VISUALIZATION TECHNIQUE FOR THE POWER TRANSIENTS OF A THERMALLY COUPLED SYSTEM

HAOYU WANG, ROBERTO PONCIROLI, THOMAS ELMER, RICHARD VILIM
Nuclear Science and Engineering Division
Argonne National Laboratory

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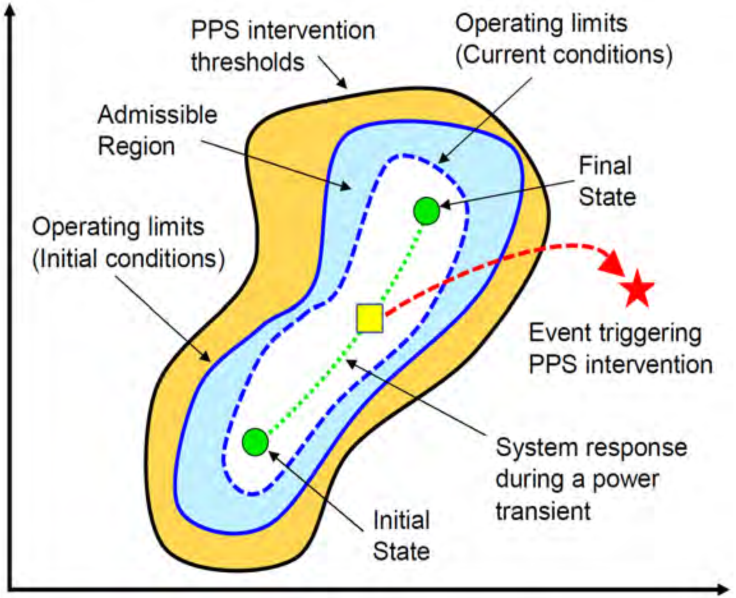
MOTIVATION AND CHALLENGES

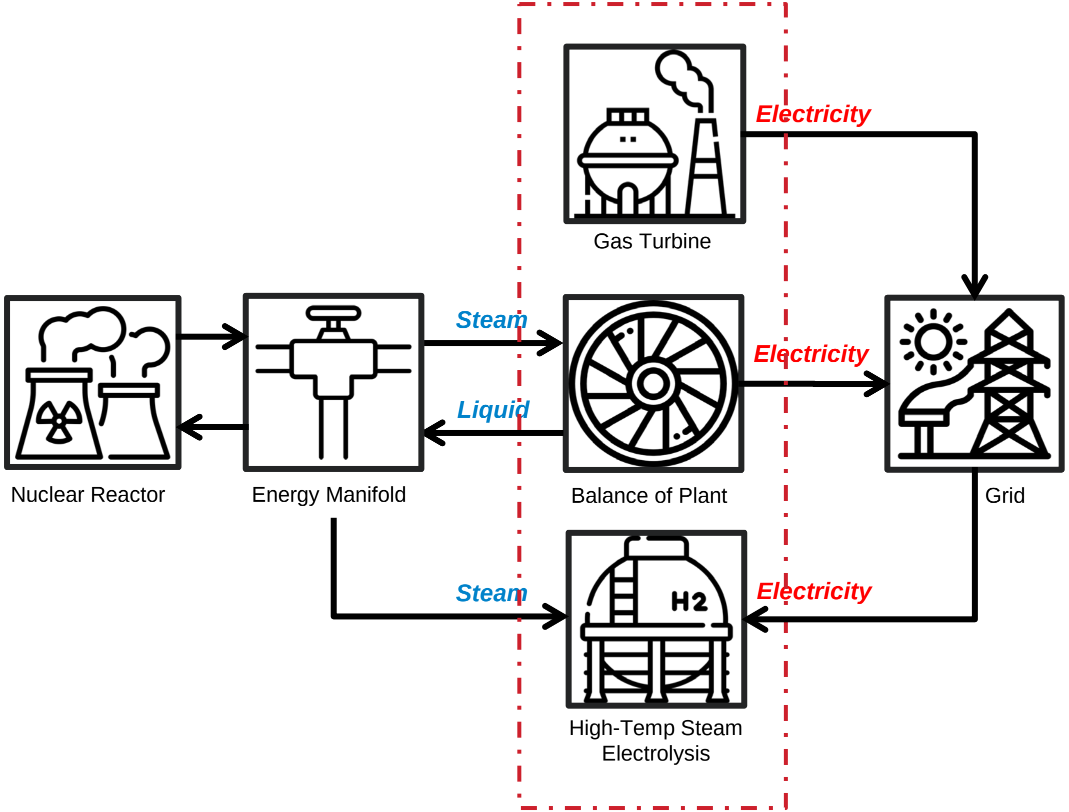
- Flexible Operation as a possible solution to cope with the evolving cost structure in U.S. electricity deregulated markets and penetration of renewable energy sources

- Q. What does this entail for Nuclear Power Plants?
  - Electrical power level adjusted on hourly basis
  - Thermo-mechanical load variations might accelerate component wear and tear → Process variables need to be constrained to limit operational and maintenance (O&M) costs.



- Advanced control techniques provide a quantitative estimate of the Normal Operation Region (NOR) and Admissible Region (AR).
- Need for a suitable tool to track and visualize the plant response during transients.

EXAMPLE TEST CASE



Three sub-systems:

- Balance of Plant
- High Temp. Steam Electrolysis (HTSE)
- Gas Turbine

Variables:

- 3 inputs (power set-points);
- 6 monitored process variables. Examples:
  - y_1: Turbine inlet temperature, $827℃ < y_1 < 1289℃$ to avoid inefficient combustion and structural degradation
  - y_3: HTSE $\mathrm{H_2}$ Production Rate, $2.0\,\mathrm{g/s} < y_3 < 10.0\,\mathrm{g/s}$ to avoid cold-start or breakdown of the Solid Oxide Electrolysis Cell

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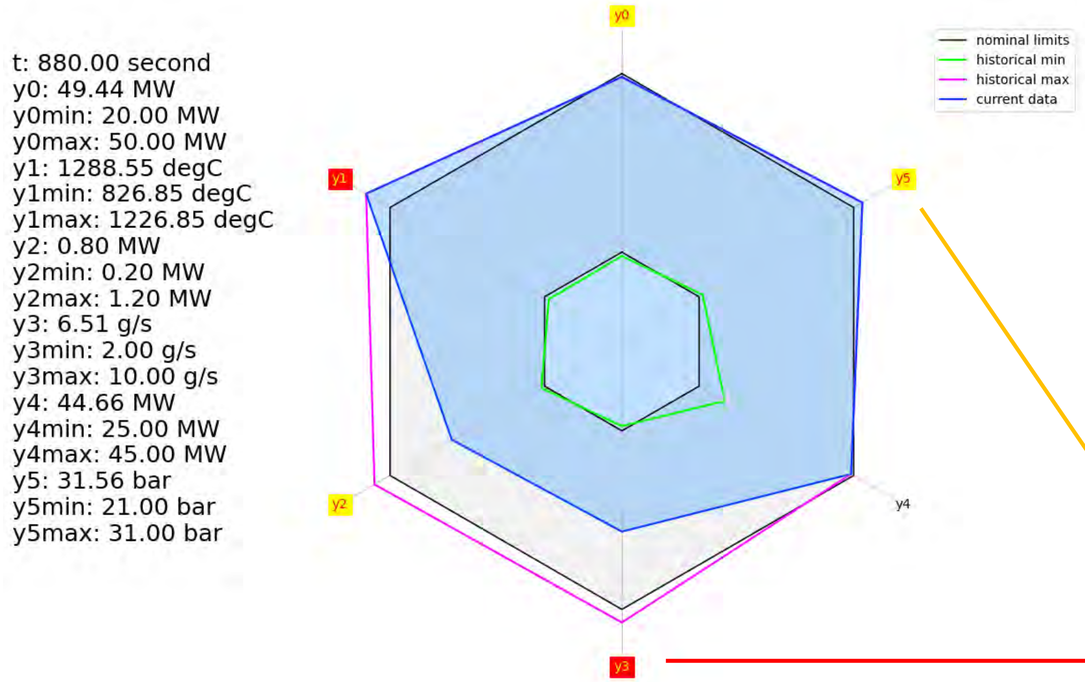
SOLUTIONS TO NOR VISUALIZATION

- Solution #1: Dynamic Spider Chart for outputs



Extension of the well-known spider chart / radar chart for static applications

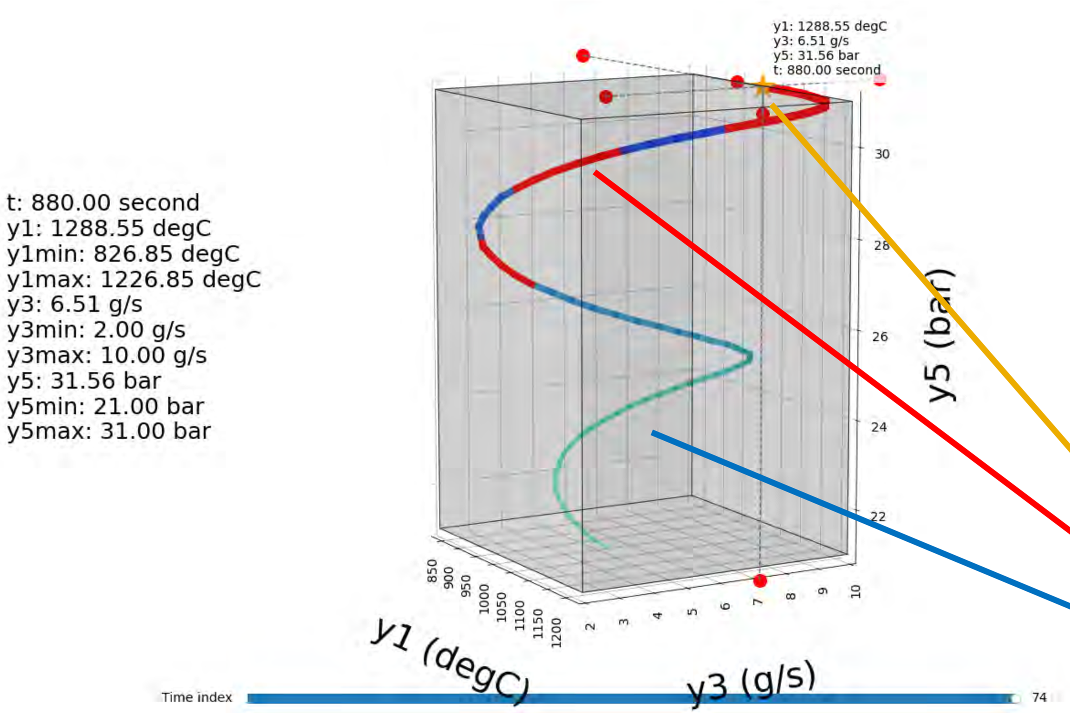
- 3+ equiangular axes starting from the same point by spokes;
- Length of spokes is proportional to the magnitude;
- Polygon to represent a data point.

Improvement by ANL:

- Animation to track data history;
- Grey ring show bounds;
- Pink / green polygon show historical max / min in each dimension
- Yellow warning indicate historical violations of either the lower or upper bounds
- Red warning indicate historical violations of either lower and upper bounds

SOLUTIONS TO NOR VISUALIZATION

- Solution #2: 3D Phase Space diagram for outputs



Extension of classic 3D trace plot:

- System response is represented by a 3D trajectory
- Each point represents the values of three selected monitored variables during the transient.

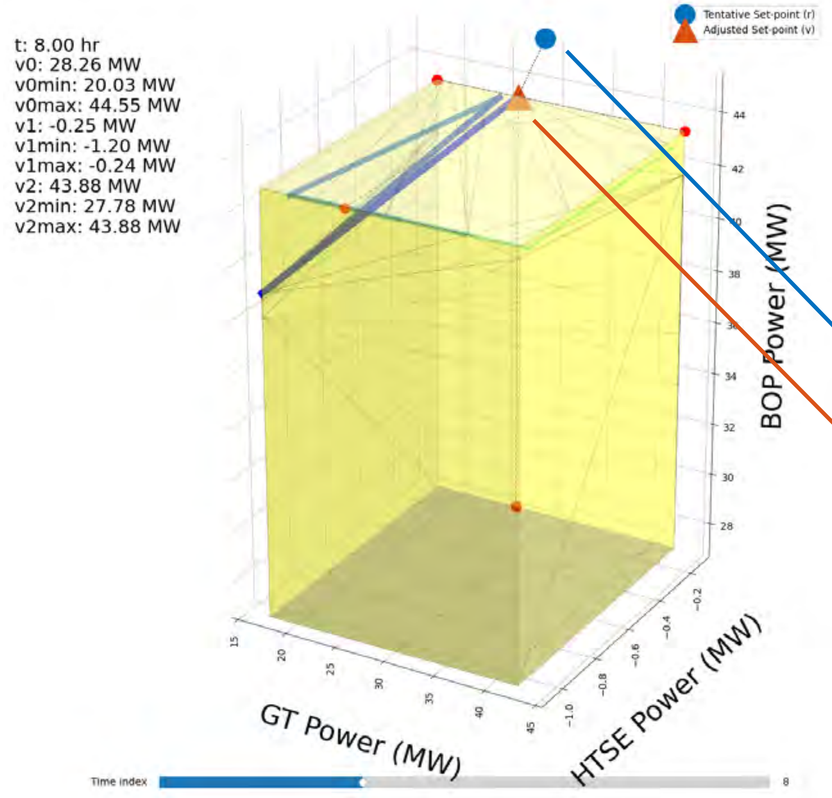
Improvement by ANL:

- Animation to track data history
- NOR is shown by grey-colored parallelepiped
- Red dots indicate the margin with respect to the NOR bounds
- Thickness of the curve to show the direction of system response;
- Gold star shows current value
- Red trace -> constraint violation
- Blue trace -> constraint compliance.

Q. In case of constraint violation, how can the operator modify the input variable?

SOLUTIONS TO AR VISUALIZATION

- 3D convex polytope for inputs



If the system dynamics can be described by a state-space representation model:

$$\vec{x}(k+1) = A^d \vec{x}(k) + B^d \vec{v}(k)$$
$$\vec{y}(k) = C^d \vec{x}(k) + D^d \vec{v}(k)$$

The bounds on output can be translated into a admissible region on input:

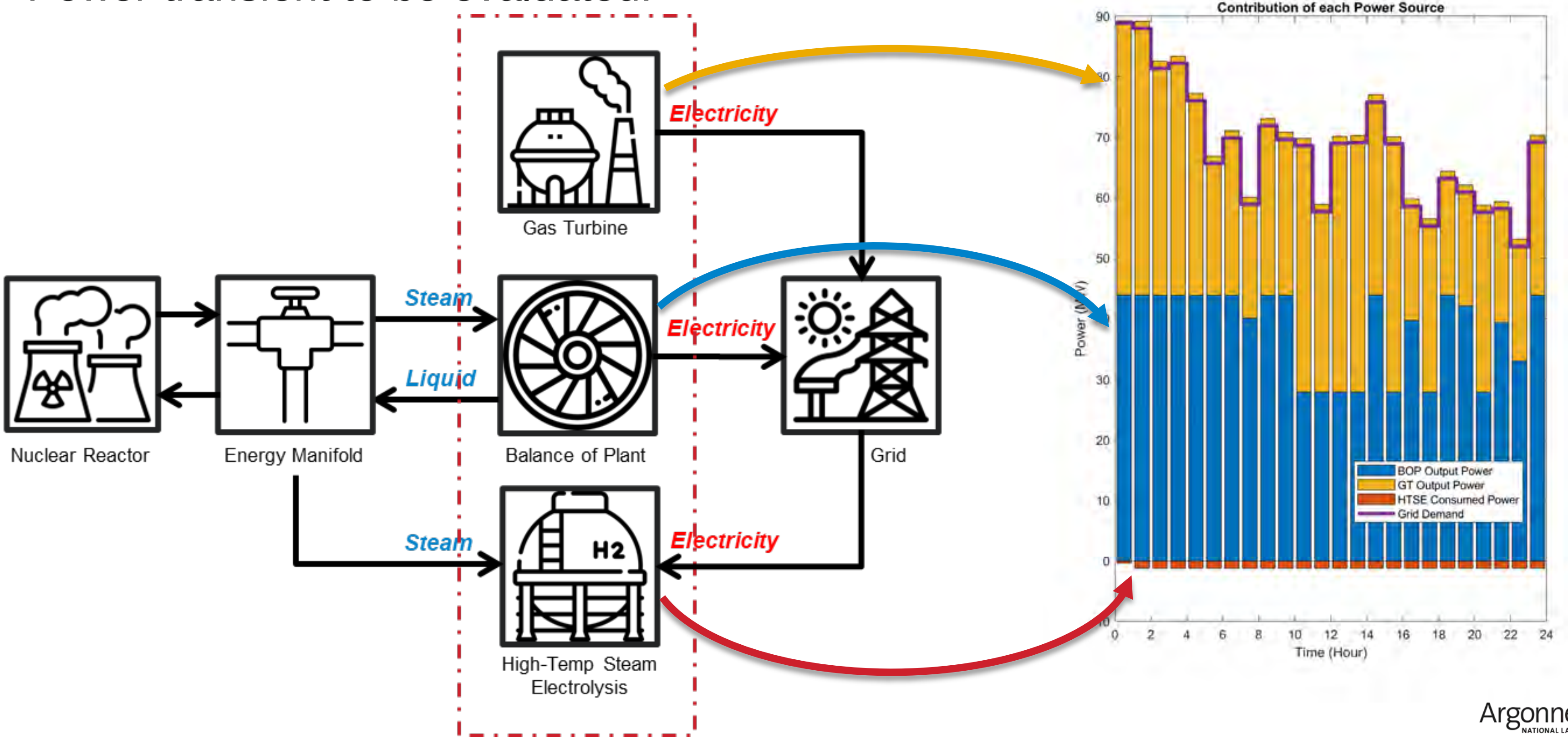
$$H \cdot \vec{v}(k) \leq h$$

And this admissible region is shown by yellow convex polytope.

- Blue Circle indicates tentative input variable;
- Orange Triangle indicates the proposed adjustment as a compromise between (1) performing the desired transient and (2) staying within the Admissible Region.

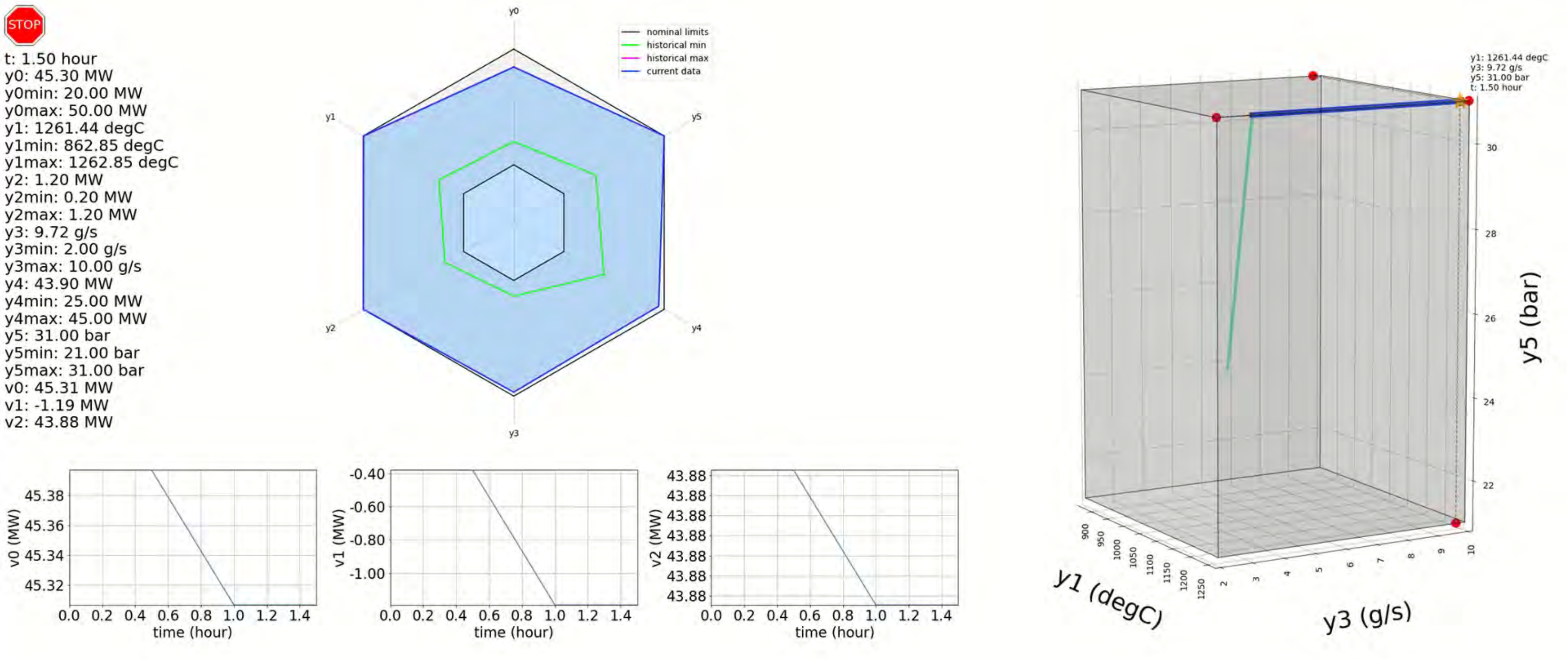
DEMONSTRATIONS

- Power transient to be evaluated:



DEMONSTRATIONS

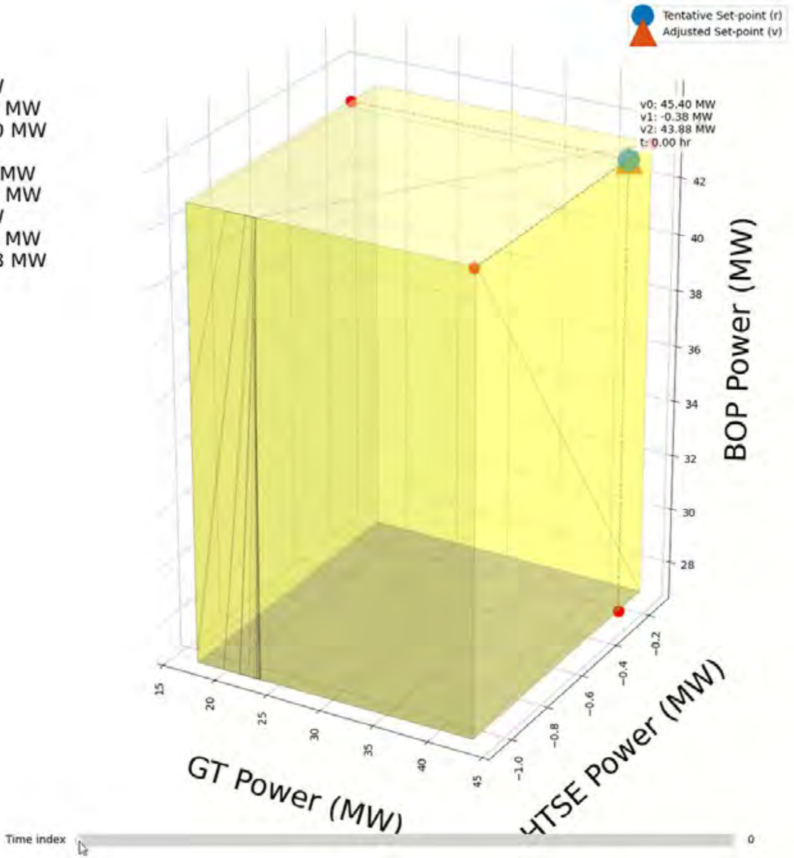
- Output variables and NOR:



DEMONSTRATIONS

- Input variables and AR:

t: 0.00 hr
v0: 45.40 MW
v0min: 20.00 MW
v0max: 45.40 MW
v1: -0.38 MW
v1min: -1.20 MW
v1max: -0.24 MW
v2: 43.88 MW
v2min: 27.78 MW
v2max: 43.88 MW



CONCLUSION

- A visualization technique to evaluate the power transients of a thermally couple system was developed and demonstrated.
- The multi-dimensional admissible region for input variables (system actuators) and the evolution history of key monitored process variables are visible to the operator.
- Any violation of operational constraints will be directly shown and brought to the user’s attention. Suggestions on input variable adjustment is also provided.
- This method would strengthen the user trust when planning and evaluating power transients.

References

- H. Wang, Quantitative Estimation and Visualization of the Normal Operation Region for Power Transient Planning, Invited Talk, 13th Nuclear Plant Instrumentation, Control & Human-Machine Interface Technologies (NPIC&HMIT 2023), Knoxville, TN, July 15-20, 2023
- H. Wang, R. Ponciroli, A.J. Dave, R.B. Vilim, “Control system for multi-system coordination via a single reference governor”, ANL/NSE-22/26, Argonne National Laboratory, Lemont, Illinois (2022).

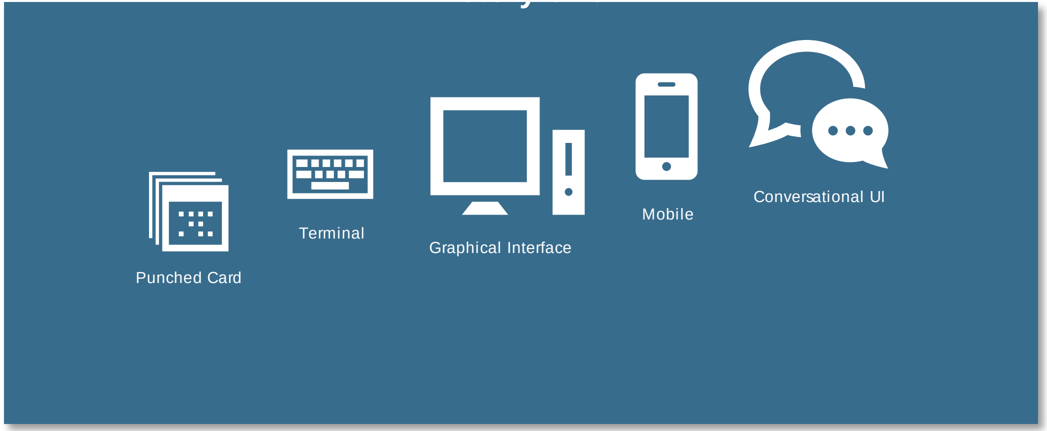
THANK YOU

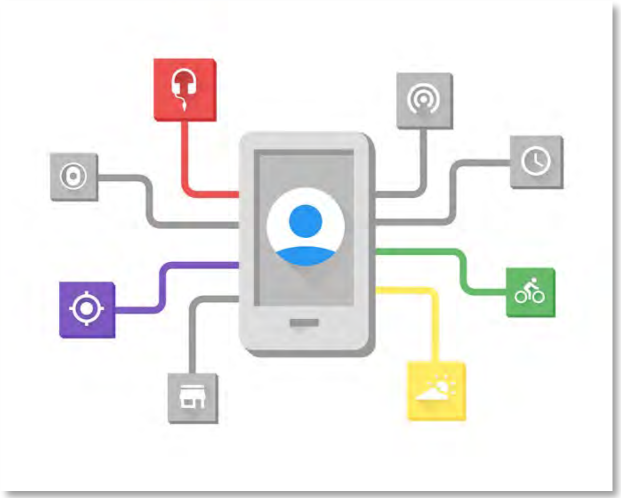
Rajiv Khadka
Visualization Researcher
Applied Visualization Laboratory

Next-Generation Context-Aware Adaptive User Interface: Challenges and Opportunities

Navigating the future of User Interaction

EVOLUTION OF USER INTERFACES





https://www.zauberware.com/en/articles/2019/conversational-ui/
https://android-developers.googleblog.com/2016/06/create-intelligent-context-aware-apps.html

CONTEXT-AWARENESS

- “*any information that can be used to characterize the situation of an entity. An entity is a person, place or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves*”. [Dey, 2001]

- Involves gathering and analyzing contextual data like user location, history, device sensors, activity, etc.

- Tailor services and interactions, providing users with personalized and timely experiences

Dey, A. K. (2001). Understanding and using context. *Personal and ubiquitous computing*, *5*, 4-7.

KEY COMPONENTS OF CONTEXT-AWARENESS

- Sensors and Data Sources
- Context Inference and Interpretation
- Adaptive Behavior and Response Mechanisms
- User Feedback Loop
- Multimodal Interaction Support

WHY CONTEXT-AWARE USER INTERFACES?

- Personalization and Customization
- Enhanced User Experience
- Contextual Decision Support
- Efficiency and Productivity
- Adaptation to Dynamic Environments
- Anticipation of User Intentions

CHALLENGES

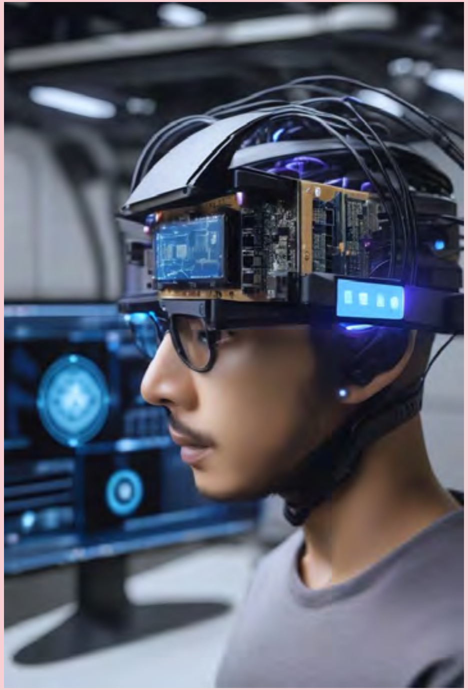
- Data Privacy and Security Concerns
- Accuracy and Reliability of Context Inference
- Scalability Across Devices and Environments
- Technical Complexity
- User Acceptance and Adoption Challenges

OPPORTUNITIES

- Enhanced Personalization and User Experience
- Contextual Collaboration
- Efficient and Improved Decision Support
- Seamless Integration Across Devices and Platforms
- Increased Efficiency and Productivity
- Potential for New Interaction Paradigms (e.g., AR/VR)

FUTURE TRENDS

- Continued Integration of AI and Machine Learning
- Advancements in Sensor Technologies
- Convergence with Internet of Things (IoT)
- Emergence of Brain-Computer Interfaces (BCI)



THANK YOU!!

rajiv.khadka@inl.gov

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Cody Walker, PhD

March 28, 2024

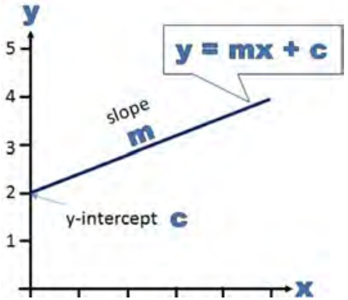
Improving Machine Learning Explainability with a Graphical User Interface

Idaho National Laboratory

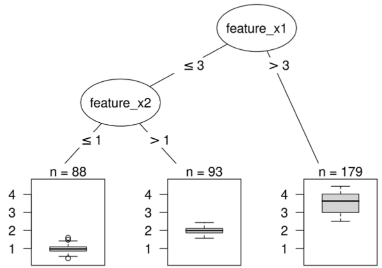
Explainability comes in different forms depending on which model you use.

- How do we explain these models to the user?
- How much would you have to explain to go from an input to an output?

Data	Hyperparameters & Optimization	Model	Post hoc
Effects model performance and explainability			Explainability



2 [m, c]



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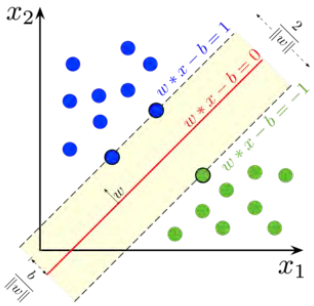
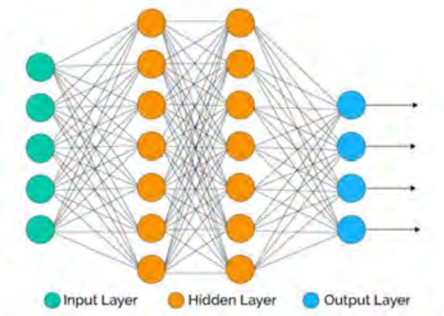


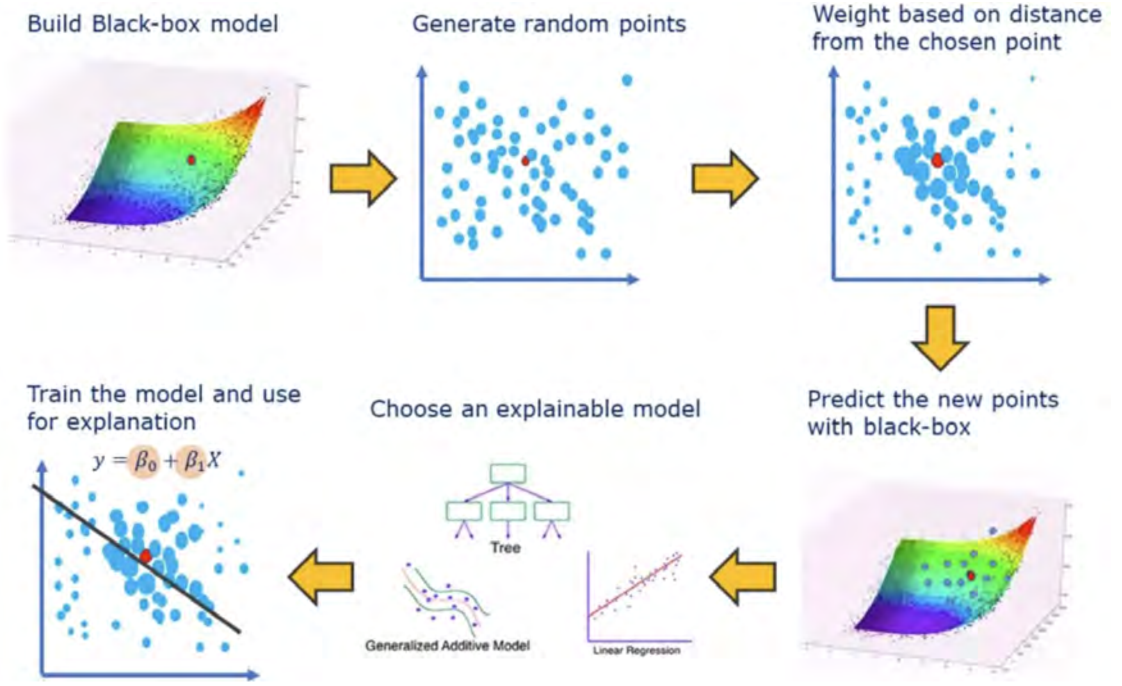
Support vectors, kernel trick and hyperplane.



Number of weights, biases, & connections.

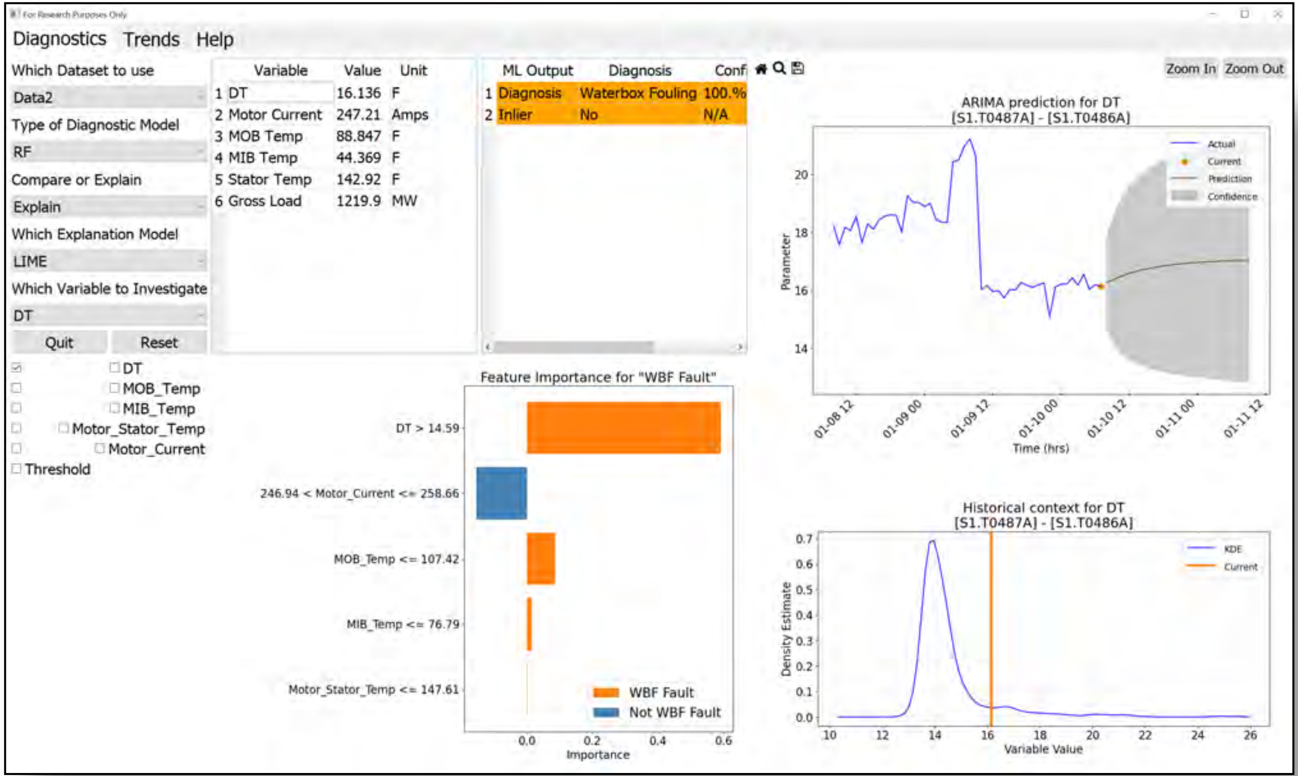
LIME is a post-hoc method for black-box models.

- Local interpretable model-agnostic explanations (LIME) can be used for any model.
- LIME is only valid **locally**.
- SHAP (Shapley Additive Explanations) are another common post-hoc method used to increase explainability.

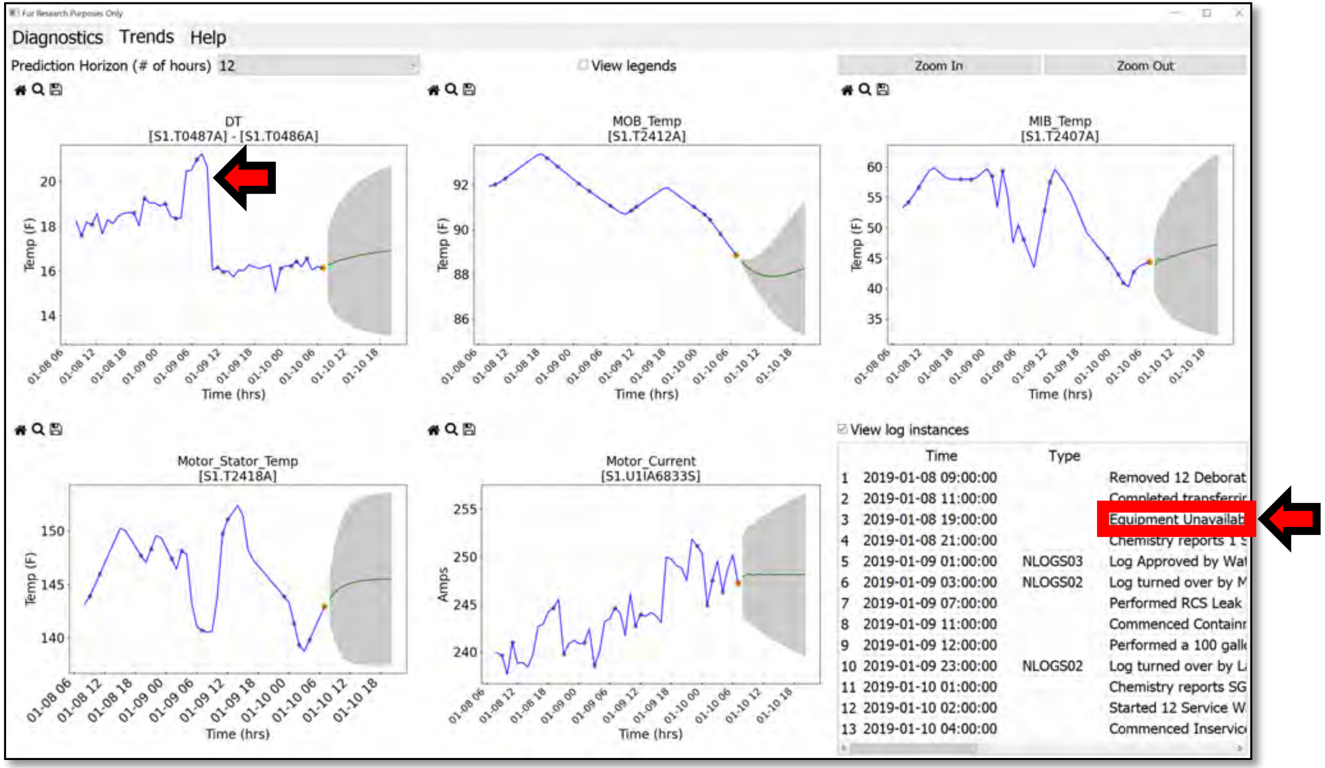


Giorgio Visani, 2020 "LIME: explain Machine Learning predictions."Accessed 2024. https://towardsdatascience.com/lime-explain-machine-learning-predictions-af8f18189bfe

Model confidence, prognostics, explainability, and historical context all provide evidence for the conclusion.



Adding context to the data can further improve understanding.



March 28, 2023

You-only-look-once (YOLO) and Radio Frequency Signal Analysis

Randall Reese
Idaho National Lab

Idaho National Laboratory

Premise

- Radio Frequency (RF) Signal analysis and Computer Vision.

- How might we identify signals of interest in the RF spectrum?

- All of this is done in the context of a tool called WiFIRE.

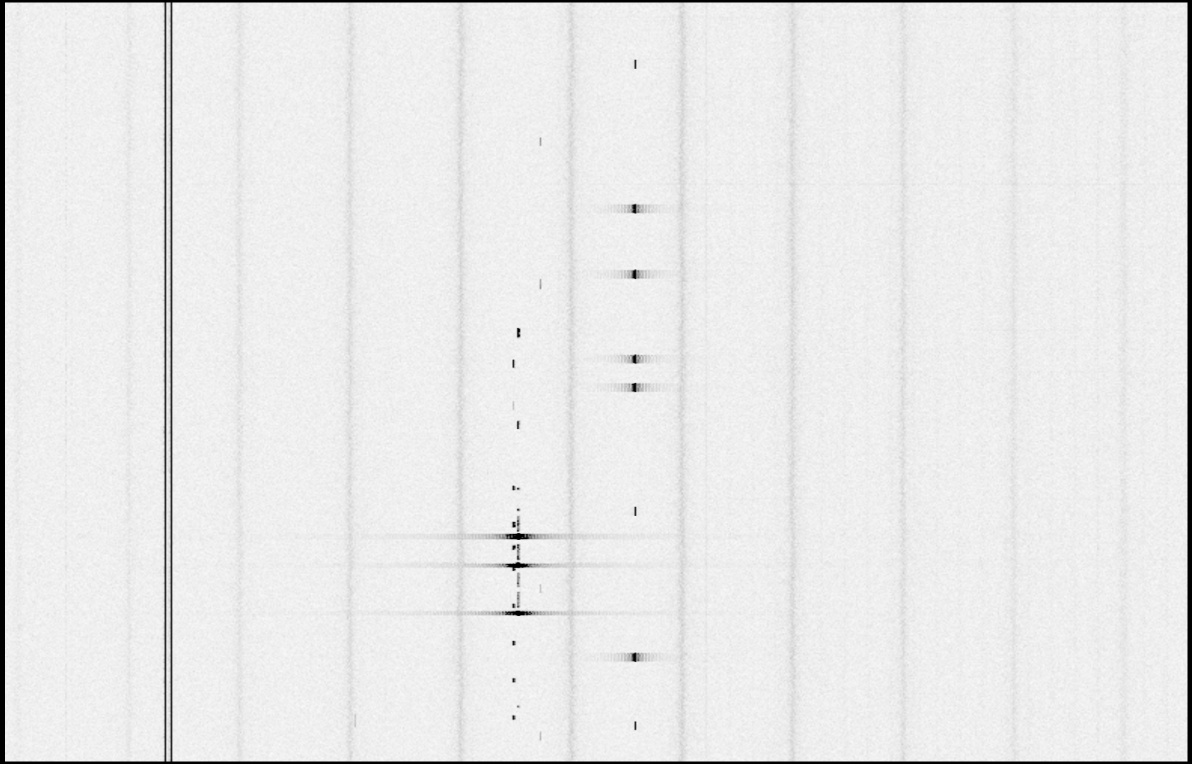
Premise: Need for Wireless Monitoring

- Signals missing that should be there
  - Equipment failures?
  - Theft?
- Signals that are there that shouldn't be
  - Jamming?
  - Data Exfiltration?
  - Unauthorized User/Device?
- Blackbox analysis
  - Ability to take a device and determine what signals are being emitted
- Signal Compliance Verification
  - Damaged/Low Quality Hardware?
  - Spectrum Misuse?

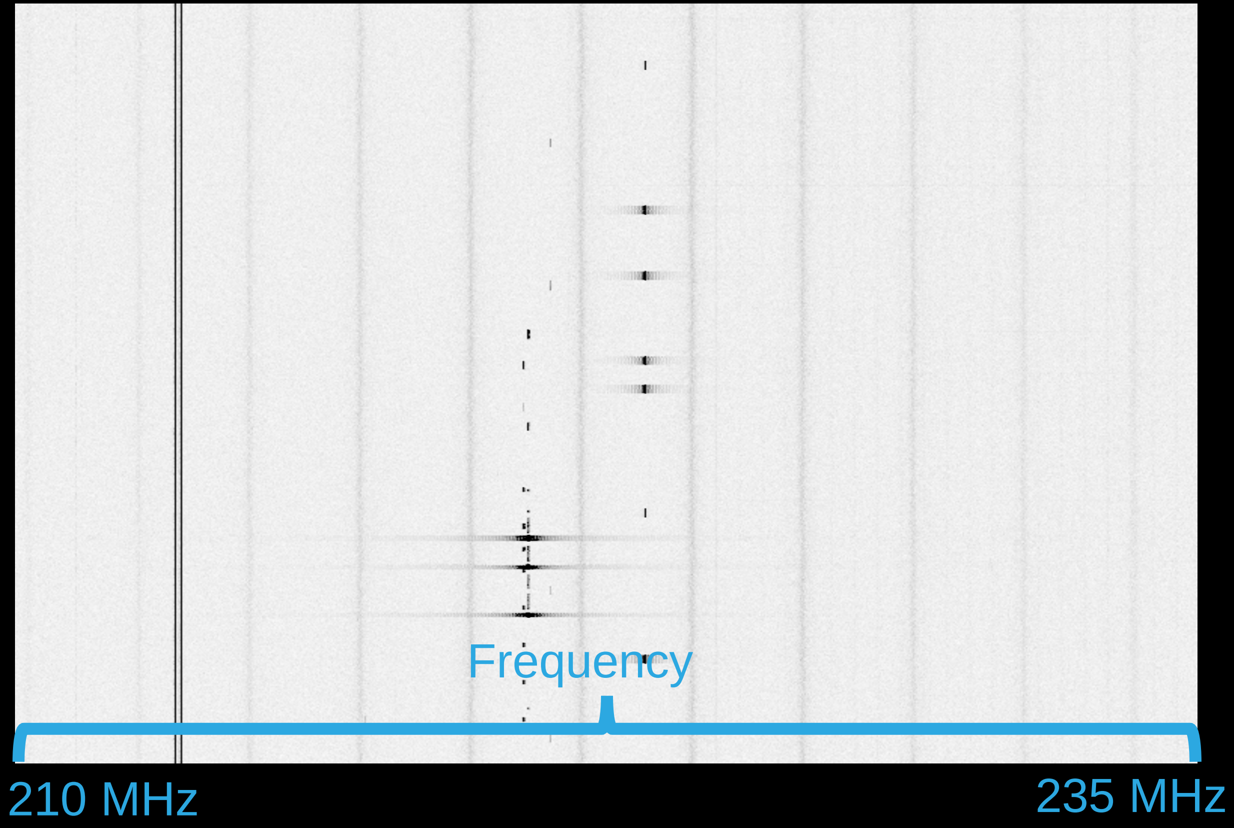
Technical Challenges

- Large amount of raw wireless data
  - 25 million samples (IQ values) per second
  - IQ value = 16 bits each for I and Q (32 bits / 4bytes total)
  - 5.6 GiB per minute
  - 7.9 TiB per day
- Differentiating signal from noise
- How to keep up with a high sample rate
- Accurate and effective machine learning algorithms for detection and classification of wireless signals

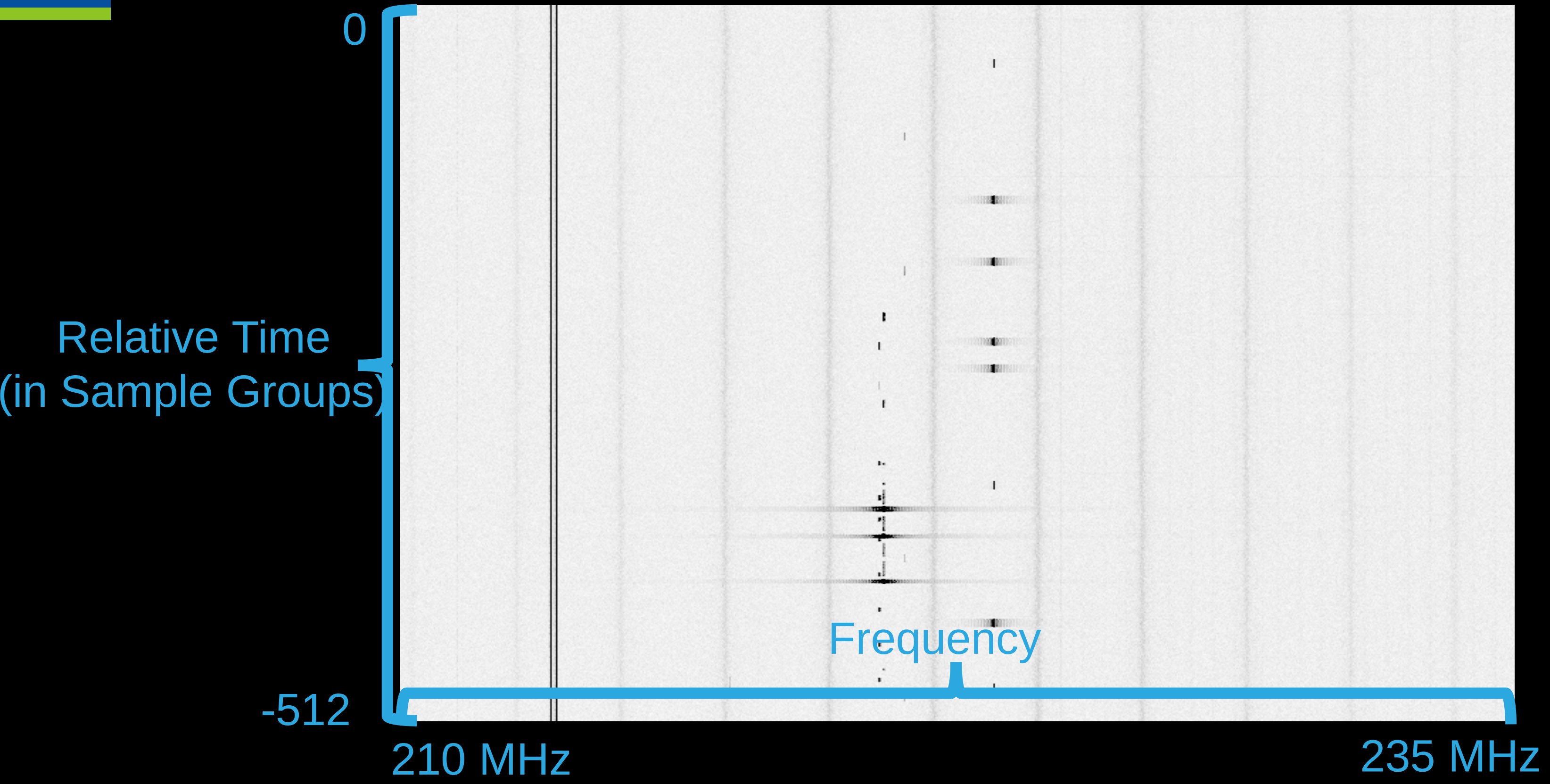
Inference Input



Inference Input

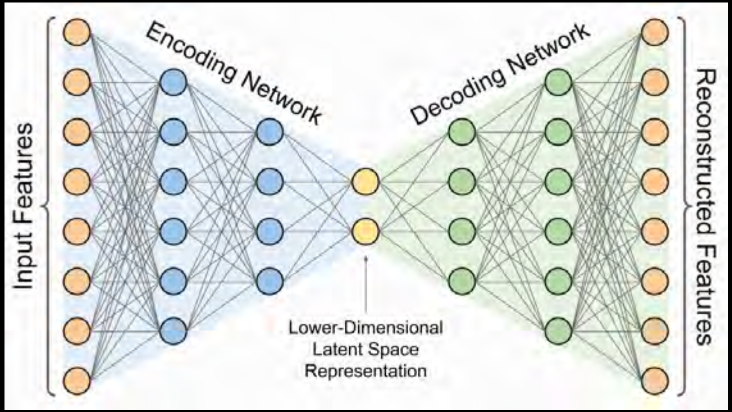


Inference Input



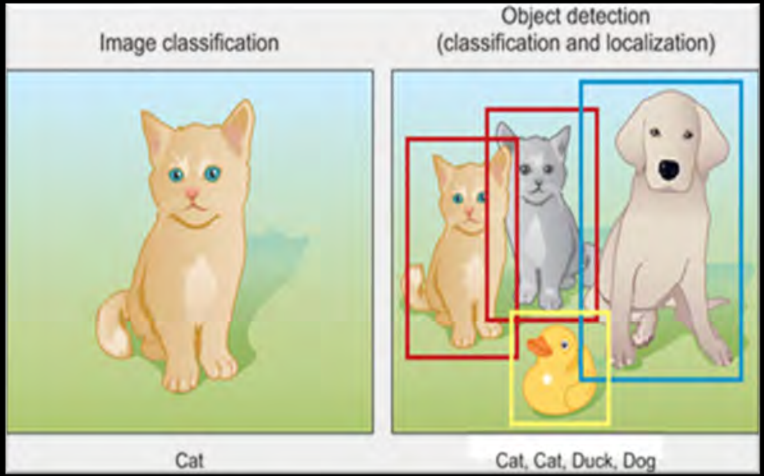
Aside: Wireless Environment Baselining

- Goal: Identify anomalous signals using an unsupervised approach
- Strategy:
  - Collect data at the target location
  - Train an autoencoder model to compress and restore the collected data – this is the baseline model
  - Apply the baseline model to a new sample and then compare the sample to the reconstructed version
  - Any signal that is reconstructed poorly – beyond a calculated threshold – is considered anomalous



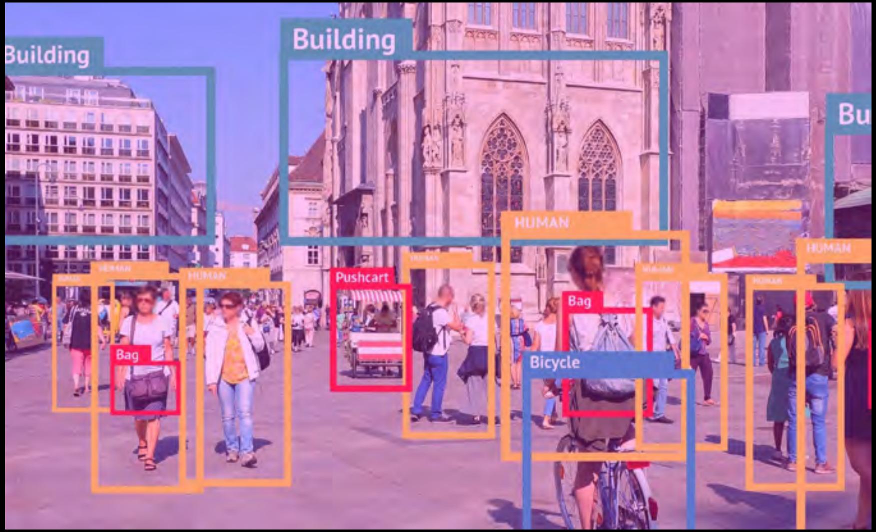
Our Focus: Signal Classification and Localization

- Goal: Identify known signals of interest. Unlike anomaly detection, this is a supervised ML problem.
- Strategy:
  - Collect data with known signals and manually label the data
  - Train an object detection model using YOLO(V7)
  - During inference, the model is used to determine bounding boxes of identified signals
  - System draws the identified bounding boxes from the model
  - Allow for multiple classes of signals to be identified in a single image (Multi-label)



How does YOLO work?

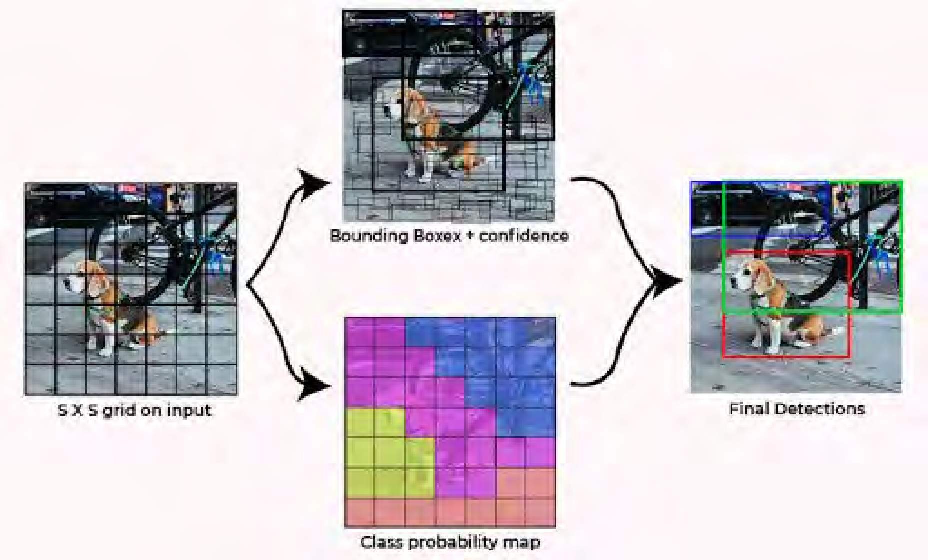
- Single pass (You only look once) as opposed to multi-pass approaches like DPM or R-CNN.
- Uses a single convolutional neural network as opposed to a complex pipeline of sliding windows and classifiers.
- Allows for global awareness within each image.



Redmon, Joseph, Santosh Divvala, Ross Girshick, and Ali Farhadi. "You only look once: Unified, real-time object detection." In *Proceedings of the IEEE conference on computer vision and pattern recognition*, pp. 779-788. 2016.

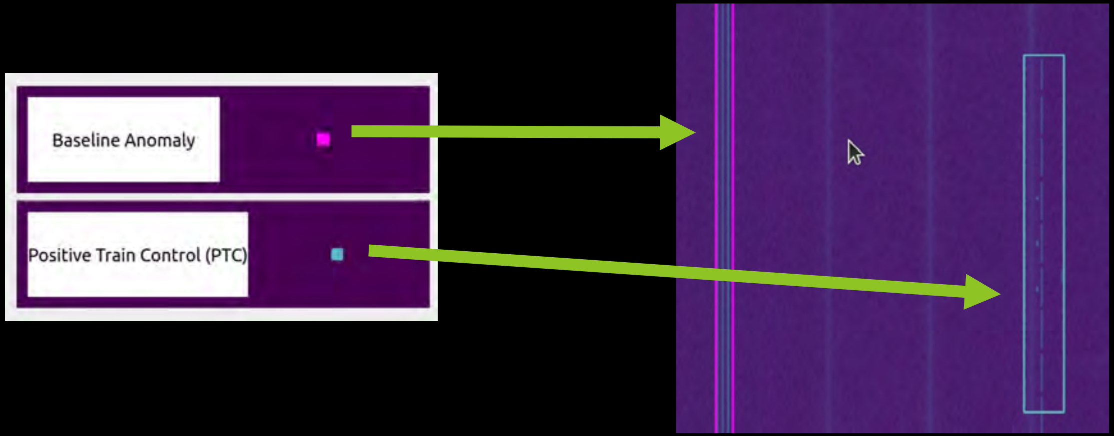
How does YOLO work? (cont.)

- Divide input image into an S x S grid (S is chosen as a hyperparameter).
- Each grid square predicts up to B many bounding boxes within that grid square.
- Calculate class probabilities for each grid square as well as confidence levels (IOU).
- Bounding box predictions and class probabilities are combined to create a final predicted set of boxes.
- Boxes with confidence below a certain threshold are dropped.

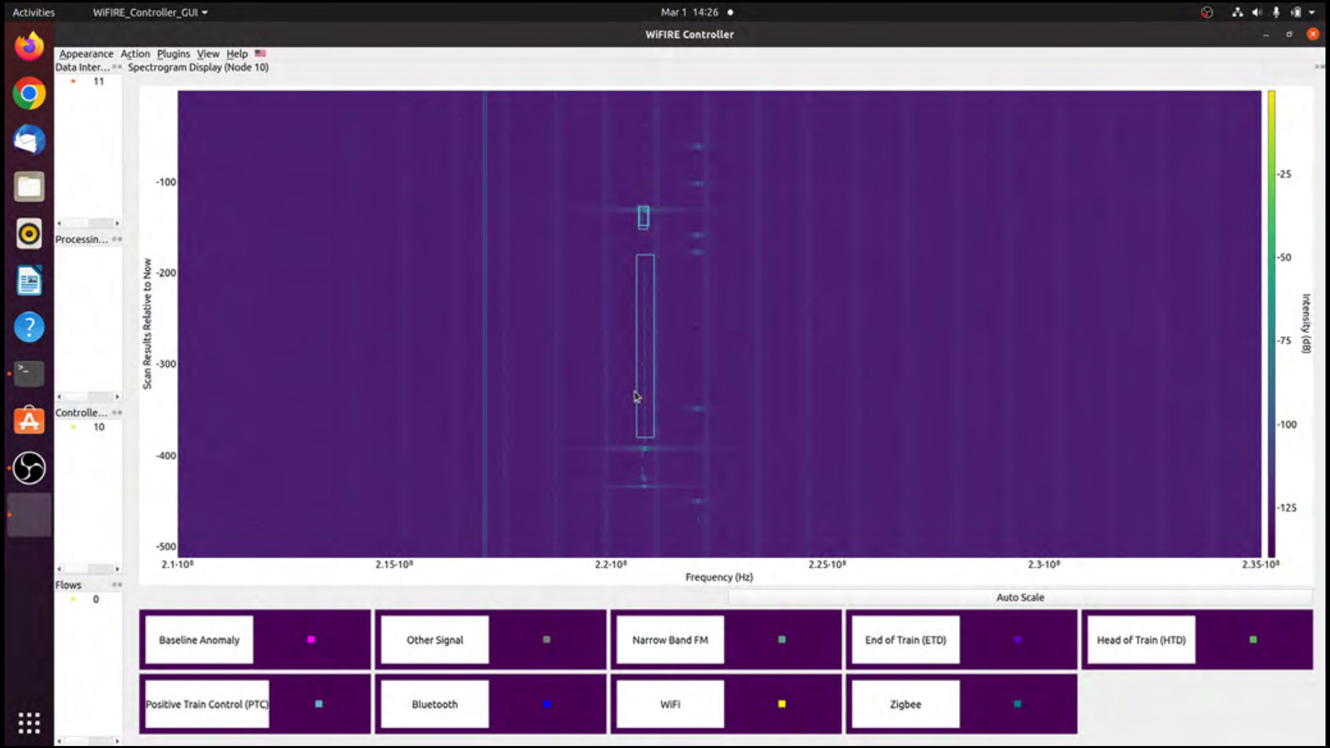


Results

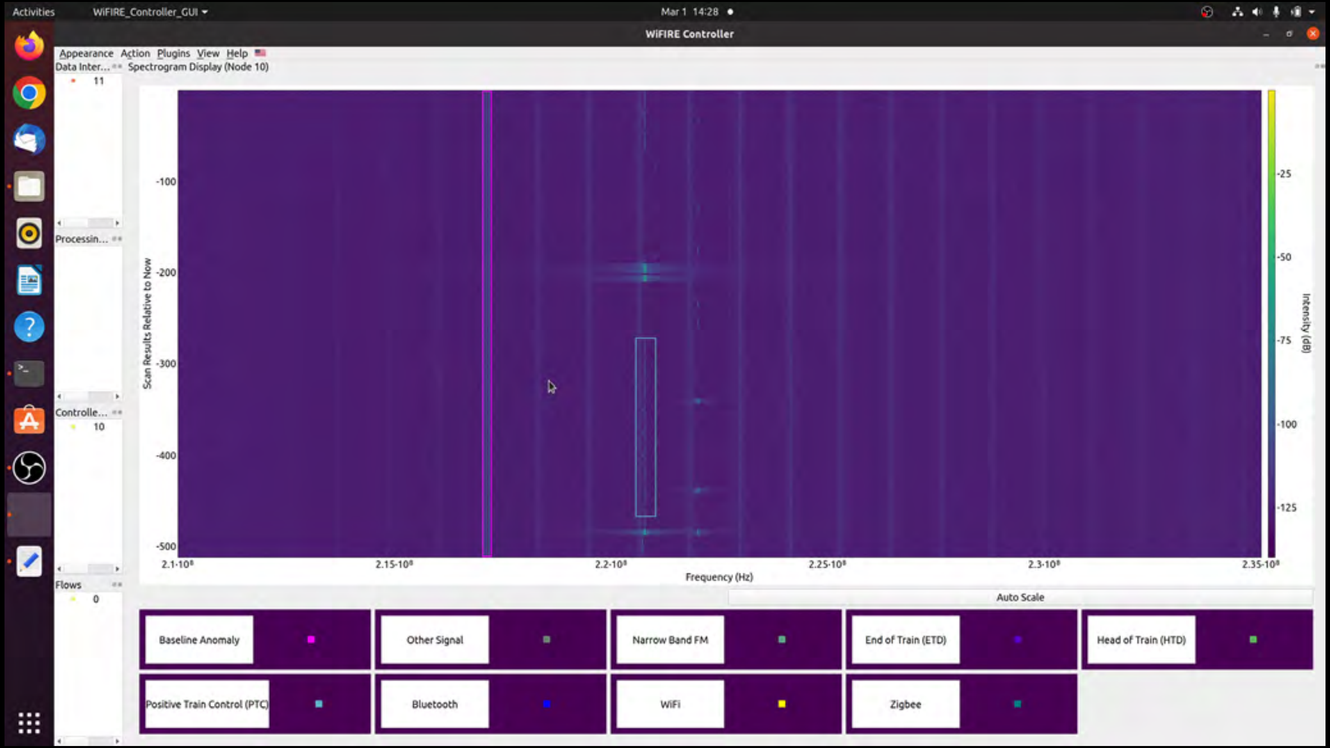
- Baseline Comparison and Signal Classification inferencing done in parallel
- Inference results are returned as a set of bounding boxes
- These bounding boxes are shown as color-coded overlays on the User Interface



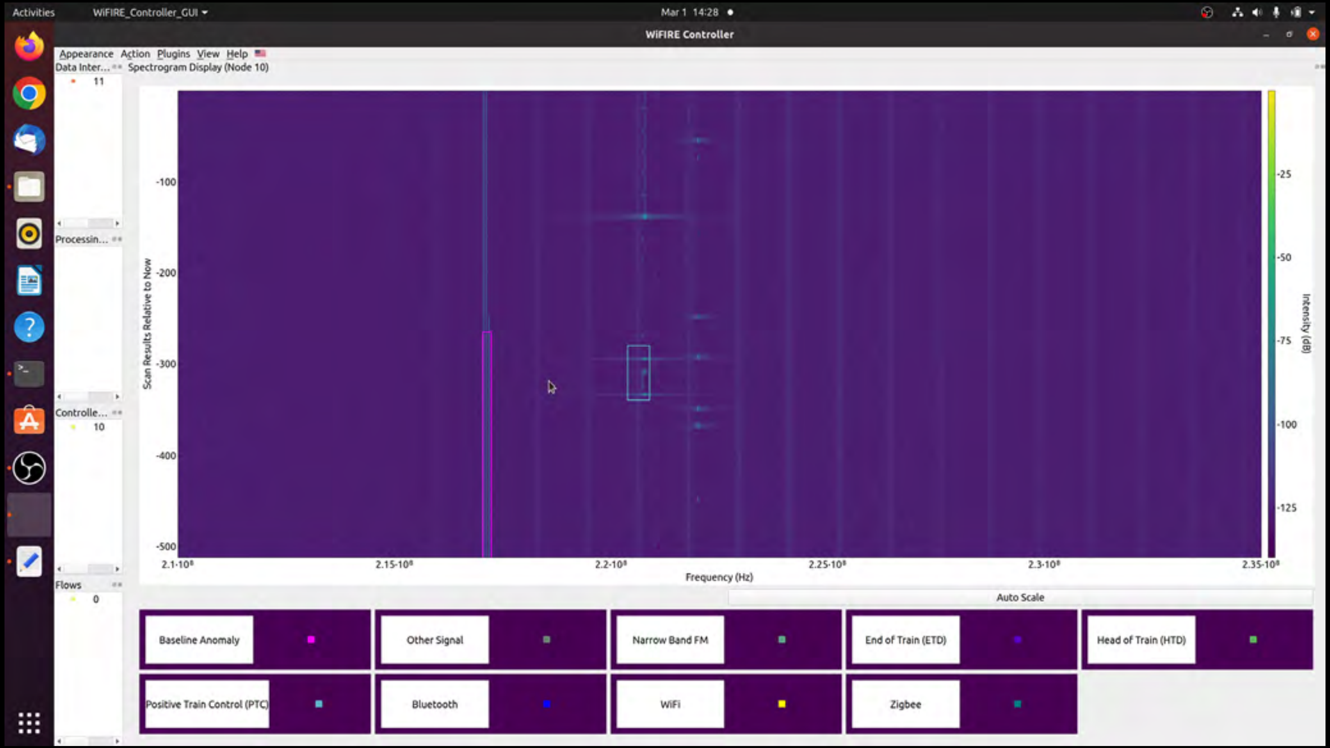
Results (cont).



Results (cont).

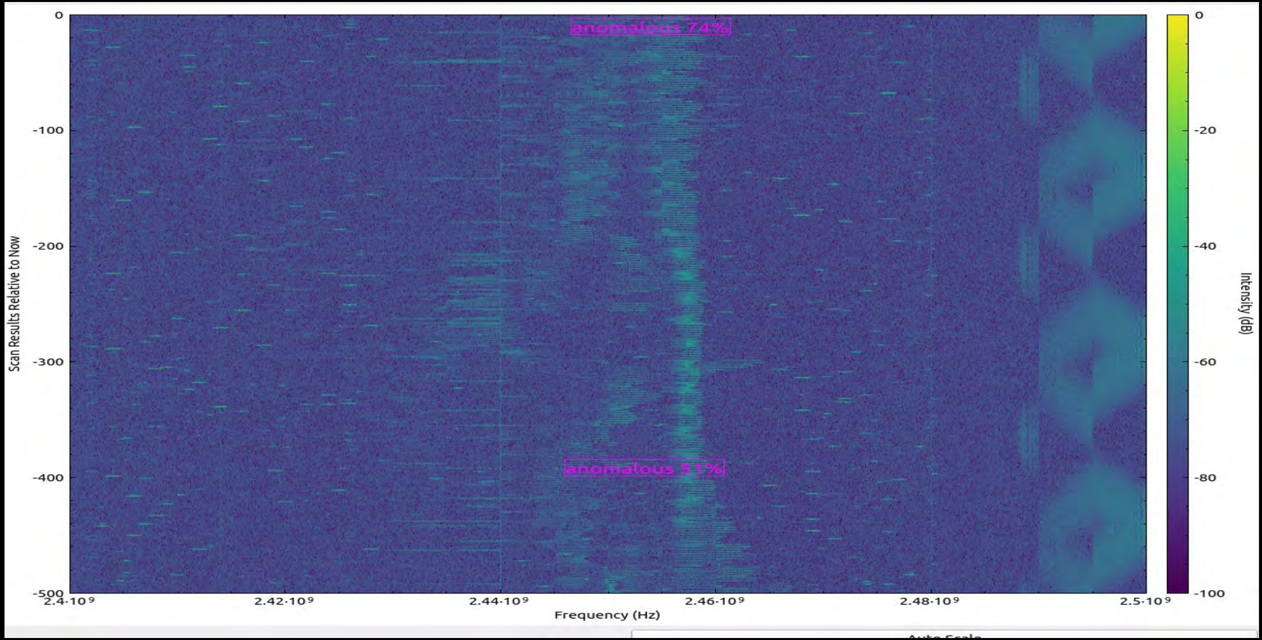


Results (cont).



Weird Anomaly Detected at C3

- Below is an anomaly that we detected using these models. It is in the 2.4 Ghz. range.



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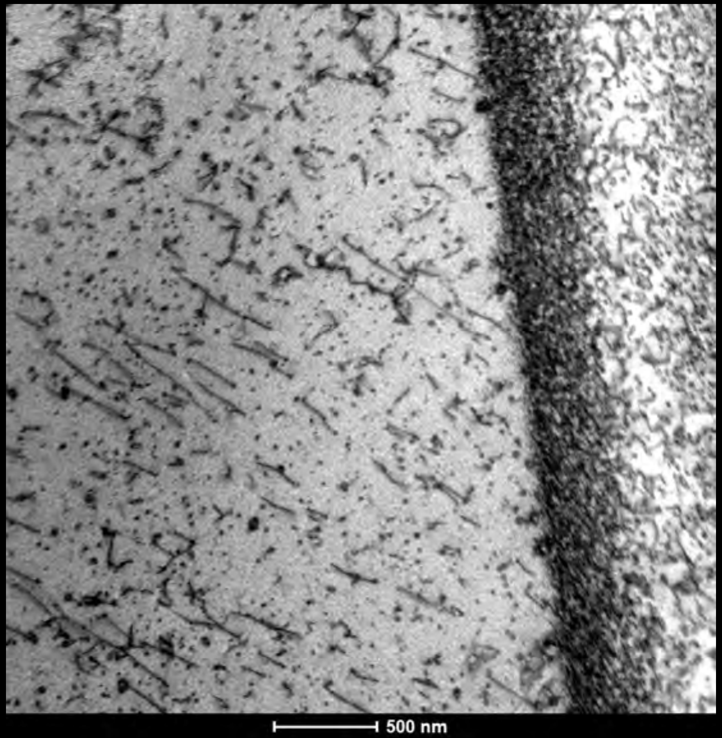
28 Mar 2024

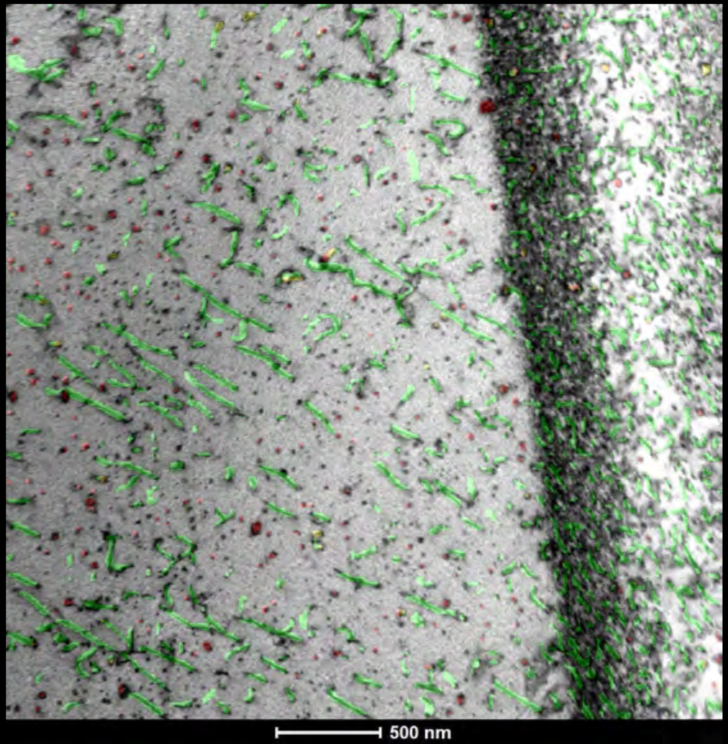
Yolo for Dislocation-Type Defects in PM-HIP Alloys via Transfer Learning

Matthew Anderson, Michael Wu, Jeremy Sharapov

Nuclear Science User Facilities

Yolo for Dislocation-Type Defects via Transfer Learning

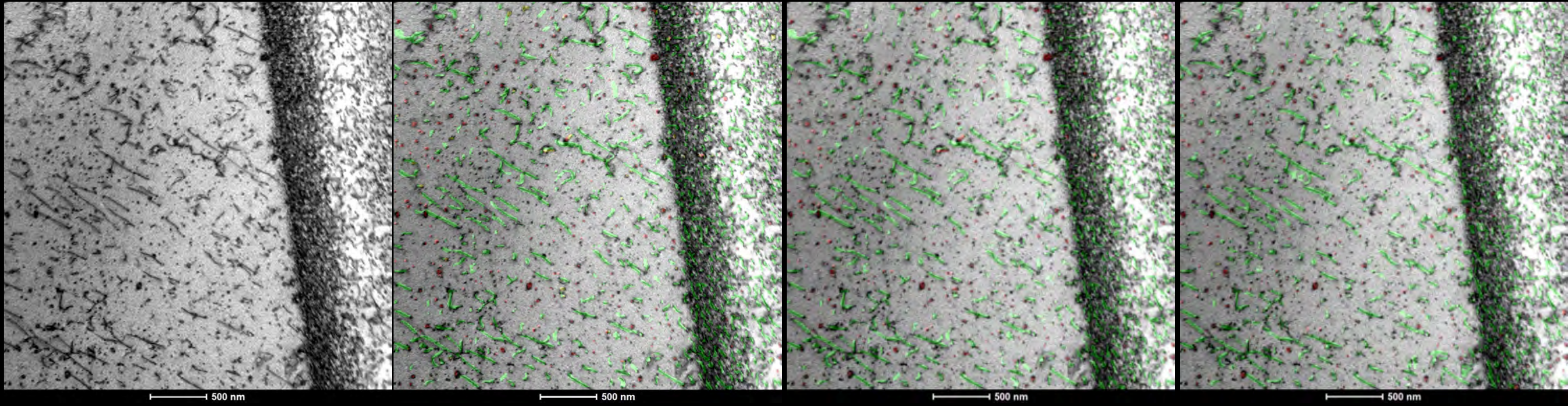




Challenges:

- Experts required to label
- TEM images can be challenging to interpret
- Very small number of images expected to be labelled
- Density and dislocation-type defect identification crucial for material property analysis
- Not a large domain field with large community support

Solution: Transfer Learning



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0.33158

INL High Performance Computing Resources

A right-sized solution for DOE Nuclear Energy research and development

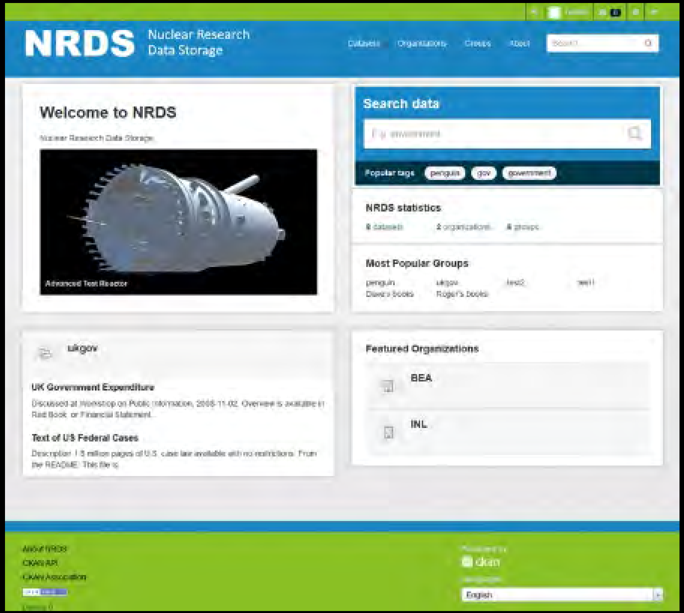
Bitterroot

- 384 Nodes
  - Node specs
    - 2 Sapphire Rapids 56 core CPUs
    - 256 GB RAM
  - 48 nodes with HBM
- 41,888 cores
- 200 Gb/s OmniPath network
- Will complement existing systems (Sawtooth, Lemhi, Hoodoo, Viz)
- Delivery 16 March 2024
- Expected commissioning date: 16 April 2024

Commodity Technology Systems-2 (CTS-2)

NSUF Nuclear Research Data System (NRDS): **https://nrds.inl.gov**

- **NRDS:**
- **Near real time analysis**
- **Publicly available**
- **FpAIRe data**
- **AI analysis**
  - Active detection



Questions?