Dr.Ram Kumar IISc Distinguished Visiting Chair Professor

Report of the Visit at IISC Bangalore Dec 2022 – Feb 2023

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The Visiting Chair Professorship

The Visiting Chair Professorship was instituted by Dr. Rakesh Agrawal and is named after his father Dr. Ram Kumar, who was a student of IISc in the field of Electrical Technology in 1945. Dr. Rakesh Agrawal, until recently, was a Microsoft Technical Fellow and headed the Search Labs in Microsoft Research. He also served as a Distinguished Visiting Chair Professor at IISc. We sincerely thank Dr. Rakesh Agrawal for enabling this visiting professorship.

As the first Dr. Ram Kumar IISc Distinguished Visiting Chair, I spent two months at IISC Bangalore from 12 December 2022 to 12 February 2023. My host was Prof Vijay Natarajan the head of the Visualization and Graphics Lab from the Department of Computer Science and Automation, and during my visit, I had the opportunity to work closely with his lab.

Interaction with the Visualization and Graphics Lab

In interacting with the Visualization and Graphics Lab I could build on an ongoing collaboration initiated by an Indo-Swedish project https://vgl.csa.iisc.ac.in/indoswedishproject/ The project focuses on data analysis and visualization from new material design research in two application areas (i) study of electronic transitions which plays an essential role in the design of organic materials (represented by a Swedish researcher Mathieu Linares), and (ii) the study of materials using CT-scans for additive manufacturing (represented by Tejas Murthy also Professor at IISC). Vijay Natarajan's lab provided a great scientific environment which made me feel "at home" at IISC during my visit. I participated in group meetings and had the chance to discuss with several of the group members and contribute to joint projects. During the visit, a joint paper has been accepted to the Transactions on Visualization and Computer Graphics [1]. Two further joint papers have been submitted to Computer Graphics International, CGI'23 [3] and a colocated workshop Visualisation in Environmental Sciences (EnvirVis) [2]. These papers are still under review.

Beyond the scientific collaboration, there have been joint lunches, after-work dinners, and cultural excursions (e.g. a trip to Lepakshi, and a visit to the Venkatappa Art Gallery)

Personal meetings with Dean, Chair, Donor

In addition to the host group, I also felt warmly welcomed by the entire department. I had the opportunity to meet the Dean of the Department of EECS (Electrical, Elec-

tronics, and Computer Sciences) Prof. Rajesh Sundaresan, and the Chair of Computer Science and Automation (CSA) Prof. Chiranjib Bhattacharyya. There were also sporadic interactions with the other professors at CSA through brief chats in the hallway or discussions after lectures. Another positive event was the online meeting with the donor Dr. Rakesh Agrawal, even though it was only a virtual meeting, the atmosphere was friendly and open.
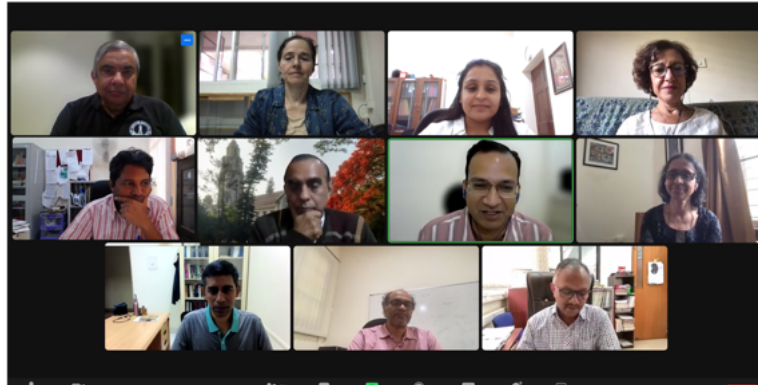
Personal meetings research groups, and Lab visits

I got a broader impression of the department through several personal meetings with researchers and their Labs mostly initiated by Prof Vijay Natarajan. During all these visits I was very impressed by the high quality of research that I have seen.

- Lab tour by Prof Tejas Murthy, Dept. of Civil Engineering researching granular materials and heterogeneous materials using image-based experiments. While we have been collaborating before through the Indo-Swedish project, I had for the first time the chance to see the experimental set-ups and meet Ph.D. students from his group. After the lab tour, we had several further research meetings and discussion opportunities for further collaborations.

- Tour of the Center for Brain Research (CBR). In a first meeting with Prof Yadati Narahari, the director of the CBR, he organized a tour through the center together with a presentation by himself about the ambitious ideas of the center. I met Prof Yadati Narahari several times again on other occasions and we had many interest-

ing discussions. Toward the end of my stay, I visited the Center again for a talk. I hope, that we can follow up on some of the ideas we discussed in the future.

- Lab tour and demos at the Centre for Product Design and Manufacturing by Prof Pradipta Biswas and his Ph.D. students. During the visit, I could try out a flight simulator and I saw other works on human-machine interaction and visual and auditory perception. We also had a second meeting later during my visit where we discussed possible collaborations on testing my work in the field of molecular visualization in a VR setting and possibly using eye-tracking for an evaluation of our software.

- Lab tour and demos kindly agreed by Prof Soma Biswas and her group. She is a faculty in EE and an expert on computer vision and image processing demonstrating several of her projects.

- Visit of IIIT. As one of my first Ph.D. students has a faculty position at IIIT, I also had a chance to visit this institute. Together with Vijay Natarajan, we gave a guest lecture in one of the topology classes at the institute.

Talks and lectures given

CSA Distinguished Lecture, Jan 13: Visualization - data analysis with the human in the loop. Abstract: Effective analysis of increasingly large and complex data from simulations and experiments is a major step in the scientific process. If understanding or knowledge generation is the major goal of the process it is essential to keep the scientist in the loop. Practically this means building environments for scientific reasoning through interactive exploration of the data. This requires an effective interplay of automatic analysis methods providing some guidance through appropriate data abstraction and interaction methods that give the user control over the analysis process. Solutions must be found in close collaboration with the domain experts while developing generic tools and concepts that also can be adapted to other applications. In this talk, I will discuss a few visual analysis applications from our recent research including use cases from engineering, chemistry, and medicine.

Guest lecture IIITB, Jan 18. Topological feature tracking in visualization applications. Abstract: As time plays a fundamental role in many physical processes also the analysis of dynamic data becomes increasingly important. Thereby, visualization

supporting the data analysis plays an essential role in understanding the evolution of features over time. Examples include evolving cyclones in weather modeling, vortex formation in flow simulations, or the detection of activity patterns in time-varying measurements of brain activity. Typical visualization and analysis tasks include the identification and tracking of features as well as the detection of changes in structural properties. As topological descriptors provide a powerful abstraction of the data they are frequently used as a basis for feature definition and identification. Tracking then requires the choice of appropriate similarity measures to detect structural changes and establish a correspondence between individual features respecting their spatial embedding. One way to approach both demands is to consider labeled merge trees as the feature descriptor. In this talk, different examples of such approaches for tracking features in visualization applications are discussed.

Institute colloquium EECS, Faculty Hall Tower Building, Jan 27. Visualization research – from data analysis to science communication Abstract: Visualization is omnipresent in everyday life serving many different purposes, examples range from plots in the newspapers to illustrations in textbooks. However, visualization goes far beyond such examples and pretty pictures. Visual data analysis has developed into an essential component of modern scientific workflows supporting understanding and reasoning about data. In this talk, I will mainly focus on the use of visualization for data analysis and exploration, and conclude with an outlook on how similar methods can be used in science communication. As data is increasingly large and complex effective data exploration requires abstractions that serve as a backbone for easy navigation through data. To this end, topological data analysis (TDA) has proven to provide fundamental tools in visualization applications. It provides multi-scale data summaries with nice mathematical properties and guarantees. In the talk, I will demonstrate a few examples using topological descriptors for feature tracking in time time-dependent scalar fields. The examples include cyclone evolutions in weather modeling and structure tracking in flow simulations.

Talk Center for Brain Research, Feb 02. Visualization applications related to brain research. Abstract: In this talk, I will present some visualization applications related to brain research that have been developed in collaboration with neuroscientists or chemists. The first application is aimed at the interactive visual analysis of brain imaging data (including fMRI data) and clinical measurements to support neuroscientists in understanding correlations between active brain regions and physiological

or psychological factors [Visual Neuro. Jonsson et al. 2020]. The second application concerns visual pattern recognition experiments in fMRI data [Rasheed et al. 2023]. As the last contribution, I will present the software VIA-MD: Visual Interactive Analysis of Molecular Dynamics https://github.com/scanberg/viamd [Skånberg et al.2018/19/21], which is used for the integrated analysis and exploration of molecular trajectories was developed, e.g., to understand docking processes of ligands in highly dynamic data.

Attended talks

During my stay, I also profited from many interesting talks that have been given at IISC given by internal and external researchers, including

- CSA Seminar, Prof. Margaret Martonosi, NSF (USA) and Princeton Univeristy, Seismic Shifts: Challenges and Opportunities in the 'Post ISA' Era of Computer Systems Design.

- Infosys Science Foundation lecture. Shafi Goldwasser, ACM Turing Award Winner, The Right to Deny.

- Nobel Laureate Harold Eliot Varmus, Auditorium, new biological Sciences Building, Axioms from a life in science.

- SERC auditorium, Prof. Yannis Ioannidis, University of Athens and Athena Research Center President ACM. Digital Story Experiences for Affective Engagement.

- CSA Seminar Hall: P Habeeb. (Faculty Advisor Deepak D'Souza) Verification of Camera-Based Autonomous Systems

Summary   In summary, my visit to the IISC was very rewarding for me as a researcher, but also from a personal point of view. I met many interesting people, both researchers and non-scientists, all of whom showed a high level of hospitality. I had many interesting scientific discussions and personal encounters. I have seen a fascinating city, with visits to museums, theatre, dance and music events. Whenever I needed it, I received the necessary support. I hope that I will have the opportunity to come back sometime.

The visit will most likely also have an impact on future collaborations. This certainly concerns the ongoing research collaboration with Vijay Natarajan and Tejas Murthy, but I also see opportunities for new collaborations, e.g. with the Center for Brain Research, where we could build on our previous work on the analysis of brain

data. A visit by Vijay Natarajan to Sweden is already planned for this year, where we will organize a summer school together.

So I close with a big thank you to everyone who made this visit possible and some personal impressions from the visit.

References:

[1] Mohit Sharma, Talha Bin Masood, Signe S. Thygesen, Mathieu Linares, Ingrid Hotz, and Vijay Natarajan. "Continuous Scatterplot Operators for Bivariate Analysis and Study of Electronic Transitions". In: IEEE Transactions on Visualization and Computer Graphics (TVCG) (2023, to appear).

[2] Toshit Jain, Vijay Kumar Boda, Varun Singh, Upkar Singh, Ingrid Hotz, Sathish S. Vadhiyar, P.N. Vinayachandran, and Vijay Natarajan. "py- ParaOcean: A System for Visual Analysis of Ocean Data". In: Workshop on Visualisation in Environmental Sciences (EnvirVis) (2023) (2023, under review).

[3] Farhan Rasheed, Talha Bin Masood, Vijay Natarajan, Tejas Murthy, and Ingrid Hotz. "Multi-scale visual analysis of cycle characteristics in spatially-embedded graphs". In: Computer Graphics International, CGI'23 (2023, under review).