Anomaly Onset in the Fermilab LINAC using L-CAPE

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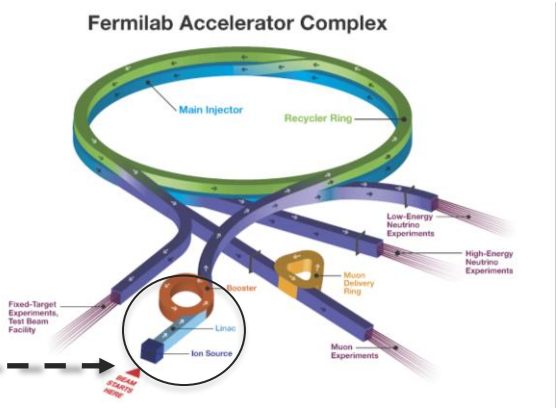
Objective

Use Anomaly Detection to predict beam outages, and clustering to identify classes of outages in the LINAC (Linear Accelerator). Beam outages mean less beam for research, and lost time, while identifying outage classes is a necessary first step to automating mitigation or prevention measures.

Linac

- Beginning of accelerator complex
- 500-foot straight accelerator
- Brings proton beams up to energies of 400 MeV (~ 70% of the speed of light)
- Provides a proton beam for the Booster accelerator and the rest of the chain of accelerators

- Uses radiofrequency(RF) power
- 2500+ control system devices including RF system devices



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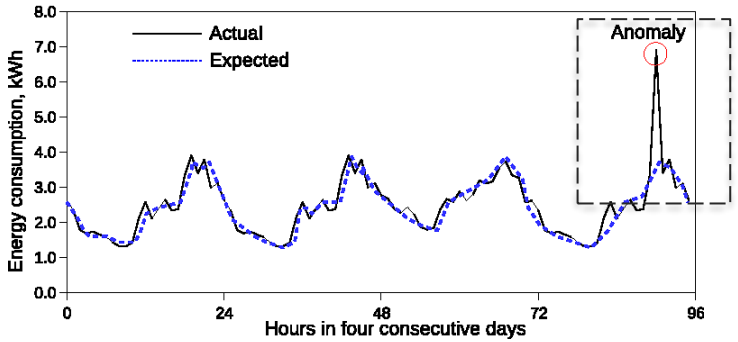
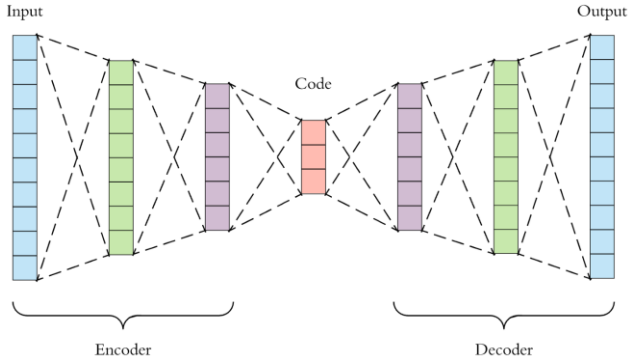
Anomaly Detection

- Machine learning tool/Handles large datasets
- Used here to predict beam outages
- Trained an autoencoder on each device so increasing **reconstruction errors** will suggest anomalies
- Difference between expected data and actual data is the **reconstruction error** for one device
- Identifying data points in data that are outliers





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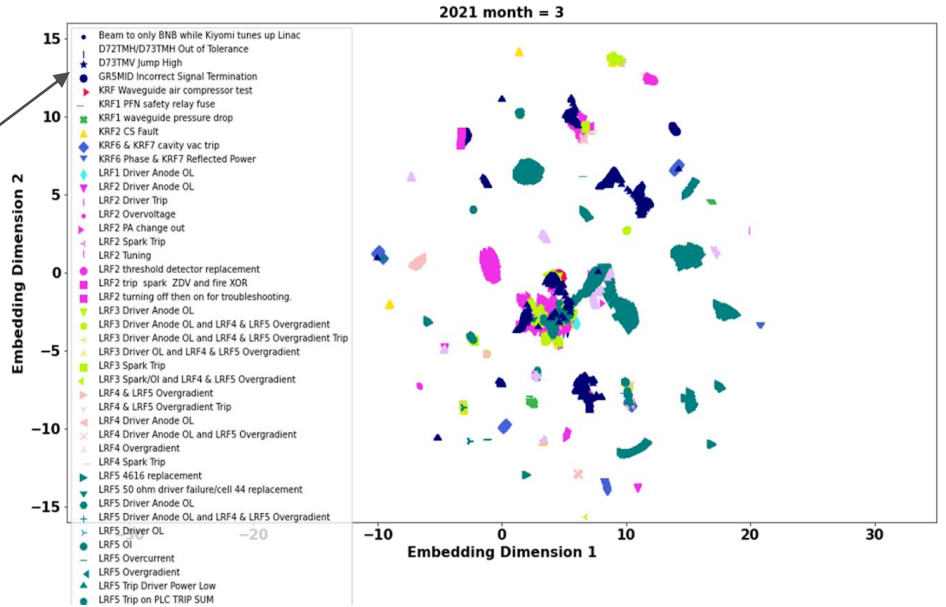
Characterizing Outages

- Dimensionality reduction by **UMAP**(Uniform Manifold Approximation and Projection) projecting 250 dimensions (**reconstruction error)** to two
- One entry for every 10secs of outage
- Color-coded by group and RF Station
- Shape-coded by fault type (cluster characterization)



- Where is normal operation on this plot?
- How do we transition to anomalies? Quickly? Slowly?
- Can we predict an upcoming anomaly?

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Reference

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Thank you!!