Department of Computational and Data Sciences (CDS)

Indian Institute of Science, Bengaluru

Research Admissions Interview Procedure

Ph.D. and M.Tech. (Research) Aug 2022 Cycle

Overview

Research activities at the Department of Computational and Data Sciences (CDS) are categorized into two streams: *Computational Science (CDS-CP)* and *Computer and Data systems (CDS-CS)*. The admissions process is common to both streams.

The admission process for the Aug 2022 cycle comprises two phases. Phase I will be an **online aptitude test** on the HackerEarth platform, which serves as the first part of the evaluation and Phase II will be an **in-person oral interview** for all candidates who qualified in the aptitude test conducted in Phase I.

Candidates shortlisted for the **online aptitude test** (Phase I of interview) will receive a call letter or email from the IISc Admissions office (please login to the IISc admissions portal and check for the call letter). The aptitude test is scheduled on **10 May 2022 (Tuesday) at 3 pm**. You will receive a separate email from the CDS department for your test and instructions such as the test link, rules, guidelines, practice test, etc. This online aptitude test is of 75 minutes duration. This will have multiple choice and programming questions as per the syllabus given below.

The Phase II ***in-person oral interview*** is only for students who qualified in the online aptitude test conducted in Phase I. The day after the aptitude test, an email with the results will be sent to you. In case you qualify, your interview date and session will be as listed in the call letter from IISc Admissions Office. The syllabus for the interview (similar to the aptitude test, with lab-specific readings) is also given in detail below.

About a week before the oral interview, the shortlisted candidates will be sent an email from the CDS department to fill out an **online student information Google form**. This must be completed and submitted in order to participate in the oral interview. As part of this, candidates should choose up to three labs for which they will be considered. These labs are described below. Orientation sessions and lab introductions to help candidates make the right choice based on their interest will be conducted online through webinars for which shortlisted candidates will be invited.

Pre-interview familiarization of CDS and lab introductions will be conducted through webinars and dates will be displayed on the CDS Research Admissions Website.

Online Aptitude Test

The Phase I online objective and programming test will be conducted using the "HackerEarth" online platform. Candidates will need a **desktop/laptop with an internet connection, Chrome, Firefox or Safari browsers, and a webcam**. Candidates will be sent an email with a link to the online test a few days before the test date. The test will be enabled at the start of your session and will last for **75 mins.** It must be completed in a single sitting. You will need to create a **free HackerEarth account** to take the test. You MUST use the **same email address** as the one used for your IISc Admissions Application. Please do this ahead of time. That email will also have another link to let you take a **practice test**, to test your browser and webcam, and get familiar with HackerEarth. These practice questions are not from the test syllabus. Candidates may take the practice test as many times as they want. Candidates should get familiar with the programming IDE, compilation, and testing interface of HackerEarth to ensure that the programming questions are attempted properly.

The online aptitude test will have 15 questions. There will be 12 multiple choice questions and 3 programming questions. The **topics** for the objective test are:

- Combinatorics, Linear Algebra/Matrices, Probability and Statistics, Differential Equations, Plotting, Data Structures and Algorithms.

The programming languages that you can use are **C, C++** and **Java**. The HackerEarth interface will allow you to type the program, compile it and run test cases, all within the browser. We will provide a basic code template for reading and writing the inputs and outputs for each problem. The candidates should focus on the actual code logic and brush up on concepts such as if/then/else conditions, for/while loops and arrays/data structures.

Students are encouraged to first solve the problems that they are comfortable with and then move on to more difficult problems.

In-Person Oral Interview

Students who qualify in the online aptitude test (Phase I of the interview) will attend an in-person oral interview at the CDS Department, IISc (Phase II of the interview). In the oral interview, you will be questioned on the following basic topics, and on advanced topics that are based on your lab preferences:

Basic Topics: Linear Algebra; Probability & Statistics; Programming, Data Structures, Algorithms; Numerical Methods; Ordinary Differential Equations; Discrete Mathematics. Final year undergraduate level preparation is required.

Advanced Topics: You will be questioned on the topics related to labs selected in the student information Google form. The topics for each lab and the prior training expected are listed below. Candidates choosing a lab must be prepared on *at least one* of the lab-related interview topics.

> **Note:** Most labs give preference to applicants for the Ph.D. program over the M.Tech. (Research) program. Some labs may not even take any students for the M.Tech. (Research) program. Students with a B.E./B.Tech degree are also eligible to apply for the Ph.D. program.
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> Candidates for the Ph.D. program should prepare well on their fundamentals, come with a focus and knowledge of the research areas they would like to target in their PhD, and have clarity on the preferred lab(s) and the kind of work done in them. Review the research topics and the papers from the labs you are interested in.

B. List of labs that are admitting students

The following labs (ATCG, AMCL, BioMedIA, CMG, QUEST) accept students from all background qualifications.

1. Algorithmic Techniques for Computational Genomics (ATCG)

Faculty: Chirag Jain

Website: https://at-cg.github.io

Lab Description: We work at the intersection of computer science and biology to accelerate scientific discovery by designing novel algorithms, data structures and open-source software tools. We are interested in addressing computational /mathematical problems related to DNA or RNA sequencing.

Interview topics: Algorithms design and analysis, data structures, graph algorithms

Prior training: Students must have a Bachelors' or Masters' degree in either Computer Science, Information Technology, Electrical, Electronics, Communications, Biosciences/ Bioengineering or Applied Mathematics. Strong programming, algorithms and interdisciplinary teamwork skills are required.

2. Applied Mathematics and Computing Lab

Faculty: Ratikanta Behera

Website: https://scholar.google.co.in/citations?hl=en&user=8jKAiq8AAAAJ

Lab Description: Our research interests are in the field of scientific computing with particular emphasis on the wavelets methods, numerical multilinear algebra, and neural networks. In numerical multilinear algebra, we develop novel HPC-driven algorithms and theories for solving important existing and emerging multidimensional problems. Specifically, interested in developing fast tensor algorithms for solutions to multilinear systems, nonlinear optimization problems, low-rank approximation, generalized inverses of tensors, and solutions to partial differential equations in high dimensions problems. In wavelet methods, we propose HPC-centric adaptive wavelet methods and algorithms for solving partial differential equations and integral equations, data compression, signal recognition, and signal & image processing. Further, in neural networks, we design adaptive recurrent neural networks to solve time-varying problems. In particular, we aim to prove theoretically and numerically the behavior of adaptive recurrent neural networks under various activation functions.

Interview Topic: Numerical Analysis, Linear Algebra, basic programming, and basic calculus with functional analysis.
Student background: Mathematics is preferrable. Physics, Computer Science, Earth Science, and Mechanical Engineering will also be considered.

3. Biomedical Image Analysis (BioMedIA) Lab

Faculty*:* Vaanathi Sundaresan

Website: https://scholar.google.co.in/citations?user=Pr3C3V0AAAAJ&hl=en

Lab Description: Our aim is to develop innovative AI-based methods for computational analysis of multidisciplinary biomedical images for clinical applications. We specifically focus on building scalable and translatable tools for big data applications in neuroimaging. We are also interested in tackling key challenges

of medical image analysis including label scarcity and data diversity, model generalisability and interpretability.

Our current research areas include computer vision and machine learning-based methods for identification of MR imaging biomarkers for various neurological diseases, semi-supervised techniques for analysis of various imaging modalities, data harmonisation/domain adaptation, image reconstruction and quality improvement.

Interview topics: Signal Processing, Image Processing, Probability and Machine Learning basics.

Prior Training: We are looking for students with engineering/applied physics/applied mathematics background, interested in the following research areas: deep learning, pattern recognition, medical imaging, neuroimaging, computer vision.

4. Computational Mathematics Group (CMG)

Faculty: Sashikumaar Ganesan

Website: *http://cds.iisc.ac.in/faculty/sashi/*

Lab description: The research group focuses on developing and advancing robust numerical (finite element) methods and solvers for data-driven models accelerated with ML/AI with applications to "Digital Twin". Further, the implementation of efficient MPI/OpenMP with GPU parallel algorithms is also a key focus.

In Aug 2022 admissions, CMG is looking for three to four enthusiastic and hard-working Ph.D. candidates interested to work on Edge Computing, Physics Informed Neural Networks and Digital Twin technology.

Interview topics: Numerical Linear Algebra, Numerical Methods, Parallel computing

Prior training: Any degree. Prior knowledge of modelling, simulation and strong programming knowledge is expected but not necessary.

5. QUEST Lab

Faculty: Deepak Subramani

Website: *http://cds.iisc.ac.in/faculty/deepakns/*

Lab description: We work on developing and applying machine learning and deep learning methods for Spatio-temporal data analytics problems, focusing on fluid flow, ocean and atmospheric science applications. Our lab alumni are placed in major tech companies and universities in the US and Europe (e.g.: IBM Research, UC Irvine, Georgia Tech).

For the Aug 2022 admissions, we are looking for candidates with an interest in data-driven modelling, Bayesian methods, data assimilation, reinforcement learning and physics-informed deep neural networks.

Interview topics: Numerical Linear Algebra, Probability, Computational Thinking (approach problems in a structured/algorithmic approach). Candidates are advised to revise by watching the following YouTube videos:

Computational Thinking [CS 50 Harvard – watch the first couple of lectures]:
https://www.youtube.com/watch?v=1tnj3UCkuxU&list=PLhQjrBD2T383f9scHRNYJkior2VvYjpSL&index=2

Calculus/Linear Algebra/Deep Learning: (There are 4 seasons. Watch all and study)
https://www.youtube.com/playlist?list=PLZHQObOWTQDPD3MizzM2xVFitgF8hE_ab

Also please study problems of probability, combinatorics, calculus from NCERT Mathematics textbook of classes 11 and 12 https://ncert.nic.in/textbook.php

Prior training: Candidates with any background are welcome. Interest in fluid flow, PDEs, ML, Deep Learning and coding is mandatory. Prior knowledge is not necessary but demonstrated interest is non-negotiable. You should also have enjoyed doing the above study for interview topics.

The following labs (CSL, DREAM, MARS, VAL, VCL) only accept students from CS/EE background qualification.

1. Cloud Systems Lab

Faculty: J. Lakshmi

Website: http://www.serc.iisc.ac.in/faculty/jlakshmi and http://www.serc.iisc.ac.in/faculty/jlakshmi/cloud-system-lab

Lab Description: Cloud System Architectures for end-to-end QoS of hosted applications with regard to performance, security, dependability and fault tolerance; virtualization stack for compute, network and storage clouds; Cloud middleware for elasticity, placement optimization, resilience and other QoS properties.

Interview topics: Operating Systems, Distributed Systems, Computer Organization

Prior training: Students must have a Bachelors' or Masters' degree in Computer Science, Information Technology, Electrical, Electronics and/or Communications.

2. DREAM:Lab (Distributed systems Research on Emerging Applications & Machines)

Faculty: Yogesh Simmhan

Website: http://cds.iisc.ac.in/faculty/simmhan

Lab Description: Focuses on distributed systems, graph algorithms and scalable software platforms. Research topics on Distributed and Streaming Graphs Algorithms, and platforms for Graph Neural Network; Scalable platforms for distributed and federated deep learning; Storage, query and management of Big Data; Middleware for Cloud and Edge computing and Internet of Things (IoT); Distributed software platforms and algorithms for drones/UAVs, video analytics and genomics.

For the 2022 Admissions cycle, the DREAM:Lab is looking for 3-4 students interested in:

- Incremental algorithms for large graphs and distributed platforms for graph neural networks
- Machine learning for optimizing cloud and distributed applications
- Federated Deep learning using GPU-accelerated edge and cloud computing
- NoSQL and Big Data platforms for spatio-temporal and video data
- Distributed analytics and coordination algorithms for drone fleets

Students must have a strong aptitude in systems software, algorithms and programming.

Interview topics: Operating Systems (or) Graph Algorithms (or) Distributed Systems.

Recommended Reading:

1. Operating System Concepts by Silberschatz, Gavin and Gagne
2. Introduction to Algorithms: A Creative Approach, Chapter 7: Graph Algorithms, by Udi Manber
3. Distributed Systems: Concepts and Design by Coulouris, et al.
4. Pregel: A System for Large-Scale Graph Processing, Malewicz, et al., *SIGMOD* 2010

Prior training: Students must have a Bachelors' or Masters' degree in Computer Science, Information Technology, Electrical, Electronics and/or Communications. Strong programming, algorithms and systems skills are required. Ph.D. candidates are preferred.

3. Middleware And Runtime Systems (MARS) Lab

Faculty: Sathish Vadhiyar

Website: http://cds.iisc.ac.in/faculty/vss and http://mars.cds.iisc.ac.in

Lab Description: High performance computing (HPC), Parallel computing – middleware, system software, algorithms and applications on large-scale parallel computers and GPUs.

Some of the recent research topics in the MARS lab are the following.

- Identifying scalability bottlenecks, and providing high performance and scalable solutions for parallel scientific applications.
- High performance parallel I/O solutions for scientific and ML/DL applications.
- Harnessing the power of both CPUs and GPUs in a hybrid manner in modern-day parallel systems.
- Novel models of parallelism for Machine Learning (ML)/Deep Learning (DL) applications.
- Communication-minimization strategies for Exascale applications including development of asynchronous methods, one-sided communications and approximate computing.
- Fault tolerance frameworks for parallel scientific and ML/DL applications.

Interview topics:

1. Operating Systems including pthreads, filesystems.
2. Computer architecture including multi-core CPUs and modern GPUs, differences between shared memory and distributed memory parallel architectures, different network topologies (e.g., ring, mesh etc.)
3. Graph Algorithms (or) MPI parallel programming interface (Google for "MPI Complete reference" and read Introduction, Point-to-Point and Collective Communications chapters.

Prior training: Students must have a Bachelors' or Masters' degree in Computer Science, Information Technology, Electrical, Electronics and/or Communications. Strong programming, algorithms and systems skills are required. Ph.D. candidates are preferred.

4. Video Analytics Lab (VAL)

Faculty: R. Venkatesh Babu

Website: http://cds.iisc.ac.in/faculty/venky/ and http://val.cds.iisc.ac.in

Lab Description: Deep Learning for Computer Vision, Representation Learning, Domain Adaptation, Adversarial Learning, Self-supervised and unsupervised learning, Object Detection, Learning on long-tail data, Generative modeling, 3D reconstruction

Interview topics: Signal Processing, Image Processing, Probability and Machine Learning basics.

Prior training: Students must have a Bachelors' or Masters' degree in Computer Science, Information Technology, Electrical, Electronics and/or Communications or in any other closely related areas.

5. Visual Computing Lab (VCL)

Faculty: Anirban Chakraborty

Website: http://visual-computing.in/

Lab Description: At VCL, we are interested in developing novel computer vision and machine learning algorithms to solve visual analytics problems arising from real-world applications. The majority of our ongoing research projects can be categorized into one of the following three areas – 1. Data-efficient deep learning

(zero-shot/few shot learning etc.), 2. Learning across modalities/domains (e.g., text-based image retrieval, sketch-guided localization, visual question answering, domain adaptation etc.) and 3. Video surveillance (e.g., person-reidentification, anomaly detection, human gait and pose analysis etc.)

Interview topics: Image Processing, Linear Algebra, Probability and Machine Learning basics.

Prior training: Students must have a Bachelors' or Masters' degree in Computer Science, Information Technology, Electrical, Electronics and/or Communications or in any other closely related areas. Strong programming and algorithms skills are necessary. Prior experience in image/video analysis and/or machine learning would be a plus.

Preference Sheet – Research Admissions Aug 2022 Cycle

Eligibility for labs taking only CS/EE graduates (please see below for these labs): *B.E./B.Tech., Masters' or equivalent degree in Computer Science/Engineering; Information Technology/Science; Computer Application, Electrical, Electronics, Instrumentation, and/or Communication Engineering; Good programming skills are required for all labs.*

- You need to fill this Preference Sheet through an **online Google Form link** you will receive by email from the CDS department.
- Carefully review the Admissions Brochure, the Research Lab descriptions and their websites before filling the Online Form.
- You may choose up to three labs for which you are eligible and rank order them.
- The labs chosen in the Form are binding and cannot be changed later. Your interview questions will be based on the labs you choose.
- Choose the lab(s) whose research areas most closely match your own interests.

1. Name: _____
2. Application No: _____
3. Program *(Select all that apply)*: [ ] Ph.D. [ ] M. Tech. (Research)
   Note: Students with a B.E./B.Tech. degree are also eligible to select the Ph.D. program.

Rank up to three research labs you are eligible for, using numbers 1, 2 and 3.

All backgrounds are welcome	**Labs taking only CS/EE graduates**
[ ] ATCG Lab [ ] AMCL [ ] BioMedIA Lab [ ] CMG [ ] QUEST	[ ] Cloud Systems Lab [ ] DREAM Lab [ ] MARS Lab [ ] Video Analytics Lab [ ] Visual Computing Lab

I have read and understood the brochure and the instructions before filling in this preference sheet.

Signature: _____ Date: _____ Place: _____