# AI and IoT for Flow Modeling

The workshop is organized as part of the Indo-Dutch project, "Digital Twins for pipeline transport networks". The aim of the project is to develop a digital twin that connects sensor data and advanced fluid solvers in order to detect possible leakage of fluid from the pipeline in real-time. Of particular interest then is also the development of AI based fluid flow solvers, as traditional fluid flow models are typically much too slow for real-time applications. We thank the NWO (the Netherlands), MeiTY (India) and Shell (the Netherlands) for funding the project. As part of the workshop the following talks have been scheduled:

## Speaker 1: Professor Jan S. Hesthaven

**"Digital Twins at the interface between modeling, measurements, and machine learning"**
Abstract: TBA

**Bio:** Jan S. Hesthaven is Professor of mathematics and Chair of Computational Mathematics and Simulation Science at EPFL. Furthermore, he is the dean of the School of Basic Sciences at EPFL.

## Speaker 2: Professor Yogesh Simhan

**IoT and Analytics for Social Good**
Internet of Things (IoT) lies at the convergence of affordable sensors, pervasive communications, democratized computing and advances in AI. It's applications are diverse, ranging from smarter cities to personalized healthcare. This talk will explore the translation of IoT and analytics to two projects of societal relevance that enhance the livability of cities: SATVAM, which is enabling an network low-cost urban air quality monitors, and EqWATER for equitable and safe water distribution networks. The first will discuss an end-to-end IoT stack for air quality monitoring, from sensing and sense-making using ML models to ad hoc communication networks and fabric management. The latter will focus on the use of graph analytics to efficiently place water quality monitors in a water distribution network to rapidly detect contamination.

**Bio:** Yogesh Simmhan is an Associate Professor in the Department of Computational and Data Sciences and a Swarna Jayanti Fellow at the Indian Institute of Science, Bangalore. His research explores abstractions, algorithms and applications on distributed systems. These span Cloud and Edge Computing, Scalable Graph Processing, and Distributed storage and analytics to support emerging Big Data and Internet of Things (IoT) applications. He has published over 100 peer-reviewed papers, and won the Best Paper Award at IEEE International Conference on Cloud Computing (CLOUD) 2019, IEEE TCSC SCALE Challenge Award in 2019 and 2012, the Distinguished Paper award at EuroPar 2018, and the IEEE/ACM Supercomputing HPC Storage Challenge Award in 2008. He is an Associate Editor-in-Chief of the Journal of Parallel and Distributed Systems (JPDC), and earlier served as an Associate Editor of IEEE Transactions on Cloud Computing and a member of the IEEE Future Directions Initiative on Big Data.

## Speaker 3: Vineet Tyagi

**Neural Networks for predicting flow parameters in a pipeline network**

In the work being presented, we use Neural Networks to predict flow parameters in a pipeline network. Flow parameters (flowrate and pressure) in a water pipeline network can be determined using a combination of empirical relationships between 'network parameters' like pipe properties (diameter, roughness), and layout of the network, and flow and mass balance relationships. Several softwares are available that can solve for flow parameters given the network parameters. For the purpose of our study, we have adapted a widely used open source software, EPANET, to simulate data to be fed as input for our experiments with neural networks. It was observed that neural networks with basic architecture could be trained to learn the empirical relationship that determines flow in a given network. Experiments also observed the impact of neural networks model architecture and hyper parameters on the quality of predictions.

**Bio:** Vineet Tyagi has over 10 years of experience in wealth management, business consultancy and operations. His inclination for attaining deeper understanding of the world through numbers drove him to Machine Learning. Vineet completed his BTech and MTech studies in Metallurgical Engineering and Materials Science from IIT Bombay. During his Masters program, he worked on simulating viscous flow using CFD equations which could help in understanding workings of a blast furnace.

## Speaker 4: Amritendu Mukherjee

**A comprehensive study to understand the relationship of urbanization and population density with GRACE $\Delta$TWS for selected study regions in India during 2003-2017**

This pan-India study investigates the relationship of urbanization and population density with Ground Water Storage (GWS) indicated by Gravity Recovery and Climate Experiment (GRACE) derived terrestrial water storage changes (TWS) for the time period of January'2003 to January'2017. Analysis of GRACE TWS across India reveals the evidence of significant declining trend ($0.912 \pm 0.455$ cm/year) of the same in northern part of India encompassing Ganga-Brahmaputra river basin and North-West India during this time. Interestingly, for the same time period (2002-Quarter1 To 2016-Quarter4), this particular belt with declining TWS, has observed significant positive trend in precipitation ($17.89 \pm 11.32$ mm/year) and no significant trend for temperature. In addition, for the mentioned time period, we've observed higher growth rate in agricultural electricity consumption (80.60% Growth with CAGR of 7.67%) in this region compared to the same for the rest of India (72.30% Growth with CAGR of 7.04%). We believe that the increasing uncertainty in precipitation as indicated by the rising trend of it's temporal variability, could have led to higher dependence on groundwater withdrawal in agricultural sector, measured indirectly using agricultural electricity consumption data. Also, significant negative correlation ($\rho$ = - 0.3128 p-Value $<$ 0.05) between changes in TWS and associated changes in population density has been found for this region during the same period of 2003-17.

These observations strongly suggest that the depletion of TWS in this region could be primarily attributed to anthropogenic activities rather than to changes in meteorological variables. As urbanization drives population density, in order to understand the relationship of the same with $\Delta$TWS, panel data regression analysis has been conducted for 9 selected study sites of 1° spatial resolution across different geographic locations in India during 2003-2017. Population density, precipitation and temperature along with urbanization, have been used as explanatory variables in the panel data regression for understanding the variations in GRACE TWS. Results suggest that precipitation urbanization exhibit significant positive ($\beta$ = 14.1535 p-Value = 3.018e-08) negative ($\beta$ = -11.5961 p-Value = 8.394e-05) slopes respectively with TWS and together they could explain 66.93% of variability of the same. Similarly, it has been observed that interaction effect of urbanization population density exhibit a significant negative association ($\beta$ = - 0.0053 & p-Value = 5.127e-07 ) with GRACE TWS and 77.76% of variation in $\Delta$TWS could be explained with the help of the same along with precipitation which demonstrates significant positive slope ($\beta$ = 14.7984  p-Value = 6.009e-08) w.r.t $\Delta$TWS. Thus, increase in anthropogenic indicators like urbanization  population density, indicates decrease in GRACE TWS reflecting depletion in GWS.

**Bio:** Amritendu Mukherjee is a Ph.D.(Engineering) student in Department of Management Studies at Indian Institute of Science (IISc), Bangalore. Recently he has submitted his PhD thesis entitled "Effect of urbanisation and population density on groundwater in India using satellite remote sensing data”. His primary research activity is in the application of statistical analysis and machine learning methods to build decision models and efficient algorithms for extracting insights from remote sensing satellite data. He is also interested in high performance computing, deep learning, computer vision, data mining and time series analysis. He has published research articles in high impact peer reviewed international journals like Journal of Hydrology (JoH), IEEE Transactions on Geoscience  Remote Sensing (IEEE TGRS) etc. Prior to joining the PhD program at IISc, he received his B.E. in Electrical Engineering from Indian Institute of Engineering Science and Technology (IIEST), Shibpur and MBA (major in Information Systems and Operations Research) from Vinod Gupta School of Management (VGSoM), Indian Institute of Technology (IIT), Kharagpur. Mr. Mukherjee has around 8 years of work experience, primarily in technology consultancy and software research & development organisations including Infosys, PwC Advisory, Lexmark RD and Intel AI.

## Speaker 5: Nikolaj T. Mücke

**Reduced Order Modeling for Fluid Dynamics using Deep Learning**
Numerical simulations play important role in modern decision making for fluid systems. Being able to simulate fluid flows accurately allows one create optimal control strategies, quantify the uncertainty, and determine the state of giving system. However, with increasing model complexity and available data conventional numerical algorithms cannot always satisfy time constraints. This is especially the case in real-time applications. Therefore, the development of reduced order models are a necessity to speed up the computations. In this talk, a methodology based on various deep learning architectures is presented with that exact purpose. The resulting scheme is purely data-driven which makes it very flexible and enables the possibilities of making predictions based either models or observations.

**Bio:** Nikolaj T. Mücke is a Ph.D. student in the Scientific Computing group at Centrum Wiskunde & Informatica (CWI) and at Delft Institute of Applied Mathematics at Delft University of Technology. His research is in the area of physics-informed machine learning and digital twins with applications primarily in fluid dynamics and engineering.

## Speaker 6: Ruud Henkes

**The role of simulation in leak detection for pipeline operations**
Principal Technical Expert Fluid Flow, Shell Projects & Technology For the design and operation of onshore and offshore pipelines, as used for the transport of single phase or multiphase gas/oil/water, the presence of a leak detection system is often a safety requirement. As part of the ongoing energy transition also pipelines used for the transport of CO2 or hydrogen require an early warning for possible loss of containment. Reliability with prevention of false alarms of the leak detection system is of importance, and requires improvement. Currently various vendors offer such leak detection systems, based on models augmented with online measurement data. What precisely is in the models is not always clear as it is the vendor’s proprietary. This presentation gives an overview of the current state

of the art of leak detection systems, and sketches opportunities to improve them through developing and applying new digital insights.

**Bio:** Ruud Henkes is Professor at the section of fluid mechanics at Delft University of Technology. Furthermore, he is a Principal Technical Expert at Shell.