

WAPITI  CONSULTING



University of Idaho
College of Engineering



Amalgamated
Sugar

Explainable AI solutions for Industry and Water

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Software Developer/ PhD Candidate



Presentation Overview

- Personal Background
- Brief AI Overview From Specialists Perspective
 - AI Onion
 - LLM Comments
 - ML High Level Workflow and Flowchart
- **Industry Examples**
 - Amalgamated Sugar AI Project Example via High Level ML Workflow
 - Aquifer Pumped Hydro
- UI CDA

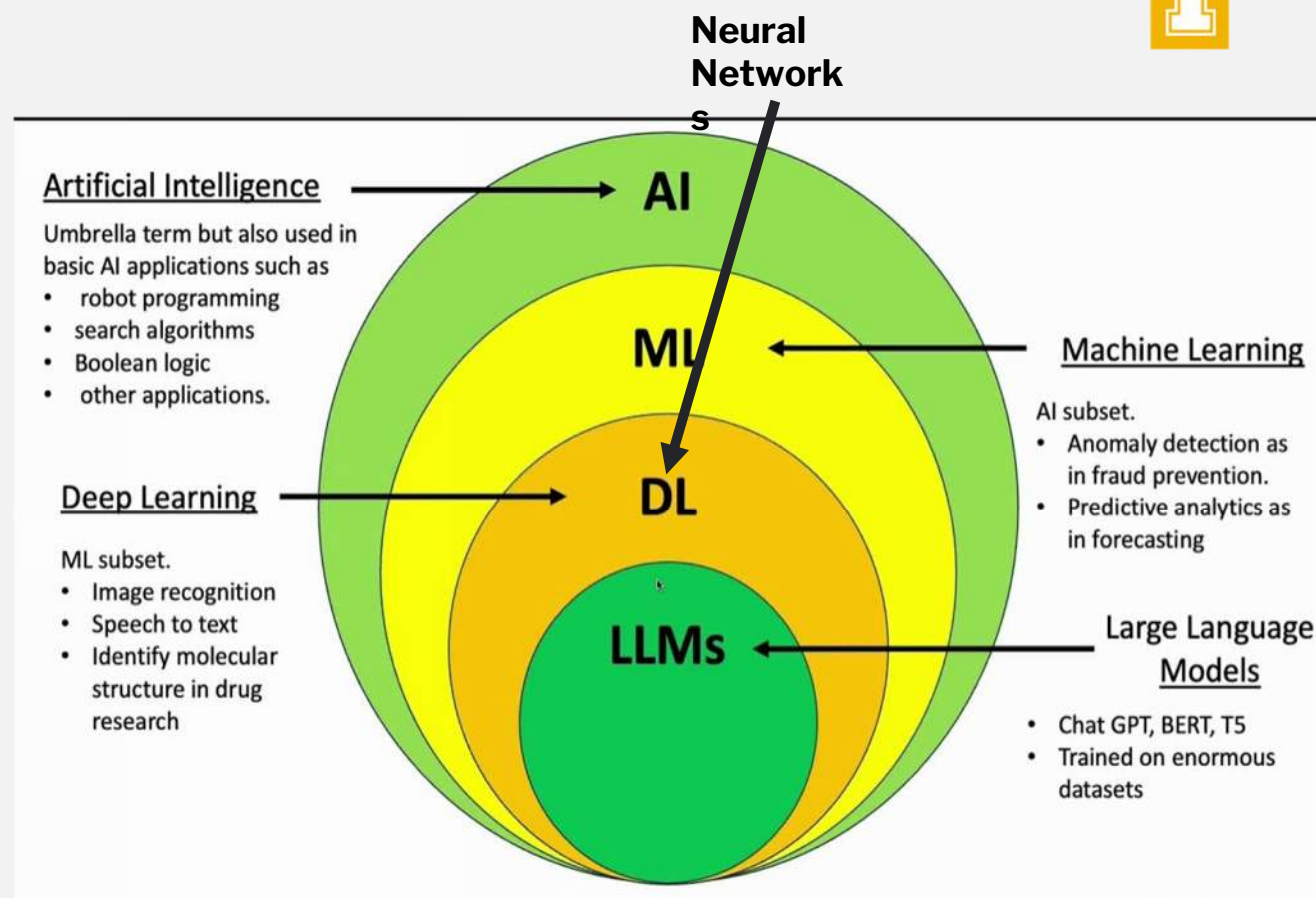


Personal Background

- Education
 - A.S from North Idaho College in Computer Science
 - B.S from University of Idaho (Moscow) Computer Science and Mathematics
 - M.S from University of Idaho (CDA) Computer Science
 - Worked with National Institute for Advanced Transportation Technologies/ PacTrans
 - PhD Candidate as of July 2025
 - Working on Amalgamated Sugar AI research project
- Work
 - NASA Artemis Mission
 - Graduate Researcher
 - Wapiti Consulting
- Career Goal: Solve complex problems in infrastructure and manufacturing using explainable AI models

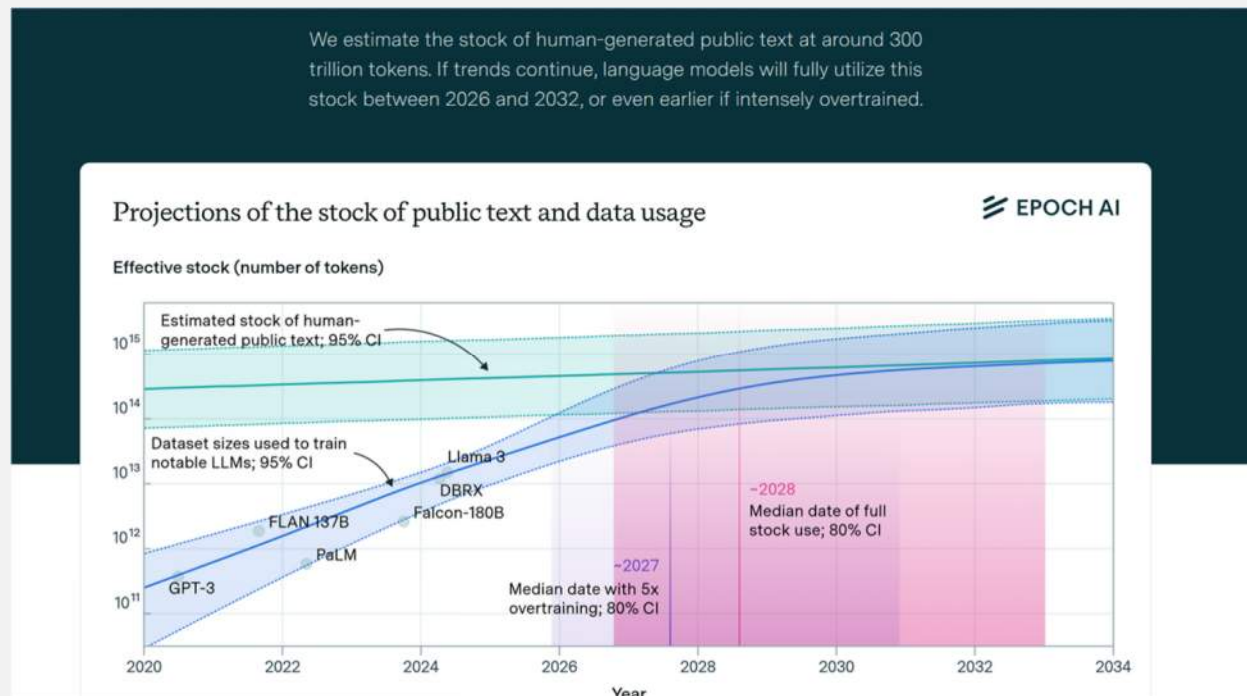
AI Onion

- AI = Very broad Field
 - Started in 1956 at Dartmouth
- Too many acronyms
 - Multiple websites dedicated to defining these acronyms
- Combines science with engineering
 - Writing code = engineering
 - Why is my model inaccurate? = Science
- Would not be surprised if AI eventually becomes its own degree
- Many people think it's just ChatGPT

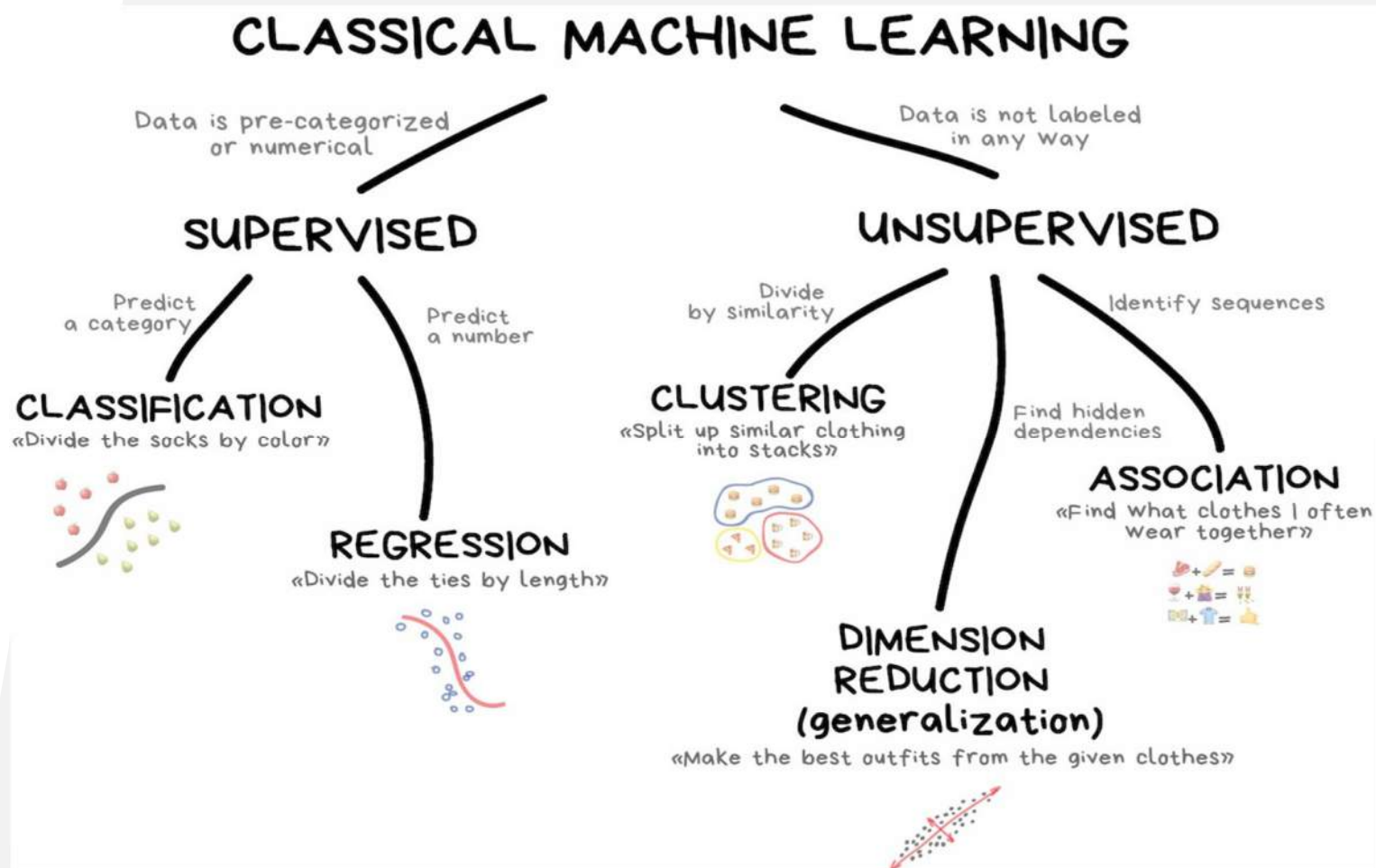


Why I Think You Should Minimally Rely on LLMS

- The amount of new data being produced on the internet is significantly slower than the models consumption
 - 2026-2032 peak
- Companies understanding the value of the data
 - New York Times Sueing OpenAI (ChatGPT) for copyright infringement
- Maybe models themselves will improve on learning from the data but it seems far out
- Synthetic data has a questionable impact



Machine Learning Flowchart



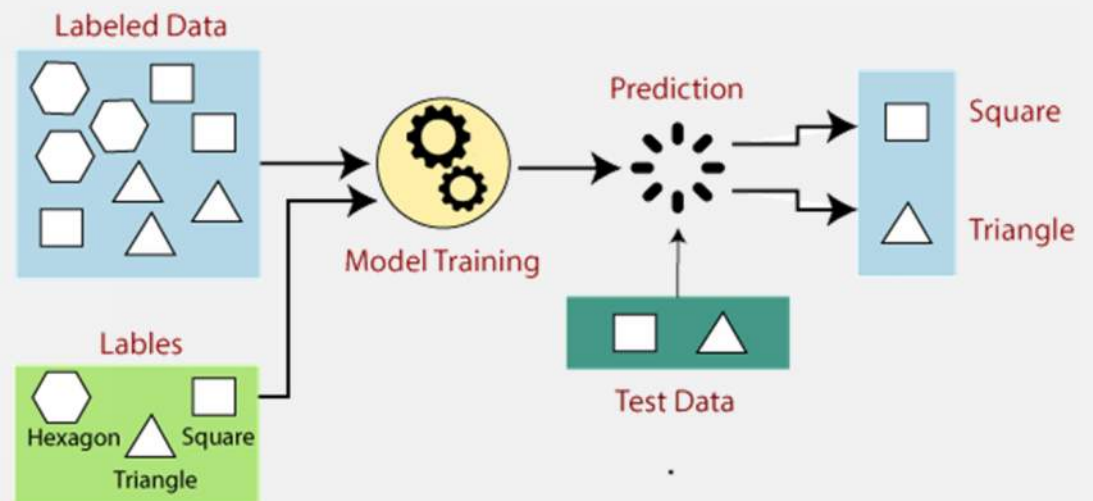
High Level ML Model Development Workflow

- **DATA GATHERING**

- Garbage in = garbage out
- More data is better
 - Can always remove later
 - Hard to know what's relevant.
 - Storage has gotten cheap

- Data formatting/ preprocessing
- Model Selection
- Training the model(s)
- Evaluating and testing the model(s)
 - Need a subject matter expert to help verify models
- Model Integration

EX: Supervised Classification ML Model





AS Research Background

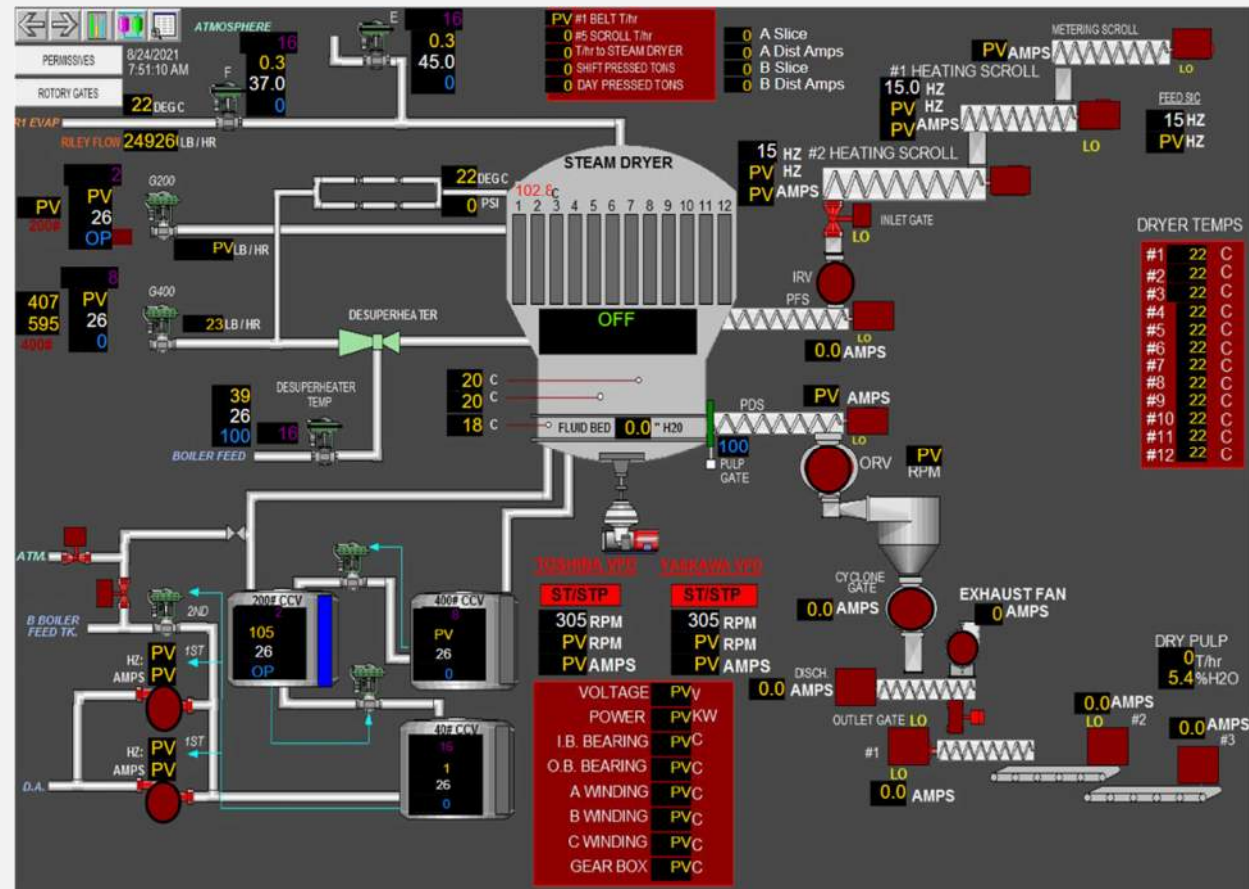
- Amalgamated Sugar
 - Complex real time multimodal process environment
 - Second largest sugar manufacturer in US
 - 1.7% of Idaho's GDP and employs over 1700 individuals
 - Have multiple complex process problems
- Wanted research conducted on their Steam Dryer
 - Biggest issue being a plugging event
 - No engineering solution so far (just guesses)
 - Attempt a “hot standby”
 - 2020 steam dryer malfunction led to 5 individuals going to the emergency room





Steam Dryer Details

- 4 stories tall
- Uses a 200lb and 400lb boiler to dry beet cossettes in roughly 90 seconds.
 - Roughly 75% humidity to around 11%
 - Used for animal feed
- Carries significant financial and safety risks if not properly managed



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Sort & Filter Find & Select Sensitivity Add-ins Analyze Copilot

Timestamp

	A	B	C	D
1	Timestamp	Plugged	Hot Standby Issue	
2	2022-09-3	0	0	0
3	2022-09-3	0	0	0
4	2022-09-3	0	0	0
5	2022-09-3	0	0	0
6	2022-09-3	0	0	0
7	2022-09-3	0	0	0
8	2022-09-3	0	0	0
9	2022-09-3	0	0	0
10	2022-09-3	0	0	0
11	2022-09-3	0	0	0
12	2022-09-3	0	0	0
13	2022-09-3	0	0	0
14	2022-09-3	0	0	0
15	2022-09-3	0	0	0
16	2022-09-3	0	0	0
17	2022-09-3	0	0	0
18	2022-09-3	0	0	0
19	2022-09-3	0	0	0
20	2022-09-3	0	0	0
21	2022-09-3	0	0	0
22	2022-09-3	0	0	0
23	2022-09-3	0	0	0
24	2022-09-3	0	0	0
25	2022-09-3	0	0	0
26	2022-09-3	0	0	0
27	2022-09-3	0	0	0
28	2022-09-3	0	0	0

combined_campaign

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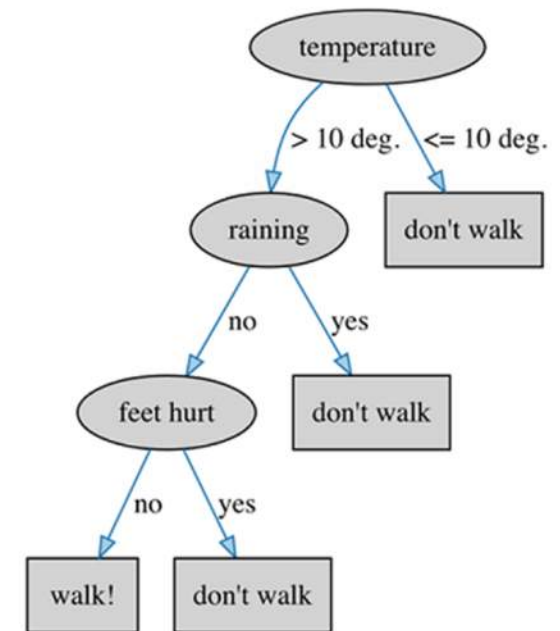
AS Data Formatting/ Processing

- This process changes based upon the “condition” of the data and the models you are using
- Some Data Formatting we did:
 - Establish AS data from 2022 and 2023 as training data and 2024 as testing data
 - ~750,000 data points
 - Remove data points that got removed from the physical process
 - Create labels for issue events
 - **Only ~5% of the time are they in an issue event**
 - Fill in a single missing datapoint with average of before and after data points
 - Fill in chunk of missing data points with mean of column
 - Normalize data points from 0-1



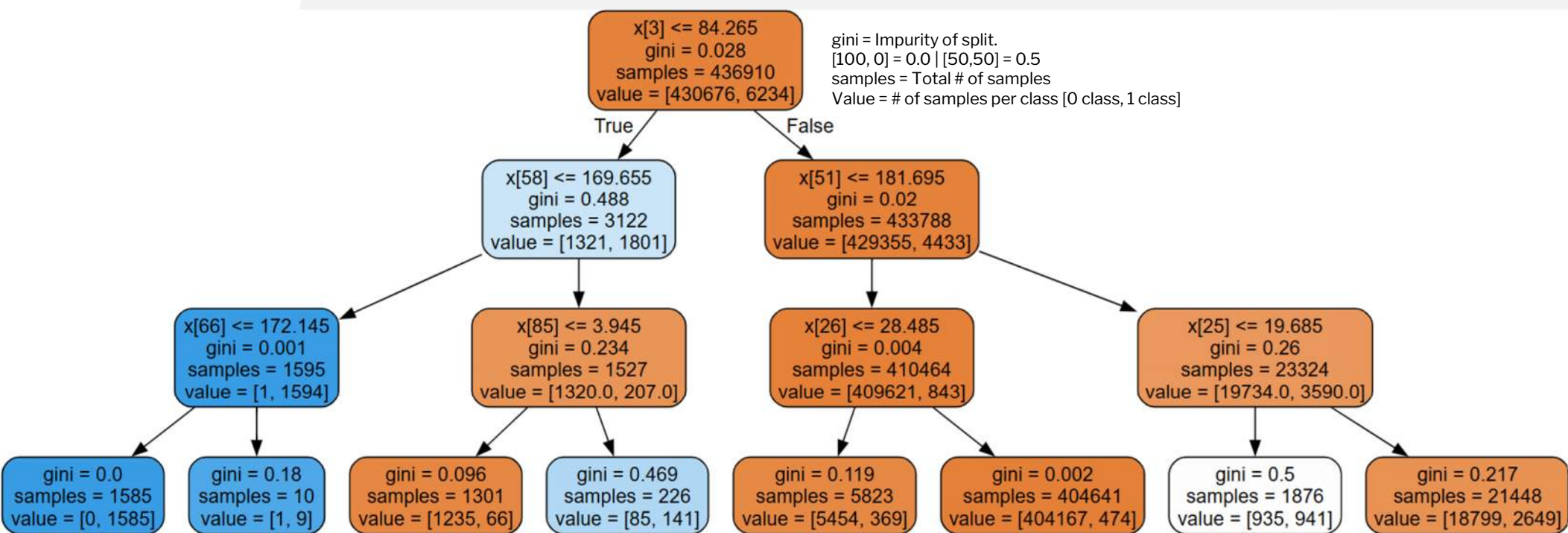
AS Model Selection Decision Tree

- Usually there is some light research to be done here to select a model that fits your problem and data
 - Engineering decision to choose the right tool for the job
- The first model I chose was a decision tree model which functions in a flow chart like fashion
 - Just wanted to see if data showed a solution (without time involved)
- With this model to increase the accuracy I implemented:
 - Hyperparameter Tuning: changing how the model learns
 - IE: Counting with two hands compared to one
 - Adaboosting: Using multiple decision trees in conjunction in a voting fashion
 - IE: Three trees voting if there is an issue or not
- During PhD literature review I found this being used to determine bridge health

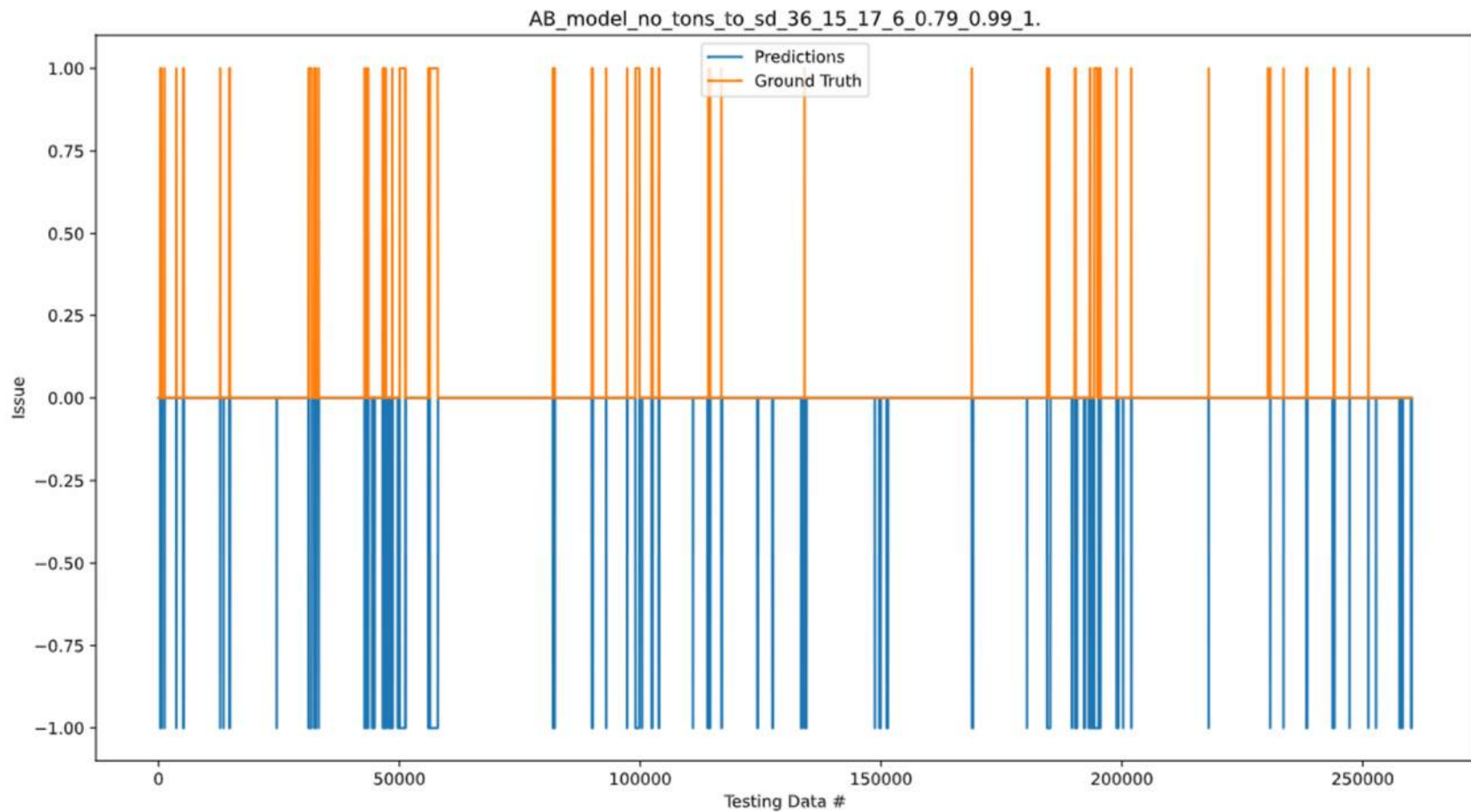




OLD AS Decision Tree Model

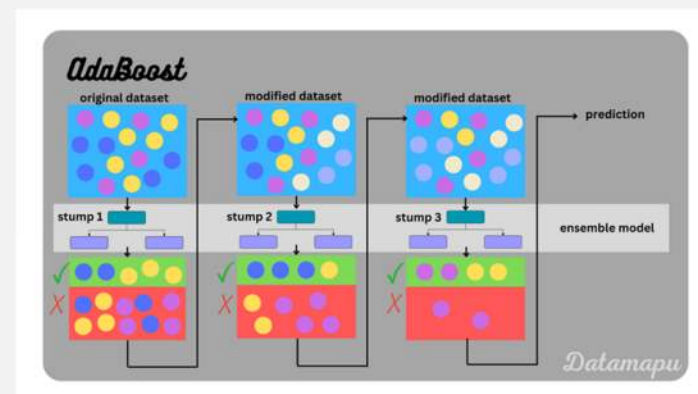


OLD AS Decision Tree Model Results



AS Model Selection Time Offset Dec Tree

- Basically I needed a way to take my decision tree model and incorporate a time aspect so we could predict future issues
- To do this I took a group of data points at a particular time and gave them an outcome/label that was a variable number of minutes in the future
- This is one of the contributions/ unique things I am working on for my PhD
- This model also leveraged hyperparameter tuning and adaboosting



5 Minute Offset Decision Tree Logic

Feature [0,0]	Feature [0,1]	Feature [0,2]		Feature_[0,n]	Label [5]
Feature [1,0]	Feature [1,1]	Feature [1,2]		Feature_[1,n]	Label [6]
Feature [2,0]	Feature [2,1]	Feature [2,2]		Feature_[2,n]	Label [7]
....					
Feature [m-5, 0]	Feature [m-5,1]	Feature [m-5,2]		Feature[m-5,n]	Label [m+5]

N = Number of features (99 for Amalgamated Sugar Project)
M = Number of feature vectors

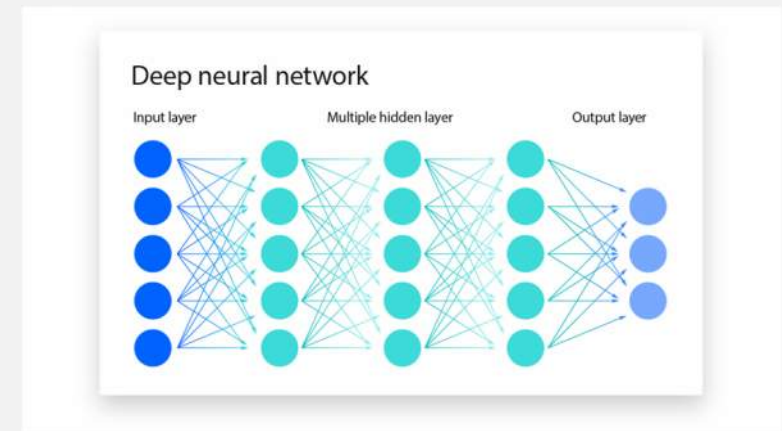
10 Minute Offset Decision Tree Logic

Feature [0,0]	Feature [0,1]	Feature [0,2]		Feature_[0,n]	Label [10]
Feature [1,0]	Feature [1,1]	Feature [1,2]		Feature_[1,n]	Label [11]
Feature [2,0]	Feature [2,1]	Feature [2,2]		Feature_[2,n]	Label [12]
....					
Feature [m-10, 0]	Feature [m-10,1]	Feature [m-10,2]		Feature[m-10,n]	Label [m+10]

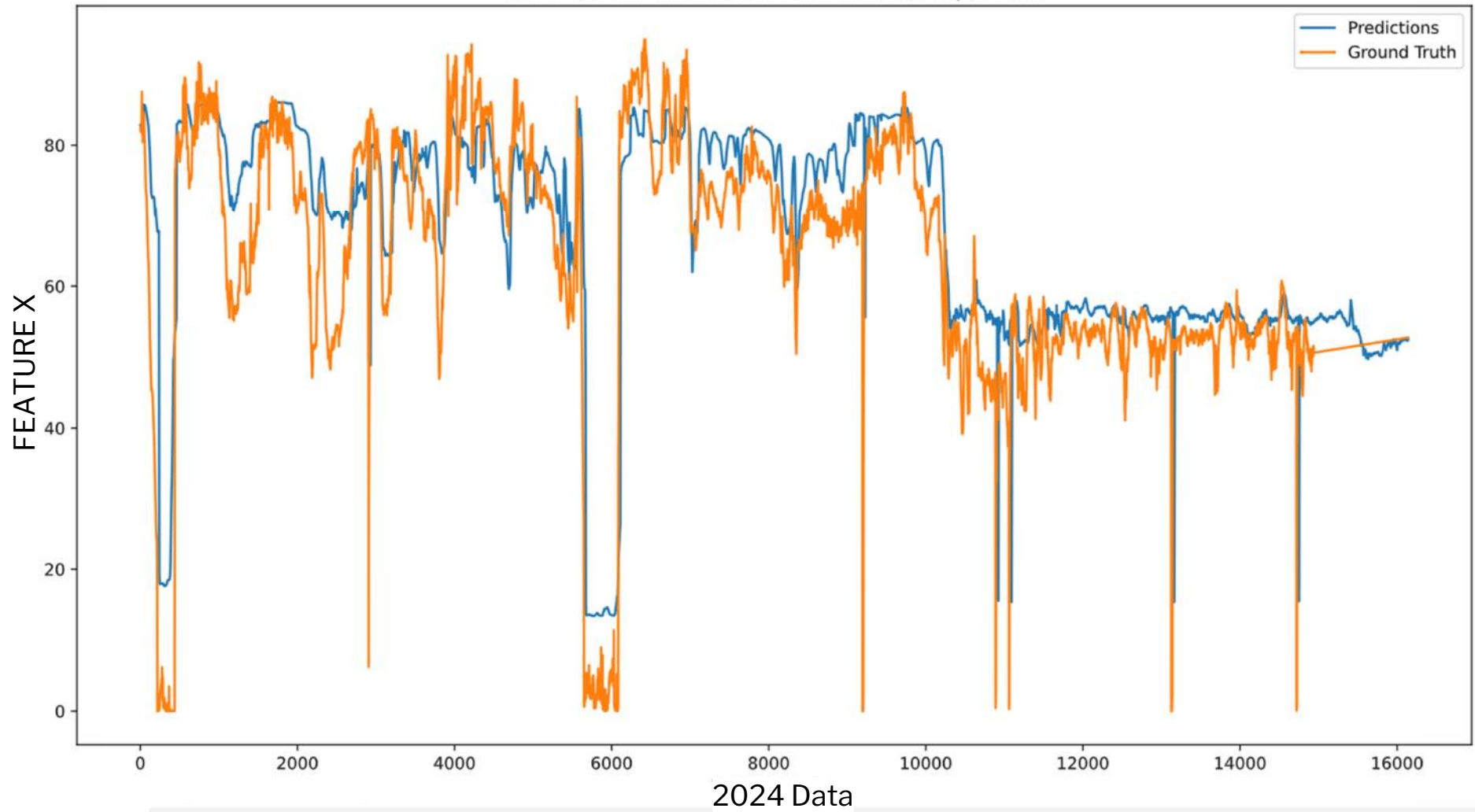
N = Number of features (99 for Amalgamated Sugar Project)
M = Number of feature vectors

AS Model Selection Long Short Term Memory Model

- Defacto model used for future time predictions
- Deep learning model
 - Multiple nodes (neurons) chained together
- Generally has a higher prediction accuracy compared to a decision tree model but lacks explainability
- Takes in a matrix of data where each row is a datapoint and each column is that data points value at that given time
 - This gives the model its “memory”
- For AS it is being used for regression compared to classification (Actually predicting a value)
- In PhD literature review found this model being used for future traffic forecasting

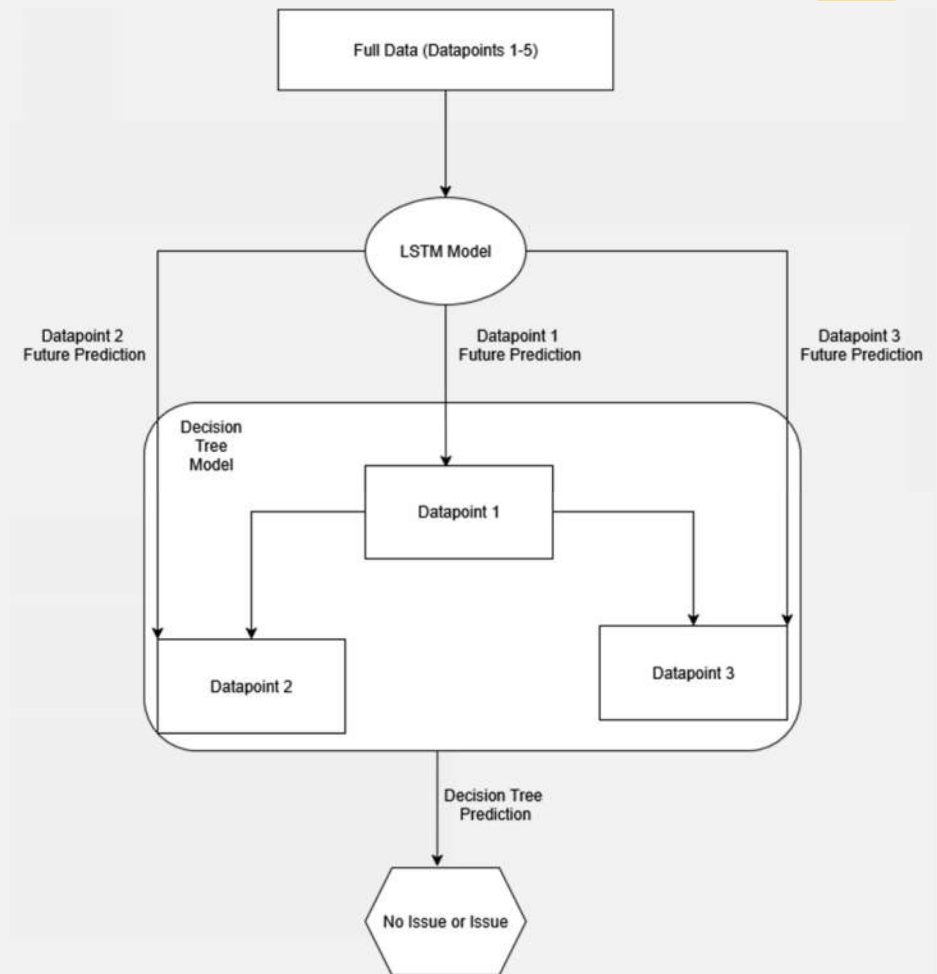


25 Mins LSTM Not Normalized(Seq Len 35)



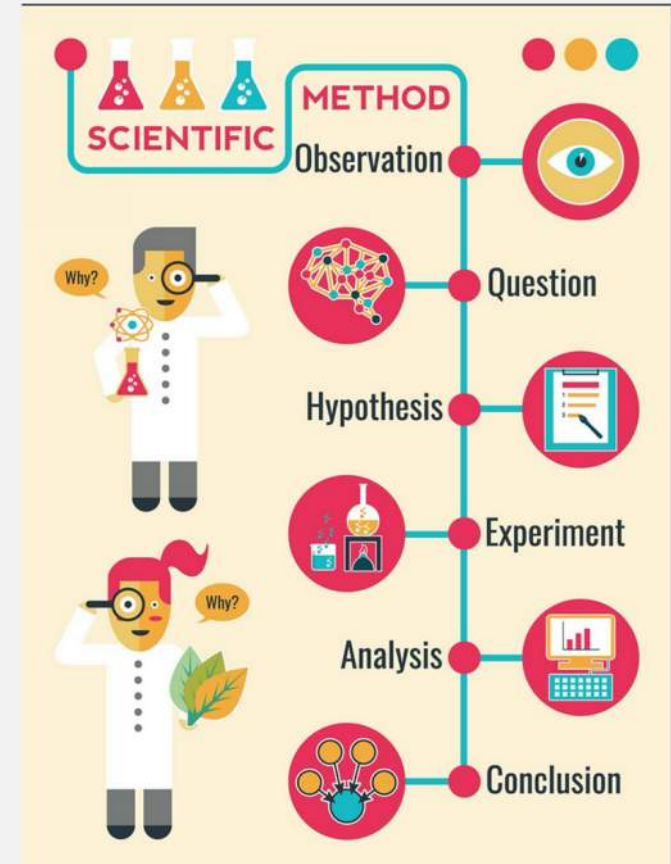
AS Model Selection Hybrid Model

- Very technical model but basically I am using the data points that a decision tree is using to make a issue classification and trying to predict those in the future with the LSTM model
- Unique thing I am implementing for my PhD
- Trying to combine the predictive power of the LSTM with the explainability of the LSTM
- Has been developed but is undergoing testing



Training the Models

- This is where the science kicks in
- Generally this process takes the longest amount of time as there is a large amount of trial and error
 - Many many iterations of highly inaccurate models that take forever to train
- For the Amalgamated Sugar Project the offset decision trees took about 96 days to train and resulted in about 600,000 models that scored above 65% accuracy
- The LSTM models we currently have take about a day per model to train and we are on our 54th iteration
 - Our data point we are predicting ranges from 0-120 units and we are on average off 6.6 units or 5.5%
- Hybrid models are more of an integration challenge given both models are already trained





Testing the models

- Varies based upon the model type
- Decision Trees scored on F1 and Recall
 - F1 = Overall Accuracy
 - Recall = Accuracy of issue events
- Offset Decision Trees Scored on F1, Recall, Overall Time Scoring, Number of Preempted Events and Average Heads up
 - Overall time score = preemptive time - reactive time
 - Number of Preempted Events = Total events out of 95 the model preempted
 - Average heads up = If the model was preemptive how many minutes on average did it give as a heads up

	A	B	C	D
1	Model Name	Overall Time Score	Number of Preempted Events	Average Heads up (Minutes)
2	AB_off_model_no_tons_to_sd_38_57_30_6_0.69_1.0_19.173469387755102		72	12.583333333333334
3	AB_off_model_no_tons_to_sd_19_8_28_6_0.67_0.83_18.540816326530612		71	12.309859154929578
4	AB_off_model_no_tons_to_sd_25_3_27_6_0.74_0.99_18.918367346938776		71	12.43661971830986
5	AB_off_model_no_tons_to_sd_35_44_26_6_0.73_1.0_19.173469387755102		71	12.76056338028169
6	AB_off_model_no_tons_to_sd_44_39_29_6_0.7_0.99_19.551020408163266		71	13.295774647887324
7	AB_off_model_no_tons_to_sd_53_12_29_6_0.69_0.88_8.887755102040817		71	12.408450704225352
8	AB_off_model_no_tons_to_sd_41_23_29_6_0.7_1.0_1_9.265306122		69	13.318840579710145
9	AB_off_model_no_tons_to_sd_11_46_29_6_0.71_0.99_6.622448979591836		68	12.602941176470589
10	AB_off_model_no_tons_to_sd_10_30_28_6_0.7_0.99_17.010204081632653		68	13.161764705882353
11	AB_off_model_no_tons_to_sd_21_43_28_6_0.7_0.99_17.010204081632653		68	13.161764705882353
12	AB_off_model_no_tons_to_sd_20_22_29_6_0.71_0.99_6.622448979591836		68	12.602941176470589
13	AB_off_model_no_tons_to_sd_11_56_28_6_0.7_0.99_17.010204081632653		68	13.161764705882353
14	AB_off_model_no_tons_to_sd_14_3_28_6_0.71_0.99_16.622448979591836		68	12.602941176470589
15	AB_off_model_no_tons_to_sd_13_22_29_6_0.71_0.99_6.622448979591836		68	12.602941176470589
16	AB_off_model_no_tons_to_sd_17_27_29_6_0.71_0.99_6.622448979591836		68	12.602941176470589
17	AB_off_model_no_tons_to_sd_1_1_28_6_0.7_0.99_1_17.010204081632653		68	13.161764705882353
18	AB_off_model_no_tons_to_sd_1_20_28_6_0.7_0.99_1_7.010204081632653		68	13.161764705882353
19	AB_off_model_no_tons_to_sd_22_0_29_6_0.71_0.99_16.622448979591836		68	12.602941176470589

Testing the models Cont

- LSTM in simple terms is scored on average how many units off is the prediction
 - Our data point we are predicting ranges from 0-120 units and we are on average off 6.6 units or 5.5%
- The hybrid model can be scored on all the prior metrics.
 - For PhD will we find all of these out
 - For the project itself we just care how many events it preempted and what was its average heads up
- Lastly subject matter expert verification
 - Do data points make sense
 - ML researchers are really bad at overestimating their model accuracies



Basic Decision Tree Results

- Basic Decision Tree (No hyperparameter Tuning & No adaboosting)
 - Recall 42% and 50% on F1
- Enhanced Decision Tree (Hyperparameter Tuning)
 - Highest Recall Scoring Model: 99% recall and 78% on F1
 - Highest F1 Scoring Model: 93% recall and 85% on F1
- Advanced Decision Tree (Hyperparameter Tuning and Adaboosting)
 - Highest Recall Scoring Model: 99% recall and 79% on F1
 - Highest F1 Scoring Model: 96% recall and 86% on F1



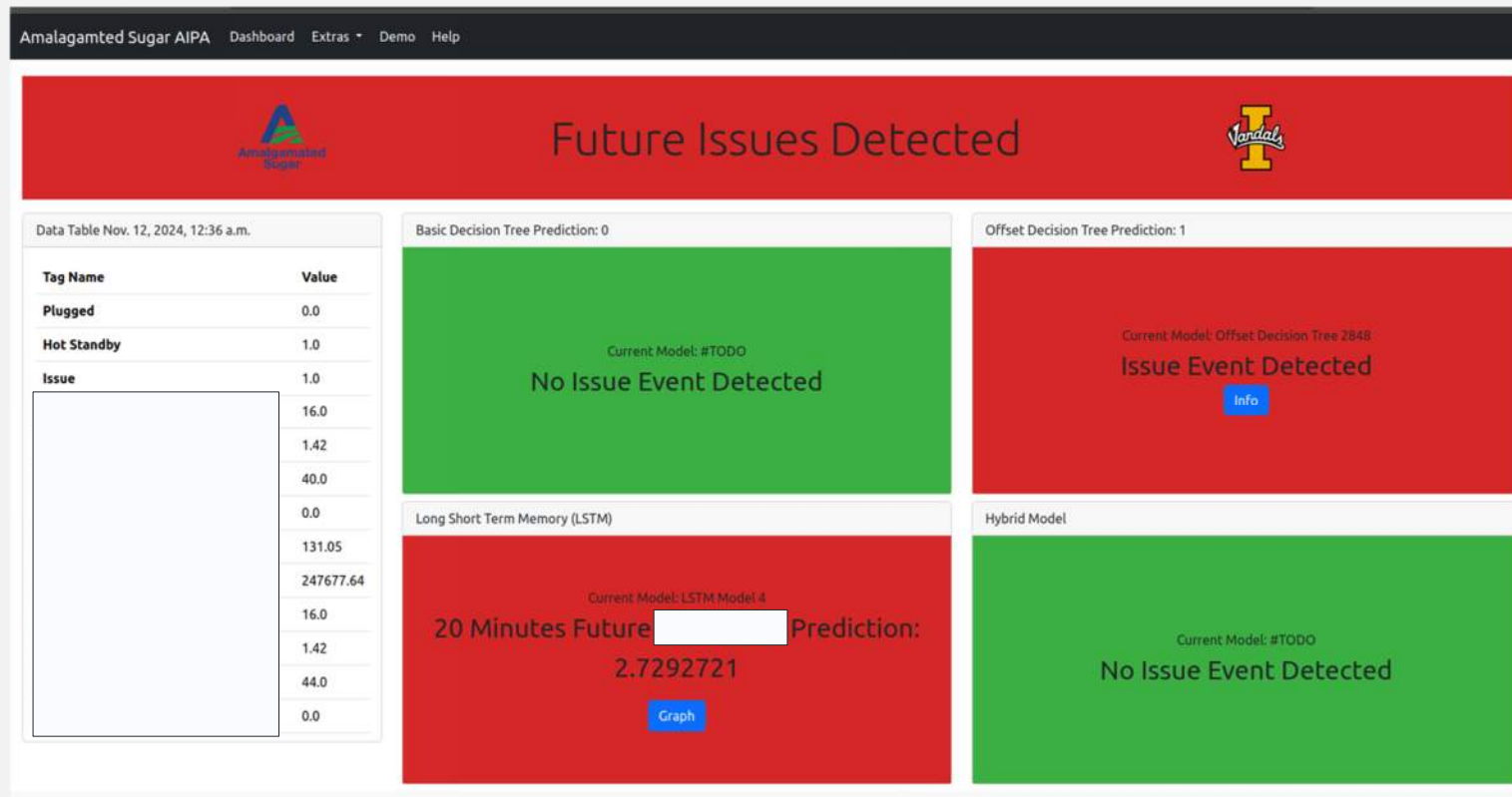
Offset Decision Tree Results

- Over 600,000 tree combinations scored above 65% on Recall and F1
- Not fully finished testing these models but the best predicted 75 of the 95 events in 2024 with an average heads up of 13 minutes
- Project ROI is hard to guess (due to safety being involved) but from a product standpoint we estimate a break even of 7.11 hours of prevented down time



Model Integration: AI Predictive Appliance (AIPA)

- Informative display of ML model predictions for an operator
- Will down the line be a basis for additional AI/ML projects
- The next steps:
 - Create digital twin of steam dryer
 - Have model make control decisions on simulator





AS Problems Encountered

- Non labeled data
 - Did not log when there was an issue so we needed to generate labels for the data
- Very few times where the steam dryer was labeled as an “Issue” (~5%)
 - Similar to infrastructure with minimal downtime
- Processes changes through campaigns
 - Decide what data points to keep and what to toss
- Cyber attack in 2024 which messed with testing data



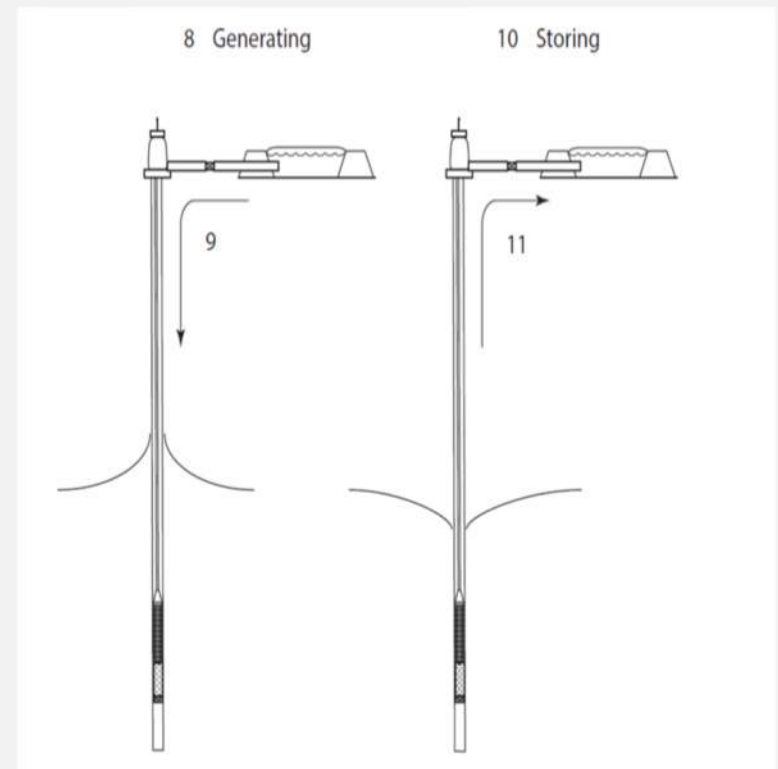
AS Return on Investment

- Does not include safety and cascading problems into ROI
- Preventing 1 plugging event basically equals out the cost of the project
- Best model preempted 72/95 (75%) total events in 2024
- Beet processing is ~4 months or ~2880 hours
 - Roughly 5% of the 2,880 hours the SD is down
 - 144 hours of being down
 - If we can prevent 75% of the 144 hours
 - 108 more hours of the steam dryer being running
- $108 * 25,500 = \$2.7$ Million Cost savings
 - 25% preemption = \$918,000 Cost Savings

40lbs of beet feed	\$17	https://www.tractorsupply.com/tsc/product/s
40lb beet feed * Store 50% Markup	\$8.5 AS selling price	
60 tons an hour on average	120,000 lbs an hour on average	Convert Tons to lbs
120,000 lbs / 40 lbs (sellable size)	3,000 40lb bags made in an hour	
3,000 bags * \$8.50 per bag	\$25,500 loss for being down for 1 hour	Assuming Total Loss of beets during that time
Project Cost \$200K / \$25,500	7.84 hours of prevented shutdowns to break even	

Aquifer Pumped Hydro Background

- “The liquid battery that you already have”
 - Essentially taking a municipal well and allowing it to make power
- Hydropower generation by the potential energy difference between surface and groundwater via a well
- During the aquifer recharge or aquifer storage process a pumping motor is allowed to run in reverse and therefore is converted to a generator
 - Take power from the DC bus of Variable Frequency Drive and feed that into a inverter that synchronizes with the 3 phase AC power grid



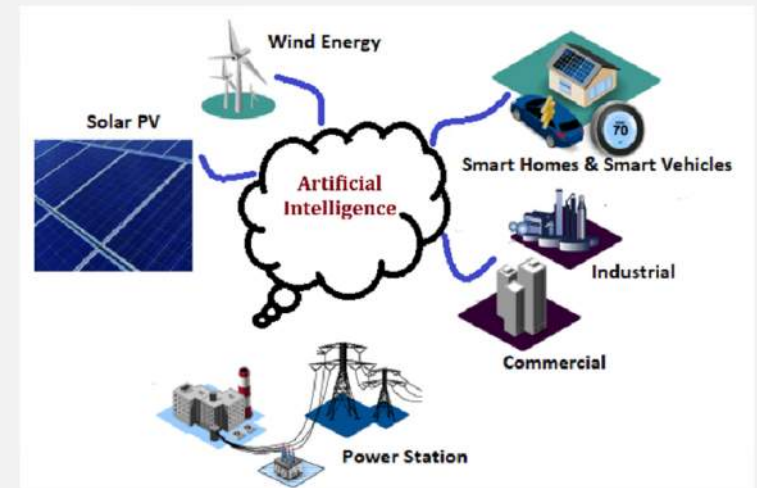


Benefits of Aquifer Pumped Hydro

- Works with both above ground vertical line shaft applications and submersible pumps
- Can also be easily retrofitted to existing well systems.
- NSF Certified
- Currently being funded by the California Energy Commission (CEC) and FERC
 - Current capacity cost estimate of \$380/kWh is less than a lithium battery at about \$470/kWh.
Also has a service life of 25-50 years compared to 3.
 - Right around 45% round trip efficient but there are lots of improvements that can be made
 - Biggest limiting factor is Hydraulic transmissivity of the aquifer (which should improve over time)
- “ The flat Central Valley has over **100,000 wells**. They could be retrofitted to release energy.
Each well could become a small energy storage facility.”

Aquifer Pumped Hydro Need for AI

- The U.S. grid consists of 6,400 power plants, 3,000 companies, and 55,000 substations, but they're usually not manned.
- In California's central valley alone there could be over 100,000 APH units
 - How do you control these? Each well is unique
 - Solar Integration?
 - Controlling the grid's power factor?
 - How to you ensure there is enough surface water for demand?
 - How do ensure there are no more rolling blackouts?
- There is the need for advanced prediction and controls capabilities



- [illegible]



UI CDA Overview

- Located directly on the North Idaho College campus in downtown CDA
- Home of the Center for Intelligent Robotics (CIIR)
 - Industry focused research center. Want to solve really hard problems
 - Currently have 4 main research areas with endless application areas
 - Robotics
 - Manufacturing
 - Artificial Intelligence/ Machine Learning
 - Precision Agriculture
 - Some notable industry projects
 - Inland Empire Paper Wastewater Treatment Project
 - Wildwood Grilling Rejection System
 - ATC Manufacturing (3D Scanner to use AI to compare scan to CAD file for inspection differences)
 - Laurel Grove Wine Farm (Predict frost events in future)
 - Sensor Collection and Remote Environment Care Reasoning Operation (Scarecro)
 - USDA & USFS Weed Eradication Robot
 - Schweitzer Engineering Lab Defect Detection



UI CDA Project Structure

- Senior Capstone Project:
 - 4 undergraduates for 10 hours a week.
 - Good to improve on something already existing, or small prototypes. Occasionally product oriented
 - Approx cost: \$2000 + expenses
 - Example Projects: Simulate Paper cutting, wildwood grilling rejection system, etc
- Masters Project:
 - Graduate student for 20 hours a week for 2 years
 - Can be work or research focused
 - Approx cost: \$120K
 - Example Projects: LoRaWAN, AIPA dashboard and OPCUA connection, etc
- PhD Project:
 - Graduate student for 30 hours a week for 2 years.
 - Must be research. Application of the research is generally required
 - Approx Cost: \$170K
 - Amalgamated Sugar AI Fault Prediction, SEL Manufacturing Data Analysis, IEP Wastewater Analysis etc.
- Contact jshovic@uidaho.edu



Sources

- AI Onion Image: https://www.youtube.com/watch?v=LoTuTu_Z4Pk
- ML Flow Chart: <https://devopedia.org/supervised-vs-unsupervised-learning>
- Data Quality Image: <https://www.cloudfactory.com/training-data-guide>
- AI workflow Image: <https://www.acte.in/wp-content/uploads/2022/01/What-is-Supervised-Learning-ACTE.png>
- Dec Tree Graph: <https://help.pyramidanalytics.com/Content/Root/MainClient/apps/Model/Model%20Pro/Data%20Flow/ML/DecisionTree.htm>
- APH 1 https://img1.wsimg.com/blobby/go/5d9ba30a-393d-4213-b97e-e1e678db29b6/downloads/EPC-20-008%20Executive_Summary%20Group_1%20200%20kW.pdf?ver=1732641454730
- APH 2 <https://img1.wsimg.com/blobby/go/5d9ba30a-393d-4213-b97e-e1e678db29b6/downloads/EPC20-008%20Attachments.pdf?ver=1732641454730>
- APH 3 <https://img1.wsimg.com/blobby/go/5d9ba30a-393d-4213-b97e-e1e678db29b6/downloads/EPC-15-049%20Aquifer%20Pumped%20Hydro.pdf?ver=1732641455211>
- APH 4 <https://img1.wsimg.com/blobby/go/5d9ba30a-393d-4213-b97e-e1e678db29b6/downloads/NGWA%20MAR%20presentation%20April2023.pdf?ver=1732641455144>
- APH 5 <https://aquiferpumpedhydro.com/home>
- Power Grid Facts: <https://www.heritage.org/homeland-security/commentary/substations-the-weakest-link-americas-power-grid>
- AI Power Grid Image: https://www.researchgate.net/figure/AI-and-Distributed-Energy-Resources-utilization-of-existed-energy-resources-With-this_fig1_372174005
- LLM Issue Image: <https://epoch.ai/blog/will-we-run-out-of-data-limits-of-llm-scaling-based-on-human-generated-data>
- Epoch AI Image: <https://epoch.ai/blog/will-we-run-out-of-data-limits-of-llm-scaling-based-on-human-generated-data>
- Adaboosting Image: https://datamapu.com/posts/classical_ml/adaboost/
- History of AI: https://en.wikipedia.org/wiki/History_of_artificial_intelligence
- Feature Vector: <https://www.hopsworks.ai/dictionary/feature-vector>

Questions?

