh, J. R, *Introduction to Nuclear Engineering*, Addison-Wesley, 1983.
2. Glasstone, S. and A. Sesonske, *Nuclear Reactor Engineering*, D Van Nostrand, 1981.
3. Rahman, I. U. and Sheikh P. S., *Introduction to Nuclear Engineering*, Krieger, 1981.
4. Graves H. W. Jr., *Nuclear Fuel Management*, John Wiley, 1979.

CIS-502: Stochastic Processes

Status	Optional
Credits	2
Prerequisites	Nil

Random variables and their types; Discrete and continuous random variables; Distribution and Density function; Cumulative distribution function; Independence; Conditional distributions; Expectations; Limit theorem; Functions of random variables; Multiple random variables; Gaussian processes; Continuous time stochastic processes; Discrete time stochastic process; Markov chains; Hidden Markov model.

References

1. Yates R. D. and Goodman D. J., *Probability and Stochastic Processes: A Friendly Introduction for Electrical and Computer Engineers*, John Wiley & Sons, 2004.
2. Papoulis A. and Pillai S. U., *Probability, Random Variables and Stochastic Processes* 4th ed., McGraw-Hill, 2002.
3. Stark 1. H. and Woods J., *Probability, Random Processes and Estimation Theory for Engineers,* 2nd ed., Prentice-Hall, 1994.
4. Garcia L. A., *Probability and Random Processes for Electrical Engineers*, 2nd ed., Addison-Wesley, 1994.

CIS-504: Algorithms Design

Status	Core
Credits	3
Prerequisites	Nil

Review of algorithmic basics; Brute force and divide & Conquer approaches; Dynamic programming: Optimization, Matrix chain multiplication, Assembly-line scheduling, Knapsack problem, Longest common subsequence, Optimal binary search trees; Greedy algorithms: Activity selection, Fractional Knapsack, Huffman coding problem; Graph algorithms: Review of basic graph algorithms, All-pairs shortest paths, Floyd-Warshall algorithm, Johnson's algorithm; Network flow: Bipartite matching, Hopcroft-Karp paths, Ford-Fulkerson algorithm, Edmonds-Karp algorithm, String algorithms: Rabin-Karp algorithm, Finite automaton algorithm, Knuth-Moris-Pratt algorithm; Polynomials and Fast Fourier Transform: Matrix multiplication on polynomials, The Discrete Fourier Transform (DFT) and Fast Fourier Transform (FFT); NP completeness: Circuit satisfiability, 3-CNF, Cliques; Approximation algorithms: Vertex-cover and TSP, 1.5-approximation set-cover; Randomized algorithms: Randomized max 3-SAT, Probabilistic Maxcut, Derandomization of MST, Randomized median; Geometric algorithms: convex hull, segment intersection, closest-pair, voronoi, flip algorithm.

References

1. Kleinberg J., and Tardos É., *Algorithm Design*, Pearson, 2006.
2. Sedgewick R., and Wayne K., *Algorithms*, 4th ed., Addison-Wesley, 2012.
3. Cormen T. H., Leiserson C. E., Rivest R. L., and Stein C., *Introduction to Algorithms*, 3rd ed., MIT Press, 2009.
4. Skiena S., *The Algorithms Design Manual*, 2nd ed., Springer, 2008.

CIS-505: Theory of Computation

Status	Core
Credits	3
Prerequisites	Nil

Automata theory; Formal languages; The pigeonhole principle; Turing machines; Context-free grammars; Parsing and ambiguity; Recursively enumerable languages; Unrestricted grammars; The Chomsky hierarchy; Computability theory and reducibility; Randomness; Determinism; Non-determinism; Time hierarchy; Space hierarchy; Recursive functions; The Ackermann's Function and its inverse; P and NP completeness.

References

1. Sipser M., *Introduction to the Theory of Computation*, 3rd ed., Cengage Learning, 2012.
2. Rosenberg A. L., *The Pillars of Computation Theory: State, Encoding, Nondeterminism*, Springer, 2009.
3. Puntambekar A. A., *Theory of Computation*, Technical Publications, 2009.
4. Kozen D. C., *Theory of Computation*, Springer, 2006.

EE-508: Computational Intelligence

Status	Optional
Credits	3
Prerequisites	Nil

Basic concepts of computational intelligence; Single-layer and multi-layer feedforward neural networks; Feedback and recurrent neural networks; Learning vector quantizer (lvq); Self-organizing feature maps; Radial basis function neural networks; Support Vector Machines; Genetic algorithms, Genetic programming; Fuzzy sets and fuzzy logic, Fuzzy neural networks; Swarm intelligence and Ant colony optimization, Hidden Markov Models.

References

1. Engelbrecht, A. P., *Computational Intelligence: An Introduction*, 2nd Ed., Wiley, NY, 2007.
2. Hastie, T., Tibshirani, R., and Friedman, J., *The Elements of Statistical Learning*, 3rd Ed., Springer, 2009.
3. Zurada, J., *Introduction to Artificial Neural Systems*, West Publishing Company, St. Paul, 1992.

CIS-521: Soft Computing

Status	Optional
Credits	3
Prerequisites	Nil

Introduction to Soft Computing; Artificial Neural Networks: Biological and artificial neurons, Supervised, Unsupervised and Competitive Learning paradigms, perceptron and multilayer perceptron; Backpropagator, Radial Basis Functions, SOFM; Fuzzy Inference Systems: Fuzzy sets and fuzzy logic, Fuzzy operators and Fuzzy systems, knowledge base, inference engine; Evolutionary Algorithms: Genetic Algorithm, Genetic Programming, Differential Evolution, Cultural Algorithms; Swarm Intelligence: Particle Swarm Optimization, Ant Colony Optimization, Artificial Bee Colony optimization, Bat Algorithm, Predator-Prey Optimization; Imperialistic Competitive optimization; Tabu Search; Simulated Annealing; Support vector Machine; Hybrid Intelligent Systems; Applications of soft computing in pattern recognition and image processing.

References

1. Kecman, Vojislav., *Learning and soft computing: support vector machines, neural networks, and fuzzy logic models*, MIT press, 2001.
2. Goldberg E. D., *Genetic Algorithms in Search, Optimization, and Machine Learning*, 1st edition, Addison-Wesley, 1989.
3. Engelbrecht A. P., *Computational Intelligence: An Introduction*, 2nd Edition, Wiley, New York, 2007.
4. Haykin S., *Neural Networks: A comprehensive Foundation*, 2nd Edition Pearson Education Press, 1998.
5. Banzhaf W., Francone D. F., Keller E. R., Nordin P., *Genetic Programming: An Introduction on the Automatic Evolution of Computer Programs and its Applications*, Morgan Kaufmann Publishers, San Francisco, CA, 1998..

CIS-522: Human Computer Interaction

Status	Optional
Credits	3
Prerequisites	Nil

Overview of Human Computer Interaction (HCI); Human capabilities: Perception, Memory, Cognition; Human diversity; Input devices and interaction techniques; Decision making; HCI tasks and metrics; Models of design: Goals Operators Methods Selection rules (GOMS), Keystroke Level, and Norman's 7 Stages; Principles and rules for interface verification, testing, and evaluation; Designing and building visual interfaces, multimodal interfaces, and perceptual interfaces.

References

6. Preece J., Rogers Y., Sharp H., Benyon D., Holland S., and Carey T., *Human-Computer Interaction: Concepts and Design*, Addison Wesley, 1994.
7. Rogers Y., Sharp H., and Preece J., *Interaction Design: Beyond Human - Computer Interaction*, 3rd ed., Wiley, 2011.
8. Shneiderman B., and Plaisant C., *Designing the User Interface: Strategies for Effective Human-Computer Interaction*, 5th ed., Addison Wesley, 2009.
9. Dix A. J., Finlay J. E., Abowd G. D., and Beale R., *Human-Computer Interaction*, 3rd ed., Prentice Hall, 2004.

CIS-523: Evolutionary Computing

Status	Optional
Credits	3
Prerequisites	Nil

Issues in classical optimization techniques; Introduction to evolutionary computation: Principles of evolutionary processes, Genetic algorithms, Genetic Programming, Evolutionary programming, Evolutionary strategies; Representation of data; Selection methods; Search operators; Fitness evaluation; Constraint handling techniques; Population structure; Meta evolutionary approaches; Self-adaptation; Implementation issues.

References

1. Eiben E. A. and Smith, E. J., *Introduction to Evolutionary Computing*, Natural Computing Series, Springer, 2010.
2. Adrieas P. E., *Computational Intelligence: An Introduction*, 2nd ed., John Wiley & Sons, 2007.
3. Baeck T., *Evolutionary Computation*, Vol. 1 and 2, Taylor & Francis, 2000.
4. Jin Y. C. (Ed.), *Knowledge Incorporation in Evolutionary Computation*, Springer, 2005.
5. Poli R., Langdon B. W. and McPhee F. N, *A Field Guide to Genetic Programming*, Lulu Enterprises, UK Ltd, 2008.

CIS-524: Information Retrieval and Data Mining

Status	Optional
Credits	3
Prerequisites	Nil

Overview of structure of data systems, Basics of Information Retrieval (IR) and Data Mining; Ranking principles: Boolean IR, TF-IDF (Term frequency-Inverted document frequency), IR evaluation, Probabilistic IR, BM25, Statistical language models, latent topic models, Relevance feedback, novelty & diversity; Indexing and searching: Inverted lists, Merging vs. hashing, Index compression, Top-k query processing; Kernel methods for information retrieval; Information extraction (IE): Rule- and learning-based extraction, HMMs, Entity reconciliation, Knowledge base construction, Open-IE; Graph Mining: Centrality, random graphs, and frequent subgraph mining; Two matrix factorization methods.

References

1. Manning C. D., Raghavan P. and Schuetze H., *Introduction to Information Retrieval*, Cambridge University Press, 2008.
2. Baeza Yates R., Ribeiro Neto R., *Modern Information Retrieval: The concepts and technology behind search*, Addison-Wesley, 2010.
3. Croft W. B., Metzler D., Strohman T., *Search Engines: Information Retrieval in Practice*, Addison-Wesley, 2009.
4. Zaki M. J. and Meira Jr. W., *Data Mining and Analysis: Fundamental Concepts and Algorithms*, Cambridge University Press, 2014.
5. Han J. and Kamber M., *Data Mining: Concepts and Techniques*, 3rd Edition. Morgan Kaufmann, 2012.
6. Tan P., Steinbach M., Kumar V., *Introduction to Data Mining*, Addison-Wesley, 2006.

PAM-524: Linear Algebra

Status	Optional
Credits	3
Prerequisites	Nil

Basics of linear algebra: Gaussian elimination and matrices, two-point boundary value problems, ill-conditioned systems, homogeneous & non homogeneous systems, electrical circuits, matrix algebra, matrix inversion, factorization, elementary matrices & equivalence, determinants and its properties; Vector spaces: spaces and subspaces, four fundamental subspaces, linear independence, basis and dimension, classical least squares, change of basis and similarity, invariant subspaces, linear transformations, normed spaces, metric vector spaces, metric spaces, Hilbert spaces, complex vector spaces and its properties; Norms, inner products, and orthogonality: vector & matrix norms, inner-product spaces, complex inner product spaces, orthogonal vectors, Gram–Schmidt procedure, unitary and orthogonal matrices, orthogonal reduction, discrete Fourier transform, complementary subspaces, range-nullspace decomposition, orthogonal decomposition, singular value decomposition, orthogonal projection, angles between subspaces; Eigenvalues and eigenvectors: elementary properties of eigen system, diagonalization by similarity transformations, functions of diagonalizable matrices, systems of differential equation, normal matrices, positive definite matrices, nilpotent matrices and Jordan structure, functions of nondiagonalizable matrices, difference equations, limits, and summability, minimum polynomials and Krylov methods; Perron–Frobenius theory: Introduction, positive matrices, nonnegative matrices, stochastic matrices and Markov chain.

References

1. Meyer, C.D., *Matrix Analysis and Applied Linear Algebra*, 3rd Ed., siam, 2000.
2. Lay D.C., *Linear Algebra and Its Applications*, 3rd Ed., Pearson Addison-Wesley, 2006.
3. Anton H. and Rorres C., *Elementary Linear Algebra with Applications*, 9th Ed., John Wiley & Sons, 2005.
4. Strang G., *Linear Algebra and Its Applications*, 3rd Ed., Wellesley-Cambridge Press, 1988.

CIS-525: Pattern Classification and Recognition

Status	Optional
Credits	3
Prerequisites	Nil

Basic concepts; Linear and piece-wise linear classification techniques; Potential and stochastic approximation; Boolean and sequential decision making; Contextual; Linguistic and array techniques; Coefficient analysis; Pattern preprocessing and feature selection; Learning decision functions; Pattern classification by distance functions; Bayesian classification; Estimation of Densities; Pattern classification by likelihood functions; Trainable pattern classifiers; Deterministic and stochastic approach; Syntactic pattern recognition.

References

1. Theodoridis S., and Koutroumbas K., *Pattern Recognition*, 4th ed., Elsevier Inc., 2009.
2. Devroye L., Györfi L. and Lugosi G., *A Probabilistic Theory of Pattern Recognition*, Springer Verlag, 1997.
3. Duda R.O., Hart P. E. and Stork D. G., *Pattern Classification*, 2nd ed., John Wiley & Sons, 2001.
4. Tou J.T. and Gonzales R.C., *Pattern Recognition Principles*, Addison-Wesley, MA, 1981.
5. Bishop C. M., *Neural Networks for Pattern Recognition*, Clarendon Press-Oxford Press, 1996.

CIS-526: Digital Image Processing and Analysis

Status	Optional
Credits	3
Prerequisites	Nil

Image processing fundamentals: Visual perception, Image sensing and quantization; Digital image enhancement: spatial and frequency domain enhancement, histogram processing, smoothing and sharpening filters; Color Image Processing: Colors models and transformations; Wavelets and multi-

resolution processing; Image compression: compression models, Lossy and lossless compressions; Morphological image processing; Image segmentation: Thresholding and region based segmentation.

References

1. Gonzolez R. C., and Woods R. E., *Digital Image Processing*, 3rd ed., Addison Wesely, 2008.
2. Umbaugh S. E., *Digital Image Processing and Analysis: Human and Computer Vision Application with CVIPtools*, 2nd ed, CRC Press, 2011.
3. Marques O., *Practical Image and Video Processing Using MATLAB*, Wiley/IEEE Press, 2011 .
4. Seul M., O'Gorman L., and Sammon M. J., *Practical Algorithms for Image Analysis*. 2nd ed, Cambridge University Press, 2008.
5. Gonzolez R. C., Woods R. E., and Eddins S. L., *Digital Image Processing using Matlab*, Pearson Education, 2004.

CIS-527: Natural Language Processing

Status	Optional
Credits	3
Prerequisites	Nil

Introduction to various fields of NLP; Challenges in NLP; Language characteristics and ambiguities; Linguistic NLP; Language modeling: Morphology, Syntax, Phonology, Phonetics, Semantics; Statistical NLP: Zipf's Law, N-gram models, Parameter estimation, Lexicon - word classes and tagging, Parsing: Deterministic parsing, Statistical methods of parsing; Combined linguistic and statistical approaches for NLP; Evaluation of NLP applications.

References

1. Manning C. D., and Schütze H., *Foundations of Statistical Natural Language Processing*, MIT Press, 1999.
2. Jurafsky D., and Martin J. H., *Speech and Language Processing: An Introduction to Natural Language Processing, Computational Linguistics, and Speech Recognition*, Prentice Hall**,** 2009.
3. Jackson P., and Moulinier I., *Natural Language Processing for Online Applications: Text Retrieval, Extraction, and Categorization*, 5th ed., John Benjamins Publishing Company, 2002.

CIS-528: Knowledge Engineering

Status	Optional
Credits	3
Prerequisites	Nil

Knowledge engineering and knowledge systems; Historical perspective; Methodological pyramid principles; Model suite; Process roles; Impact and improvement analysis; Task and agent modeling; Guidelines for the context modeling process; Knowledge management; Knowledge model components; Knowledge model construction; Knowledge elicitation techniques and characteristics; Modeling communication aspects; Role and overview of the communication model; Designing knowledge systems.

References

1. Sowa J. F., *Knowledge Representation: Logical, Philosophical, and Computational Foundations*, Brooks Cole Publishing Co., 1999.
2. Brachman R. and Levesque H., *Knowledge Representation and Reasoning*, Morgan Kaufmann, 2004.
3. Schreiber G. and Akkermans H., *Knowledge Engineering and Management: The CommonKADS Methodology*, The MIT Press, 1999.
4. Gonzalez A. J. and Dankel D. D., *The Engineering of Knowledge-Based Systems*, Prentice Hall, 1993.
5. Poole D., Mackworth A. and Goebel R., *Computational Intelligence: A Logical Approach*, Oxford University Press, 1998.

CIS-529: Bio Informatics

Status	Optional
Credits	3
Prerequisites	Nil

Introduction to bioinformatics: biological sequence, DNA, RNA, submitting DNA sequences to the database; Phylogenetic and mutation studies; Proteins-only submission; Sequence types and genome centers; Protein Structure: Introduction to structures, Protein data banks, Structure file formats, visualizing structural information, structure similarity searching; Sequence Alignment: evolutionary basics of sequence alignments, FASTA, BLAST, Multiple alignment; Proteins identity based on composition, Motifs and Patterns; EST; TIGR Gene indices; STACK; GENE prediction; Protein subcellular Localization; Systems Biology.

References

1. Lesk A., *Introduction to Bioinformatics*, Oxford University Press, 3rd ed., 2008.
2. Jones N. C., and Pevzner A. P., *An Introduction to Bioinformatics Algorithms*, MIT Press, 2004.
3. Pevsner j., *Bioinformatics and Functional Genomics*, 2nd ed., Wiley-Blackwell, 2009.
4. Agostino M., *Practical Bioinformatics*, Garland Science, 2012.

CIS-530: Artificial Intelligence

Status	Optional
Credits	3
Prerequisites	Nil

Fundamentals of AI, Uninformed, heuristic and local search, Constraint Satisfaction Problems, Intelligent Game Programming, Propositional and First Order Logic Agents, Probabilistic Reasoning, Automatic Planning and Scheduling, Learning from Data.

References

1. Russell S. J. and Norvig P., *Artificial Intelligence: A Modern Approach*. Prentice Hall, 2010.
2. Bratko, *Prolog Programming for Artificial Intelligence*, 4th edition, Pearson Education Canada, 2011.
3. Millington and Funge J., *Artificial Intelligence for Games*, 2nd edition. Burlington, MA: CRC Press, 2009.
4. Heaton J., *Artificial Intelligence for Humans*, Volume 1: Fundamental Algorithms, CreateSpace Independent Publishing Platform, 2013.

CIS-531: Medical Image Processing

Status	Optional
Credits	3
Prerequisites	Nil

Sources of medical images (X-ray, CT, MRI, PET and Ultrasound); Medical image formats (DICOM, PACS, etc.); Medical image Analysis: Enhancement, Registration, Segmentation and Transformation of medical images, reconstruction methods; Medical image classification and computer aided diagnoses; Protection and Authentication of medical images; Medical image compression and communication; Functional imaging; Neuro imaging; Tele radiology; Tele diagnosis.

References

1. Birkfelln W., *Applied Medical Image Processing: A Basic Course*, Taylor & Francis , 2010.
2. Epstein C. L., *Introduction to the Mathematics of Medical Imaging*, Prentice Hall, 2003.
3. Fitzpatrick J.M., and Sonka M., *Handbook of Medical Imaging*, Society of Photo Optical, 2000.
4. Gonzalez R. C., and Woods R. E., *Digital Image Processing*, 3rd ed., Prentice Hall, 2007.

CIS-532: Graphics and Visualization

Status	Optional
Credits	3
Prerequisites	Nil

Applications of visualization; Object representation and modeling; Graphics libraries: Graphics functions, Basics of OpenGL; Basic raster graphics output primitives: Coordinate specifications, Rasterization algorithms, Drawing points, lines, curves, and filled areas; Projection and viewing geometric transformations; Polygonal geometries: Classification of polygons, Inside-outside tests, Front and back polygon faces; Culling and hidden surface removal; Geometry subdivision; Color and illumination models.

References

1. Theoharis T., Papaioannou G., Platis N., Patrikalakis N.M., *Graphics and Visualization: Principles & Algorithms*, A.K.Peters/CRC Press, 2008.
2. Hearn D. D., Baker M. P., and Carithers W., *Computer Graphics with OpenGL*, 4th ed., Pearson, 2010.
3. Angel A., *OpenGL: A Primer*, 3rd ed., Addison-Wesley, 2007

CIS-534: Applied Bioinformatics

Status	Optional
Credits	2+1
Prerequisites	Nil

Introduction to Genomics, Primer on molecular biology, Introduction to Linux and Python Scripting, Sequence Databases (Uniprot, Swissprot etc.). Bioinformatics work environments: UGENE, Galaxy, Sequence alignments (Local and global alignments, BLAST and FASTA), Multiple Sequence alignments: CLUSTAL, MUSCLE, T-Coffee, Sequence based remote homology detection: PSI-BLAST, HH-BLITS, Phylogenetic analysis: MEGA, Introduction to Next Generation Sequencing, Denovo Assembles: CLC Bio, Violet, SOAP denovo, Short read Alignments: Bowtie, Genome visualization: SpliceGrapher, Exome sequencing, SNP calling, Introduction to RNA-Seq Alignment Tools: TopHat, Cufflinks, Alternative Splicing Prediction (optional): SpliceGrapher, Differential expression analysis: DESeq, edgeR, Introduction to protein sequence-structure-function relationship, Protein structure prediction tools: Homology modeling (SWISS-Model), I-TASSER, Protein Redesign, Rosetta Modeling or SHARPEN, Solvers for protein design, protein energetics, Molecular energetics, GROMACS.

References

1. Keating A., *Methods in protein design*, Academic Press, 2013.
2. Guerois R., Manuela L. , Paz la., *Protein Design: Methods and Applications,* No. 340. Springer Science & Business Media, 2006.
3. Sidhartha Chaudhury, *Interactive platform for protein structure prediction and design*, Lulu Publishers , 2010.
4. Agostino Michael, *Practical bioinformatics*, Garland Science, 2012.
5. Pevzner P. and Ron S., *Bioinformatics for biologists*, Cambridge University Press, 2011.
6. Tore Samuelsson, *Genomics and Bioinformatics: An Introduction to Programming Tools for Life Scientists*, Cambridge University Press; 2012.
7. Phillip C., Pavel P., *Bioinformatics Algorithms: An Active Learning Approach*, Active Learning Publishers 2014.
8. David Whitford, *Proteins: Structure and Function*, 2013

CIS-541: Cloud Computing

Status	Optional
Credits	3
Prerequisites	Nil

Cloud computing: Overview, Cloud types, Cloud deployment models; Cloud computing architecture: Software as a Service (SaaS), Service-Oriented Architecture (SOA), Cloud Architectures SOA, Platform as a Service (PaaS), Infrastructure as a Service (laaS), Identity as a Service (lDaaS); Data Storage in the Cloud; Virtualization: Characteristics, Taxonomy, Technology examples; Cloud security; Disaster recovery in cloud; Managing the cloud; Migrating to the cloud; Designing and coding cloud-based applications; Cloud and mobile devices; Application scalability; Future trends.

References

1. Velte A. T., Velte T. J., and Elsenpeter R., Cloud Computing: *A Practical Approach*, McGraw-Hill, 2010.
2. Jamsa K., *Cloud Computing: SaaS, PaaS, IaaS, Virtualization, Business Models, Mobile, Security and More*, Jones & Bartlett Learning, 2013.
3. Rittinghouse J. W., and Ransome J. F., *Cloud Computing: Implementation, Management, and Security*, CRC Press, 2010.

CIS-542: Optimization Techniques

Status	Optional
Credits	3
Prerequisites	Nil

Introduction to optimization techniques; Linear programming: the simplex method, duality in linear programming, sensitivity analysis; One variable optimization: search methods, polynomial approximations, Golden Section method; Unconstrained optimization techniques: zero-order methods, first-order methods, second-order methods, convergence criteria; Constrained optimization techniques: Direct methods: random search, sequential linear programming, the method of feasible directions, generalized reduced gradient method, sequential quadratic programming; Indirect methods: penalty function methods, augmented lagrange multiplier method; Integer linear programming.

References

1. Reklaitis G. B., Ravindran A., and Ragsdell K. M., *Engineering Optimization Methods and Applications*, 2nd ed., John Wiley & Sons, 2006.
2. Singiresu S. Rao, *Engineering Optimization: Theory and Practice*, 4th ed., John Wiley & Sons, 2009.
3. Taha H. A., *Operations Research: An introduction*, 9th ed., Pearson Education, 2010.

CIS-543: GPU Computing

Status	Optional
Credits	3
Prerequisites	Nil

Parallel Computing Platforms, Parallel Computing Performance Metrics, Parallel Programming Libraries, GPUs as Parallel Computers, GPU Programming Model, GPU Hardware and Parallel Communication, Parallel Algorithms, NVIDIA/AMD GPU, Basics of GPU Programming, GPU memory model, Control flow in GPU, Floating point precision in GPU, Debugging and profiling of GPU programs, Performance optimization on GPUs, Transforming algorithms to GPUs, Advanced algorithmic implementations on GPUs.

References

1. Kirk David B., and W. Hwu Wen-mei, *Programming massively parallel processors: a hands-on approach*, Newnes, 2012.
2. Sanders J. Edward K., *CUDA by example: an introduction to general-purpose GPU programming*, Addison-Wesley Professional, 2010.
3. Scarpino Matthew, *Opencl in Action: How to Accelerate Graphics and Computation*, Manning Publication, 2012.
4. Gaster Benedict, *Heterogeneous Computing with OpenCL: Revised OpenCL 1*, Newnes, 2012.

CIS-544: Monte Carlo Simulations

Status	Optional
Credits	3
Prerequisites	Nil

Overview of Monte Carlo Methods; Types of Randomness; Uniform Random Number Generators; Randomness Tests; Review of Discrete and Continuous Probability Distributions; Discrete Random Variate Generation; Continuous Random Variate Generation; Monte Carlo Evaluation of Finite-Dimensional Integrals; Variance Reduction Techniques; Markov Chain Monte Carlo: Discrete Markov Chains, Metropolis Algorithm, Ising Model, Random Walks, Brownian Motion; Optimization by Monte Carlo Methods: Simulated Annealing, Genetic Algorithms; Optimization Applications.

References

1. Kalos, M. H. and Whitlock P. A., *Monte Carlo Methods*, 2nd ed., Wiley-VCH, 2008.
2. Ronald W. Shonkwiler,Franklin Mendivil,., *Explorations in Monte Carlo Methods*, Springer, 2009.
3. William L. Dunn, J. Kenneth Shultis, *Exploring Monte Carlo Methods*, Elsevier, 2012.
4. Ivan T Dimov., *Monte Carlo Methods for Applied Scientists*, World Scientific, 2008.

CIS-546: Parallel Computing

Status	Optional
Credits	3
Prerequisites	Nil

Parallel Programming Platforms; Memory Architectures; Basic Communication Operations: Broadcast, Scatter and Gather; Computational Overheads; Level of Abstraction, Principles of Parallel Computation: Decomposition Techniques, Mapping Techniques, Model of Computations and Parallel Overheads: Sources of Overheads, Performance Metrics, Scalability; Parallel programming using message passing paradigm; Programming shared memory address space platforms.

References

1. Grama A., Gupta A., Karypis G., and Kumar V., *Introduction to Parallel Computing*, 2nd ed., Addison-Wesley, 2003.
2. Culler D. E., Singh J. P., and Gupta A., *Parallel Computer Architecture: A Hardware/Software Approach*, Morgan Kaufmann Publisher, 1999.
3. Foster I., *Designing and Building Parallel Programs: Concepts and Tools for Parallel Software Engineering*, Addision-Wesley, 1995.

CIS-548: Computer Animation

Status	Optional
Credits	3
Prerequisites	Nil

Applications of Computer Animation; Principles of Animation; Modeling and Rendering; Key Framing; Kino-Dynamic Planning; Kinematics and Inverse Kinematics; Space-Time Constraints; Least Constraint; Multidimensional Motion Interpolation; Collision Detection; Motion Signal Processing; Reusable Motion Synthesis using State-Space Controllers; Limit Cycle Control and its Application to Animation; Dynamical Particle Animation.

References

1. Rick P., *Computer Animation: Algorithms and Techniques*, Morgan Kaufmann, 2002.
2. Giambruno M., *3D Graphics & Animation*, 2nd ed., New Riders Press, 2002.
3. Kerlow I.V., *The Art of 3-D Computer Animation and Effects*, 3rd ed., John Wiley & Sons, 2003.

CIS-549: Finite Element Computations

Status	Optional
Credits	3
Prerequisites	PAM-568

Overview of Structure and Continuum Mechanics; Variation Methods (Rayleigh-Ritz and Galerkin); Finite Element Analysis for Elliptic Equations; Base Functions and Techniques of Interpolation; Local Stiffness Matrix and Global Stiffness Matrix; Time Dependant Problems; Computational Implementations; Overview of Non-Linear Finite Element Analyses; Formulation of Geometrically Non-Linear Finite Elements; Solution of Non-Linear Equations; Computer Implementation of Non-Linear Analyses.

References

1. Kythe, P. K. K., and Wei, D., *An Introduction to Linear and Nonlinear Finite Element Analysis*, Birkhauser Verlag, Basel, 2003.
2. Rao S.S., *The Finite Element Method in Engineering*, 5th ed., Butterworth Heinemann, 2011.
3. Smith I.M., and Griffiths D.V., *Programming the Finite Element Method*, 4th ed., John Wiley & Sons, 2004.
4. Hughes T. J. R., *The Finite Element Method: Linear Static and Dynamic Finite Element Analysis*, Prentice-Hall, 2000.
5. Brebbia C.A., and Ferrante A.J., *Computational Methods for the Solution of Engineering Problems*, 3rd ed., John Wiley & Sons, 1986.

CIS-550: Advanced Computer Architecture

Status	Core
Credits	3
Prerequisites	Nil

Overview of modern processor architectures; Processor Design; Memory Hierarchy: Cache and Cache Coherence; Bus Architecture; Types of parallel machine: Vector Pipeline Architectures, Replicated Architectures, SIMD/MIMD, Shared Memory and Distributed Memory; Connectivity; Clusters; Networks; Routing; Performance Comparison; Dataflow; Virtual Concurrency; Branch prediction; TLB; Emulated instruction sets; VLIW; Out of order execution; Latency hiding; Case Studies: iA64, Linux clusters and IBM SP; Microcontrollers: Intel, PIC; Real-time processors: TMS320.

References

1. Hennessy J. L. and Patterson D. A., *Computer Architecture -- A Quantitative Approach*, 5th Ed., Morgan Kaufmann Publications, Elsevier, Inc., 2012.
2. Stallings W., *Computer Organization and Architecture*, 9th Ed., Pearson Education Ltd, 2012.
3. Murdocca M. J., Heuring V. P., *Computer Architecture and Organization: An Integrated Approach*, John Wiley & sons Inc, 2007.
4. Englander I., *The Architecture of Computer Hardware and System Software: An Information Technology Approach*, International Student Version, 4th Ed., John Wiley & sons Inc, 2010.

CIS-551: Advanced Operating Systems

Status	Core
Credits	3
Prerequisites	Nil

Process Synchronization: Synchronization Mechanisms, Process Deadlocks; Distributed Operating Systems: Architectures, Mutual Exclusion, Deadlock Detection, Agreement Protocols; Distributed Resource Management: File Systems, Share Memory, Scheduling; Failure Recovery and Fault Tolerance; Protection and Security: Resource Security and Protection, Data Security; Multiprocessor Operating Systems; Database Operating Systems.

References

1. Singhal M., and Shivaratri N. G., *Advanced Concepts in Operating Systems*, McGraw-Hill Series in Computer Science, 2008.
2. Silberschatz A., Galvin, P. B., Gagne G., *Operating System Concepts*, 9th ed., John Wiley & Sons, 2013.
3. Stalling W., *Operating Systems*, 5th ed., Pearson Education, 2006.
4. Tanenbaum A. S., Modern Operating Systems, 3rd ed., Prentice Hall, 2007.

CIS-552: Advanced Database Systems

Status	Optional
Credits	3
Prerequisites	Nil

Database life cycle; Data modeling; Extended ER Constructs; Database transactions; Concurrency control: Concurrency problems, Deadlocks, Serializability; Query execution; Query optimization; Distributed database architecture; Rationale for distribution; Components of distributed database system: Data placement, Placement of DDBMS; Synchronization problem; Models and applications; Problems of distributed systems; Temporal databases; Logic-based databases; Object databases; Object/Relational Databases.

References

1. Toby J. T., *Database Modeling and Design*, Morgan Kaufman Pub, 2011.
2. Philip A. B., and Eric N., *Principles of Transaction Processing*, Morgan Kaufmann Pub, 2009.
3. Ozsu M. T., and Valduriez P., *Principles of Distributed Database Systems*, Springer, 2011.
4. Date C.J., and Darwen H., *Foundation for Object/Relational Databases: The Third Manifesto*, Addison Wesley, 1998.

CIS-555: Cluster System Management

Status	Optional
Credits	2+1
Prerequisites	Nil

Overview of Cluster Computing; Cluster Computer and its Architecture; Constructing Scalable Services; Cluster Interconnects; Deploying a High Throughput Computing; Cluster Setup and its Administration; Load Balancing in Clusters; Cluster Middleware; Resource Management and Scheduling; Programming Environments and Tools; Cluster Administration Tools; Cluster Workload Management; Parallel Debuggers and Profilers; Performance Analysis Tools; Numerical and Scientific Software for Clusters.

References

1. Buyya R. (ed.), "*High Performance Cluster Computing: Systems and Architectures*", Prentice Hall, 1999.
2. Kopper K.,"*The Linux Enterprise Cluster*", No Starch Press, 2005.
3. Gropp W., Lusk e., and Sterling T. (eds), "*Beowulf Cluster Computing with Linux*", Second Edition, The MIT Press, 2003.
4. Bookman C., "*Linux Clustering: Building and Maintaining Linux Clusters*", New Riders Publishing, 2002.
5. Hwang K., Dongarra J., and Fox G., "*Distributed and Cloud Computing: From Parallel Processing to the Internet of Things* ", Morgan Kaufmann, 2012.

CIS-571: Digital Forensics

Status	Optional
Credits	3
Prerequisites	Nil

The Evolution of Hacking, Footprinting the Environment, Scanning the Environment and Network, System Enumeration and System Hacking, Sniffers, Backtrack R3, System Forensics Fundamentals, Overview of Computer

Crime, Challenges of System Forensics, Forensics Methods and Labs, System Forensics Technologies, Controlling a Forensic Investigation, Collecting, Seizing, and Protecting Evidence, Investigating Information-Hiding Techniques, Recovering Data, Investigating and Scrutinizing E-mail, Performing Network and Internet Analysis, Searching Memory in Real Time with Live Systems Forensics, Incident/Intrusion Response, Mobile System Forensics, Future Directions.

References

1. Sean-Philip Oriyano, Michael Gregg, *Hacker Techniques, Tools, and Incident Handling*, Jones & Bartlett Learning Publication, 2011.
2. John R. Vacca, K Rudolph, *System Forensics, Investigation, and Response*, Jones & Bartlett Learning Publication, 2011.
3. Nelson B., Phillips A., Steuart C., *Guide to Computer Forensics and Investigations*, 4th ed., Cengage Learning, 2010.
4. Albert J. Marcella, Jr. Doug Menendez, *Cyber Forensics-a Field Manual for Collecting, Examining, and Preserving Evidence of Computer Crimes*, 2nd ed., Auerbach Publications, 2008.
5. Altheide C., and Carvey H., *Digital Forensics with Open Source Tools*, Elsevier, 2011.

CIS-562: Information Theory and Coding

Status	Optional
Credits	3
Prerequisites	Nil

Theory of information: Entropy, Mutual information, Source coding theorem; Lossless compression of data, Optimal lossless coding; Communication channels: Channel capacity, Noisy communication channels, Channel coding theorem, Source channel separation theorem, Multiple access channels, Broadcast channels, Gaussian noise, and time-varying channels; Huffman coding; Universal source coding; Differential entropy; Block codes and Convolutional codes; Error correction code; Reliable and efficient communication systems.

References

1. Cover T. M, and Thomas J. A, *Elements of Information Theory*, 2nd Ed., John Wiley & Sons, 2006.
2. Wicker B. S., *Error Control systems for Digital Communication and Storage*, Prentice-Hall, 1994.
3. Gallagher R. G., *Information Theory and Reliable Communication*, Springer-Verlag, 1970.

CIS-567: Cryptography

Status	Optional
Credits	3
Prerequisites	Nil

Definitions: Cryptography, cryptanalysis, steganography, encryption, decryption, plaintext, cipher text, etc; Mathematics of Cryptology: Number theory, Abstract algebra: groups, rings, fields; modular Arithmetic; Classical Cryptology: Simple Substitution ciphers, Transposition ciphers, ploy-alphabetic ciphers; Secret Key Cryptography: Modern Block Ciphers: Data Encryption Standard (DES), Advanced Encryption Standard (AES), Pseudorandom Number Generation and Stream ciphers: LFSR-based stream ciphers, RC4; Modes of Cipher operations: ECB, CBC, CFB, OFB, XTS-AES; Public Key Cryptography: Key agreement: Diffie-Hellman, Elgamal, Elliptic Curve Cryptography; RSA, Digital Signatures Integrity and authentication; Hash Functions: MD5, SHA-3; Message Authentication Codes : HMAC, DAA and CMAC, Authenticated Encryption using CCM and GCM.

References

1. Stallings W., *Cryptography and Network Security: Principles and Practice*, 5th ed, Prentice Hall, 2011.
2. Jonathan Katz and Yehuda Lindell, *Introduction to Modern Cryptography*, CRC Press, 2007.
3. Niels Ferguson, Bruce Schneier, Tadayoshi Kohno, *Cryptography Engineering*. Wiley, 2010.
4. Christof Paar and Jan Pelzl, *Understanding Cryptography*, Springer, 2010.

CIS-564: Computer System Security

Status	Optional
Credits	3
Prerequisites	Nil

Software Flaws and Malwares: Viruses and their countermeasures, Worms, Trojan Horses, Bots, Rootkits; Buffer Overflow: Basics, Stack Buffer Overflow, Heap Overflow, Global Data Area Overflow; Compile Time and Runtime Defenses; Denial of service (DoS) attacks and defenses, Hostile Scripts: CGI Scripts, Web Scripts, Handling Script Security Miscellaneous, Spyware; Mobile Agent Security; Software-Based Attacks: Software Reverse Engineering, Software Tamper Resistance, Content Filtering; Digital Rights Management; Secure Software Development; Storage Security: Storage Media, Local file systems, Network File systems, RAID, Clustering, Backup Systems, File Integrity; Operating Systems and Security; Linux Security; Windows and Windows Vista Security; Processor security features ; Database Security; Securing Digital Contents.

References

1. Stallings W., Brown L., *Computer Security: Principles and Practice* 2nd ed. Prentice Hall, 2012.
2. Kizza J. M., *A Guide to Computer Network Security*, Springer, 2009.
3. Robert C Newman, *Computer Security: Protecting Digital Resources*, Jones & Bartlett Learning, 2010.
4. Mike Harwood, Marcus Goncalves, Matthew Pemble, *Security Strategies in Web Applications and Social Networking*, Jones & Bartlett Learning, 2011.
5. Jason Albanese,Wes Sonnenreich, *Network Security Illustrated*, McGraw-Hill,2004.

CIS-565: Information System Security Management

Status	Optional
Credits	3
Prerequisites	Nil

Elements of Information Protection, Difference between Information and Computer Security, Roles and Responsibilities, Common Threats, Policies and Procedures, Risk Management, Fraud and Theft, Malicious Hackers, Denial-of-Service Attacks, Social Engineering, Information Security Architecture, Enterprise wide Security Program, Business Unit Responsibilities, Information Security Awareness Program, Information Security Program Infrastructure, Employment, Standards of Conduct, Conflict of Interest, Performance Management, Employee Discipline, Corporate Communications, Workplace Security, Business Continuity Plans (BCPs), Procurement and Contracts, Records Management, Asset Classification, Access control, Organization wide Policy Document Standards: ISO 27001/27002, COBIT, NIST FISMA, Legal Requirements, Physical Security, Security Technologies, Trusted Computing , Multilevel Security, Multilateral Security.

References

1. Robert Johnson, Mark Merkow, *Security Policies and Implementation Issues*, Jones & Bartlett Learning, 2011.
2. Thomas R. Peltier et al., *Information Security Fundamentals*, Auerbach Publications, 2005.
3. Ross J. Anderson, *Security Engineering: A Guide to Building Dependable Distributed Systems*, 2nd ed., John Wiley & Sons, 2008.
4. Tudor J. K., *Information Security Architecture-An Integrated Approach to Security in the Organization*, Auerbach Publications, 2001.
5. Steve Purser, *A Practical Guide to Managing Information Security*, Artech House, 2004.

CIS-566: Auditing and Risk Management

Status	Optional
Credits	3
Prerequisites	Nil

Auditing: Principles, Standards and Frameworks, Tools and Techniques, Planning Audit for Compliance, Audit Reports, Compliance Within the Domains: User: the Workstation, the LAN, the LAN-to-WAN in, the WAN,

Remote Access, the System/Application; Risk Management: Fundamentals, Threats, Vulnerabilities, Exploits, Maintaining Compliance, Developing a Risk Management Plan, Risk Assessment Approaches, Risk Assessment: Assets Identification, Activities to be Protected, Identifying Risk Mitigation: Security Controls, Planning throughout the Organization, turning assessment into a plan, Business Impact Analysis, with a Business Continuity Plan, with a Disaster Recovery Plan, Computer Incident Response Team Plan.

References

1. Martin Weiss, Michael G. Solomon, *Auditing IT Infrastructures for Compliance*, Jones & Bartlett Learning, 2011.
2. Chris Jackson, *Network Security Auditing Tools and Techniques*, Cisco Press, 2010.
3. Darril Gibson, *Managing Risk in Information Systems*, Jones & Bartlett Learning, 2011.
4. Andy Jones, Debi Ashenden, *Risk Management for Computer Security- Protecting Your Network and Information Assets*, Elsevier, 2005.

CIS-563: Essential Mathematics for Cryptography

Status	Optional
Credits	3
Prerequisites	Nil

Numbers: Divisibility criteria, Prime numbers, Euclidean algorithm, Fermat numbers and factorization methods. Linear Diophantine equations; Congruences: Introduction to congruence, Linear congruence, The Chinese remainder Theorem, Systems of linear congruences, Fermat's Little Theorem and Euler's Theorem, Modular exponentiation, Extended Euclidean algorithm; Primitive Roots: Primitive roots, Primality testing using primitive roots, Theory of indices, discrete logarithms, quadratic residues, Legendre and Jacobi symbols; Algebraic Preliminaries: Groups, Finite fields, irreducible polynomials, Polynomial ring over R, Introduction to elliptic curves: Elliptic Curves, Elliptic Curves over the Reals, Elliptic Curves Modulo a Prime; Mathematics for Stream Ciphers: Minimal Polynomial and Families of Recurring Sequences.

References

1. K. H. Rosen, *Elementary Number Theory and its Applications*, 6th ed , Addison –Wesley, 2010
2. R. Lindl and H. Niederreither, *Introduction to Finite Fields and Their Applications*, 2nd ed., Cambridge Univ. Press, 1994.
3. N.Koblitz, *A Course in Number Theory and Crytography*, 2nd ed, Springer Verlag, 1994.

CIS-568: Network Security

Status	Optional
Credits	3+1
Prerequisites	Nil

Introduction to Network Security, User Authentication: Password-bases, token-based, biometric, remote authentication; Access Control: Principles, Discretionary and Role based; Key Management and Distribution, Security at the data link layer: MAC Flooding, ARP Spoofing, STP attacks, VLAN attacks; Security at the network layers: Attacks and Countermeasures for RIP, OSPF and BGP, IPSec and IKE, VPN, NAT, Secure Multicasting; Intrusion detection, Firewalls, IP spoofing prevention, Secure communication at the transport and application layers: SSL/TLS,HTTPS, Secure Shell; Email security: PGP, S/MIME, DKIM; Domain name server (DNS) security, Wireless networks security, Network Management Security.

References

1. Stallings W., *Network Security Essentials: Applications and Standards*, 4th ed, Publisher: Prentice Hall, 2011.
2. Alan Yeung, Angus Wong, *Network Infrastructure Security*, Springer, 2009.
3. J. Michael Stewart, *Network Security, Firewalls, and VPNs*, Jones & Bartlett Learning, 2011.

4. Bill Ballad, Tricia Ballad, Erin Banks, *Access Control, Authentication, and Public Key Infrastructure*, Jones & Bartlett Learning, 2011
5. Bryan Burns et al., *Security Power Tools*, O'Reilly Media, 2007.

PAM-568: Numerical Solution of Differential Equations

Status	Optional
Credits	3
Prerequisites	Nil

Review of Differential equations; Numerical solution of ODEs; One-step and Multi-step methods, Explicit and Implicit Methods, Euler's method, Runge-Kutta methods, Adams methods, Predictor-Corrector methods, Stiff Differential Equations, Backward Difference Methods for Stiff problems, Extrapolation Methods; Accuracy and Stability; Boundary Value Problems; Linear and Non-linear finite difference methods, Linear and Non-linear Shooting methods, Variational Techniques; Partial Differential equations; Classification, Time-dependent problems; Finite Difference and Finite Element Methods, Solution of Sparse Linear Systems: Direct and Iterative methods; Multi-grid methods.

References

1. Granville S., *The Numerical Solution of Ordinary and Partial Differential Equations*, 2nd ed., John-Wiley and Sons, 2005.
2. Randall J. L., *Finite Difference Methods for Ordinary and Partial Differential Equations – Steady State and Time Dependent Problems*, Society of Industrial and Applied Mathematics (SIAM) Pub. Philadelphia, PA 2007.
3. Lambert J. D., *Numerical Methods for Ordinary Differential Equations*, John-Wiley and Sons, 1997.
4. Ŝolín P., *Partial Differential Equations and The Finite Element Method*, John-Wiley and Sons, 2006.

CIS-569: Public Key Infrastructure

Status	Optional
Credits	3
Prerequisites	Nil

Overview of Cryptography; Message Digests; Digital Signatures; Digital Certificates: Certification and Registration Authority; Key Management: Management Techniques, Distributing and controlling key usage, Multiple domains, Key life cycle, Trusted third party services; Key Establishment Protocols: Classification, Key transport based, Key agreement based , Secret sharing; Public Key Infrastructure (PKI): Basic functionality PKI components, Security Services, key–pair and the certificate request, Signing by the CA, Certification Authority chains; PKI Architectures: Single, Hierarchical, Mesh PKI, Trust lists, Bridge CAs; The Path Development Problem: Validation and implementation, Internet X.509 Public Key Infrastructure (PKIX): Risks of PKI: Smart cart integration: Some alternatives to PKI; Email based identification and authentication.

References

1. John R. Vecca, *Public Key Infrastructure: Building Trusted Applications and Web Services*, CRC,2004
2. Carlisle Adams, Steve Lloyd, *Understanding PKI: Concepts, Standards, and Deployment Considerations*, 2nd ed., Addison-Wesley, 2002.
3. Stefan A. Brands, *Rethinking Public Key Infrastructures and Digital Certificates*, 5th ed., MIT Press, 2000.
4. Symeon (Simos) Xenitellis, *the Open–source PKI Book: A guide to PKIs and Open–source implementations*, Version 2.4.6 Edition, 2000.

CIS-570: Digital Watermarking and Its Applications

Status	Optional
Credits	3
Prerequisites	Nil

Digital Watermarking; Difference between Watermarking, Steganography, and Cryptography; Embedding and Extraction of a Watermark; Properties of a Digital Watermarking System: Imperceptibility, Capacity, Robustness, Security; Types of Watermarking Techniques: Robust Watermarking, Fragile Watermarking, Semi-Fragile Watermarking, Reversible Watermarking; Watermarking in Spatial and Transform Domains; Cover Mediums for Watermarking: Image Watermarking, Video Watermarking, Audio Watermarking, Text Watermarking, and Database Watermarking; Watermarking Applications: Integrity Control, Tamper Detection and Recovery, Tell-Tale Watermark, Copyright Enforcement, Broadcast Monitoring, Transaction Tracking, Biometric Watermarking, Watermarking for Teleradiology and Telediagnosis, Watermarking for Wireless Sensor Networks, DNA Sequence Watermarking, 3D Watermarking; Watermarking Benchmarks: StirMark, Checkmark.

References

1. Cox I. J., Miller M. L., et. al., *Digital Watermarking and Steganography*, 2nd ed., Morgan Kaufmann, 2008.
2. Barni M., and Bartolini F., *Watermarking Systems Engineering: Enabling digital assets security and other application*, Marcel Dekker, 2004.
3. Shih F.Y., *Digital Watermarking and Steganography: Fundamentals and Techniques*, CRC Press, 2008.
4. Arnold M. K., Schmucker M., Wolthusen S. D., *Techniques and Applications of Digital Watermarking and Content Protection*, Artec House Inc., Computer Security Series, 2003.

PAM-585: Numerical Methods and Optimization Techniques

Status	Optional
Credits	3
Prerequisites	Nil

Review of eigen-value problems, Numerical solution; Solution of system of ODEs; Boundary value problems; Classical optimization techniques: constrained and unconstrained sets, line search, trust region approaches, Simplex, Newton's Quasi-Newton, conjugate direction, and Levenberg-Marquardt methods; elimination, Lagrangian, and active set methods, quadratic and mixed integer programming; Stochastic optimization, simulated annealing, particle swarm and game theory optimization; Evolutionary algorithms; Applications.

References

1. Cavazzuti M., *Optimization Methods: From Theory to Scientific Design*, Springer-Verlag, 2013.
2. Burden R.L., and Faires J.D., *Numerical Analysis*, 9th ed., Brooks-Cole, Cengage Learning, 2010.
3. Gupta C. B., *Optimization Techniques in Operation Research*, I.K. Intl. Pub. House, New Delhi, 2007.
4. Marti K., *Stochastic Optimization Methods*, 2nd ed., Springer-Verlag, 2008.

CIS-595: Special Topics in CIMV-I

Status	Optional
Credits	3
Prerequisites	Nil

This course may be used for advanced topics not already covered in the syllabus. The special paper may be conducted as a lecture course or as an independent study course. The faculty must approve the topic and contents of the course.

CIS-596: Special Topics in SC-I

Status	Optional
Credits	3
Prerequisites	Nil

This course may be used for advanced topics not already covered in the syllabus. The special paper may be conducted as a lecture course or as an independent study course. The faculty must approve the topic and contents of the course.

CIS-597: Special Topics in ISS-I

Status	Optional
Credits	3
Prerequisites	Nil

This course may be used for advanced topics not already covered in the syllabus. The special paper may be conducted as a lecture course or as an independent study course. The faculty must approve the topic and contents of the course.

CIS-621: Machine Learning

Status	Optional
Credits	3
Prerequisites	Nil

Introduction to Machine Learning: Examples, Supervised and Unsupervised Learning, Discriminative vs. Generative Learning, Regression; Bayesian Decision Theory; Parametric and Non Parametric Methods; Dimensionality Reduction; Clustering Approaches; Classification Techniques: Artificial Neural Networks, Competitive Learning, Support Vector Machines, Decision Trees and Random Forests, Combining Multiple Classifiers: Bagging, Boosting, Stacked Generalization; Reinforcement Learning; Transfer Learning; Adversarial Learning; Deep Learning; Design and Analysis of Machine Learning Experiments; Lab Assignments.

References

1. Witten, Ian H., *Data Mining: Practical Machine Learning Tools and Techniques*, Morgan Kaufmann, 2016.
2. Alpaydin, Ethem, *Introduction to Machine Learning*, MIT press, 2014.
3. Sergios T., Konstantinos K., *Pattern Recognition*, 4rth Ed., 2008.
4. Duda, R. O., Peter E. H. and David G. S., *Pattern Classification*, John Wiley & Sons, 2012.
5. Fausett L., Laurene F., *Fundamentals of Neural Networks: Architectures, Algorithms, and Applications*, No. 006.3. Prentice-Hall, 1994.

CIS-622: Machine Learning in BioInformatics

Status	Optional
Credits	3
Prerequisites	Nil

Specialized learning schemes for non-standard data (sequences, tree and graph data) in Bioinformatics. Data mining and feature analysis for biological data, large scale learning, design principles and practices for development of intelligent systems in Bioinformatics, Computational intelligence schemes for prediction of biological macromolecular structures (kernels for protein structures), Learning schemes for heterogeneous data (multi-kernel and classifier fusion specific for Bioinformatics), Machine learning in the design of proteins, Unsupervised and semi-supervised learning schemes for macromolecular interactomics, protein interactions and interface prediction using machine learning, Applications of computational intelligence techniques for analysis of next generation sequencing data, machine learning in genome assembly.

References

1. Schölkopf B., Tsuda K., and Vert J.-P., *Kernel Methods in Computational Biology*, MIT Press, 2004.
2. Yang Z. R., *Machine Learning Approaches to Bioinformatics*, John Wiliey and Sons, 2009.
3. Maulik U., Bandyopadhyay S., and Wang J. T., *Computational Intelligence and Pattern Analysis in Biology Informatics*, John Wiley & Sons, 2011.
4. Jones N. C. and Pevzner P. A., *An Introduction to Bioinformatics Algorithms*, 1 edition. Cambridge, MA: The MIT Press, 2004.
5. Petsko G. A. and Ringe D., *Protein Structure and Function*, New Science Press, 2004.

CIS-623: Biometrics Computing

Status	Optional
Credits	3
Prerequisites	Nil

Overview of biometrics; Existing biometric technologies: Fingerprints, Face, Iris, Hand geometry, Palmprint, Ear, Voice, Retina, etc.; Performance evaluation and comparison of biometrics: Performance measures, Reliability, Uniqueness, and Comparison; Multimodal biometric authentication: Types of fusion, Score normalization, Intramodal and multimodal fusion, Strategies; Biometric security: Anti-spoofing measures, Liveness detection; Issues of privacy: Public concerns, Research issues in personal identification; Biometric watermarking.

References

1. Ashbourn J., *Practical Biometrics: From Aspiration to Implementation*, Springer, 2004.
2. Ashbourn J., *Biometrics: Advanced Identity Verification*, Springer-Verlag, 2000.
3. Jain A.K., Bolle R., and Pankanti S., *Biometrics: Personal Identification in Networked Society*, *International Series in Engineering and Computer Science*, Springer, 1999.
4. Wayman J., Jain A.K., Maltoni D., and Maio D., *Biometric Systems: Technology, Design and Performance Evaluation*, Springer, 2010.

CIS-624: Machine Vision

Status	Optional
Credits	3+1
Prerequisites	Nil

Overview of a machine vision system; Image formation; Feature extraction and matching; 2D and 3D Transformations; 2D and 3D Projective geometry; Camera models; Camera calibration; Single view geometry; Epipolar geometry; Stereo vision; Structure from motion; Shape from single image cues; Shape from more than one images: Contours, Stereo; Pose estimation; Image mosaicing; Image-based rendering.

References

1. Forsyth D. A. and Ponce J., *Computer Vision: A Modern Approach*, Prentice Hall, 2011.
2. Szeliski R., *Computer Vision: Algorithms and Applications*, Springer, 2010.
3. Hartley R, and Zisserman A., *Multiple View Geometry in Computer Vision*, 2nd Ed., Cambridge University Press, 2004.
4. Trucco and Verri A., *Introductory Techniques for 3-D Computer Vision*, Prentice Hall, 1998.

CIS-625: Computational Biomolecular Design

Status	Optional
Credits	3
Prerequisites	NIL

Introduction to protein design, Primer on molecular biology, Protein Sequence-Structure-Function relationships and homology, protein visualization tools (PyMOL), Combinatorial optimization and molecular state scoring for protein structure optimization, Designing for structure, designing for function, Molecular and Directed Evolution, Design of macromolecular assemblies, Protein folding, energy function modeling of molecular dynamics (CHARMM), MD-Simulation Techniques (GROMACS, etc.).

References

1. Jones N. C. and Pevzner P. A., *An Introduction to Bioinformatics Algorithms*, 1 edition. Cambridge, MA: The MIT Press, 2004.
2. Petsko G. A. and Ringe D., *Protein structure and function*, New Science Press, 2004.

CIS-627: Deep Neural Networks

Status	Optional
Credits	3
Prerequisites	CIS-521/525/526 or equivalent

Artificial Neural Networks, Supervised, Unsupervised and Competitive Learning paradigms, Backpropagator, Radial Basis Functions; Visual Cortex, Deep Learning in human brain; Training Deep Models, approximate 2nd order methods, multi-task learning, adversarial training, and dropout; Representation Learning, Restricted Boltzman Machine, Deep Belief Networks (DBN), feature generation and classification using DBN; Deep Convolutional Neural Networks, Visualization of features in Convolutional Neural Networks; Deep Recurrent Networks, Stacked Deep Denoising Autoencoders, Prominent Deep Neural Networks, Deep NN Toolboxes/Libraries.

References

1. Bengio Y., Goodfellow I. J., and Courville A., *Deep Learning*, MIT Press, 2016.
2. Haykin S., *Neural Networks: A comprehensive Foundation*, 3rd Edition Pearson Education Press, 2008.
3. Engelbrecht A. P., *Computational Intelligence: An Introduction*, 2nd Edition, Wiley, New York, 2007.
4. Deng Li., *A tutorial survey of architectures, algorithms, and applications for deep learning*. APSIPA Transactions on Signal and Information Processing 3, 2014.

CIS-630: Advanced Evolutionary Computing

Status	Optional
Credits	3
Prerequisites	CIS-523

Theoretical foundations of Genetic Algorithms (GA); Applications of GA in constrained nonlinear optimization problems; Diploid genetic algorithms; Differential Evolution; Genetic Programming: Recent advances in Genetic Programming (GP), GPlab toolbox; Multi-objective optimization: Applications of evolutionary algorithms in multi-objective optimization problems, Non-dominated Sorting Genetic Algorithm (NSGA-II); Immune inspired systems and their performance comparison with GA and GP; Hybrid evolutionary computing techniques.

References

1. Goldberg, D. E., *The Design of Innovation: Lessons from and for Competent Genetic Algorithms*, Boston, MA: Kluwer Academic Publishers, 2002.
2. Fogel, D. B., *Evolutionary computation: Toward a new philosophy of machine intelligence*, IEEE Press, New York, 3rd edition, 2005.
3. Haupt, L. R., and Haupt, E. S., *Practical Genetic Algorithms*, 2nd ed., Wiley-Interscience, 2004.

CIS-631: Intelligent Watermarking Techniques

Status	Optional
Credits	3
Prerequisites	Nil

Watermarking and intelligent techniques: Evolutionary algorithms based watermarking, Intelligent watermarking in spatial and transform domain; Watermarking based on vector quantization and spread spectrum; Intelligent audio and video watermarking; Benchmarks of watermarking; Robust watermarking schemes using machine learning approaches; Practical issues and limitations in watermarking; Optimal tradeoff of watermarking properties using intelligent approaches.

References

1. Huang H. C., Jain L. C., and Pan J. S., *Intelligent Watermarking Techniques*, World Scientific Pub Co Inc, 2004.
2. Barni M., and Bartolini F., *Watermarking Systems Engineering: Enabling digital assets security and other application*, Marcel Dekker, 2004.
3. Cox I. J., Miller M. L., et. al., *Digital Watermarking and Steganography*, Morgan Kaufmann, 2007.

CIS-641: Grid Computing

Status	Optional
Credits	3
Prerequisites	Nil

Grid Architectures; Networking Infrastructure; Protocols and Quality of Service; Computing Platforms, Operating Systems and Network Interfaces; Compilers; Languages and Libraries for the Grid; Grid Scheduling; Resource Management: Resource Brokers, Resource Reservations; Instrumentation and Measurement; Performance Analysis and Visualization; Security; Accounting and assurance; The Globus Toolkit: Core Systems and Related Tools such as the Message Passing Interface Communication Library, The Remote I/O (RIO) Library and the Nimrod Parameter Study Library; Legion and Related Software; Open grid service architecture and Data grids.

References

1. Silva V., *Grid Computing For Developers*, Charles River Media, 2005.
2. Abbas A., *Grid Computing: Practical Guide to Technology & Applications*, Charles River Media, 2003.
3. Juhasz Z., Kacsuk P., and Kranzlmuller D., *Distributed and Parallel Systems: Cluster and Grid Computing*, Springer, 2004.

CIS-642: Virtual Reality

Status	Optional
Credits	3
Prerequisites	CIS-526/532

Overview of Virtual Reality (VR) and Augmented Reality (AR); Projective geometry; Camera calibration; Visual coherence; Visualization techniques; Real-time tracking and pose estimation; Rendering; Characterization of virtual environments; Hardware to create virtual environments; 3D interaction and collaboration in virtual environments; Human factors and human perception; Virtual characters; Modelling and creating virtual environments; AR Tool kit.

References

1. Behringer R., Klinker G., and Mizell D., *Augmented Reality: Placing Artificial Objects in Real Scenes*, CRC Press, 1999.
2. Ong S. K., and Nee A. Y. C., *Virtual and Augmented Reality Applications in Manufacturin* , Springer, 2013.
3. Fuchs P., Moreau G., and Guitton P., *Virtual Reality: Concepts and Technologies*, CRC Press, 2011.
4. Bowman D. A., Kruijff E., LaViola J. J., and Poupyrev I., *3D User Interfaces: Theory and Practice*, Addison-Wesley, 2004.
5. Sherman W. R., and Craig A. B., *Understanding Virtual Reality: Interface, Application, and Design*, Morgan Kaufmann, 2002.
6. Burdea G. C., and Coiffet P., *Virtual Reality Technology*, 2nd ed., Wiley-IEEE Press, 2003.

CIS-643: Mobile Vision

Status	Optional
Credits	3
Prerequisites	Nil

Mobile architecture; Mobile operating system; Mobile application development framework; Computational photography; Mobile visual search; Sensor and video analytics; Sensor fusion; Power and memory efficient acceleration of visual computing; Mobile cloud; 3D reconstruction; Scene understanding, modeling, and virtual augmentation.

References

1. Kapur S., Thakker N., *Mastering OpenCV Android Application Programming*, Packt Publishing, 2015.
2. Howse J., *Android Application Programming with OpenCV 3*, Packt Publishing, 2015.

3. Raskar R., Tumblin J., *Computational Photography: Mastering New Techniques for Lenses, Lighting, and Sensors*, A K Peters, 2015.
4. Lukac R., *Computational Photography: Methods and Applications*, CRC Press, 2010.
5. Wohler C., *3D Computer Vision: Efficient Methods and Applications*, X Media, 2nd edition, 2013.
6. Prince J. D., *Computer Vision: Models, Learning, and Inference*, Cambridge University Press, 2012.
7. Ellis B., *Real-Time Analytics: Techniques to Analyze and Visualize Streaming Data*, Wiley, 2014.
8. Shan C., Porikli F., *Video Analytics for Business Intelligence*, Springer, 2012.
9. Since majority of the topics is state-of-the-art, students will be referred to the relevant publications.

CIS-645: Parallel Algorithms

Status	Optional
Credits	3+1
Prerequisites	CIS-546

Principals of parallel algorithms; Dense/sparse matrix algorithms: matrix-vector and matrix-matrix multiplication using 1D and 2D decomposition techniques; Sorting algorithms: issues in sorting, sorting networks, bubble sort, quick sort, other sorting algorithms; Graph algorithms: definition and representation, Prim's algorithm, Dijkstra's algorithm, sparse graphs algorithms; Search algorithms for discrete optimization problems; Fast Fourier Transform (FFT): binary-exchange and transpose algorithms; Iterative solution of linear systems; Analysis of computation, communication and synchronization; Parallel numerical libraries.

References

1. Roosta S. H., *Parallel Processing and Parallel Algorithms: Theory and Computation*, Springer-verlag, 2000.
2. Rauber T., and Rünger G., *Parallel Programming: for Multicore and Cluster Systems*, Springer, 2010.
3. Grama A., Gupta A., Karypis G., and Kumar V., *Introduction to Parallel Computing*, 2nd ed., Addison-Wesley, 2003.
4. Quinn M., Parallel *Programming in C with MPI and OpenMP*, McGraw-Hill 2003.
5. Foster I., *Designing and Building Parallel Programs*, Addison-Wesley, 1995.

CIS-646: Advanced Optimization Techniques

Status	Optional
Credits	3
Prerequisites	PAM-585

Non-Simplex methods: Khachiyan's, Affine Scaling, Karmarkar's Method; Non-linear optimization with equality and inequality constraints; Network models: Minimal Spanning Tree Algorithm, Shortest-Route Problem, Maximal flow models; Goal programming; Deterministic and probabilistic dynamic programming; Inventory models: Static Ecol1omic-Order-Quantity (EOQ) Models, Dynamic EOQ Models; Forecasting models: Moving Average Technique, Exponential Smoothing, Regression; Decision analysis and games; Markovian decision process: Finite-Stage Dynamic Programming, Infinite-Stage Model; Geometric programming; Non-Smooth optimization.

References

1. Reklaitis G. V., Ravindran A., and Ragsdell K. M., *Engineering Optimization: Methods and Applications*, John Wiley & Sons, 2nd edition, 2006.
2. Fletcher R., *Practical Methods of Optimization*, 2nd ed., John Wiley & Sons, 2000.
3. Taha H. A., *Operations Research: An introduction*, 9th ed., Pearson Education, 2010.
4. Deb K., Optimization for Engineering Design: Algorithms and Examples, Prentice Hall, 2005.

CIS-661: Data Warehousing

Status	Optional
Credits	3
Prerequisites	Nil

Data warehouse essentials; Need for a DW; Decision support vs. transaction processing; Evolution of a DW; Business requirements; Matching information to classes of users; Dimensional modeling; Architecture and Infrastructure; Data extraction; Transformation and loading; Selected De-normalizations; Horizontal and vertical partitioning; Materialized views; Physical design of DW; Data mart design; Web data warehousing; Data quality management; Knowledge discovery: Prediction, Market-basket analysis, Clustering.

References

1. Anahory S., *Data Warehousing in the Real World*, Pearson Education, 2003
2. Ponniah P., *Data Warehousing Fundamentals*, John Wiley & Sons, 2001.
3. Kimball R., *The Data Warehouse Lifecycle Toolkit: Expert Methods for Designing, Developing and Deploying Data Warehouses*, John Wiley & Sons, 1998.
4. Corr L., *Agile Data Warehouse Design*, DecisionOne Press, 2011.

CIS-662: Cryptanalysis

Status	Optional
Credits	3
Prerequisites	CIS-567

Cryptanalysis of Classical Cryptosystems; Cryptanalysis of Block Ciphers: Hellman's Time Memory trade-off attack, Linear Cryptanalysis, The Piling-up Lemma, Linear Approximations of S-boxes, A Linear Attack on an SPN, Differential Cryptanalysis, Differential Cryptanalysis of DES, Slide Attack, Related Key attacks Introduction to Side Channel attacks; Cryptanalysis of Stream Ciphers: Correlation attack and fast correlation attack, Algebraic attack, distinguishing attacks, Fast Walsh Transform, Correlation Immunity and Algebraic Immunity of Boolean functions; Cryptanalysis of Asymmetric Cryptosystems: Factoring Algorithms, The Pollard p1 Algorithm, The Pollard Rho Algorithm, Dixon's Random Squares Algorithm, Security of the Rabin Cryptosystem, Semantic Security of RSA, Factoring Algorithms: Pollard's p-1 , Pollard Rho, Dicson Randomized Square Root, Pomerance Quadratic Sieve for factor bases , Wiener's Low Decryption Exponent, Continued Fraction, Quadratic Sieve, Elliptic curve factorization method, Algorithms to attack Discrete Log Problem on Finite Fields: The Silver-Pohling-Hellman, The Index-Calculus, Attacks on basic key exchange and key transport protocols;

References

1. Richard A. Mollin, . *An introduction to Cryptography*, 2nd ed., Chapman and Hall/CRC,2006
2. Mark Stamp, Richard M. Low, *Applied Cryptanalysis- Breaking Ciphers in the real world*, Wiley-IEEE, 2007.
3. Alfred J. Menezes, Paul C. Van Oorschot, Scott A. Vanstone, *Handbook of Applied Cryptography*, CRC, 1996.

CIS-663: Secure Software Development

Status	Optional
Credits	3
Prerequisites	Nil

Secure software attributes, Requirements engineering for secure software, Software engineering of secure application, Security-aware SDLC, System complexity drivers and security, Threat Modeling, Least privilege coding, privilege hierarchy, Least common mechanism, Code analysis, Fail-safe defaults in coding, Vulnerability cycles, Integration of application with Security architecture, Secure data structure design, Secure database services, Secure transport protocols, Penetration Testing and Application Security Testing, Constrained data access models, Secure procedure design, Development of security focused test cases, Security Mechanism and Protocols, Implementation of Security Mechanism, Secure Programming in: C /C++, Java & Microsoft.NET.

References

1. Robert C. Seacord, *Secure Coding in C and C++*, 2nd ed., Addison-Wesley, 2013
2. Mark G. Graff, Kenneth R. van Wyk, *Secure Coding: Principles and Practices*, O'Reilly, 2003.
3. Messier M., Viega J., *Secure Programming Cookbook for C and C++*, O'Reilly, 2003.
4. Alan Cooper et al., "*About Face 3: The Essentials of Interaction Design*", John Wiley & Sons, 2007.

CIS-664: Mobile System Security

Status	Optional
Credits	3
Prerequisites	Nil

Security in Wireless Networks and Devices: Cellular Wireless Communication, Wireless LANs, Wireless Application Protocol; Bluetooth Security: Introduction, Technology, Architecture, Weaknesses and Countermeasures; Mobile Telecom Networks: GPRS, UMTS, Architectures; Security in Mobile Ad Hoc Networks (MANETs): Introduction, Routing Protocols, Vulnerabilities, Preventing Attacks, Cryptographic Tools; Wireless Sensor Networks: Introduction, Sensor Devices, Sensor Network Security, Mitigating the threat of stolen devices, Security analysis of iOS 7, Android 4.4, End-to-end mobile security, Mobile Malware, Mobile Security Design and Management;

References

1. Douligeris C., and Serpanos D. N., *Network Security Current Status and Future Directions*, John Wiley & Sons, 2007.
2. Ronald L. Krutz, *Securing SCADA Systems*, Wiley Publishing, 2006.
3. Sutton R. J., *Secure Communications Applications and Management*, John Wiley & Sons, 2002.
4. Tara M. , and Elden C. R., *Wireless Security and Privacy: Best Practices and Design Techniques*, Addison Wesley, 2002.
5. Peter van de Put, *Professional iOS Programming*, John Wiley, 2014.

CIS-665: Embedded System Security

Status	Optional
Credits	3
Prerequisites	CIS-550/567

Embedded System Security: Trends, Policies and Threats; Systems Software Considerations: Operating System Role and Requirements, Multiple Independent Levels of Security, Access Control and Capabilities; Secure Embedded Software Development: Principles of High-Assurance Software Engineering, Minimal Implementation, Component Architecture, Independent Expert Validation; Embedded system Cryptography; Data Protection Protocols for Embedded Systems : Data-in-Motion Protocols, Data-at-Rest Protocols, Emerging Applications; Secure Rabbit Processor; FPGA Security, Secure Processors: IBM 4758, AEGIS, ARM Trust zone; SCADA System: Security Issues, SCADA Protocols, Vulnerabilities and Attacks, Security Methods and Techniques.

References

1. David Kleidermacher, Mike Kleidermacher, *Embedded Systems Security- Practical Methods for Safe and Secure Software and Systems Development*, Elsevier, 2012.
2. Stapko T., *Practical Embedded Security: Building Secure Resource-Constrained Systems*, Elsevier, 2008.
3. Gebotyes C.H., *Security in Embedded Devices*, Springer, 2006.
4. F. Rodriguez-Henriquez, N. A. Saqib, A. Diaz-Perez, C. K. Koc , *Cryptographic Algorithms on Reconfigurable Hardware*, Springer, 2006.

CIS-666: Formal Methods for Information Security

Status	Optional
Credits	3
Prerequisites	Nil

Introduction, Limitations of testing and need for formal verification, Basics of formal methods for security (principles and techniques), Overview of logic and propositional calculus, Calculational Logic, Logical Connectives, Boolean Equality, Continued Equivalence, Disjunction, Conjunction, Implication, Introduction to Hoare's Logic, Weakest pre-condition, The assignment axiom, Calculating assignments, Sequential composition, Conditional statements,

Reasoning about conditional statements, Constructing conditional statements, Inductive proofs and constructions, Patterns and invariant, From verification to construction, Design by Contract (DBC), The six principles of Design by contract, UML and Formal Methods, The Object Constraint Language (OCL), Algebraic Specifications, Specifications of abstract data types, Completeness, Axioms and term rewriting, Modularity and re-usability, Model-based specifications, The Z (Zed) specification Language, Z Schemas and Schema Calculus, Promotions, Data and functional refinements, Petri Nets, Access Control Systems (RBAC, Identity Management Models), Formal Verification of Web Protocols, Limitations and Acceptance of Formal Methods, Seven Myths of Formal Methods, Formal Verification Tools(Alloy).

References

1. Giampaoli Bella, *Formal Correctness of Security Protocols*, Springer, 2007.
2. Benantar, Messaoud, *Access Control Systems: Security, Identity Management and Trust Models*, Springer, 2006.

CIS-667: Network Security Monitoring

Status	Optional
Credits	3
Prerequisites	CIS-568

Network Security Monitoring (NSM) Cycle, Planning Data Collection, Sensor Platforms, Detection Mechanisms, Indicators of Compromise and Signatures, Reputation-Based Detection, Signature-Based Detection, Anomaly-Based Detection with Statistical Data, Packet Analysis, Threat Intelligence, Analysis Process, Analysis Tools.

References

1. Sanders Chris, and Jason Smith, *Applied Network Security Monitoring: Collection, Detection, and Analysis*, Elsevier, 2013.
2. Bejtlich Richard, *The Practice of Network Security Monitoring: Understanding Incident Detection and Response*, No Starch Press, 2013.
3. Blask, Chris, et al. *Security Information and Event Management (SIEM) Implementation*, McGraw-Hill, 2011.
4. Marty Raffael, *Applied security visualization*, Upper Saddle River: Addison-Wesley, 2009.

CIS-668: Security and Privacy in Cloud Computing

Status	Optional
Credits	3
Prerequisites	CIS-541

Cloud Computing Models, Secure Data Outsourcing, Secure Computation Outsourcing, Proof of Data Possession / Retrieveability, Virtual Machine Security, Trusted Computing Technology and Clouds, Cloud-Centric Regulatory Compliance Issues And Mechanisms, Business and Security Risk Models, Applications of Secure Cloud Computing.

References

1. Winkler Vic JR, *Securing the Cloud: Cloud computer Security techniques and tactics*, Elsevier, 2011.
2. Pearson Siani and George Yee., *Privacy and security for cloud computing*, Springer, 2012.
3. Krutz Ronald L. and Russell Dean Vines, *Cloud security: A comprehensive guide to secure cloud computing*, John Wiley & Sons, 2010.
4. Halpert, Ben, *Auditing cloud computing: A security and privacy guide*, John Wiley & Sons, 2011.
5. Alliance C., *Security guidance for critical areas of focus in cloud computing v3. 0.*, Cloud Security Alliance, 2011.

CIS-695: Special Topics in CIMV-II

Status	Optional
Credits	3
Prerequisites	Nil

This course may be used for advanced topics not already covered in the syllabus. The special paper may be conducted as a lecture course or as an independent study course. The faculty must approve the topic and contents of the course.

CIS-696: Special Topics in SC-II

Status	Optional
Credits	3
Prerequisites	Nil

These courses for advanced topics not already covered in the syllabus. The special paper may be conducted as a lecture course or as an independent study course. The faculty must approve the topic and contents of the course.

CIS-697: Special Topics in ISS-II

Status	Optional
Credits	3
Prerequisites	Nil

This course may be used for advanced topics not already covered in the syllabus. The special paper may be conducted as a lecture course or as an independent study course. The faculty must approve the topic and contents of the course.

MS THESIS RESEARCH IN SPRING and SUMMER SEMESTER

CIS-698: MS Thesis Research

Status	C
Credits	6+6
Prerequisites	Relevant courses in previous semester

Under this title, student will conduct research based project on some Computer Science related problem. He/She may take part in the on-going research or may introduce a novel approach in a specific field in consultation with his/her supervisor.

Under CIS-698 a proposal for Thesis Research should be developed for the project to be taken, being offered by the faculty member within the institute or outside and full time Thesis Research should be carried out based on the Thesis Research Proposal developed. The nature of the project may be research, development or design and may involve experimental or computational work or combination of both. Student performance in these activities will also be counted towards the overall evaluation.