- **Expectation-Maximization Algorithm**

Dr. Jagendra Singh

Machine Learning

WHAT IS AN EM ALGORITHM?

- The Expectation-Maximization (EM) algorithm is defined as the combination of various unsupervised machine learning algorithms, which is used to determine the **local maximum likelihood estimates (MLE)** or **maximum a posteriori estimates (MAP)** for unobservable variables in statistical models.

- It is a technique to find maximum likelihood estimation when the latent variables are present. It is also referred to as the **latent variable model.**
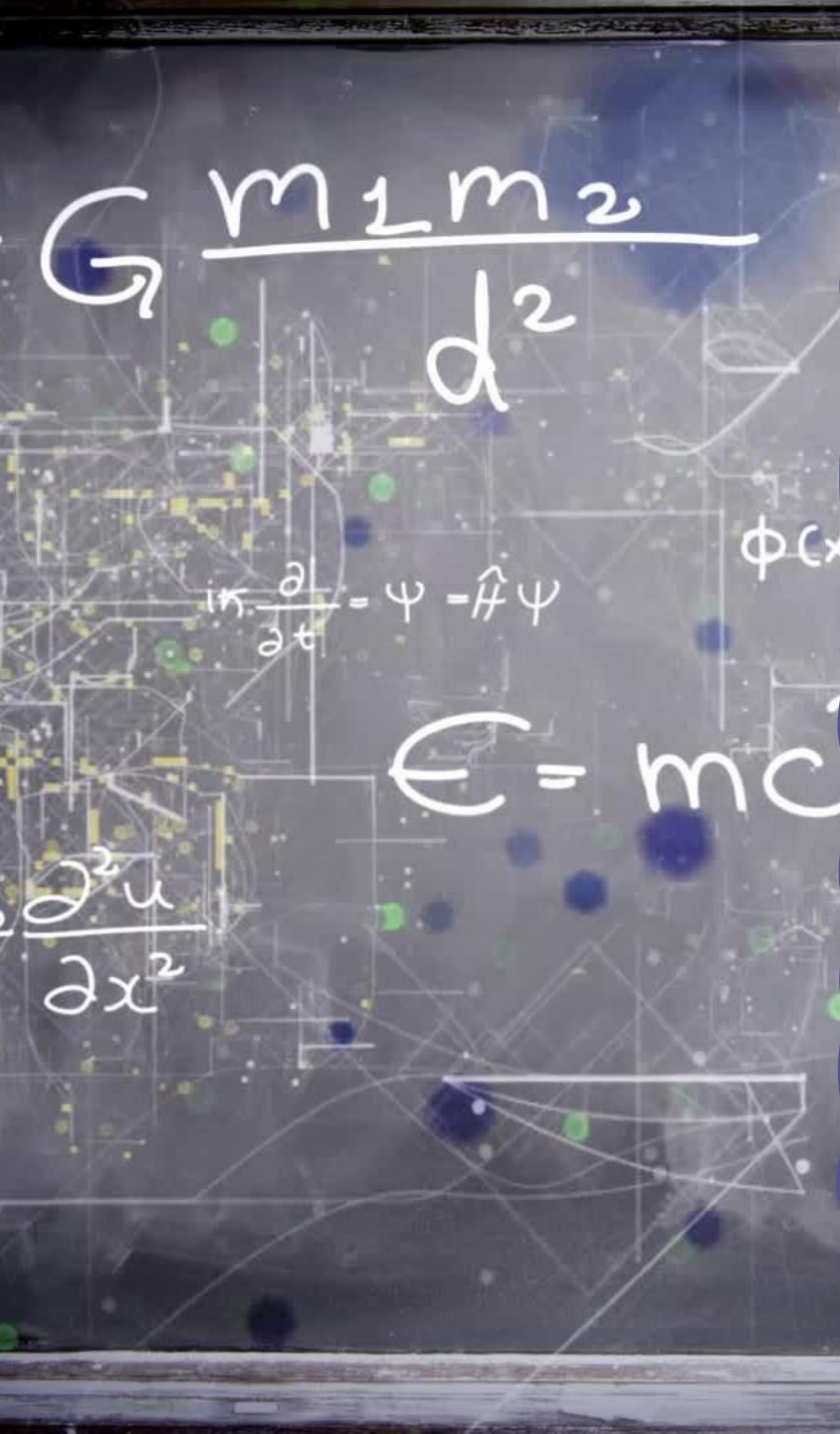
WHAT IS AN EM ALGORITHM?

- A latent variable model consists of both observable and unobservable variables where observable can be predicted while unobserved are inferred from the observed variable.

- These unobservable variables are known as latent variables.

- It is used to predict values of parameters in instances where data is missing or unobservable for learning, and this is done until convergence of the values occurs.

EM ALGORITHM

- The EM algorithm is the combination of various unsupervised ML algorithms, such as the **k-means clustering algorithm**.

- Being an iterative approach, it consists of two modes. In the first mode, we estimate the missing or latent variables. Hence it is referred to as the **Expectation/estimation step (E-step)**.

- Further, the other mode is used to optimize the parameters of the models so that it can explain the data more clearly. The second mode is known as the **maximization-step or M-step.**

EM ALGORITHM
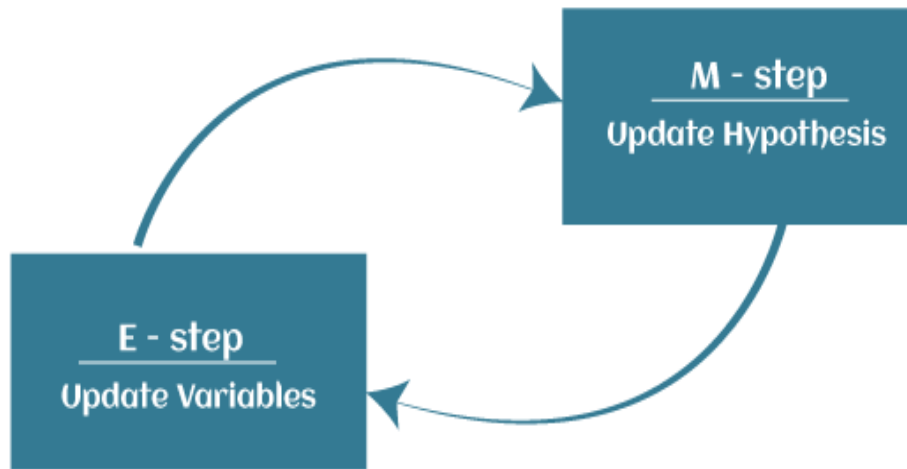
- **Expectation step (E - step):** It involves the estimation (guess) of all missing values in the dataset so that after completing this step, there should not be any missing value.

- **Maximization step (M - step):** This step involves the use of estimated data in the E-step and updating the parameters.

- **Repeat E-**step and M-step until the convergence of the values occurs.

EM ALGORITHM

○ The primary goal of the EM algorithm is to use the available observed data of the dataset to estimate the missing data of the latent variables.

○ And then use that data to update the values of the parameters in the M-step.

WHAT IS CONVERGENCE IN THE EM ALGORITHM?

- ***Convergence is defined as the specific situation in probability based on intuition***, e.g., if there are two random variables that have very less difference in their probability, then they are known as converged.

- In other words, whenever the values of given variables are matched with each other, it is called convergence.
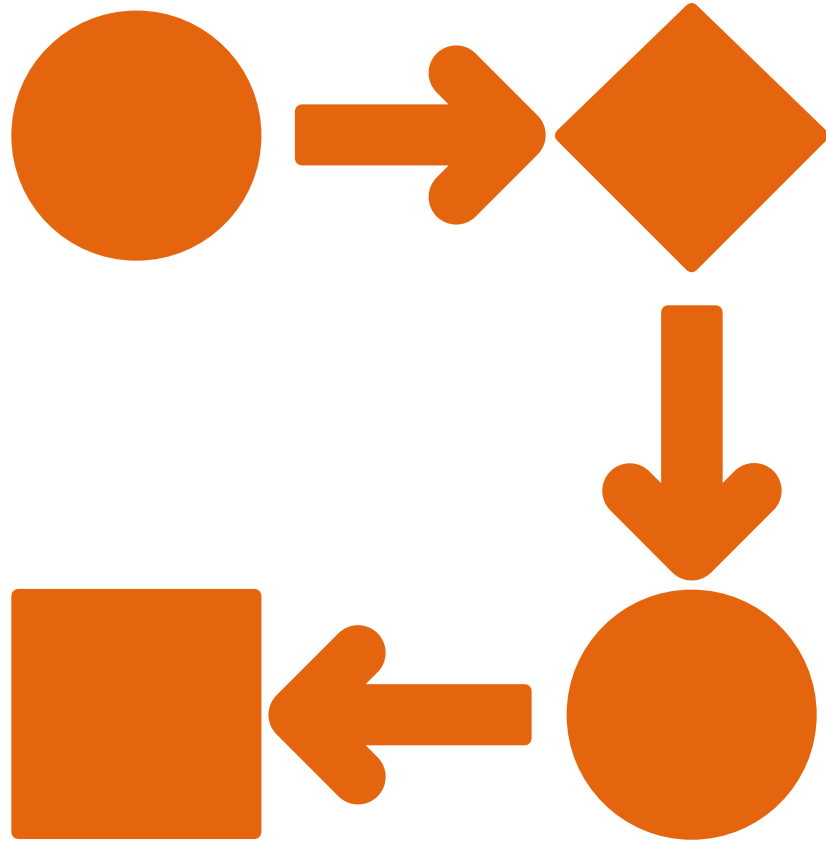
STEPS IN EM ALGORITHM

- The EM algorithm is completed mainly in 4 steps, which include *Initialization Step, Expectation Step, Maximization Step, and convergence Step*.

- These steps are explained as follows:
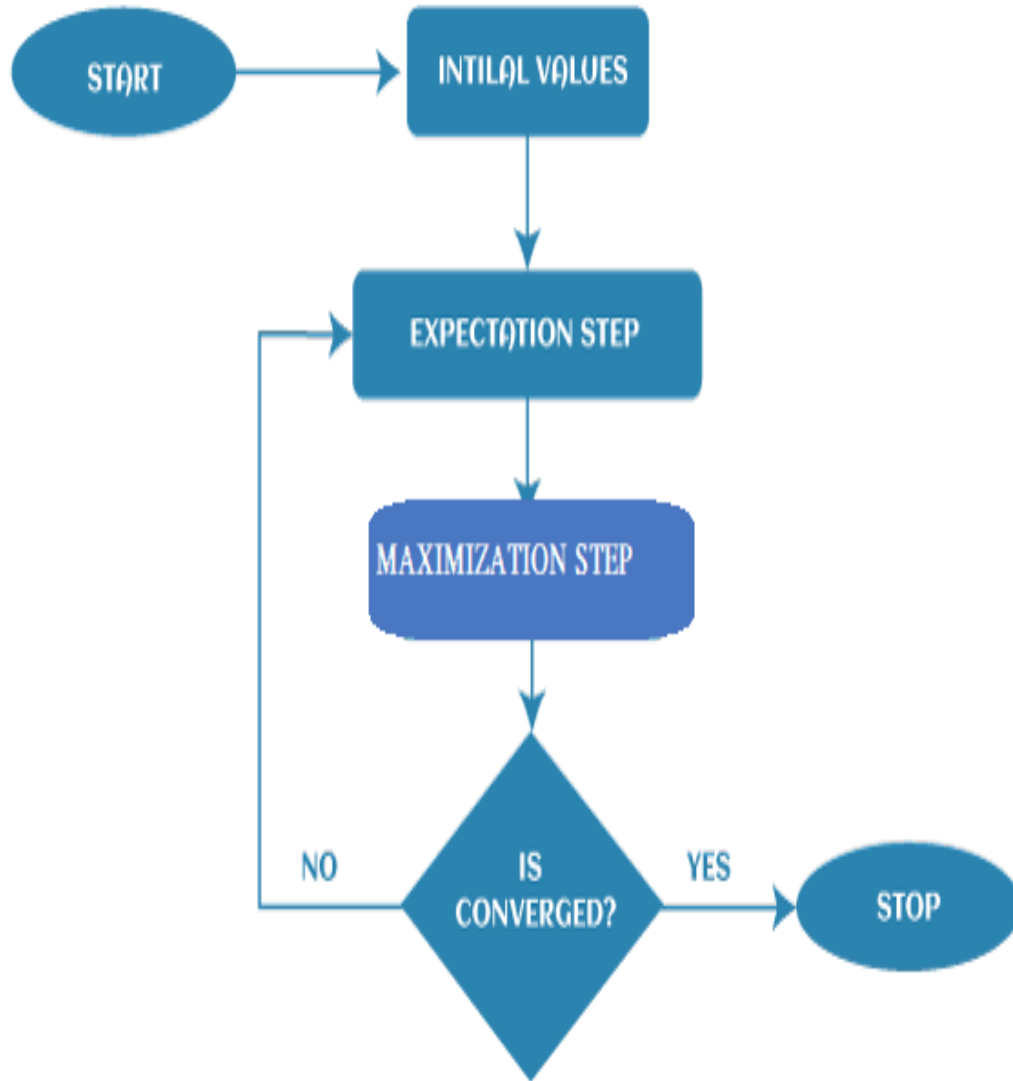
STEPS IN EM ALGORITHM

- **1st Step:** The very first step is to initialize the parameter values. Further, the system is provided with incomplete observed data with the assumption that data is obtained from a specific model.

- **2nd Step:** This step is known as Expectation or E-Step, which is used to estimate or guess the values of the missing or incomplete data using the observed data. Further, E-step primarily updates the variables.

STEPS IN EM ALGORITHM

○ **3rd Step:** This step is known as Maximization or M-step, where we use complete data obtained from the 2nd step to update the parameter values. Further, M-step primarily updates the hypothesis.

○ **4th step:** The last step is to check if the values of latent variables are converging or not. If it gets "yes", then stop the process; else, repeat the process from step 2 until the convergence occurs.

APPLICATIONS OF EM ALGORITHM

1. The primary aim of the EM algorithm is to estimate the missing data in the latent variables through observed data in datasets.

2. The EM algorithm or latent variable model has a broad range of real-life applications in machine learning. These are as follows:

- The EM algorithm is applicable in data clustering in machine learning.

- It is often used in computer vision and NLP (Natural language processing).

- It is used to estimate the value of the parameter in mixed models such as the **Gaussian Mixture Model** and quantitative genetics.

APPLICATIONS OF EM ALGORITHM

- It is also used in psychometrics for estimating item parameters and latent abilities of item response theory models.

- It is also applicable in the medical and healthcare industry, such as in image reconstruction and structural engineering.

- It is used to determine the Gaussian density of a function.

ADVANTAGES OF EM ALGORITHM

- It is very easy to implement the first two basic steps of the EM algorithm in various machine learning problems, which are E-step and M- step.

- It is mostly guaranteed that likelihood will enhance after each iteration.

- It often generates a solution for the M-step in the closed form.

DISADVANTAGES OF EM ALGORITHM

○ The convergence of the EM algorithm is very slow.

○ It can make convergence for the local optima only.

○ It takes both forward and backward probability into consideration. It is opposite to that of numerical optimization, which takes only forward probabilities.

THANK YOU