BANARAS HINDU UNIVERSITY

(Established by Parliament by Notification No. 225 of 1916)

Ordinance for Special Postgraduate Course

On

Master of Science (M.Sc.) Computational Science and Applications in Signal Processing

w.e.f. 2017-18

OFFERRED BY:

DST-Centre for Interdisciplinary Mathematical Sciences (CIMS)
Faculty of Science
Banaras Hindu University

CONTENTS

1. ADMISSION

Admission in the course is made according to the merit in the Entrance test (70%) & interview (30%), subject to fulfilling of eligibility requirements mention below. However, if the number of applicants for a particular course is less than twice the minimum number of seats, no entrance test shall be conducted. In that case, admission to the course would be made on the basis of merit in the qualifying examinations and/or written/subjective test conducted by the Departments/Faculty. In case the number of applicants is less than minimum number of seats in the course, the course would not run in that session.

1.1. MINIMUM ELIGIBILITY CRITERION, NUMBER OF SEATS, FEE, AND DURATION OF THE COURSE

NOTE:	Relaxation in minimum eligibility for Scheduled Castes (SC) / Scheduled Tribes (ST) / Other Backward Classes (OBC)/OBC-Minorities/Physically Challenged (PC) candidates given as other 'special courses' of faculty of science.
Course Name:	Master of Science (M.Sc.) Computational Science and Application in Signal Processing
Duration:	4 Semester (2 year)
Minimum Eligibility Criterion*	(A) B.Sc. (Hons.) / B.Sc. under at least 10+2+3 pattern securing minimum 50% marks in aggregate in science subjects (considering all the three years of B.Sc. Courses) and (B) candidate must have offered Physics / Electronics / Computer Science as one of the subject at the undergraduate level with Mathematics / Statistics. ***OR*** B.Tech. / B.E. (in Electronics / Communication / Electrical / Computer / Instrumentation related discipline) securing minimum 65 % marks in aggregate in engineering and science subject (Considering all four / five years of course). **Note:** Degrees like Bachelor in computer application (BCA), Bachelor in Information Technology (B-IT), etc. are not eligible.
Number of Seat	Minimum: 5 Maximum: 20
Fee	Rs. 25,000/- per semester

***NOTE 1:** For all courses the applicants having a degree equivalent to the degree of qualifying examination recognized by the Banaras Hindu University are also eligible (if they satisfy all other requirements for admission in the concerned course).

***NOTE 2:** *Relaxation in minimum eligibility for scheduled castes (SC), scheduled tribes (ST), other backward classes (OBS), other backward classes-minorities (OBC-minorities) and physically challenged (PC) candidates* are same as other 'special courses' of faculty of science BHU.

***NOTE 3:** Rules regarding minimum eligibility requirement other than given above is same as other 'special courses' of faculty of science BHU.

1.2. Reservation / Supernumerary seat / Employee: Reservation for *SC/ ST/ OBC/ OBC-minorities/ PC* / supernumerary seats and employee word is same as other 'special courses' of faculty of science BHU.

1.3.Scheme of Entrance Examination: The examination shall comprise of one paper of two hours duration consisting of objective type questions. The question is divided into following group:

i. Mathematics, Statistics, and Computer Science.

1.4.Syllabus for the Entrance Examination

The question papers shall be based on B.Sc. courses up to 2nd year and Engineering courses up to VI th semester generally taught at graduation level. The detail entrance syllabus and guideline will be given in admission broacher.

1.5.Merit List for Admission

1.5.1. Candidates shall be selected in order of merit on the basis of the aggregate marks secured in the entrance and interview provided that a candidate has obtained not less that 35% marks in the aggregate marks of entrance and interview. In case SC/ST candidates it shall be 30% in aggregate marks of entrance and interview.

1.5.2. In the case of equal marks the *inter-se* ranking of the candidates shall be decided in the following order:

i. The aggregate marks obtained by the candidates at the qualifying examination recognized for the purpose of appearing in the entrance examination.

ii. If the marks at the above examination are equal the aggregate per cent of marks obtained at Intermediate or equivalent examination.

iii. If the marks at the above [1.5.2. (i) –(ii)]examination happen to be the same, the date of birth would be the basis, i.e. the candidate senior in the age would rank higher.

1.5.3. In all matters relating to M.Sc. computational science and applications to signal processing admission decision of a Committee comprising the admission committee of the centre shall be final.

1.5.4. No scrutiny / revaluation of the answer books of the Entrance test shall be allowed.

1.5.5. The candidates selected for admission will be informed individually by registered post / e-mail / telephone.

1.5.6. A candidate/ candidates selected for admission may be referred to a Medical Board for Medical Examination for fitness by the Admission Committee.

2. Cancellation of Admission

i. The admission of an M.Sc. student is liable to be cancelled on the occurrence of any of the following :

ii. If he /she fails to attend classes, and absents regularly for 15 days or more without permission.

iii. If he /she fails to register in any course / project credits in any of the semester(s) unless he/she has dropped that semester(s).

iv. If his/ her attendance is less than 15% in any semester.

v. On an act of indiscipline as per university rules

3. Residential Requirement

Minimum residential requirement shall be four (4) semesters, extendable to a maximum of Eight (8) semesters in total.

4. Credit and course requirement

4.1. In order to qualify for the M.Sc. computational science and applications in signal processing degree a student shall offer not less than 80 credits. The distribution of the credits is given below:

4.1.1. Compulsory theory and practical course not less than 56 credits shall be taken by all the students as prescribed.

4.1.2. Minor 4 credits (2 credits in 2^{nd} semester and 2 credits in 3^{rd} semester) from other departments of faculty.

4.1.3. Elective courses not less than 12 credits shall be taken by all the students as prescribed.

4.1.4. Project credits : 8

4.2. A student cannot offer the same course again in any degree programme unless failed.

Part II: EVALUATION OF THE COURSE WORK AND EXAMINATION SYSTEM

5. Examination:

5.1. There shall be sessionals / tutorials / class tests / seminars in class / group discussions in each theory and practical paper (Core Courses, Elective papers) except CSA - 410: Project Work in Semester – IV.

5.2. Each theory paper, irrespective of their nature and credits shall be of 100 marks out of which 70 marks shall be assigned to the end semester theory examination and 30 marks to the sessionals / tutorials / class tests / seminars in class / group discussions.

5.3. The Theory papers shall be of THREE HOURS duration consisting of Eight full length questions in all out of which a student will be required to answer any five questions.

5.4. Each Practical paper will be of 100 marks out of which 30 marks will be assigned on sessionals / tutorials / class tests / seminars in class / group discussions and 70 marks will be assigned on the end semester examination out of which 50 marks will be on the performance in practical examination and 10 marks will be assigned each on practical record book and viva – voce.

5.5. All the practical papers shall be of FOUR HOURS duration.

5.6. Mentor for the Project (Course No. CSA – 412 of semester – IV,) will assigned in the semester –III and it will be spread over the whole semester –III and IV. The topic and problem will decided by the mentor. A project may be undertaken by a group of students. However, the project report shall be submitted by each member of the group separately. A project report shall clearly state the problem addressed, the methodology adopted, the assumptions and the hypotheses formulated, any previous reference to the study undertaken, simulation / experiment result, personal opinion and the broad conclusion drawn. There shall be an external examiner and an internal examiner (preferably the mentor of the student) for the evaluation of the project work. Out of total 100 marks assigned to the project, 60 marks will be assigned on the evaluation of the project work separately by both the examiners and 40 marks will be assigned jointly by the examiners on the oral presentation and viva – voce.

5.7. Students should earn credit for the two MINOR ELECTIVE THEORY papers (CSA-204 of semesters – II and CSA-302 of semester III) from other departments of the faculty.

Note: The titles, contents of theory papers as well as practical papers and distribution of credits to papers are given in course structure and syllabi section.

6. Allotment of project mentor / supervisor

6.1. The supervisor of the project, appointed by the academic committee / board of study of the department concerned in the beginning of 3rd semester, shall be the advisor - chairman. The Chairman will nominate the other two members of the project advisory committee from the related discipline in consultation with Head of Department.

6.2. Functions of the Advisory Committee
The advisory committee shall guide a student in the selection of suitable research / development problem for project and in all other matters relating to his/ her project related academic activities.

6.3. The details of the programme of work prepared by the project Advisory Committee shall be submitted to the Head of the Department end of each Semester.

7. Attendance

7.1. A student is required to have full, i.e., 100%, attendance and condonation upto 30% can be considered for specific cogent reasons. Out of this 30%, only 10% condonation shall be permitted without taking any application from the student. Rest 20% condonation may be given by the Dean, Faculty of Science/Principal. Further, a student shall be deemed to have minimum percentage of attendance only if, apart from above, he/she has attended at least 50% of the classes in each course also. The cogent reasons for condonation are given below:

a. Participation in NCC/NSC/NSS Camps duly supported by certificate.
b. Participation in University or College Team Games or Inter-State or Inter University tournaments, duly supported by certificate from the Secretaryof the University Sports Board or President of the College Athletic Association concerned.
c. Participation in Educational Excursion, which forms a part of teaching in any subject conducted on working days duly certified by the Dean, Faculty of Science.
d. University Deputation for Youth Festival duly certified by the Dean, Faculty of Science.
e. Prolonged illness duly certified by the Medical Officer or the Superintendent, S.S. Hospital, Banaras Hindu University or any other Registered Medical Practitioner, provided such certificate is submitted to the Coordinator of the center.
f. **No relaxation beyond 30% shall be considered in any case.**

7.2. The attendance of a newly admitted candidate shall be counted from the date of his/her admission, or date of starting of classes which ever is later while in the case of promoted candidates, attendance shall be counted from the date on which respective class begins. However, in case of promotion after declaration of results of supplementary examination (if any), the attendance will be counted from the date of admission in the respective case.

7.3. There shall be an Attendance Monitoring Committee in the centre underthe Chairmanship of the coordinator of the centre.

8. The Performance Indicator

8.1. Calculation of performance indicator: The performance indicator of a candidate in a semester or upto a semester shall be measured by SGPA and CGPA, details of which are given below:

SGPA : Semester Grade Point Average.
CGPA : Cumulative Grade Point Average.

$$SGPA = \frac{\sum_{i=1}^{n} C_i P_i}{\sum_{i=1}^{n} C_i}$$

Where C_i = Number of credits assigned for the i^{th} course of a semester for which SGPA is to be calculated.
P_i = Grade point earned in the íth course. i = 1, ------- n, represent the number of courses in which a student is registered in the concerned semester.

Note: For calculation of SGPA and CGPA, credits of compulsory and optional courses shall not be taken into account.

$$\mathrm{CGPA} = \frac{\sum_{j=1}^{m} C_j P_j}{\sum_{j=1}^{n} C_j}$$

where, C_j= Number of credits assigned for the j^{th} course, up to the semester for which CGPA is to be calculated.
P_j = Grade point earned in j^{th} course. j = 1, ------- m; represent the number of courses in which a student was registered up to the semester for which CGPA is to be calculated.

8.2. Grading System: The grading system, as detailed hereunder in **Table 1** shall be applicable for each course.

Table - 1
Award of Grades Based on Absolute Marks
(If the number of candidates in the paper is less than 20)

Marks Range (Out of 100)	Grade	Grade Point
90 -100	S	10
80 - 89	A	9
70 - 79	B	8
60 - 69	C	7
50 - 59	D	6
40 - 49	E	5
Passed with Grace	P	4
00 - 39	F	0
Non-appearance in examination (Incomplete)	I	0
Incomplete Project	X	0

Explanation:

Latter grades **S, A, B, C, D, E and P** in a course mean that the candidate has passed that course.

The F Grade: denotes poor performance, i.e., failing in the course. A student has to appear at subsequent examination(s), if provided under the ordinances in all courses in which he/she obtains "F" grade, until a passing grade is obtained.

The I Grade: The "I" Grade is awarded, when a student does not appear in the examination of course/courses. This shall be treated as "F" Grade.

The X Grade: An "X" Grade is awarded to a student if he / she does not complete Project/Dissertation/Training. This will be converted to a regular grade on the completion of the Project/Dissertation/Training Work and its evaluation. The "X" Grade shall be treated as "F" Grade.

8.3. Grace Rule: Tabulators shall award grace marks as per the following guidelines:

i. A student who fails in not more than 3 theory courses by total marks of not morethan ½ the number of total theory courses of the semester (any) fraction is rounded off to the next higher number), shall be awarded grade "P" (in place of grade "F") of Grade Point 4 in the concerned courses.

ii. Grace mark will not be awarded for making up shortfall in minimum SGPA/CGPA or improving the grade.

CONFIDENTIAL CLAUSE

9. Evaluation of sessionals / tutorials / class tests / seminars in class / group discussions in each theory paper (30 marks)

i. At the discretion of the concerned Head/Coordinator, a student who could notappear in the internal test(s) already conducted on account of some cogent reasons, such as late admission, illness etc., may be allowed to appear in the internal assignment/test held for such a student.

ii. The class tests shall be conducted by the teacher (or group of teachers) teaching the course and the marks shall be displayed on the Notice Board.

iii. Centre-coordinators shall ensure that all internal assessment marks of sessionals are sent to Controller of Examination prior to the commencement of End Semester Examination.

iv. Seasonal marks of a course shall be carried over for failed students in the course.

10. End Semester Examination and Evaluation (for 70 marks):

i. The question papers shall be set and the answer-scripts shall be evaluated by the teachers of the concerned courses. If there are more than one teacher teachingthe course, the question paper shall ordinarily be set and evaluated by a teacher of the group, appointed by the Board of Examiners.

ii. The End Semester examination answer-scripts shall be shown to the students after evaluation by the concerned teachers within 7 days of the last examination for the semester. Thereafter, within a week, all the answer books along with the statement of marks shall be sent by the examiner to the Office of the Controller of Examinations for declaration of the results.

iii. In case of any objection by a student in the evaluation, the same shall be looked after by a panel of two senior faculty members, to be nominated by the Dean, whose decision shall be final.

iv. In cases of practical examination and project/ dissertation evaluation, external examiner may be appointed if and where considered necessary.

v. **There shall be no provision for re-evaluation**.

vi. **Admit Card (for End Semester Examinations)**: A candidate may not be admitted into examination room unless he/she produce his/her admit card to the officer conducting the examination or satisfies such officer that it will be subsequently produced. The Centre-coordinator / Controller of Examinations may, if satisfied that an examinee's admit card has been lost or destroyed, grant duplicate admit card on payment of fee decided by university.

11. PROMOTION RULES AND SUPPLEMENTARY EXAMINATION

There shall be no supplementary examination for Ist & IInd semesters. However, there shall be supplementary examination for IIIrd and IVth semesters after declaration of the results of IVth Semester. Students failing in courses of IIIrd and IVth semesters may appear in supplementary examination(s) or subsequent main examination(s).

11.1. First Semester Course & Examination*:*

The candidates who have taken admission in the First Semester of a 2-year programme in a session can be put in the following two categories on the basis of their attendance in the Semester:

Category I:

i. Those who have put in the required minimum percentage of attendance for appearing in the First Semester Examination and filled up the examination form in time for appearing at the First Semester Examination.

ii. Those who did not put in the required minimum percentage of attendance for appearing at the First Semester Examination or did not fill up examination form in time for appearing at the First Semester Examination.

Candidates under Category I-(i) are eligible for appearing at the examination of First Semester, while **candidates under Category. I-(ii)** are not allowed toappear at the examination of the Semester. However, category **I-(ii)** candidates are allowed to reappear at the Post-graduate Entrance Test (PET) of subsequent year(s) for seeking admission afresh. This implies that **no readmission is permissible to those who do not put in the required percentage of attendance for taking the examination or did not submit the examination form in time**.

Category II:

After appearing at the Examination of First Semester the candidates can be put in the following categories in the context of declaration of the results of the First Semester Examination:

i. **Passed,** i.e., those who have passed in examinations of all courses of the Semester.

ii. **Promoted,** i.e., those who have not passed in examinations of all the courses of the Semester.

iii. **Minimum passing grade** – Grade 'E' for each course. However, candidates with grade 'P' in a course shall also be considered as passed in that course.

iv. **Promotion to Second Semester**: All students who have put in the minimum percentage of attendance in Semester I and filled up the examination form in time shall be promoted to the Semester II.

11.2. Second Semester Course & Examination:

As in the First Semester, in all subsequent Semesters, all the candidates who have put in the minimum percentage of attendance for appearing at the Examination and have filled in the examination form in time for appearing at the End Semester Examination shall be allowed to appear at the respective examinations. However, students who have not put in the minimum percentage of attendance or did not fill up the Examination form in time in Semester shall be allowed to take re-admission in that Semester **(except in the First Semester where re-admission is not permitted)**.

11.3. Declaration of results after IInd Semester (based on the results of Ist and IInd Semester Examinations):

After declaration of results of the First & Second Semesters, a candidate can be put in the following categories:

(i) **Passed:** A candidate who has passed in examinations of all the courses of the First & Second Semesters.

(ii) **Promoted:** A student, who has not passed in all the courses of either Ist or IInd semester or both, shall bepromoted to the IIIrd semester if he/she has obtained at least 4.0 CGPA. All such students shall have the option to clear the courses, in which they had failed, in the subsequent available examination(s) of the concerned semester as ex-students.

(iii) **Failed:** A candidate who has failed in one or more courses or failed to appear at any of the examinations of Ist and IInd Semesters taken together, and has obtained less than 4.0 CGPA shall be treated as failed.

Note: *There shall be no supplementary examination for the courses of Ist and IInd semesters.*

11.4. Promotion to the Third Semester:

(i) A candidate who comes under the category **'Passed or Promoted'** is eligible to be promoted to the third Semester, if otherwise eligible.

(ii) Failed candidates shall not be promoted to the IIIrd Semester. However, they shall be promoted to the third semester when they become eligible to come under the category of either 'Passed' or 'Promoted' as explained above after passing the failed courses in the subsequent available examination(s) as exstudents.

11.5. Promotion to the Fourth Semester:

All students who have put in the minimum percentage of attendance in IIIrd Semester and filled in the examination form in time shall be promoted to the IVth Semester.

11.6. Declaration of Results after Fourth Semester (Based on the results of the Ist, IInd, IIIrd and IVth Semester Examination):

After declaration of results of IIIrd and IVth Semesters, a candidate can be put in the following two categories:

i. **Passed:** A candidate who has passed in all the courses of I, II, III and IV Semesters and obtained at least CGPA of 5.0.

ii. **Failed:** All those students who have not "Passed" shall be categorized as "Failed". Such failed students may clear their failed courses in subsequent examinations as exstudents. There shall be a provision of supplementary examinations for III and IV Semesters after declaration of results of IV Semester. Students failing in courses of III and IV Semesters may appear in the supplementary examination or subsequent main examination(s).

A student who has failed in a course shall get two more chances to clear this course subject to the maximum duration for passing the course. Further, each candidate shall have to clear all the courses within the maximum period of 4 years from the date of his/her latest admission.

11.7. Maximum duration for passing the course:

The maximum duration for passing the 2-years PG programme shall be 4 years, which shall be counted from the year of latest admission in the Ist semester of the PG programme. No student shall be allowed to take further admission in the programme after the expiry of four years.

11.8. Deposition of Fees:

All students eligible for promotion to third semester shall deposit the requisite fee for semesters 3 & 4 (Second academic year) within the time prescribed by the University.

12. Declaration of Division

A candidate who has passed in all the papers/ courses of Ist, IInd, IIIrd and IVth Semesters shall be declared as 'Passed'. Such passed candidates may be awarded with the division according to the following criteria:

i. First Division with distinction : CGPA 8.5 and above

ii. First Division : CGPA 6.5 and above, but below 8.5

iii. Second Division : CGPA 5.0 and above, but below 6.5

Note: The SGPA and CGPA shall be computed upto 2 places of decimals (truncated at the second place).

The conversion formula for converting CGPA to the corresponding Percentage of Marks will be as follows:

$$X = 10\,Y - 4.5$$

where, X = Percentage of Marks

Y = CGPA

13. Further Clarification

A student who is promoted to a higher semester or readmitted to a semester due to shortage of attendance shall be required to study the same syllabus as being taught in that year.

14. Syllabus

The syllabi for the various PG programmes shall be framed by the Department/ School concerned.

15. Ranking to the candidates

Ranking shall be given to only those candidates who pass all the courses of the programme in one attempt.

Notwithstanding any provision in the ordinances to the contrary, the following category of examinee is also eligible for ranking:

The student who, having been duly admitted to a regular examination of the programme, was unable to take that examination in full or in part due to some disruption of examination, and took the next following examination of that programme and passed the course(s).

The marks obtained by him/her at the examination shall be considered as the basis for the University Ranking, Scholarships and other distinctions.

In order to get the benefit of this provision, the student should claim that he/she is eligible for this benefit and get a decision in writing after proving his/her eligibility therefore.

16. Re-admission to the Programme/semester

A student who does not put in at least the minimum percentage of attendance required in the Ist semester shall not be promoted to the higher semesters. However, such students can take fresh admission after appearing in the Entrance Examination of this course and being eligible for admission in the course on the basis of result of the Entrance test of the concerned year.

All such students of IInd, IIIrd, IVth, Vth or VIth semesters who have not put in the required minimum percentage of attendance or not filled in the examination form in time shall have the option to be re-admitted in the concerned semester available in the subsequent year(s). No student who has been promoted to the IInd or higher semester and continues to be a student shall be allowed to reappear in the Entrance examination of the same programme for taking fresh admission in the programme.

17. Break in the Course

Any student taking admission in M.Sc. Computational Science and Applications in Signal Processing shall not be allowed to pursue any other full time programme/ course in the Banaras Hindu University or elsewhere in the entire period of the programme meaning thereby that if a student leaves the programme after passing some of the semesters/ courses and takes up a full-time programme/ course elsewhere, then he/she shall not be allowed to continue the programme further.

18. Definition

i. A ‘Regular Student’ is one who has pursued a regular programme of study and obtained prescribed attendance mentioned in the ordinances and is eligible to appear in the examination.

ii. ‘Ex-student’ means one who has studied in the Faculty/MMV for at least one semester preceding the date of the examination and had filled up the examination form but failed or had failed to appear in the examination, though otherwise eligible.

Note: *Academic calendar for the odd and even semesters shall be notified at the beginning of every academic year.*

Detail Course Structure & Syllabi

FOUR SEMESTER POST - GRADUATE COURSE
IN
COMPUTATIONAL SCIENCE AND APPLICATIONS IN SIGNAL PROCESSING

1. The Post Graduate Course in COMPUTATIONAL SCIENCE AND APPLICATIONS IN SIGNAL PROCESSING shall be Two – Year Degree Course comprising of FOUR SEMESTERS (Two Semesters in each year). The total credits including all the four semesters will be 80 including Minor Elective Papers.

2. There shall be sessionals / tutorials / class tests / seminars in class / group discussions in each theory and practical paper (Core Courses, Major and Minor Elective papers) except Paper No. CSA - 412: Project Work in Semester – IV.

3. Each theory paper, irrespective of their nature and credits shall be of 100 marks out of which 70 marks shall be assigned to the end semester theory examination and 30 marks to the sessionals / tutorials / class tests / seminars in class / group discussions.

4. The Theory papers shall be of THREE HOURS duration consisting of Eight full length questions in all out of which a student will be required to answer any five questions.

5. Each Practical paper will be of 100 marks out of which 30 marks will be assigned on sessionals / tutorials / class tests / seminars in class / group discussions and 70 marks will be assigned on the end semester examination out of which 50 marks will be on the performance in practical examination and 10 marks will be assigned each on practical record book and viva – voce.

6. All the practical papers shall be of FOUR HOURS duration.

7. Mentor for the Project (Course No. CSA – 412 of semester – IV,) will assigned in the semester –III and it will be spread over the whole semester –III and IV. The topic and problem will decided by the mentor. A project may be undertaken by a group of students. However, the project report shall be submitted by each member of the group separately. A project report shall clearly state the problem addressed, the methodology adopted, the assumptions and the hypotheses formulated, any previous reference to the study undertaken, simulation / experiment result, personal opinion and the broad conclusion drawn. There shall be an external examiner and an internal examiner (preferably the mentor of the student) for the evaluation of the project work. Out of total 100 marks assigned to the project, 60 marks will be assigned on the evaluation of the project work separately by both the examiners and 40 marks will be assigned jointly by the examiners on the oral presentation and viva – voce.

8. Students should earn credit for the two MINOR ELECTIVE THEORY papers (CSA-204 of semesters – II and CSA-302 of semester III) from other departments of the faculty.

The titles, contents of theory papers as well as practical papers and distribution of credits to papers shall be as follows :

MASTER OF SCIENCE (M.Sc.) COMPUTATIONAL SCIENCE AND APPLICATIONS IN SIGNAL PROCESSING

DST-Centre for Interdisciplinary Mathematical Sciences (CIMS), Banaras Hindu University, Varanasi

DISTRIBUTION OF COURSES AND CREDITS IN VARIOUS SEMESTERS

Year	*Course Code*	*Course Title*	*Credits*
1st Year		***SEMESTER I***	
	CSA101	Fundamentals of Computer Programming : C and MATLAB	03
	CSA102	Data Structure and Design & Analysis of Algorithms	03
	CSA103	Real Analysis and Calculus	03
	CSA104	Probability Theory and Distributions	03
	CSA105	Applied Linear Algebra and Matrix Theory	04
	CSA106	Practical	04
		Total	**20**
		SEMESTER II	
	CSA201	Statistical Inference and Data Analysis	04
	CSA202	Convex Optimization	04
	CSA203	Digital Signal Processing	03
	CSA204	Minor –I: Field and Radiation	02
	CSA205	Random Processes	03
	CSA206	Practical	04
		Total	**20**

2nd Year		***SEMESTER III***	
	CSA301	Bio-Inspired Computational Methods	04
	CSA302	Minor –II : Human Machine Interaction	02
	CSA303	Fourier and Wavelet Analysis	04
		Elective Course : Any two of the following	
	CSA304 -- CSA311 CSA313	CSA 304: Brain Computer Interface (BCI). CSA 305: Biomedical Signal Processing. CSA 306: Sampled Imaging System. CSA 307: Image Processing. CSA 308: Principles of Acoustics of Speech and Hearing. CSA 309: Digital Speech Processing and Recognition. CSA 310: Graph Theory and Its Application CSA 311: Statistical Pattern Recognition CSA 313: Information Retrieval	3+3= 06
	CSA312	Practical	04
		Total	**20**
		SEMESTER IV	
	CSA 401	Local Approximation Techniques	4
	CSA 402	Advanced Digital Signal Processing	4
		Elective Course : Any two of the following	
	CSA 403 --- CSA 409 CSA 411 CSA 412 CSA 413	CSA 403: Compressive Sensing CSA 404: Image Analysis and Computer Vision CSA 405: Approximation, Denoising and Inverse Problem through Wavelet CSA 406: Array Signal Processing. CSA 407: Advanced Topics in Speech Recognition. CSA 408: Independent Component Analysis CSA 409: Advanced Biomedical Signal Analysis CSA 411: Computational Geometry and Applications CSA 412: Machine Learning CSA 413: Text Analytics	4+4 = 8
	CSA410	Project	4
		Total	**20**
		Grand Total	**80**

Detailed Curriculum

M.Sc. (Computational Sciences and Applications): SEMESTER I

CSA101	Fundamental of Computer Programming: C and MATLAB	Credits: 3

Basic Programming Concepts: Introduction to the basic ideas of problem solving and programming using principles of top-down modular design, Flowcharts, Abstraction Mechanisms, Stepwise Refinement.

Syntactic Elements of a Language, General Syntactic Criterion, Formal Definition of Syntax, Semantics, Storage Management, Static Storage Management, Stack-Based Storage Management, Heap Storage Management, Operating and Programming Environment.

Introduction to Programming Language : Data Types, Instruction and its Types, Storage Classes, Operators and Hierarchy of Operations, Expressions, Control and Repetitive Statements, break, continue, Functions: User Defined Functions and Library Functions, Local and Global Variables, Parameter Passing, Pointers, Arrays, Strings, C Preprocessors, Structures, Input and Output in C, C-Library.

Introduction to the Major Programming Paradigms: Imperative Language, Object Oriented Languages, Functional Languages, Logic Languages, Parallel Languages etc.

Suggested Readings:

1. R. Sethi, Programming Languages: concepts and constructs, Addison-Wesley, 1989.
2. T.W. Pratt, Programming Languages, McGraw Hills, 1996.
3. M. Marcotty & H.F. Ledgard, Programming Language Landscape, Galgotia Publication, 1996.
4. B.W. Kernighan and D.M.Ritchie, The C Programming Language, Prentice Hall India (PHI), 1988.
5. B.S. Gottfried, Schaum's Outline of Theory and Problems of Programming with C, McGraw-Hill, 1996.
6. Y. Kanetkar, Let Us C, BPB Publications, 2004.

CSA102	Data Structure and Design & Analysis of Algorithm	Credits: 3

Elementary Data Structures: Primitive data type – Integer, Float. Array, Stack, Queues, Linked list, Tree, Graph, Symbol table, Hashing, and Files.

Analysis of Algorithm: Simple Algorithms, Flow chart, Pseudo code, Asymptotic Notation, Recurrence relations.

Algorithms Design Strategies: General consideration, Algorithm design paradigms and representative problems. Divide and Conquer - Binary search, Merge sort, Quick sort, Arithmetic with large integers, etc., Greedy Method -Minimal spanning tree, Shortest paths, Knapsack, etc. Dynamic Programming -Chained matrix multiplication, Optimal storage on tapes, shortest paths, Optimal search trees, etc. Backtracking - 8-queens problem, Graph coloring, Hamiltonian Cycles, etc. Branch and Bound - 0/1 Knapsack problem, Travelling salesperson, etc. Approximation (Graph Colouring, Task Scheduling, Bin Packing, etc.), Probabilistic Algorithms (Numerical Integration, Primality Testing, etc.).

Graph Algorithms: BFS, DFS and its applications.

Algebraic Simplification and Transformation: General method, Polynomial evaluation and interpolation, and Fast Fourier transforms.

Intractable Problems: Basic concepts, Nondeterministic algorithms, NP completeness, Cook's theorem, Examples of NP-Hard and NP-Complete problems, and Problem reduction.

Lower Bound Techniques: Comparison tree, Reduction, Adversary argument.

Suggested Readings:

1. A.Aho, V. Alfred, J. Hopcroft and J. D. Ullman, The design and analysis of computer algorithms, Addison Wesley, 1974.
2. E. Horowitz and S. Sahani, Fundamentals of computer algorithms, Galgotia Publications, 1974.
3. S.E. Goodman and S.T. Hedetniemi, Introduction to the Design and Analysis of Algorithms, McGraw Hill.
4. Introduction To Algorithms, Thomas H Cormen, Charles E Leiserson, Ronald L Rivest, Clifford Stein, MIT Press, 2001.
5. G. Brassard and P. Bratley, Fundamentals of Algorithmics, PHI, 1996.
6. S. K. Basu, Design Methods and Analysis of Algorithms, PHI, 2005.

CSA103	**Real Analysis and Calculus**	**Credits: 3**

Sequence in R, Limit of Sequence, Algebra of Sequence, Important Sequences and Their Limits, Series and different test for their convergence, Absolute and Conditional Convergence, Uniform convergence. Term by term integration and differentiation. Introduction to metric space, generalization of convergence and limit. Sequences and Series of Functions, Calculus of Vector-Valued Functions, Improper Integrals, and Vector Algebra.

Limit, Continuity, Differentiability of a map from R^m to R^n, Jacobian matrix, Taylor's theorem, Inverse function theorem, Implicit function theorem, Line integral, Surface integral, Volume integral and applications. Maxima, minima of function of one and many variable.

Suggested Readings

1. K. Hoffman and R. Kunze, Linear Algebra, Prentice Hall of India, 1996
2. S Kumaresan, Linear Algebra: A Geometric approach, Prentice Hall of India, 2006.
3. Tom M. Apostol, One-variable calculus with an introduction to linear algebra-Vol. 1, Wiley India, 2007.
4. Tom M. Apostol: Multi-variable calculus and linear algebra with applications to differential equations and probability, Wiley India, 2007.

CSA104	Probability Theory and Distributions	Credits: 3

Random Phenomenon, Probability, Conditional Probability, Statistical Independence, Random Variable, Measure theoretic view of probability.

Univariate distribution functions - continuous and discrete, Multivariate distribution functions- continuous and discrete. Commonly used univariate and multivariate distributions functions.

Joint distributions and marginal distribution. Moment, Expectation, and Moment generating function. Central limit theorem and laws of large numbers. Random sample, Sampling distributions. Introduction to Bayesian paradigm, introduction to stochastic and Markov processes.

Suggested Readings

1. Samuel Kotz, N. Balakrishnan and Normal L. Johnson, Continuous Multivariate Distributions, Models and Applications, Volume 1, 2nd Edition. Wiley Series in Probability and Statistics, 1994.
2. Samuel Kotz, N. Balakrishnan and Normal L. Johnson, Discrete Multivariate Distributions, Wiley Series in Probability and Statistics, 1997.
3. Samuel Kotz, N. Balakrishnan and Normal L. Johnson, Univariate Discrete Distributions, 3rd Edition, Wiley Series in Probability and Statistics, 1993.
4. V. K. Rohatgi, A. K. Md. Ehsanes Saleh, An introduction to probability and statistics. Wiley Eastern, New Delhi, 1988.
5. S. M. Ross, Probability model ,7^{th} Edition Academic Press, 2001.
6. A.M. Mathai, Lecture module 6 , CMS pala, 2009.

CSA105	Applied Linear Algebra and Matrix Theory	Credits: 4

Vector space, Linearly independent and linearly dependent set of vectors, Basis and dimension of a vector space, Linear Transformations and its matrix representation, Elementary transformations, Rank of a transformation, Rank- nullity theorem, Matrix decomposition, Quadratic forms, Geometry of positive definite quadratic form, Determinant, Partitioning of matrices, Eigen value, Eigen vector, Cayley-Hamilton theorem, Similarity of matrices, Diagonalization of matrices, Inner product spaces, Isometry, Orthonormal bases, Gram-Schmidt process..

Solution of the system of linear equations. Matrix differential operators, Jacobian of matrix transformation, and function of matrix arguments. Difference and differential equation: Fibonacci sequence and difference equation, population growth model, and system of differential equations and their solutions. Maxima / minima problems: Taylor series, optimization of quadratic forms, quadratic from with quadratic constraints, quadratic from with linear constraints, bilinear forms with quadratic constraints. Matrix sequences and matrix series, matrix polynomial, and singular value decomposition.

Suggested Readings

1. A.M. Mathai, Lecture module 1, CMS pala,
2. A.M. Mathai, Lecture module 2, CMS pala,
3. Ramji Lal, Linear algebra, Vol. 2, Shail Publication, Allahabad, 2004.
4. Gilbert Strong, Introduction to linear algebra, 4^{rth} Edition, Wellesley Cambridge Press, 2009.
5. Gareth Williams, Linear algebra with applications Jones & Bartlett Pub, 2007.

6. Serge Lang, Linear algebra, Springer,1987.
7. Tom M. Apostol: Multi-Variable Calculus and linear algebra with applications to differential equations and probability, Wiley India, 2007

CSA106	**Practical**	**Credits: 4**

This practical paper will consists of programming exercises and problem solving based on course CSA101, CSA102, & CSA105. (Practical paper will be of 100 marks out of which 30 marks will be assigned on sessionals / tutorials / class tests / seminars in class / group discussions and 70 marks will be assigned on the end semester examination out of which 50 marks will be on the performance in practical examination and 10 marks will be assigned each on practical record book and viva – voce. The duration of the practical exam shall be FOUR HOURS).

SEMESTER -II

CSA201	Statistical Inference and Data Analysis	Credits: 4

Introduction to Random Sample, Statistic and Parameter, Sampling Distributions.

Theory of Estimation: Sufficient statistics, completeness, unbiased estimation, moment estimation, maximum likelihood estimation, notion of admissibility of estimators.

Testing of Statistical Hypothesis: Generalized NP lemma, Unbiased critical regions, unbiased tests and similar regions, invariant test, testing and confidence regions.

Model Building: Regression analysis, Model selection, Least square methods and application, Introduction to robust statistics and applications.

Bayesian Paradigm: Introduction, Bayesian and Minimax decision rules, selection of a prior, Bayesian point estimation, Bayesian sufficiency, and Classical approximation methods.

Suggested Readings

1. V. K. Rohatgi, A. K. Md. Ehsanes Saleh, An introduction to probability and statistics. Wiley Eastern, New Delhi, 1988.
2. E. L. Lehmann, Theory of Point estimation, 2nd edition, Springer, 1998.
3. E. L. Lehmann, Testing Statistical Hypotheses, J. Wiley & Sons, NY, 1986.
4. S. Zacks, The Theory of Statistical Inference, Wiley, New York, 1971.
5. J.O. Berger, Statistical Decision Theory and Bayesian Analysis, 2nd edition, Springer Series in Statistics, 1985.
6. C.R. Rao, Linear Statistical Inference and its Applications, 2nd edition, Wiley-Interscience, 2001.

CSA202	Convex Optimization	Credits: 4

Convex Optimization: Introduction to Mathematical optimization , Least-squares and linear programming, Convex optimization, Nonlinear optimization. Convex sets: Affine and convex sets, Some important examples,Operations that preserve convexity, Generalized inequalities, Separating and supporting hyperplanes, Dual cones and generalized inequalities. Convex functions: Basic properties and examples,Operations that preserve convexity , The conjugate function ,Quasiconvex functions ,Log-concave and log-convex functions, Convexity with respect to generalized inequalities. Convex optimization problems: Optimization problems,Convex optimization ,Linear optimization problems ,Quadratic optimization problems ,Geometric programming, Generalized inequality constraints,Vector optimization, Duality: The Lagrange dual function, The Lagrange dual problem, Geometric interpretation, Saddle-point interpretation, Optimality conditions, Perturbation and sensitivity analysis, Examples, Theorems of alternatives, Generalized inequalities

Applications: Approximation and fitting - Norm approximation, Least-norm problems, Regularized approximation, Robust approximation, Function fitting and interpolation. Statistical estimation - Parametric distribution estimation, Nonparametric distribution estimation, Optimal detector design and hypothesis testing, Chebyshev and Chernoff bounds, Experiment design

Algorithms: Unconstrained minimization - Unconstrained minimization problems, Descent methods, Gradient descent method, Steepest descent method, Newton's method, and Self-concordance. Equality constrained minimization - Equality constrained minimization problems, Newton's method with equality constraints, Infeasible start Newton method. Interior-point methods- Inequality constrained minimization problems, Logarithmic barrier function and central path, The barrier method, Feasibility and phase I methods, Complexity analysis via self-concordance, Problems with generalized inequalities, Primal-dual interior-point methods

Suggested Readings

1. Stephen Boyd Lieven, Vandenberghe, Convex Optimization, ISBN 0-521-83378-7.
2. Jorge Nocedal Stephen J. Wright, Numerical Optimization, SPRINGER.
3. C. T. Kelley, Iterative Methods for Optimization, SIAM, 1999.
4. Kalyanmoy Deb, Optimization for Engineering Design: Algorithms and Examples, PHI, 2005.

CSA203	Digital Signal Processing	Credits: 3

Digital Signal Processing: Introduction to Signals, Systems and Sensors, Discrete-time signals and systems, Z-transform and its application to the analysis of LTI system, Frequency analysis of signals and systems.

Discrete Fourier Transform (DFT): Its properties and applications, Computational issues related to DFT and Fast Fourier Transform Algorithms, Implementation of discrete time systems, Design of digital filters. Multirate Digital Signal Processing and its Relation with Multiresolution Analysis Using Wavelet, Linear Prediction and Optimum Linear Filters, Power Spectrum Estimation.

Sensor and System: Principle of the EEG and ECG Sensor and System, Optical Imaging Sensors and System, X-ray Sensor and System, Computed Tomography (CT) System, Magnetic Resonance Imaging System (MRI).

Suggested Readings:

1. John G. Proakis, Dimitris G. Manolakis, Digital Signal Processing - Principles, Algorithms and Application, 3rd edition, Pearson Education, 2004.
2. Jae S. Lim, Two Dimensional Signal and Image Processing, Prentice-Hall, Englewood Cliffs, New Jersey, 1989.
3. Rangaraj M. Rangayyan, Biomedical Signal Analysis- A case-study approach, IEEE Press, 2005.
4. D.C. Reddy, Biomedical Signal Processing – principles and techniques, Tata McGraw-Hill, New Delhi, 2009.
5. A.K. Jain, Fundamentals of Digital Image Processing, PHI, 1995.
6. R. H. Vollmerhausen and R.G. Driggers, Analysis of Sampled Imaging System, SPIE Press, 2001.

CSA204	Minor –I: Field and Radiation	Credits: 2

(The course will involve only the concepts and uses of theories rather than rigorous derivations of the results and Technology used).

Electromagnetic spectrum, Imaging with Infrared (IR) and Ultraviolet (UV)– Night vision & Surveillance with near IR – Imaging, Forensic imaging with near IR and near UV , animal UV vision, optical property of material in the near UV and near IR, IR photography and Heat detection.

Thermal Imaging – Thermal imaging and biology, thermal imaging in astronomy, thermal imaging in surveillance and law enforcement, and thermograph.

Millimeter and Microwave Imaging – Seeing through clothing and fog, and application in radio astronomy.

X-rays and Gamma Rays – Gamma ray imaging, PET scan for living biological tissue, and CT –Scan.

Acoustic Imaging – Seeing with sound: Underwater acoustic imaging, ultrasound medical imaging, and acoustic imaging of sound sources.

Suggested Readings

1. A.K. Jain, Fundamentals of Digital Image Processing, PHI, 1995.
2. R. H. Vollmerhausen and R.G. Driggers, Analysis of Sampled Imaging System, SPIE Press, 2001.
3. Austin Richard, Alien Vision, SPIE Press, 2001.

CSA205	Random Processes	Credits: 3

Introduction to random processes, Gaussian processes, Markov processes, stochastic processes, and stationary processes.

Poisson process, birth process, death process, generalized birth and death process, Gambler's Ruin Problem, Markov chains, Martingales and their properties.

Finite-state Markov chains, Non-homogeneous Poisson processes, Ruin models, Martingale approach to ruin theory.

Stochastic calculus, Ergodicity and duality, spectral density, Noise model for receiving system, matched filtering and sisgnal detection, Weiner filtering and signal extraction, Random signal detection, Autoregressive models and Linear prediction.

Suggested Readings

1. Parzen, E., *Stochastic Processes*, Holden-Day, San Francisco.
2. Wolff, P.W., *Stochastic Modeling and the Theory of Queues*, Prentice-Hall, Engelwood Cliffs, NJ.

3. Tijms,H.C.;*Stochastic Modelling and Analysis:A Computational Approach,*Wiley,Chichester (UK)
4. Geckil, I.K. & Anderson, P.L.; *Applied Game Theory and Strategic Behavior*, CRC Press..
5. Prabhu, N. U.; Foundations of Queueing Theory, Kluwer Academic Publishers, Boston..
6. Andrew H. Jazwinski, Stochastic processes and filtering theory, Academic Press.
7. Henry Stark, Probability and random processes with applications to signal processing, Prentice Hall.
8. William A. Gardner, Introduction to random processes with applications to signal and systems, MCGRAW-HILL.

CSA206	**Practical**	**Credits: 4**

This practical paper will consists of programming exercises and problem solving based on course CSA201, CSA202, & CSA203, CAS204, and CSA 205.

(Practical paper will be of 100 marks out of which 30 marks will be assigned on sessionals / tutorials / class tests / seminars in class / group discussions and 70 marks will be assigned on the end semester examination out of which 50 marks will be on the performance in practical examination and 10 marks will be assigned each on practical record book and viva – voce. The duration of the practical exam shall be FOUR HOURS).

SEMESTER -III

CSA301	Bio-Inspired Computational Method	Credits: 4

Evolutionary Algorithm: State Space Search, Traditional vs Heuristic Search, Review of Single State Methods: Hill Climbing, Simulated Annealing, Tabu Search, Iterated Local Search; Population-based Methods**:** Genetic Algorithms- Representation & Encoding, Operators, Convergence, Steady State vs Generational GA, Elitism; Differential Evolution- Representation, Operators, Algorithm, Variants and Hybrids; Particle Swarm Optimization: Representation, Algorithmic Approach, Local and Global Best. Combinatorial Optimization Problems (COPs): Characteristics of COPs, Greedy Randomized Adaptive Search procedures, Ant Colony Optimization.

Artificial Neural Network: Biological Neural Networks, Mathematical Model of Neuron, Mc Culloch and Pitts Model, Concepts of Threshold and Activation Functions, Typically used Non-linearity. ANN Topologies and Learning: Rosenblatt Perceptron, Linear Separation and MLP, Feed-forward and Feed-backward Networks; Delta and Gradient Descent learning rules, Hebbian Learning, Back Propagation learning, Radial basis Function Networks, Associative Memory Paradigms, Hopfield Networks, Recurrent Networks, Self-organizing feature Maps.

Applications: ANN for Pattern Classification, Pattern Matching and Time Series Analysis.

Suggested Readings

1. David E. Goldberg, Genetic Algorithms in Search Optimization Machine Learning, ADDISON WESLEY, 1989.
2. N.K. Bose and P. Liang, Neural Network Fundamentals with Graphs, Algorithms and Applications, TATA McGRAW-HILL, 1996.
3. Mohammad H. Hassoun, Fundamentals of Artificial Neural Networks, PHI, 2010.
4. T. M. Mitchell, Machine Learning, Mcgraw-Hill, 1997.
5. Crisitanini Shawe-Taylor, An introduction to Support Vector Machines, Cambridge Press, 2000.
6. B. SchÖlkopf and A.J. Smola, Learning with Kernels, MIT Press, 2002.
7. Laurance Fausett et al., Fundamentals of Neural Networks, Pearson.
8. Simon Haykin, Neural Networks, Pearson
9. S. Luke, Essentials of Metaheuristics, lulu press.
10. R.C.Eberhart, J. Kennedy and Y. Shi, Swarm Intelligence, Morgan Kauffman..
11. K. Deb, Multi-objective Optimization using Evolutionary Algorithms, Wiley.

CSA302	Minor – II: Human Machine Interaction	Credits: 2

(The course will involve only the concepts and uses of theories rather than rigorous derivations of the results and Technology used).

Brain Computer Interface (BCI) - Human brain and its function, cognitive process and brain state model, different brain waves, and measurement instrument for brain wave and an introduction to brain robot interface (BRI).

Robotics – History, some well known robot, their functionality and possible application.

Human Computer Interaction: Model of natural communication of human with computer, conversational interfaces, machine translation, computer vision, virtual reality.

Suggested Readings

1. Guido Dornhege, Jos´e del R. Mill´an Thilo Hinterberger, Dennis J. McFarland, Klaus-Robert Muller, Toward Brain-Computer Interfacing ,MIT Press Cambridge, 2007.
2. Rangaraj M. Rangayyan, Biomedical Signal Analysis- A case-study approach, IEEE Press, 2005.
3. D.C. Reddy, Biomedical Signal Processing – principles and techniques, Tata McGraw-Hill, New Delhi, 2009.

CSA303	Fourier and Wavelet Analysis	Credits: 4

Introduction to Metric and Normed Spaces : Metric Space, Normed Space, Inner Product Space, Orthogonality, L^2,$l^2$and L^p spaces and their properties, concept of convergence, point wise and uniform convergence, different inequalities in L^2,$l^2$and L^p spaces. The Bases - Best approximation, Orthogonal complement and projection theorem, Orthonormal basis and some common example, Orthogonal direct sums, Dual Spaces, and Adjoints.

The Fourier Series: Historical perspective, Computation of fourier series - on interval $[-\pi, \ \pi]$, on general interval, Cosine and Sine Expansion. The complex form of Fourier series. Convergence of Fourier series – Riemann-Lebesgue Lemma, Convergence at a point of continuity, Convergence at a point of discontinuity, Uniform convergence, Convergence in the Mean.

The Fourier Transform ($L^1(R)$ $L^2(R)$,): Development of Fourier transform, Fourier inversion theorem, Properties of the Fourier Transform – Basic properties, Poisson summation formula, Fourier transform of a convolution, approximate identity, Adjoint of the Fourier transform. Linear filters, Sampling theorem, and Uncertainty Principle. Idea of discrete Fourier transform- Definition, Properties, and Fast Fourier Transform approximation to the Fourier Transform.

Wavelet Analysis and Wavelet Transform: Why wavelets, Haar wavelet – Scaling function and its different properties. Haar decomposition and reconstruction algorithm. Daubechies wavelets - Daubechies construction; classification, Moments, and Smoothness; Computational issues; The scaling function at dyadic points. Wavelet Transform - Definition of Wavelet transform, Relation with Fourier Transform, Inversion formula for the Wavelet Transform, Local properties.

Other Wavelet Topics: Idea of multiresolution analysis, Wavelets in higher dimensions, Wavelet packets, Orthogonality and Scaling equation via Fourier transform.

Application: Signal enhancement, function approximation, deconvolution, image processing, speech processing etc.

Suggested Readings

1. Albert Boggess and Francis J.Narcowich, A First Course in Wavelets with Fourier Analysis, WILEY, 2009.
2. Stephen Mallat, A Wavelet tour of signal processing the sparse way, 3rd edition, Academic Press, 2009.
3. George Bachman, Lawrence Narici, Edward Beckenstein, Fourier and Wavelet Analysis, SPRINGER, 2000.
4. Ingrid Daubechies, Ten Lectures on Wavelets, SIAM, 1992.
5. E.Hernandez, G. Weiss, A first Course on Wavelets, CRC Press, 1996.

6. John G. Proakis, Dimitris G. Manolakis, Digital Signal Processing - Principles, Algorithms and Application, 3rd edition, Pearson Education, 2004.

CSA304	Brain Computer Interface (BCI).	Credits: 3

Module –I: Brain Structures and Scalp Potentials, Neural Activities, Measuring Electric Activity in the brain EEG, MEG and SSVEP, Wearable and Wireless EEG Monitoring, Brain Rhythms.

Module-II: 10-20 Electrode Placement System, EEG Recording and Measurement, Wireless multi-channel EEG Recording System, Artifact identification from EEG and MEG, ERD and ERS, Lapalacian Referencing, Common Average Referencing.

Module-III: Cognitive State Estimation Problem, Spatial filters, Common Spatial Pattern, CSP based Cognitive State Estimation.

Module-IV: Instantaneous BSS, BSS based EEG Signal Analysis, Validity of the basic ICA model, Artifact removal from EEG and MEG, Topography Mapping of Independent Components.

Module-V: Wearable and Wireless EEG based Brain-Computer Interface, Wireless Electroencephalogram, Information System using WLAN, BCI performance Evaluation parameters, Feature Extraction, Thought Recognition, Linear classification.

Module-VI: EEG source localization, General Approaches to Source Localization, ICA Method, MUSIC Algorithm, RAP MUSIC, FOCUSS Algorithm, Determination of the Number of Sources.

Module-VII: Event-Related Potentials, Detection, Separation, Localization, and Classification of P300 Signals.

Suggested Readings

4. Saied Sanei and J.A. Chambers, EEG Signal Processing, John Wiley & Sons Ltd., 2007.
5. Guido Dornhege, Jos´e del R. Mill´an Thilo Hinterberger, Dennis J. McFarland, Klaus-Robert Muller, Toward Brain-Computer Interfacing ,MIT Press Cambridge, 2007.
6. Rangaraj M. Rangayyan, Biomedical Signal Analysis- A case-study approach, IEEE Press, 2005.
7. D.C. Reddy, Biomedical Signal Processing – principles and techniques, Tata McGraw-Hill, New Delhi, 2009.

CSA305	Biomedical Signal Processing	Credits: 3

Introduction to discrete-time signals and system, discrete Fourier transform, and Z-transform.

Cardiological Signal Processing: Basics of electrocardiography, ECG data acquisition, ECG lead system, ECG parameter and their estimation, Multi-scale analysis for parameter estimation of ECG waveform. Arrhythmia analysis in monitoring. Cardiopulmonary sensing using microwave sensor.

Adaptive Interference / Noise Cancellation: Concept and theory of Wiener filtering problem, principle of adaptive filter, steepest decent algorithm, Least mean square adaptive algorithm,. Modeling of different noise and interference sources. Adaptive noise canceller.

ECG data reduction techniques: Direct ECG data compression, Transform compression techniques for ECG.

Prony's Method: Exponential modeling, exponential parameter estimation, the original prony problem, least square Prony method, covariance method of linear prediction, Pron's method in the presence of noise, and clinical applications of Prony's method.

Suggested Readings

1. Saied Sanei and J.A. Chambers, EEG Signal Processing, John Wiley & Sons Ltd., 2007.
2. Rangaraj M. Rangayyan, Biomedical Signal Analysis- A case-study approach, IEEE Press, 2005.
3. D.C. Reddy, Biomedical Signal Processing – principles and techniques, Tata McGraw-Hill, New Delhi, 2009.

CSA 306	Sampled Imaging System	Credits: 3

Introduction: Description of sampled imager, description of the sampling process, linearity and shift invariance, signal reconstruction, and ways of viewing sampling process.

Fourier integral representation of an optical image: Linear shift-invariant (LSI) optical systems, spatial and frequency domain filters and reducing LSI imager to one dimension. The modulation transfer function (MTF) associated with typical imager components – Optical filtering, detector spatial filter, electronic filtering, display filtering, filtering by human eye, and temporal filters.

Sampled imager response function: Fourier transform of a sampled image, derivative of the sampled imager response function, example of sampled imager response functions – effect of changing sampling rate, optical and midwave infrared sensors. Definition and calculation of the spurious response ratio.

Sampled imager design and optimization: Interpolation and image reconstruction, classical design criterion for sampled imaging systems, Minimum resolvable temperature difference, minimum resolvable contrast, and the half sample limit, and sampled imager optimization.

Interlace and dither: Sampling improvement with static scene, resolution and sensitivity, and effect of scene to sensor motion.

Dynamic sampling, resolution enhancement, and super resolution: Sampling limitations of the focal plane array topology, dynamic sampling, ambient optical flow as a novel sampling mechanism, and Image restoration.

Performance measurement criterion of sampled imaging system a case study to optical and infrared system: Sensitivity, Resolution-modulation transfer function (MTF), Human performance – minimum resolvable temperature difference.

Suggested Readings

1. R. H. Vollmerhausen, R.G. Driggers, Analysis of Sampled Imaging Systems, SPIE Press, 2001.
2. G. D. Boreman, Modulation Transfer function in Optical and Electro Optical, System, SPIE Press, 2001.

3. J.W. Goodman, Introduction to Fourier Optics, McGraw-Hill, 1997.
4. B.G. Boone, Signal processing using optics, Oxford University Press, 1998.
5. Norman S. Kopeika, A System Engineering Approach to Imaging, SPIE, 1998
6. Bruke Miachel W, Image acquisition, Chapman & Hall, 1996.
7. T. L. Williams, The Optical Transfer Function of Imaging Systems, Taylor & Francis, 1998.
8. Mark Johnson, Photodetection and Measurement, McGraw-Hill, 2003.

CSA307	Image Processing	Credits: 3

Digital Image Fundamental: Elements of Visual Perception- Structure of the human eye, Image formation in the eye, Brightness adaptation and discrimination; Light and electromagnetic spectrum, Image sensing and acquisition, Image sampling and quantization, Basic relationships between pixels, linear and nonlinear operations.

Enhancement: Point Processing: Contrast Stretching, Power-law and Gamma Transformation. Histogram Processing: Histogram Equalization and Matching.

Filtering and Restoration: Degradation function and Noise Models, Spatial Domain Filtering: Correlation and Convolution, Smoothing Linear and Nonlinear Filters: Mean and Median Filters, Adaptive Filtering, Sharpening Linear and Nonlinear Filters: Derivative, Laplacian, Unsharp Masking, High-boost Filtering. Frequency Domain Filtering: Filtering: Low-pass (Smoothing) & High-Pass (Sharpening) Ideal, Butterworth and Gaussian Filtering, Unsharp Masking and High-Boost Filtering, Homomorphic Filtering, Periodic Noise Reduction and Inverse Filtering & Wiener Filtering.

Image reconstruction from projections: Transmission tomography, reflection tomography, emission tomography, magnetic resonance imaging, and projection based image processing. Radon transform, back projection operator, projection theorem, inverse radon transform, convolution filter back projection, reconstruction from blurred noisy projections, Fourier reconstruction, fan-beam reconstruction, algebraic methods and three dimensional tomography.

Image data compression : Introduction, Error Criterion- Objective and subjective criterion; Lossy compression- Transform domain compression, JPEG compression, block truncation compression, vector quantization compression; Lossless compression- Huffman coding, arithmetic coding, transformed coding, run-length coding, block coding, quad tree coding, and contour coding.

Suggested Readings

1. A. K. Jain, Fundamentals of digital image processing, PHI, 1995.
2. Jae S. Lim, Two dimensional signal and image processing, Prentice-Hall, Englewood Cliffs, New Jersey, 1989.
3. D. E. Dudgeon, Russell M. Mersereau, Multidimensional Signal Processing, PRENTICE HALL, 1983.
4. R. H. Vollmerhausen, R.G. Driggers, Analysis of Sampled Imaging Systems, SPIE Press, 2001.
5. Stephen G. Wilson, Digital Modulation and Coding, PEARSON EDUCATION, 2003.
6. B. Chanda, D.D. Majumder, Digital Image Processing and Analysis, PHI.

CSA308	Principles of Acoustics of Speech and Hearing	Credits: 3

The Quantification of Sound and the Wave Equation: The Basic Physical Attributes of Sound- What is Sound? How is it Produced? How does it Propagate?, Simple Sounds- the Pure Tone. Periodic Complex Signals, The Propagation of Sound in Time and Space- The Wave Equation, The Equations of Linear Acoustics, and Derivation of the wave equation.

One-Dimensional 'Traveling Waves' : The One-Dimensional Wave Equation for Plane Waves- Wave propagation, Similarity to Transmission Line Equations , Solutions to the Wave Equation , Sinusoidal Traveling Waves- The separation of time and space dependence. Reflections at Rigid Boundaries - The Spatial Dependence of the Total Sound Pressure in Rigid Wall Reflection, The Spatial Dependence of the Specific Acoustic Impedance in Rigid Wall Reflection

Spherical Waves: Near & Far Field, Radiation Impedance, and Simple Sources, Review of Wave Equations for Plane Waves, Spherically symmetric waves: Another kind of one-dimensional wave, Combinations of Simple Sources, Output of Arrays.

The Interaction of Sound and Objects: Scattering and Diffraction, Model's of Diffraction. Diffraction and Scattering of plane waves by a rigid Sphere. Contribution to external ear to the directionality of the human auditory system, Contribution of the external-ear components to the sensitivity of the ear.The External-Ear and the Directionality of the Ear : Head-Related Transfer Functions, Interaural time and phase differences , The 'Duplex Theory' for the localization of tones in the horizontal plane.

Lumped analysis of Acoustic Circuits Elements *:* The Concept of Finite (Lumped) Elements, Acoustic Circuits, Acoustic Elements, Connections of Acoustic Elements, Equivalent Circuits, System Functions, The Sinusoidal Steady State, Power and Energy.

Mechano-Acoustic Transformers & Transducers: The microphone. An acoustic – mechanical – electric transducer, electrostatic and dynamic speaker, Middle Ear Structure-Function & Pathology , Sound propagation in tube, acoustic losses in tube, Vocal tract for various articulation involved in the production of speech, Speech perception

Suggested Readings

1. P. Denes, & E. Pinson, The speech chain: The physics and biology of spoken language, New York: W.H. Freeman & Co., 1993.
2. G.A., Miller, The science of words. New York: Scientific American Library, 1991.
3. S. Pinker, The language instinct. New York: Harper-Collins (paper), 1993.
4. W.J.M Levelt, Models of speech produdction. *Trends in Cognitive Sciences,* 3, pp. 223-230, 1999 .

CSA309	Digital Speech Processing and Recognition	Credits: 3

Introduction to Digital Speech Processing: Review of DSP Fundamentals, Acoustic Theory of Speech Production, Speech Perception--Auditory Models, Sound Perception Models, MOS Methods, Sound Propagation in the Vocal Tract.

Speech Coding and Synthesis: Time Domain Methods in Speech Processing, Methods of Pitch Period Estimation, Speech Representations Based on STFT Analysis-Synthesis Methods, Homomorphic Speech Processing, Linear Predictive Coding (LPC) Methods, Speech Coding Methods--Model-Based Approaches. Cepstral Analysis.

Speech Enhancement: Introduction, Classification of Speech Enhancement Methods, Short-Term Spectral Amplitude Techniques, Speech Modeling and Wiener Filtering, Speech Enhancement and All-Pol Modeling, Sequential Estimation via EM Theory, Constrained Iterative.

Speech Quality Assessment: The Need for Quality Assessment, Quality Versus Intelligibility. Subjective Quality Measures - Intelligibility Tests , Quality Tests. Objective Quality Measures - Articulation Index , Signal-to-Noise Ratio, Itakura Measure, Other Measures Based on LP Analysis, Weighted-Spectral Slope Measures, Global Objective Measures, Example Applications. Objective Versus Subjective Measures.

The Speech Recognition Problem**:** Introduction , Speaker-Dependent Versus Speaker-Independent, Recognition , Vocabulary Size, Isolated-Word Versus Continuous-Speech, Recognition, Linguistic Constraints, Acoustic Ambiguity and Confusability, Environmental Noise, Speaker Recognition and Verification. Dynamic Time Warping, Hidden Markov Model(HMM) based speech modeling, N-Gram Statistical Models, and Other Formal Grammars, standard Databases for Speech-Recognition Research.

Suggested Readings

1. JRDeller, Jr, JG Proakis & JHL Hansen, Discrete-Time Processing of Speech Signals, Macmillan, 1993.
2. LR Rabiner & RW Schafer, Digital Processing of Speech Signals, Prentice-Hall, 1978.
3. F Jelinek, “Statistical Methods for Speech Recognition”, MIT Press, 1998.

CSA310	Graph Theory and Its Application	Credits: 3

Fundamentals of graph theory, families of graphs, and digraphs. Computer representation of graphs, graph isomorphism, reconstruction problem, and recursively constructed graphs. Basic digraph models and properties, directed acyclic graphs, Tournaments, Connectivity properties and structure, Eulerian graphs, Chinese postman problems, DeBruijn graphs and sequences, Hamiltonian graphs, Traveling salesman problems. Graph coloring, independent sets and cliques, Factors and factorization, Perfect graphs, Applications to timetabling.

Algebraic graph theory - Automorphisms, cayley graphs, enumeration, graphs and vector spaces, spectral graph theory, and matroidal methods in graph theory. Topological graph theory - Graphs on surfaces, minimum and maximum imbeddings, genus distribution, voltage graphs, genus of a group, maps, representativity, triangulations, graphs and finite geometries. Analytic Graph Theory - Extremal graph theory, random graphs, ramsey graph theory, and probabilistic methods.

Graphical measurement - Distance in graphs, domination in graphs, tolerance graphs and bandwidth. Applications in computer science – searching, dynamic graph algorithms, drawings of graph, and algorithms on recursively constructed graphs. Application in networks and flows - Maximum flows, minimum cost flows, matchings and assignments, and communication networks.

Suggested Readings:

1. Jonathan L Gross, Jay Yellen, Handbook of Graph Theory, 2003.
2. Richard A. Brualdi, Introductory Combinatorics, Prentice Hall, 4 edition, 2004.
3. G. Chartrand and L. Lesniak, Graphs and Digraphs, Chapman & Hall/CRC, 4 edition, 2004.
4. Bondy J.A. and U.S. R. Murty, Graph Theory with Applications, The Macmillan Press Ltd.
5. Deo Narsingh, Graph Theory with Applications to Engineering and Computer Science, Prentice-Hall, India, 1994.

CSA311	**Statistical Pattern Recognition**	**Credits: 4**

Introduction: Description of patterns, Probabilistic formulation of PR, Geometrical interpretation, Applications of PR, Scope of statistical PR.

Linear and nonlinear classification theory: Elementary Bayes decision theory, statistical criterion and discriminant functions, linear decision functions, piecewise linear decision functions, minimum distance classifier, nonlinear classification theory, multiple pattern classification.

Representation of patterns: Representation of binary random patterns – Orthogonal series expansion procedures, and Markov dependence considerations. KL expansion of patterns and its properties.

Feature Selection and Extraction: Information measures of feature effectiveness, Distance measure and performance bounds, Multiclass distance measures, Feature selection criterion, Evaluation of feature subset, Algorithm of dimensionality reduction, dimensionality and sample size.

Supervised and Unsupervised Learning : Bayesian estimation for Gaussian patterns, Comments on supervised Bayesian estimation, parameter estimation of slowly varying patterns, Bayes solution to unsupervised estimation, Estimation of mixture parameters, and decision-directed estimation. Graph theoretic method, component analysis – ICA, PCA, Artificial neural network.

Recursive Algorithm using Stochastic Approximation: Supervised parameter estimation using stochastic approximation, Estimation of probability density function, Unsupervised estimation using stochastic approximation.

Nonparametric methods and compound decision theory: Basic concepts and tools, Sample set construction, Nearest – Neighbor decision procedure, compound decision procedure, nonparametric estimation of multivariate density function, and nonparametric feature selection.

Cluster and Mode-Seeking Techniques: Distance and similarity measures, clustering methods.

Sequential pattern recognition systems: Bayes sequential decision procedure and the computational problems, Sequential probability ratio test (SPRT) and generalized sequential probability ratio test

(GSPRT), Bayes sequential analysis, Feature-ordering and selection problems, and Nonparametric sequential ranking procedure.

Contextual Analysis in PR: Bayes decision making in Markov chains, compound decision theory for contextual analysis, a practical context algorithm for image interpretation.

Recognition with strings: Strings matching, edit distance, computational complexity, string matching with errors, string matching with 'don't care' symbols.

Grammatical method, grammatical interface, rule based methods.

Suggested Readings

1. A. K. Jain, Fundamentals of digital image processing, PHI, 1995.
2. R.C. Gonzalez, R. Woods, Digital Image Processing, Prentice Hall, 2008.
3. R.O. Duda, P.E. Hart and D.G. Stork, Pattern Classification, Wiley and Sons, 2001.
4. S. Theodoridis and K. Koutroumbas, Pattern Recognition, Academic Press, 1999.
5. T. M. Mitchell, Machine Learning, Mcgraw-Hill, 1997.
6. Crisitanini Shawe-Taylor, An introduction to Support Vector Machines, Cambridge Press, 2000.
7. B. SchÖlkopf and A.J. Smola, Learning with Kernels, MIT Press, 2002.

CSA312	Practical	Credits: 4

This practical paper will consists of programming exercises and problem solving based on course CSA301, CSA303, & elective course chosen by the student.

(Practical paper will be of 100 marks out of which 30 marks will be assigned on sessionals / tutorials / class tests / seminars in class / group discussions and 70 marks will be assigned on the end semester examination out of which 50 marks will be on the performance in practical examination and 10 marks will be assigned each on practical record book and viva – voce. The duration of the practical exam shall be FOUR HOURS).

CSA313	Information Retrieval	Credits: 4

Introduction: Information, Information Need and Relevance; The IR System; Early developments in IR, User Interfaces.

Retrieval Evaluation: Notion of Precision and Recall; Precision-Recall Curve, Standard Performance Measures such as MAP, Reciprocal ranks, F-measure, NDCG, Rank Correlation.

Retrieval and IR Models: Boolean Retrieval; Term Vocabulary and Postings list; Index Construction; Ranked and other alternative Retrieval Models.

Document Processing: Representation; Vector Space Model; Feature Selection; Stop Words; Stemming; Notion of Document Similarity; Standard Datasets.

Applications / Laboratory Exercises.

Suggested Readings:

1. Ricardo Baeza-Yaets and Berthier Ribeiro-Neto, Modern Information Retrieval: The Concept and Technology behind Search, 2nd Edition, Addison-Wesley.
2. C.D. Manning, P. Raghvan and H. Schutze, Introduction to Information Retrieval, Cambridge University Press.
3. David A. Grossman and Ophir Frieder, Information Retrieval: Algorithms and Heuristics, 2nd Ed., Springer.
4. Stephen Buettcher, Charles L.A. Clarke and Gordon V. Carmack, Information Retrieval: Implementing and Evaluating Search Engines, MIT Press.
5. Bruce Croft, Donald Metzler and Trevor Strohman, Search Engines: Information Retrieval in Practice, Addison Wesley.

SEMESTER –IV

CSA401	Local Approximation Techniques	Credits: 4

Introduction: Linear and local approximation, Anisotropy, Nonlinear local approximation, MRA, Imaging applications.

Discrete Local Polynomial Approximation (LPA): Introduction, Basis of LPA, Kernel LPA estimates, Nonparametric regression, Nonparametric Interpolation. Shift-Invariant LPA Kernels: Regular grid kernel, Vanishing moments, Frequency domain- Frequency response, DTFT, Vanishing moments, and DFT. Numerical shift-invariant kernels- Square uniform window, Gaussian window. Numerical differentiation – Univariate and multivariate differentiation.

Integral LPA : Integral kernel estimators – Integral LPA, multivariate kernels and estimates, limit LPA estimates, Frequency domain. Analytic kernels, generalized singular functions, potential derivative estimates. Discrete LPA accuracy: Bias and variance of estimates, Ideal scale – Varying scale and invariant scale, accuracy and potential differentiators. Adaptive –Scale Selection: ICI Rule, Multiple-window estimation. Application: Image denoising.

Anisotropic LPA: Directional signal processing, Directional LPA, and Numerical directional kernels. Anisotropic LPA-ICI Algorithms: Accuracy analysis, Adaptive – scale algorithms, directional image denoising, directional differentiation, shading from depth, optical flow estimation.

Image reconstruction: Image deblurring, LAP – ICI deblurring algorithms, motion deblurring, super-resolution imaging, inverse halftoning, 3-D inverse – sectioning microscopy, observation model, 3D spatially adaptive inverse.

Nonlinear Methods: Why nonlinear methods – Basic hypothesis, M-estimation, statistical approach, and some distributions. Robust M-estimate and LPA – ICI Robust M-estimates. Nonlinear transform methods. Likelihood and Quasi-Likelihood: Local maximum likelihood, Binary and counting observations, local quasi-likelihood, and quasi-likelihood LPA-ICI algorithms.

Photon Imaging: Direct Poisson observations – Anscombe transform, local quasi-likelihood, recursive LPA-ICI algorithm, and numerical experiments. Indirect Poisson observations- ML pure inverse, Richardson – Lucy method, EM pure inverse, regularized inverse, and LPA-ICI filtering. Local ML Poisson inverse – Local ML for indirect observation, and linear inverse plus LPA-ICI filtering.

Computerized Tomography: Emission tomography, transmission tomography, and adaptive LPA-ICI algorithms.

Multi-resolution Analysis: Basic concepts, Nonparametric LPA spectrum, thresholding, and parallels with wavelets.

Suggested Readings

1. Astola J. and P. Kuosmanen, Fundamentals of Nonlinear Digital Filtering,New York, CRC Press, 1997.
2. V. Katkovnic, K. Egiazarian, J. Astola, Local approximation techniques in Signal and Image processing. SPIE, 2006.

3. Fan J. and Gijbels I., Local polynomial modelling and its application.London: Chapman and Hall, 1996.
4. Loader C., Local regression and likelihood, Series Statistics and Computing,Springer-Verlag New York, 1999.
5. B. W. Silverman, Density Estimation for Statistics and Data Analysis. London: Chapman and Hall / CRC, 1998.
6. B. W. Silverman, P. J. Green, Nonparametric Regression and Generalized Linear Models: A Roughness Penalty Approach. London: Chapman and Hall, 1994.

CSA402	Advanced Digital Signal Processing	Credits: 4

Multirate digital signal processing: decimation, interpolation, sampling rate conversion, digital filter banks. Linear Prediction and Optimum Linear Filters: linear prediction algorithms and properties, Wiener filters. Adaptive filters: LMS algorithm, RLS algorithm. Power spectral estimation: nonparametric algorithms, parametric algorithms, filter bank methods.

Time-Frequency methods: Gabor representation (continuous time). Tiling options of the time-frequency domain. The continuous wavelet transform, Discrete wavelet transforms. Frame theory, Gabor and wavelet frames, the construction of orthonormal wavelet bases and Multiresolution Analysis. Orthonormal wavelet bases of finite support with Examples. Wavelet analysis of discrete-time signals and Malat's algorithm. Wavelets and perfectly-reconstructable filter-banks. Bi-orthogonal wavelet bases: Symmetry and linear-phase. Spline wavelets, Implementation: complexity and numerical efficiency, Adaptive decompositions: Information cost functions, library of bases.

Orthogonal and Bi-orthogonal Wavelet Packets: Additive cost functions and complexity, Adaptive decompositions based on local-trignometric libraries. Advantages and drawbacks compared to Wavelet Packets. The importance of shift-Invariance in various applications. Discrete, shift-invariant decompositions. Shift-Invariant Wavelet Packets libraries and decompositions and Examples.

The weakness of wavelet decompositions in representing (first order) line-discontinuities. Lin-discontinuities in Radon space. Donoho's Ridgelets and curvelet related concepts. Time-Frequency Distributions: Expectations and basic properties. The Winger Distribution: Its outstanding properties and drawbacks and modified Winger Spaces.

Suggested Readings

1. John G. Proakis and Dimitris G. Manolakis, Digital Signal Processing: Principles, Algorithms, and Applications, 4th edition, Pearson Education, 2007.
2. D. G. Manolakis, V. K. Ingle, and S.M. Kogon, Statistical and Adaptive Signal Processing, McGraw-Hill, 2000.
3. P. Stoica and Randolph Moses, Introduction to Spectral Analysis, Prentice Hall, 1997.
4. M. Vetterli and J. Kovaceive, Wavelets and Subband Coding, Prentice-Hall, PTR, Englewood Cliffs, NJ, 1995.
5. Ingrid Daubechies, Ten Lectures on Wavelets, SIAM, 1995.
6. Stephen Mallat, A Wavelet tour of signal processing the sparse way, Academic Press, 2009.
7. C.S. Burns, R.A. Gopinath, and H. Guo, Introduction to Wavelet and Wavelet Transform, Prrintice Hall, New Jersey, 1998.
1. G. Strang and T. Nguyen, Wavelets and Filter Banks, Wellesley-Cambridge Press, 1996.

2. M. Vetterli and J. Kovaceive, Wavelets and Subband Coding, Prentice-Hall, PTR, Englewood Cliffs, NJ, 1995.
3. M.V. Wickerhauser, A.K. Peters, Adapted Wavelet Analysis: from Theory to Software, Wellesley, MA, 1994.

CSA403	Compressive Sensing / Sampling and its Application	Credits: 4

Introduction: Introduction to compressive sensing.

Sparse and Compressible Signal Models: Introduction to vector spaces, Bases and frames, Sparse representations, and Compressible signals.

Sensing Matrices: Sensing matrix design, Null space conditions, The restricted isometry property, The RIP and the NSP, Matrices that satisfy the RIP, and Coherence

Sparse Signal Recovery via l_1 Minimization: Signal recovery via l_1 minimization, Noise-free signal recovery, Signal recovery in noise, Instance-optimal guarantees revisited, and The cross-polytope and phase transitions.

Algorithms for Sparse Recovery: Sparse recovery algorithms, Convex optimization-based methods, Greedy algorithms, Combinatorial algorithms, and Bayesian methods.

Applications of Compressive Sensing: Linear regression and model selection, Sparse error correction, Group testing and data stream algorithms, Compressive medical imaging, Analog-to-information conversion, Single-pixel camera, Hyperspectral imaging, Compressive processing of manifold-modeled data, Inference using compressive measurements, Compressive sensor networks, Genomic sensing.

Suggested Readings

1. Stephen Mallat, A Wavelet tour of signal processing the sparse way, Academic Press, 2009.
2. Richard Baraniuk, Mark A. Davenport, Marco F. Duarte, and Chinmay Hedge, An Introduction to Compressive Sensing, online Rice University Resource, http://cnx.org/content/col11133/1.5
3. Gitta Kutyniok, Compressed Sensing: Theory and Applications, online Rice University Resource.
4. ,Mark A. Davenport, Marco F. Duarte, Yonina C. Eldar, Gitta Kutyniok, Introduction to Compressed Sensing , online Rice University Resource.
5. Massimo Fornasier and Holger Rauhut, Compressive Sensing, online Rice University Resource.
6. http://dsp.rice.edu/cs

CSA404	Image Analysis and Computer Vision	Credits: 4

Morphological Image Processing: Basic concept of set theory, logic operation involving binary images, dilation and erosion, opening and closing, and hit-or-miss transformation. Some basic morphological algorithms – Boundary extraction, region filling, extraction of connected components, convex hull, thinning, thickening, skeletons, and pruning. Extensions to gray-scale images – Dilation, Erosion, Opening and closing, and application of gray scale morphology.

Image segmentation: Detection of discontinuities – Point detection, line detection, edge detection – gradient operators, compass operators, laplace operators and zero crossing, stochastic gradients, performance of edge detector operators. Amplitude thresholding or window slicing, component labeling, boundary based approaches, region-based approaches and clustering, template matching, and texture segmentation.

Boundary Extraction: Connectivity, Contour following, Edge linking and heuristic graph searching, dynamic programming, and Hough transform.

Boundary Representation: Chain code, Fitting line segments, B-spline representation, Fourier descriptors, shape number, and autoregressive model.

Region Representation: Run-length codes, Quad-trees, topological descriptor, texture and projections.

Moment representation: Moment representation theorem, Moment matching, Orthogonal moments, Moment invariants. Applications of moment invariants.

Shape feature: Geometry features, Moment-based features.

Texture: Statistical approaches, structural approaches, and other approaches.

Scene matching: Image subtraction, template matching and area correlation, and matched filtering.

Object recognition and image understanding: Patterns and pattern classes, decision theoretic and structural methods.

Suggested Readings

1. A. K. Jain, Fundamentals of digital image processing, PHI, 1995.
2. R.C. Gonzalez, R. Woods, Digital Image Processing, Prentice Hall, 2008.

CSA405	**Approximation, Denoising and Inverse Problem through Wavelet**	**Credits: 4**

Introduction: Fourier transform, Frames- Frame and Riesz bases, Translation-Invariant dyadic wavelet transform, Windowed Fourier frame, Directional wavelet frame, and curvelet frames. Wavelet bases – Orthogonal wavelet bases, Wavelet and filter banks, Biorthogonal wavelet bases, MRA.

Approximation in Bases: Linear approximations, nonlinear approximation, sparse image representation.

Denoising: Estimation with additive noise – Bayes estimation, Minimax estimation, Diagonal estimation in a bases - diagonal estimation with oracles, thresholding estimation, Thresholding sparse representation – wavelet thresholding, wavelet and curvelet image denoising, Nondiagonal block thresholding, Denosing minimax optimality.

Inverse problems: Review of classical method for image restoration, Ill-conditioning, Linear inverse estimation- Quadratic and Tikhonov Regularization, Singular value decomposition. Thresholding estimators for Inverse problems – Thresholding in bases of almost singular vectors, thresholding deconvolution. Super-resolution – Sparse super-resolution estimation, sparse spike deconvolution, recovery of missing data, Compressive sensing, Blind source separation – Blind mixing matrix separation, source separation.

Spatial context modeling using wavelets for image denoising: Markov random field (MRF) priors in wavelet domain denoising: MRF, Gibbs distribution, common MRF model. The MAP-MRF approach – Joint MAP coefficient estimation, MAP mask estimation, optimization algorithm. Bayesian shrinkage with MRF priors – Prior and conditional models, Stochastic sampling method of Malfait and Roose.

Statistical modeling in MRF based wavelet denoising: Significance measures – A discretized approximation of interscale ratios, statistical characterization via simulation, performance evaluation, a joint significant measures. A new MRF prior model using class of anisotropic potentials, Practical algorithms and its implementation.

Generalized likelihood ratio in denoising: Joint detection and estimation(JDE) – General principles, JDE under statistically independent observations. A wavelet domain GenLike approach – Notation and model assumptions, spatial adaptation, global prior probability ratio, Estimation of conditional densities, Signal of interest and performance evaluation, Algorithm. An empirical GenLik Approach – The main idea and the global concept. A versatile algorithm for various noise types – The practical algorithm, on medical applications, application to ultrasound and MRI images. Application in image deblurring.

Suggested Readings

1. Stephen Mallat, A Wavelet tour of signal processing the sparse way, Academic Press, 2009.
2. Marten Jansen, Noise reduction by wavelet thresholding, Lecture note in statistics 161, Springer, 2001.
3. W. Hardle, G. Kerkyacharian, Wavelet Approximation and Statistical Application, Lecture note in statistics 129, Springer, 1998.
4. A.K. Katsaggelos, Digital image restoration, Springer Series in Information Sciences 23, Springer-Verlag, 1989.
5. P.A. Jansson, Deconvolution of Images and spectra, Academic Press, 1997.

CSA406	**Array Signal Processing**	**Credits: 4**

Introduction: Some motivating applications- sonar and radar, radio communication, remote sensing, astronomy, navigation, biology, tomography, medical imagining.

Spectral analysis, system identification, inverse estimation, imaging.

Array sensors: Signals in space and time, Propagating waves, Basic mathematical models. Narrow- and wide-band signals.

Beamforming: Direction-of-arrival (DOA) and waveform estimation. Delay-and-sum beamforming. Space-time filtering. Band-pass filter design. Optimal filters.

Adaptive array processing: Minimum variance Capon's beamforming, High-resolution eigenvalue decomposition methods: MUSIC, ESPRIT, Maximum likelihood array signal processing.

Beamforming in nonstationary environment: Moving sources. DOA and waveform estimation, Nonparametric estimation and parametric models of nonstationary processes.

Interferometric synthetic aperture radar (SAR) imaging: Basic mathematical models, 2D Fourier transform, Microwave radiometry algorithms, Tomographic foundation for SAR imaging. Mathematics of computerized tomography. Inverse problems. Resolution. Phase errors and autofocus in SAR imaginary. Interferometric processing of SAR data.

Mathematics of inverse problems: Nonparametric methods, Ill-conditioned problems, Regularization. Optimal filtering, and Parametric methods.

Robust estimation with respect to impulse style noises (minimax M-estimation), Robust beamforming. Estimation of DOA and waveform, Robust beamforming and estimation for moving sources.

Suggested Readings

1. Don H. Johnson & Dan E. Dudgeon, Array Signal Processing: Concepts and technique, Prentice-Hall, N.J, 1993.
2. Introduction to Spectral Analysis, P. Stoica and Randolph Moses, Prentice Hall, 1997.
3. J. C. Liberti, Theodore S. Rappaport, Smart Antenna for Wireless Communications, ,Prentice Hall, 1999.
4. Prabhakar S. Naidu, Sensor Array Signal Processing, CRC Press, 2000.
5. D. G. Manolakis, V. K. Ingle, and S.M. Kogon, Statistical and Adaptive Signal Processing, McGraw-Hill, 2000.
6. M. D. Srinath, P. K. Rajsekaran, R. Viswanathan, Introduction to Statistical Signal Processing with Applications, Prentice Hall, 1996.

CSA407	**Advanced Topics in Speech Recognition**	**Credits: 4**

The Speech Recognition Problem**:** Introduction , Speaker-Dependent Versus Speaker-Independent, Recognition , Vocabulary Size, Isolated-Word Versus Continuous-Speech, Recognition, Linguistic Constraints, Acoustic Ambiguity and Confusability, Environmental Noise, Speaker Recognition and Verification.

Dynamic Time Warping: Introduction, Dynamic Programming, Dynamic Time Warping Applied to IWR - DTW Problem and Its Solution Using DP, DTW Search Constraints, Typical DTW Algorithm: Memory and Computational Requirements. DTW Applied to CSR- Introduction, Level Building, The One-Stage Algorithm, A Grammar-Driven Connected-Word Recognition System, Pruning and Beam Search , and Resource Requirements for DTW Algorithms, Training Issues in DTW Algorithms

The Hidden Markov Model: Introduction**,** Theoretical Developments - Generalities , The Discrete Observation HMM, The Continuous Observation HMM, Inclusion of State Duration Probabilities in the Discrete Observation HMM, Scaling the Forward-Backward Algorithm, and Training with Multiple Observation Sequences. Alternative Optimization Criteria in the Training of HMMs - A Distance Measure for HMMs, Practical Issues, Acoustic Observations, Model Structure and Size, Training with Insufficient Data, Acoustic Units Modeled by HMMs. First View of Recognition Systems Based on HMMs. **-** IWR Without Syntax, CSR by the Connected-Word Strategy Without Syntax.

Language Modeling: Introduction, Formal Tools for Linguistic Processing, Formal Languages, Perplexity of a Language, Bottom-Up Versus Top-Down Parsing, HMMs, Finite State Automata, and Regular Grammars. Principles of "Top-Down" Recognizers -Focus on the Linguistic Decoder, Focus on the Acoustic Decoder, Adding Levels to the Linguistic Decoder, and Training the Continuous-Speech Recognizer. Other Language Models - N-Gram Statistical Models, and Other Formal Grammars. IWR as "CSR". Standard Databases for Speech-Recognition Research .

The Artificial Neural Network: The Multilayer Perceptron, Learning Vector Quantizer, Applications of ANNs in Speech Recognition, Recognizing Dynamic Speech, ANNs and Conventional Approaches, Language Modeling Using ANNs.

Suggested Readings

1. JRDeller, Jr, JG Proakis & JHL Hansen, Discrete-time Processing of Speech Signals, Macmillan, 1993.
2. LR Rabiner & RW Schafer, Digital Processing of Speech Signals, Prentice-Hall, 1978.
3. F Jelinek , Statistical Methods for Speech Recognition, , MIT Press, 1998.
4. Louis L. Scharf, Statistical signal processing (detection, estimation, and time series analaysis), Addison – Wesley, 1991.

CSA408	**Independent Component Analysis**	**Credits: 4**

Module –I: Cocktail Party Problem, Overview of Independent Component Analysis, Strategies for Blind Source Separation, the Geometry of Mixtures, Un-mixing Using the Inner Product.

Module-II: Principal Component Analysis, Uncorrelatedness and whitening, Whitening transform, Robust Prewhitening, Blind Source Separation via Generalized Eigenvalue Decomposition,

Module-III: Methods using time structure, Separation by Autocovariances, The AMUSE algorithm, The SOBI algorithms, Separation by nonstationarity of variances, The SEONS algorithms, A fixed-point algorithm, ICA and kolmogoroff complexity

Module-IV: Convolutive Mixtures and Blind Deconvolution, Bussgang methods, Cumulant-based methods, The convolutive BSS problem, Natural gradient methods, Spatio-temporal de-correlation methods.

Module-V: ICA by maximization of non-gaussianity, Non-gaussian is independent, Measuring non-gaussianity by kurtosis, Measuring non-gaussianity by Negentropy, Gradient algorithm using Negentropy.

Module-VI: ICA by maximum likelihood Estimation, The likelihood of the ICA model, Algorithms for maximum likelihood Estimation, The Bell-Sejnowski Algorithm, The INFOMAX Principle,

Module-VII: Nonlinear ICA, Existence and uniqueness of nonlinear ICA, Separation of post-nonlinear mixtures, nonlinear BSS using self-organizing maps, A generative topographic mapping approach to nonlinear BSS, An ensemble learning approach to nonlinear BSS.

Suggested Readings

1. Aapo Hyvarinen, Juha Karhunen, Erkki Oja, Independent Component Analysis, Wiley-Interscience Publication, 2001.
2. Andrzej Cichocki, Shun-ichi Amari, Adaptive Blind Signal and Image Processing Learning Algorithms and Applications, JOHN WILEY & SONS Ltd.
3. James V. Stone, Independent Component Analysis: A Tutorial Introduction, A Bradford Book, 2004.
4. Stephen Roberts, Richard Everson, Independent Component Analysis: Principles and Practice, Cambridge University Press, 2001.

CSA409	Advanced Biomedical Signal Analysis	Credits: 4

Nature of biomedical signals, Examples of biomedical signals – the action potential, electroneurogram (ENG), electromyogram (EMG), the electrocardiogram (ECG), electroencephalogram (EEG), event-related potential (ERPs), electrocardiogram (ECG), phonocardiogram (PCG), carotid pulse (CP), speech signal, vibromyogram (VMG), and vibroarthrogram(VAG). Objectives and challenges in biomedical signal analysis.

Concurrent, Coupled, and Correlated Processes: ECG and phonocardiogram, phonocardiogram and the carotid pulse, ECG and the atrial electro gram, cardio-respiratory interaction

Filtering for removal of artifacts: random noise, structured noise, and physiological interference, stationary vs. nonstationary processes. Different type of noise and their model: Noise in event related potentials, high frequency noise in the ECG, motion artifact in the ECG, power line interference in ECG, Maternal interference in fetal ECG. Different filtering methods in time domain as well frequency domain. Application: Remval of artifacts in ECG, Maternal – Fetal ECG, Muscle-contraction interference.

Event Detection: P, QRS, and T waves in the ECG. First and second heart sound. EEG rhythms, waves and transients. Derivative-based methods for QRS detection. Correlation analysis of EEG channels. Application: ECG rhythm analysis, detection of aortic component S2.

Waveshape and Waveform complexity: Morphological analysis, Envelope extraction and analysis, analysis of activity. Application: normal and ectopic ECG beats, analysis of exercise ECG, analysis of respiration, correlates of muscular contraction.

Frequency Domain Characterization: Fourier spectrum, Estimation of power spectral density function, measures derived from power spectral density. Application: Evaluation of prosthetic valves.

Modeling Biomedical Systems: Illustration of the problems motor-unit firing patterns, cardiac rhythm, formants and pitch in speech, and patella-femoral crepitus. Point processes, Parametric system modeling, autoregressive or all-pole modeling, pole-zero modeling, electromechanical models of signal generation. Application: Heart rate variability, coronary artery disease.

Analysis of Nonstationary Signals: Illustration of the heart sound and murmurs, EEG rhythms and waves, and articular cartilage damage and knee – joint vibrations. Time-variant systems, fixed segmentation, adaptive segmentation, and use of adaptive filters for segmentation. Application: Adaptive segmentation of EEG signals, Time-varying analysis of Heart-rate variability.

Pattern classification and diagnostic decision: Pattern classification, supervised pattern classification, unsupervised pattern classification, probabilistic models and statistical decision, logistic regression analysis, training and test setup, neural networks. Application: Normal vs. Ectopic ECG beats.

Suggested Readings

1. Saied Sanei, J.A. Chambers, EEG Signal Processing, John Wiley and Sons, 2007.
2. Guido Dornhege, Jose del R. Millan Thilo Hinterberger, Dennis J. McFarland, Klaus-Robert Muller, Toward Brain-Computer Interfacing, MIT Press Cambridge, 2007.
3. D.C. Reddy, Biomedical Signal Processing, Tata McGraw – Hill, New Delhi, 2009.
4. Rangaraj M. Rangayyan, Biomedical Signal Analysis, IEEE Press, 2005.
5. John G. Proakis and Dimitris G. Manolakis, Digital Signal Processing: Principles, Algorithms, and Applications, 4th edition, Pearson Education, 2007.

CSA410	**Project**	**Credits: 4**

Project problem is decided by student and his mentor. The final project will contain the following documents:

i. Summary of the background and the author's motivation to deal with stated problem, i.e., why should the problem at hand be of interest.
ii. Summary of the proposed solution: Methodology, results, advantages (or drawbacks) compared to the earlier work.
iii. A comprehensive reference list representing the subject matter at hand.
iv. Your personal opinion:
- Is the paper presented clearly and convincingly?
- Do the provided references facilitate a complete understanding, of the stated problems and method of solutions?
- Is the stated problem important or is it of marginal significance?
- Is the proposed solution complete or is it, at best, an intermediate remedy to the stated problem (e.g., owing to questionable assumptions or approximations, inefficient numerical procedures, etc.)?
- If you observe the drawbacks associated with the proposed methodology- try to suggest alternatives that, in your opinion, appear to be better. Such statements should be reasoned, substantiated and if possible exemplified (e.g., by appropriate simulation).

SUMMERY OF THE STEPS AND REMARK:

1. **First step:** Conduct a comprehensive search of recent literature. The search is an integral part of the project and should be fully reported.
2. **Second step:** Study the papers and report as indicated above.
3. **Third step:** Your 'personal opinions'(in the sense of iv above) should be represented with extra clarity and emphasis.
4. **Remark:** List explicitly all the background reference that you had to study in order to gain complete understanding of the selected paper.

CSA411	Computational Geometry and Applications	Credits: 4

Geometric primitives, Line intersection,Triangulation and visibility, Linear programming in two and three dimensions, Orthogonal range searching, Point location and Binary Space Partitions, Voronoi diagrams and Delaunay triangulation, Convex hulls, Non-orthogonal range searching, arrangements of hyperplanes, Curved Elements (Bezier, B-Splines), Curve Reconstruction [reconstruction a curve(surface) from sample points], 3-Dimensional Geometry. Search problems: advanced data structures; subdivision search; various kinds of range searches. Models of computation; lower bounds**.**
Applications: Image registration and analysis- Cortical surface parameterization and registration, Geometric optimization in machine learning, Shape analysis on the Manifold of Diffeomorphism.

Books Recommended:

1. de Berg, van Kreveld, Overmars, and Schwarzkopf, *Computational Geometry Algorithms and Applications,* Springer-Verlag, 2008.
2. J D Foley, A van Dam et al., *Introduction to Computer Graphics,* Addison-Wesley, 1994.
3. D Hearn and M P Baker, *Computer Graphics with Open GL* , Prentice-Hall, 2004
4. Franco P. Preparata, Michael Shamos, Computational Geometry: An Introduction, Springer
5. Joseph O'Rourke, Computational Geometry in C, CUP.
6. Anand Arvind Joshi, Geometric Methods for Image Registration and Analysis, Ph.D. Thesis.
7. Minh H.Q., Murino V., Algorithmic Advances in Remanian Geometry and Applications for Machine Learning, Computer Vision, Statistics, and Optimization, SPRINGER, 2016.

CSA412	Machine Learning	Credits: 4

Machine Learning Concepts: Designing a Learning System, Styles of Learning; Supervised learning; Unsupervised Learning; Semi-Supervised Learning; Basics of Decision Theory,Information Theory and Probability Distributions; Linear and Logistic Regression.

Bayesian Learning: Notion of Prior, Likelihood and Posterior; Naïve Bayes and Conditional Independence; Estimation using Maximum Likelihood; Hidden variables and Missing Data; Bayesian Models.

Applications: Naive Bayes, Nearest Neighbour and Linear Classification Models; K-means and Expectation Maximization for Clustering; Mixture Models.

Machine Learning Applications and Laboratory Exercises.

Suggested Readings:

1. David Barber, Bayesian Reasoning and Machine Learning, CUP.
2. Christopher M. Bishop, Pattern Recognition and Machine Learning, Springer.
3. Tom M. Mitchell, Machine Learning, Mc Graw Hill. Kevin P. Murphy, Machine Learning: A Probabilistic Perspective, MIT Press.
4. Daphne Koller and Nir Friedman, Probabilistic Graphical Models: Principles and Techniques, MIT Press.
5. Peter Harrington, Machine Learning in Action, Manning Publications.

CSA413	Text Analytics	Credits: 4

Basics of Text Processing: Statistical and Graphical NLP; Representation; Boolean and Vector Space Models; Feature Selection; Stop Words; Stemming; Parts of Speech Tagging; Graph Based Representations; IR view of Text Processing; Similarity measures; Notion of Information Need, Precision and Recall.

Classification and Clustering: Supervised and Unsupervised methods for Text Processing; Classification Methods such as Naïve Bayes, Nearest Neighbour, Rochio's and Support Vector Machines; Clustering Methods such as Partitional and Hierarchical, Soft and Hard, K-Means, EM, Agglomerative Clustering; Datasets and Performance Measures.

Applications: Open and Targeted Information Extraction; Named Entity Recognition; Question Answering; Sentiment Analysis; Semantic Annotation; Document Summarization.
Laboratory Exercises.

Suggested Readings:

1. C.D. Manning, P. Raghvan and H. Schutze, Introduction to Information Retrieval, CUP..
2. R. Mihalcea and D. Radev, Graph based Natural Language Processing and Information Retrieval, CUP.
3. U.S. Tiwary and Tanveer Siddiqui, Natural Language Processing and Information Retrieval, OUP.
4. G.S. Ingersol, T.S. Morton and A.L. Farris, Taming Text: How to Find, Organize and Manipulate It, Manning Publications.
5. S. Bird, E. Klein and E. Loper, Natural Language Processing with Python, O'Reilly.