BANARAS HINDU UNIVERSITY

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

Ordinance for Special Postgraduate Course

On

M.Sc. in Computational Science and Applications

(with specialization in Data Science or Software Engineering or Signal Processing)

w.e.f. 2021-2022

OFFERRED BY:

DST-Centre for Interdisciplinary Mathematical Sciences (CIMS)

Institute of Science

Banaras Hindu University

CONTENTS

1. Admission

Admission in the course will be made strictly in accordance with the merit in the Entrance test conducted by the University, subject to fulfilling of eligibility requirements mentioned below. The details about the entrance test,

types of the questions to be asked and the syllabi of the entrance test will be announced by the University in Post-graduate entrance test information bulletin. Admission cannot be claimed by any candidate as a matter of right.

1.1. Minimum eligibility criterion, number of seats, fee, and duration of the course

NOTE:	Relaxation in minimum eligibility for Scheduled Castes (SC) / Schedule Tribes (ST) / Other Backward Classes (OBC)/OBC-Minorities/Physically Challenged (PC) candidates given as other 'special courses' of Institute of Science.
Course Name:	Master of Science in **Computational Science and Applications** with specialization in Data Science or Signal Processing or Software Engineering
Duration:	04 Semesters (02 years)
Course Description:	Master of Science in **Computational Science and Applications** (with specialization in Data Science or Signal Processing or Software Engineering) is a two-year (four-semester) program offered by DST Centre for Interdisciplinary Sciences.
Minimum Eligibility Criterion*	B.Sc. (Hons)/B.Sc./ under 10+2+3 pattern securing a minimum of 50% marks in the aggregate* (considering all the three years of B.Sc. Course). The candidate must have studied at least two of Mathematics, Statistics or Computer Science as two of the subjects for at least two years. Besides, he/she must have studied one of the subjects Statistics, Mathematics or Computer Science for all the three years.
Number of Seat	Minimum: 05 Maximum: 50
Fee	Rs. 50,000/- per annum besides the regular fee of the University

***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 (OBC), other backward classes-minorities (OBC-minorities)and physically challenged (PC) candidates_ are same as other 'special courses' of Institute of Science, BHU.

***NOTE 3:** Rules regarding minimum eligibility requirement other than those given above are same as those for other 'special courses' of Institute of Science, BHU.

1.2. Reservation / Supernumerary seat / Employee: The reservation under these categories shall be as per University rules.

1.3. Scheme *of Entrance Examination:* There shall be one paper of 120 minutes duration carrying 360 marks containing 120 multiple-choice questions on Statistics (40 MCQs), Mathematics (40 MCQs) and Computer Science (40 MCQs). The question paper will be in English language only.

1.4. Syllabus for the Entrance Examination: The question papers shall be based on graduate level courses up to 2nd year of Banaras Hindu University.

1.5. Merit List for Admission

1.5.1. Candidates shall be selected strictly in order of merit on the basis of the aggregate marks secured by them in the entrance test. Any specific guidelines in this regard will be provided by the University in the post graduate information bulletin to be announced every year by the University.

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 percentage 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 admission, decision of a Committee comprising the admission committee of the centre shall be final.

1.5.4. The candidates selected for admission will be informed individually by / e-mail / sms and through online portal of the University.

1.5.5. 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

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

i. If he /she fails to attend classes, and absents regularly for 15 days or more without permission.
ii. 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).
iii. If his/ her attendance is less than 15% in any semester.
iv. 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 M.Sc. Computational Science and Applications degree a candidate shall offer not less than 80 credits. The distribution of the credits is given below:

4.1.1. Compulsory theory and practical courses not less than 53 credits shall be taken by all the students as prescribed.

4.1.2. SWAYAM elective 4 credits (2 credits in 2nd semester and 2 credits in 3rd semester) to be opted by the candidate from SWAYAM courses of SWAYAM Website(https://swayam.gov.in/).

4.1.3. Elective courses not less than 22 credits shall be taken by all the students as prescribed.

4.1.4. Dissertation credits : 05

4.2. A candidate will be given specialization in either Data Science or Signal Processing or Software Engineering based on the choice of specialization courses. Specialization 1 corresponds to Data Science, Specialization 2 corresponds to Signal Processing and Specialization 3 corresponds to Software Engineering. If courses that are selected do not as per any of the specialization degree in M.Sc. Computational Science and Applications with no specialization will be given.

4.3. Dissertation-I in 3rd semester and Dissertation-II in 4th semester will also be based on a topic from the selected specialization by the candidate. Candidates who do not opt any specialization can choose any topic for their dissertation as per discussion with their supervisor.

4.4. 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 CSA306: Dissertation-I in Semester III and CSA401: Dissertation-II 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. 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.

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

5.6. Supervisor for the dissertation will be assigned during 3rd semester and it will be spread over the remaining period. The topic and problem will be decided by the candidate in consultation with the Supervisor. In every case the decision of the Supervisor shall remain final. A Dissertation may be undertaken by a group of students. However, the dissertation shall be submitted by each member of the group separately. The 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.

5.7. The candidates who are selected for M.Sc. Computational Science and Applications will have at least two full semesters (3rd and 4th) and one summer vacation for their dissertation. Such students will be required to submit a proposed plan of their work, title and broad area of the proposed work, literature review, etc. and they will give a presentation in the front of external examiner and the allotted supervisor at the end of 3rd semester. 60 marks will be assigned for the evaluation of their submitted

plan separately by both the examiners and 40 marks will be assigned jointly by the examiners on the oral presentation and viva – voce.

5.8. Such candidates who are selected for M.Sc. in Computational Science and Applications may be encouraged to carry collaborative work in their dissertations. Besides, their allotted supervisors, they may choose any external teacher (in consultation with their supervisors) either from other institutions in India or from an institution abroad. During summer vacation after 3rd semester, such candidates may go to their chosen Institution for such collaborative work. Such candidates will be encouraged to get at least one presentation in an International Conference out of their Research dissertation.

5.9. In dissertation-II of 4th semester candidates will continue to work on same topic selected in Dissertation-I in 3rd semester. In dissertation-II they will implement and compare their approach with existing ones and show the results etc. There shall be an external examiner and an internal examiner (preferably the Supervisor of the student) for the evaluation of the Dissertation at the end of 4th semester. Out of total 100 marks assigned to the Research Project/Research dissertation, 60 marks will be assigned on the evaluation of the submitted project work separately by both the examiners and 40 marks will be assigned jointly by the examiners on the oral presentation and viva – voce.

5.10. Students will earn 4 credits for the two SWAYAM elective papers (CSA206 of Semesters – III, CSA302 of Semester III, each of two credits) from UGC SWAYAM website.

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 dissertation **supervisor**

6.1. The supervisor of the dissertation, appointed by the appropriate academic committee of the centre during 3rd semester, shall be the advisor - chairman. The Chairman may nominate, if necessary, other two members of the project advisory committee from the related discipline in consultation with the Coordinator.

6.2. Functions of the Advisory Committee

The advisory committee shall guide a student in the selection of suitable research / development problem for dissertation 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 coordinator at the 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/Director, Institute of Science. 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:

i. Participation in NCC/NSC/NSS Camps duly supported by certificate.
ii. Participation in University or College Team Games or Inter-State or Inter University tournaments, duly supported by certificate from the Secretary of the University Sports Board or President of the College Athletic Association concerned.
iii. 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.
iv. University Deputation for Youth Festival duly certified by the Dean, Faculty of Science.
v. 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.
vi. **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 start of classes whichever 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 under the 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 up to 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.

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

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 (th 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 be taken into account.

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

where, C_j= Number of credits assigned for thej^{th} course, up to the semester for which CGPA is to be calculated.

P_j = Grade point earned inj^{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 means 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 more than 1/2 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 not appear 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 is more than one teacher teaching the 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 Coordinator, 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 in** practical examination and Research project/dissertation evaluation.

vi. **Admit Card (for End Semester Examinations)**: A candidate may not be admitted into examination room unless he/she produces 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 the university.

11. PROMOTION RULES AND SUPPLEMENTARY EXAMINATION

1. **2-YEAR M.Sc. (FOUR SEMESTER) PROGRAMMES**

There shall be no supplementary examination for 1st & 2nd semesters. However, there shall be supplementary examination for 3rd & 4th semesters after declaration of the results of 4th Semester. Students failing in courses of 3rd & 4th semesters may appear in supplementary examination(s) or subsequent main examination(s).

(A) First Semester Course & Examination:

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

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

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

Candidates under Category I (i) are eligible for appearing at the examination of I Semester, while candidates under Category I (ii) are not allowed to appear 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.

II. After appearing at the Examination of I Semester the candidates can be put in the following categories in the context of declaration of the results of the Semester I 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 2nd Semester:

All students who have put in the minimum percentage of attendance in 1st Semester and filled up the examination form in time shall be promoted to the 2nd Semester.

(B) Second Semester Course & Examination

As in the 1st 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 on the subsequent session only (except in the First Semester where re-admission is not permitted).

(C) Declaration of results after 2nd Semester (based on the results of 1st and 2nd Semester Examinations):

After declaration of results of the 1st & 2nd 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 1st & 2nd Semesters.

(ii) Promoted: A student, who has not passed in all the courses of either 1st or 2nd semester or both, shall be promoted to the 3rd 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 1st & 2nd 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 1st & 2nd semesters.

(D) 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 3rd 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 ex-students.

(E) Promotion to the Fourth Semester

All students who have put in the minimum percentage of attendance in 3rd Semester and filled in the examination form in time shall be promoted to the 4th Semester.

(F) Declaration of Results after Fourth Semester (Based on the results of the Ist, IInd, IIIrd and IVth Semester Examinations):

After declaration of results of 3rd & 4th Semesters, a candidate can be put in the following two categories:

(i) Passed: A candidate who has passed in all the courses of 1st, 2nd, 3rd & 4th 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 ex-students. There shall be a provision of supplementary examinations for 3rd & 4th Semesters after declaration of results of 4th Semester. Students failing in courses of 3rd & 4th Semesters may appear in the supplementary examination or subsequent main examination(s).

A student who has failed in a course shall get one more chance 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.

(G) Maximum duration for passing the two years PG Programme:

The maximum duration for passing the 2-years PG programme shall be 4years, which shall be counted from the year of latest admission in the 1st semester of the PG programme. No student shall be allowed to take further admission in the programme after the expiry of four years.

(H) Deposition of Fees:

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

11. 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.

12. SYLLABUS

The syllabi for the programme shall be framed by the Department/School/Centre concerned.

13. 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 examinees 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.

14. RE-ADMISSION TO THE PROGRAMME/SEMESTER

A student who does not put in at least the minimum percentage of attendance required in the 1st semester shall not be promoted to the higher semesters. However, such students can take fresh admission in the PG programme after appearing in the PET of Faculty of Science and being eligible for admission in the course on the basis of result of the PET of the concerned year.

All such students of 2nd, 3rd, 4th, 5th or 6th 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 2nd or higher semester and continues to be a student shall be allowed to reappear in the PET of the same programme for taking fresh admission in the programme.

15. BREAK IN THE COURSE

Any student taking admission in any of the M.Sc. programmes of the Faculty shall not be allowed to pursue any other full time programme/course in the Faculty 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 in the Faculty.

DEFINITION

1. 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.
2. '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 (by the University) at the beginning of every academic year.

M.Sc. in Computational Science and Applications

1. The Post Graduate Course in Computational Science and Applications shall be a Two – Year Degree Course comprising of FOUR SEMESTERS (Two Semesters in each year). The total credits for all the four semesters will be 80 including two SWAYAM Elective Papers. A candidate may be given specialization in either Data Science or Signal Processing or Software Engineering depending on the elective papers selected by a candidate.
2. There will be no provision of any specialization if a candidate selects elective papers that do not cover any specialization on successful completion of four semesters or two years.
3. There are three specializations. The candidates are required to select courses at the start of 3rd semester as well as the courses at the start of 4th semester such that it belongs to one specialization. Then only a particular specialization will be provided in the degree.
4. There shall be sessionals / tutorials / class tests / seminars in class / group discussions in each theory and practical paper (Core Courses, SWAYAM and Elective papers) except Paper No. CSA306: Dissertation-I in Semester – III and Paper No. CSA401: Dissertation-II in Semester – IV.
5. 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.
6. 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.
7. 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 based on the problems done by the candidate in his/her lab examination and Viva-voce.
8. Paper No. CSA306: Dissertation-I and Paper No. CSA401: Dissertation-II will be based on the selected specialization, if any, and will be decided by the candidate in consultation with his/her supervisor . In every case the decision of the supervisor on the topic will be final. A dissertation work spread over whole semester may be undertaken by a group of students at the beginning of 3rd semester. However, the Dissertation report shall be submitted by each member of the group separately. The Dissertation report/dissertation shall clearly state the problem addressed, the methodology adopted, the assumptions and the hypotheses formulated, any previous reference to the study undertaken at the end of the 3rd semester while implementation, analyses, comparison performed and the broad conclusion drawn at the end of the 4th semester. In both semester (Semester-III and Semester-IV) there shall be an external examiner and an internal examiner (preferably the supervisor of the student) for the evaluation of the dissertation 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.
9. Three SWAYAM elective papers (one in each of Semester-II and Semester-III) will be offered by students from UGC SWAYAM website.

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

M.Sc. in Computational Science and Applications

(with specialization in Data Science or Software Engineering or Signal Processing)

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

DISTRIBUTION OF COURSES AND CREDITS IN VARIOUS SEMESTERS

Year	*Course Code*	*Course Title*	*Credits*
1st		***SEMESTER I***	
	CSA101	Programming Languages with Introduction to C and Java	03
	CSA102	Database Management Systems	03
	CSA103	Discrete Mathematics	03
	CSA104	Probability Theory and distributions	03
	CSA105	Statistical Inference and Data Analysis	03
	CSA106	Practical	04
		Total	**19**
		SEMESTER II	
	CSA201	Data Structure	03
	CSA202	Design and Analysis of Algorithms	03
	CSA203	Software Engineering	03
	CSA204	Bayesian Statistics	03
	CSA205	Artificial Intelligence	03
	CSA206	SWAYAM Course	02
	CSA207	Practical	03
		Total	**20**
2nd		***SEMESTER III***	
	CSA301	Theory of Computation	03

	CSA302	SWAYAM Course	02
	CSA303	Machine Learning	03
	CSA304	Programming with R and Python	03
	CSA305	Practical	03
	CSA306	Dissertation-I	01
		Elective Course: Select Any Two of the following	
	CSA307	Computer Organization and Architecture	03
	CSA308	Data Communication and Computer Networks	03
	CSA309	Analysis of Multivariate Data	03
	CSA310	Statistical Data Mining-I	03
	CSA311	Digital Signal Processing	03
	CSA312	Image Processing	03
	CSA313	Advanced Software Engineering	03
	CSA314	Software Metrics	03
	CSA315	Graph Theory and Its Applications	03
		Total	**21**
		SEMESTER IV	
	CSA401	Dissertation-II	04
		Elective Course: Select Any Four of the following	
	CSA402	System Software and Operating System	04
	CSA403	Compiler Design	04
	CSA404	Computer Graphics	04
	CSA405	High Performance Computing	04
	CSA406	Longitudinal Data Analysis	04

	CSA407	Big Data Analytics	04
	CSA408	Advanced Machine Learning	04
	CSA409	Statistical Data Mining-II	04
	CSA410	Deep Learning for Natural Language Processing	04
	CSA411	Introduction to Pattern Recognition	04
	CSA412	Inverse Problems	04
	CSA413	Image Analysis & Computer Vision	04
	CSA414	Software Testing and Quality Assurance	04
	CSA415	Software Process and Project Management	04
	CSA416	Software Dependability and Security	04
		Total	**20**
	Total Credits		**80**

There shall be sessionals / tutorials / class tests / seminars in class / group discussions in each theory and practical paper except CSA306: Dissertation-I in semester - III and CSA401: Dissertation-II in Semester – IV.

If a candidate selects courses as categorized below he/she will be given any of the following specialization otherwise degree in M.Sc. Computational Science and Applications without any specialization will be given.

Specialization1: Data Science

If a candidate selects the following courses in semester -III

Course No Title of the Course

CSA309: Analysis of Multivariate Data
CSA310: Statistical Data Mining-I

If a candidate selects any three from the following courses in Semester -IV:

Course No Title of the Course

CSA405: High Performance Computing
CSA406: Longitudinal Data Analysis
CSA407: Big Data Analytics
CSA408: Advanced Machine Learning
CSA409: Statistical Data Mining-II
CSA410: Deep Learning for Natural Language Processing
Note: One more course in the 4th semester can be selected based on his/her choice.

Specialization2: Signal Processing

If a candidate selects the following courses:

Course No	Title of the Course
CSA311:	Digital Signal Processing
CSA312:	Image Processing
CSA411:	Introduction to Pattern Recognition
CSA412:	Inverse Problems
CSA413:	Image Analysis & Computer Vision

Note: One more course in the 4th semester can be selected based on his/her choice.

Specialization3: Software Engineering

If a candidate selects the following courses

Course No	Title of the Course
CSA313:	Advanced Software Engineering
CSA314:	Software Metrics
CSA414:	Software Testing and Quality Assurance
CSA415:	Software Process and Project Management
CSA416:	Software Dependability and Security

Note: One more course in the 4th semester can be selected based on his/her choice.

Detailed Curriculum

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

CSA101	Programming Languages with Introduction to C and Java	Credits: 3

Language Design and Translation Issues: Programming Language Concepts, Paradigms and Models, Programming Environments, Virtual Computers and Binding Times, Programming Language Syntax, Stages in Translation, Formal Transition Models.
Elementary Data Types: Properties of Types and Objects; Scalar and Composite Data Types.
Programming in C: Tokens, Identifiers, Data Types, Sequence Control, Subprogram Control, Arrays, Structures, Union, String, Pointers, Functions, File Handling, Command Line Arguments, Preprocessors. **Object Oriented Programming:** Class, Object, Instantiation, Inheritance, Encapsulation, Abstract Class, Polymorphism.
Programming in Java: Tokens, Identifiers, Variables and Constants; Data types, Operators, Control statements, Functions Parameter Passing, Virtual Functions, Class and Objects; Constructors and Destructors; Overloading, Inheritance, Templates, Exception and Event Handling; Streams and Files; Multifile Programs.
Web Programming: HTML, DHTML, XML, Scripting, Servlets, Applets.

Books Recommended:

1. B.W. Kernighan and D.M.Ritchie, the C Programming Language, PHI.
2. R.C. Hutchinson and S.B. Just, Programming using the C Language, McGraw-Hill.
3. B.S. Gottfried, Schaum's Outline of Theory and Problems of Programming with C, McGraw-Hill.
4. Simon Kendal, Object oriented programming using java, Ventus Publishing.
5. C. Thomas Wu, An introduction to Object Oriented Programming with JAVA, Mc Graw Hill.
6. Rajkumar Buyya, S Thamarai Selvi, Xingchen Chu, Object Oriented Programming with Java: Essentials and Applications, Mc Graw Hill.
7. E. Balagurusamy, Programming with Java, TMH

CSA102	Database Management systems	Credits: 3

Database System Concepts and Architecture: Data Models, Schemas, and Instances; Three-Schema Architecture and Data Independence; Database Languages and Interfaces; Centralized and Client/Server Architectures for DBMS.
Data Modeling: Entity-Relationship Diagram, Relational Model - Constraints, Languages, Design, and Programming, Relational Database Schemas, Update Operations and Dealing with Constraint Violations; Relational Algebra and Relational Calculus; Codd Rules.
SQL: Data Definition and Data Types; Constraints, Queries, Insert, Delete, and Update Statements; Views, Stored Procedures and Functions; Database Triggers, SQL Injection. Normalization for Relational **Databases:** Functional Dependencies and Normalization; Algorithms for Query Processing and Optimization; Transaction Processing, Concurrency Control Techniques, Database Recovery Techniques, Object and Object-Relational Databases; Database Security and Authorization.

Books Recommended:

1. C.J. Date, An Introduction to Database Systems, Vol I & II, Addison Wesley.
2. Korth Silberschatz, Data Base System Concepts, McGraw Hill.
3. J.D. Ullman, Principles of Database Systems, Galgotia.
4. Wiederhold, Database Design, McGraw Hill.
5. R. Elmasri, and S.B. Navathe, Fundamentals of Database Systems, Pearson Education Asia.
6. Raghu Ramakrishnan, Database Management Systems, McGraw-Hill Education.

CSA103	Discrete Mathematics	Credits: 3

Mathematical Logic: Propositional and Predicate Logic, Propositional Equivalences, Normal Forms, Predicates and Quantifiers, Nested Quantifiers, Rules of Inference.
Sets and Relations: Set Operations, Representation and Properties of Relations, Equivalence Relations, Partially Ordering. Counting,
Mathematical Induction and Discrete Probability: Basics of Counting, Pigeonhole Principle, Permutations and Combinations, Inclusion- Exclusion Principle, Mathematical Induction, Probability, Bayes' Theorem.
Group Theory: Groups, Subgroups, Semi Groups, Product and Quotients of Algebraic Structures, Isomorphism, Homomorphism, Automorphism, Rings, Integral Domains, Fields, Applications of Group Theory.
Graph Theory: Simple Graph, Multigraph, Weighted Graph, Paths and Circuits, Shortest Paths in Weighted Graphs, Eulerian Paths and Circuits, Hamiltonian Paths and Circuits, Planner graph, Graph Coloring, Bipartite Graphs, Trees and Rooted Trees, Prefix Codes, Tree Traversals, Spanning Trees and Cut-Sets.
Boolean Algebra: Boolean Functions and its Representation, Simplifications of Boolean Functions.
Optimization: Linear Programming - Mathematical Model, Graphical Solution, Simplex and Dual Simplex Method, Sensitive Analysis; Integer Programming, Transportation and Assignment Models,
PERT-CPM: Diagram Representation, Critical Path Calculations, Resource Levelling, Cost Consideration in Project Scheduling.

Books Recommended:

1. J.P. Trembley and R.P.Manohar, Discrete Mathematical Structures with Applications to Computer Science, McGraw Hill.
2. Dornhoff and Hohn, Applied Modern Algebra, McMillan.
3. N. Deo, Graph Theory with Applications to Engineering and Computer Science, PHI.
4. C.L. Liu, Elements of Discrete Mathematics, McGraw-Hill.
5. Rosen, Discrete Mathematics, Tata McGraw Hill.
6. K.L.P. Mishra, N. Chandrasekaran, Theory of Computer Science: Automata, Languages and Computation, PHI.

CSA104	Probability Theory and Distributions	Credits: 3

Review of Basic concept of probability and Bayes theorem, discrete and continuous random variables and probability distributions, joint, marginal and conditional probability distributions. Mathematical Expectations, Generating functions and Characteristics function. Discrete and continuous transforms and random incidence, special discrete and continuous distributions, Law of large numbers and Central limit theorem. Distribution of function of random variable, Sampling Distributions. Compound, truncated and mixture distributions, Markov, Chebyshev, Holder, Jensen, Lyapunov inequalities. Order Statistics.
Introduction to stochastic process, Poisson Process, Bernoulli Process, Markov Chain and Random Walk, Wiener process.

Books Recommended:

1. V.K. Rohatgi, An Introduction to Probability and Mathematical Statistics, Wiley Eastern (New Delhi), 1988.
2. C.R. Rao, Linear Statistical Inference and its Applications, Wiley Eastern, 1973.
3. J. Pitman, Probability, Narosa Publishing House, 1993.
4. S. Jonson and S. Kotz, Distribution in Statistics, Vol. I, II & III, Houghton and Mifflin, 1972.
5. E. Cinlar, Introduction to Stochastic Processes, Prentice Hall, 1975.
6. T.E. Harris, The Theory of Branching Processes, Springer-Verlag, 1963.
7. P.G. Hoel, S.C. Port and C.J. Stone, Introduction to Stochastic Processes, Houghton Miffin& Co., 1972.

CSA105	Statistical Inference and Data Analysis	Credits: 3

Review of properties of Good estimators. Minimum variance bounds, Bhattacharya bounds, minimum variance unbiased estimators, sufficiency, complete sufficient statistic, Rao Blackwell Theorem, Lehmann Scheffe theorem with applications.

Different methods of estimations: Method of moment estimator, Maximum likelihood estimator (MLE) and it properties, Estimation of asymptotic variance, MLE for multi parameter case, Successive approximation to MLE. BAN and CAN estimators.

Confidence intervals, Shortest length confidence intervals, Confidence interval for large samples.

Tests of hypotheses: Type I and Type II error, power of test, Neyman-Pearson fundamental lemma with application to standard probability distributions, Power function, UMP and UMPU test. Likelihood ratio test with properties and Applications. Sequential Analysis.

Elements of Decision Theory, Loss Function, Risk Function, Bayes Risk. Prior distributions, Bayes and minimax estimators.

Books Recommended:

1. V.K. Rohatgi, An Introduction to Probability and Mathematical Statistics, Wiley Eastern (New Delhi), 1988.
2. E.L. Lehmann, Theory of Point Estimation, Student Edition, J. Wiley (NY), 1983.
3. Ferguson, Thomas S. Mathematical statistics: A decision theoretic approach. Vol. 1. Academic press, 2014.
4. Casella, George, and Roger L. Berger. Statistical inference. Vol. 2. Pacific Grove, CA: Duxbury, 2002.
5. B.K. Kale, A First Course on Parametric Inference, Narosa Publishing House, 1999.
6. E.L. Lehmann, Testing Statistical Hypotheses, 2nd ed., J. Wiley (NY), 1986.
7. C.R. Rao, Linear Statistical Inference and its Applications, Wiley Eastern, 1973.

CSA106	Practical	Credits: 4

(This practical paper is based on theory papers MSCS101 and MSCS102. 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 paper shall be THREE HOURS).

M.Sc. (Computational Science and Applications): SEMESTER II

CSA201	Data Structure	Credits: 3

Introduction: Basic terminology, data organization, concept of operations on data structures traversing, searching, inserting, deleting, Arrays, pointers and records, Mathematical background to create and analysze programs.

Linked lists: Introduction, representation of linked list in memory, traversing a linked list, searching a linked list, memory allocation, insertion and deletion in linked list, header linked list, two way lists.

Stacks and queues Recursion: Operation on Stacks and queues.

Trees: Definition, binary trees, repressnting binary trees in memory, traversing binary search trees, searching, inserting and deleting in binary search trees.

Hashing: hash tables, Hash functions, table overflow, Hash table implementation, analysis.

AVL search trees, m-way search trees, B trees, Heap.

Books recommended:

1. E. Balaguruswamy, C Programming and Data Structures with C, McGraw Hill, 2013.
2. G. L. Heileman, Data Structures, Algorithms and Object Oriented Programming, Tata McGraw Hill, 1996.

3. M. T. Goodrich and R. Tamassia, Data Structures and Algorithms in JAVA, Wiley, 2006.
4. A.V. Aho and J. E. Hopcroft, Data Structures and Algorithms, Addison-Wesley, 1983.

CSA202	Design and Analysis of Algorithms	Credits: 3

Analysis of Algorithm: Simple Algorithms, 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.

Books Recommended:

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, CliffordStein, 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.

CSA203	Software engineering	Credits: 3

Introduction to Software Engineering: Definition, Software development and life-cycle models, CMM, Software Quality, role of metrics and measurement.
Requirements Analysis and Specification: SRS Building Process, Specification Languages, Validation of SRS, metrics, monitoring and control, Object Oriented analysis.
Software Project Planning: Software Cost Estimation Techniques, Project Scheduling & Tracking, Project Team Standards, software configuration management.
Software Architecture: Role of Software Architecture, Architecture Views, Component and Connector View, Architecture Styles for C&C View, Architecture Evaluation
Software Design and Implementation: Design Concepts and Notations, Functional & Object Oriented Design Concepts, Design Strategies, Design specification and verification, Metrics, Design Translation Process.
Software Testing and Reliability: Strategies & Techniques, Debugging, Software Maintenance, Software Reliability and Availability Models, Software Reengineering, Cleanroom Approach, Software Reuse. Introduction to IEEE Standards, Case Studies.

Books Recommended:

1. PankajJalote, ''An Integrated Approach to Software Engineering'', IIIrd Edition, Narosa Publishing House.
2. Waman S. Jawadekar ''Software Engineering: Principles and Practices'', Tata McGraw-Hill.
3. Roger S. Pressman, ''Software Engineering: A Practitioner's approach'', McGraw-Hill.

4. Ian Sommerville, "Software Engineering: Pearson Education.
5. Carlo Ghezzi, Mehdi Jazayeri, Dino Mandrioli "Fundamentals of Software Engineering", PHI.
6. S. L. Pfleeger, Software Engineering: Theory and Practice, Pearson Education.
7. R. Mall, Fundamentals of Software Engineering, PHI.

CSA204	Bayesian Statistics	Credits: 3

Subjective and objective notions of probability, elicitation of prior distributions in univariate and multivariate cases (general guidelines only), histogram approach, relative likelihood approach and matching a general given functional form to prior elicitation, Different Kinds of prior distributions: Proper priors, Improper priors, informative and non-informative prior (Jeffrey's), location and scale invariant priors, conjugate priors.

Bayesian decision and Bayes risk, concept of admissibility and minimaxity in Bayes decision, Bayesian point estimation, Bayesian interval estimation and Bayes testing with special reference to simple hypothesis, composite hypothesis and point null hypothesis, Lindley's paradox, predictive distribution and predictive inferences, examples based on binomial, Poisson and normal distributions.

Bayesian sufficiency and its comparison with classical sufficiency, Bayesian robustness with reference to prior and loss function.

Parametric and non-parametric empirical Bayes inference, hierarchical Bayes inference, hierarchical prior, complete and partial exchangeability.

Bayes computation: Conjugate analysis, analytic and asymptotic approximation (Standard cases only), Monte Carlo Markov Chain, procedures for analytically intractable posteriors: Gibbs Sampler, Metropolis Hasting algorithm and hybrid algorithm based on the two (Only implementation issues with mathematical proof)

Books Recommended:

1. J.O. Berger, Statistical Decision Theory and Bayesian Analysis, 2nd ed., Springer-Verlag, 1985.
2. T.S. Ferguson, Mathematical Statistics – A Decision Theoretic Approach, Academic Pres, 1967.
3. CP. Robert, The Bayesian Choice: A Decision Theoretic Motivation, 2nd ed., Springer, 2001.
4. J.M. Bernando and A.F.M. Smith, Bayesian Theory, John Wiley and Sons, 1994
5. G.P. Box and G.C. Tiao, Bayesian Inference in Statistical Analysis, Addison-Wesley, 1973.

CSA205	Artificial Intelligence	Credits: 3

Approaches to AI: Turing Test and Rational Agent Approaches; State Space Representation of Problems, Heuristic Search Techniques, Game Playing, Min-Max Search, Alpha Beta Cutoff Procedures.

Knowledge Representation: Logic, Semantic Networks, Frames, Rules, Scripts, Conceptual Dependency and Ontologies; Expert Systems, Handling Uncertainty in Knowledge.

Planning: Components of a Planning System, Linear and Non-Linear Planning; Goal Stack Planning, Hierarchical Planning, STRIPS, Partial Order Planning.

Natural Language Processing: Grammar and Language; Parsing Techniques, Semantic Analysis and Prgamatics.

Multi Agent Systems: Agents and Objects; Agents and Expert Systems; Generic Structure of Multiagent System, Semantic Web, Agent Communication, Knowledge Sharing using Ontologies, Agent Development Tools.

Fuzzy Sets: Notion of Fuzziness, Membership Functions, Fuzzification and Defuzzification; Operations on Fuzzy Sets, Fuzzy Functions and Linguistic Variables; Fuzzy Relations, Fuzzy Rules and Fuzzy Inference; Fuzzy Control System and Fuzzy Rule Based Systems.

Genetic Algorithms (GA): Encoding Strategies, Genetic Operators, Fitness Functions and GA Cycle; Problem Solving using GA.

Artificial Neural Networks (ANN): Neural Model and Network Architectures, Perceptron Learning, Supervised Hebbian Learning, Backpropagation, Associative Learning, Competitive Networks, Hopfield Network, Computing with Neural Nets and applications of Neural Network.

Books Recommended:

1. S. Russel, P. Norvig, Artificial Intelligence: A Modern Approach, Pearson.
2. E. Rich and K. Knight, Artificial Intelligence, Tata McGraw Hill.
3. N.J. Nilsson, Artificial Intelligence: A New Synthesis, Morgan Kaufmann.
4. R.C.Eberhart, J. Kennedy and Y. Shi, Swarm Intelligence, Morgan Kauffman.
5. S.N. Sivanandam and S.N. Deepa, Principles of Soft Computing, Wiley.
6. M.T. Hagan, H. B. Demuth and M. Beale, Neural Network Design, Thompson Learning, 1996.
7. G. J. Klir, and B. Yuan, Fuzzy Sets and Fuzzy Logic: Theory and Applications, Prentice-Hall, 1995.

CSA206	Swayam Course	Credits: 2

Students will select one course (of at least two credits) from SWAYAM website (https://swayam.gov.in/) and complete this course online. Two credits will be assigned for this course. For details regarding examinations and evaluation of this paper visit the website (https://swayam.gov.in/). Suggestions regarding selection of SWAYAM courses will be provided by the centre. A SWAYAM coordinator will monitor this course.

CSA207	Practical	Credits: 3

(This practical paper is based on theory papers CSA201, CSA202 and CSA205. 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 paper shall be THREE HOURS).

M.Sc. (Computational Science and Applications): SEMESTER III

CSA301	Theory of Computation	Credits: 3

Grammars: Production systems, Chomsky Hierarchy, Right linear grammar and Finite state automata, Context free grammars, Normal forms, Derivation trees and ambiguity

Finite state Automata: Non deterministic and deterministic FSA, NFSA with ε- moves, Regular Expressions, Equivalence of regular expression and FSA, Pumping lemma, closure properties and decidability, Myhill - Nerode theorem and minimization, Finite automata with output.

Pushdown automata: Acceptance by empty store and final state, Equivalence between pushdown automata and context-free grammars, Closure properties of CFL, Deterministic pushdown automata.

Turing Machines: Techniques for Turing machine construction, Generalized and restricted versions equivalent to the basic model, Godel numbering, Universal Turing Machine, Recursively enumerable sets and recursive sets, Computable functions, time space complexity measures, context sensitive languages and linear bound automata.

Decidability: Post's correspondence problem, Rice's theorem, decidability of membership, emptiness and equivalence problems of languages. Time and tape complexity measures of Turing machines, Random access machines, the classes P and NP, NP-Completeness, Satisfiability and Cook's theorem, Polynomial reduction and some NP-complete problems.

Books Recommended:

1. J.E.Hopcraft, R. Motwani and J.D. Ullman, ‘‘Introduction to Automata Theory, Languages and Computation’’, Pearson.
2. Cohen, ‘‘Introduction to Computer Theory’’, John Wiley.
3. M. Sipser, Introduction to Theory of Computation, PWS Publishing Corporation.
4. T.C. Martin, Theory of Computation, Tata McGraw-Hill.
5. H.R. Lewis, C.H. Papadimitrou, Elements of the Theory of Computation, PHI.

6. K.L.P. Mishra, N. Chandrasekaran, Theory of Computer Science: Automata, Languages and Computation, PHI.

CSA302	Swayam Course	Credits: 2

Students will select one course (of at least two credits) from SWAYAM website (https://swayam.gov.in/) and complete this course online. Two credits will be assigned for this course. For details regarding examinations and evaluation of this paper visit the website (https://swayam.gov.in/). Suggestions regarding selection of SWAYAM courses will be provided by the centre. A SWAYAM coordinator will monitor this course.

CSA303	Machine Learning	Credits: 3

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.

Books Recommended:

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.
4. Kevin P. Murphy, Machine Learning: A Probabilistic Perspective, MIT Press.
5. Daphne Koller and Nir Friedman, Probabilistic Graphical Models: Principles and Techniques, MIT Press.
6. Peter Harrington, Machine Learning in Action, Manning Publications.

CSA304	Programming with R and Python	Credits: 3

Programming and computing techniques for the requirements of data science: acquisition and organization of data; visualization, modelling and inference for scientific applications; presentation and interactive communication of results
Overview of R, R data types and objects (vector, matrix, data frame, list, array, factor, time series), reading and writing data (both from console and external files) and different types of indexes in R.
Control structures and switches; conditional and unconditional transfers, implicit looping (apply, lapply, tapply, etc.), explicit looping (for, while and repeat) and built in constructs (next and break statement).
Functions and Functional Programming, Function Objects and Function Calls, Scoping Rules in R, mutable state, recursive function, list of functions and function factories.
Data visualization using R. Calling C and FORTRAN programs in R and linking to data bases.
Software development with emphasis on R, plus other key software tools.
Python: Fundamental concepts: Literals, variables and identifiers, operators, expressions and data types; Control structures: Boolean expressions, selection control, iterative control; Lists: List structures, Lists, (sequences), iterating over lists; Functions: Program routines, calling value-returning functions, calling non value-returning functions, parameter passing, variable scope; Dictionaries and Sets; Recursion; Text Files: Using text files, string passing, exception handling; , Python Object Oriented Programming, Python Regular Expression, Python Exception Handling, Python Database Interaction.
Visual analytics: tableau, visualization using Python, R shiny, ggplots etc.

Books Recommended:

1. John Chambers, Software for Data Analysis: Programming with R, Springer, 2008.
2. Phil Spector, Data Manipulation with R, Springer, 2008.
3. Hadley Wickham, Advanced R, Chapman & Hall/CRC The R Series, 2014
4. W.H. Press, S.A. Teukolsky, W.T. Vellering and B.P. Flannery, Numerical Recipes in C, Second edition, Cambridge University Press, 1993.
5. John M. Zelle, Python Programming: An Introduction to Computer Science, 2004.
6. W. J. Chun (2010), Core Python Programming, Pearson.

CSA305	Practical	Credits: 3

(This practical paper is based on theory papers CSA303 and CSA304. 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 paper shall be THREE HOURS).

CSA306	Dissertation-I	Credits: 1

Dissertation-I will be based on the selected specialization, if any, and will be decided by the candidate in consultation with his/her supervisor. In every case the decision of the supervisor on the topic will be final. The dissertation work spread over whole semester may be undertaken by a group of students at the beginning of 3rd semester. However, the Dissertation report shall be submitted by each member of the group separately. The Dissertation report/dissertation shall clearly state the problem addressed, the methodology adopted, the assumptions and the hypotheses formulated, any previous reference to the study undertaken. There shall be an external examiner and an internal examiner (preferably the supervisor of the student) for the evaluation of the dissertation work. Out of total 100 marks assigned to the project, 60 marks will be assigned on the evaluation of the Dissertation work separately by both the examiners and 40 marks will be assigned jointly by the examiners on the oral presentation and viva – voce.

CSA307	Computer Organization and Architecture	Credits: 3

Basic Organization: Stored Program Concept, Components of a Computer System, Machine Instruction, Opcodes and Operands, Instruction Cycle, Organization of Central Processing Unit: ALU, Hardwired & Micro programmed Control Unit, General Purpose and Special Purpose Registers.
Memory Organization: Memory Hierarchy, Cache Memory, Main Memory (DRAM and ROM), Secondary Memory, Virtual Memory, Characteristics of different types of Memory.
I/O Organization: Peripheral devices, I/O interface, Modes of Transfer, Priority Interrupt, Direct Memory Access, Input-Output Processor, and Serial Communication. I/O Controllers, Asynchronous data transfer, Strobe Control, Handshaking.
Functioning of CPU: Instruction Formats, Op Codes, Instruction Types, Addressing Modes, Common Microprocessor Instructions, Multi-core Architecture, Multiprocessor and Multicomputer.

Books Recommended:

1. M. M. Mano, Computer System Architecture, PHI.
2. V. Rajaraman, T. Radhakrishnan, An Introduction to Digital Computer Design, PHI.
3. William Stallings, Computer Organization and Architecture: Designing For Performance, Prentice Hall.

CSA308	Data Communication and Computer Networks	Credits: 3

Data Communication: Components of a Data Communication System, Simplex, HalfDuplex and Duplex Modes of Communication; Analog and Digital Signals; Noiseless and Noisy Channels; Bandwidth, Throughput and Latency; Digital and Analog Transmission; Data Encoding and Modulation Techniques; Broadband and Baseband Transmission; Multiplexing, Transmission Media, Transmission Errors, Error Handling Mechanisms.
Computer Networks: Network Topologies, Local Area Networks, Metropolitan Area Networks, Wide Area Network, Wireless Networks, Internet.
Network Models: Layered Architecture, OSI Reference Model and its Protocols; TCP/IP Protocol Suite, Physical, Logical, Port and Specific Addresses; Switching Techniques. Functions of OSI and TCP/IP Layers: Framing, Error Detection and Correction; Flow and Error Control; Sliding Window Protocol, HDLC, Multiple Access – CSMA/CD, CSMA/CA, Reservation, Polling, Token Passing, FDMA, CDMA, TDMA, Network Devices, Backbone Networks, Virtual LANs. IPv4 Structure and Address Space; Classful and Classless Addressing; Datagram, Fragmentation and Checksum; IPv6 Packet Format, Mapping Logical to Physical Address (ARP), Direct and Indirect Network Layer Delivery; Routing Algorithms, TCP, UDP and SCTP Protocols; Flow Control, Error Control and Congestion Control in TCP and SCTP.
World Wide Web (WWW): Uniform Resource Locator (URL), Domain Name Service (DNS), Resolution - Mapping Names to Addresses and Addresses to Names; Electronic Mail Architecture, SMTP, POP and IMAP; TELNET and FTP. Network Security: Malwares, Cryptography and Steganography; Secret-Key Algorithms, Public-Key Algorithms, Digital Signature, Virtual Private Networks, Firewalls.

Books Recommended:

1. B. A. Forouzan: Data Communications and Networking, Fourth edition, THM .
2. A. S. Tanenbaum: Computer Networks, Fourth edition, PHI.
3. Douglas E. Comer: Computer Networks and Internets, Pearson.

CSA309	Analysis of Multivariate Data	Credits: 3

Multivariate normal distribution and its properties. Random sampling from multivariate normal distribution. Maximum likelihood estimators of parameters, distribution of sample mean vector.
Wishart matrix – its distribution and properties, distribution of sample generalized variance, null and non-null distribution of multiple correlation coefficients.
Hotelling's T^2 and its sampling distribution, application in test on mean vector for one and more multivariate normal population and also on equality of components of a mean vector in multivariate normal population.
Classification problem- Standards of good classification, procedure of classification based on multivariate normal distributions. Principal components, dimension reduction, canonical variates and **canonical correlation**—definition, use, estimation and computation.

Books Recommended:

1. T.W. Anderson, An Introduction to Multivariate Statistical Analysis, 2nd Ed., Willey, 1983.
2. N.C. Giri, Multivariate Statistical Inference, Academic Press, 1977.
3. A.M. Kshirsagar, Multivariate Analysis, Marcel Dekker, 1972.
4. D.F. Morrison, Multivariate Statistical Methods, 2nd Ed. McGraw Hill, 1976.
5. R.J. Muirhead, Aspects of Multivariate Statistical Theory, J. Wiley, 1982.

CSA310	Statistical Data Mining	Credits: 3

Type of data, Attribute and Measurement, discrete and continuous attributes, General Characteristics of dataset, Transaction data, Data matrix, graph based data, document term matrix, ordered data, sequential data, sparse data matrix, Data quality, precision, bias, accuracy, outliers and missing value, data preprocessing (aggregation, dimension reduction, sampling, feature subset selection, Discretization, Binarization, Variable transformation), Measures of similarity and Dissimalarity.
Considerations and issues that arise with high-dimensional dimensional data (N<<p).

Data mining from a statistical perspective, supervised learning methods, linear and logistic regression, discriminant analysis, shrinkage methods, subset selection, dimension reduction techniques. Classification: General approach to solving a classification problem, Accuracy, Error rate, Decision Tree induction with detailed algorithm, Model Over fitting in decision tree, Occam's Razor, Pessimistic error Estimate, Rule based Classification Techniques, Nearest Neighbour Classifier

Books Recommended:

1. Jiawei Han and Micheline Kamber, "Data Mining: Concepts and Techniques", Academic Press, © 2001 by Academic Press.
2. Arun K Pujari, "Data Mining Techniques", Universities Press (India) Ltd., Hyderabad 2001, First Edition
3. PN Tan, M Steinbach and V. Kumar (2015) Introduction to Data Mining, Pearson.
4. B.D. Riple, Pattern Recognition and Neural Networks. Cambridge University Press, 1996.

CSA311	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).

Books Recommended:

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.
   R. H. Vollmerhausen and R.G. Driggers, Analysis of Sampled Imaging System, SPIE Press, 2001.

CSA312	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.

Books Recommended:

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.

CSA313	Advanced Software Engineering	Credits: 3

Software Reuse: The reuse landscape, Application frameworks, Software product lines, COTS product reuse.
Component-based software engineering: Components and component models, CBSE processes, Component composition.
Distributed Software Engineering: Distributed systems, Client–server computing, Architectural patterns for distributed systems, Software as a service.
Service-oriented Software Engineering: Service-oriented architectures, RESTful services, Service engineering, Service composition.
Embedded Software: Embedded systems design, Architectural patterns, Timing analysis, Real-time operating systems.
Aspect-Oriented Software Engineering: The separation of concerns, Aspects, join points and products, software engineering with aspects.

Books Recommended:

1. Ian Sommervielle, Software Engineering, Addison-Wesley, Pearson.
2. Software Architecture: Foundations, Theory, and Practice, Taylor et al., John Wiley, 2010.

CSA314	Software Metrics	Credits: 3

Theoretical foundations for software metrics, Introduction to the measurement theory.The representational theory of measurement. Empirical and numerical systems. Representation condition. Measurement scales. Meaningfulness in measurement. Operations on measures. Data collection and analysis, Statistical analysis and tools, The Goal-Question-Metric based framework for software measurement, Classification of software measures, Specification measures, Design measures. Complexity measures, Code related measures, Software testing measures, Software reliability measures and models, Measuring the software development and maintenance processes. Experimental design and analysis, Software metrics validation, Predication systems. Calibration and validation of predication systems. Setting up a measurement program, Application of software metrics.

Books Recommended:

1. Norman fenton, James Bieman, Software Metrics: A Rigorous and Practical Approach, CRC Press, Taylor & Francis Group, 2014.
2. Software Metrics Edited by Alan J Perlis, Frederick Sayward and Mary Shaw

CSA315	Graph Theory and Its Applications	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.

Books Recommended:

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. 1976.
5. Deo Narsingh, Graph Theory with Applications to Engineering and Computer Science, Prentice-Hall, India, 1994.

M.Sc. (Computational Science and Applications): SEMESTER IV

CSA401	Dissertation-II	Credits: 4

Supervisor for the Dissertation-II will be assigned during 3rd semester and it will be spread over the remaining period. Dissertation-I will be continued in Dissertation-II. The dissertation work spread over whole semester may be undertaken by the same group of students who did Dissertation-I at the beginning of 3rd semester. However, the Dissertation report shall be submitted by each member of the group separately. The Dissertation-II report shall clearly state the problem addressed, the methodology adopted, the assumptions and the hypotheses formulated, any previous reference to the study undertaken, implementation, analyses, comparison performed and the broad conclusion drawn at the end of the 4th semester. There shall be an external examiner and an internal examiner (preferably the supervisor of the student) for the evaluation of the dissertation work. Out of total 100 marks assigned to the project, 60 marks will be assigned on the evaluation of the Dissertation work separately by both the examiners and 40 marks will be assigned jointly by the examiners on the oral presentation and viva – voce.

CSA402	System Software and Operating System	Credits: 4

System Software: Machine, Assembly and High-Level Languages; Compilers and Interpreters; Loading, Linking and Relocation; Macros, Debuggers.
Basics of Operating Systems: Operating System Structure, Operations and Services; System Calls, Operating-System Design and Implementation; System Boot.

Process Management: Process Scheduling and Operations; Interprocess Communication, Communication in Client–Server Systems, Process Synchronization, Critical-Section Problem, Peterson's Solution, Semaphores, Synchronization.
Threads: Multicore Programming, Multithreading Models, Thread Libraries, Implicit Threading, Threading Issues.
CPU Scheduling: Scheduling Criteria and Algorithms; Thread Scheduling, MultipleProcessor Scheduling, Real-Time CPU Scheduling.
Deadlocks: Deadlock Characterization, Methods for Handling Deadlocks, Deadlock Prevention, Avoidance and Detection; Recovery from Deadlock.
Memory Management: Contiguous Memory Allocation, Swapping, Paging, Segmentation, Demand Paging, Page Replacement, Allocation of Frames, Thrashing, Memory-Mapped Files.
Storage Management: Mass-Storage Structure, Disk Structure, Scheduling and Management, RAID Structure.
File and Input/Output Systems: Access Methods, Directory and Disk Structure; FileSystem Mounting, File Sharing, File-System Structure and Implementation; Directory Implementation, Allocation Methods, Free-Space Management, Efficiency and Performance; Recovery, I/O Hardware, Application I/O Interface, Kernel I/O Subsystem, Transforming I/O Requests to Hardware Operations.
Security: Protection, Access Matrix, Access Control, Revocation of Access Rights, Program Threats, System and Network Threats; Cryptography as a Security Tool, User Authentication, Implementing Security Defenses.
Virtual Machines: Types of Virtual Machines and Implementations; Virtualization.
Linux Operating Systems: Design Principles, Kernel Modules, Process Management, Scheduling, Memory Management, File Systems, Input and Output; Interprocess Communication, Network Structure.
Windows Operating Systems: Design Principles, System Components, Terminal Services and Fast User Switching; File System, Networking. Distributed Systems: Types of Network based Operating Systems, Network Structure, Communication Structure and Protocols; Robustness, Design Issues, Distributed File Systems.

Books Recommended:

1. Silberschatz and Galvin, Operating System Concepts, Addison Wesley.
2. William Stalling, Operating Systems: Internals and Design Principles, PHI.
3. Tanenbaum, Modern operating Systems, PHI.

CSA403	Compiler Design	Credits: 4

Syntax Analysis: Associativity, Precedence, Grammar Transformations, Top Down Parsing, Recursive Descent Predictive Parsing, LL(1) Parsing, Bottom up Parsing, LR Parser, LALR(1) Parser.
Semantic Analysis: Attribute Grammar, Syntax Directed Definitions, Inherited and Synthesized Attributes; Dependency Graph, Evaluation Order, S-attributed and L-attributed Definitions; Type-Checking.
Run Time System: Storage Organization, Activation Tree, Activation Record, Stack Allocation of Activation Records, Parameter Passing Mechanisms, Symbol Table.
Intermediate Code Generation: Intermediate Representations, Translation of Declarations, Assignments, Control Flow, Boolean Expressions and Procedure Calls.
Code Generation and Code Optimization: Control-flow, Data-flow Analysis, Local Optimization, Global Optimization, Loop Optimization, Peep-Hole Optimization, Instruction Scheduling.

Books Recommended:

1. Aho, Ullman and Sethi, Principles of Compiler Design, Addison Wesley.
2. J. P. Trembley and P. G. Sorensen, The Theory and Practice of Compiler Writing, McGraw Hill.
3. Holub, Compiler Design in C, PHI.

CSA404	Computer Graphics	Credits: 4

Computer Graphics: Video-Display Devices, Raster-Scan and Random-Scan Systems; Graphics Monitors, Input Devices, Points and Lines; Line Drawing Algorithms, Mid-Point Circle and Ellipse Algorithms; Scan Line Polygon Fill Algorithm, Boundary-Fill and Flood-Fill.
2-D Geometrical Transforms and Viewing: Translation, Scaling, Rotation, Reflection and Shear Transformations; Matrix Representations and Homogeneous Coordinates; Composite Transforms, Transformations Between Coordinate Systems, Viewing Pipeline, Viewing Coordinate Reference Frame, Window to View-Port Coordinate Transformation, Viewing Functions, Line and Polygon Clipping Algorithms.
3-D Object Representation, Geometric Transformations and Viewing: Polygon Surfaces, Quadric Surfaces, Spline Representation, Bezier and B-Spline Curves; Bezier and B-Spline Surfaces; Illumination Models, Polygon Rendering Methods, Viewing Pipeline and Coordinates; General Projection Transforms and Clipping.

Books Recommended:

1. Computer Graphics (Principles and Practice) by Foley, van Dam, Feiner and Hughes, Addisen Wesley.
2. Computer Graphics by D Hearn and P M Baker, PHI.
3. Mathematical Elements for Computer Graphics by D F Rogers, McGraw Hill.

CSA405	High Performance Computing	Credits: 4

Parallel Processing Concepts: Introduction to Parallel Computing: Motivating Parallelism, Scope of Parallel Computing, Parallel Programming Platforms: Implicit Parallelism: Trends in Microprocessor & Architectures, Limitations of Memory System Performance, Dichotomy of Parallel Computing Platforms, Physical Organization of Parallel Platforms, Communication Costs in Parallel Machines, Scalable design principles ,Levels of parallelism (instruction, transaction, task, thread, memory, function)
Parallel Programming: Principles of Parallel Algorithm Design: Preliminaries, Decomposition Techniques, Characteristics of Tasks and Interactions, Mapping Techniques for Load Balancing, Methods for Containing Interaction Overheads, Parallel Algorithm Models, The Age of Parallel Processing, the Rise of GPU Computing, A Brief History of GPUs, Early GPU, GPGPU Technology. Programming Models in high performance computing architecture examples: Intel Xion Phi, Nvidia Tesla GPU
Fundamental Design Issues in HPC: Programming Using the Message-Passing Paradigm: Principles of Message-Passing Programming, The Building Blocks: Send and Receive Operations, **MPI:** the Message Passing Interface, **OpenMP:** a Standard for Directive Based Parallel Programming, One-Dimensional Matrix-Vector M
CUDA Architecture: Introduction to CUDA, CUDA Architecture, Programming model of CUDA with NVIDIA GPU, Introduction to CUDA with Python- PyCUDA, Parallel programming in PyCUDA, Manage GPU memory, Manage communication and synchronization. multiplication, Two-Dimensional Matrix-Vector Multiplication

Books Recommended:

1. Kai Hwang,"Advanced Computer Architecture: Parallelism, Scalability, Programmability", McGraw Hill 1993
2. David Culler Jaswinder Pal Singh, "Parallel Computer Architecture: A hardware/Software Approach", Morgan Kaufmann,1999
3. Ananth Grama, Anshul Gupta, George Karypis, and Vipin Kumar, "Introduction to Parallel Computing", 2nd edition, Addison-Welsey, c 2003
4. Jason sanders, Edward Kandrot, ‘‘CUDA by Example’’, Addison-Wesley, ISBN-13: 978-0- 13-138768-3
5. Kai Hwang,, "Scalable Parallel Computing", McGraw Hill 1998.
6. George S. Almasi and Alan Gottlieb, "Highly Parallel Computing", The Benjamin and

Cummings Pub. Co., Inc
7. William James Dally and Brian Towles, "Principles and Practices on Interconnection Networks", Morgan Kau_man 2004.
8. Hubert Nguyen, GPU Gems 3 - by (Chapter 29 to Chapter 41)
9. David A. Bader (Ed.), Petascale Computing: Algorithms and Applications,Chapman & Hall/CRC Computational Science Series, c 2007.
10. BoS Content: Books, Course Notes, Digital contents, Blogs developed by the BoS for bridging the gaps in the syllabus, problem solving approaches and advances in the course

CSA406	Longitudinal Data Analysis	Credits: 3

Longitudinal studies: Examples, merits, approaches, design considerations. Exploring Longitudinal data (graphical representation, curve fitting and exploring correlation structure). General Linear model for **longitudinal data:**
uniform correlation model, exponential correlation model, weighted least square estimation, ML estimation and restricted ML Estimation. Parametric covariance model (models and their fitting, Time by Time ANOVAs, Generalized linear model for longitudinal data. Random effect models, Transition models, Likelihood based method for categorical data, time dependent covariates, missing values for longitudinal data.
Random coefficient regression models, growth curve analysis, hierarchical linear models, general mixed models, autoregressive and moving average models for time series data, and the analysis of cross-section time series data.

Books Recommended:

1. Peter Diggle, Patrick Heagerty, Kung-Yee Liang, Scott (2019), Analysis of Longitudinal Data, Oxford University Press.
2. Donald Hedeker, Robert D. Gibbons(2006), Longitudinal Data Analysis, Wiley-Interscience.

CSA407	Big Data Analytics	Credits: 4

Introduction to Big Data: Big data definition, enterprise / structured data, social / unstructured data, unstructured data needs for analytics, what is Big Data, Big Deal about Big Data, Big Data Sources, Industries using Big Data, Big Data challenges.
Hadoop: Introduction of Big data programming-Hadoop, History of Hadoop, The ecosystem and stack, The Hadoop Distributed File System (HDFS), Components of Hadoop, Design of HDFS, Java interfaces to HDFS, Architecture overview, Development Environment, Hadoop distribution and basic commands, Eclipse development, The HDFS command line and web interfaces, The HDFS Java API (lab), Analyzing the Data with Hadoop, Scaling Out, Hadoop event stream processing, complex event processing, MapReduce Introduction, Developing a Map Reduce Application, How Map Reduce Works, The MapReduce Anatomy of a Map Reduce Job run, Failures, Job Scheduling, Shuffle and Sort, Task execution, Map Reduce Types and Formats, Map Reduce Features, Real-World MapReduce,
Hadoop ETL, Hadoop Reporting Tools, Introduction to Pig and HIVE- Programming Pig, Programming with Hive, Relational manipulation, HDFS – Overview and concepts, data flow (read and write)
Hadoop Environment, Introduction to Apache Spark and Use Cases, Apache Spark APIs for large-scale data processing, Apache Phoenix, Apache ingestion tools: Kafka and Flume.

Books Recommended:

1. Tom White, Hadoop: The Definitive Guide, 3rd Edition, O'Reilly Meida.
2. Eric Sammer, Hadoop Operations, A Guide for Developers and Administrators, O'Reilly Meida.

CSA408	Advanced Machine Learning	Credits: 4

Mathematics of machine Learning Overview of supervised, unsupervised, and multitask techniques

Advanced Machine Learning Topics: Bayesian Modeling and Gaussian Processes, randomized method, Bayesian neural networks, approximate inference, variational auto encoders, generative models, and applications.
Application of Machine Learning in Natural Language Processing: recurrent neural networks, back propagation through time, long short term memory, attention networks, memory networks, neural Turing machine, machine translation, question answering, speech recognition, syntactic and semantic parsing, GPU optimization for neural networks.

Books Recommended:

1. Kevin P. Murphy, Machine Learning: A Probabilistic Perspective. MIT Press 2012.
2. Ian Goodfellow, YoshuaBengio and Aaron Courville, Deep Learning, MIT Press 2016.

CSA409	Statistical Data Mining-II	Credits: 4

Classification: Bayesian Classifier, Naïve Bayes Classifier, Bayesian belief Network, Artificial Neural Network, Support Vector Machines.
Association Analysis (Market basket analysis): Frequent Item set Generation, Support Counting and Candidate pruning, Rule Generation, FP Growth algorithm, Handling categorical and continuous attributes, Sequential Patterns.
Clustering: hierarchical and center-based clustering.
Computer Vision, eigen faces, data visualization, graphical models. Applications to high-dimensional data (N<<p) and big data (N>>p) will be highlighted

Books Recommended:

1. Jiawei Han and Micheline Kamber, "Data Mining: Concepts and Techniques", Academic Press, © 2001 by Academic Press.
2. Arun K Pujari, "Data Mining Techniques", Universities Press (India) Ltd., Hyderabad 2001, First Edition
3. PN Tan, M Steinbach and V. Kumar (2015) Introduction to Data Mining, Pearson.
4. B.D. Riple, Pattern Recognition and Neural Networks. Cambridge University Press, 1996.

CSA410	Deep Learning for Natural Language Processing	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 Partitioned 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.

Books Recommended:

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 TanveerSiddiqui, 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

CSA411	Introduction to Pattern Recognition	Credits: 4

Introduction – Definitions, data sets for Pattern Recognition, Different Paradigms of Pattern Recognition, Representations of Patterns and Classes, Metric and non-metric proximity measures, Feature extraction, Different approaches to Feature Selection, Nearest Neighbour Classifier and variants, Efficient algorithms for Nearest Neighbour classification, Different approaches to Prototype Selection, Bayes Classifier, Decision Trees, Linear Discriminant Function, Support Vector Machines, Clustering, Clustering Large datasets, Combination of Classifiers, Applications – Document Recognition.

Books Recommended:

1. Devi V.S.; Murty, M.N.(2011) Pattern Recognition:An Introduction, Universities Press, Hyderabad.
2. R. O. Duda,P.E. Hart and D. G.Stork,Pattern Classification, Wiley, 2000.

CSA412	Inverse Problems	Credits: 4

Introduction to inverse problem in image, speech, and other areas, and ill-conditioning behavior of the problem.

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 andmodel assumptions, spatial adaptation, global prior probability ratio, Estimation of conditionaldensities, 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.

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.

Books Recommended:

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.

CSA413	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.

Books Recommended:

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

CSA414	Software testing and Quality Assurance	Credits: 4

Methods and Types of Testing: Static White Box Testing, Dynamic White Box Testing, Configuration Testing, Compatibility Testing, User Interface Testing, Documentation Testing, Security Testing, Web Site Testing.
Testing Tools, Bug Bashes & Beta Testing, Planning Testing, Test Cases, Bug Life Cycle and Tracking System.
Verification and Validation, Quality assurance processes and techniques, ISO 9000/SEI CMM process evaluation.

Books Recommended:

1. Jeff Tian, Software Quality Engineering: testing, Quality Assurance and Quatifiable Improvement, Wiley, ISBN 0-471-71345-7
2. KshirasagarNaik, PriyadarshiTripathy, Software Testing and Quality Assurance: Theory and Practice, Wiely, 2011.

CSA415	Software Process and Project Management	Credits: 4

Project Management: Risk management, managing people, team work.
Project planning: Software pricing, Plan-driven development, Project scheduling, Agile planning, Estimation techniques.
Quality Management: Software quality, software standards, reviews and inspections, software measurement and metrics.

Configuration Management: Change management, version management, system building, release management.
Process improvement: The process improvement process, Process measurement, Process analysis, Process change, The CMMI process improvement framework

Books Recommended:

1. Software Engineering: A Practitioner's Approach: McGraw-Hill Series in Computer Science, Roger S. Pressman.
2. Ian Sommervielle, Software Engineering, Addison-Wesley, Pearson.

CSA416	Software Dependability and Security	Credits: 4

Sociotechnical systems: Complex systems, Systems engineering, System procurement, System development, System operation.
Dependability and security: Dependability properties, Availability and reliability, Safety, Security.
Dependability and security specification: Risk-driven requirements specification, Safety specification, Reliability specification, Security specification, Formal specification.
Dependability engineering: Redundancy and diversity, Dependable processes, Dependable system architectures, Dependable programming.
Security engineering: Security risk management, Design for security, System survivability.
Dependability and security assurance: Static analysis, Reliability testing, Security testing, Process assurance, Safety and dependability cases.

Books Recommended:

1. Ian Sommervielle, Software Engineering, Addison-Wesley, Pearson.
2. James Ransome, AnmolMisra , Core Software security: Security at the Source, CRC Press, 2018.
3. Allen, Barnum, Ellison, McGraw, Mead, Software Security Engineering A Guide for Project Managers, Published by Dorling Kindersley India Pvt. Ltd., 2009
4. Gary Mcgraw, Software Security: Building security in, Addison Wesley Professional, 2006.

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