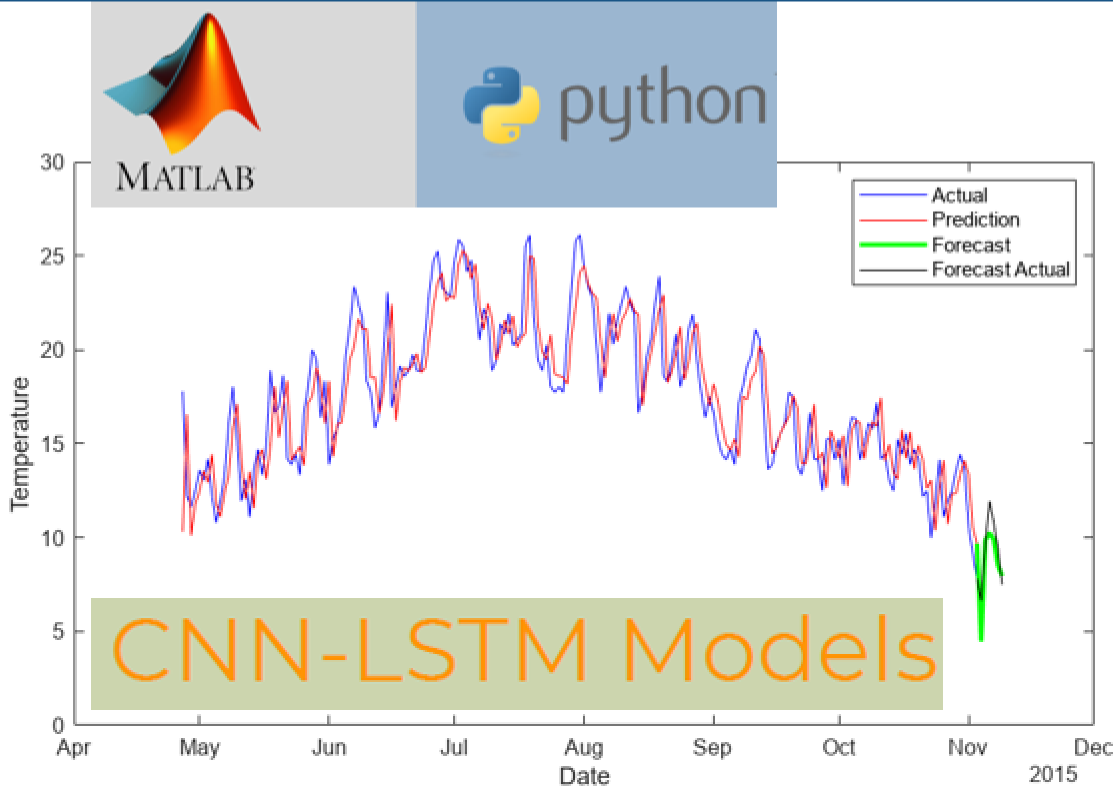
**Control Tech LAB**

- Data Generation and Preparation
- LSTM Model Build
- LSTM Model Training
- LSTM Prediction Validation
- LSTM Forecast Validation

## Unsupervised Learning

Unsupervised learning explores unlabeled data to find patterns and structures without explicit guidance or predefined labels.



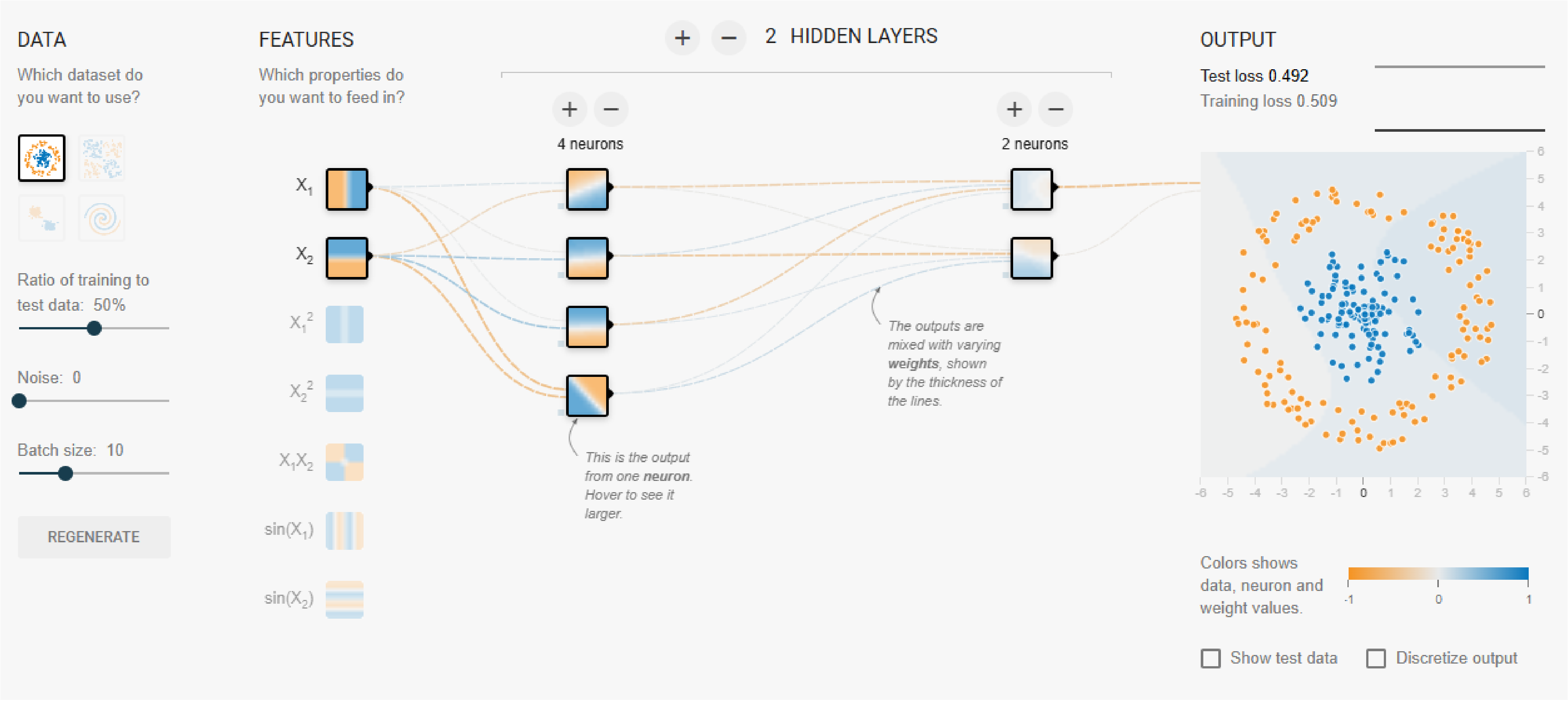

# Machine learning

Control Tech LAB

## Working with:

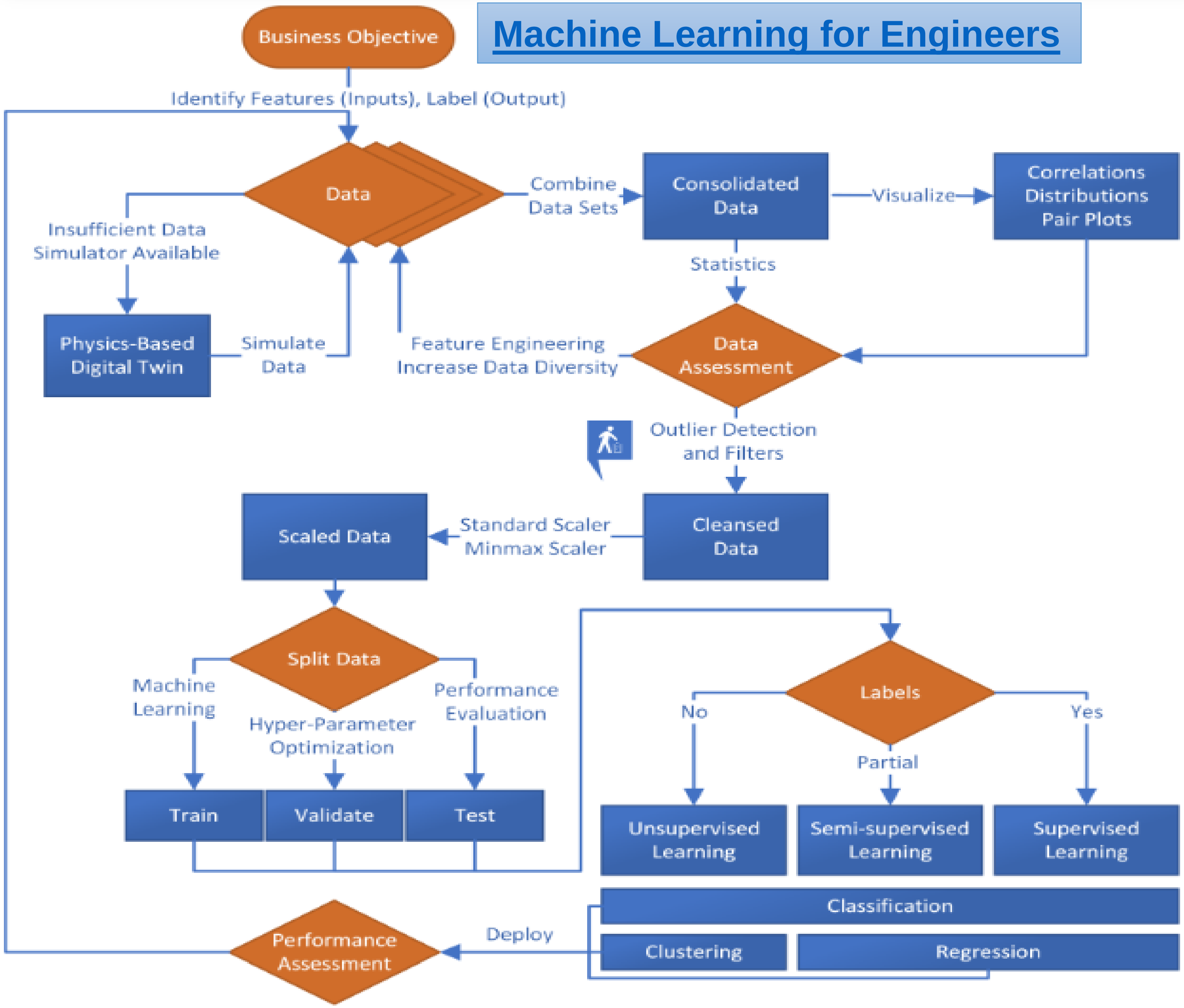
1. Introduction to Machine Learning Unsupervised Learning with a Presentation
2. Live Script Python and MATLAB RRN LSTM Model for Prediction and Forecasting Temperature

# playground.tensorflow



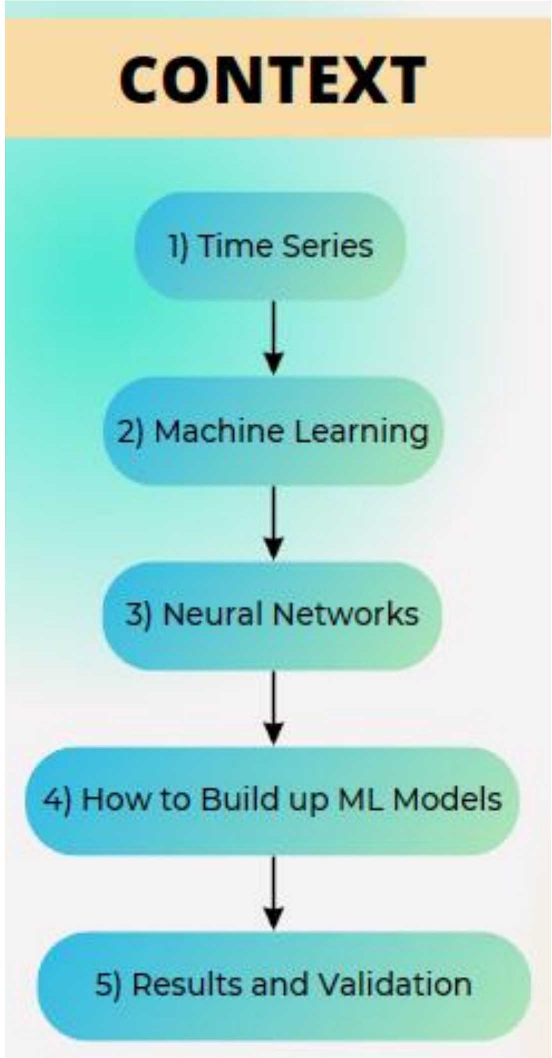

https://playground.tensorflow.org/#

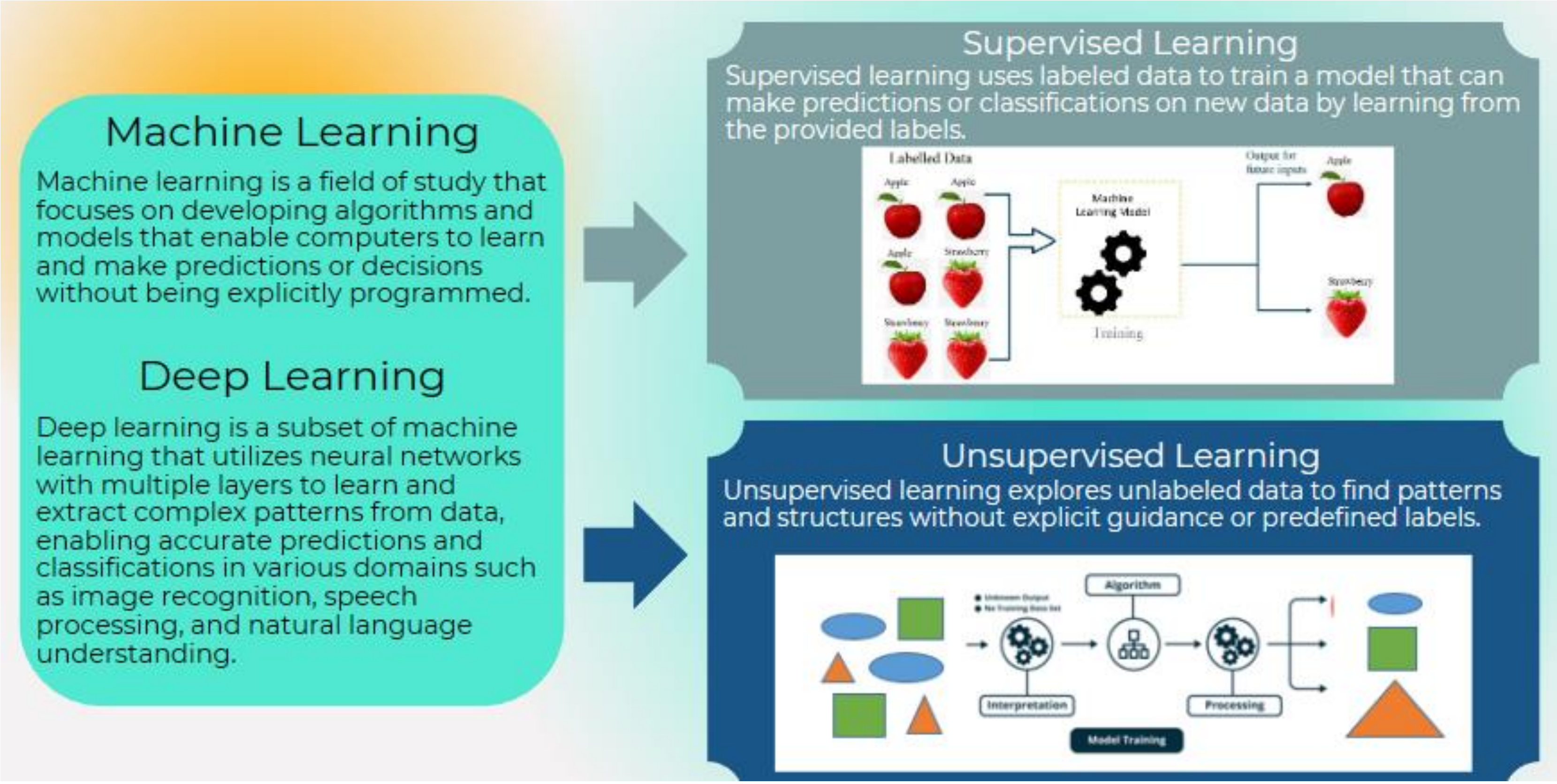
# Machine Learning for Engineers




https://apmonitor.com/pds/index.php/Main/CourseSchedule

# An Optimized Deep Learning Approach for Forecasting Temperature



## Selecting the Right Algorithm

Selecting the right machine learning algorithm involves balancing trade-offs between flexibility, interpretability, speed, accuracy, and complexity, with no single best method available. Trial and error is essential, as even experienced data scientists need to test different algorithms to find the most effective one.

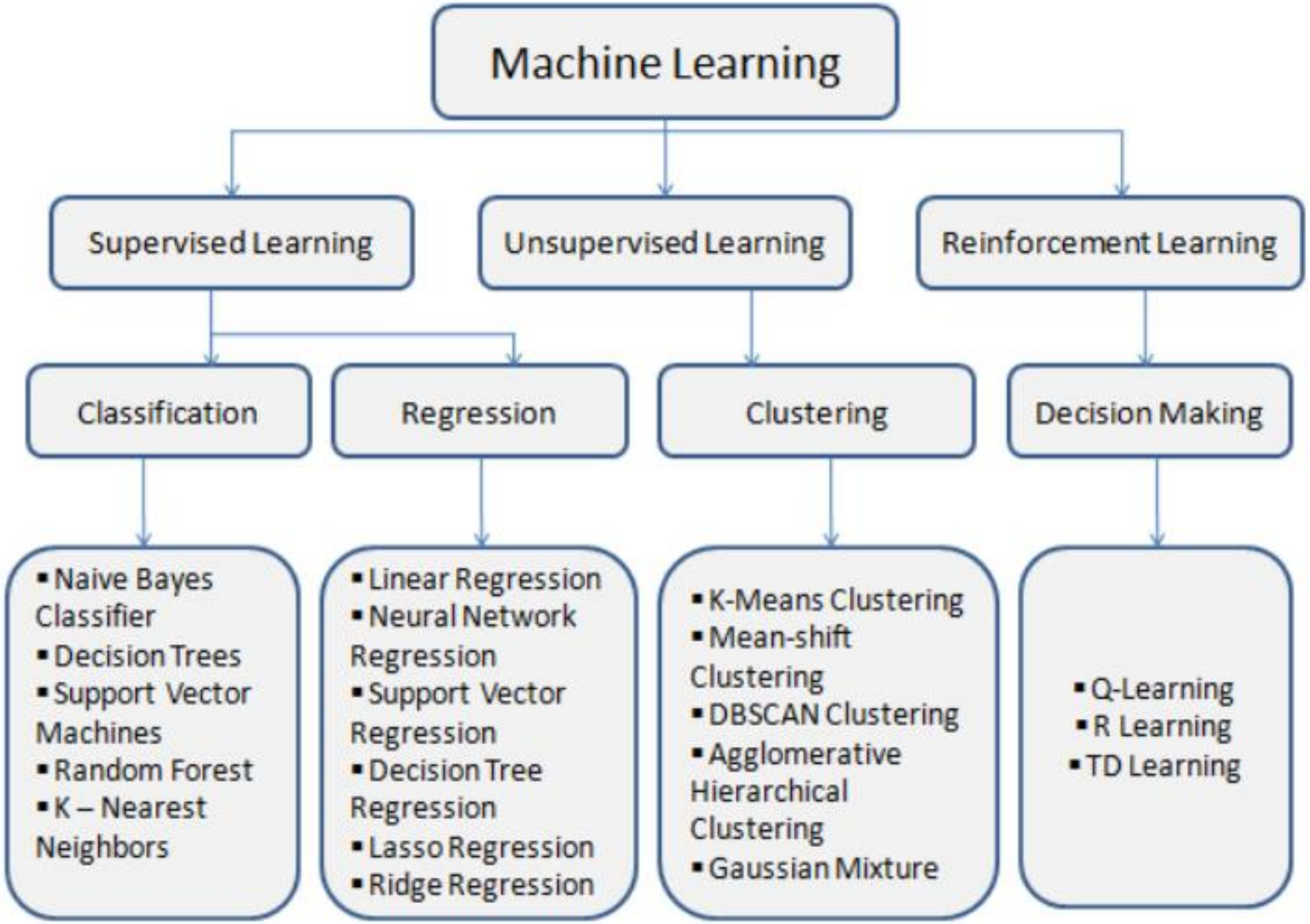
# Model Statistics

**Model 2**: Tree
Status: Trained

**Training Results**

| | |
|---|---|
| RMSE (Validation) | 3.2821 |
| R-Squared (Validation) | 0.82 |
| MSE (Validation) | 10.772 |
| MAE (Validation) | 2.3731 |
| Prediction speed | ~5000 obs/sec |
| Training time | 3.5947 sec |

| Statistic | Description | Tip | |
|---|---|---|---|
| RMSE | Root mean squared error. The RMSE is always positive and its units match the units of your response. | Look for smaller values of the RMSE. | $RMSE = \sqrt{\sum_{i=1}^{n} \frac{(\hat{y}_i - y_i)^2}{n}}$ |
| R-Squared | Coefficient of determination. R-squared is always smaller than 1 and usually larger than 0. It compares the trained model with the model where the response is constant and equals the mean of the training response. If your model is worse than this constant model, then R-Squared is negative. | Look for an R-Squared close to 1. | $R^2 = 1 - \frac{SS_{RES}}{SS_{TOT}} = 1 - \frac{\sum_i (y_i - \hat{y}_i)^2}{\sum_i (y_i - \bar{y})^2}$ |
| MSE | Mean squared error. The MSE is the square of the RMSE. | Look for smaller values of the MSE. | $\mathrm{MSE} = \frac{1}{n} \sum_{i=1}^{n} (y_i - \tilde{y}_i)^2$ |
| MAE | Mean absolute error. The MAE is always positive and similar to the RMSE, but less sensitive to outliers. | Look for smaller values of the MAE. | $MAE = \frac{1}{n} \sum_{i=1}^{n} \lvert Y_i - \hat{Y}_i \rvert$ |




https://www.analyticsvidhya.com/blog/2021/03/everything-you-need-to-know-about-machine-learning/

# **Stationarity:** We do not have independence but consistency.

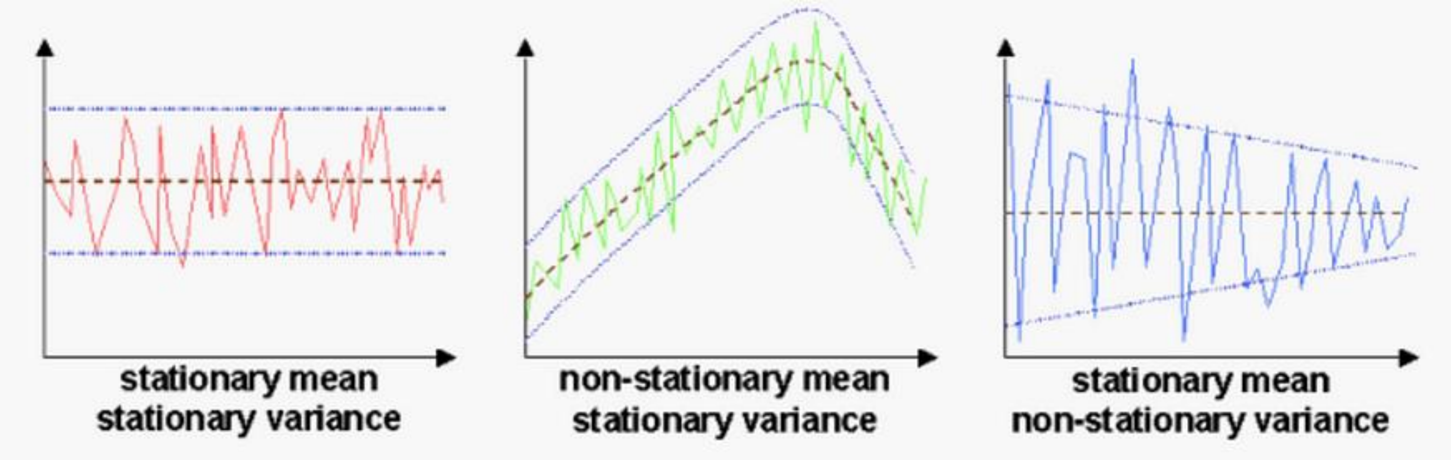
Stationarity is an important concept in time series analysis:

1. Stationarity means that the statistical properties of a time series do not change over time.
2. Stationarity is important because many useful analytical tools, statistical tests and models rely on it.

The ability to determine if a time series is stationary is important. This usually means being able to ascertain, with high probability, that a series is generated by a stationary process.

Test stationarity!

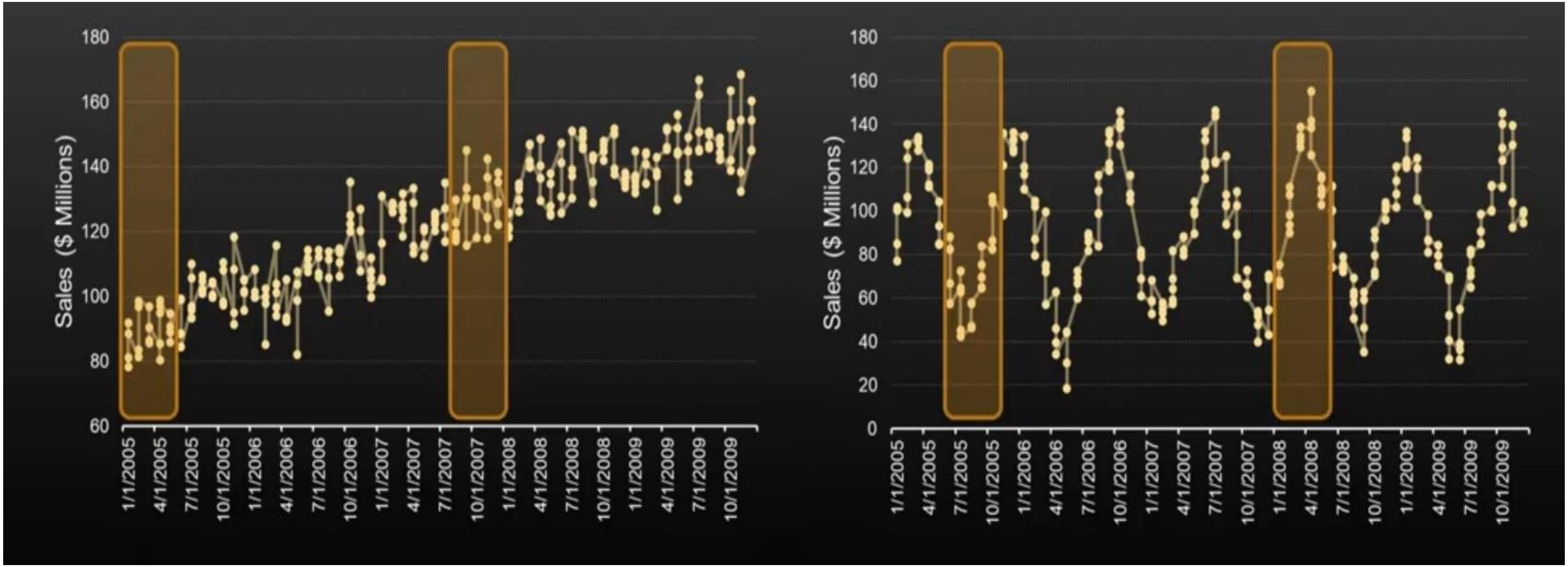
Mean, variance, autocorrelation depends **only** on difference in time, **not** location in time.



Not stationarity !
They do not have the same mean

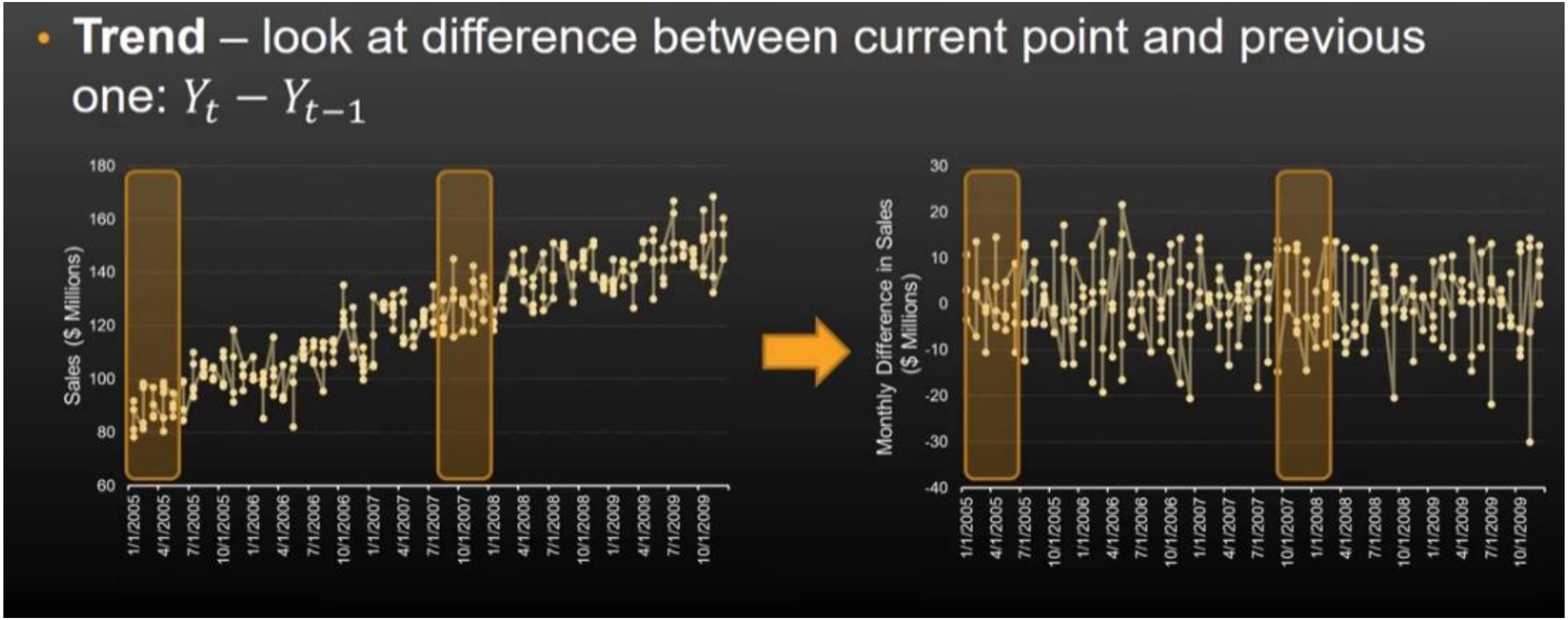
Trending

Seasonality



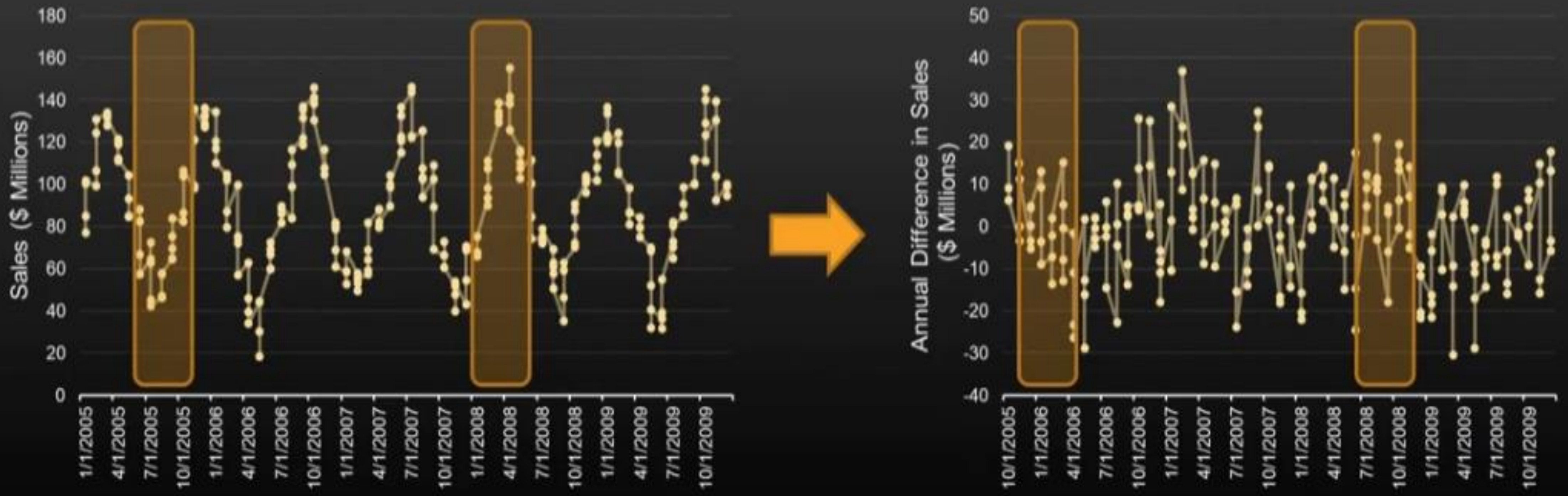
Trending

Stationarity!



# Stationarity!

- **Season** – look at difference between current point and the same point in the previous season: $Y_t - Y_{t-s}$



# Correlation

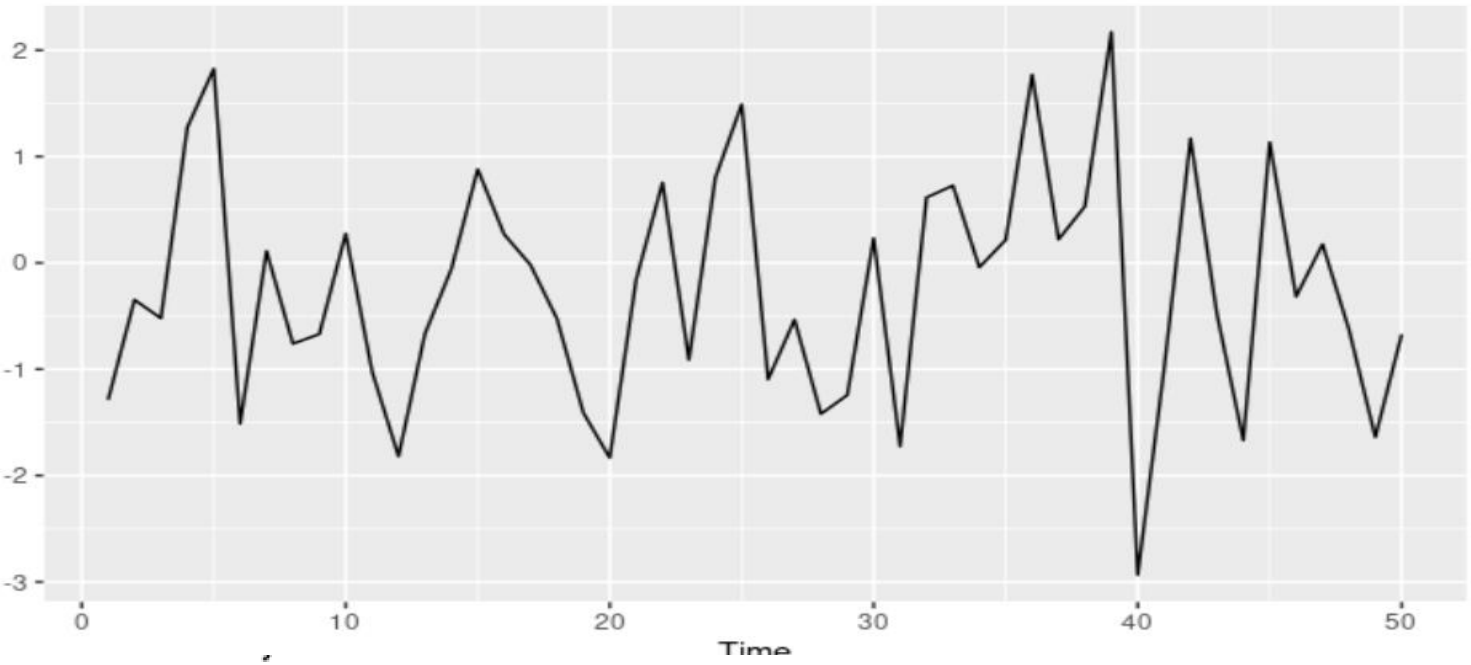
**Correlation is a single statistic or data point, whereas regression is the entire equation with all of the data points that are represented with a line.**

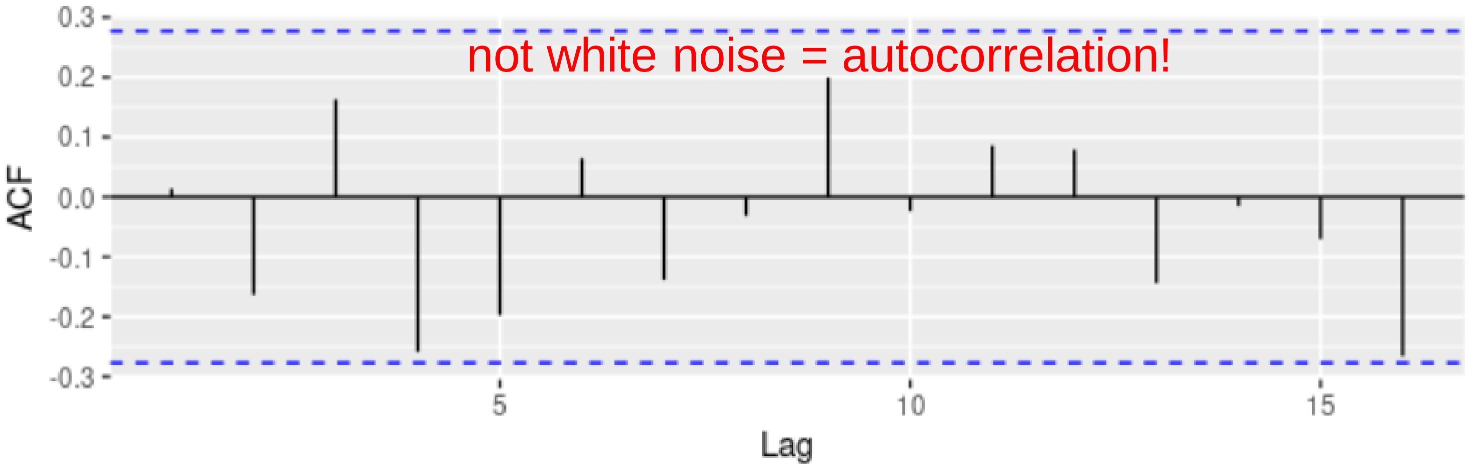
**Correlation shows the relationship between two variables, while regression allows us to see how one affects the other.**

**Difference between Correlation and Regression**

| Basis For Comparison | Correlation | Regression |
|---|---|---|
| Meaning | Correlation is a statistical measure that determines the association or co-relationship between two variables. | Regression describes how to numerically relate an independent variable to the dependent variable. |
| Usage | To represent a linear relationship between two variables. | To fit the best line and to estimate one variable based on another. |
| Dependent and Independent variables | No difference | Both variables are different. |
| Indicates | Correlation coefficient indicates the extent to which two variables move together. | Regression indicates the impact of a change of unit on the estimated variable ( y) in the known variable (x). |
| Objective | To find a numerical value expressing the relationship between variables. | To estimate values of random variables on the basis of the values of fixed variables. |

# Time series that show no autocorrelation are called white noise




For white noise series, we expect each autocorrelation to be close to zero. They will not be exactly equal to zero as there is some random variation. We expect 95% of the spikes in the ACF to lie within $\pm 2/\sqrt{T}$ where $T$ is the length of the time series.

It is common to plot these bounds on a graph of the ACF (the blue dashed lines above). If one or more large spikes are outside these bounds, or if substantially more than 5% of spikes are outside these bounds, then the series is probably not white noise.

**LSTM (Long Short Term Memory) networks** are a special type of RNN (Recurrent Neural Network) that is structured to remember and predict based on long-term dependencies that are trained with time-series data. An LSTM repeating module has some interacting components.

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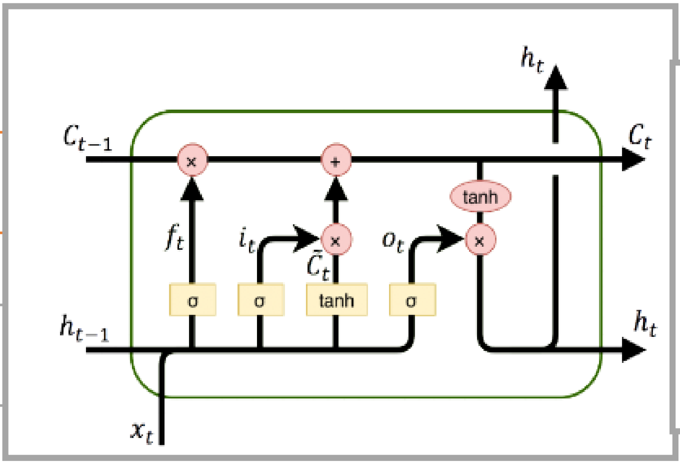
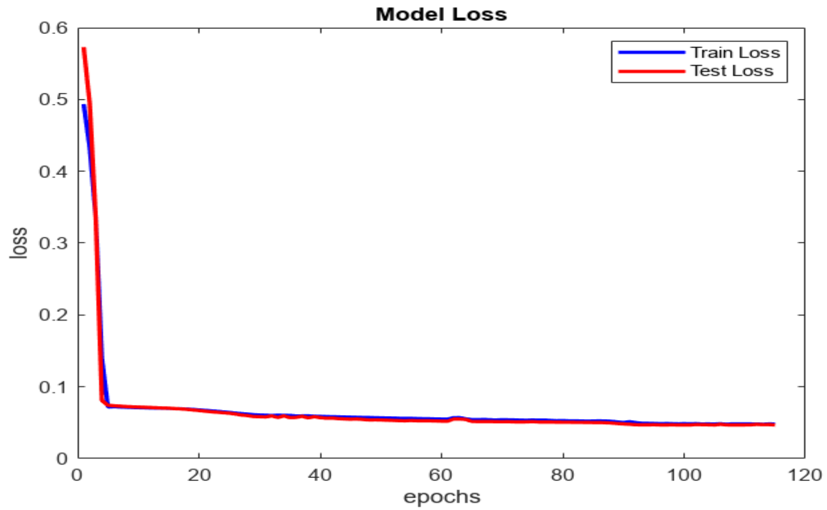
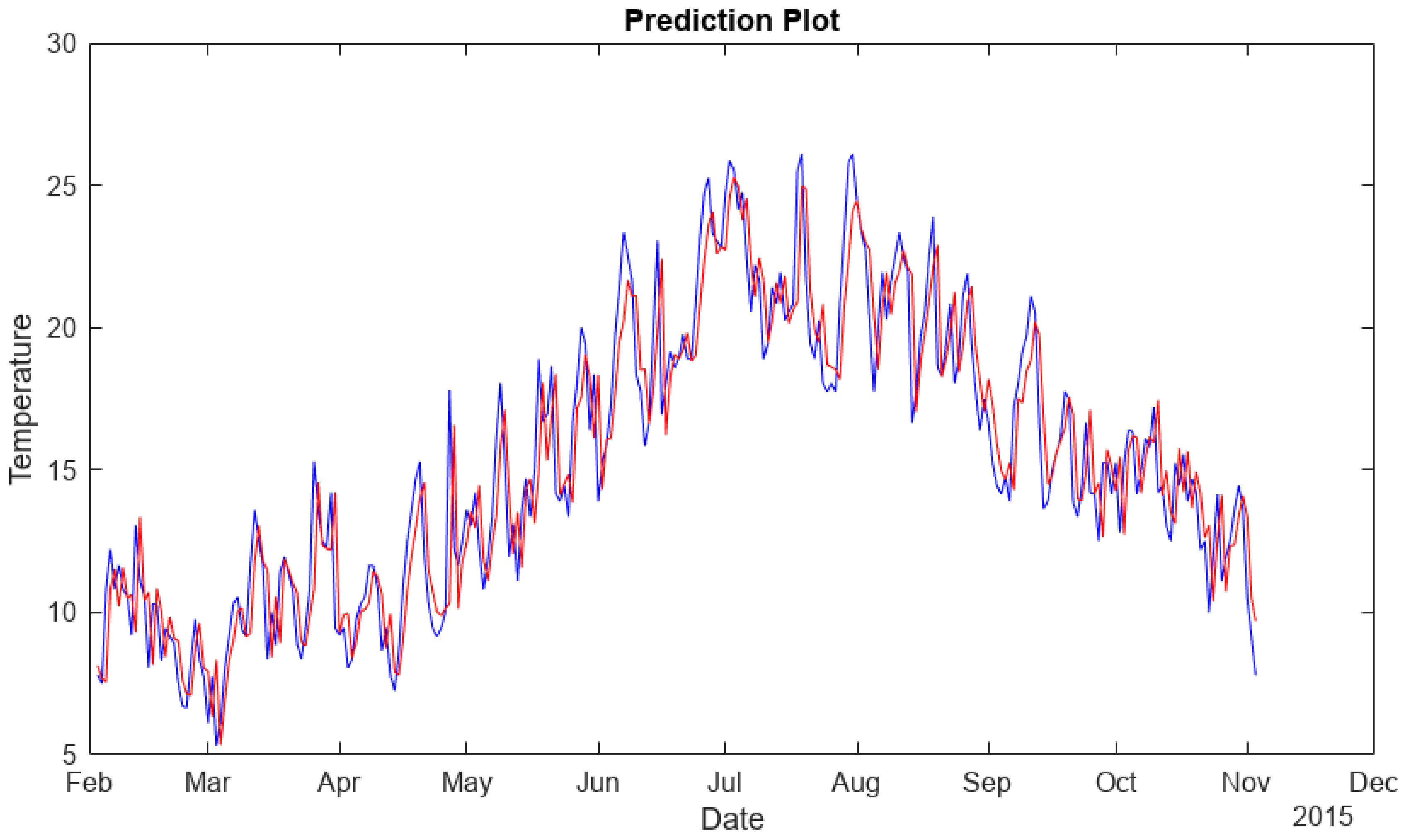



An LSTM network relates the input data window to outputs with layers. Instead of just one layer, LSTMs often have multiple layers.



## LSTM Prediction Validation

The validation test set assesses the ability of the neural network to predict based on new conditions that were not part of the training set. The validation is performed with the last 20% of the data that was separated from the beginning 80% of data.



## LSTM Forecast Validation

When performing the validation it is also important to determine how the model performs with without measurements when it uses prior predictions to predict the next outcome. This is important to determine how well the model performs in a predictive application such as model predictive control where the model is projected forward over the control horizon to determine the sequence of optimal manipulated variable moves and possible future constraint violation. Generating predictions without measurement feedback is a forecast.