RESTRICTED BOLTZMANN MACHINE (RBM): STRUCTURE & LEARNING

- Presented by: Drishta Grover (00417702722)

  Ishaan Jain (06117702722)

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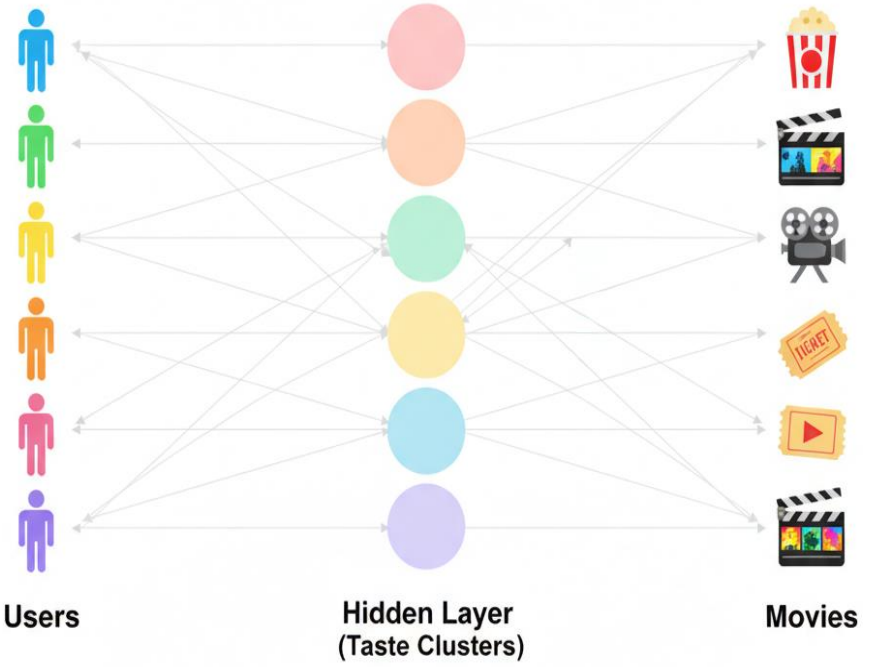
- Subject: Unsupervised Learning

INTRODUCTION

- RBM is a **probabilistic graphical model** and a **generative stochastic neural network**.
- Designed for **unsupervised learning**: finds hidden structures in unlabeled data.
- Learns a **joint probability distribution** of inputs (visible layer) and features (hidden layer).
- Applications:
- Dimensionality reduction
- Collaborative filtering
- Feature learning
- Pretraining deep neural networks

REAL-WORLD USE CASE: NETFLIX RECOMMENDATION SYSTEM

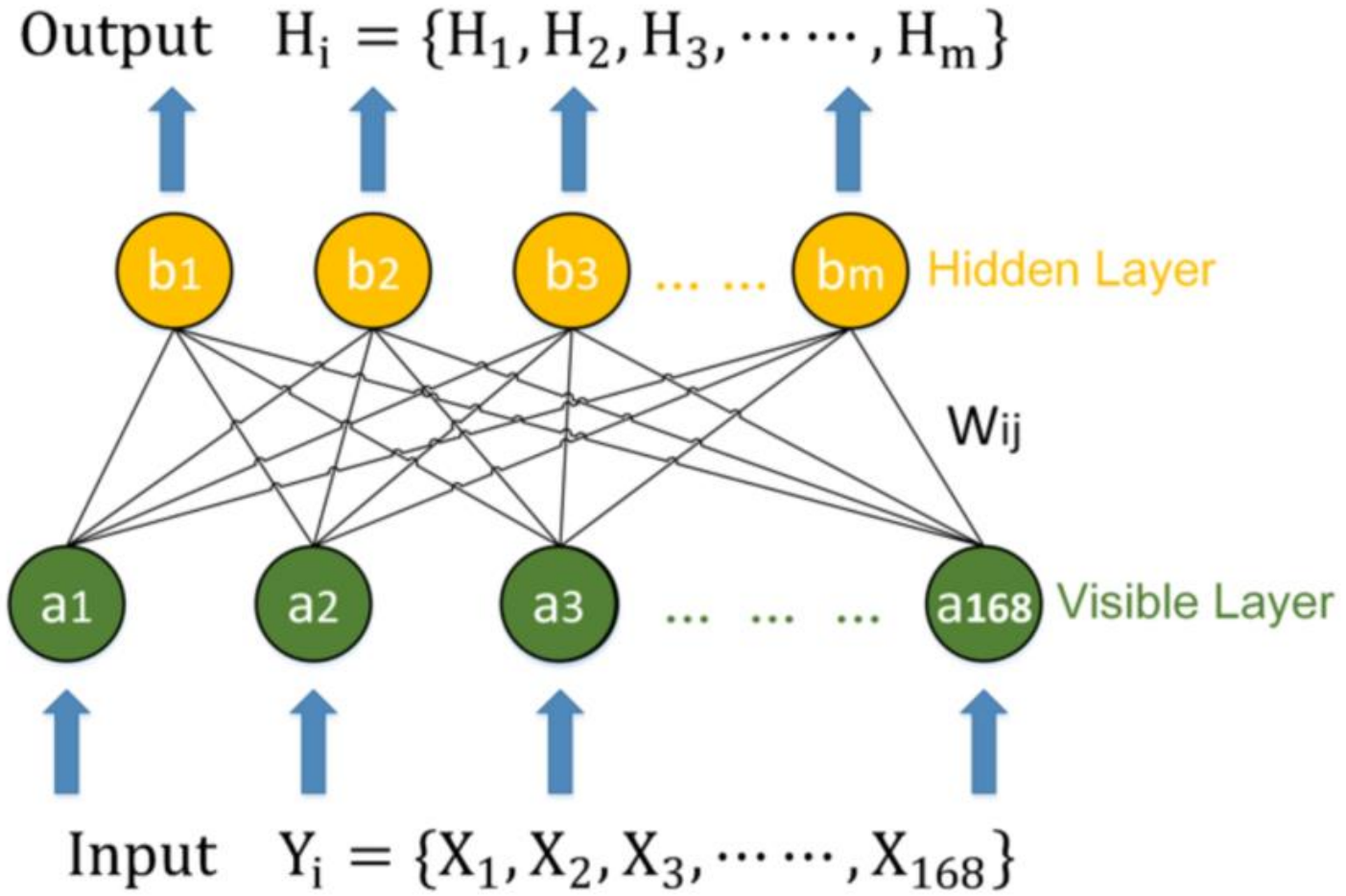
- **Netflix Prize (2006):** $1M challenge to improve movie recommendation accuracy.
- **RBM as Collaborative Filtering:** Predicted user ratings by learning hidden patterns.
- **Taste Clusters:** RBM discovered user preference groups (action lovers, rom-com fans, etc.).
- **Impact:** Outperformed many algorithms; inspired modern recommendation systems (Netflix, YouTube).



RBM STRUCTURE

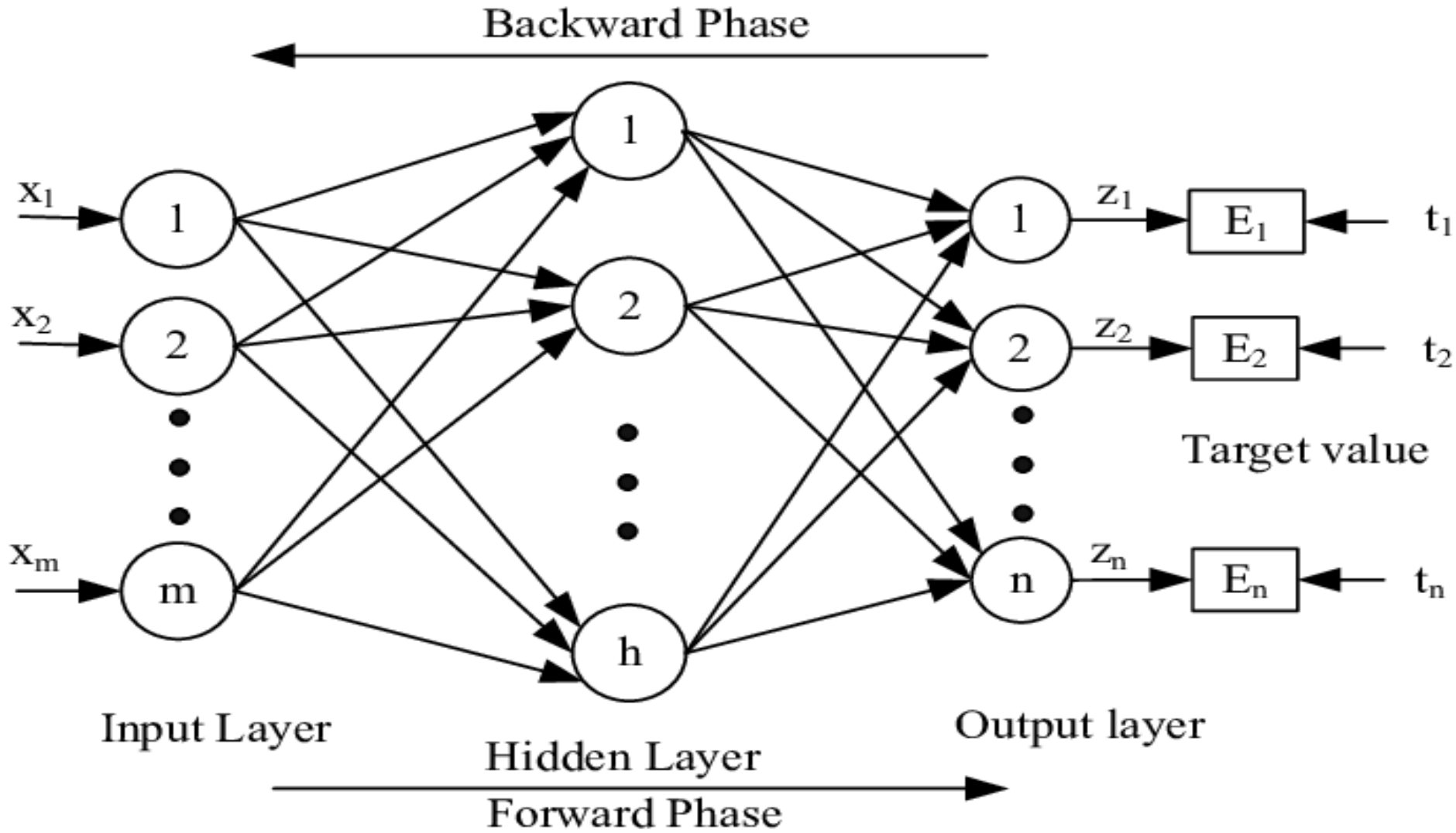
- RBM is a **probabilistic, two-layer neural network**.
- **Visible Layer:** Receives input data (e.g., user ratings, images).
- **Hidden Layer:** Learns patterns or latent features from inputs.
- **Fully Connected Bipartite Graph:** Every visible node connects to every hidden node; no connections within a layer.
- **Weights & Biases:**
- Each edge has a **weight** indicating the strength of association.
- Each node has a **bias** to adjust activation probability.
- **Activation:** Hidden nodes are activated based on weighted inputs passed through a **sigmoid function**.
- *Training occurs in two main phases: feed-forward pass and feed-backward pass.*

RBM DIAGRAM


Output $H_i = \{H_1, H_2, H_3, \cdots\cdots, H_m\}$
b1
b2
b3
... ...
bm
Hidden Layer
Wij
a1
a2
a3
... ...
a168
Visible Layer
Input $Y_i = \{X_1, X_2, X_3, \cdots\cdots, X_{168}\}$

FEED-FORWARD PHASE IN RBM

- **Input to Visible Layer:** Training data (e.g., ratings, pixel values) is fed into visible nodes.
- **Weighted Connections:** Each visible node sends values through weights to all hidden nodes.
- **Bias Addition:** Hidden nodes add bias terms to adjust activation thresholds.
- **Sigmoid Activation:** The sum of weighted inputs + bias is passed through a **sigmoid function** to calculate activation probabilities.
- **Feature Detection:**
- **Positive association:** Strong weights indicate important patterns.
- **Negative association:** Weak or negative weights ignore irrelevant features.


Backward Phase
x1
x2
xm
1
2
m
1
2
h
1
2
n
z1
z2
zn
E1
E2
En
t1
t2
tn
Target value
Input Layer
Hidden Layer
Output layer
Forward Phase

FEED-BACKWARD PHASE (RECONSTRUCTION & ADJUSTMENT)

- **Reconstruction:** Hidden nodes send signals back to reconstruct the visible layer.
- **Adjustments:** Weights and biases are updated based on reconstruction error.
- **Probability Logging:** The network calculates probabilities of connections for each edge.
- **Goal:** Minimize difference between the original input and reconstructed input.
- **Outcome:** Model learns patterns more accurately and strengthens important connections

FEED FORWARD VS FEED BACKWARD PHASE

Feature	Feed-Forward Phase	Feed-Backward Phase
Direction	Visible → Hidden	Hidden → Visible
Purpose	Detect latent features from input data	Reconstruct input and adjust weights & biases
Computation	Weighted sum + bias → sigmoid → hidden probabilities	Weighted sum + bias → sigmoid → reconstructed visible values
Focus	Identify positive & negative associations	Minimize reconstruction error
Outcome	Activates hidden nodes representing patterns	Updates model parameters to improve accuracy
Role in Training	First phase	Second phase

SUMMARY

- RBM is a **probabilistic, generative model** that captures hidden patterns.
- Works via **feed-forward and backward passes** for feature learning.
- Trained using **Contrastive Divergence**.
- Pioneered recommendation systems (Netflix Prize) and **inspired Deep Belief Networks**.

REFERENCES

- Geoffrey Hinton: *A Practical Guide to Training Restricted Boltzmann Machines* (2010)
- *Deep Learning* by Goodfellow, Bengio, Courville
- Netflix Prize papers