NSF Award #2119691

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AI SUSTEIN

EPSCoR RII Track-2 FEC

Newsletter

volume #2

"Where AI SUSTEIN has taken us…"

Updates from the AI SUSTEIN Team

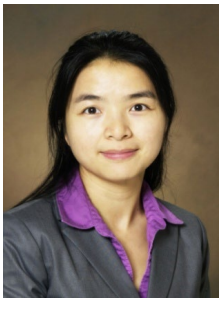
Where we have been, and where we are going!

Artificial Intelligence on SUSTainable Energy Infrastructure Networks (AI SUSTEIN) has 3 Research Themes (1-3), and one with the focus on Education/Workforce Development. The themes allow the AI SUSTEIN team to breakdown our large goal of enhancing technological and economic growth with regard to energy network with the use of AI into 4 main ideas that can be further broken down into manageable pieces.

Research Theme 1 has the main idea of understanding interdependencies within infrastructure networks so that we can carry out economic and risk assessment with the use of AI. So far, our team has been addressing the challenges of power outages, particularly on socioeconomic risk and public perception. A total of 4 cities with a population of less than 10,000 in North Dakota (Watford City, Beulah, Tioga, and Stanley) with a high number of power outages during the last several years have been chosen to serve as microcosms for studying. We have also completed a critical review journal manuscript with the focus on public perception regarding power outages, energy security, and renewable energy. This revealed that individuals' perception of these things is significantly influenced by their national political system and educational background. It was also revealed that public knowledge, cost effectiveness, and community incentives shape the attitude of these things. This information will be helpful to policy makers to encourage the adoption of renewable energy. We will continue our studies with a risk assessment study for developing a predictive model to quantify severity/risk associated with power failure in terms of socioeconomic loss. Along with this we are pursuing suitable locations for renewable infrastructure with GIS and decision-making analysis with Nevada as the potential linchpin because of its renewable energy prospects. ~ Eakalak Khan (UNLV)

Research Theme 2 is all about creating a decentralized AI-based health monitoring and predicting system for energy infrastructure. For the system to be able to capture the degradation/failure behavior and changes in the topology of multiple networks indicative of cascading failures, it needs to be able to handle an extensive amount of heterogeneous data. Our industry partners (page 13) supplied us with that data, and we have used it in the new methods and algorithms we developed. These new developments include a new method of synchrophasor data management that incorporates machine learning (ML) techniques to identify and correct concerns in using synchrophasor data for power system planning, and 2 new AI-based algorithms that predict the causes of pipeline failure and investigate their interdependency. We also investigated the cybersecurity of Internet of Things (IoT) devices with publicly available cyber-attacks. This is a great start that we will continue to refine, incorporate new data sources, and analyze. We will consolidate and validate ML methods of large scale synchrophasor data processing models for realistic gris-scale systems to help ensure reliable operation of energy infrastructure. There is also much investigation to be done with multi-faced impacts of pipeline incidents, as well as temporal failures to see potential interactions between failure events over time. Lastly, we will expand our IoT database with benign traffic samples from a smart grid. ~ Trung (Tim) Le (NDSU)

Research Theme 3's main goal is to improve energy infrastructure networks' resilience with the help of AI to keep them running smoothly. The idea is to build a strategic framework that can manage maintenance planning, resource allocation, and decision making. To reach this goal we have explored reliability estimation of an all-terminal network with surrogate models and Quantum Computing. From here we developed a deep reinforcement learning (DRL)-based network design optimization approach that enhances the reliability of the all-terminal network. Another challenge arose in our research, that being the assessment of the performance of critical infrastructure under natural and manmade hazards that are recurrent and dependent. We studied optimal preventative inspection and maintenance polices considering flexible risk preferences for a potential solution. We came across condition-based monitoring/maintenance (CBM) planning and found it has a significant impact in the enhancement of resilience of energy infrastructure networks. Then we went to work on gathering weather related pattern data of energy infrastructure to be used in our later work. Moving forward we plan on facing our challenge by modeling availability and resilience of a system with multiple performance measures that are vulnerable to recurrent dependent hazards, and using the data we acquired to initiate AI-based CBM applications that characterize complex extreme weather events with physics-based dynamic spatio-temporal models. ~ Haitao Liao (UARK)



When it comes to the Education/Workforce Development Theme, the main goal is to create and spread knowledge of AI to build a diverse workforce with the skills to further enhance industries that can or have incorprate(d) AI. The four institutions that are part of AI SUSTEIN, North Dakota State University (NDSU), Nueta Hidatsa Sahnish College (NHSC), University of Arkansas (UARK), and University of Nevada, Las Vegas (UNLV), have been working towards creating classes, certificates, and even an AI minor to offer their students. Till date, NDSU has developed and approved IME 796: Graph-Based Data Analytics for the fall of 2023. This is a graduate course, currently being taught by Harun Pirim, is designed to equip students with the skills to analyze and interpret data from complex networks using descriptive and predictive analysis. Its primary focus is understanding graph theory, network analysis, and ML technics on graphs. UARK is promoting their Data Scientist program in the Stats department to their undergraduate students. UNLV has been considering multiple versions of their AI minor, and one has been adopted and is currently under review by the Department Chairs before moving to the college curriculum committee. This minor consists of 18 credit hours, and completable within 4 semesters alongside the students' major. It's anticipated to be available the fall of 2024! NHSC is still working on training their computer science students toward AI focus. For instance, a college student from NHSC was recently able to attend the 2023 TribalNet conference and tradeshow to showcase their training and research. TribalNet was formed in 1999 with the primary purpose of bringing tribes, tribal employees, and resources together to connect and seek opportunities in solutions, best practices, and technology among tribal government, gaming, and healthcare industries. ~ Ying Huang (NDSU)

Pictured:

Top: Dr. Eakalak Khan (UNLV) and Dr. Trung (Tim) Le (NDSU)

Bottom: Dr. Haitao Liao (UARK) and Dr. Ying Huang (NDSU)

Congratulations to Our Seed Awardees!

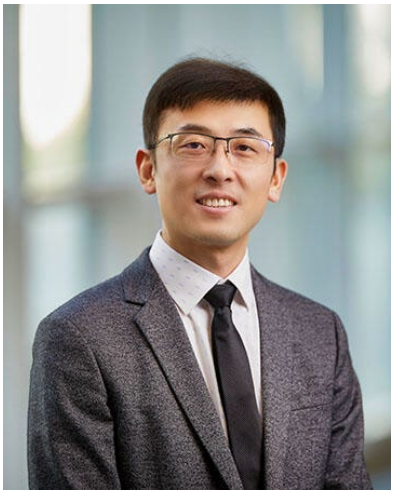
In the year of 2023-2024, AI SUSTEIN has selected six wonderful faculty members as the Seed and Start-up grant awardees. Congratulations to: Inbae Jeong, Thi Hoang Ngan Le, Shengjie (Patrick) Zhai, Rob Curry, Trung B. Le, and Youjin Jang! Let's meet them!

Inbae Jeong (NDSU)

Inbae Jeong is an Assistant Professor in Mechanical Engineering at NDSU. Before coming to NDSU in 2020, he was a Postdoctoral Research Associate in Civil and Environmental Engineering at the Georgia Institute of Technology. Inbae Jeong has developed several types of robots in a variety of situations where he focused on motion planning algorithms and motion control. For example, he has created many soccer robots, a fish, and even a human-sized humanoid! (Links to videos of the robots can be found here: https://www.linkedin.com/in/inbae-jeong-a68275143) His interests are robotics, artificial intelligence, and motion planning.

Thi Hoang Ngan Le (UARK)

Thi Hoang Ngan Le is an Assistant Professor in Computer Science & Engineering at UARK. Recognize her? She was the seed grant awardee in volume #1! Before coming to UARK she was a research associate in the Department of Electrical and Computer Engineering (ECE) at Carnegie Mellon University (CMU). She is currently a guest editor of Frontier and MDPI journals and has served as a reviewer for the top 10+ conferences and journals. Her current research interests include Image Understanding, Video Understanding, Computer Vision, Robotics, ML, Deep Learning, Reinforcement Learning, Biomedical imaging, and SingleCell-RNA.



Shengjie (Patrick) Zhai (UNLV)

Shengjie (Patrick) Zhai is an Assistant Professor in Electrical and Computer Engineering at UNLV. Patrick has been on a journey with UNLV since being a visiting researching at the Nevada Nanotech Center in October of 2008. He pursued his Ph.D at UNLV and has been part of the team since! He has many areas of expertise

and interests, those include: novel nanomaterials and patterning techniques for biometrics, optoelectronics, and photovoltaics; plasmonic-enhanced biosensors for single-molecule biomedical analysis; micro/nanoelectromechanical systems, physiological organ biometric system built on a microfluid chip; Multi external driven forced scaffold-free engineering human tissue models; and AI-assisted health assessment.

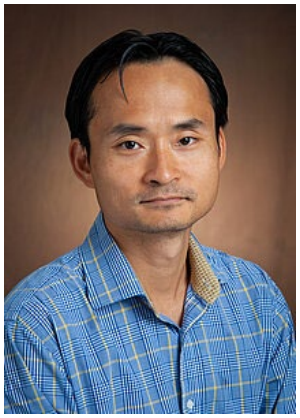
Rob Curry is an Assistant Professor in Industrial Engineering at UARK. Previously he taught at the United States Naval Academy where he was an Assistant Professor in the Mathematics Department. He has been sponsored by the Office of Naval Research and has had his work published in high-quality journals like the IISE Transactions, and Networks and Naval Research Logistics. His research consists of methodologies for modeling and solving large-scale network optimization models having applications in defense settings, sensor networks, and cyber-physical infrastructure settings. His interests consist of linear and integer programming, network optimization modeling and algorithms, and applied probability and statistics.

Trung B. Le is an Assistant Professor in Construction at NDSU. Trung B. Le has been with NDSU since September of 2018, but before that he had worked at a variety of other universities such as the University of Minnesota, Stony Brook University, Thuy Loi University, and the Medical College of Wisconsin/Marquette University. He has taken part in working on many projects regarding water in general, specifically flood/drought forecasting, and water quality. He is mainly interested in fluid mechanics and hydraulics with different temporal and spatial scales. One example of his contribution so far is "The first high resolution simulation of blood flow in human heart using patient-specific Magnetic Resonance Imaging data".

Youjin Jang is an Assistant Professor in Civil, Construction and Environmental Engineering at NDSU. Youjin Jang has been with NDSU since 2020, but previously had been a research associate of the School of Civil and Environmental Engineering at Georgia

Rob Curry

(UARK)



Trung B. Lee

(NDSU)

Youjin Jang

(NDSU)

Zuobin Xiong

(UNLV)

Institute of Technology. Since 2021 she has been a Co-Chair of the NDSU CCEE Awards Committee, as well as an Advisor to the NDSU National Association of Home Builders (NAHB) Student Chapter. She is interested in a variety of things that include Construction Automation, Human-Robot Collaboration, Human-Building Interaction, Sustainability, Data Analytics, Data-driven Decision making, and Emerging Technologies Adoption.

Zuobin Xiong is an Assistant Professor in Computer Science at UNLV. Zuobin and has been with UNLV since July 2023, and previously was a Graduate Research Assistant at Georgia State University.

Congratulations once again on your efforts and joining the team!

Farid Hashemian

(UARK)

Haitao Liao

(UARK)

Other Awards

Another year that has gone by and proves hard work shines! Beside the success that we have had with AI SUSTEIN our members have also been chosen for other Awards or Grants! Congratulations to everyone who has received an award or got their project funded!

Jose Carlos Hernandez, Farid Hashemian, Haitao Liao, and Edward Pohl received 2023 Stan Ofsthun Award for the Best Student Paper of the Society of Reliability Engineers (SRE) in January of 2023. This award is the best technical paper from a Society of Reliability Engineers student author or coauthor who presented at the Reliability and Maintainability Symposium.

Ed Pohl

(UARK)

Haitao Liao and Ed Pohl were also given the 2022 William A. Golomski Award for the paper titled "Bayesian Design of a D-Optimal Accelerated Degradation Test Considering Random Effects". This award recognizes an outstanding paper from the symposium above and is authored or co-authored by a member of the Quality Control and Reliability Engineering division of the Institute of Industrial and Systems Engineers.

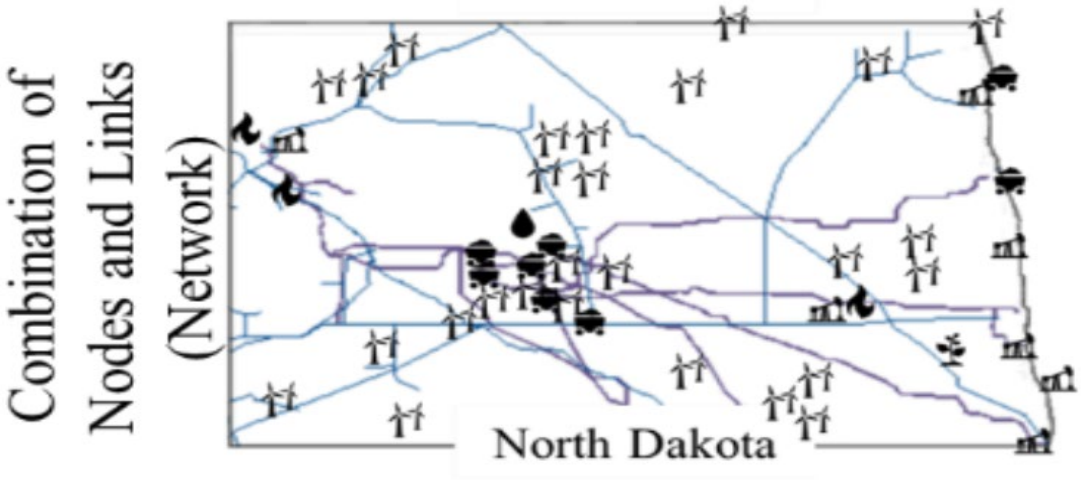
Ying Huang received the Best Paper Award from the 8th International Conference on Civil, Structural and Transportation Engineering 2023 (ICCSTE'23) for her paper titled "Weather Impact

Ying Huang

(NDSU)

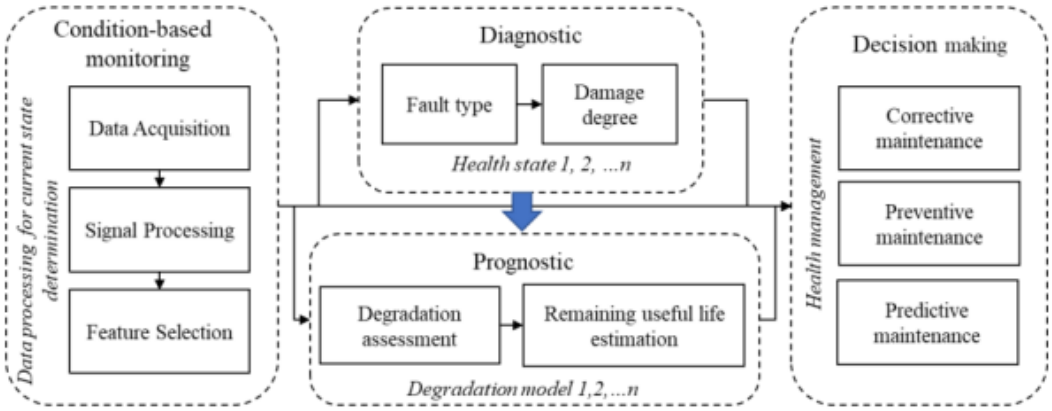
on Pipeline Temperature Distribution". This award is given to one member of each field supported that fosters a new idea or collaboration. Check out the paper and the award at https://www.aisustein.com/news-and-events !

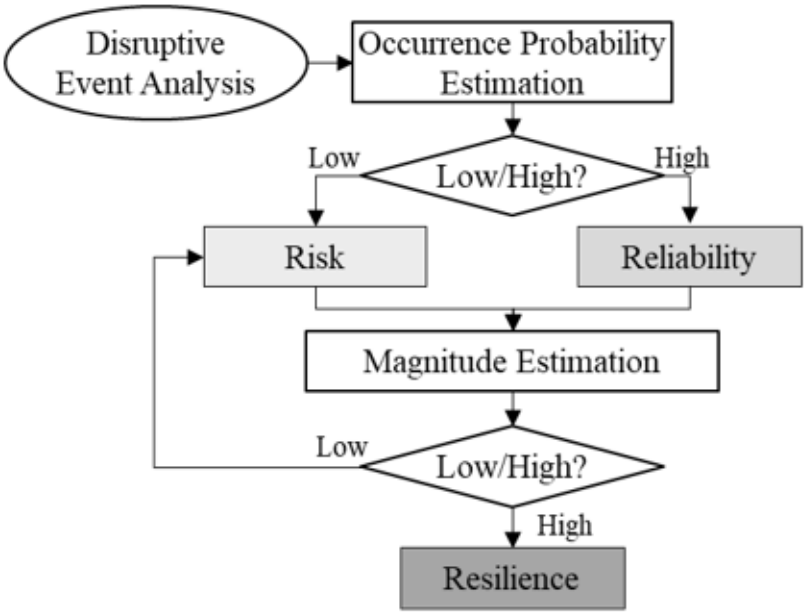
SHOWCASES



#5 Resilience Is Key

Following the showcases from the last newsletter we have our fifth showcase called "Condition-Based Monitoring as a Robust Strategy Towards Sustainable and Resilient Multi-Energy Infrastructure Systems" by Nita Yodo, Tanzina Afrin, Om Prakash Yadav, Di Wu, and Ying Huang is about improving energy systems so that when disaster strikes, as they have been more frequently, the energy systems can push through with the help of effective planning decisions and maintenance strategies. Here the use of condition-based monitoring (CBM) is utilized to predict failure by monitoring a system's health in real time. This is an essential part of preventive maintenance! The way CBM works is shown in the image below; data is acquired, then processed, certain attributes are selected based on the processing of the data, and these attributes determine the system's current condition. From there any anomalies can be detected after further data processing (diagnostic and prognostic), and that data can then be processed to select the most effective solution (decision making). Used correctly, CBM could be used for early preventative maintenance as well as determining the most effective restoration plan.



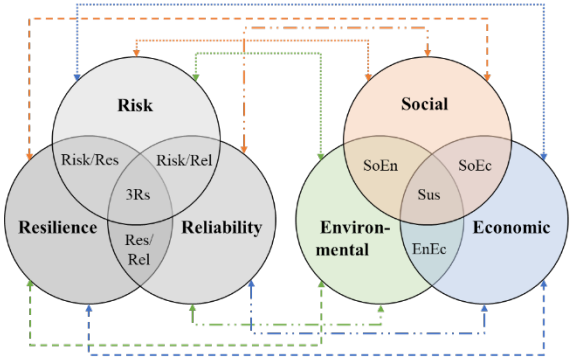


(a) 3Rs Flowchart

(b) Sustainability Pyramid

#6 Sustainability with the 3 R's

This showcase puts the focus on embodying sustainable development practices into the oil and gas industry for a smoother transition to renewable energy with a holistic risk, reliability, and resilience perspective. Written by Yasir Mahmood, Tanzina Afrin, Ying Huang, and Nita Yodo this study, "Sustainable Development for Oil and Gas Infrastructure from Risk, Reliability, and Resilience Perspectives" takes a deep dive into the characterization of sustainability and how the 3 R's can be integrated into each character (as shown below). The table below on the right centers on direct and immediate impact and can be quantified. However due to the nature of the characters, they may not be able to be easily separated from one another, and that is where the Venn diagram chart below on the left comes into play. This chart, called the coupling matrix, focuses on the indirect and long-term impacts of activities to reach sustainability. It also shows that there is a need for a more holistic approach towards sustainability because of the interconnectedness between the characters of sustainability. With this understanding stakeholders and policy makers can collaborate to minimize negative impacts and develop more positive impacts that eventually will reach the goal of sustainability.



(a) Integrated Sustainable Development

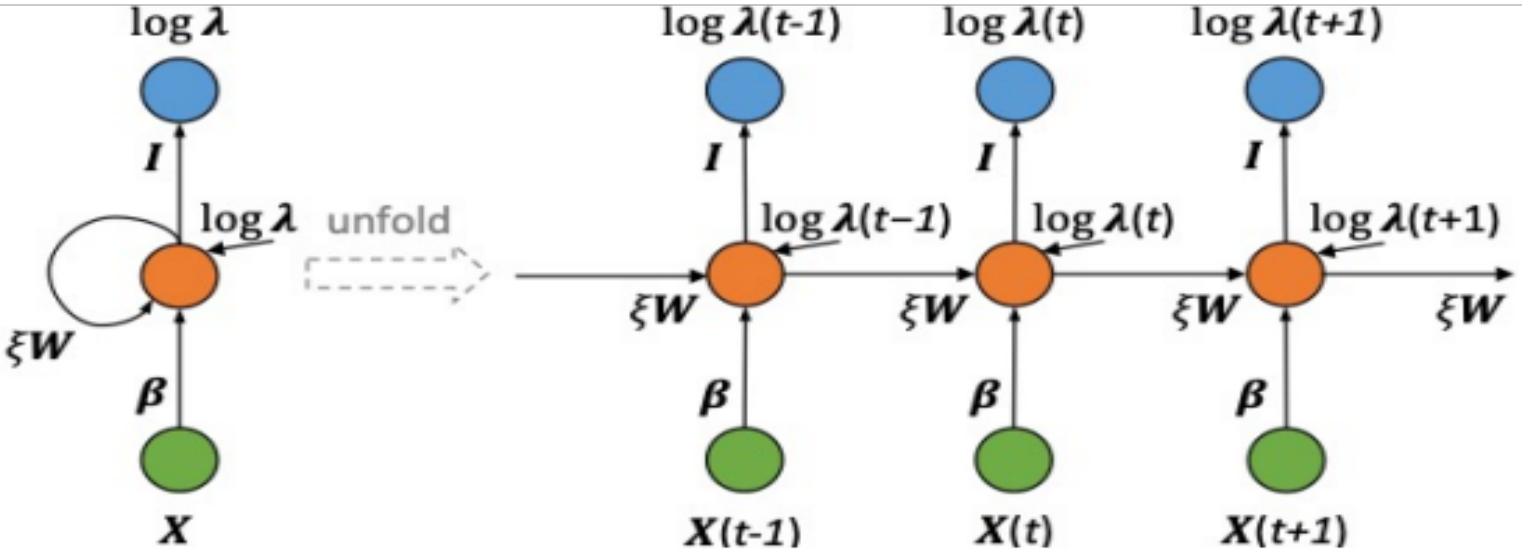
Risk — Reliability — Resilience
Social — Economic — Environmental

	Sustainability		
3Rs	**Social**	**Economic**	**Environmental**
Risk	Social Risk	Economic Risk	Environmental Risk
Reliability	Social Reliability	Economic Reliability	Environmental Reliability
Resilience	Social Resilience	Economic Resilience	Environmental Resilience

Coupling Matrix

Fundamental Matrix

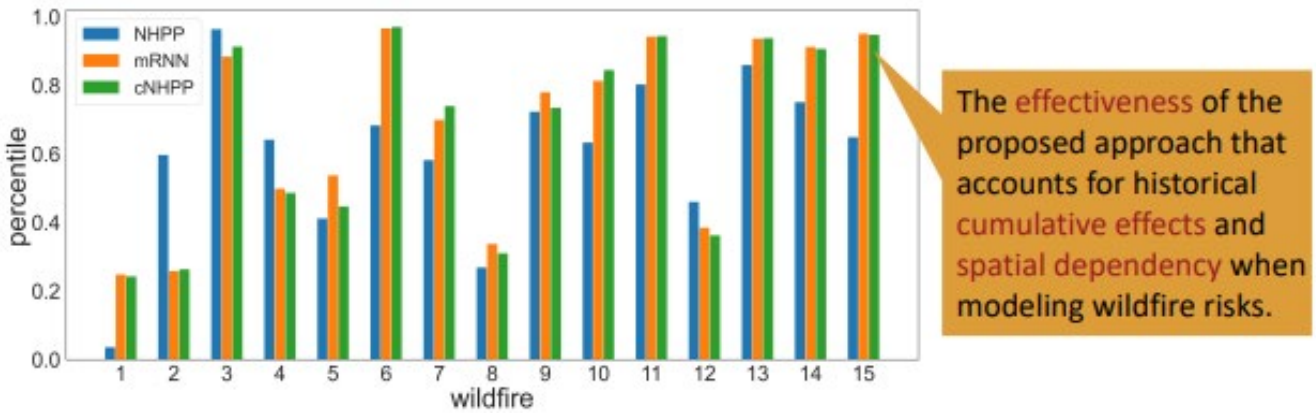
(b) Sustainable Development 3Rs Matrix

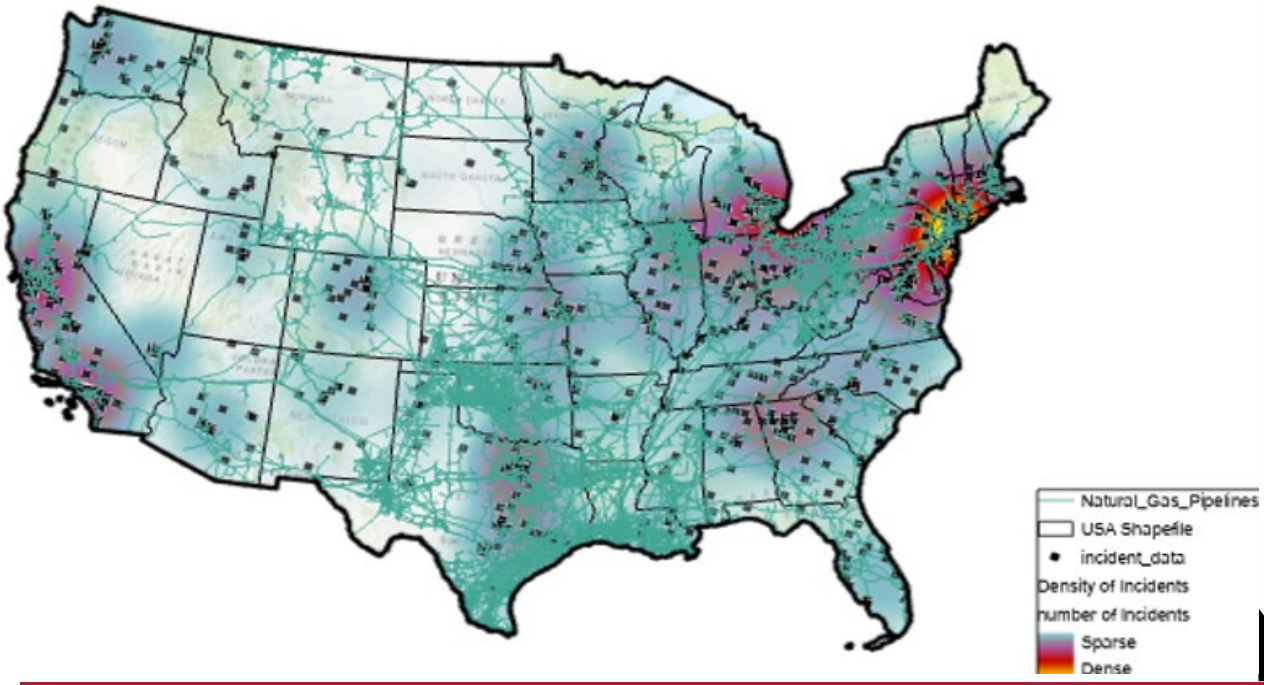


$$h(t) \triangleq \xi \boldsymbol{W} \boldsymbol{h}(t-1) + X(t)\beta, o(t) \triangleq Ih(t) = \log \lambda\,(t)$$

#7 Predicting Risks

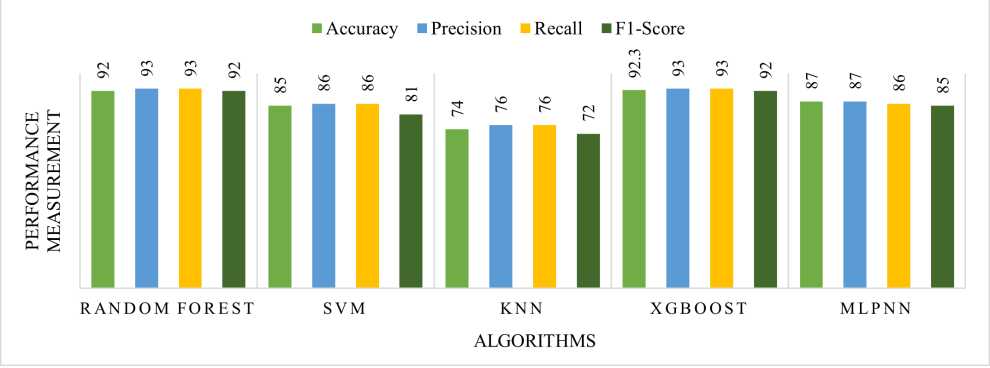
The seventh showcase is called "Convolutional Non-homogeneous Poisson Process with Application to Wildfire Risk Quantification for Power Delivery Networks" by Guanzhou Wei, Xiao Liu, and Feng Qiu we are looking at a data-driven approach to quantify wildfire risks based on the power grid with dynamic environmental factors. With the use of real datasets from major transmission lines in California, this showcase proposes a new spatio-temporal point process model known as the Convolutional NHPP (cNHPP in the bar chart below) on a linear network. This model shows that different power lines and segments of power lines have a different wildfire risk. This is due to the spatially and temporally varying covariate information that are contained within each segment. This model also shows that over time the change in predictions of wildfires change smoothly. This means that trends can be identified. As shown in the bar chart below, this model is very effective at estimating the risk for the power lines with fires among them along all the lines.

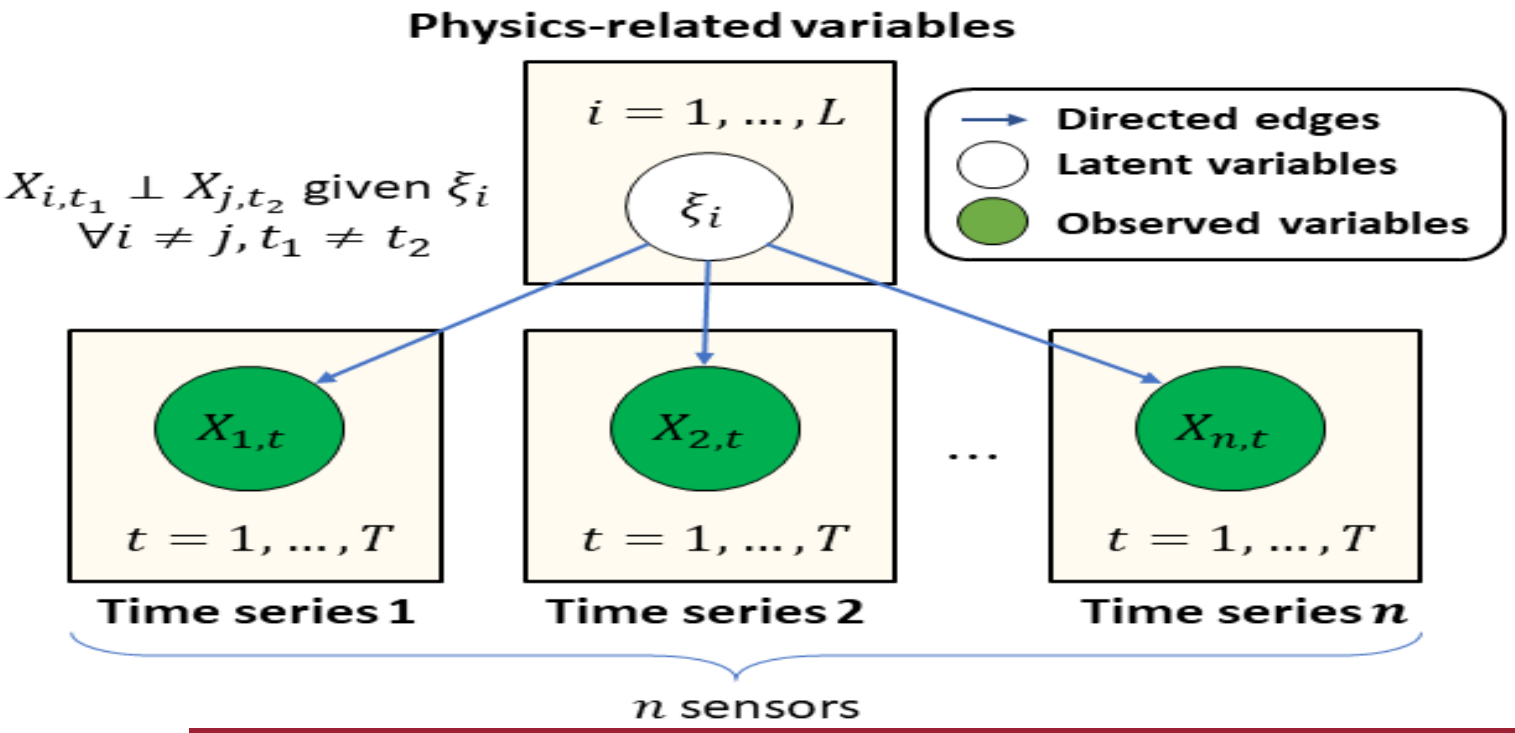




#8 AI Predicts Failure

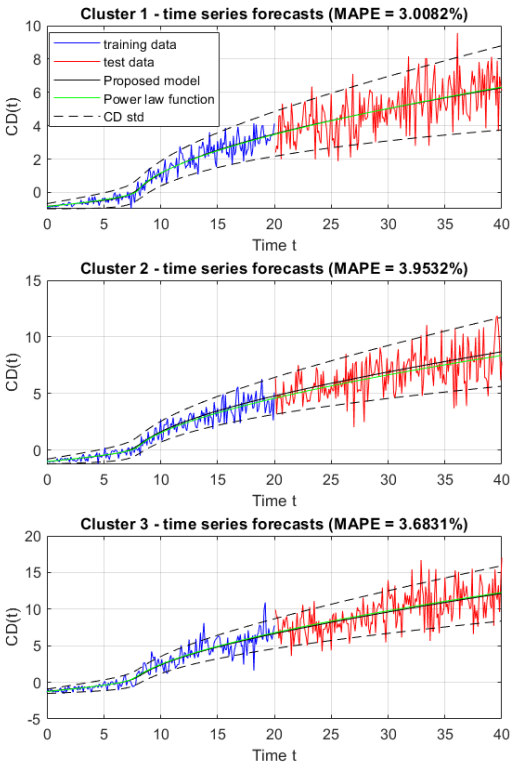
The eighth showcase in the lineup is called "Predicting Natural Gas Pipeline Failures Caused by Natural Forces: An Artificial Intelligence Classification Approach" by Bright Awuku, Ying Huang, and Nita Yodo. Here the main idea is to use machine learning for more precise forecasting of natural force failure causes to enhance prediction and mitigation of impacts on pipeline infrastructure. To start with, data is collected from publicly available sources provided by the Pipeline and Hazardous Material Safety Administration (PHMSA). From there the data is pre-processed to remove any incomplete or missing instances. Then we get to the machine learning algorithms that are chosen. These include the Random Forest, multiclass support vector machine (multiclass SVM), k-nearest neighbors (KNN), extra gradient boosting classifier (XGBoost), and multilayer perceptron neural network (MLPN) classifiers shown in the diagram below. Lastly, these models are evaluated with an independent test dataset to gauge their accuracy, recall (ability to find all relevant cases in a data set), precision (how close measurements were to actual dataset), and F1-Score (average rate). The diagram below showcases that machine learning algorithms can be used efficiently to predict and avoid potential dangers.





#9 Modeling Corrosion

Our last showcase in the lineup this year is called "A Physics-informed Latent Variables of Corrosion Growth in Oil and Gas Pipelines" by Phat K. Huynh, Abdulsalam A. Alqarni, Om P. Yadav, and Trung Q. Le. This showcase recognizes the need for another model to address the corrosion growth in pipelines. Previous models exist in deterministic, stochastic, and machine-learning-based, however these models fail to apply the hidden physics-driven nature of the corrosion growth process. The model proposed here takes that into account by using the agglomerative hierarchical clustering and physics-informed regression models to identify any latent variables and underlying relationships between the time series and those latent variables. To evaluate this model, the engineering assessment of corrosion defects, called high-resolution inline inspections (ILI), was simulated and used as training data. The end result is the data shown to the right is the forecast of corrosion depth time series from 3 different clusters.



For a more in-depth summary for any showcases or their full articles, visit our site and click on the corresponding pdf associated with that showcase at https://www.aisustein.com/showcase.

REU Program

Pictured above from left to right are our summer 2023 REU Students: Omar Qedan, Winston Bounsavy, Rabbi Cephas Bassoubouh-Ba-Dimai, Vera Bueler-Faudree, Jade Easter, Michael Ofodile, Armon Afrasiabi and not pictured Jacob Brecheisen.

This year the 8-week summer REU program was organized by Dr. Haitao Liao and held at the University of Arkansas in Fayetteville, AK. A new series was introduced that had wonderful feedback from the students. This series, among many different training and weekly workshops, focused on leadership. The basis of the series is based on Don Clifton's book *Strengths-Based Leadership: Great Leaders, Teams, and Why People Follow*. The 3 main components we incorporated into the class were reviewing strategies for leading effective creative problem-solving teams, reviewing successful leaders and leadership strategies, and putting leadership into practice with the focus in technology driven organizations.

Each REU student had a mentor that accompanied them on their journey of learning new things about AI, energy networks, leadership, and economic impact analysis. At the end of their 8 weeks, the presented their knowledge with a poster session. Photos of the group and their mentors are shown on the right.

2023 AI SUSTEIN Annual Meeting

The AI SUSTEIN second annual meeting was held at University of Arkansas in Fayetteville, AR from August 14-15th, 2023. Those who attended include the external advisory board, faculty, and students.

On the first day 10 graduate students presented their research and among them 4 were selected by the external advisory board to receive the Best Graduate Student Presentation Award! The awardees are shown in the pictures to the right.

On the second day the focus shifted to the following:

- External Advisory Board Presentations
    - (Real-World Challenges from Industry)
- Closer Collaboration with the External Advisory Board and Industry Partners
    - (Solving AI SUSTEIN Related Real-World Challenges)
- Enhancing Inter-Jurisdictional Collaborations
- Enhancing Diversity in the Education/Workforce Theme
- Planning for Year 3

This meeting held a multitude of efficient solutions that will be implemented during year 3. The next meeting will be held November 2024 at the University of Nevada, Las Vegas in Las Vegas, NV.

Karuna Bhaila

1st Place

Talha Ahmed

2nd Place

Lemlem Asaye

3rd Place

Mojtaba Ahanch

4th Place

Meet the AI SUSTEIN Team!

Our members are from different backgrounds and disciplines to create a holistic view of this program. Names will be listed in alphabetical order starting with NDSU, NHSC, UARK, UNLV, then our external advisory board, students, and lastly our industry partners. For more information go to https://www.aisustein.com/about.

The NDSU team includes Di Wu in Computer and Electrical Engineering, James Caton in Economics, Jun Kong in Computer Science, Kirstin Saulsbury as the project coordinator, Nita Yodo in Industrial and Manufacturing Engineering, Saeed Salem in Computer Science, Trung (Tim) Le in Industrial and Manufacturing Engineering, Ying Huang in Civil, Construction, and Environmental Engineering, Chau Le in Civil, Construction and Environmental Engineering, and Harun Pirim in Industrial and Manufacturing Engineering

The NHSC team has Kerry Hartman, the Academic Dean. A student was recently able to attend the 2023 TribalNet conference and tradeshow. TribalNet was formed in 1999 with the primary purpose of bringing tribes, tribal employees, and resources together to connect and seek opportunities in solutions, best practices, and technology among tribal government, gaming, and healthcare industries.

The UARK team consists of Ed Pohl in Dean of Graduate School and Interational Education, Haitao Liao in Industrial Engineering, Roy A. McCann in Electrical Engineering, Haoming Shen in Industrial Engineering, Xintao Wu in Computer Science/Engineering, and Yue Zhao in Engineering.

The UNLV team includes Eakalak Khan in Civil and Environmental Engineering, Erica Marti in Civil and Environmental Engineering, and Krystyna Stave in Public Policy and Leadership.

The external advisory board consists of Brij Singh from John Deere, Darcy Neigum from Montana-Dakota Utilities Company, Douglas Bowman from Southwest Power Pool, and Elsayed A. Elsayed, the

Director of the NSF/Industry/University Co-operative Research Center for Quality and Reliability Engineering.

Postdocs include Shuomang Shi, Fei Yan, and Xingyu Wang.

Students include Abiodun Idowu, Allison Hedtke, K'adesh Hepburn, Kauruna Bhaila, Melika Ansrinejad, Mireille Tankoua Sandjong, Mojtaba Ahanch, Phat Kim Huynh, Quoc Huu Nguyen, Seyyed Farid Hashemian, and Yasir Mahmood Ahmadreza Khatamgooya, Shams Rothee, Nour Hakim, Morteza Nazaripour, Sandra Canas, Olabode Amusan, Talha Ahmed, Bright Awuko, Ratna Yasoda, Wei Wang, Saima Ahmedi, Tongxin Shi, Riyad Hakim, Ayman Akash, Muhammad Ali Moriyani, Miao Tan, Muhammad Kazim, Melika Ansarinejad, Lemlem Asaye. The list of students grows as the project progresses.

Lastly, our industry partners are Montana-Dakota Utilities Company (MDU), Oklahoma Gas and Electric Company (OGE), and Southwest Power Pool (SPP).

Contact Us!

AI SUSTEIN

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