3rd International Symposium on Water, Feedbacks, and Complexity

June 30 – July 1, 2015

International Center for Converging Technology
Room 601 (미래융합기술관 601 호)
Korea University

Organized by

Research Center for Disaster Prevention Science and Technology
고려대학교 방재과학기술연구소

Welcome Again

Two years ago, we have launched inaugural symposium on water, feedbacks, and complexity with 5 speakers in the Seoul campus of Korea University. While it was a small event, its spirit was not trivial. The symposium was planned to provide an excellent opportunity to introduce various aspects of hydrology and Earth's surface processes to graduate students in different disciplines. Following that endeavor, Gavan McGrath has hosted consequent symposium at University of Western Australia, Perth, on Aug. 2014 with much larger number of speakers.

Now, we are very excited to host this function again here at Korea University. In this symposium, we have 16 speakers from Austria, Australia, Germany, Korea, and USA. The theme of 3rd Symposium is 'water networks' which is broad and exciting subject, associated with key words of water, feedbacks, and complexity. This symposium is in conjunction with 3 weeks long program, named Synthesis Workshop on "Dynamics of Structure and Functions of Complex Networks." Many international students who join this workshop will attend this Symposium. Welcome and thank you for your participation.

This event was possible through strong supports from key speakers who have financially supported international travel of their graduate students. I appreciate their contribution sincerely. I also acknowledge financial support from Korea University for this Symposium.

Kyungrock Paik

On behalf of organizing team

Presentation Schedules

June 30 AM (Open for public)

Location: International Center for Converging Technology Room 601

Session	Time	Speaker	Title of talk	Themes
Opening	8:30-9:00	Registration		
	9:00-9:30	**Introductory Comments & Welcome (Center Director)**		
Session-1	9:30-10:00	Gavan McGrath	Emergent properties from dynamic networks	**Natural Networks**
	10:00-10:30	Kyungrock Paik	What we learn from river networks	
	10:30-11:00	**BREAK**		
Session-2	11:00-11:30	James Jawitz	Landscape heterogeneity: Humans + Hydrology	
	11:30-12:00	Seoung-Bum Kim	Deep learning for reducing dimensionality of graph data	
	12:00-12:30	Dietrich Borchardt	Ecological impacts of urban storm water and wastewater discharges to stream networks	
	12:30-1:30	**LUNCH**		

Presentation Schedules

June 30 PM (Open for public)

Location: International Center for Converging Technology Room 601

Session	Time	Speaker	Title of talk	Themes
Session-3	1:30-2:00	Peter Krebs	Peaks in sewers – a link between infrastructure network and receiving water impact	Engineered Networks
	2:00-2:30	Wolfgang Rauch	Transition in urban water systems – A modeling perspective	
	2:30-3:00	Jeryang Park	Network topology and resilience as emergent properties	
	3:00-3:30	BREAK		
Session-4	3:30-4:00	Seungmo Kang	Operation planning of multi-type passenger rail system in trunk-and-branch lines	Hybrid (Coupled) Networks
	4:00-4:30	Satish Ukkusuri	Modeling Flow, Dynamics and Strategic Interaction in [Coupled] Transportation Networks	
	4:30-5:00	Ana Deletic	TBD	
	5:00-5:30	Suresh Rao	Dynamics and resilience of coupled complex systems experiencing stochastic disturbance regime	
Closing Comments (Paik)				

Presentation Schedules

July 1 AM (Participants only)

Location: International Center for Converging Technology Room 601

Session	Time	Speaker	Title of talk	Themes
Session-5	9:00-9:30	Frank Blumensaat	Sewer model development under minimum data requirements	Data and Models
	9:30-10:00	Sumit Singha	Examining the impact of network configuration on water quantity and quality signals at the catchment outlet	
	10:00-10:30	Christain Urich	TBD	
	10:30-11:00	Jongmin Byun	Modeling river network development using numerical landscape evolution models	

Abstract

Emergent properties from dynamic networks

Gavan McGrath

University of Western Australia
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The self-organization of hydrological networks occurs within the context of processes occurring within the wider landscape. While theories for river network self-organization have been successful despite assuming homogeneity in catchments there is a clear need to link the patterns of organization of the flesh with the backbone of networked landscapes. From the pore-scale, to the hill and catchment scales there is ample evidence that ecological and biogeochemical processes feedback and interact with hydrological network development and function. I'll present several case studies to illustrate and to offer open questions for this workshop. The examples stem from various collaborations that investigated such things water flow at hillslope scales, self-organized vegetation patterning in semi-arid landscapes, the partitioning of chemicals in preferential flow pathways, and dynamic aspects of water repellent soils.

About the Presenter

Gavan McGrath is currently a Lecturer at the School of Earth and Environment, The University of Western Australia. He received a Bachelor in Engineering (Environmental) from UWA in 1998. After several years as an environmental consultant Gavan returned to UWA and was awarded a Ph.D. degree (Soil Physics) in 2007. His PhD research included a stint at Forschungzentrum, Juelich, Germany as part of a German Academic Exchange Program (DAAD) scholarship. After a year consulting again, Gavan returned to UWA with several postdoc positions and now has a teaching a research role in the Faculty of Science. His research areas broadly cover the intersection of biology and hydrology focusing on understanding how climate moderates the interactions in various systems. With research in stochastic hydrology, soil water flow processes, solute fate and transport, geomorphology and eco-hydrology he attempts develop understanding of complex systems with simple models as well as on-ground and remote sensed data. In his teaching role Gavan currently coordinates two units in Environmental Science at UWA and teaches into four others, as well as supervising 5 PhD students. He has been awarded $1.6 M (AUD) in competitive research grants since 2012 and is currently engaged in soil water repellency, paleoclimate, eco-hydrology and ecosystem restoration research.

Abstract

What we learn from river networks

Kyungrock Paik

Korea University

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River networks are excellent examples of binary tree networks. Beautiful patterns of natural landscapes have motivated scientists to advance our understanding on natural systems in general. Since Horton's law of stream orders has been introduced 70 years ago, we have achieved much better understanding about natural river network. In this talk, I will review our understanding on topological organization, hydrological function, and evolution of river networks. Modeling endeavors for each of these subjects will be highlighted. The ultimate goal of this talk is to provide a basic motivation of how we can integrate knowledge about river networks into more general network studies.

About the Presenter

Kyungrock Paik is currently an Associate Professor at the School of Civil, Environmental, and Architectural Engineering at Korea University. He received degrees of B.E. and M.E. at Korea University (Civil Engineering) in 1995 and 2001, respectively. He received the Ph.D. degree (Civil Engineering) in 2006 at the University of Illinois at Urbana-Champaign. Upon completion of his Ph.D. study, Kyungrock Paik started his career as an academic staff at the School of Environmental Systems Engineering, at the University of Western Australia as an Assistant Professor. He moved to Korea University in 2009. His research area covers physical hydrology and fluvial geomorphology. In particular, his research focus is on the understanding of feedback mechanisms of the environmental systems at various scales which can be reflected through climatic, geomorphological, and hydrological signatures. The multi-disciplinary nature of his research is reflected as a wide range of journal titles where his publications appear. He has received several faculty teaching awards from both the University of Western Australia and Korea University. He received 'Crimson Professor' title in 2014. He serves as a Section Secretary of Hydrological Sciences for Asia Oceania Geosciences Society and a Board Member of Asia Pacific Association of Hydrology and Water Resources.

Abstract

Landscape heterogeneity: Humans + Hydrology

James W. Jawitz

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The human population is distributed heterogeneously on the landscape. The sizes of human settlements are also highly heterogeneous. It is well known that city populations are well described by power-law type models, which facilitates prediction of the size distribution of human settlements. However, it is not straightforward to predict their arrangement in space. Among the hypotheses for describing the spatial pattern of cities are Christaller's central place theory and Krugman's 'new' economic geography. These theories are largely based on general economic principles, but do not explicitly account for the highly heterogeneous nature of natural resources. Our group is interested in coupling socio-economic models of human-human interactions together with hydrologic models of human-natural system interactions. Here, we examine how network-based perspectives can be incorporated into such a coupling of human settlements and natural systems. We consider how the spatio-temporal evolution of trade and transport networks from natural to engineered systems controls or influences the human population distribution. We also propose how these concepts can be adapted towards fruitful research directions.

About the Presenter

James Jawitz is a professor and the associate chair of the Soil and Water Science Department at the University of Florida, USA. His degrees are in environmental engineering, including a PhD from the University of Florida in 1999. He taught in the civil engineering departments at Purdue University and the University of Illinois at Chicago prior to returning to the University of Florida in 2001. He directs the Environmental Hydrology Laboratory with research related to water resource sustainability, specifically focusing on securing sufficient water resources for urban and agricultural users while also ensuring protection for natural hydrologic systems. He has made significant impacts in the fields of hydrology of wetlands and managed landscapes, groundwater quality protection, and catchment-scale water quality modeling. His work encompasses field experiments, laboratory studies, theoretical developments, and mathematical modeling. He also teaches about Renaissance hydraulic engineering at Florence University of the Arts, Italy.

Abstract

Deep learning for reducing dimensionality of graph data

Seoung Bum Kim

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Analysis of graph data has become an important research topic recently because of its numerous applications in social networking, metabolic networks in biology, community detection, and computer networks. However, learning from graphs is very difficult because of their complex structure with high dimensionality, resulting in high-level abstractions in data. Therefore, dimensionality reduction is critical in graph data. In this study, we propose to use a deep learning algorithm that has the capability of dealing with high-level abstractions for dimensionality reduction of vertex-multi-labeled graph data. Experiments on simulated datasets were conducted to compare the performance of deep learning with that of principal component analysis and locally linear embedding, which are existing unsupervised feature extraction methods. The experimental results showed that the deep learning outperformed its competitors in terms of reduced dimensionality and robustness.

About the Presenter

Seoung Bum Kim has been a professor at the School of Industrial Management Engineering, Korea University since 2009. Dr. Kim received an MS in Industrial and Systems Engineering in 2001, and MS in Statistics in 2004, and a PhD in Industrial and Systems Engineering in 2005 from the Georgia Institute of Technology. From 2005-2009, He was an Assistant Professor in the Department of Industrial and Manufacturing Systems Engineering at the University of Texas at Arlington. Dr. Kim' research interests utilized statistical methodologies to create new methods for various problems appearing in engineering and science. He has expertise in the data mining, theoretical statistics, statistical modeling, and statistical quality control. He has published more than 100 internally recognized journals and refereed conference proceedings on theoretical and application problems in data mining. He was awarded the Jack Youden Prize as the best expository paper in Technometrics for the Year 2003. Dr. Kim has actively participated in his academic societies as a journal editor, technical reviewers for international journals and conferences, conference organizer, and so on. He is a member of the Institute for Operations Research and Management Science (INFORMS), Korean Institute of Industrial Engineers, Korean Business Intelligence and Data Mining Society, and Korean Society for Quality Management. He is actively involved with INFORMS, serving as president, vice president, council members, and session organizers for the INFORMS Section on Data Mining.

Abstract

Ecological impacts of urban storm water and wastewater discharges to stream networks

Dietrich Borchardt

UFZ Helmholtz Center-Magdeburg

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Urban water and wastewater infrastructures co-evolve and co-exist with the natural water systems. Widely distributed are settings with sewerage and wastewater treatment systems draining into running water networks. They interfere with regard to numerous structural and functional characteristics including typology, flows, water constituents and biologically. The urban water supply and sewerage systems have been typically designed as “systems in itself” by using technical criteria for given human purposes such as provision of flow capacities, flood control, minimum treatment requirements for wastewater and for limiting emissions to the environment. However, from a synoptical and network related perspective there are emerging patterns, if we compare the structural and functional patterns of these coexisting systems that could provide a basis for new management approaches. In this talk, I will review the technical design criteria for constructing urban systems and will identify key limitations of the existing design approaches with regard to their ecological consequences in the receiving water systems. Then, I will review our current capabilities for jointly analyzing urban water infrastructures and natural river networks from a systems perspective. My outlook will propose an innovative functional and network based framework for managing urban water systems and running water networks in an ecologically more compatible and more resilient way.

About the Presenter

Dietrich Borchardt holds a Master in fisheries biology having worked on fish population dynamics under pollution pressures (University of Hamburg in 1986), a PhD in Hydrobiology studying the ecological impact of urban stormwater run-off in rivers (University of Karlsruhe 1992) and a Habilitation on modelling anthropogenic impacts upon aquatic ecosystems functions (University of Kassel 2001). He currently holds a full professorship at Technical University of Dresden, Germany and is head of Department Aquatic Ecosystem Analysis and Management at Helmholtz Centre for Environmental Research – UFZ in Magdeburg, Germany.

He has more than 25 years of extensive research experience in aquatic ecology, ecological modelling, urban water management and integrated management of aquatic ecosystems within the terrestrial environment. This includes the interdisciplinary collaboration among natural sciences, engineers and social scientists and transdisciplinary transfer. The results are published in scientific journals (84 papers, including 42 peer reviewed, 21 reviewed) and in more practice-targeting form (Technical and scientific guidelines, public reports and publications using new media).

His current research is on integrated analysis of aquatic ecosystems in which the characteristics, that are influenced by natural dynamics and anthropogenic impacts are investigated on a catchment scale. Hydro-ecological processes are studied and understood to predict developments under changing conditions, e.g. water management measures and natural environmental dynamics. The information obtained from this research into the natural sciences, engineering and social sciences is brought together and transferred into concepts of integrative water resource management. The regions of focus include various catchments across Germany and Europe as well as specific hydrologic sensitive regions around the world.

Abstract

Transition in urban water systems – A modeling perspective

Wolfgang Rauch

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Conventional urban water systems have served society well in industrialized countries for more than 150 years, but the fundamental concept is becoming compromised by climatic and urban changes. Numerous small scale projects have been successfully realised, but the transition from a conventional urban water system to an adaptable and sustainable one on a city scale is still unknown. Especially the mixture of existing centralised and new decentralised system causes complex interactions within the urban water system. To deepen our understanding of the interactions on city scale, and to identify possible transition strategies, new analysis tools are required.

It is possible to model urban development, the changes and transition in the water infrastructure and the dynamics of transition in a socio-economic context within a cyclic sequence of submodels. However, due to the nature of the problem investigated, the submodels are usually both deterministic and stochastic, which does not give stringent results but more a suite of possible outcomes. Such framework is to be based on the concept of virtual infrastructure enabling the evaluation of different technologies and strategies within a dynamic – in space and time – urban environment by means of a stochastic modelling approach. As input data, GIS information is used, including: land use, population densities, topography, soil character, natural and man-made water systems but also storylines for the future development - including urban development and strategies for the infrastructure adaptation as well as climate change scenarios. The presentation will give an overview on the background, the structure of the models used as well as examples for application.

About the Presenter

Wolfgang Rauch is professor for sanitary engineering at University Innsbruck in Austria. After his graduation as civil engineer from ETH Zürich in 1985, he pursued a research career at University Innsbruck, Danish Technical University and EAWAG in Switzerland. In 2002 he returned to University Innsbruck to launch a research group for modeling and systems analysis of urban water systems. Current research covers the application of innovative software methods in the field as well as modeling of urban water management on a city scale. Next to his research Prof. Rauch is also internationally active as chairman of the program committee of IWA and in 2014 as chairman of the evaluation committee of the engineering sector of Norway. He is editor of the journal Water Research and editor in chief of Water Science and Technology.

Abstract

Network topology and resilience as emergent properties

Jeryang Park

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The emergent properties found in topological features of networks sometimes seem universal but sometimes different by the types of network and their temporal change (e.g., growth and evolution). Although, several previous studies offered interesting results on the relationship between network topology and tolerance to either random failure or attack, the full understanding of those relationships are still more required given that many types of man-made infrastructure networks are initially built and grow with topology that is different from natural networks. In this talk, I review previous studies that explored the relationship between network topology and resilience and the fundamental processes that induces the emergent properties in infrastructure network topology given that resilience is not the only required attribute for designing infrastructures. Then, to give more weight on resilience for the design and management of infrastructure networks, I present our initial attempt to model the resilience of road and power grid networks after disruptions.

About the Presenter

Jeryang Park is an Assistant Professor at the School of Urban and Civil Engineering at Hongik University, Seoul, Korea since 2013. He received B.S. and M.S. at Civil, Urban and GeoSystem Engineering at Seoul National University. He received the Ph.D. degree in 2012 at the School of Civil Engineering at the Purdue University. Before his Ph.D. study, Jeryang Park worked for Dohwa Consulting Engineers Company, LTD, from 2002 to 2006 as a consultant for designing waste treatment and management facilities. He then moved to Korea Environmental Industry and Technology Institute, a government institute, as a researcher and worked from 2006 to 2008. His research interest includes complex networks modeling, resilience engineering, and wetland ecohydrology. His works have been published in various journal titles, such as Advances in Water Resources, Journal of Contaminant Hydrology, Atmospheric Environment, Landscape Ecology, Risk Analysis, Water Policy, Integrated Environmental Assessment and Management, of which the coverage is as broad as his research area.

Abstract

Operation planning of multi-type passenger rail system in trunk-and-branch lines

Seungmo Kang

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The purpose of this research is to optimize the operation planning of the intercity passenger railway system with trunk-and-branch type network. Suggested model has been formulated into a mixed integer programming by minimizing both user costs (passenger's total travel time) and operator costs (operation, maintenance and vehicle costs) with multiple train types including High Speed Rail (HSR). The solution defines the line and stop combination, the number of train per day, and daily passenger ridership for each type of train. Lagrangian Relaxation method has been used to decompose the problem and solve it efficiently. Case study in Korea presents a comparison with the current operation along with various scenario analyses.

About the Presenter

Dr. Seungmo Kang received the B.S. and M.S. degrees in civil engineering from Seoul National University, South Korea, in 1994 and 1998, respectively, and the Ph.D. degree in civil engineering from University of Illinois at Urbana-Champaign in 2008.

He is an associate professor in School of Civil, Environmental and Architectural Engineering at Korea University. His research interest lies in developing mathematical models to address challenging problems that arise in the fields of transportation planning and logistics

Abstract

Modeling flow, dynamics and strategic interaction in [Coupled] transportation networks

Satish V Ukkusuri

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The structure and function of networks are co-dependent when modeling the complexity of engineering, social and natural networks. While there is much recent literature on the structural aspects of networks, the role of flow and strategic decision making of agents on networks is not well characterized in many networks. This talk will discuss the notion of strategic interaction of agents on networks both in static and dynamic contexts and the flow modeling in transportation networks.

This talk is divided into three parts: (1) I will discuss the role of strategic decision making of agents on networks using game theory. To formalize this decision-making, I will discuss the notions of user equilibrium and system optimum, the inefficiency characterization in networks and the implications of selfish behavior on the design of networks using transportation systems as an example; (2) Next, the notion of traffic dynamics will be discussed. I will briefly discuss various models to compute travel time distributions in transportation networks based on micro (agent-based), macro and meso scale models of traffic flow modeling. Recent advances using spatial queuing models will be discussed. I will then characterize the notion of dynamic equilibrium and some of the challenges of modeling strategic flow in dynamic transportation networks; (3) Finally, since many networks operate within other networks, I will discuss the notion of coupled networks. Recent approaches to collect social network data and social media data, their value to understanding contagion behavior and influence will be briefly discussed. Emerging challenges in this area will be highlighted.

About the Presenter

Dr. Satish V. Ukkusuri is a Professor in the Lyles School of Civil Engineering at Purdue University where he teaches courses in transportation systems and freight and logistics planning. Dr. Ukkusuri is a member of the Transportation and Infrastructure group at Purdue. Dr. Ukkusuri is a co-lead of the Building Sustainable Communities cluster hire at Purdue University with a goal of hiring seven faculty in this interdisciplinary area.

Dr. Ukkusuri is recognized nationally and internationally in the area of transportation network modeling and disaster management. He leads the Interdisciplinary Transportation Modeling and Analytics Lab at Purdue. His current areas of interest include: complex network modeling, coupled systems modeling, network resilience, big data analytics for transportation systems, dynamic traffic modeling, innovative signal control algorithms, connected vehicle environment, behavioral issues in natural hazards such as hurricanes, evacuation modeling, modeling transportation sustainability policies such as cap and trade, emissions pricing etc, sustainable freight logistics and safety modeling.

His research emphasizes the importance of interdisciplinary notions that exist in multiple disciplines to produce solutions to the complex and multifaceted problems in infrastructure networks. His research derives knowledge from social sciences and computational sciences to create meaningful solutions for problems in transportation modeling, disaster management and freight logistics. He blends the development of new science-based approaches with practical applications and implementation. He has published more than 200 peer reviewed journal and conference papers in the above topics. Dr. Ukkusuri's work has been funded by various grants from the National Science Foundation, the U.S. Department of Transportation, New York Metropolitan Transportation Council (NYMTC), State Departments of Transportation including INDOT, NYSDOT, NJDOT and NYCDOT, Global Policy Research Institute and Purdue Research Foundation.

Dr. Ukkusuri received the 2005 SWUTC Robert Herman Award given for outstanding research and leadership in transportation. He also received the Blitman Endowed Chair Professorship during his tenure at Rensselaer Polytechnic Institute from August 2005 - August 2009. He received the CP-STIO Award from Government of India and the 2007 Emerging Scholars Grant from UTRC. In 2011, Dr. Ukkusuri received the CUTC-ARTBA New Faculty Award given for "outstanding research and leadership by a new faculty member in the United States". He was a Discovery Park Research Scholar from Jan 2013-Dec 2014. Currently, he is a Fulbright Innovation award winner in 2015-16 and a High End Foreign Expert to the Government of China from 2015-2018.

Dr. Ukkusuri is a member of the Transportation Network Modeling committee at Transportation Research Board (National Academies). He is a member of the Transportation Network Modeling Committee (ADB 30) and the Freight Transportation Planning and Logistics (ATO 15). He was the previous chair of the ITS Special Interest Group (SIG) at the Institute for Operations Research and Management Science (INFORMS). Dr. Ukkusuri is an Area Editor for the journal, Networks and Spatial Economics and an Associate Editor for Transportmetrica Part B. He is on the Editorial Advisor Board of Transportation Research Part-B and Transportation Research

Part-C and was the Editor of overview papers for the journal of Transportation Research Part-C (Emerging Technologies) from January 2008-December 2011. He reviews papers and proposals for various leading journals and funding agencies respectively.

Abstract

Dynamics and resilience of coupled complex systems experiencing stochastic disturbance regime

Suresh Rao[1], Harold Klammler[2], and Kirk Hatfield[2]

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We present a model for simulating the dynamics of coupled systems, and for a quantitative assessment of the system-scale resilience. The coupled systems of interest are: engineered infrastructure systems, which provide critical services to the social systems that design, build and maintain the infrastructure. The system states of interests are: (1) the loss of critical services [$\phi(t)$] provided by the engineered system, resulting from a series of disturbances, and (2) the adaptive capacity [$\Omega(t)$] of the social system to cope with and repair the system damage from disturbances. The disturbance regime comprises of a series of stochastic (Poisson) shocks of random magnitudes and return periods. Several hypothetical scenarios were selected to simulate time series of $\phi(t)$ and $\Omega(t)$ to illustrate the long-term dynamics of the coupled systems. Statistical and power-spectral analyses of these simulation outputs were then used to derive various metrics of system-scale resilience: (1) robustness, the system's ability for minimizing initial loss due to shock; (2) rapidity, the rate of recovery from shocks;; (3) contingency, the dependence on antecedent states of the system at the time of the shocks; and (4) non-stationarity, the long-term variations of system attributes. Model analyses, based on hypothetical case studies, revealed complex behavior and inter-dependence of the coupled socio-technical systems. In addition, stability analyses illustrated the existence of multiple stable states, which serve as "attractors" for the coupled system. Initial analyses examined system persistence within a given regime, and trajectories towards these attractors, under deterministic and stochastic disturbance regimes. It is shown that system resilience in not a

static property, but emergent under specific scenarios, and that resilience metrics based loss-recovery analysis under discrete disturbance events are insufficient for characterizing the long-term behavior. Current efforts are focused on compiling experimental data to evaluate the model, and to extend the model to coupled networks.

About the Presenter

Suresh Rao is the Lee A. Reith Distinguished Professor of Environmental Engineering in the Lyles School of Civil Engineering at Purdue University, with a joint appointment in Agronomy Department. Before moving to Purdue in 1999, he was on the faculty at the University of Florida for 25 years. Dr. Rao's professional interests emphasized inter-disciplinary research and graduate education at the intersection of engineering and science, with diverse environmental and ecological applications. Dr. Rao's work has spanned from lab-scale, and process-level studies on environmental fate and transport of various contaminant classes, to aquifer-scale and watershed-scale studies on water-quality impacts of agricultural, urban, and industrial land uses. Dr. Rao has been involved in development and use of models for research purposes and parsimonious models for decision making, with applications in soil quality assessments, groundwater vulnerability, aquifer remediation, and watershed management. His most recent research and educational interests have focused on: (1) multi-scale modeling/analysis of hydrologic and biogeochemical responses of agricultural and urban catchments under natural and anthropogenic forcing; and (2) resilience analysis of coupled, complex (natural, engineered, social) systems, including inter-dependence of infrastructure networks and systems.