

## INTERNATIONAL EXCELLENCE FELLOWSHIPS

### Experience Report 2022

<b>Name and title of fellow</b>	Hoshin V Gupta
<b>Duration and time of research stay</b>	Aug 29 – Oct 07, 2022 (six weeks)
<b>Host professor and host institute at KIT</b>	Uwe Ehret

### PART 1: Achievement of the objectives of the research stay, and future plans

Please answer the following questions to produce a 1 - 2-page report on your research stay at KIT within the International Excellence Fellowship Program.

**1. To what extent have the research project objectives laid down in the nomination form been achieved? How did the collaboration proceed with your host institute or research group?**

*Please give a short description of the outcomes of your research stay at KIT. How has the cooperation within the host institute or research group developed so far? Did you take part in any scientific or academic events at your host institute or KIT in general? If possible, please mention some notable milestones and joint breakthroughs (e.g. joint publications, project proposals, etc.).*

The research stay at KIT was extremely productive. KIT International Excellence Fellow *Prof. Gupta* met with the KIT IWG-HYD Host *Prof Ehret* (in his workplace office) on almost every weekday, and on many weekend days as well, to advance the collaborative research agenda. During this time:

- 1) *Prof. Gupta* met with several students and other faculty and research staff to learn about their research, and to offer suggestions and advice. One expected outcome is a 2023 research visit to the University Arizona by one of these students.
- 2) Early during the visit, *Prof. Gupta* delivered a talk to the local machine-learning group, and hosted a discussion on the topic of “*Autoencoding and its Relevance to Hydrological Science*”.
- 3) Just before the end of the stay, *Prof. Gupta* delivered an “*International Excellence Seminar*” on the topic of “*Towards Physical-Conceptual Modeling of Mass, Energy and Information Flows Using Machine Learning Technology*”; the talk was very well attended and sparked considerable discussion.
- 4) Profs *Ehret* and *Gupta* prepared and submitted a successful funding proposal to the DFG for support to convene the “*2023 Three-Day International Workshop on Information Theory as a Bridge Across the Geosciences and Modeling Sciences*”. This workshop will be hosted at the Schneefernerhaus at Zugspitze in Germany (Sept 11-13, 2023), and will explore the nexus of (i) Information Theory, (ii) Modeling Sciences, and (iii) Domain Relevant Theory, with the goal of developing a general framework by which Information Theory can act as a foundation for

enhancing the predictive capabilities of Geoscientific Models, and their suitability as a basis for Reasoning and Understanding.

- 5) Profs *Ehret* and *Gupta* developed the theory and preliminary methodology for a Bayesian Markov Discrete Probability Network machine-learning approach to the modeling of dynamical systems. This enables such systems to be analyzed, interpreted and understood using universal Information Theoretic concepts. This work is ongoing and is in the process of being developed into publications and future proposals for funding support.
- 6) Profs *Ehret* and *Gupta* developed a conceptual approach for seamlessly linking conceptual physically-based representations of systems (that are more amenable to physical interpretation) with mathematical machine-learning-based representations (that are more amenable to regularized learning directly from data). This so-called “Model-Zoo” formulation helps to resolve the confusion regarding how these approaches are related, and how to map from one representation to another, thereby taking full advantage of the information provided by both prior (conceptual/theoretical) knowledge and by data – the latter serving to expose and resolve gaps in current knowledge. This work is being developed into one or more publications.
- 7) Prof *Gupta* and Dr. *Loritz* discussed and developed an approach to assessing extrapolation ability of dynamical systems models (whether physically-based or data-based) that addresses the question of whether any given model has extracted sufficient information from the data (or theory) to enable reliable projections to be made beyond the range of the available data – a common concern. This collaboration has resulted in an abstract submitted to the 2023 Annual Meeting of the European Geosciences Union, to be held in Vienna in April, and will be further developed into a publication.

**2. What was the output of your research stay at KIT? Please elaborate on future plans, projects, or other kinds of synergies and cooperation projects.**

*Please describe how the research stay has helped to further strengthen the cooperation between you and the host institute or research group. Please name specific activities, topics, work plans, if any. Please indicate how the research stay promoted the internationalization strategy of your home institution and KIT in general (e.g. through fostering strategic partnerships or regional research networks, creating synergies and clusters, initiating multidisciplinary research projects).*

As mentioned above, the research stay facilitated an intense period of collaboration and discussion, that will guide and enable our collaborative research over the next 5-10 years. The clear outputs include (but are not limited to):

- 1) Co-advising of students.
- 2) A successful funding proposal to the DFG for support to convene the “2023 Three-Day International Workshop on Information Theory as a Bridge Across the Geosciences and Modeling Sciences”, at the Schneefernerhaus at Zugspitze in Germany (Sept 11-13, 2023).
- 3) The theory and preliminary methodology for a Bayesian machine-learning approach to the modeling of dynamical Markov Discrete Probability Networks that is in process of being developed into publications and future proposals for funding support.

- 4) A conceptual approach for seamlessly linking conceptual physically-based representations of systems with mathematical machine-learning-based representations, that will be developed into one or more publications.
- 5) An approach to assessing extrapolation ability of dynamical systems models, that will be further developed into a publication.
- 6) Plans for Prof *Gupta* to return to KIT in Sept 2023 to continue the second half of the research stay.

## PART 2: Testimonial

Your feedback is very important to us and the next fellows. We would therefore appreciate if you provided a short testimonial to be posted on our website by answering the following questions:

<b>My research field is</b>
The modeling of physical (mainly hydrological and hydrometeorological) systems using a combination of theoretical and data-based information, rooted in an Information Theoretic approach to analysis and model development.
<b>How my research field is going to affect the world of science?</b>
This work uses an Information Theory perspective to bridge across the Geosciences and Modeling Sciences, and helps to develop a more unified approach to model development that can maximize the extraction of information from data, leading to better understanding and improved predictions, in support of scientific discovery.
<b>My main finding / highlight during my research work at KIT was</b>
that models can be viewed at multiple representational levels, from sub-symbolic (hard for humans to understand, but readily amenable to computational machine-based learning) to highly symbolic (easy for humans to understand, but less readily amenable to correction based on model-data discrepancies). This understanding sets the stage for a seamless approach to model representation and development that spans from the base algorithmic representations that are native to computational environments to the high-level abstract representations that form the basis of understanding, communication, and generalization across domains.
<b>I have chosen the Karlsruhe Institute of Technology because</b>
KIT has an excellent reputation as an institution for higher education and learning. Further, I have developed excellent collaborative relationships with faculty, staff and students at KIT.
<b>If you want to, you can give advice to the next fellows. What should they know about Karlsruhe, KIT and the International Excellence Fellowships program?</b>
Use the opportunity to not only develop your scientific collaborations, but to also explore the fascinating history and culture of the German people ☺.

*Please feel free to add any other information you would like to share with us and everybody interested in KIT and the International Excellence Fellowship Program.*



**Thank you very much for your participation and your feedback!**

**Declaration**

I hereby confirm that the details provided are correct and complete. I also confirm that I acknowledge the [Privacy Policy of KIT](#). In addition, I agree that INTL may contact me for follow-up purposes.

Date: \_\_\_\_ 01/04/2023 \_\_\_\_

Signature \_\_\_\_\_  
(a digital signature is sufficient)

A handwritten signature in black ink, appearing to be 'M. G.', is written over a horizontal line. The signature is stylized and somewhat abstract.