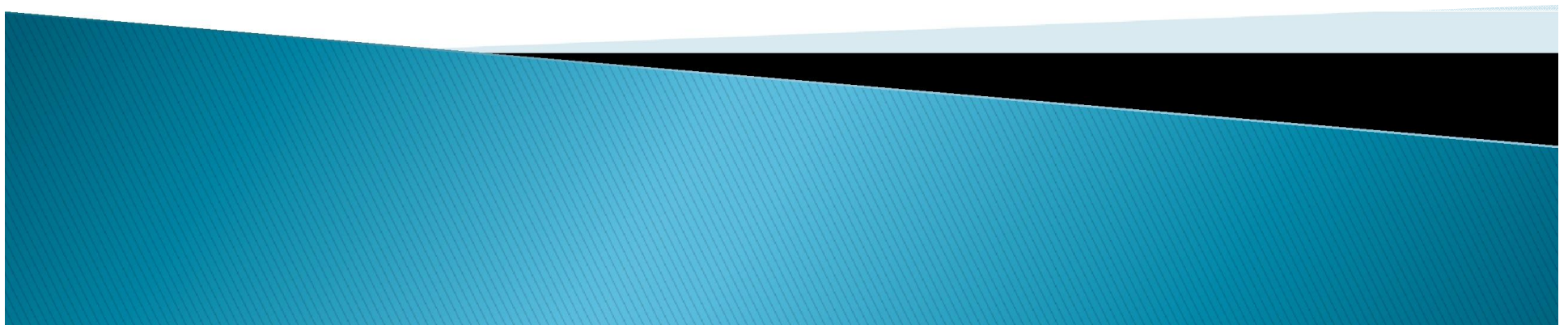


Multiclass

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Topics

- ❑ Multiclass prediction
 - **Decision Tree** example
- ❑ One vs. All
- ❑ Non-Parametric Models
- ❑ No free lunch theorem
- ❑ UCI machine learning repository



Handwriting Digit Recognition

0 1 2 3 4 5 6 7 8 9

0 1 2 3 4 5 6 7 8 9

Features:

Multiclass Prediction (example)



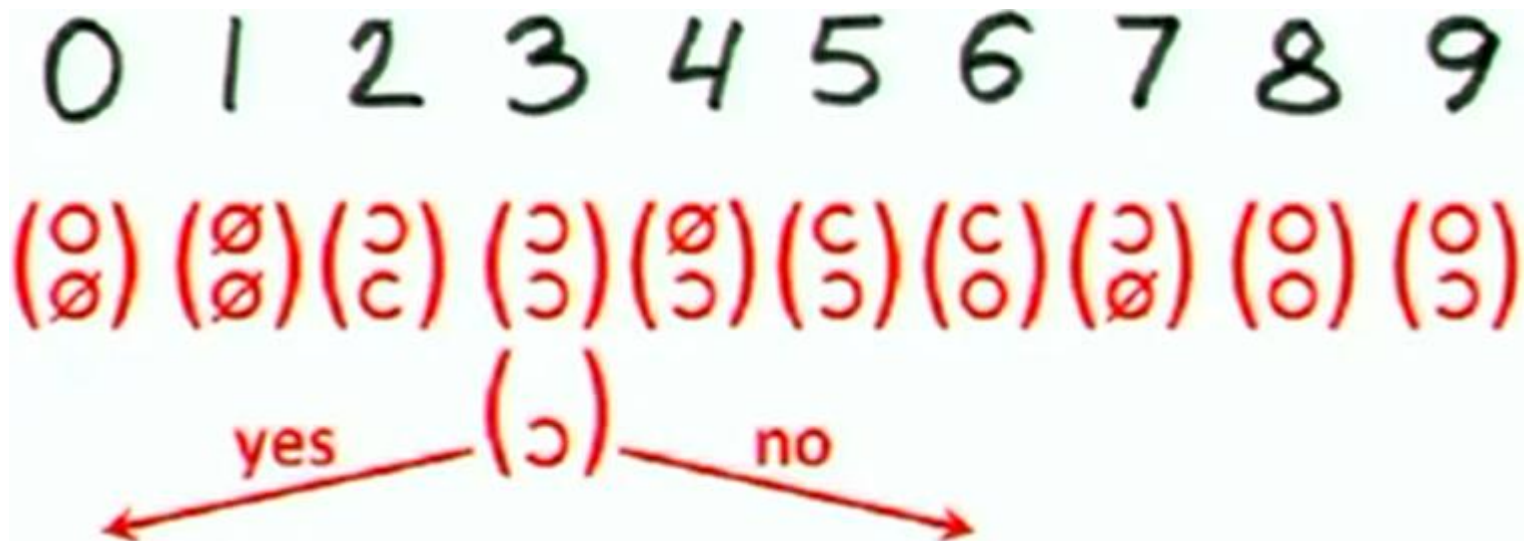
Feature Set

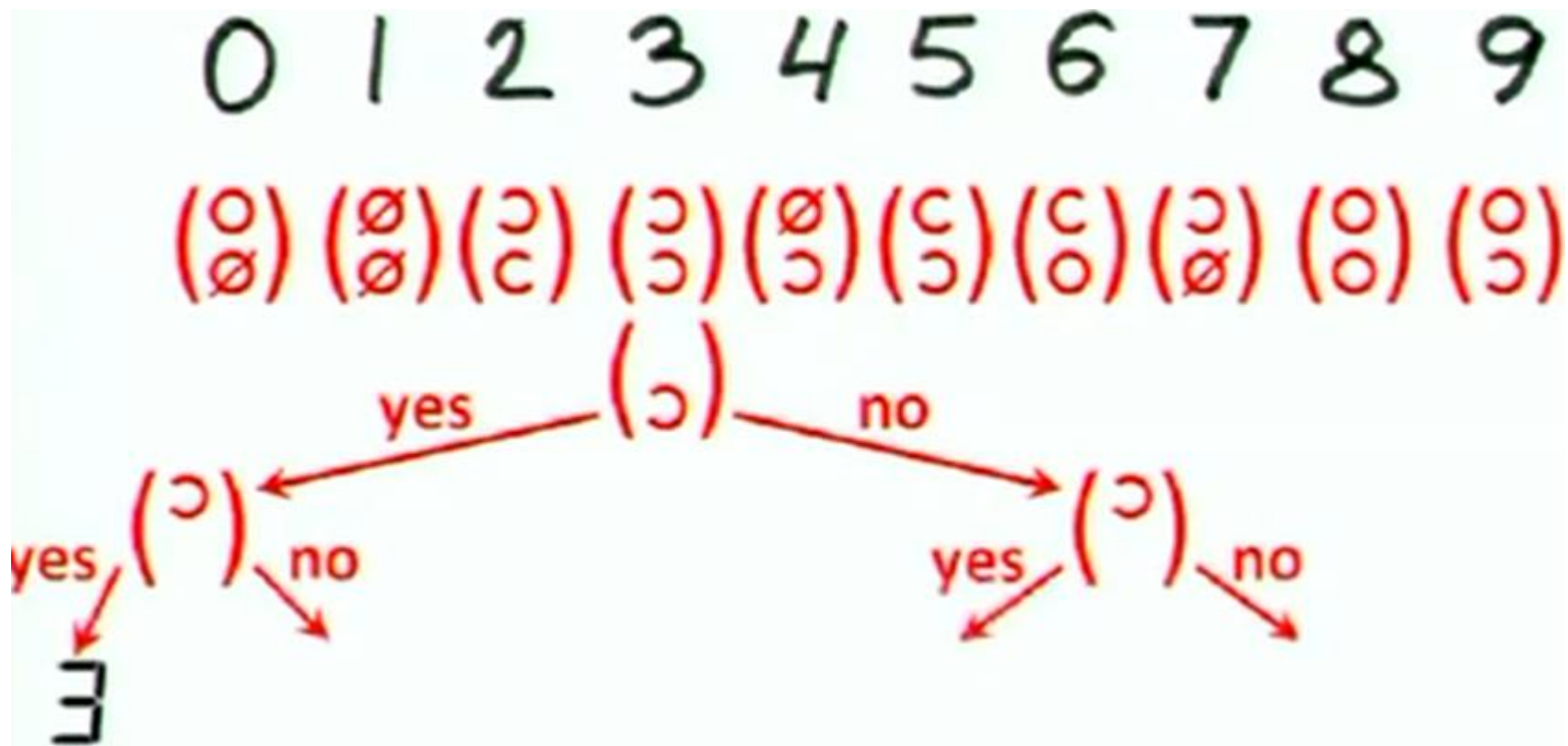


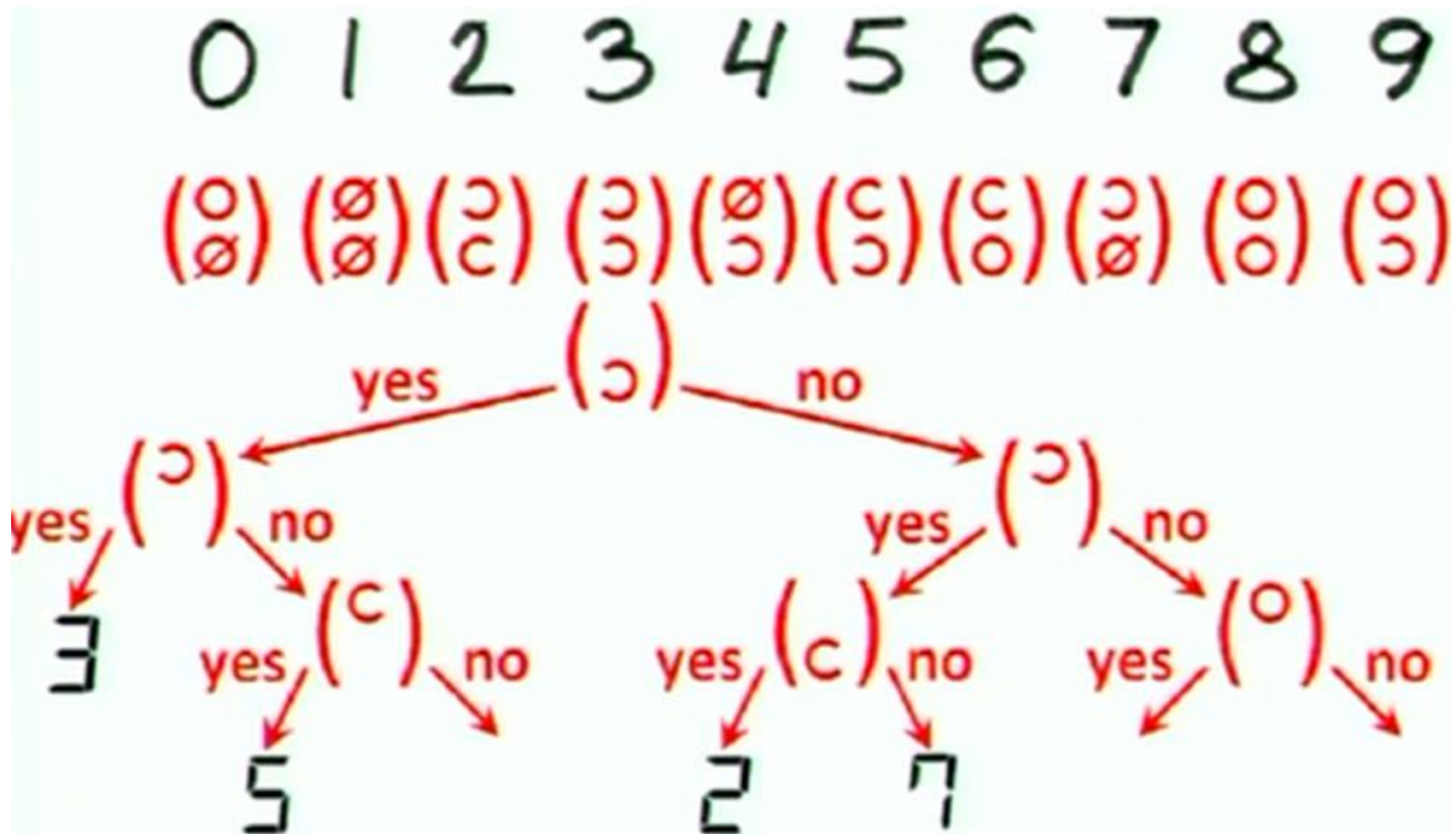
Feature Set (cont.)

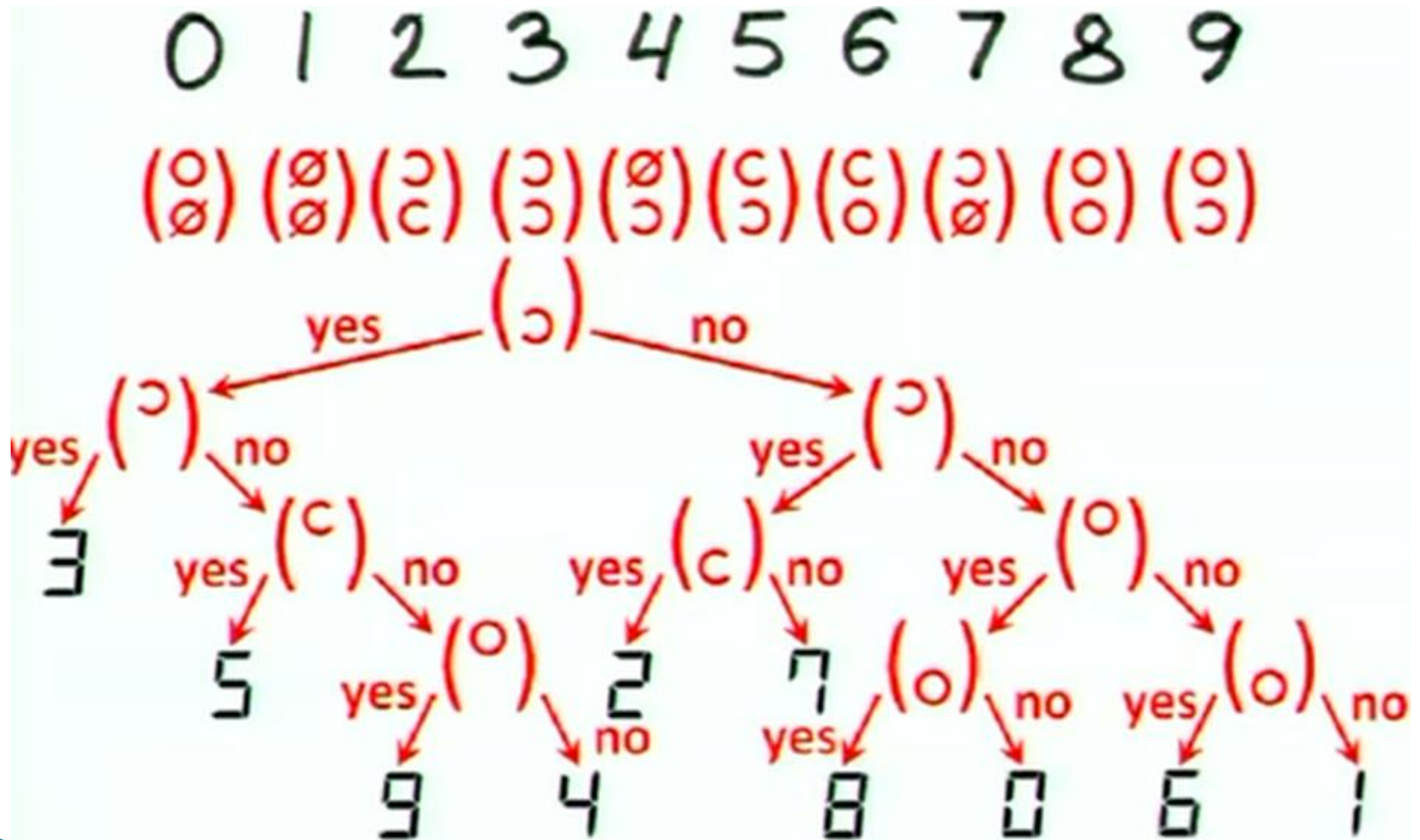
0	1	2	3	4	5	6	7	8	9
$\begin{pmatrix} 0 \\ \emptyset \end{pmatrix}$	$\begin{pmatrix} \emptyset \\ \emptyset \end{pmatrix}$	$\begin{pmatrix} \supset \\ c \end{pmatrix}$	$\begin{pmatrix} \supset \\ \supset \end{pmatrix}$	$\begin{pmatrix} \emptyset \\ \supset \end{pmatrix}$	$\begin{pmatrix} c \\ \supset \end{pmatrix}$	$\begin{pmatrix} c \\ 0 \end{pmatrix}$	$\begin{pmatrix} \supset \\ \emptyset \end{pmatrix}$	$\begin{pmatrix} 0 \\ 0 \end{pmatrix}$	$\begin{pmatrix} 0 \\ \supset \end{pmatrix}$

Decision Tree









Confusion Matrix

- A multiclass (A, B, ..., E) prediction:

		Predicted				
		A	B	C	D	E
Actual	A					
	B					
	C					
	D					
	E					

Confusion Matrix (cont.)

- A multiclass prediction:

		Predicted				
		A	B	C	D	E
Actual	A	$\#TP_A$	$\#E_{AB}$	$\#E_{AC}$	$\#E_{AD}$	$\#E_{AE}$
	B	$\#E_{BA}$	$\#TP_B$.	.	.
	C	$\#E_{CA}$.	$\#TP_C$.	.
	D	$\#E_{DA}$.	.	$\#TP_D$.
	E	$\#E_{EA}$.	.	.	$\#TP_E$

Confusion Matrix (cont.)

- A multiclass prediction:

		Predicted					Accuracy
		A	B	C	D	E	
Actual	A	TP_A	E_{AB}	E_{AC}	E_{AD}	E_{AE}	—
	B	E_{BA}	TP_B	.	.	.	—
	C	E_{CA}	.	TP_C	.	.	—
	D	E_{DA}	.	.	TP_D	.	—
	E	E_{EA}	.	.	.	TP_E	—

Performance Metrics

□ How to Compute the followings (one vs. all):

- Accuracy
- True Positive (TP)
- False Negative (FN)
- False Positive (FP)
- True Negative (TN)
- Sensitivity
- Precision
- ...



Non-Parametric Models

- A non-parametric model
 - Does it refer to a model with no parameters?
 - Examples:
 - K-nearest neighbors
 - Decision Tree
 - ...



Miscellaneous

- ❑ No free lunch (NFL) theorem
 - The theorem states that no learner can succeed on all learnable tasks – every learner has tasks on which it fails while other learners succeed [1].

- ❑ UCI machine learning repository
 - <https://archive.ics.uci.edu/ml/>



Further Reading

1. [Understanding Machine Learning: From Theory to Algorithms](#), Shai Shalev-Shwartz and Shai Ben-David, Cambridge University Press, 2014.
(Available online – No for distribution)

