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Hello and Welcome to AI Camp

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XGBOOST

EXTREME GRADIENT BOOSTING WITH XGBOOST

HARIS BEL.
TURKI

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LET'S TALK ABOUT ENSAMBLE TECHNIQUES FIRST

ENSAMBLE TECHNIQUES :

- **BAGGING :**
  - Random forest classifier
  - Random forest regressor
- **BOOSTING :**
  - Adaboost
  - Gradient boosting
  - XGBoost

BOOSTING :

- **WHAT IS BOOSTING :**
  - **Ensemble sequential meta-algorithm used to convert many weak learners into a strong learner**
- **HOW BOOSTING WORKS :**

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TRAINING DATA

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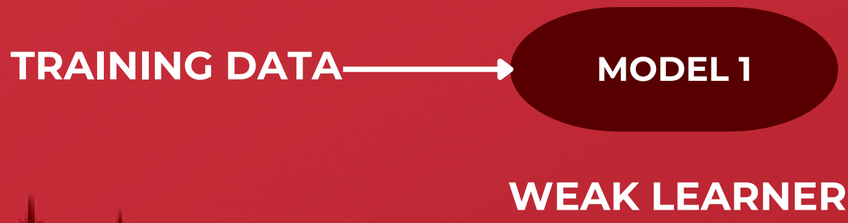

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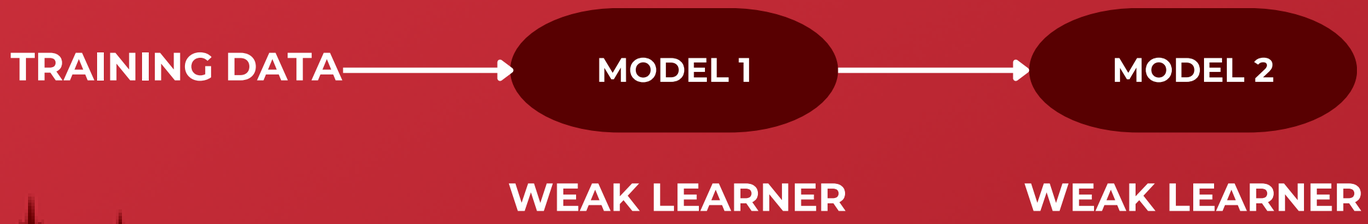

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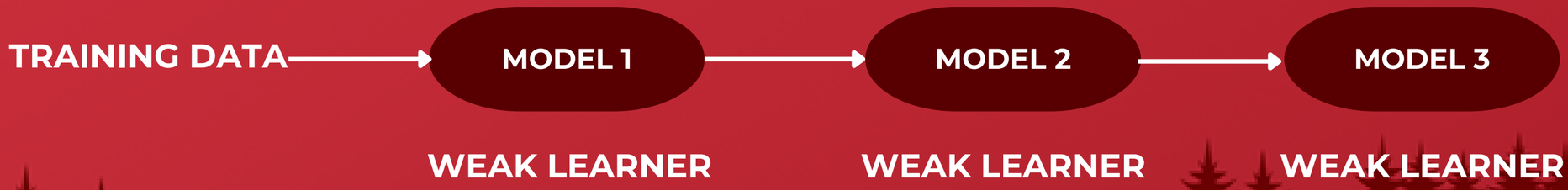

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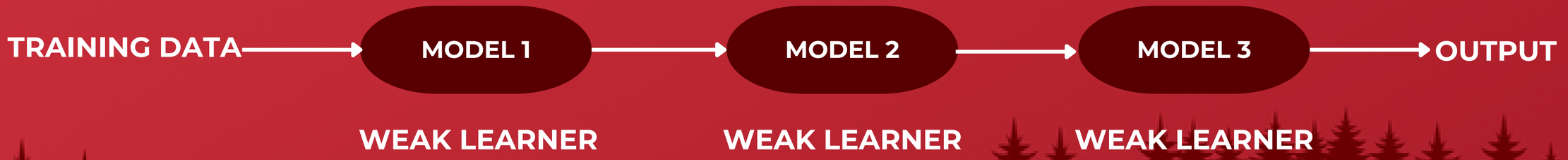

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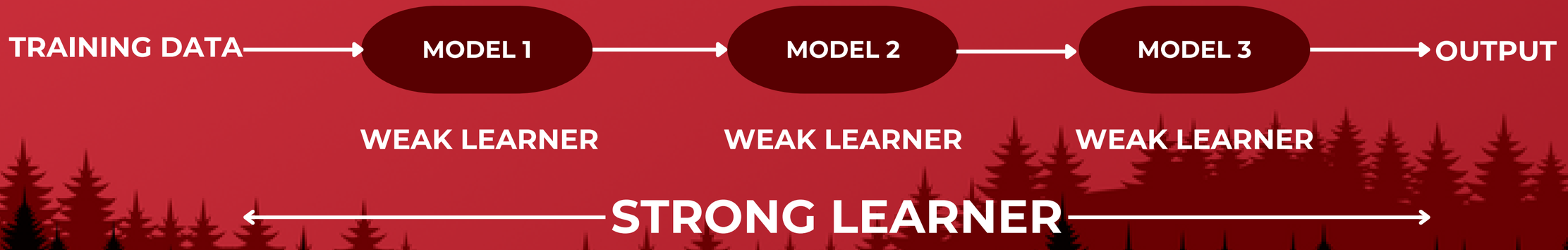

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WEAK LEARNERS AND STRONG LEARNERS :

- **WEAK LEARNER :**
  - ML algorithm that is slightly better than chance
  - Slightly better than chance means we are always going to have an error rate which is less than 1/2
- **STRONG LEARNER :**
  - Any algorithm that can be tuned to achieve good performance

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LET'S TALK ABOUT XGBOOST!

EXTREME GRADIENT BOOSTING WITH XGBOOST

WHAT IS XGBOOST (eXtreme Gradient Boosting) :

- Open source implementation of boosted trees
- Optimized gradient-boosting machine learning library
- Originally written in C++
- Has API’s in several languages :
  - Python
  - R
  - Java

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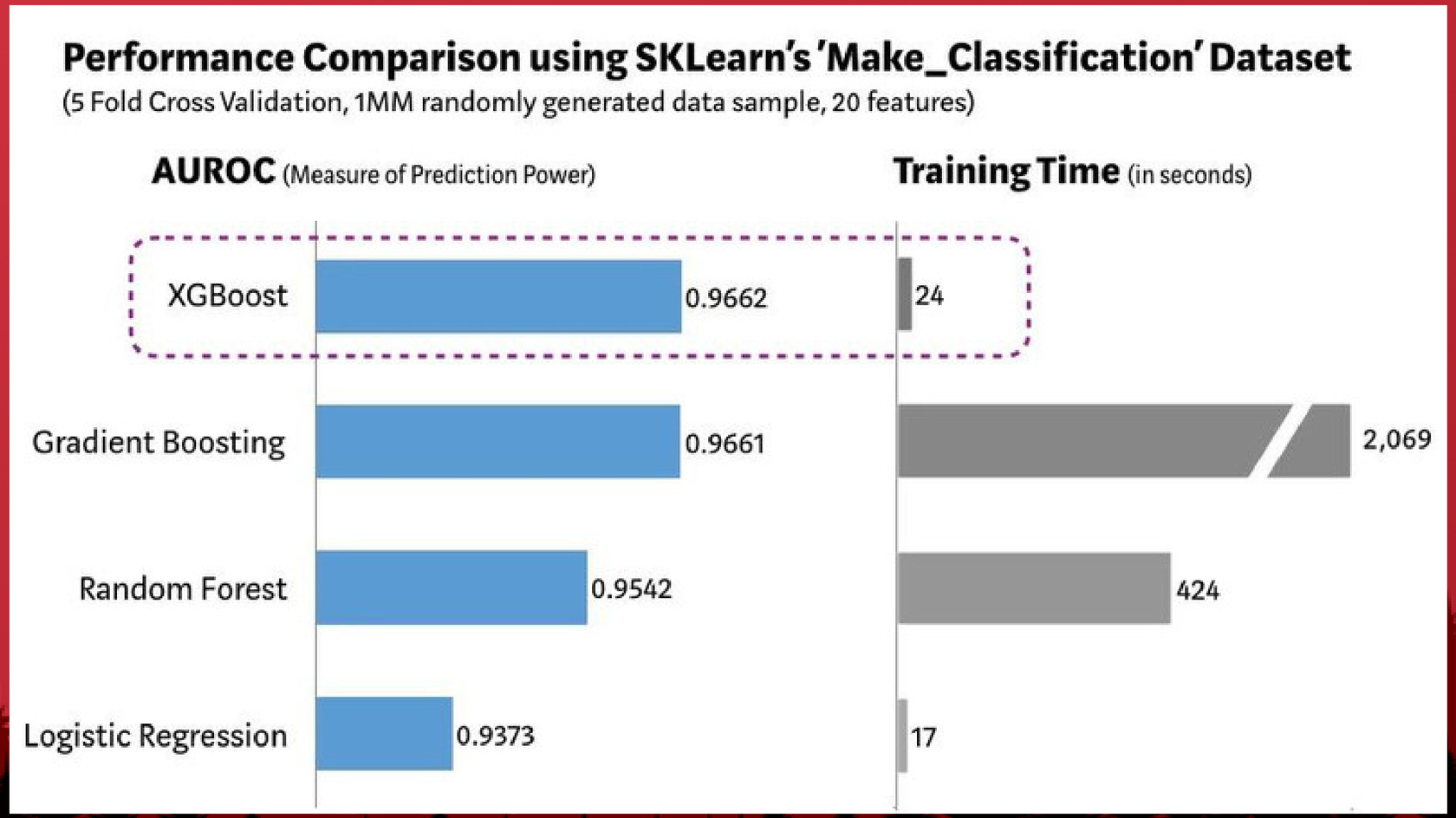
WHAT MAKES XGBOOST SO POPULAR :

- Fast & Efficient Implementation
- Speed and performance
- Core algorithm is parallelizable
- Consistently outperforms single-algorithm methods
- State-of-the-art performance in many ML tasks
- Built in regularization to prevent overfitting
- Highly competitive algorithm for machine learning competitions (eg: kaggle competitions)

WHAT MAKES XGBOOST SO POPULAR :

- **Comparison between XGBoost and other models :**



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WHAT MAKES XGBOOST SO POPULAR :

- **Comparison between XGBoost and Keras :**

Category	XGBoost	Keras Deep Learning	Winner?
Performance on test set			
Accuracy	80.1%	78.1%	XGBoost
recall: true positive / (true positive + false negative)	0.89	0.68	
false negatives	1,200	3,500	
Training time	1 minute 24 seconds	2 minutes – 3 minutes for 50 epoch experiment depending on hw env and call back patience setting	Inconclusive – deep learning training time varies
Code complexity	• Extra steps required to transform data coming out of pipeline • 1 line to build model	• Data from pipeline ready to train model • Complex model build	Inconclusive
Flexibility	Handles continuous & categorical columns	Handles continuous, categorical and text columns	Deep learning

XGBOOST STEPS :

- XGBoost is an implementation of gradient boosting that goes through cycles to iteratively add models into an ensemble

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- XGBoost is an implementation of gradient boosting that goes through cycles to iteratively add models into an ensemble
- It begins by initializing the ensemble with a single model, whose predictions can be pretty naive. (even if its predictions are wildly inaccurate, subsequent additions to the ensemble will address those errors.)

BASE / INITIAL MODEL

XGBOOST STEPS :

- Then, we start the cycle:
- First, we use the current ensemble to generate predictions for each observation in the dataset. To make a prediction, we add the predictions from all models in the ensemble.

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- First, we use the current ensemble to generate predictions for each observation in the dataset. To make a prediction, we add the predictions from all models in the ensemble.
- These predictions are used to calculate the errors(residuals) based on the previous model residuals for each observation in the dataset.

XGBOOST STEPS :

- **Then, we build a new model to predict those errors (residuals)**

XGBOOST STEPS :

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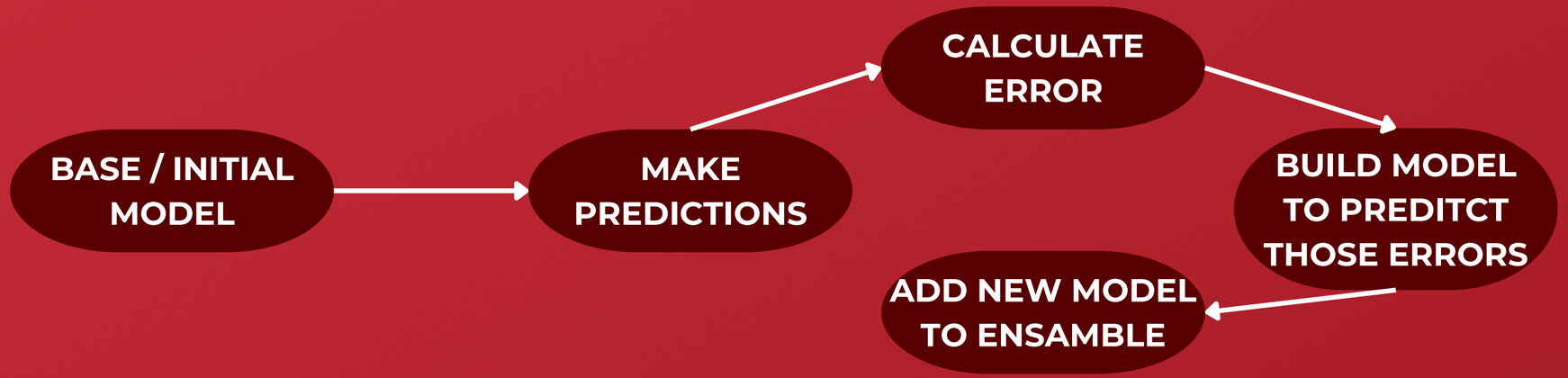
- Finally, we add the new model to ensemble, and ...



XGBOOST STEPS :

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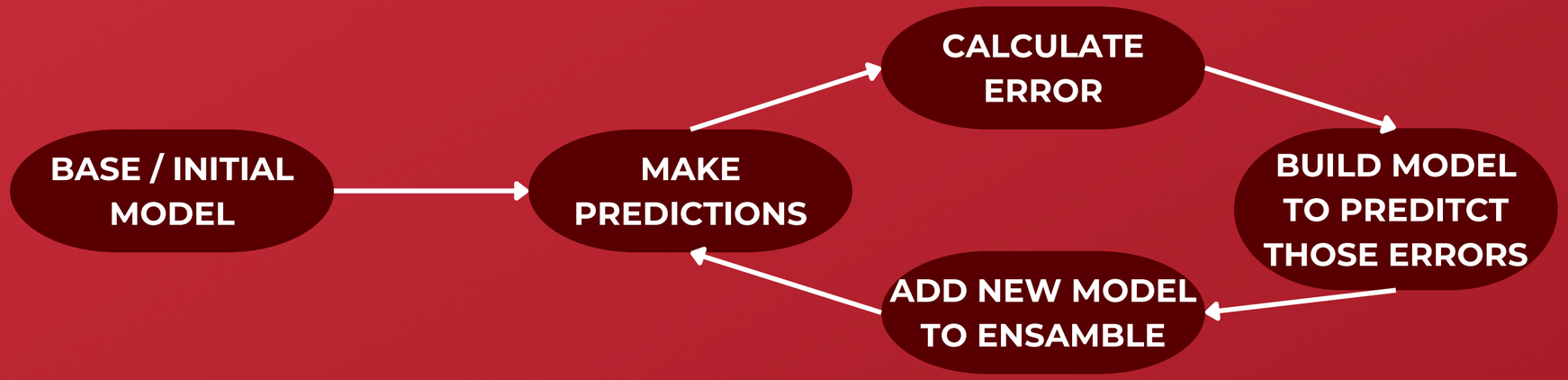
- ... repeat!



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LET'S BEGIN USING XGBOOST!

EXTREME GRADIENT BOOSTING WITH XGBOOST

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LET'S START WITH XGBOOST FOR CLASSIFICATION

EXTREME GRADIENT BOOSTING WITH XGBOOST

XGBOOST CLASSIFICATION :

- **Dataset :**

Pr =0.5

BASE / INITIAL MODEL

SALARY	CREDIT	APROVAL	RES
<=50K	B	0	
<=50K	G	1	
<=50K	G	1	
>50K	B	0	
>50K	G	1	
>50K	N	1	
<=50K	N	0	

- **STEPS :**
  - Calculate Residuals and Construct tree with root
  - Calculate Similarity Weight = $\frac{\sum(\text{Residuals})^2}{\sum(Pr(1-Pr))+\lambda}$
  - Calculate the gain = SWL+SWR-SW(ROOT)

Knowing That : RES=APROVAL-Pr , λ=0

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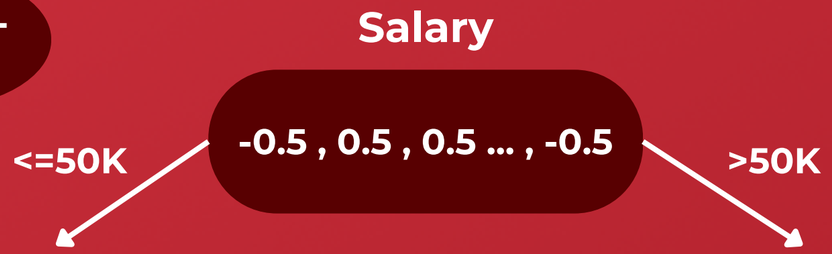

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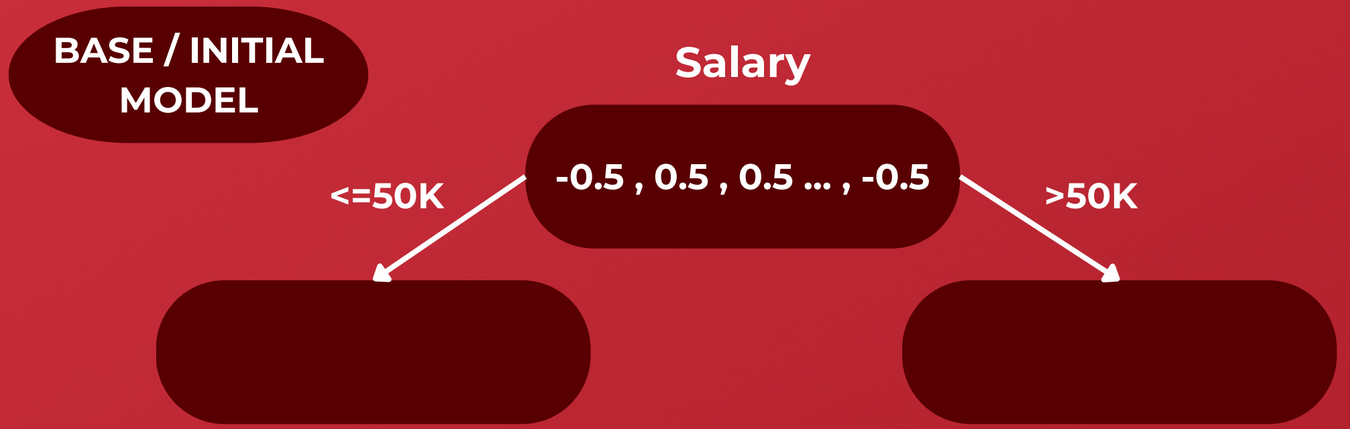

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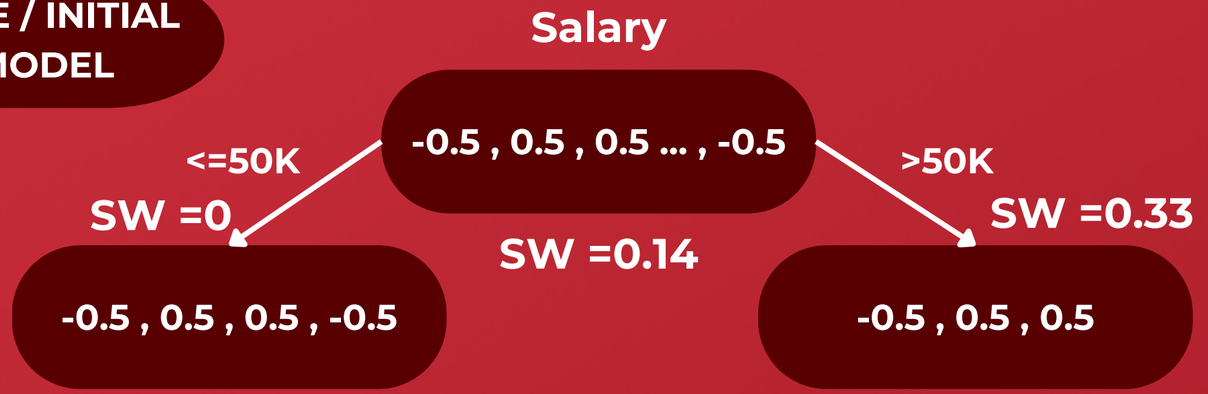

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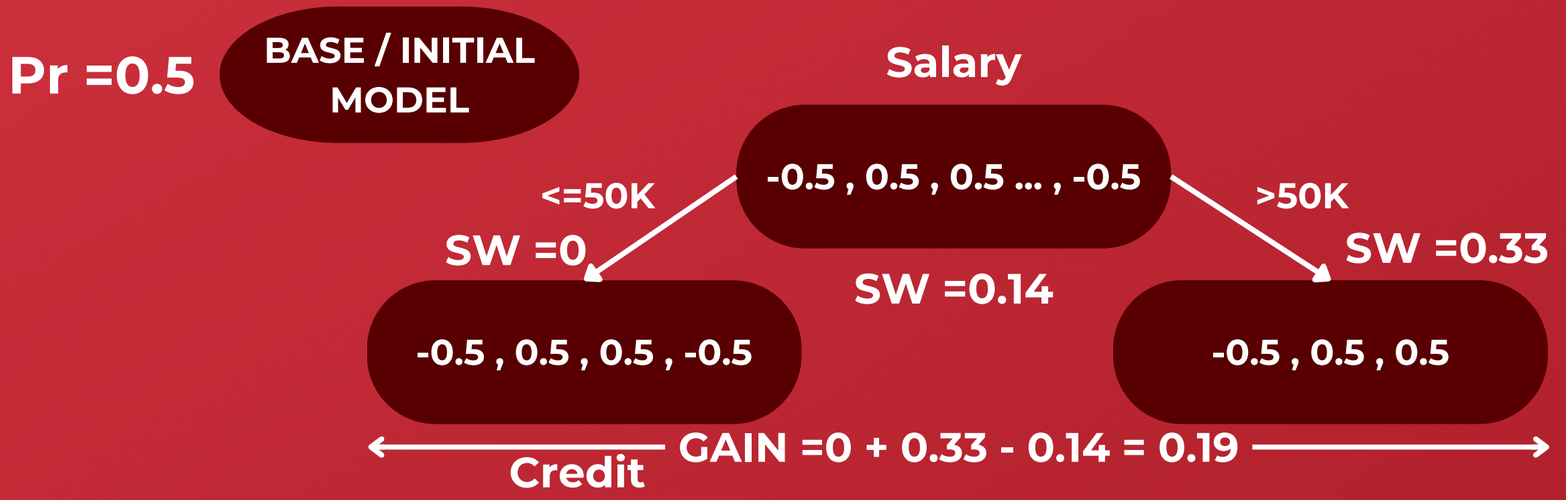

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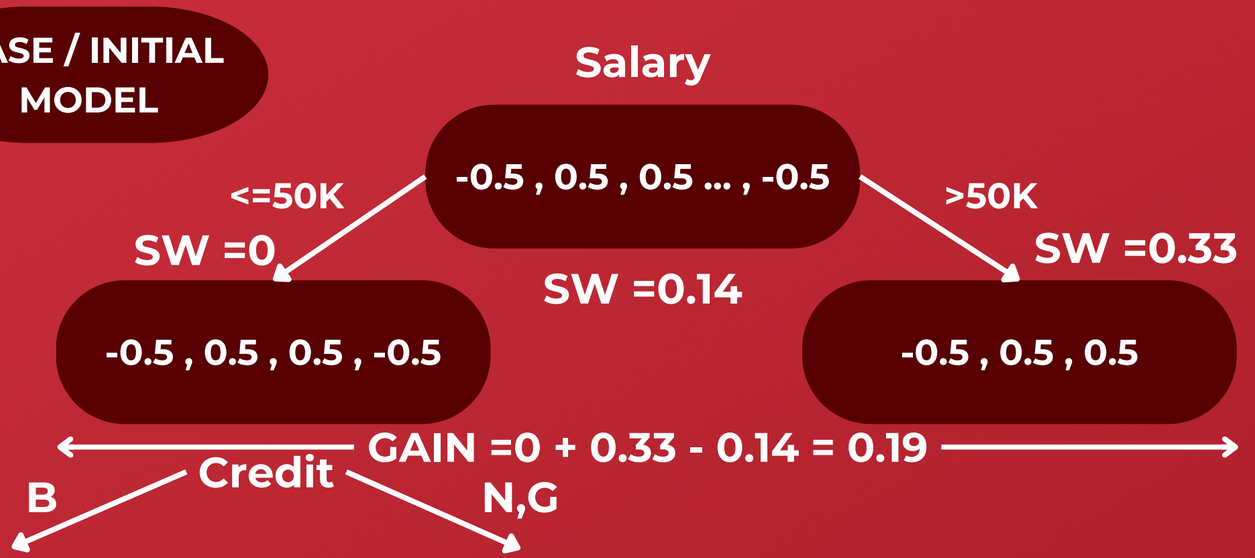

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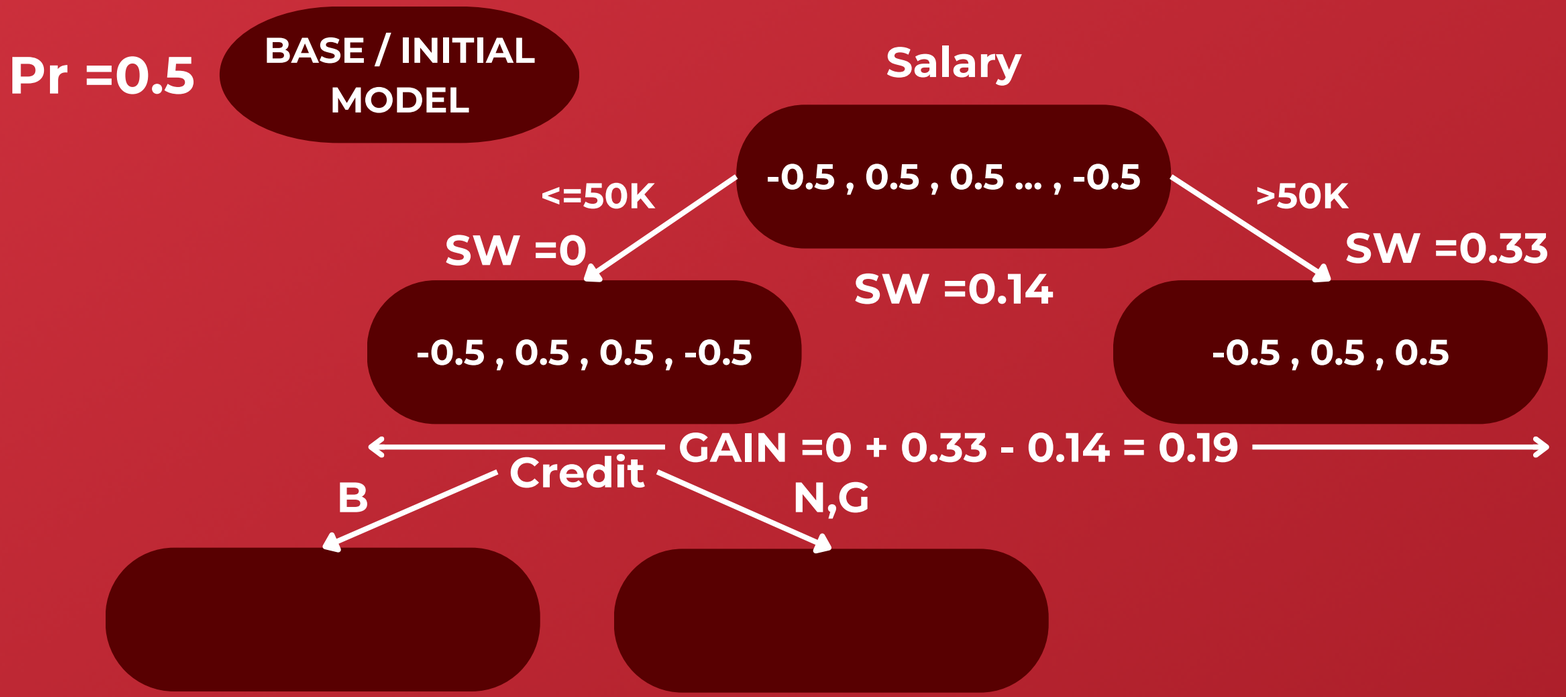

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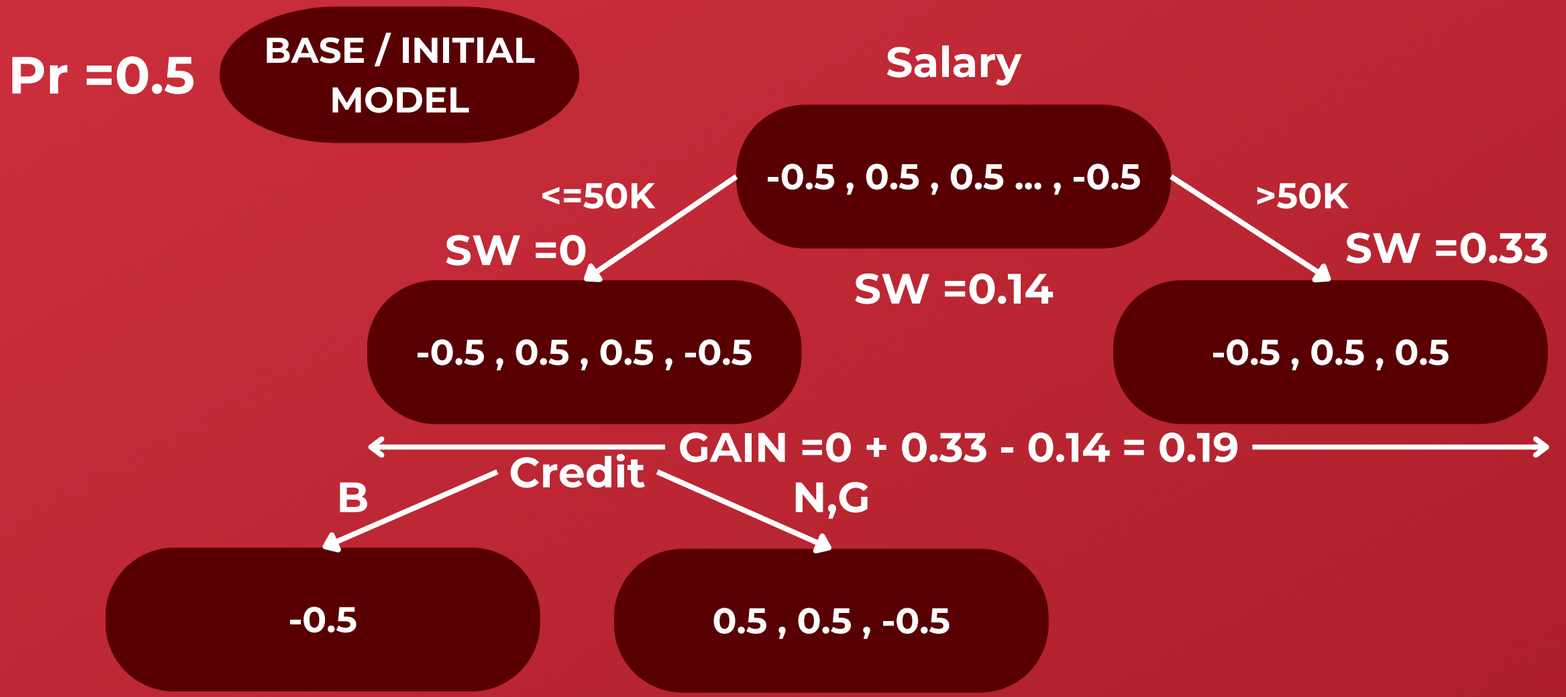

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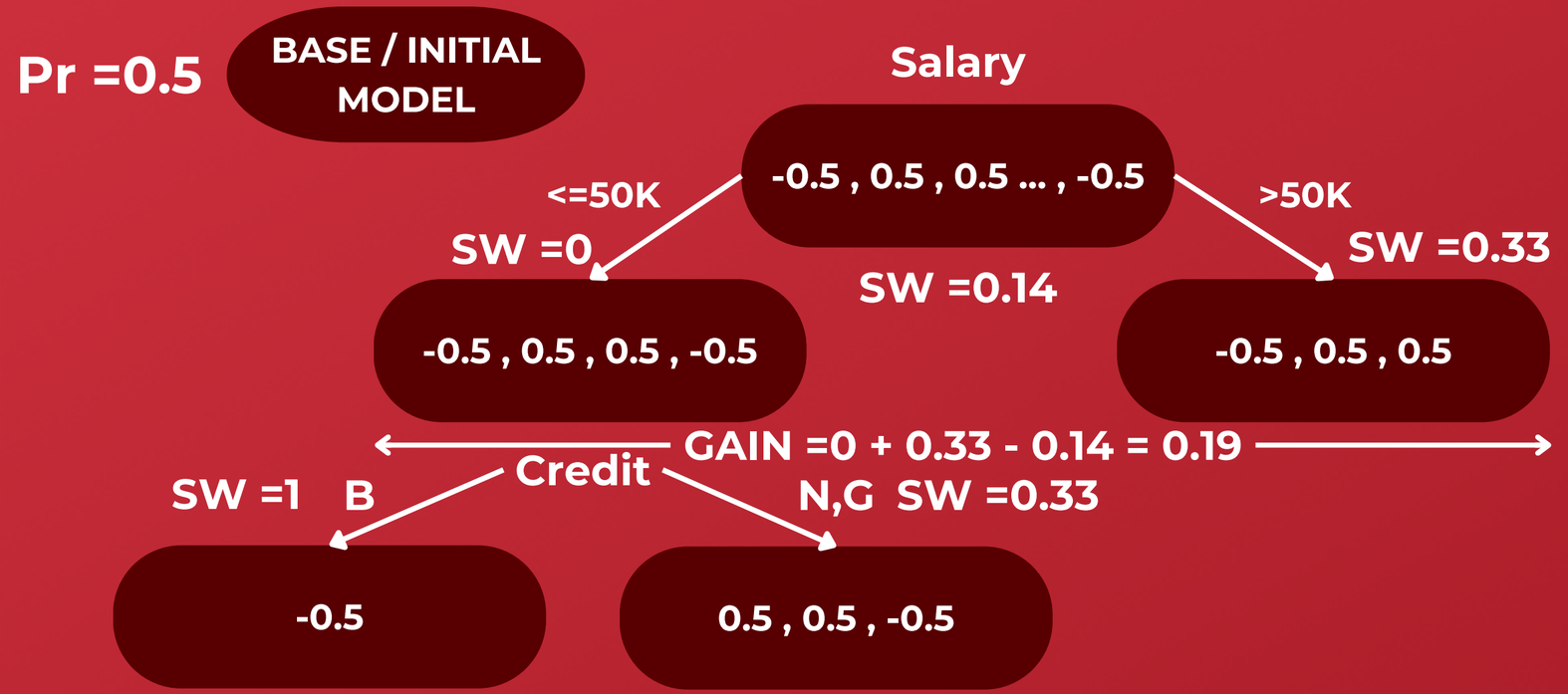

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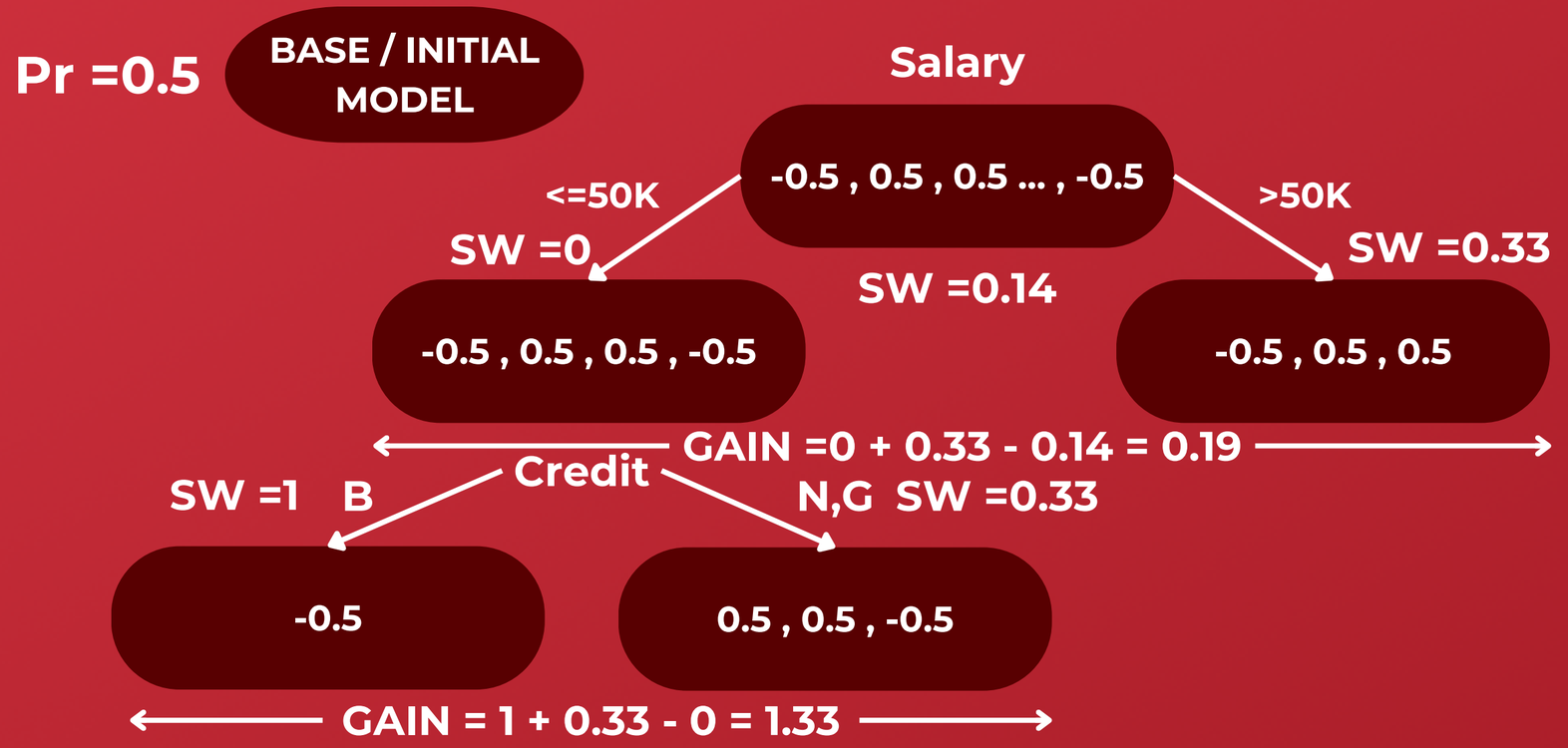
>50K	B	0	-0.5
>50K	G	1	0.5
>50K	N	1	0.5
<=50K	N	0	-0.5



- **STEPS :**
  - Calculate Residuals and Construct tree with root
  - Calculate Similarity Weight = $\frac{\sum(\text{Residuals})^2}{\sum(Pr(1-Pr))+\lambda}$
  - Calculate the gain = SWL+SWR-SW(ROOT)

Knowing That : RES=APROVAL-Pr , λ=0

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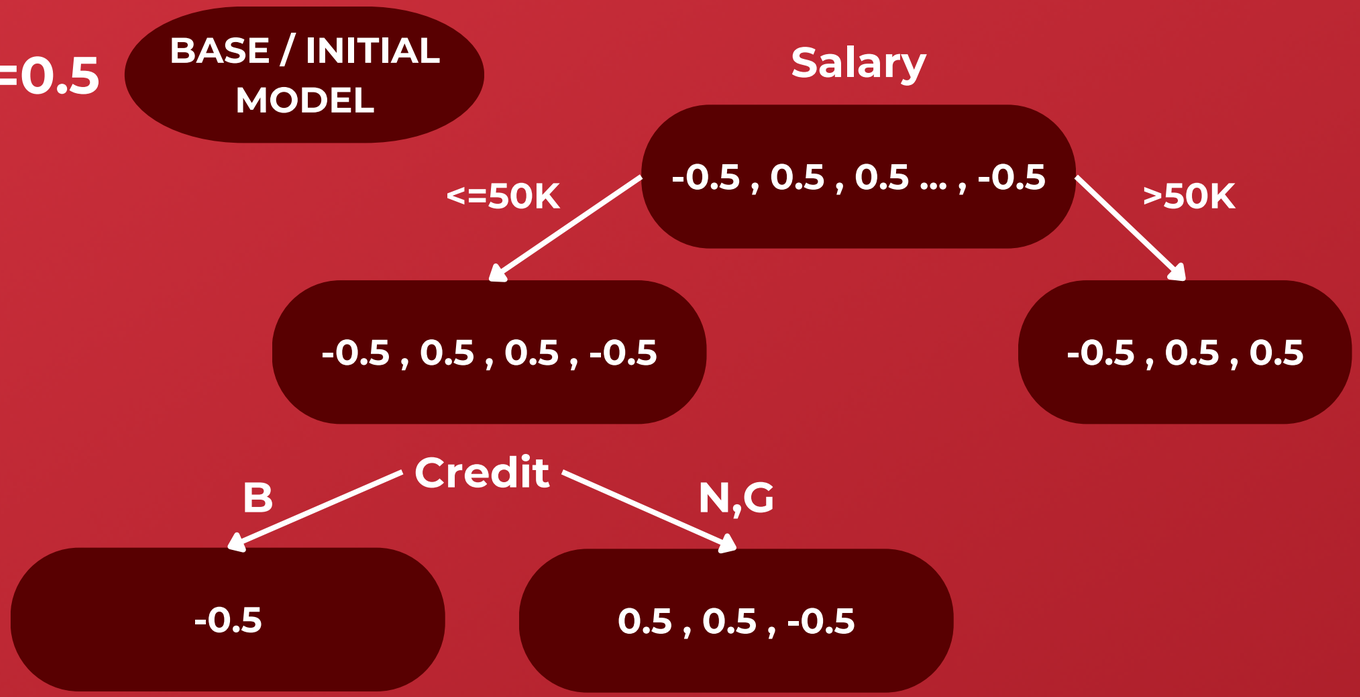
XGBOOST CLASSIFICATION :

- **STEPS (COVER) :**
  - **Calculate the cover = ∑(Pr(1-Pr)) for each leaf**
  - **Compare each leaf cover and and the default minimum value of the cover (which is by default = 1)**
  - **Eliminate all the leaves that have a cover < minimum cover**



- **Example Minimum Cover = 1 :**
- **in Python :**
  By Default

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XGBOOST CLASSIFICATION :

- **STEPS (COVER) :**
  - **Calculate the cover = ∑(Pr(1-Pr)) for each leaf**
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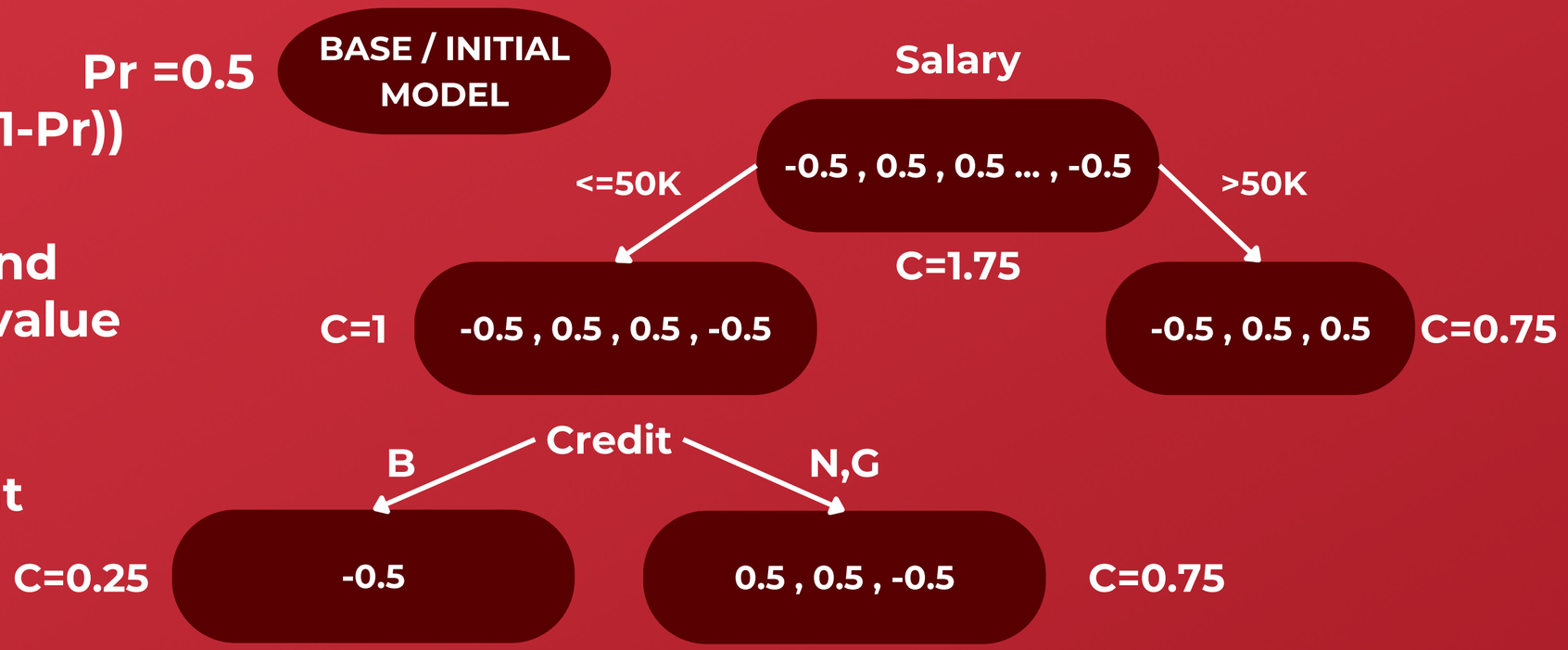

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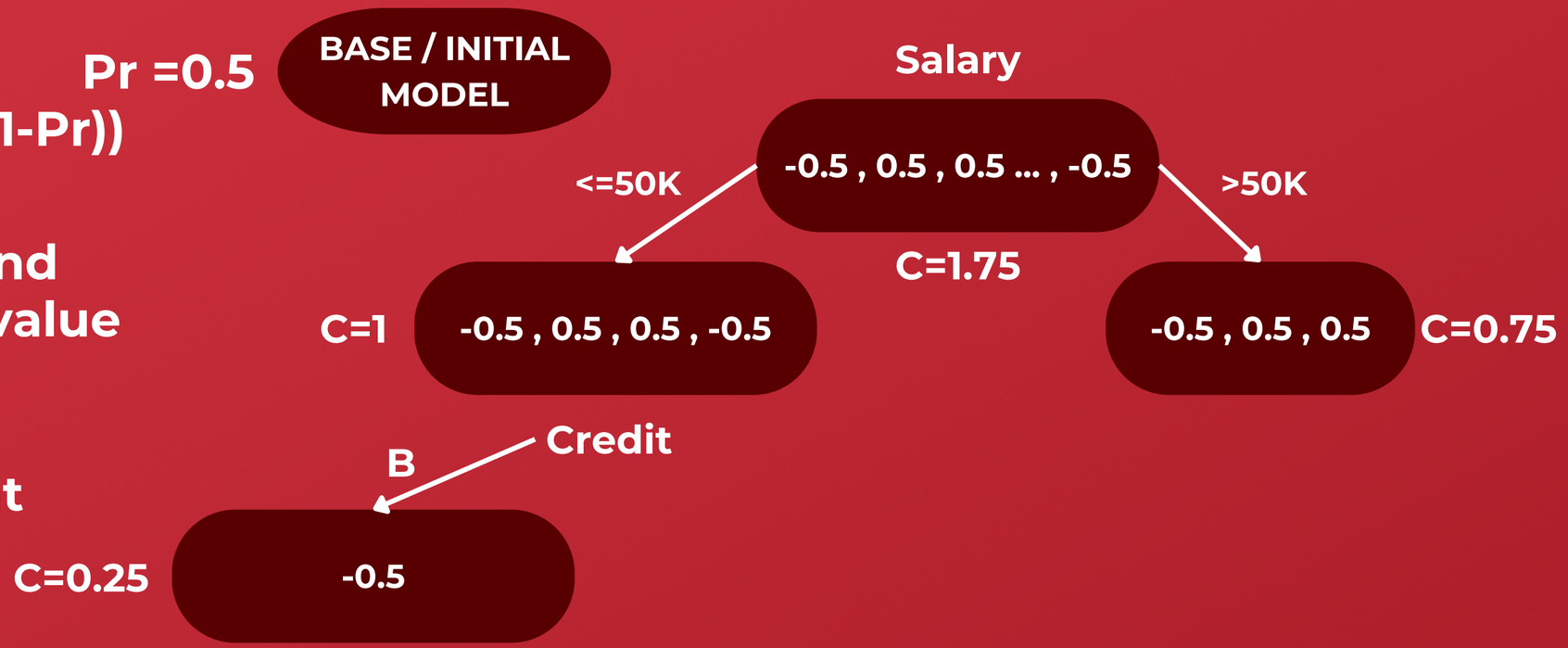

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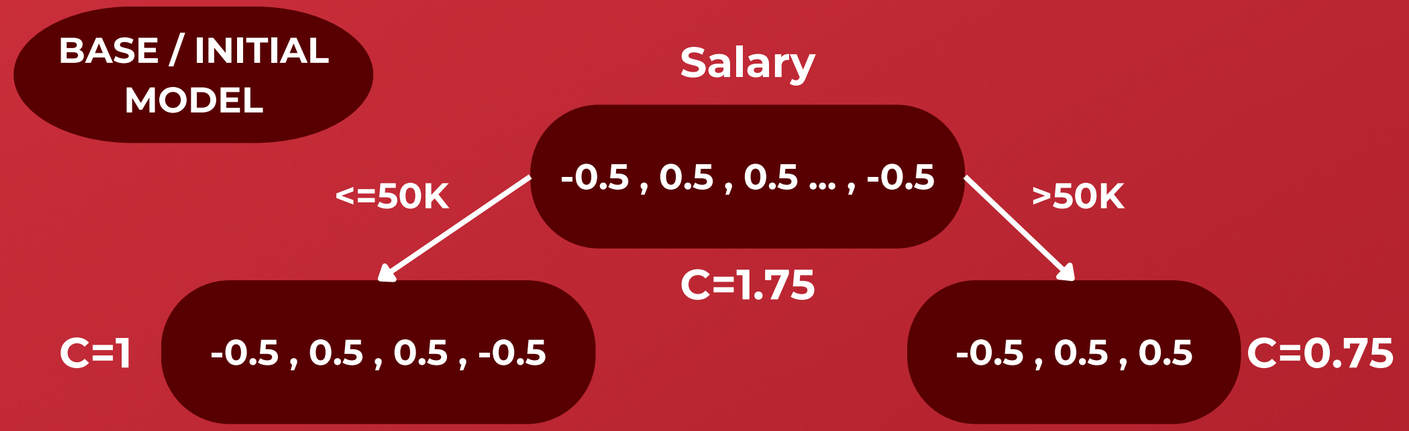

- **Example Minimum Cover = 1 :**
- **in Python :**
  By Default

XGBOOST CLASSIFICATION :

- **STEPS (COVER) :**
  - **Calculate the cover = ∑(Pr(1-Pr)) for each leaf**
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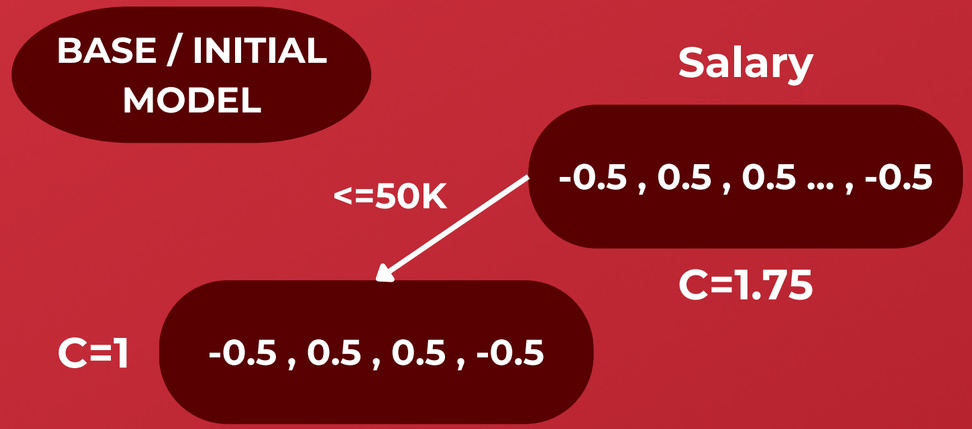

- **Example Minimum Cover = 1 :**
- **in Python :**
  By Default

XGBOOST CLASSIFICATION :

- **STEPS (COVER) :**
  - **Calculate the cover = ∑(Pr(1-Pr)) for each leaf**
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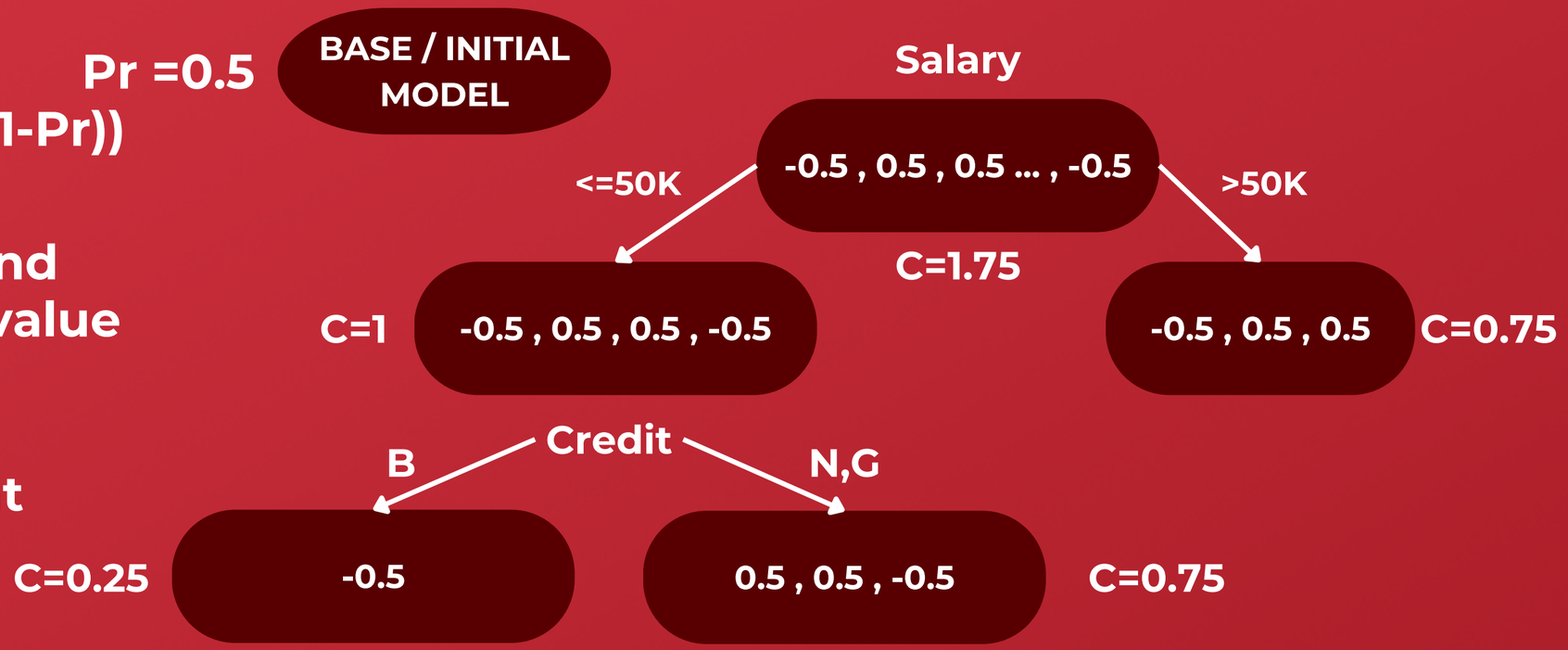

- **Example Minimum Cover = 3 :**
- **in Python : min_child_weight=3**

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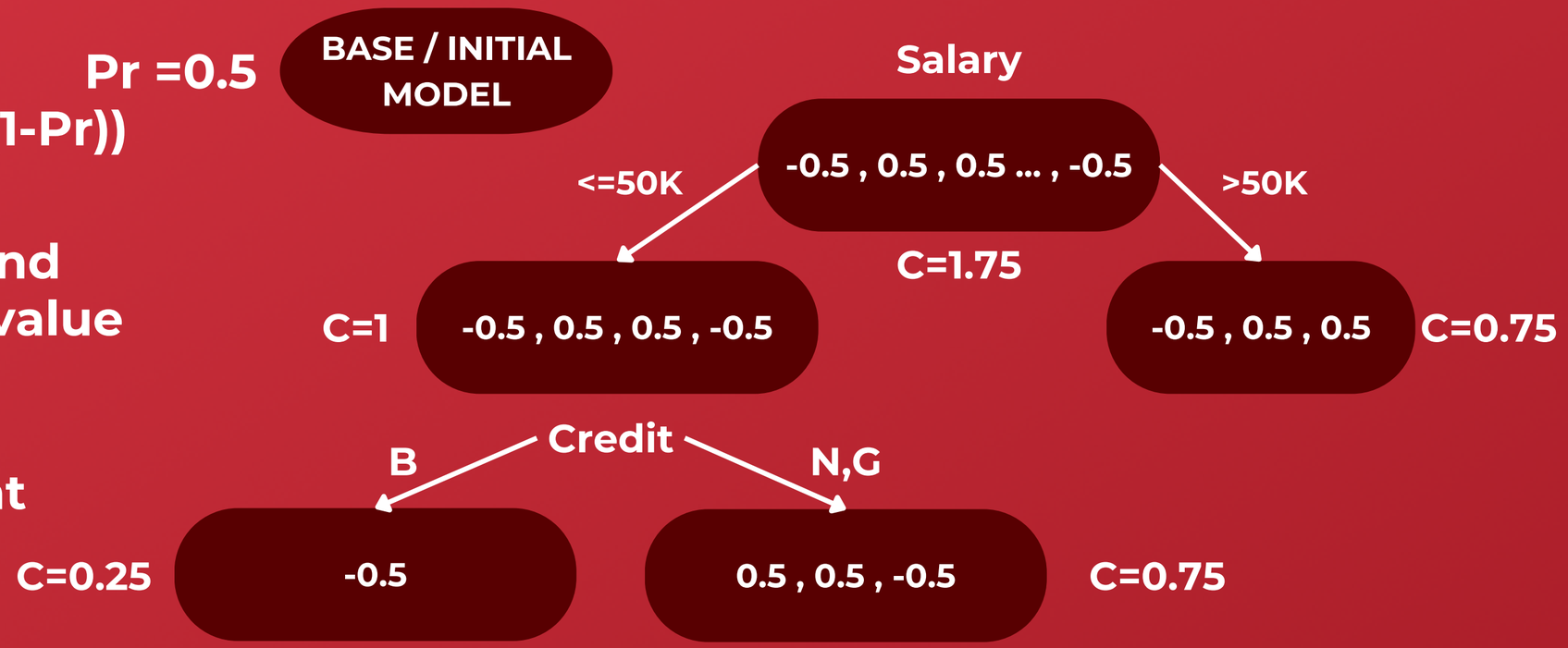
XGBOOST CLASSIFICATION :

- **STEPS (COVER) :** Pr =0.5 BASE / INITIAL MODEL
  - Calculate the cover = ∑(Pr(1-Pr)) for each leaf
  - Compare each leaf cover and and the default minimum value of the cover (which is by default = 1)
  - Eliminate all the leaves that have a cover < minimum cover

- Example Minimum Cover = 3 :
- in Python : min_child_weight=3

XGBOOST CLASSIFICATION :

- **STEPS (COVER) :**
  - Calculate the cover = ∑(Pr(1-Pr)) for each leaf
  - Compare each leaf cover and and the default minimum value of the cover (which is by default = 1)
  - Eliminate all the leaves that have a cover < minimum cover



- **Example Minimum Cover = 0 :**
- **in Python :**
  min_child_weight=0

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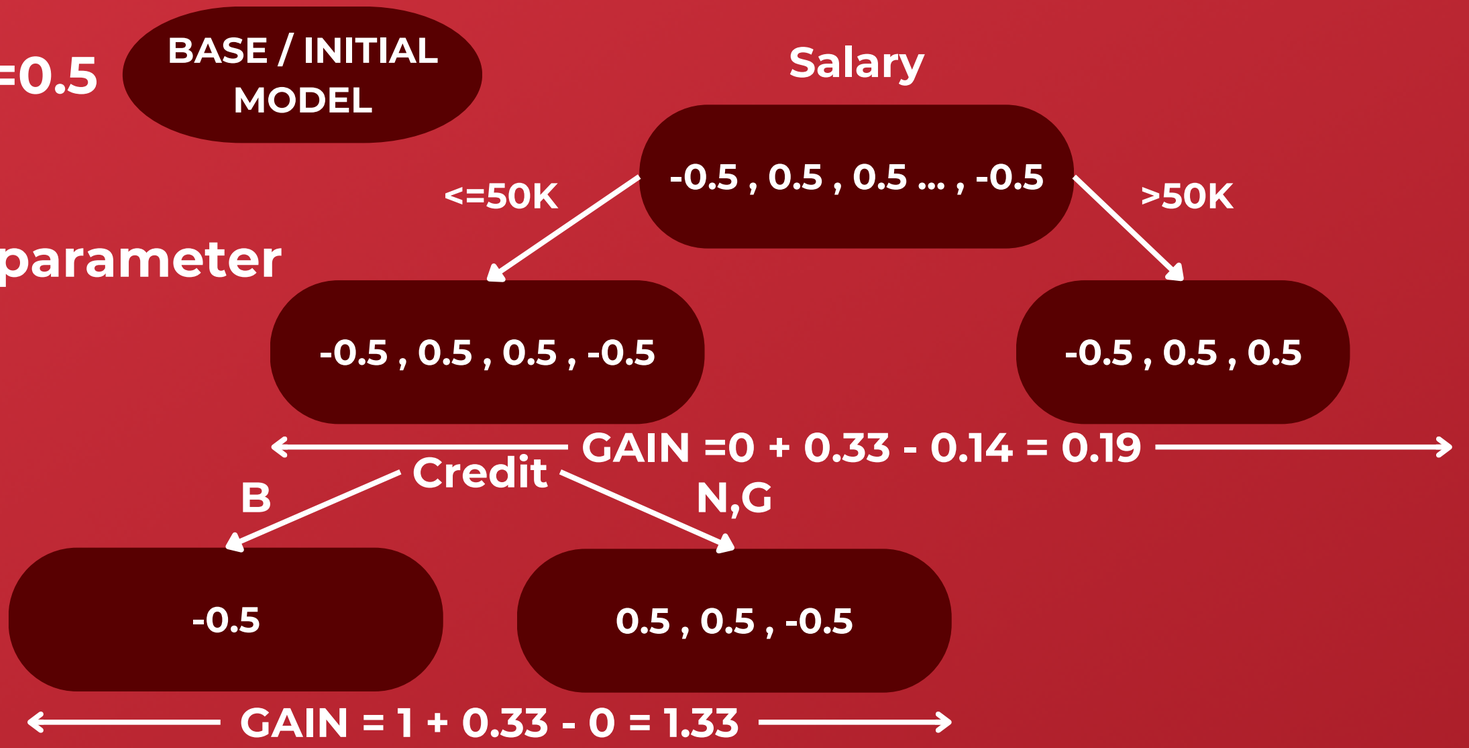
XGBOOST CLASSIFICATION :

- **STEPS (PRUNING) :**
  - **Calculate the :**
    Gain of the branch - γ (Gamma)
    - **γ(Gamma) is Tree Complexity parameter**
  - **If The Gain - γ < 0 :**
  - **We Prune the branch**
  - **If we Prune we Calculate the :**
    Next Gain - γ
  - **Etc ...**



- **Example γ = 2 :**

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XGBOOST CLASSIFICATION :

- **STEPS (PRUNING) :**
  - **Calculate the :**
    Gain of the branch - γ (Gamma)
    - **γ(Gamma) is Tree Complexity parameter**
  - **If The Gain - γ < 0 :**
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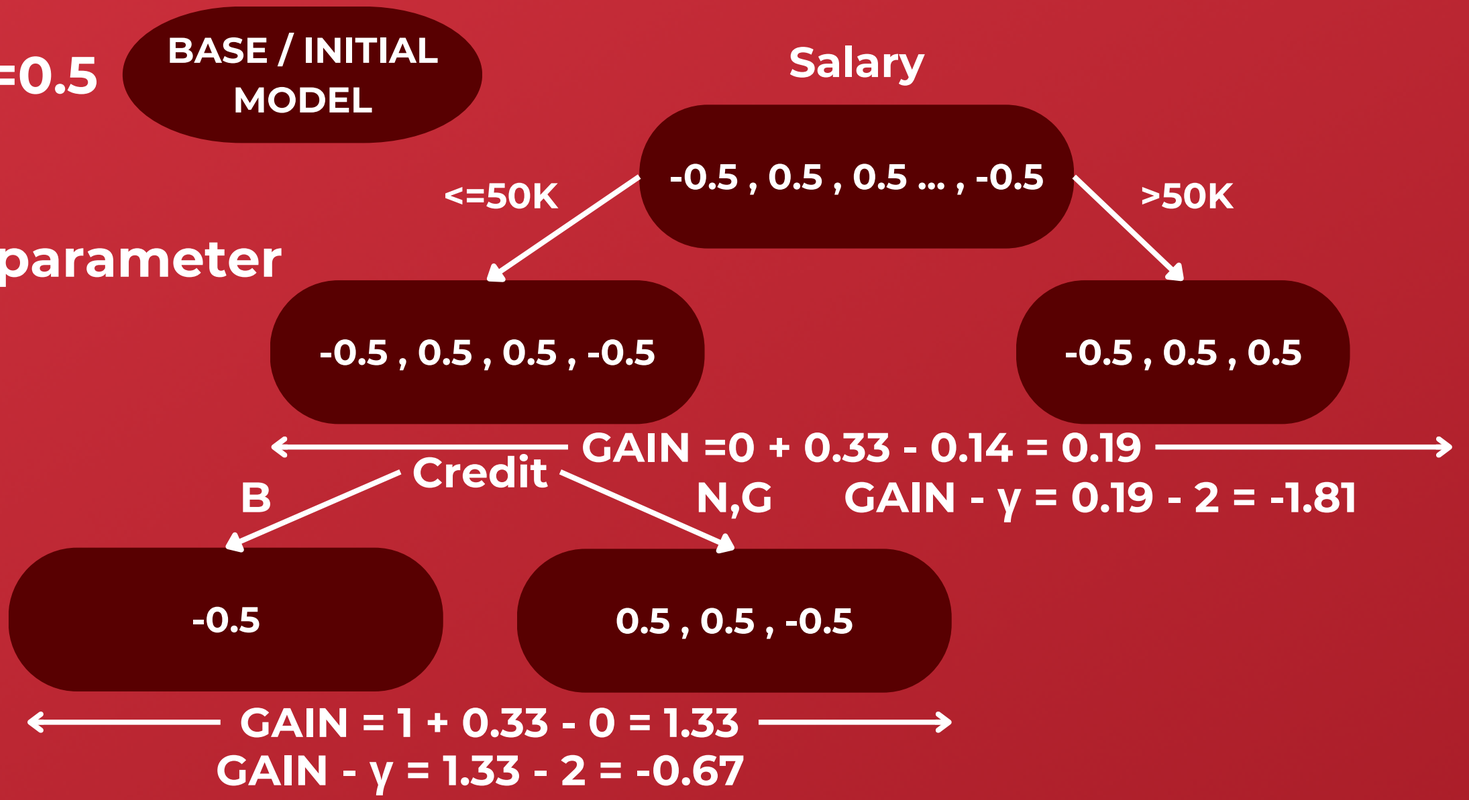
  - **If we Prune we Calculate the :**
    Next Gain - γ
  - **Etc ...**



- **Example γ = 2 :**

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XGBOOST CLASSIFICATION :

- **STEPS (PRUNING) :** Pr =0.5 BASE / INITIAL MODEL
  - Calculate the :
    Gain of the branch - γ (Gamma)
    - γ(Gamma) is Tree Complexity parameter
  - If The Gain - γ < 0 :
  - We Prune the branch
  - If we Prune we Calculate the :
    Next Gain - γ
  - Etc ...

- Example γ = 2 :

XGBOOST CLASSIFICATION :

- **STEPS (PRUNING) :**
  - **Calculate the :**
    Gain of the branch - γ (Gamma)
    - **γ(Gamma) is Tree Complexity parameter**
  - **If The Gain - γ < 0 :**
  - **We Prune the branch**
  - **If we Prune we Calculate the :**
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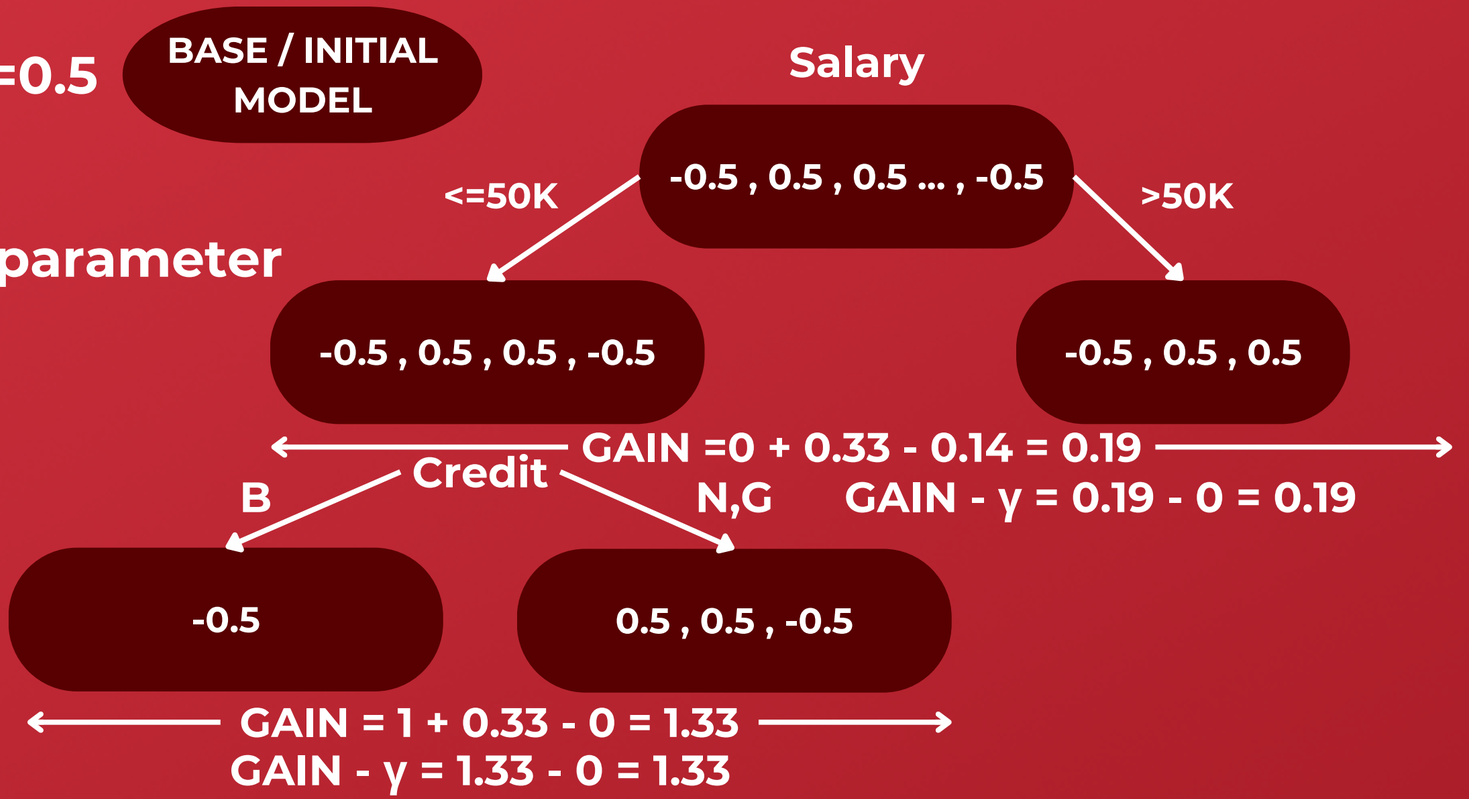
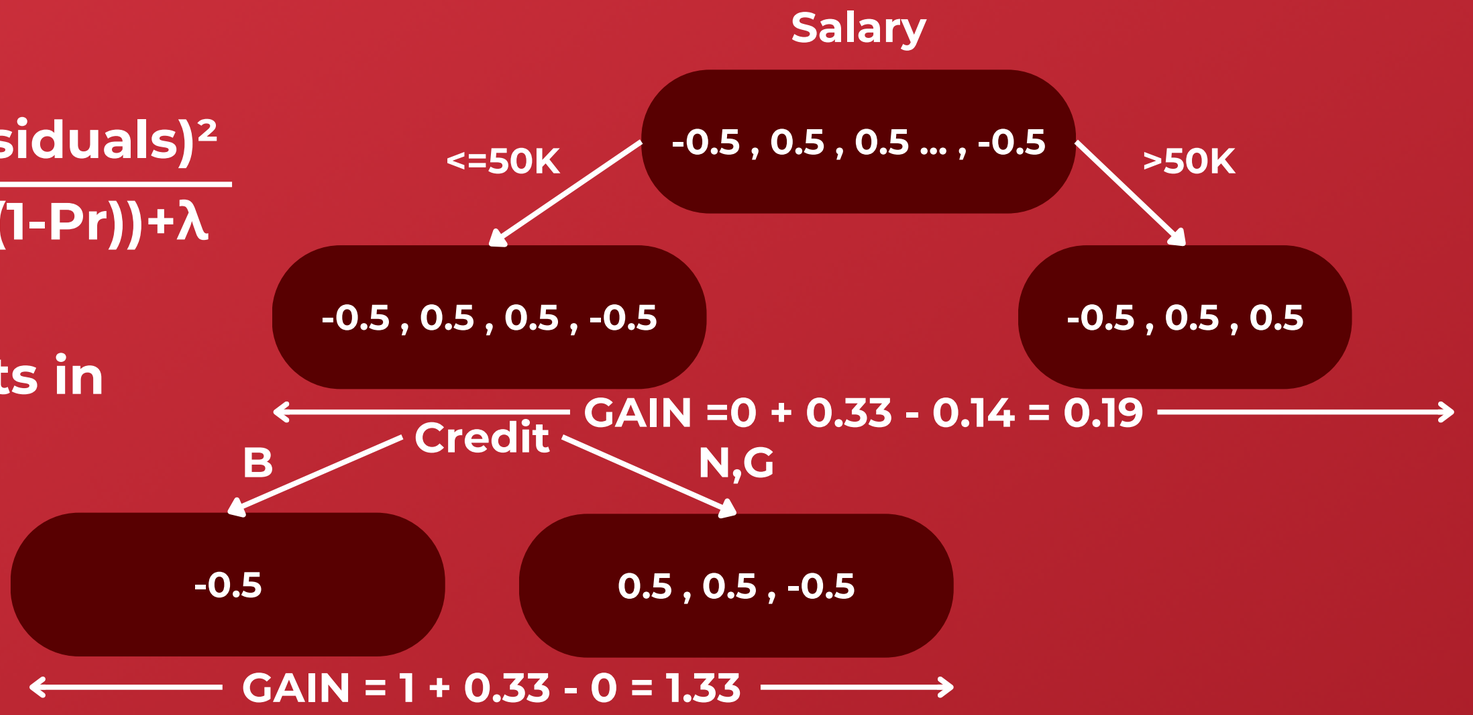
  - **Etc ...**



- **Example γ = 0 :**

XGBOOST CLASSIFICATION :

- **STEPS (PRUNING) :**
  - **Lastly, We Know That SW =** $\frac{\sum(\text{Residuals})^2}{\sum(Pr(1-Pr))+\lambda}$
  - **So λ (Lambda) is a Regularization Parameter and when λ>0, it results in more pruning by shrinking the Similarity Weights and branches gains .**
  - **Example γ=0 & λ=0:**

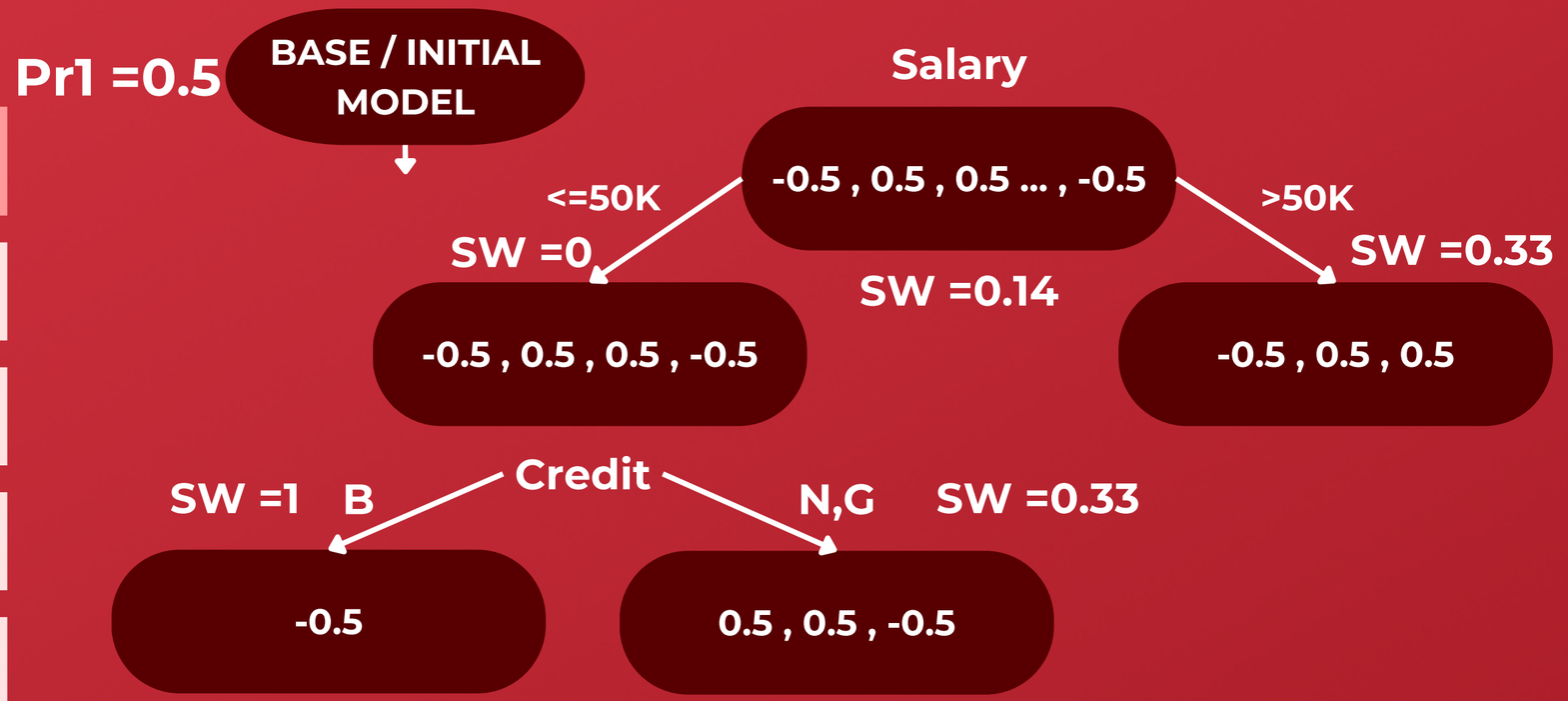


- **WHY PRUNING ? :**
  - **Pruning removes less important branches of decision trees, reducing complexity and making the model less likely to overfit and also, smaller pruned trees are often easier to understand and interpret**

XGBOOST CLASSIFICATION :

- **Dataset :**

SY	CR	AP	R1	Pr2	R2
<=50K	B	0	-0.5		
<=50K	G	1	0.5		
<=50K	G	1	0.5		
>50K	B	0	-0.5		
>50K	G	1	0.5		
>50K	N	1	0.5		
<=50K	N	0	-0.5		



- **FINAL STEPS :**
  - **Calculate the output of the Base Model using : log(odds) = log(Pr/1-Pr). In our case it is 0**
  - **Calculate the new probability of each record using : σ(0+ α(DT 1) + α(DT 2) + ... + α(DT N))**

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Knowing That : σ(x) =(1/1-e(x)) , α is the learning rate here = 0.1

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XGBOOST CLASSIFICATION :

- **Dataset :**

SY	CR	AP	R1	Pr2	R2
<=50K	B	0	-0.5		
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>50K	G	1	0.5		
>50K	N	1	0.5		
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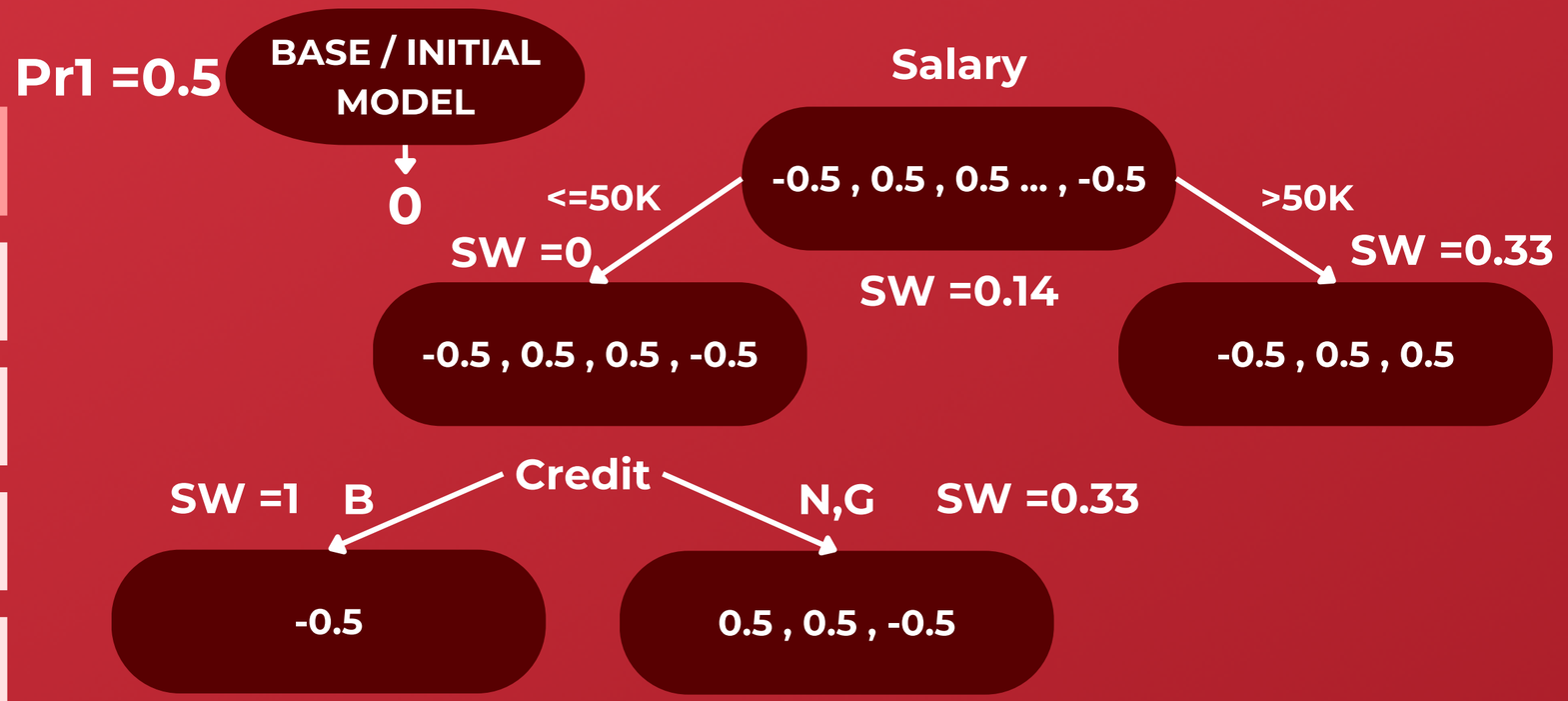

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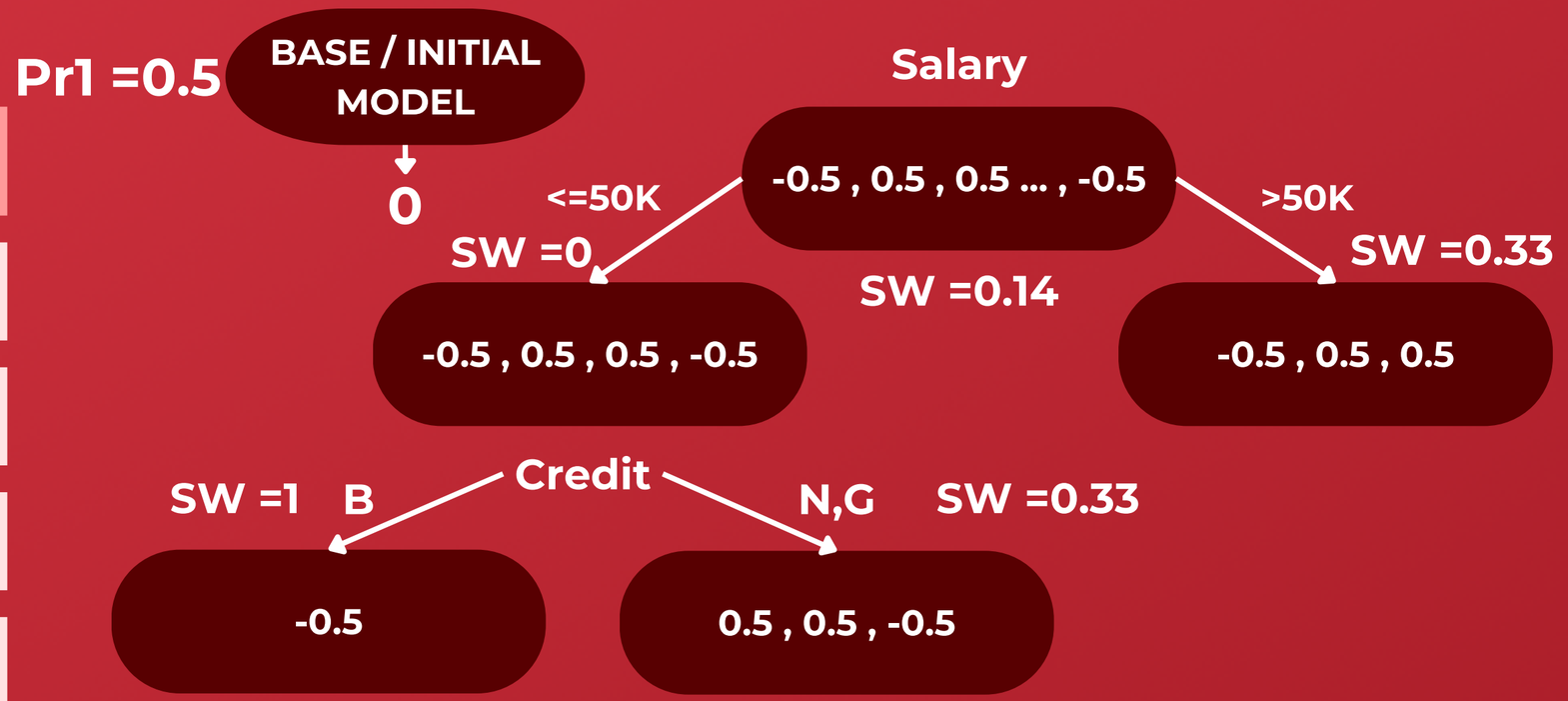
XGBOOST CLASSIFICATION :

- **Dataset :**

SY	CR	AP	R1	Pr2	R2
<=50K	B	0	-0.5	0.52	
<=50K	G	1	0.5		
<=50K	G	1	0.5		
>50K	B	0	-0.5		
>50K	G	1	0.5		
>50K	N	1	0.5		
<=50K	N	0	-0.5		



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XGBOOST CLASSIFICATION :

- **Dataset :**

SY	CR	AP	R1	Pr2	R2
<=50K	B	0	-0.5	0.52	
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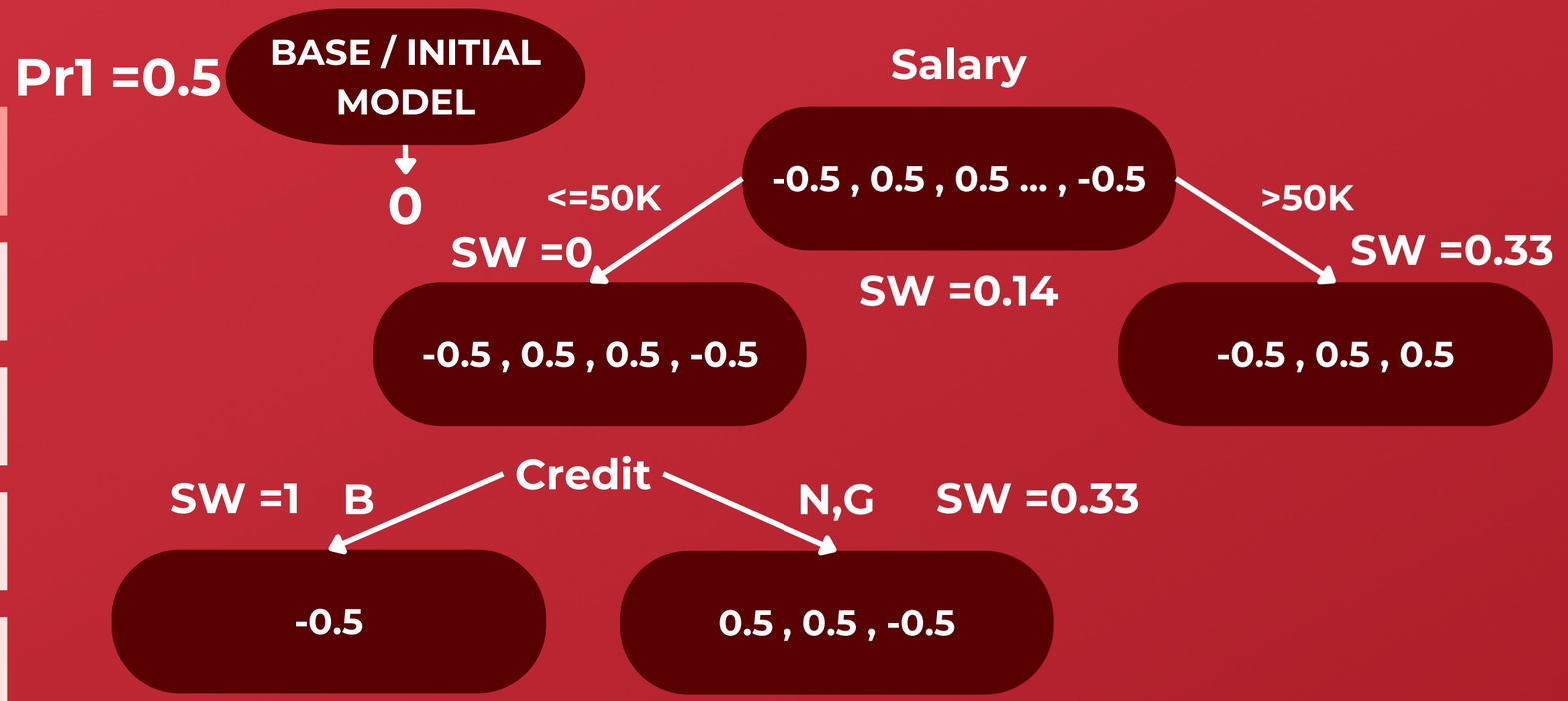
<=50K	G	1	0.5	0.5	
>50K	B	0	-0.5	0.5	
>50K	G	1	0.5	0.5	
>50K	N	1	0.5	0.5	
<=50K	N	0	-0.5	0.5	



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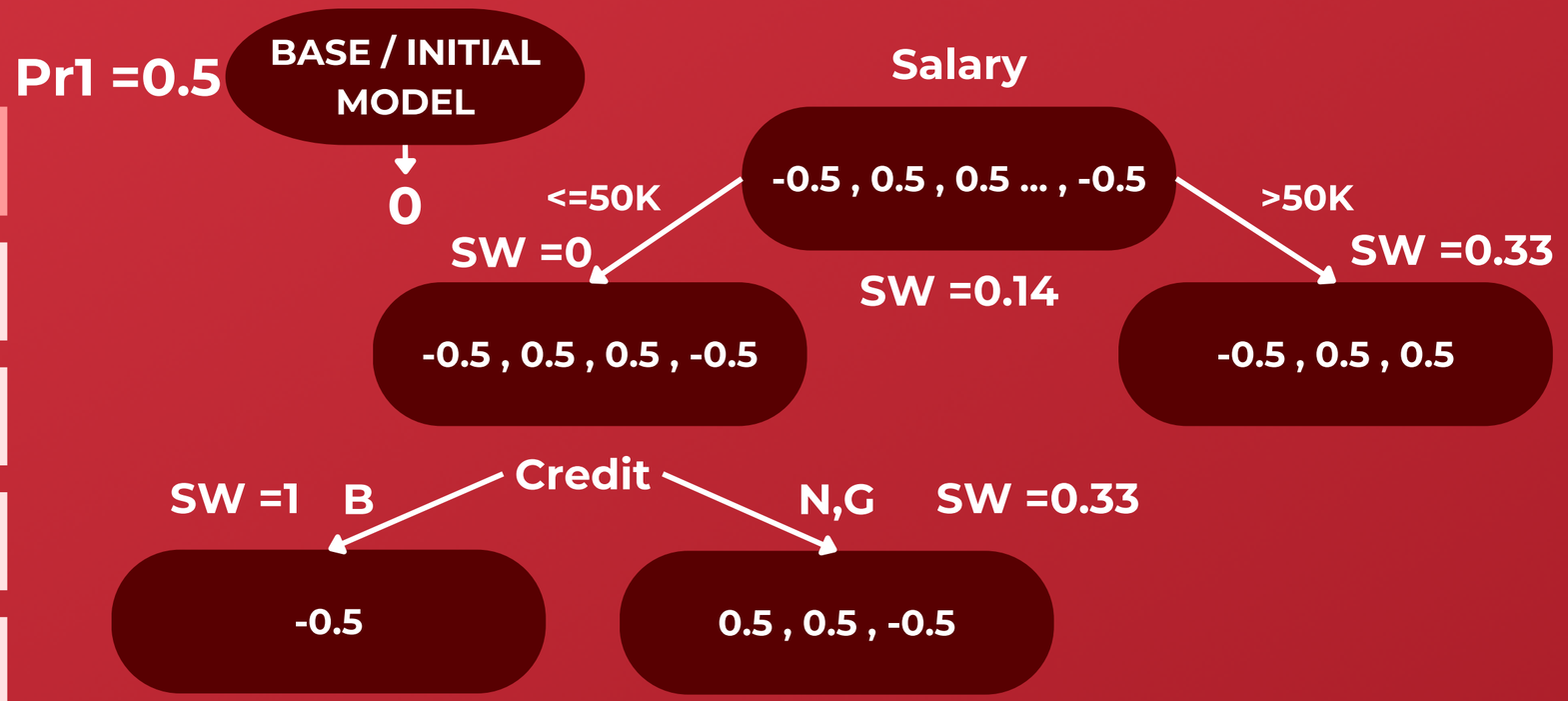
XGBOOST CLASSIFICATION :

- **Dataset :**

SY	CR	AP	R1	Pr2	R2
<=50K	B	0	-0.5	0.52	-0.48
<=50K	G	1	0.5	0.5	
<=50K	G	1	0.5	0.5	
>50K	B	0	-0.5	0.5	
>50K	G	1	0.5	0.5	
>50K	N	1	0.5	0.5	
<=50K	N	0	-0.5	0.5	



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AI CAMP

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SY	CR	AP	R1	Pr2	R2
<=50K	B	0	-0.5	0.52	-0.48
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<=50K	G	1	0.5	0.5	0.5
>50K	B	0	-0.5	0.5	-0.5
>50K	G	1	0.5	0.5	0.5
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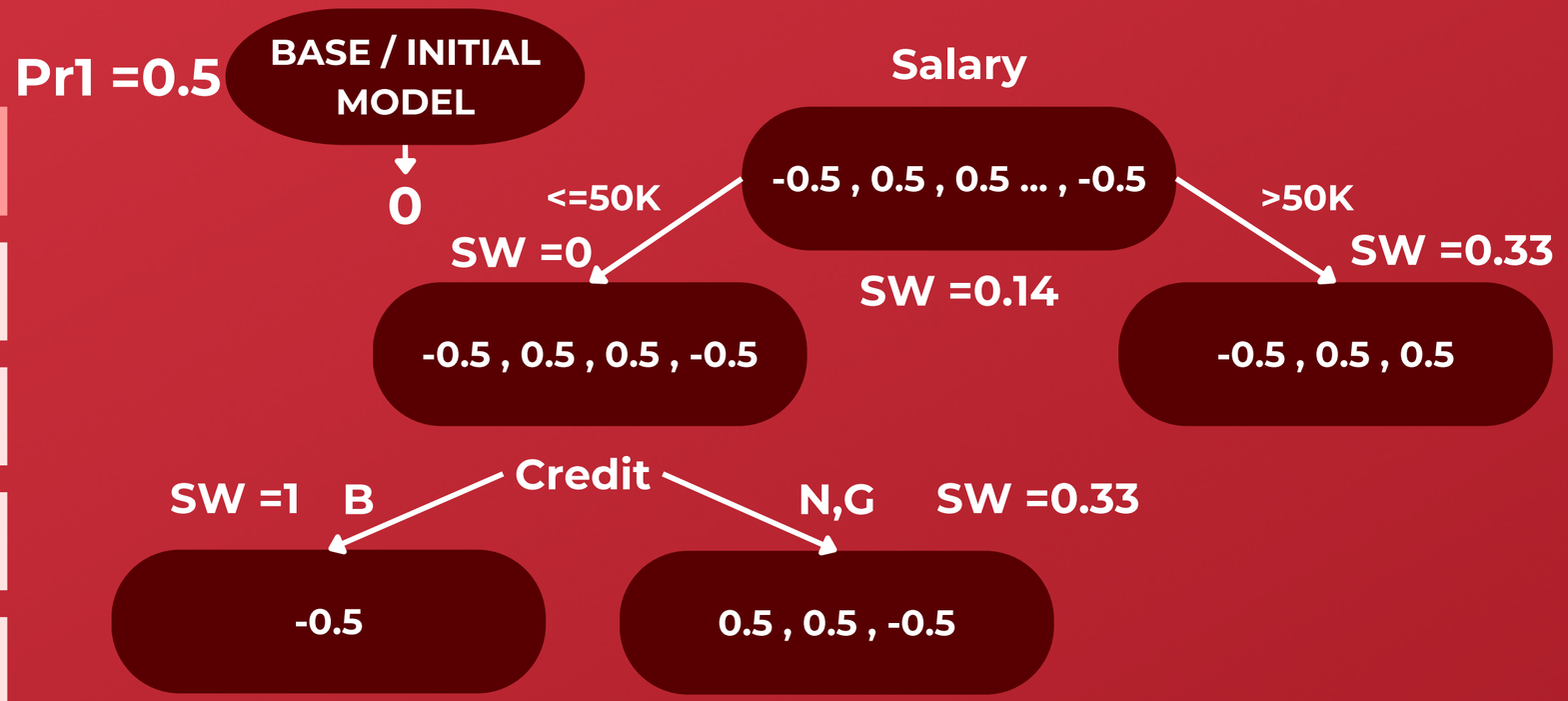
<=50K	N	0	-0.5	0.5	-0.5



- **FINAL STEPS :**
  - **Calculate the output of the Base Model using : log(odds) = log(Pr/1-Pr). In our case it is 0**
  - **Calculate the new probability of each record using : σ(0+ α x (DT 1) + α x (DT 2) + ... + α x (DT N))**

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Knowing That : σ(x) =(1/1-e(x)) , α is the learning rate here = 0.1

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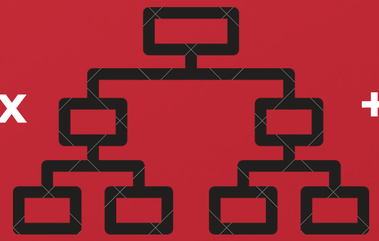
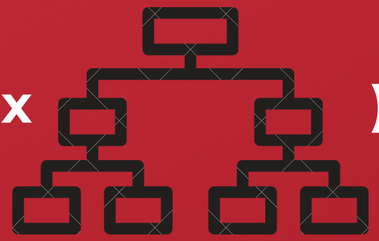
XGBOOST CLASSIFICATION :

DataSet → BASE / INITIAL MODEL → DT 1 → DT N

Probability = σ(0 + α x (DT 1) + ... + α x (DT N))

Probability = σ(BASE / INITIAL MODEL + α x  + ... + α x )

- **FINAL STEPS :**
  - **Calculate the output of the Base Model using : log(odds) = log(Pr/1-Pr). In our case it is 0**
  - **Calculate the new probability of each record using : σ(0+ α x (DT 1) + α x (DT 2) + ... + α x (DT N))**

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Knowing That : σ(x) =(1/1-e(x)) , α is the learning rate, here α= 0.1

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LET'S MOVE TO XGBOOST FOR REGRESSION

EXTREME GRADIENT BOOSTING WITH XGBOOST

XGBOOST REGRESSION :

- **Dataset :** Avg Salary= 51k

BASE / INITIAL MODEL

EXP	GAP	SALARY	RES
2	Y	40k	
2.5	Y	42k	
3	N	52k	
4	N	60k	
4.5	Y	62k	

- **STEPS :**
  - Construct tree with root
  - Calculate Similarity Weight = $\frac{\sum(\text{Residuals})^2}{\text{Nb of Res} + \lambda}$
  - Calculate the gain = SWL+SWR-SW(ROOT)

Knowing That : RES = Salary - Avg Salary , λ=1

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XGBOOST REGRESSION :

- **Dataset :** Avg Salary= 51k

BASE / INITIAL MODEL

EXP	GAP	SALARY	RES
2	Y	40k	-11k
2.5	Y	42k	
3	N	52k	
4	N	60k	
4.5	Y	62k	

- **STEPS :**
  - Construct tree with root
  - Calculate Similarity Weight = $\frac{\sum(\text{Residuals})^2}{\text{Nb of Res} + \lambda}$
  - Calculate the gain = SWL+SWR-SW(ROOT)

Knowing That : RES = Salary - Avg Salary , λ=1

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XGBOOST REGRESSION :

- **Dataset :** Avg Salary= 51k

BASE / INITIAL MODEL

EXP	GAP	SALARY	RES
2	Y	40k	-11k
2.5	Y	42k	-9k
3	N	52k	1k
4	N	60k	9k
4.5	Y	62k	11k

- **STEPS :**
  - Construct tree with root
  - Calculate Similarity Weight = $\frac{\sum(\text{Residuals})^2}{\text{Nb of Res} + \lambda}$
  - Calculate the gain = SWL+SWR-SW(ROOT)

Knowing That : RES = Salary - Avg Salary , λ=1

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XGBOOST REGRESSION :

- **Dataset :** Avg Salary= 51k

BASE / INITIAL MODEL

EXP	GAP	SALARY	RES
2	Y	40k	-11k
2.5	Y	42k	-9k
3	N	52k	1k
4	N	60k	9k
4.5	Y	62k	11k

Split 1
EXP

- **STEPS :**
  - Construct tree with root
  - Calculate Similarity Weight = $\frac{\sum(\text{Residuals})^2}{\text{Nb of Res} + \lambda}$
  - Calculate the gain = SWL+SWR-SW(ROOT)

Knowing That : RES = Salary - Avg Salary , λ=1

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XGBOOST REGRESSION :

- **Dataset :**

Avg Salary= 51k

BASE / INITIAL MODEL

EXP	GAP	SALARY	RES
2	Y	40k	-11k
2.5	Y	42k	-9k
3	N	52k	1k
4	N	60k	9k
4.5	Y	62k	11k

Split 1
EXP

-11 , -9 , 1 , 9 , 11

- **STEPS :**
  - Construct tree with root
  - Calculate Similarity Weight = $\frac{\sum(\text{Residuals})^2}{\text{Nb of Res} + \lambda}$
  - Calculate the gain = SWL+SWR-SW(ROOT)

Knowing That : RES = Salary - Avg Salary , λ=1

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XGBOOST REGRESSION :

- **Dataset :** Avg Salary= 51k

EXP	GAP	SALARY	RES
2	Y	40k	-11k
2.5	Y	42k	-9k
3	N	52k	1k
4	N	60k	9k
4.5	Y	62k	11k

- **STEPS :**
  - Construct tree with root
  - Calculate Similarity Weight = $\frac{\sum(\text{Residuals})^2}{\text{Nb of Res} + \lambda}$
  - Calculate the gain = SWL+SWR-SW(ROOT)

Knowing That : RES = Salary - Avg Salary , λ=1

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XGBOOST REGRESSION :

- **Dataset :** Avg Salary= 51k

EXP	GAP	SALARY	RES
2	Y	40k	-11k
2.5	Y	42k	-9k
3	N	52k	1k
4	N	60k	9k
4.5	Y	62k	11k

- **STEPS :**
  - Construct tree with root
  - Calculate Similarity Weight = $\frac{\sum(\text{Residuals})^2}{\text{Nb of Res} + \lambda}$
  - Calculate the gain = SWL+SWR-SW(ROOT)

Knowing That : RES = Salary - Avg Salary , λ=1

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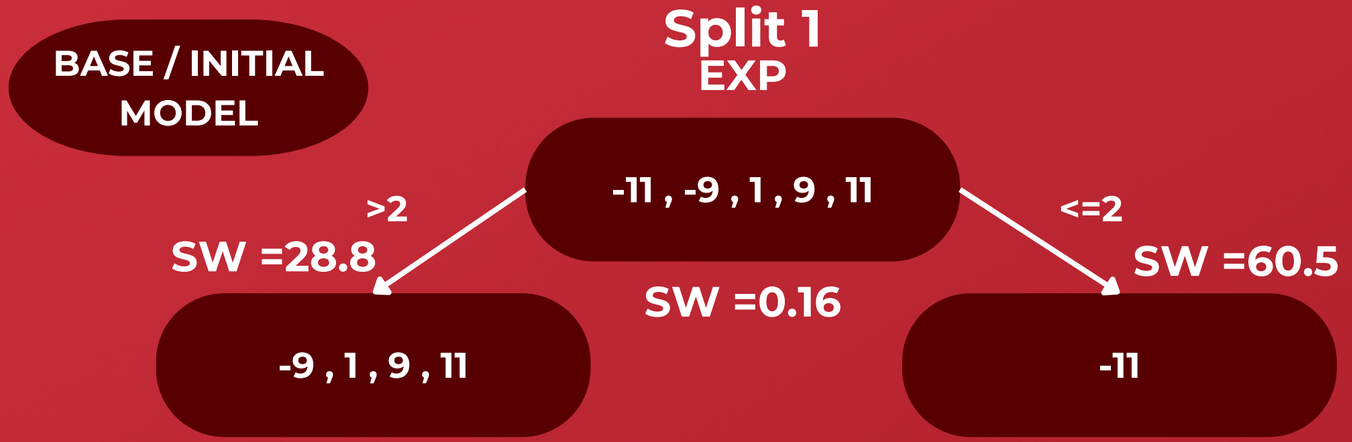
XGBOOST REGRESSION :

- **Dataset :** Avg Salary= 51k

EXP	GAP	SALARY	RES
2	Y	40k	-11k
2.5	Y	42k	-9k
3	N	52k	1k
4	N	60k	9k
4.5	Y	62k	11k



- **STEPS :**
  - Construct tree with root
  - Calculate Similarity Weight = $\frac{\sum(\text{Residuals})^2}{\text{Nb of Res} + \lambda}$
  - Calculate the gain = SWL+SWR-SW(ROOT)

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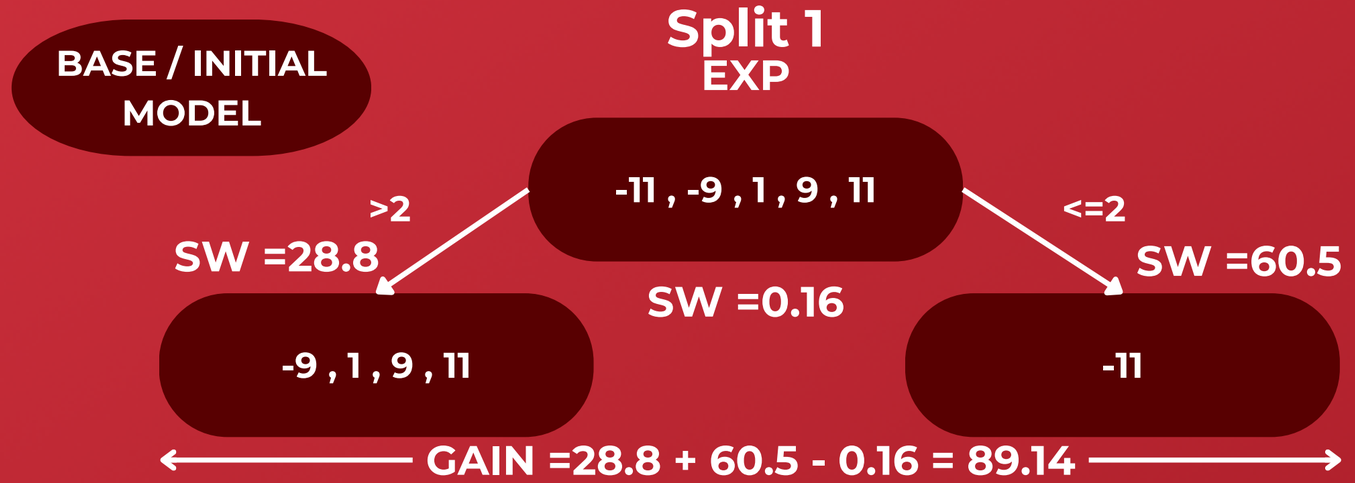
4	N	60k	9k
4.5	Y	62k	11k



- Gain Split 1 = 89.14

- **STEPS :**
  - Construct tree with root
  - Calculate Similarity Weight = $\frac{\sum(\text{Residuals})^2}{\text{Nb of Res} + \lambda}$
  - Calculate the gain = SWL+SWR-SW(ROOT)

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XGBOOST REGRESSION :

- **Dataset :** Avg Salary= 51k

BASE / INITIAL MODEL

EXP	GAP	SALARY	RES
2	Y	40k	-11k
2.5	Y	42k	-9k
3	N	52k	1k
4	N	60k	9k
4.5	Y	62k	11k

Split 2
EXP

-11 , -9 , 1 , 9 , 11

- Gain Split 1 = 89.14

- **STEPS :**
  - Construct tree with root
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  - Calculate the gain = SWL+SWR-SW(ROOT)

Knowing That : RES = Salary - Avg Salary , λ=1

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EXP	GAP	SALARY	RES
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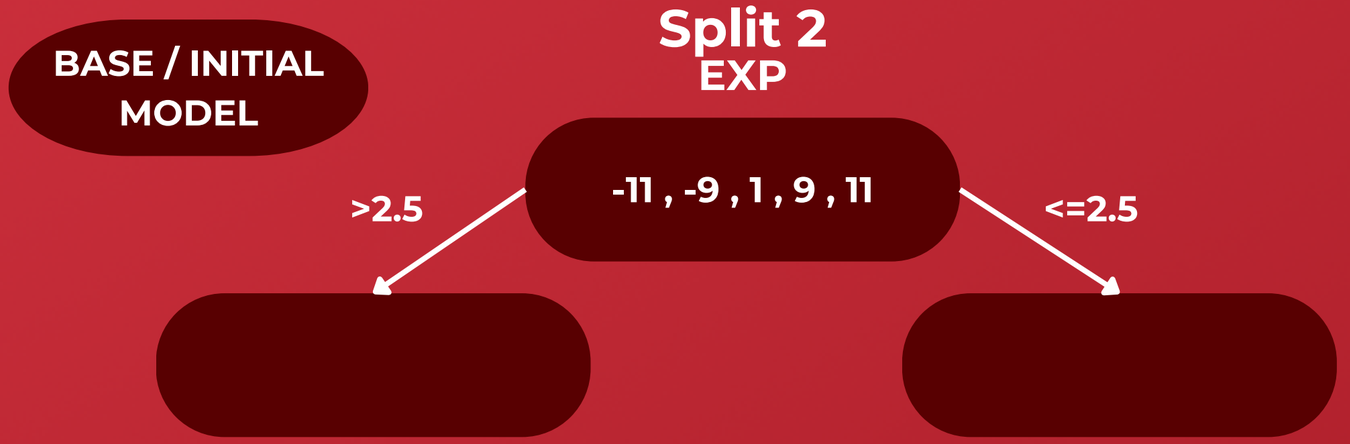
4	N	60k	9k
4.5	Y	62k	11k

- Gain Split 1 = 89.14



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4	N	60k	9k
4.5	Y	62k	11k

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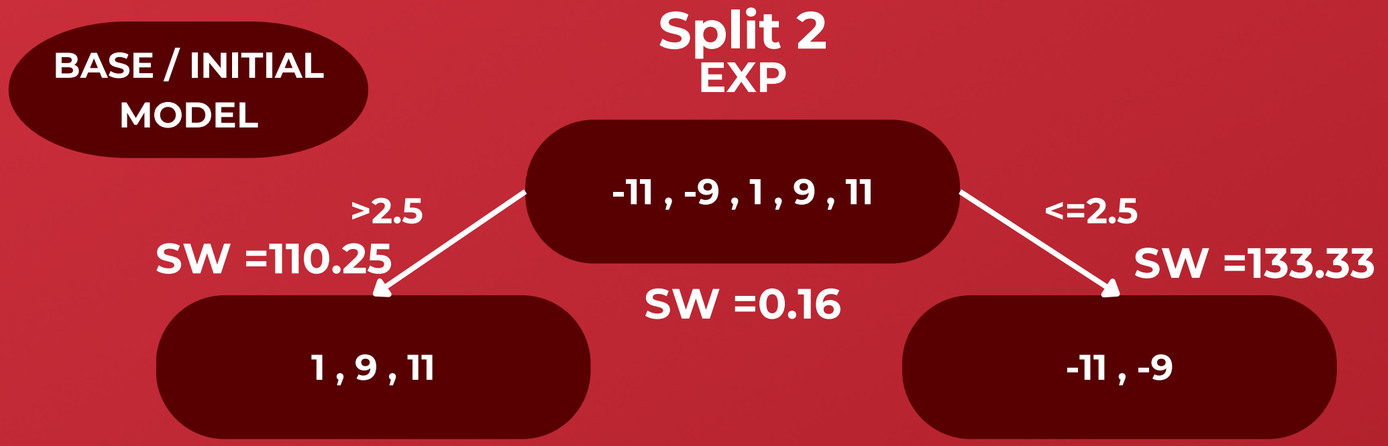

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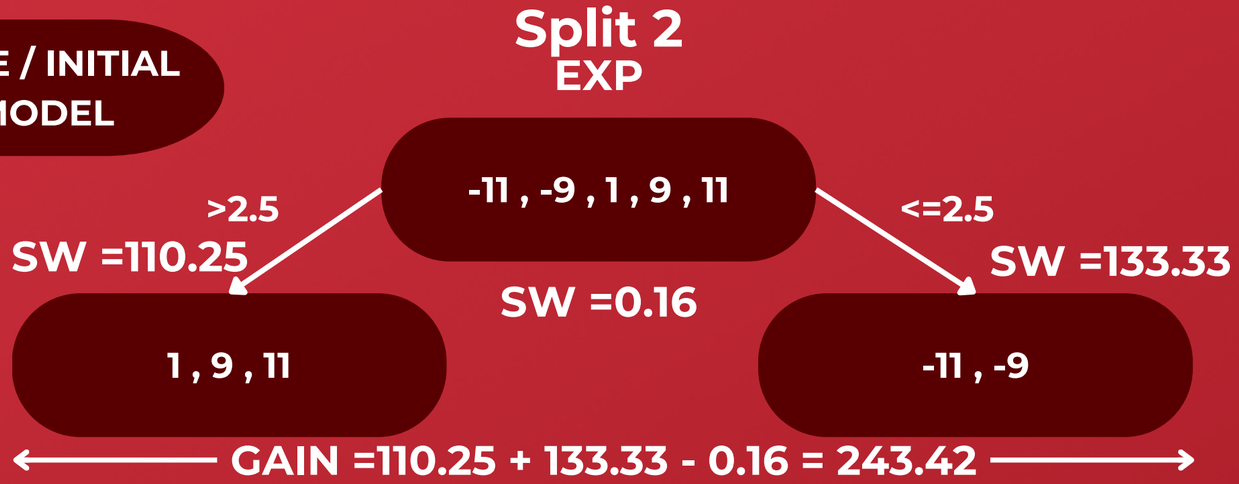

- Gain Split 1 = 89.14
- Gain Split 2 = 243.42
- Gain Split 2 > Gain Split 1 So : We keep The Split 2

- **STEPS :**
  - Construct tree with root
  - Calculate Similarity Weight = $\frac{\sum(\text{Residuals})^2}{\text{Nb of Res} + \lambda}$
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- **Dataset :** Avg Salary= 51k

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3	N	52k	1k
4	N	60k	9k
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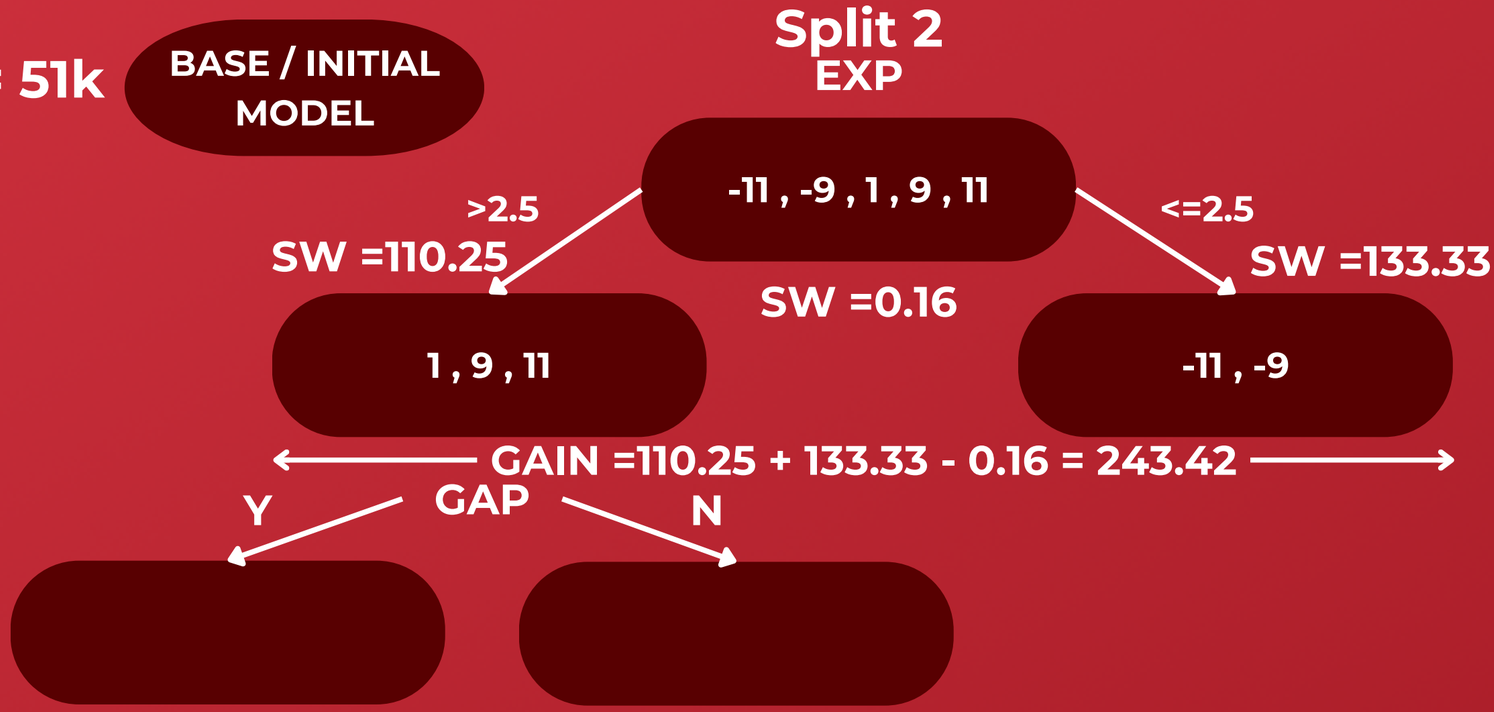

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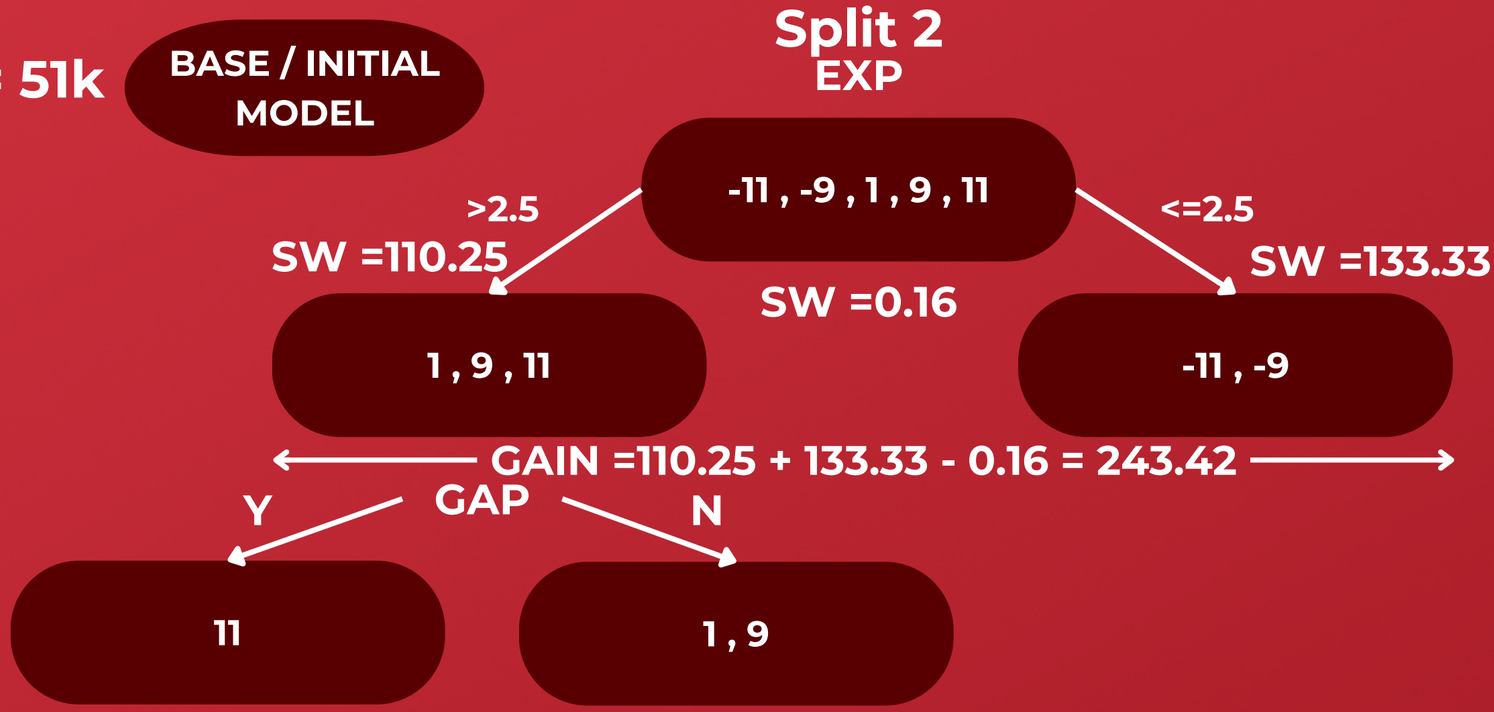
4	N	60k	9k
4.5	Y	62k	11k



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- **Dataset :** Avg Salary= 51k

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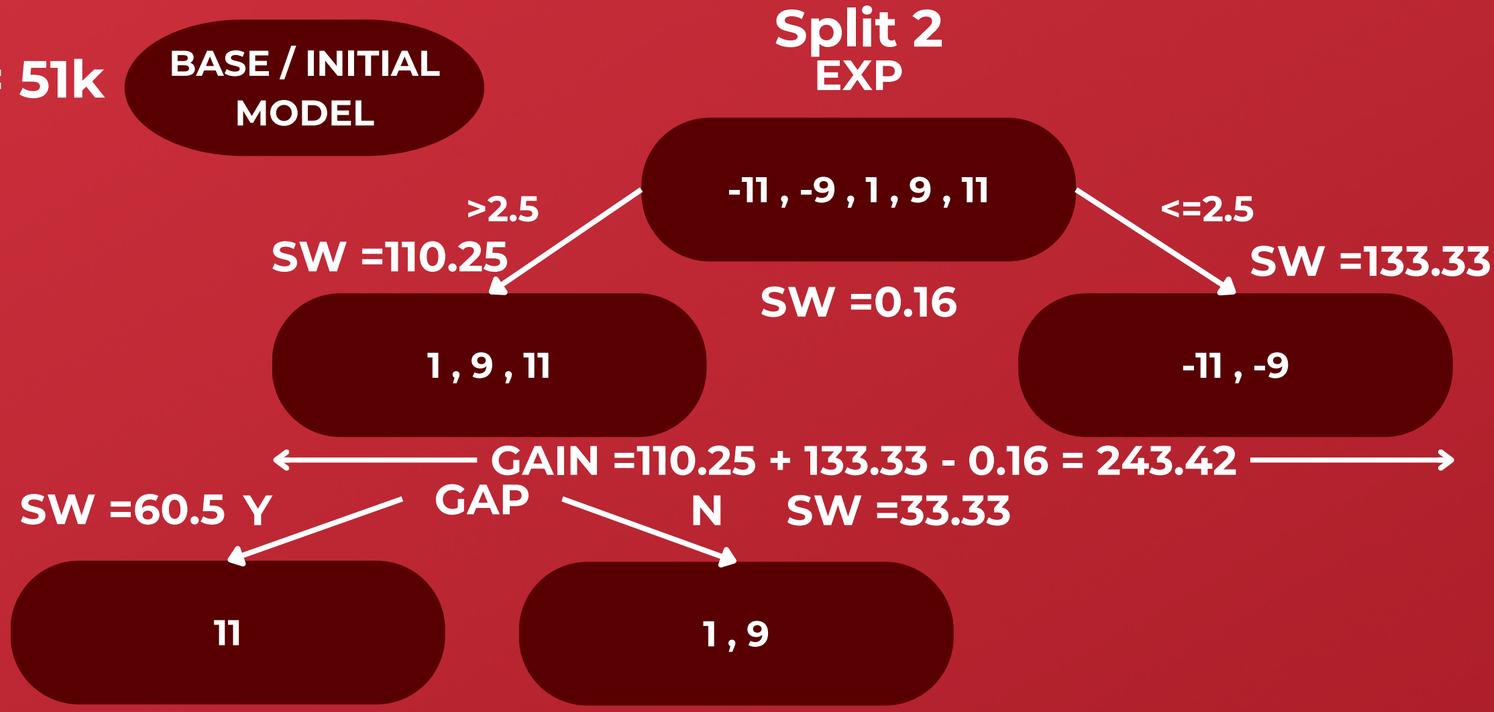
2	Y	40k	-11k
2.5	Y	42k	-9k
3	N	52k	1k
4	N	60k	9k
4.5	Y	62k	11k



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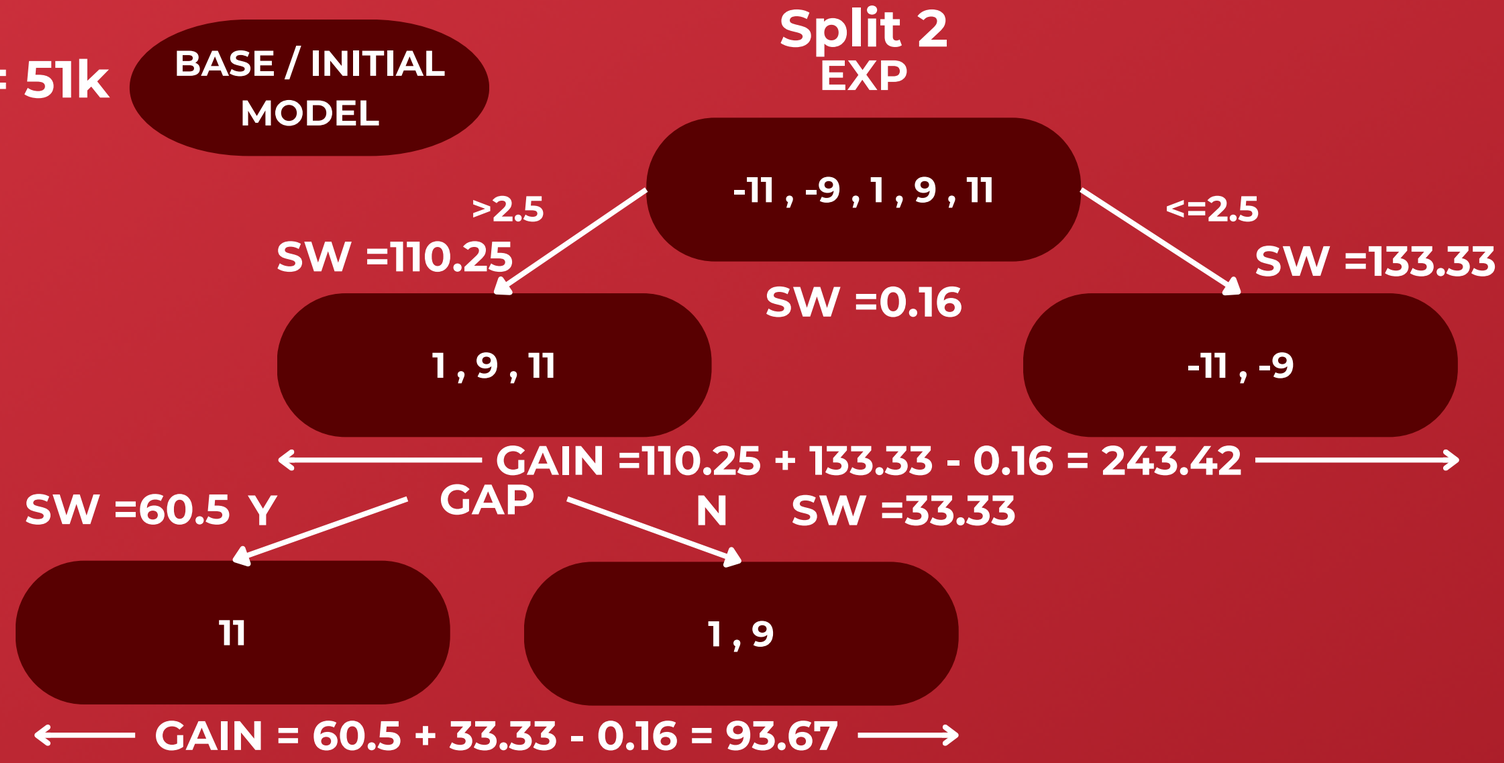

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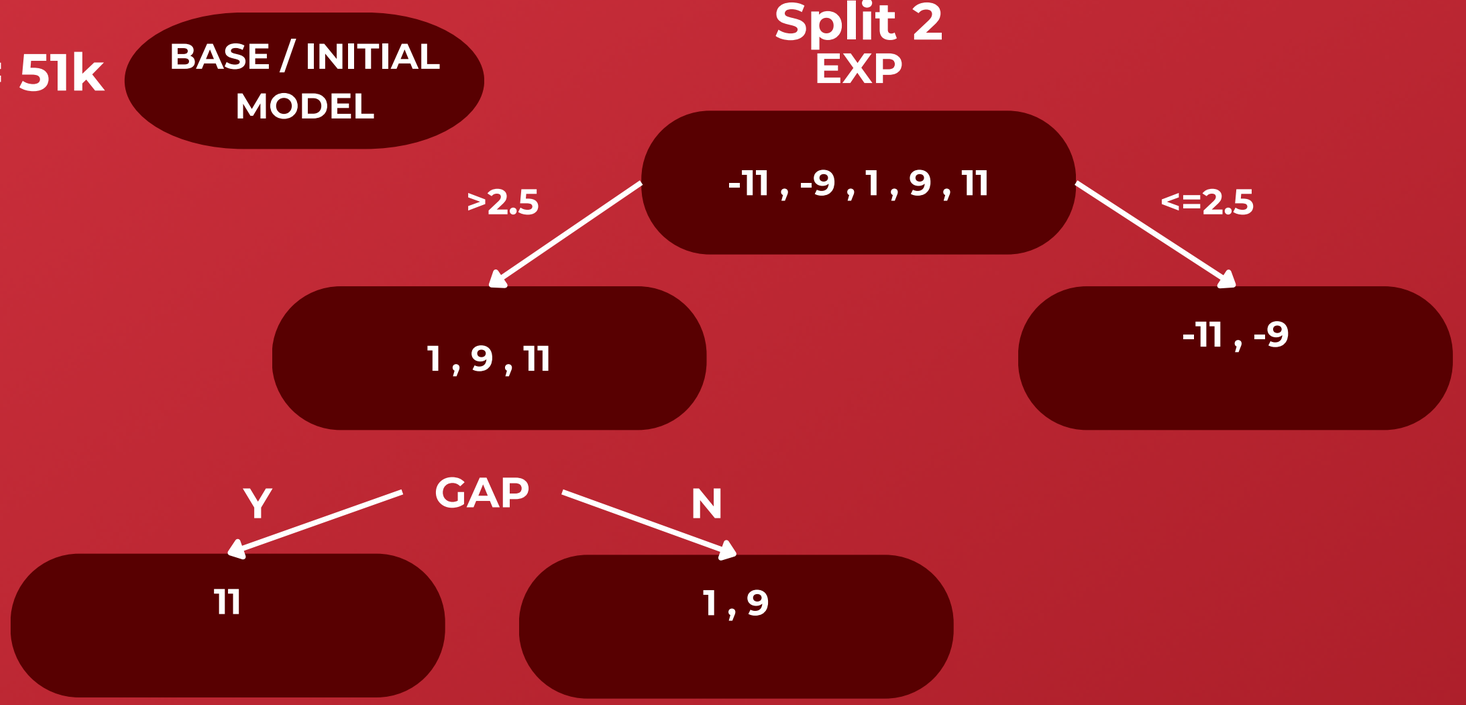
XGBOOST REGRESSION :

- **Dataset :** Avg Salary= 51k

EX	GP	SY	RS1	O/P	RS2
2	Y	40k	-11k		
2.5	Y	42k	-9k		
3	N	52k	1k		
4	N	60k	9k		
4.5	Y	62k	11k		



- **FINAL STEPS :**
  - Calculate the output of each bottom leaf using :
    Output = Avg of RES = (Sum Residuals)/(Nb Residuals)
  - Calculate the new probability of each record using :
    O/P =Base Model+ α(DT 1) + α(DT 2) + ... + α(DT N)

Knowing That : RS2 = Salary - Output , α is the learning rate = 0.5

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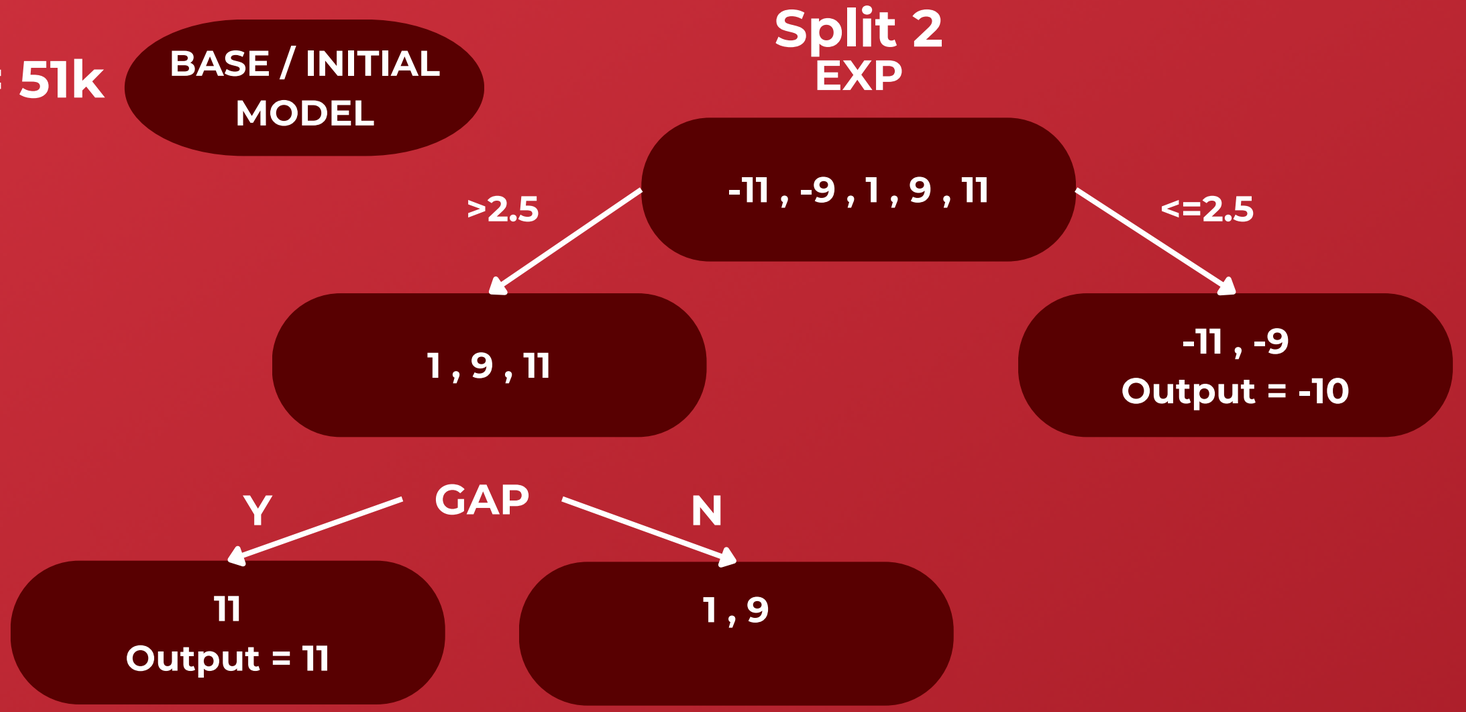
XGBOOST REGRESSION :

- **Dataset :** Avg Salary= 51k

EX	GP	SY	RS1	O/P	RS2
2	Y	40k	-11k		
2.5	Y	42k	-9k		
3	N	52k	1k		
4	N	60k	9k		
4.5	Y	62k	11k		



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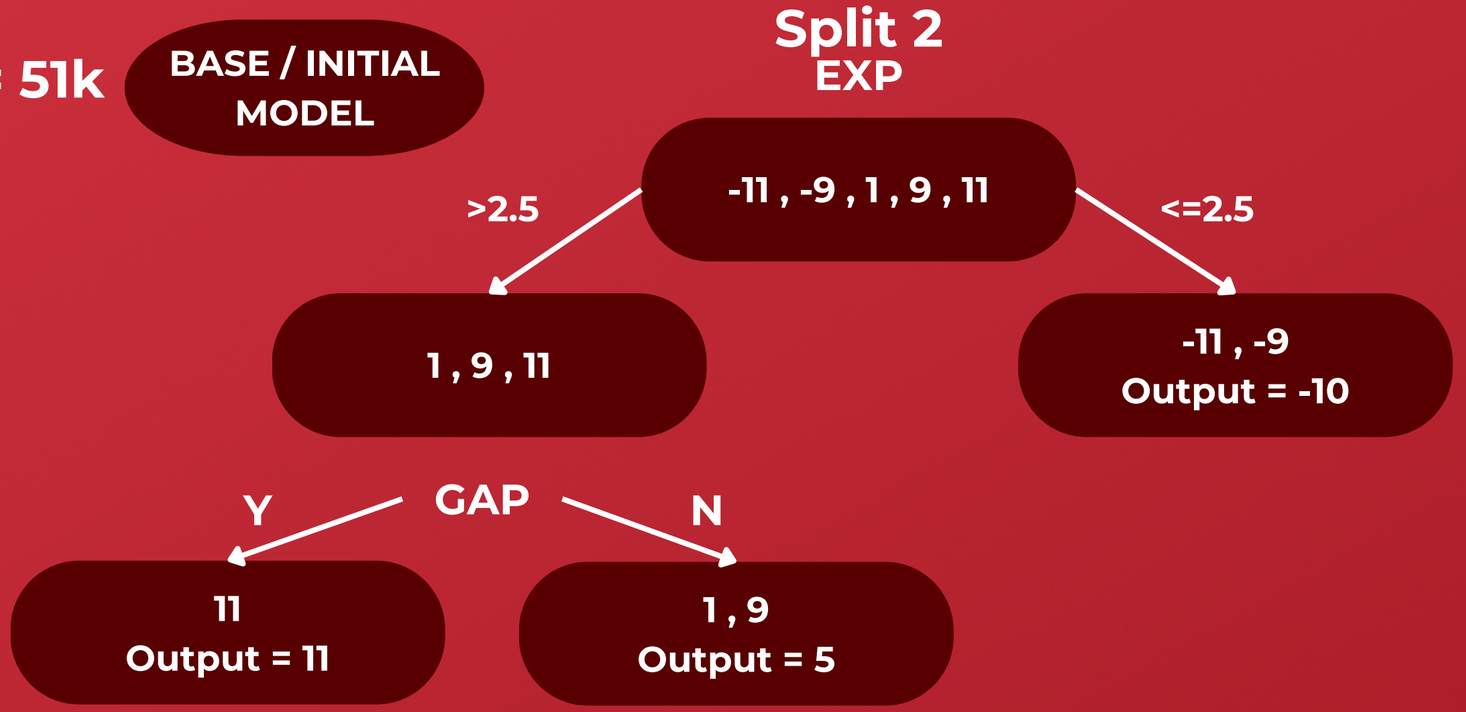
3	N	52k	1k		
4	N	60k	9k		
4.5	Y	62k	11k		



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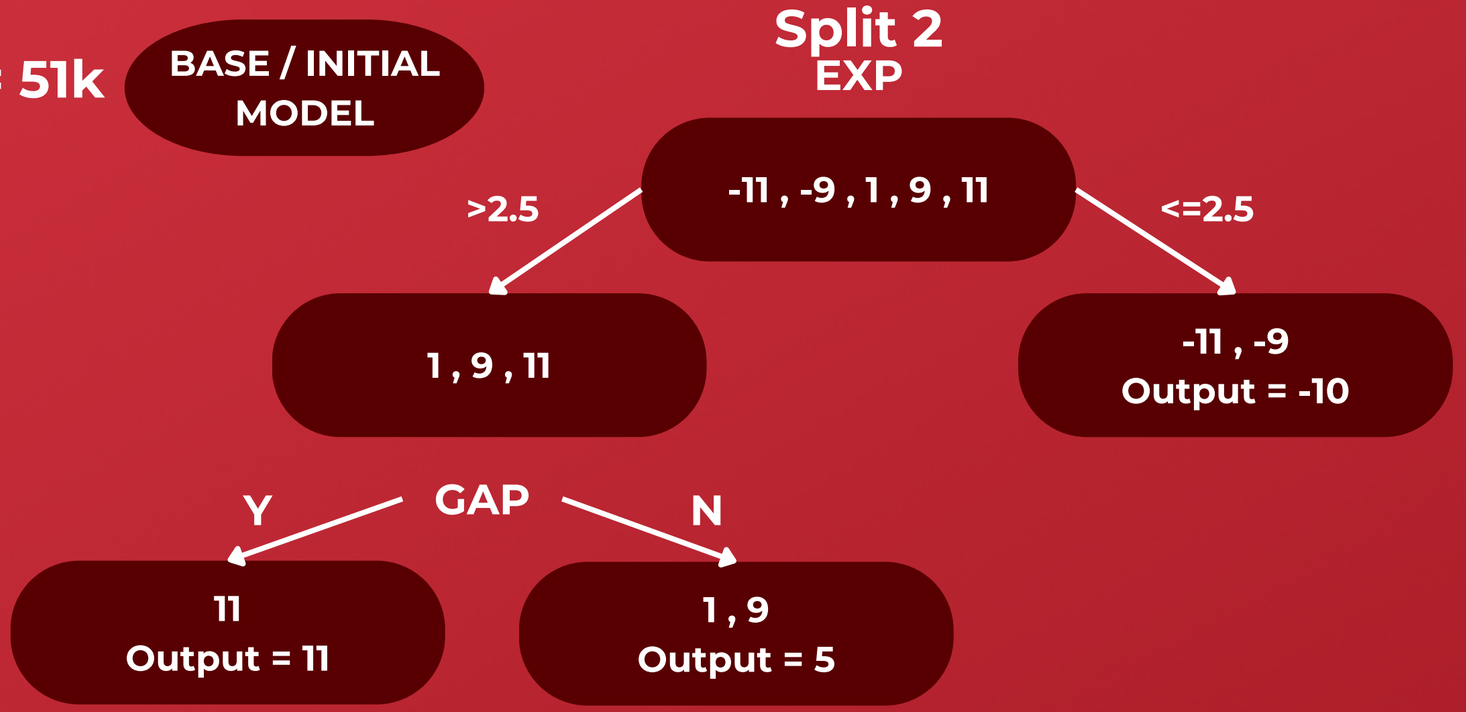
2.5	Y	42k	-9k		
3	N	52k	1k		
4	N	60k	9k		
4.5	Y	62k	11k		



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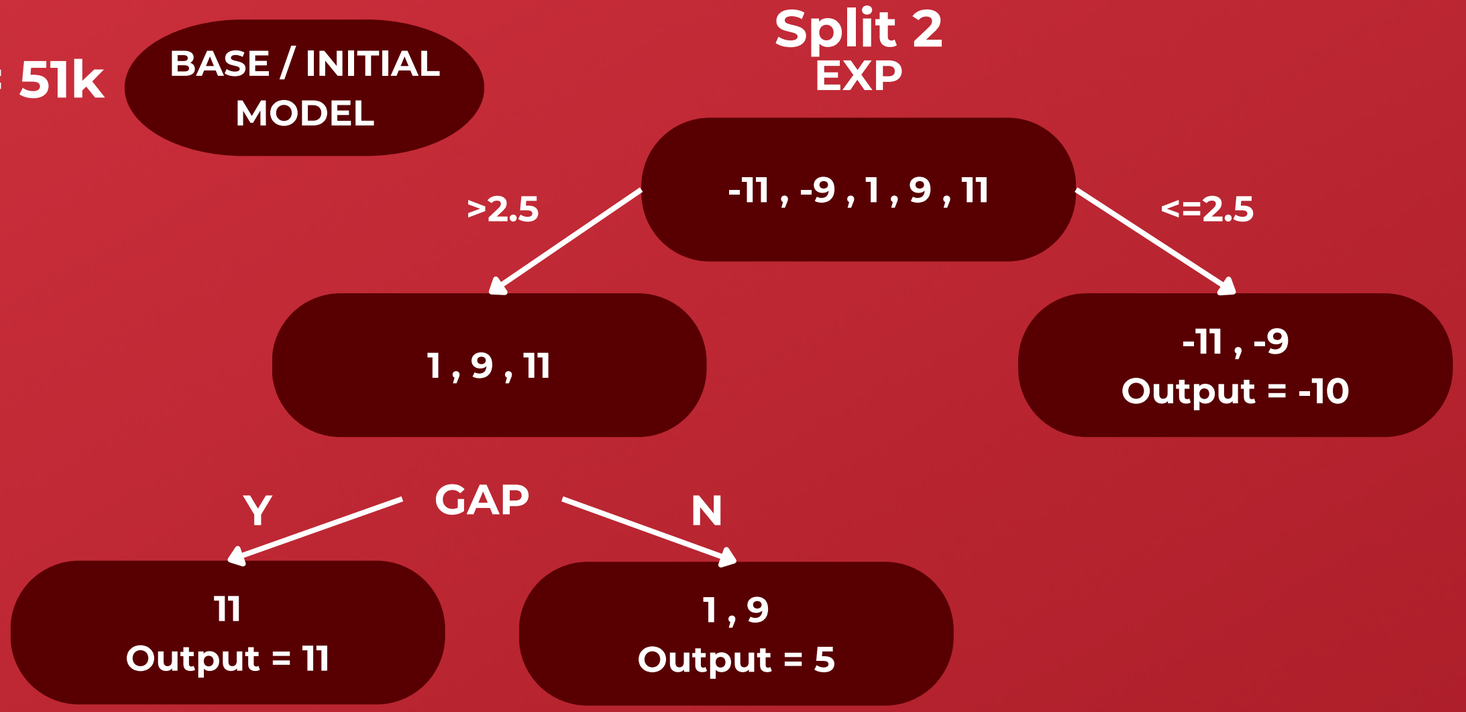
- **Dataset :** Avg Salary= 51k

EX	GP	SY	RS1	O/P	RS2
2	Y	40k	-11k	46k	
2.5	Y	42k	-9k	46k	
3	N	52k	1k	53.5k	
4	N	60k	9k	53.5k	
4.5	Y	62k	11k	56.5k	



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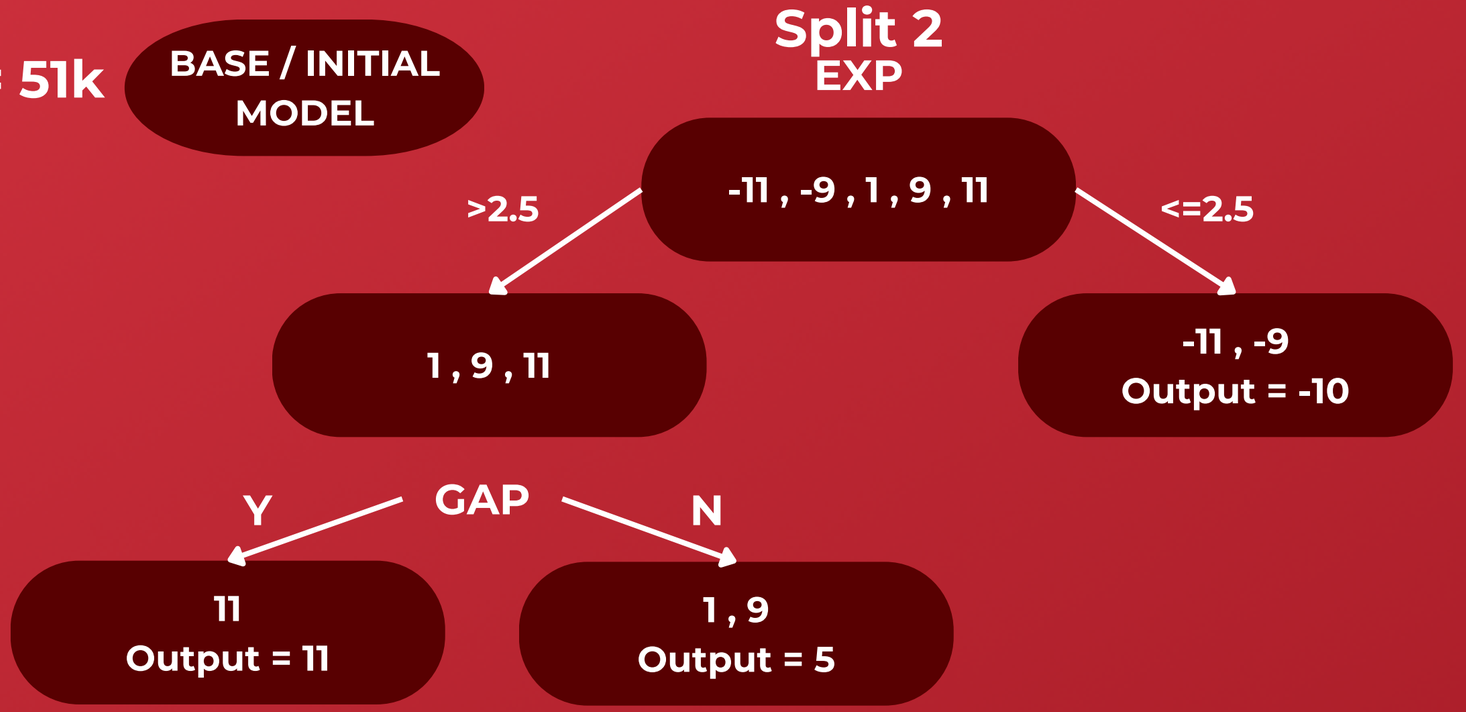
XGBOOST REGRESSION :

- **Dataset :**

Avg Salary= 51k

EX	GP	SY	RS1	O/P	RS2
2	Y	40k	-11k	46k	-6k
2.5	Y	42k	-9k	46k	
3	N	52k	1k	53.5k	
4	N	60k	9k	53.5k	
4.5	Y	62k	11k	56.5k	



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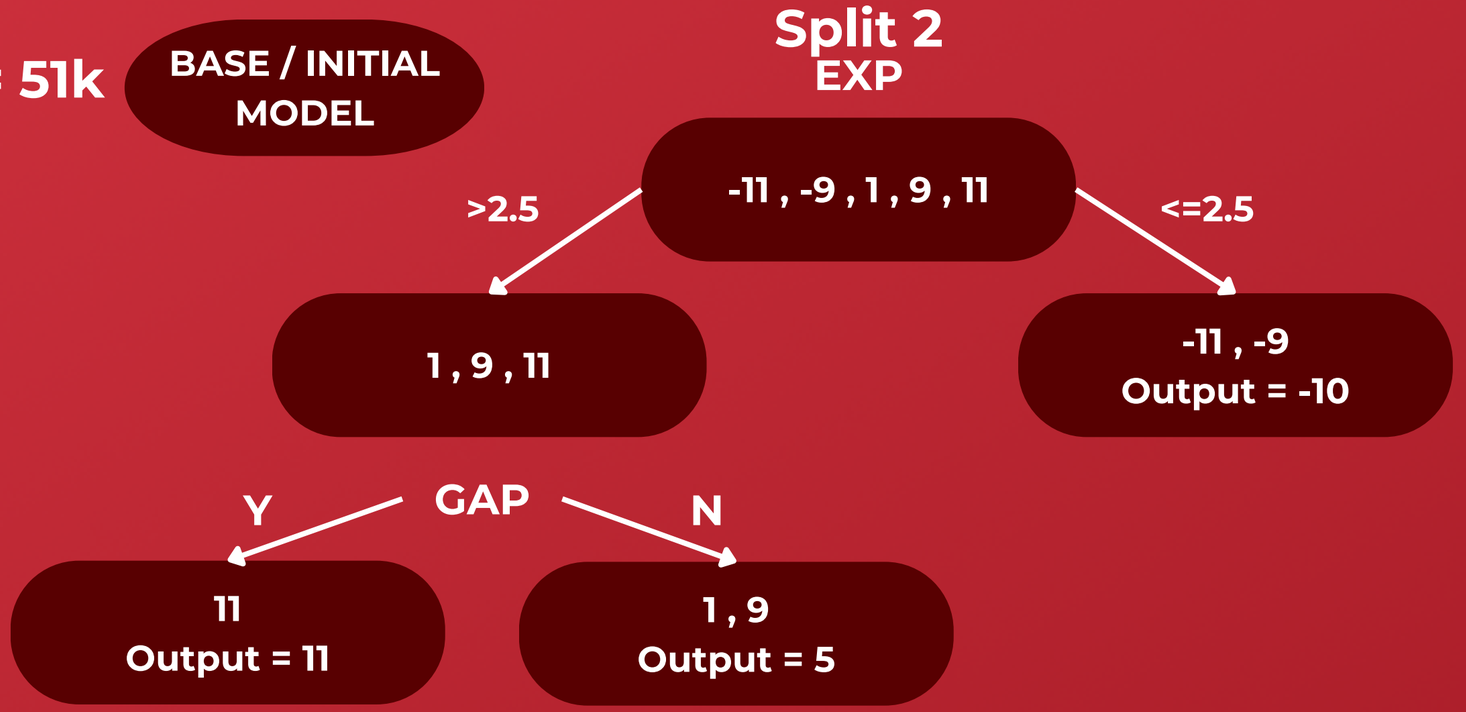
EX	GP	SY	RS1	O/P	RS2
2	Y	40k	-11k	46k	-6k
2.5	Y	42k	-9k	46k	-4k
3	N	52k	1k	53.5k	-1.5k
4	N	60k	9k	53.5k	6.5k
4.5	Y	62k	11k	56.5k	5.5k



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Knowing That : RS2 = Salary - Output , α is the learning rate = 0.5

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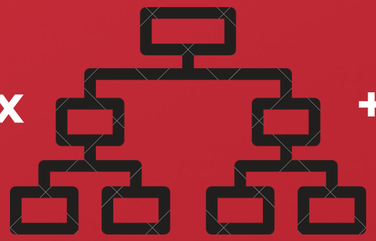
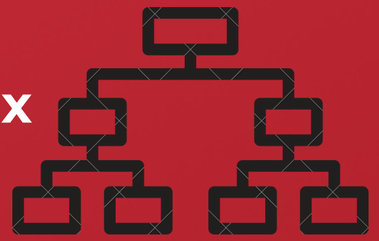
XGBOOST REGRESSION :

DataSet → BASE / INITIAL MODEL → DT 1 → DT N

Probability = INIT GUESS AVG + α x (DT 1) + ... + α x (DT N)

Probability = BASE / INITIAL MODEL + α x  + ... + α x 

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WHEN SHOULD I USE XGBOOST?

EXTREME GRADIENT BOOSTING WITH XGBOOST

WHEN TO USE XGBOOST :

- You have a large number of training samples
  - Greater than 1000 training samples and less 100 features
  - The number of features < number of training samples
- You have a mixture of categorical and numeric features

WHEN TO NOT USE XGBOOST :

- Image recognition
- Computer vision
- Natural language processing and understanding problems
- When the number of training samples is signicantly smaller than the number of features

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HOW XGBOOST IS IMPLEMENTED IN PYTHON

EXTREME GRADIENT BOOSTING WITH XGBOOST

HOW TO IMPLEMENT XGBOOST :

- **Classification :**

```
from xgboost import XGBClassifier
model = XGBClassifier()
model.fit(X_train, y_train)
y_pred = model.predict(X_test)
```

- **Regression**

```
from xgboost import XGBRegressor
model = XGBRegressor()
model.fit(X_train, y_train)
y_pred = model.predict(X_test)
```

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LET'S PRACTICE!

EXTREME GRADIENT BOOSTING WITH XGBOOST

XGBOOST : SOME HELPFUL RSOURCES

- XGBoost Paper : https://arxiv.org/pdf/1603.02754.pdf
- XGBoost Docs : https://xgboost.readthedocs.io

XGBoost: A Scalable Tree Boosting System

Tianqi Chen
University of Washington
tqchen@cs.washington.edu

Carlos Guestrin
University of Washington
guestrin@cs.washington.edu

ABSTRACT

Tree boosting is a highly effective and widely used machine learning method. In this paper, we describe a scalable end-to-end tree boosting system called XGBoost, which is used widely by data scientists to achieve state-of-the-art results on many machine learning challenges. We propose a novel sparsity-aware algorithm for sparse data and weighted quantile sketch for approximate tree learning. More importantly, we provide insights on cache access patterns, data compression and sharding to build a scalable tree boosting system. By combining these insights, XGBoost scales beyond billions of examples using far fewer resources than existing systems.

problems. Besides being used as a stand-alone predictor, it is also incorporated into real-world production pipelines for ad click through rate prediction [15]. Finally, it is the de-facto choice of ensemble method and is used in challenges such as the Netflix prize [3].

In this paper, we describe XGBoost, a scalable machine learning system for tree boosting. The system is available as an open source package[2]. The impact of the system has been widely recognized in a number of machine learning and data mining challenges. Take the challenges hosted by the machine learning competition site Kaggle for example. Among the 29 challenge winning solutions [3] published at Kaggle's blog during 2015, 17 solutions used XGBoost. Among these

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Thank you for attending

any questions ?