Course Contents of MS/Ph.D Computer Science

Department of Computer Science
University of Malakand, Pakistan

This document contains course contents of **MS/Ph.D.**, which have been designed/prepared by the Committee at the Department. The course contents are designed in the light of the revisions recommended by HEC National Computer Science Curriculum Revision Committee and HEC National Curriculum Revision Committee for Software Engineering (NCRC-SE).
Apart from HEC, various national and international websites have been visited for assistance in preparation of the stated course contents.

The schemes of studies of MS/Ph. provided in this document are already approved by the Vice Chancellor in anticipation.

Course Contents:

Prepared by:

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Approved by:

i. Prior Approval by the Vice Chancellor, UOM dated: 19-Aug-2011
ii. Approval from the Board of Studies dated: 26-May-2012

26-May-2012

Members of the Board of Studies

Dated: 26-May-2012

S.No	Name	Designation	Organization	Signature
1	Dr. Sehat Ullah	Convener (Ex-Officio)	Head, Deptt: CS & IT, UOM	
2	Dr Shah Khusro	Member (Expert)	AP, University of Peshawar.	
3	Dr Jamil Ahmad,	Member (Expert)	AP, NUST, Pakistan.	
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University of Malakand

Department of Computer Science & IT

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Dated: 19-08-2011

NOTIFICATION

It is notified of the information of all concerned that the Vice Chancellor, in anticipation of approval from the relevant bodies, has been pleased to approve the enclosed curses for MS/Ph.D (Computer Science) w.e.from 1st June, 2011.

This issues with the approval of the Competent Authority.

Encl: (Duly signed list of the approved courses)

Registrar
University of Malakand

Copy to:

1. The Controller of Examinations, University of Malakand.
2. Incharge, Department of Software Engineering
3. M.Phil/Ph.D Coordinator, University of Malakand.
4. File

Registrar
University of Malakand

List (REVISED) of Courses Offered in MS/PhD (Computer Science)
Department of Computer Science & IT
University of Malakand
Date: 14-June-2012

#	Code	Course Title	Category	Credit Hours
1	CS 701	Advanced Operating System	Core	3
2	CS 702	Advanced Algorithm Analysis	Core	3
3	CS 907	Advanced Computer Architecture	Core	3
4	CS 908	Theory of Computation	Core	3
5	CS 903	Research Methodology	Core	3
6	CS 901	Advanced Data Analysis	General Elective	3
7	CS 905	Optimization Techniques	General Elective	3
8	CS 906	Mathematical Modeling	General Elective	3
9	CS 909	Machine Learning	General Elective	3
10	CS 910	Distributed Systems	General Elective	3
11	CS 911	Model Checking	General Elective	3
Specialization Area: Software Engineering				
13	CS 912	Empirical Software Engineering	Elective	3
14	CS 913	Advanced Topics in Software Engineering	Elective	3
15	CS 914	Advanced System Re-engineering	Elective	3
16	CS 915	Graph Theory	Elective	3
17	CS 916	Software Engineering Aspects of Green Computing	Elective	3
18	CS 917	Software Verification and Testing	Elective	3
19	CS 703	Requirement Engineering	Elective	3
20	CS 704	Software Refactoring	Elective	3
21	CS 705	System Re-engineering	Elective	3
Specialization Area: Virtual Reality and Intelligent Systems				
22	CS 918	Virtual and Augmented Reality Systems	Elective	3
23	CS 919	3D Interaction Techniques in Virtual and Augmented Reality	Elective	3
24	CS 920	Virtual Reality Interfaces and haptic Systems	Elective	3
25	CS 921	Advance 3D Computer Graphics	Elective	3
26	CS 922	Ergonomics and human performance evaluation	Elective	3
27	CS 706	Evolutionary Computation/Algorithms	Elective	3
Specialization Area: Networking				
28	CS 923	Advanced Topics in Wireless Networks	Elective	3
29	CS 924	Advanced Networks Security	Elective	3
30	CS 925	Network Performance Evaluation	Elective	3
31	CS 707	Advanced Networking	Elective	3
32	CS 708	Network Security	Elective	3
33	CS 709	Wireless Networks	Elective	3
34	CS 710	Topics in Computer Networking	Elective	3

Curriculum Designed/ Prepared By:

1. Dr. Sehat Ullah (Head, Deptt: of CS & IT)
2. Dr Siffat Ullah Khan (Coordinator, MS/PhD Program)
3. Dr. Sohail Abbas (Member, MS/PhD Program)
4. Dr. Fawad Qayum

5. Dr. Shakil Arshad

MS/Ph.D in Computer Science

UOM Approved Scheme of Study for MS/PhD

Course Title: Advanced data Analysis
Course Code: CS 901
Category: General Elective
Credit Hours: 3

Course Outline:

INTRODUCATION TO STATISTICS: Definition of statistics, Population, Population parameters, Samples, Sample statistics, Random sampling, Sampling Distributions, Descriptive and inferential statistics, Importance of statics in various disciplines, Variable, discrete variables and continuous variables. **COLLECTIONS OF DATA:** Primary Data and secondary Data, Methods for collecting primary data, Methods for collecting secondary data, Types of data(levels of Data), Nominal data, Ordinal data, Interval data, Ratio data, introduction to QDA. **PRESENTATION OF DATA:** Frequency Distribution, Formation of Frequency Distribution, Diagram and Graphs, Rules for construing Diagrams, Diagrammatic presentation, Graphs, Graphic Presentation. **ANALYSIS OF DATA:** Mean, Median, Mode, Dispersion, Absolute and Relative dispersion, Measures of Dispersion, Range, Mean Deviation, Standard deviation, Variance, Coefficient of variation, Moments, Skewness, Difference between dispersion and skewness, Measures of skewness, Kurtosis, Types of kurtosis. **PROBABILITY:** probability, Experime and Random Experiment, Sample space, What is event, Combination, Permutation, Examples of probability.**PROBABILITY DISTRIBUTION:** Normal distribution, Binomial distribution, Poisson distribution, Sampling distribution, Sampling from normal population, Standard error of the mean, Histogram to depict mean of the means, Spearman's Rank Correlation Co-efficient Test. **INTRODUCATION TO SPSS:** What is SPSS, T-test, Chi squre test, Stacked bar chart, Histogram.**Advance SPSS:** Correlation and association (Practical), One variable descriptive, Two variable descriptive, One sample test, Independent sample t test, Q-Q plot test, One sample K-S test, Levene's test,

Introduction, Digital Documents and Data, Qualitative Data Analysis Approaches, Early Analysis Steps, Within-Case Data Displays, Cross-Case Data Displays, Critical Analysis (mostly literary approaches), Content Analysis (mostly quantitative approaches), Analyzing Images, Validity & Reliability

Reference Material:

- *Statistics (3rd Ed.)*by David Freedman, Robert Pisani and Roger Purves. Norton *Doing Data Analysis with SPSS Version 12 by Carver and Nesh.*
- *Qualitative Data Analysis: An Expanded Sourcebook,* by Matthew B. Miles and A. Michael Huberman. 2nd Edition. Sage Publications: Thousand Oaks, CA
- *The qualitative researcher's companion, by* Huberman, M.A., & Miles, M. B. (2002).Thousand Oaks, CA: Sage Publications.

Course Title: Research Methodology

Couse Code: CS 903

Category: Core

Credit Hours: 3

Course Outline:

Research Methods in Computer Science: What is Research?, Quantitative Vs Qualitative Research, Introduction to SLR, importance of SLR, comparison of SLR to Tradition Research Methodology. **Stages of SLR:** Define the Protocol (Planning the Review), Implementing the protocol, Reporting. **SLR Guide lines:** Procedure for performing SLR 2004(BY BARBARA KITCHENHAM), Procedure for performing SLR 2007(BY BARBARA KITCHENHAM), **Various studies:** Primary study, Secondary study, Tertiary study, Mapping study, Mapping VS SLR, **Various protocols studied:** Protocol Reviewed are SORT (Software Outsourcing Relationship Trust), Factors influencing clients in the selection of offshore software outsourcing vendors: an exploratory study using a systematic literature review, Empirical evidence in global software engineering: a systematic review, Intra cultural challenges in offshore software development outsourcing relationship "A systemic literature review", Lessons learnt undertaking a large scale systemic literature review, Software development outsourcing Relationships Trust: A SLR Protocol, Lessons from applying the systematic literature review process within the software engineering domain, Indentifying the relevant studies in software engineering, MMSE protocol.

How do researchers communicate?, Types of scientific communication, Examining examples of different types of scientific communication. **Scientific Literature:** Searching the scientific literature, Using the UOM library, Using online search engines, What is a refereed journal? , Plagiarism and how to avoid it, **Beginning to Write:** Establishing your constraints, Organizing your writing, Preparing outlines, Standard formats for scientific papers, research projects and theses, Style guides, **Content:** Creating a literature review, Preparing other sections of a research report (abstract, introduction, materials and methods, results and discussion, conclusions), **Style and grammar:** Scientific writing style, First-person vs. Third-person; Passive vs. active voice, Avoiding excessive wording
Grammar, Avoiding misuse of words, When to use footnotes. **Reference citations**: How to use references, Within the text, How to make lists of references, **Revising**: Dealing with revisions, Accepting criticism, Making sense of reviewers' comments

Making the changes. **Other communication:** research proposals, creating a fact sheet/bulletin, articles for popular press, memos, letters and emails. **Computer skills**: Microsoft Word, Microsoft Excel, Poster Presentations, Organization and formats for posters, Microsoft PowerPoint, paper and thesis writing using LATEX.
Intellectual Property rights (IPR), research ethics

Reference Material:

- Kitchenham, B., *Procedures for Performing Systematic Reviews.* Joint Technical Report, Keele University TR/SE-0401 and NICTA 0400011T.1, 2004:
- Kitchenham, B. and S. Charters, *Guidelines for performing Systematic Literature Reviews in Software Engineering*, in *EBSE Technical Report*. 2007, Software Engineering Group, School of Computer Science and Mathematics, Keele University and Department of Computer Science, University of Durham.
- Beecham, S., et al., *Protocol for a Systematic Literature Review of Motivation in Software Engineering.* School of Computer Science, University of Hertfordshire, College Lane Campus, Hatfield, Hertfordshire AL10 9AB, 2006:
- Khan, S.U., M. Niazi, and N. Ikram, *Systematic Literature Review Protocol for Software Outsourcing Relationships Trust (SORT).* TR/2009-01, School of Computing and Maths, Keele University, U.K, 2009: p. 40.
- Khan, S.U. and M. Niazi, *Systematic Literature Review Protocol for Software Outsourcing Vendors Readiness Model (SOVRM).* TR/08-01,School of Computing and Maths, KeeleUniversity,U.K, 2008: p. 28.
- How to Write and Publish a Scientific Paper. 6th Edition.
  Authors: Robert A.Day and Barbara Gastel. ISBN: 0-313-33040-9
- Alley, M. 2003. The Craft of Scientific Presentations: Critical steps to succeed and critical errors to avoid. Springer, NY. 241 pages. ISBN:0-387-95555-0.

Course Title: Optimization Techniques

Course Code: CS 905

Category: General Elective

Credit Hours: 3

Course Outline:

Overview of optimization techniques and classification of optimization problems, optimization using calculus ,Kuhn-Tucker Conditions, Linear Programming- Graphical method, Simplex method, Revised simplex method, Sensitivity analysis, Example of

transportation, assignment, water resources and other applications, Dynamic programming- introduction, Sequential optimization, computational procedure, Curse of dimensionality, Applications in water resources and structural engineering, other topic in optimization-Piece wise linear approximation, Multi objective optimization, multi level optimization, Direct and Indirect search methods, Evolutionary algorithms for optimization and search, Applications in civil engineering

Reference Material:

- An introduction to optimization by Edwin K. P. Chong, Stanislaw H. Zak 2nd Edition.
- Differential calculus by Narayan and Shanti.

Course Title: Mathematical Modeling

Course Code: CS 906

Category: General Elective

Credit Hours: 3

Course Outline:
Modeling with difference equations, Dynamical systems and Difference Equations Modeling with proportionality, Geometric similarity and Case Study, Model fitting Least squares, Experimental modelling, Polynomials and cubic splines, Deterministic behavior and random numbers, Probabilistic behavior case study, Queuing model Discrete systems and system reliability, Optimization modeling and linear programming (LP), Linear programming: geometric solutions and algebraic solutions, Linear programming: simplex method and sensitivity, Graph models, Connection to mathematical programming and case study, Dimensional analysis, A damped pendulum and examples, An arms race and modelling Energy crisis modelling Population growth Constrained optimization and maximizing profit Managing renewable resources

Reference Material:
"1. A First Course in Mathematical Modeling by Giordano et al., 4th Ed.

Course Title: Advanced Computer Architecture

Course Code: CS 907

Category: Core

Credit Hours: 3

Course Outline:

This course is aimed at the hardware aspects of parallel computer architectures including the design and protocols evaluation for memory coherence, inter-connection networks and system scalability. Advanced topics in this course will cover multiprocessors on a chip, reconfigurable computing and power aware designs. Various coarse-grained and fine-grained architectures with reference to SIMD and MIMD designs should also be covered.

Reference Material:

- "Advanced Computer Architecture: A Design Space Approach", DezsoSima, Terence Fountain, Peter Kacsuk, Addison-Wesley Publishers, 1997.
- "Scalable Parallel Computing Technology, Architecture, Programming", Kai Hwang, ZhiweiXu, McGraw Hill Publishers, 1998.

Course Title: Theory of Computation

Course Code: CS 908

Category: Core

Credit Hours: 3

Course Outline: INTRODUCTION: Model of computation, Languages and problems, theory of computation classification. FINITE AUTOMATA (FA): Deterministic finite automata (DFA), Nondeterministic finite automata (NFA), Finite Automata with Epsilon transitions, Closure Properties, Equivalence of DFA and NFA and minimization of Automata, FA with output (transducers). REGULAR EXPRESSIONS AND LANGUAGES: Regular expression, Equivalence between language accepted by FA and regular languages, Pumping lemma. GRAMMAR AND LANGUAGES: Context-Free Grammar (CFG), Parse Trees and Derivations, Ambiguity, Equivalence of FA and CFG, Pumping Lemma for CFL, Closure Properties of CFL Definition of the Pushdown automata, Languages of a Pushdown Automata, Equivalence of Pushdown automata and CFG. TURING MACHINES (TM): Turing Machine, Deterministic Turing machines (DTM), Accepting and deciding a language, Multi-tape TM, Equivalence of 1-tape and multi-tape TM's, Nondeterministic Turing machines (NTM), Equivalence of NTM and DTM, Universal TM.

Reference Material:

1. *Introduction to the Theory of Computation*, by Michael Sipser, 2nd edition, 2006.
2. *Theory of Computation an Introduction* by James L. Hein, Jones & Bartlett Publishers 1996.
3. *Introduction to Languages and The Theory of Computation*, by John C. Martin, 4th Edition.
4. *An Introduction to Formal Languages and Automata* by Peter Linz, 3rd Edition.

Course Title: Machine Learning

Course Code: CS 909

Category: General Elective

Credit Hours: 3

Course Outline:
Introduction, Linear Regression, Bayesian Regression, Discriminative algorithms, Bayesian Networks, Non parametric methods, Decision tree learning, artificial neural networks, support vector machine, SVM and VC dimensions, model selection, Model selection criteria, Description length, feature selection, Combining classifiers, boosting, Boosting, margin, and complexity, Margin and generalization, mixture models, Mixtures and the expectation maximization (EM) algorithm, EM, regularization, clustering, Spectral clustering, Markov models, Hidden Markov models (HMMs), Unsupervised learning, reinforcement learning, singular value decomposition

Reference Material:
Bishop, Christopher. *Neural Networks for Pattern Recognition*. New York, NY: Oxford University Press, 1995. ISBN: 9780198538646.
Duda, Richard, Peter Hart, and David Stork.*Pattern Classification*. 2nd ed. New York, NY: Wiley-Interscience, 2000. ISBN: 9780471056690.
Hastie, T., R. Tibshirani, and J. H. Friedman.*The Elements of Statistical Learning: Data Mining, Inference and Prediction*. New York, NY: Springer, 2001. ISBN: 9780387952840.
MacKay, David. *Information Theory, Inference, and Learning Algorithms*. Cambridge, UK: Cambridge University Press, 2003. ISBN: 9780521642989.
Mitchell, Tom. *Machine Learning*. New York, NY: McGraw-Hill, 1997. ISBN: 9780070428072.

Course Title: Distributed Systems

Course Code: CS 910

Category: General Elective

Credit Hours: 3

Course Outline: Introduction, Characterization of Modern Operating Systems; file systems, memory management techniques, Process scheduling and resource management, System Models, Architectural models, Interprocess Communication, Issues of Security in Distributed Systems (Partial coverage)
Distributed File System, Concurrency Control in Distributed Systems, Problems of coordination and agreement in Distributed Systems,- Replication – Advantages and requirements, Fault-tolerant services

Reference Material:
1. Distributed Systems Concepts and Design 5th edition by George Coulouris, Jean Dollimore and Ttim Kindberg
2. Distributed Operating Systems: Concepts and Design by Pradeep k. Sinha
3. Advanced Concepts in Operating Systems by Singhal and Shiviratri

Course Title: Model Checking

Course Code: CS 911

Category: General Elective

Credit Hours: 3

Course Outline:
This course focuses on the modeling and analysis of reactive systems using finite state machines and temporal logic, and how model checking tools can be used to verify crucial properties of safety-critical systems. The course introduces the algorithms and data structures used to model-check very large finite-state systems. An algorithmic foundation of real-time model checking, stochastic model checking, implementation strategies, tools and application case studies will also be presented. During tutorials students will solve problems and also work with the present state of the art model checking tools: HyTech, UPPAAL and PRISM.

Reference Material:

- E.-R. Olderog and H. Dierks: Real-Time Systems. Cambridge University Press, 2008.
- B. Bérard et al.: Systems and Software Verification: Model-Checking Techniques and Tools, Springer 2001.
- C. Baier and J.-P. Katoen: Principles of Model Checking, MIT Press, 2008.
- T-A. Henzinger, P-H. Ho, and H. Wong-Toi. HYTECH: A model checker for hybrid systems. International Journal on Software Tools for Technology Transfer, 1(1-2):110-122,1997.
- GoranFrehse. Phaver: Algorithmic verification of hybrid systems past HYTECH. In HSCC, pages 258-273, 2005
- A Tutorial on UPPAALGerdBehrmann, Alexandre David, and Kim G. Larsen. In proceedings of the 4th International School on Formal Methods for the Design of Computer, Communication, and Software Systems (SFM-RT'04). LNCS number 3185, Springer.

Course Title: Advanced Operating Systems

Course Code: CS 701

Category: Core

Credit Hours: 3

- **Course Outline:** Introduction to Modern Operating Systems
- Operating System Structures
- Process
- Threads
- Process Synchronization
- CPU Scheduling
- Main Memory
- Virtual Memory
- File System

Case Studies: Windows 7

Reference Material:

1. Operating System Concepts 9th edition by A. Silberschatz, P. B. Galvin, G. Gagne.
2. Distributed Systems Concepts and Design 5th edition by G. Coulouris, J. Dollimore and T. Kindberg.
3. Advanced Concepts in Operating Systems by Singhal and Shiviratri

Course Title: Advanced Algorithm Analysis

Course Code: CS 702

Category: Core

Credit Hours: 3

Course Outline:

Advanced algorithm analysis including the introduction of formal techniques and the underlying mathematical theory. NP-completeness. Search Techniques. Randomized Algorithms. Heuristic and Approximation Algorithms. Topics include asymptotic analysis of upper and average complexity bounds using big-O, little-o, and theta notation. Fundamental algorithmic strategies (brute-force, greedy, divide-and-conquer, backtracking, branch-and-bound, pattern matching, and numerical approximations) are covered. Also included are standard graph and tree algorithms. Additional topics include standard complexity classes, time and space tradeoffs in algorithms, using recurrence relations to analyze recursive algorithms, non-computable functions, the halting problem, and the implications of non-computability. Algorithmic animation is used to reinforce theoretical results. Upon completion of the course, students should be able to explain the mathematical concepts used in describing the complexity of an algorithm, and select and apply algorithms appropriate to a particular situation.

Reference Material:

- Approximation Algorithms, By Vijay V. Vazirani, Springer, 2004.
- Introduction to Algorithms, By Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, Clifford Stein, 2nd edition, Published by MIT Press, 2001.
- Algorithms and Theory of Computation Handbook, By Mikhail J. Atallah Contributor Mikhail J. Atallah, CRC Press, 1998.

Course Title: Empirical Software Engineering

Course Code: CS 912

Category: Elective

Credit Hours: 3

Course Outline:

Basic of Empirical Software Engineering: Research Design and Ethics, Evidence-based software engineering, making good research paper, Research Design, Research Ethics. **Basics of Doing Research:** Finding good research questions, Theory building, Evidence and Measurement, Peer Review Process. **Experiments:** Controlled Experiments, Quasi-experiments, Sampling, Replication. **Case Studies:** Single and Multi-case, Longitudinal Case Studies, Approaches to Data Collection, **Survey and Observation:** Surveys, Focus Groups, Ethnographies, **Interventions:** Action Research, Pilot Studies, Benchmarking. **Qualitative Analysis: Quantitative Analysis: Publishing and Reviewing: Replication and Beyond:** Bias and Influences, Threats to Validity, use empirical methods. **Empirical analysis in GSD**

Reference Material:

- Blum. B. I. Beyond Programming: To A New Era of Design. Oxford University Press. 1996.
- Chalmers, A. Science and Its Fabrication. University of Minnesota Press. 1990.
- Creswell, J. W. Research Design: Qualitative, Quantitative, and Mixed Methods Approaches. Second Edition. Sage. 2002.
- Crotty, M. Foundations of Social Research: Meaning and Perspective in the Research Process. Sage. 1998.
- Endres, A.; Rombach, D.; A Handbook of Software and Systems Engineering: Empirical Observations, Laws, and Theories. Addison Wesley, 2003.
- Meltzoff, J. Critical Thinking About Research: Psychology and Related Fields. American Psychological Association, 1998.
- Shull, F.; Singer J.; Sjoberg, D.I.K. (eds); Guide to Advanced Empirical Software Engineering. Springer, 2007.
- Strauss, A; Corbin, J; Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory.

Course Title: Topics in Software Engineering

Course Code: CS 913

Category: Elective

Credit Hours: 3

Course Outline:

Software Engineering Models:

Software outsourcing vendors' readiness Model (SOVRM)

Introduction, Offshore software development outsourcing (OSDO), Outsourcing types, SOVRM development stages, Systematic literature review (SLR), Empirical research, Qualitative research, Quantitative research, SOVRM model components, Readiness levels components, Critical success factors, Critical barriers, SOVRM assessment methods, SOVRM vs SMMI and IMM, Real world practices, Case study,

Capability Maturity Model Integration (CMMI)

Introduction to CMM and CMMI, CMMI levels, CMMI practices

Implementation Maturity Model (IMM)

Introduction, IMM levels, Critical success factors, Critical barriers, Real world practices

Global Software Development (GSD)

Introduction, Advantages and disadvantages of GSD/GSE, Issues in GSD, Types of GSD,

GSD process, Global software development process model, GSD project Management, DAR (Decision Analysis Resolution) process for making key business decisions, GSD Cost estimation, GSD Challenges, Global software development challenges, Professional practices for global software development (Intellectual Property Rights, Group working, conflict and negotiations management, Presentations, writing and referencing

Reference Material:

- PhD thesis (SOVRM Model) of Dr. Siffat Ullah Khan, Keele University, UK, 2011.

http://www.cecs.csulb.edu/~monge/2009SummerProgram/courseDescriptions.html#globalsweng

Course Title: Advanced System Re-engineering

Course Code: CS 914

Category: Elective

Credit Hours: 3

Course Outline:

Description

This module is the advance version of System Re-engineering and specifically designed for PhD students.It provides techniques to maintain and evolve existing systems instead of developing new ones and provides necessary skills to work with legacy systems. Legacy systems are valuable software systems that are still in use but are difficult to maintain, change or migrate because they were developed with technologies of the past and/or because they were not engineered properly.

Details:

Legacy Systems, Software Evolution Dynamics, Laws of Software Evolution, System Maintenance, Software aging (aging symptoms), Program Analysis (Static Analysis, Advance Control Flow Analysis, Data Flow Analysis, Program and System Dependence Graphs, Slicing), Software Testing, Software Metrics.

Reference Material:

- Keith Bennett. 1995. Legacy Systems: Coping with Success. IEEE Softw. 12, 1 (January 1995), 19-23. DOI=10.1109/52.363157 http://dx.doi.org/10.1109/52.363157
- S. Demeyer, S. Ducasse and O. Nierstrasz, “Object-Oriented Re-engineering Patterns.”
- David LorgeParnas. 1994. Software aging. In Proceedings of the 16th international conference on Software engineering (ICSE '94). IEEE Computer Society Press, Los Alamitos, CA, USA, 279-287.
- “Software Evolution” edited by T.Mens and S. Demeyer, Springer, 2008.
- A Metric Suite for Object Oriented Design. S. Chidamber, C. Kemerer, IEEE Transactions on Software Engineering, p.479-493, 1994.

Course Title: Graph Theory

Course Code: CS 915

Category: Elective

Credit Hours: 3

Course Outline:

Description

This module aims to introduce graph transformation, its basic notions, different approaches, and more advances concepts. In particular, we demonstrate the use of graph transformation to model object- and component-based systems and to specify syntax and semantics of diagram languages. Along the way we introduce the basic concepts, discuss different approaches, and mention relevant theory and tools.

Details;

Graph and Graph Morphism, Typed Graph and Typed Graph Morhpism, Basic concepts (Single push out and Double push out), Graph Grammar. Graph Transformation: (Aims and Paradigms of Graph Transformation, Graph Transformation Approaches, pplication Areas of Graph Transformation Systems), Algebraic Approaches

Reference Material:

- Handbook of Graph Grammars and Computing by Graph Transformations, Volume 1: Foundations 1997.Fundamentals of Algebraic Graph Transformation H. Ehrig, K. Ehrig, U. Prange, G. Taentzer.Springer-Verlag Berlin Heidelberg 2006.

Course Title: Software Engineering Aspects of Green Computing

Course Code: CS 916

Category: Elective

Credit Hours: 3

Course Outline:

Analyze the trade-offs among the greenness requirements themselves and other quality attributes, modeling and analyze the greenness attributes of software architecture and their trade-offs. Design patterns for achieving greenness both in and by software, Domain-specific programming abstractions to ease the implementation and analysis of the greenness of programs, Green compilers to generate energy-optimized code, Methods and techniques to reflect the greenness requirements in the test scenarios, Methods and techniques to monitor the greenness attributes of software during its operational phase, Metrics for assessing the greenness of software, Empirical evaluation of the greenness of software, Greenness by software: general principles and special qualities, Methods and techniques to measure the effect of greenness by software, Methods and techniques to achieve greenness in industrial processes by software, Methods and techniques to achieve greenness in embedded systems, Impact of multi-core programming for energy reduction, Experience reports and best-practices, Applications that enable dematerialization, Adaptable software systems based on the environmental context, Software for energy efficiency and management, smart energy systems, smart grids, smart metering

Reference Materials:

- Green Computing: Large-Scale Energy Efficiency ISBN: 1439819874 Publication Info: CRC Press Author: Wu-chunFeng
- Green IT Strategies and Applications: Using Environmental Intelligence- E-book available in the APUS Online Library ISBN: 1439837805 Publication Info: CRC Press Author: BhuvanUnhelkar

Course Title: Software Verification and Testing
Course Code: CS 917
Category: Elective
Credit Hours: 3

Course Outline:

Brief History of Software Engineering: Economic Justification for Software V& T: All Software Is Defective? Software Defect Cost Model, Find/Fix Cycle Costs, **Overview of Software Process Improvement Models**: **Software Requirements:** Why requirements are so important, Writing? Testable? Requirements, Requirements Exercise, Requirements Management, **Requirements-based Estimating and Scheduling Best Practices:** Estimates, Targets, Commitments, Schedules, Why most schedules are wrong, Estimating Best Practices, Estimating Exercise, Scheduling Best Practices, Scheduling Exercise, **Software Verification Overview:** Peer Reviews and Inspections, Unit and Integration Testing, **Software Validation Overview:** Testing Principles, Methods, Strategies, Levels, Types of Tests, Planning and Executing, Validation Exercise, Test Automation Issues,**Software Reliability Overview:** Defining Software Reliability, Measuring Software Reliability, Improving Software Reliability

Reference Material:

Software Verification and Validation for Practitioners and Managers, 2nd edition,by Steven R. Rakitin

Course Title: Requirement Engineering

Course Code: CS 703

Category: Elective

Credit Hours: 3

Course Outline:

Course Orientation & Intro to RE, Basics of RE, Project Initiation, Elicitation Techniques, Modeling Enterprises, Modeling Information and Behavior, Modeling Quality Requirements, Specifications & Validation, Managing Change and Inconsistency, Product/software integration, Requirements engineering in GSD

Reference Material:

- B. A. Nuseibeh and S. M. Easterbrook, "Requirements Engineering: A Roadmap", In A. C. W. Finkelstein (ed) "The Future of Software Engineering". (Companion volume to the proceedings of the 22nd International Conference on Software Engineering, ICSE'00). IEEE Computer Society Press
- Jackson, M. (1997). The Meaning of Requirements. Annals of Software Engineering, Vol 3, Pp5-21, Baltzer Science Publishers.
- Hickey, A.M. and Davis, A.M. (2003) Elicitation technique selection: how do experts do it? Proceedings, 11th IEEE International Requirements Engineering Conference (RE'03).
- Yu, E.S.K. (1997) Towards modelling and reasoning support for early-phase requirements engineering. Proceedings, Third IEEE International Symposium on Requirements Engineering (RE'97).
- De Landtsheer, R.; Letier, E.; van Lamsweerde, A. (2003) Deriving tabular event-based specifications from goal-oriented requirements models. Proceedings, 11th IEEE International Requirements Engineering Conference (RE'03),

Course Title: Software Refactoring

Course Code: CS 704

Category: Elective

Credit Hours: 3

Course Outline:

Description

Refactoring is a disciplined technique for restructuring an existing body of code, altering its internal structure without changing its external behaviour. Its heart is a series of small behaviour preserving transformations. Each transformation (called a 'refactoring') does little, but a sequence of transformations can produce a significant restructuring. Since each refactoring is small, it's less likely to go wrong. The system is also kept fully working after each small refactoring, reducing the chances that a system can get seriously broken during the restructuring" [Martin Fowler].

The modules envisage how to improve code quality, reliability, and maintainability throughout the software lifecycle. Code design and code quality are enhanced with refactoring. Refactoring also increases developer productivity and increases code reuse.

Details;

Non-traditional notion in Software Reengineering, Intense Evolution, Standard Legacy Problems, Semantics-preserving code transformations, Code Smells/ Bad Smells, Alphabetic list of refactorings.

Reference Material:

- Refactoring:Improvingthe Design of Existing Code, Martin Fowler et al.,1999, Addison-Wesley.
- "Refactoring to Patterns", Joshua Kerievsky, Addison-Wesley Professional, 2005.
- *Design Patterns: Elements of Reusable Object-Oriented Software* by ErichGamma, RichardHelm, RalphJohnson, and JohnVlissides (the GangOfFour), AddisonWesley Professional (November 10, 1994).
- "SERIOUS Refactoring Handbook", AitorAldazabal, Matthias Rieger, Claudio Riva, Bart Van Rompaey,JosetxoVicedo and Jan Zwanenburg. http://lore.ua.ac.be/Research/Artefacts/SERIOUSRefactoringHandbook/.

Course Title: System Re-engineering

Course Code: CS 705

Category: Elective

Credit Hours: 2

Course Outline:

Description

This module is the advance version of System Re-engineering and specifically designed for PhD students. It provides techniques to maintain and evolve existing systems instead of developing new ones and provides necessary skills to work with legacy systems. Legacy systems are valuable software systems that are still in use but are difficult to maintain, change or migrate because they were developed with technologies of the past and/or because they were not engineered properly.

Details;

Legacy Systems, Software Evolution Dynamics, Laws of Software Evolution, System Maintenance, Software aging (aging symptoms), Program Analysis (Static Analysis, Advance Control Flow Analysis, Data Flow Analysis, Program and System Dependence Graphs, Slicing), Software Testing, Software Metrics.

Resources:

- H Keith Bennett. 1995. Legacy Systems: Coping with Success. IEEE Softw. 12, 1 (January 1995), 19-23. DOI=10.1109/52.363157 http://dx.doi.org/10.1109/52.363157
- S. Demeyer, S. Ducasse and O. Nierstrasz, “Object-Oriented Re-engineering Patterns.”
- David LorgeParnas. 1994. Software aging. In Proceedings of the 16th international conference on Software engineering (ICSE '94). IEEE Computer Society Press, Los Alamitos, CA, USA, 279-287.
- “Software Evolution” edited by T.Mens and S. Demeyer, Springer, 2008.
- A Metric Suite for Object Oriented Design. S. Chidamber, C. Kemerer, IEEE Transactions on Software Engineering, p.479-493, 1994.

Course Title: Virtual and Augmented Reality Systems
Course Code: CS 918
Category: Elective
Credit Hours: 3

Course Outline:

Introduction to Virtual Reality, Human and its environment, I^3 diagram for VR (Interaction, Immersion, Imagination), Human centric reference model of VR, Sensory motor interfaces, Motion trackers, Stereoscopic vision(depth perception, stereoscopic image creation, active and passive stereoscopy), Design and evaluation of virtual environments, Application of (Medical, Psychotherapy, Fighting Simulation, Training Simulation, Assembling and Repairing, Biological and Physical Sciences, Collaborative Work, Ergonomic studies Games VR, Introduction to Augmented Reality

Reference Material:

- Handbook of Virtual Environments: Design, Implementation, and Applications (Human Factors and Ergonomics), Edited by Kay M Stanney, Lawrence Erlbaum Associates
- Virtual Reality Technology by GRIGORE C.BURDEA, PHILLIP COIFFET, 2ND Edition
- Le traité de la réalité virtuelle, Philippe Fuchs , Guillaume Moreau , Alain Berthoz , Jean-Louis Vercher 3rd edition
- Different research papers from web
- Introduction to Virtual reality by John Vince Published by Springer

Course Title: 3D Interaction Techniques in Virtual and Augmented Reality

Course Code: CS 919

Category: Elective

Credit Hours: 3

Course Outline:

Introduction , Graphical user interfaces and WIMP model, 3D Interaction, observation (visual, acoustic and tactile), Navigation and way finding (continuous and discrete control), selection, manipulation and application or system control, exocentric and egocentric interaction techniques, hybrid interaction techniques, haptic interaction, evaluation and comparison of various interaction techniques, characteristics of efficient interaction technique, design consideration for an interaction technique, 3D interaction in augmented reality.

Reference Material:

- Handbook of Virtual Environments: Design, Implementation, and Applications (Human Factors and Ergonomics), Edited by Kay M Stanney, Lawrence Erlbaum Associates
- Virtual Reality Technology by GRIGORE C.BURDEA, PHILLIP COIFFET, 2ND Edition
- Le traité de la réalité virtuelle, Philippe Fuchs , Guillaume Moreau , Alain Berthoz , Jean-Louis Vercher 3rd edition
- 3D user interfaces: theory and practice by BOWMAN Doug A., KRUIJFF Ernst, LAVIOLA Joseph J.5TH edition
- Different research papers from web

Course Title: Virtual Reality Interfaces and haptic Systems

Course Code: CS 920

Category: Elective

Credit Hours: 3

Course Outline:

Introduction, behavioral interfaces, sensory interfaces, motor interface, sensorimotor interfaces, motion captures, localization principals, specific interfaces for human body localization, manual interfaces, olfactory interfaces, introduction to haptic sense, importance of haptics in virtual environments, haptic interfaces (Tactile interfaces, force feedback interfaces), performance criteria of haptic devices, designing haptic interface, selection criteria of an haptic for VR application,

Reference Material:

- Handbook of Virtual Environments: Design, Implementation, and Applications (Human Factors and Ergonomics), Edited by Kay M Stanney, Lawrence Erlbaum Associates
- Virtual Reality Technology by GRIGORE C.BURDEA, PHILLIP COIFFET, 2ND Edition
- Le traité de la réalité virtuelle, Philippe Fuchs , Guillaume Moreau , Alain Berthoz , Jean-Louis Vercher 3rd edition
- Touch in Virtual Environments: Haptics and the Design of Interactive SystemsBy Margaret L. McLaughlin, Joao P. Hespanha, Gaurav S. Sukhatme 1st edition
- Different research papers from web

Course Title: Advanced 3D Computer Graphics

Course Code: CS 921

Category: Elective

Credit Hours: 3

Course Outline:

Introduction to Computer Graphics, Application of Computer graphics, Advantages of Computer Graphics, Display technologies, Transformations: Modeling transformation (scaling, Translation and rotation), viewing transformation, Projection transformation, Introduction to OpenGL (History of OpenGl, OpenGL Architecture, The OpenGL Utility Library, GLUT and Related Libraries , configuring OpenGl Program), Graphic Primitive in OpenGL(Point, line, polygon, triangle, triangle fan and Quad), Colors, shading and lighting in OpenGL , Texture Mapping Advance Texture Mapping, Physics in OpenGl

Reference Material:

Computer Graphics with OpenGL
By : *Donald Hearn and M. Pauline Baker* (3rd edition)

OpenGL Game programming ()
By: Kevin Hawkins and Dave Astle

Redbook of OpenGL
By: Addison-Wesley Publishing Company

Course Title: Ergonomics and human performance evaluation

Course Code: CS 922

Category: Elective

Credit Hours: 3

Course Outline:

Introduction to ergonomics and human machine interaction, usability, From 2D to 3D: Three essential aspects for the ergonomic study of interfaces, specialized or general devices, 3D interfaces and 3D interaction, role of gestures in interaction, ergonomics for designing interface and interaction, user representation in the virtual world, evaluation of interfaces and interaction through user studies, experimental set up and protocol designing, data collection and analysis in user studies.

Reference Material:

- Handbook of Virtual Environments: Design, Implementation, and Applications (Human Factors and Ergonomics), Edited by Kay M Stanney, Lawrence Erlbaum Associates
- Virtual Reality Technology by GRIGORE C.BURDEA, PHILLIP COIFFET, 2ND Edition
- Le traité de la réalité virtuelle, Philippe Fuchs , Guillaume Moreau , Alain Berthoz , Jean-Louis Vercher 3rd edition
- Handbook Human factors and ergonomics Edited by GavrielSalvendy, John Wiley and sons Inc.
- Different research papers

Course Title: Evolutionary Computation/Algorithms
Course Code: CS 706
Category: Elective
Credit Hours: 3

Course Outline:

Introduction, What is an Evolutionary Algorithm?, Genetic Algorithms, Evolution Strategies, Evolutionary Programming, Genetic Programming, Learning Classifier Systems, Parameter Control in Evolutionary Algorithms, Multi-Modal Problems and Spatial Distribution, Hybridisation with Other Techniques: Memetic Algorithms, Theory of EAs, Constraint Handling Special Forms of Evolution, Working with Evolutionary Algorithms, Practical implementation of EAs.

Reference Material:

1. Introduction to Evolutionary Computing
   by Agoston E. Eiben, J.E. Smith.
2. Introduction to Genetic Algorithms
   by S.N. Sivanandam, S. N. Deepa
3. Evolutionary Computation
   by Kenneth A. de De Jong,Kenneth A. De Jong
4. Genetic Algorithms in Search, Optimization, and Machine Learning
   David E.Goldberg.
5. Genetic Algorithms + Data Structures = Evolution Programs
   by ZbigniewMichalewicz

Course Title: Advanced Topics in Wireless Networks

Course Code: CS923

Category: Elective

Credit Hours: 3

Course Outline:

This course will survey current research in wireless communication networks. These types of networks have been growing exponentially in the past several years and include a host of different network types: mobile ad hoc, sensor, etc. The topics to be covered are given below.

- Transport Layer Protocols for Mobile Ad Hoc Networks
- Routing in Mobile Ad Hoc Networks
- Effect of Interference on Routing in Multihop Wireless Networks
- Collision Avoidance Protocols
- Energy Conservation
- QoS Issues in Ad-hoc Networks
- Security in Mobile Ad-Hoc Networks

Reference Material:

1. Algorithms And Protocols For Wireless And Mobile Ad Hoc Networks (publishers: Wiley)
2. Ad Hoc Networks: Technologies and Protocols (publishers: Springer)
3. Research Papers

Course Title: Advanced Networks Security

Course Code: CS 924

Category: Elective

Credit Hours: 3

Course Outline:

A study of network security policies, models, and mechanisms, topics include:

- Introduction to the course and computer security
- Security problems: viruses, worms, and denial of service
- Introduction to cryptography and its Applications
- Security Problems in the TCP/IP Protocol Suite
- Firewalls and intrusion detection
- Security architectures and models
- Web Security
- Wireless Security
- Administering Security

Reference Material:

1. William Stallings, Cryptography and Network Security, Principles and Practices, 5th Edition Publisher: Prentice Hall
2. C.P. Pfleeger & S. Pfleeger, Security in Computing 4th Edition Prentice-Hall International, 2006.
3. Kaufman, R. Perlman, M. Speciner, Network Security: Private Communication in a Public World – Prentice Hall PTR, Upper Saddle River, NJ, 2002.
4. Stinson, Cryptography: Theory and Practice, CRC Press, Boca Raton, FL, 1995.
5. Richard A. Mollin, An Introduction to Cryptography, Chapman and Hall/CRC, 2001.
6. B. Schneier, Applied Cryptography, John Wiley and Sons, NY, 1996.
7. Research Papers

Course Title: Network Performance Evaluation
Course Code: CS 925
Category: Elective
Credit Hours: 3

Course Outline:

This is an advanced course in networks and protocols. Analytical, simulation and experimental methods should be used to evaluate and design networks and protocols. Investigate network management tools and techniques.

Reference Materials:

1. T. G. Robertazzi, Computer Networks and Systems: Queuing Theory and Performance Evaluation, Springer-Verlag, 2nd edition, 1994.
2. Raj Jain, *The Art Of Computer Systems Performance Evaluation*, (publishers: Wiley)
3. Research Papers

Course Title: Advanced Networking

Course Code: CS 707

Category: Elective

Credit Hours: 3

Course Outline:

- Introduction: Computer Networks and the Internet
- Application Layer: Principles of Network applications, The Web and HTTP, DNS, Peer-to-peer application.
- Transport Layer: Transport layer services, multiplexing and de-multiplexing, connection and connectionless transport protocols, principles of reliable data transfer and congestion control.
- Network Layer: Forwarding and routing, virtual circuits and datagram networks, the router, forwarding and addressing in the Internet, routing algorithms.
- Data Link Layer: link layer services, error detection and correction techniques, multiple access protocols, link layer addressing and switching, the point-to-point protocol PPP.

Reference Material:

1. James F. Kurose and Keith W. Ross, ―Computer Networking – A Top-Down Approach Featuring the Internet, 5th Edition, Addison Wesley.
2. Coulouris, Dollimore, Kindberg, ―Distributed Systems – Concepts and Design, Addison Wesley.
3. William Stallings, "Data and Computer Communications", Prentice-Hall ― Sixth Edition (for those who want to review basics of networking).

Course Title: Network Security
Course Code: CS 708
Category: Elective
Credit Hours: 3

Course Outline:

Cryptology and simple cryptosystems; Conventional encryption techniques; Stream and block ciphers; DES; More on Block Ciphers; The Advanced Encryption Standard. Confidentiality & Message authentication: Hash functions; Number theory and algorithm complexity; Public key Encryption. RSA and Discrete Logarithms; Elliptic curves; Digital signatures. Key management schemes; Identification schemes; Dial-up security. E-mail security, PGP, S-MIME; Kerberos and directory authentication. Emerging Internet security standards; SET; SSL and IPsec; VPNs; Firewalls; Viruses; Miscellaneous topics.

Reference Material:

- W. Stallings, Cryptography and Network Security, Prentice Hall PTR, Upper Saddle River, NJ, 2003.
- Kaufman, R. Perlman, M. Speciner, Network Security: Private Communication in a Public World - Prentice Hall PTR, Upper Saddle River, NJ, 2002.
- M. Bishop, Computer Security: Art and Science - Addison-Wesley, 2003.
- Stinson, Cryptography: Theory and Practice, CRC Press, Boca Raton, FL,1995.
- Richard A. Mollin, An Introduction to Cryptography, Chapman and Hall/CRC, 2001

Course Title: Wireless Networks
Course Code: CS 709
Category: Elective
Credit Hours: 3

Course Outline:

This course covers fundamental techniques in design and operation of first, second, and third generation wireless networks: cellular systems, medium access techniques, radio propagation models, error control techniques, handoff, power control, common air protocols (AMPS, IS-95, IS-136, GSM, GPRS, EDGE, WCDMA, cdma2000, etc), radio resource and network management. As an example for the third generation air interfaces, WCDMA is discussed in detail since it is expected to have a large impact on future wireless networks. This course is intended for graduate students who have some background on computer networks.

Reference Material:

- W. Stallings, “Wireless Communications and Networks”, Prentice Hall, 2002.
- T.S. Rappaport, “Wireless Communications: Principles & Practice”, Second Edition, Prentice Hall, 2002.
- J. Schiller, “Mobile Communications”, Addison Wesley, 2000.
- V.K. Garg, “IS-95 CDMA and cdma 2000”, Prentice Hall PTR, 2000.

Course Title: Topics in Computer Networking
Course Code:CS 710
Category: Elective
Credit Hours: 3

Course Outline:

This course offers an advanced introduction and research perspectives in the areas of switch/router architectures, scheduling for best-effort and guaranteed services, QoS mechanisms and architectures, web protocols and applications, network interface design, optical networking, and network economics. The course also includes a research project in computer networking involving literature survey, critical analysis, and finally, an original and novel research contribution. Typical topics can be listed below:
Overview of packet switching networks and devices. Fundamentals of Internet Protocol (IP) networking. Route lookup algorithms. Router architecture and performance. Detailed operation of Internet routing protocols such as Open Shortest Path First (OSPF) and Border Gateway Protocol (BGP). Integrated and differentiated network service models. Traffic Engineering (TE) concepts and mechanisms including label assignment, label distribution, and constraint-based routing algorithms. Multi-protocol label switching and its generalization. Quality of service mechanisms for multimedia and real-time communications. TE-based routing and signaling protocols. Fundamentals of per-flow and aggregate scheduling algorithms. Application-level and network-level signaling protocols for data, voice, and video communications. Resource signaling and resource reservation protocols. Worst-case analysis for multimedia networking.

Reference Material:

- Puzmanov, Switching and Routing, Addison Wesley, 2002.
- Garica and Widjaja, Communication Networks: Fundamentals Concepts and Key Architectures, McGraw-Hill,2001.
- Peterson and Davie, Computer Networking a Systems Approach, 3rd Edition, Morgan Kaufman, 2003.
- William Stallings, High-Speed Networks: TCP/IP and ATM Design Principles, Prentice Hall; 1998, ISBN: 0135259657.
- Andrew S. Tanenbaum, Computer Networks, 3rd Edition. Prentice Hall,

March1996.