Let Your Muscles Do the Talking

Myoelectrically Controlled Prostheses

to

Myoelectric Speech Recogntion

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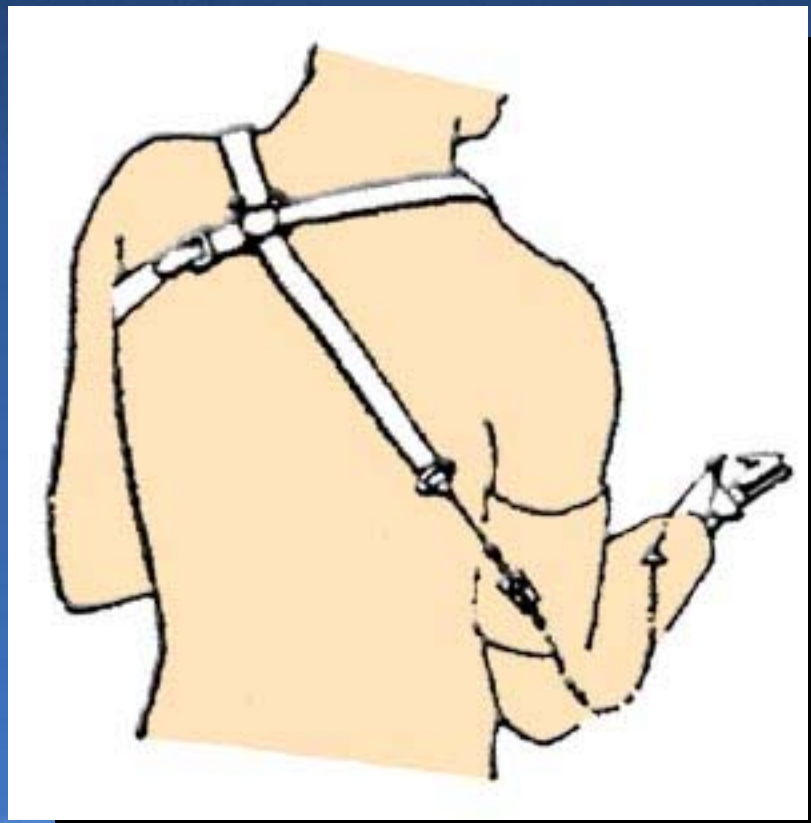
Upper Arm Prostheses

Body Powered Prostheses

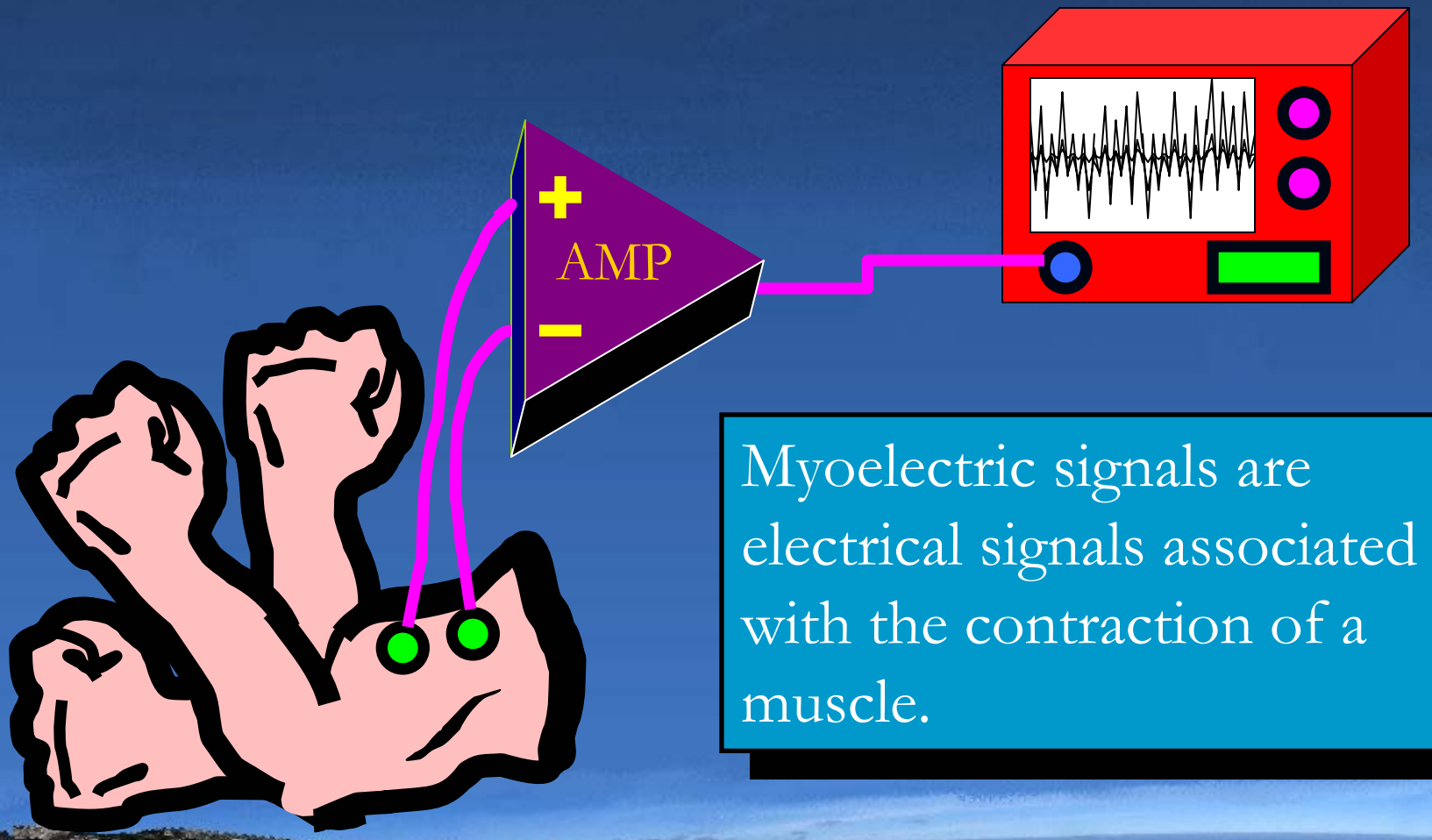
- Advantages
  - Simple
  - Proprioception
- Disadvantages
  - Comfort
  - Restricted range of motion
  - Limited function envelope



Powered Prostheses

- Advantages
  - Frees user from straps and harnesses
  - Effort needed to actuate approximately the same as intact limb
- Disadvantages
  - Battery life
  - Complexity
  - Controllability

Myoelectric Signals

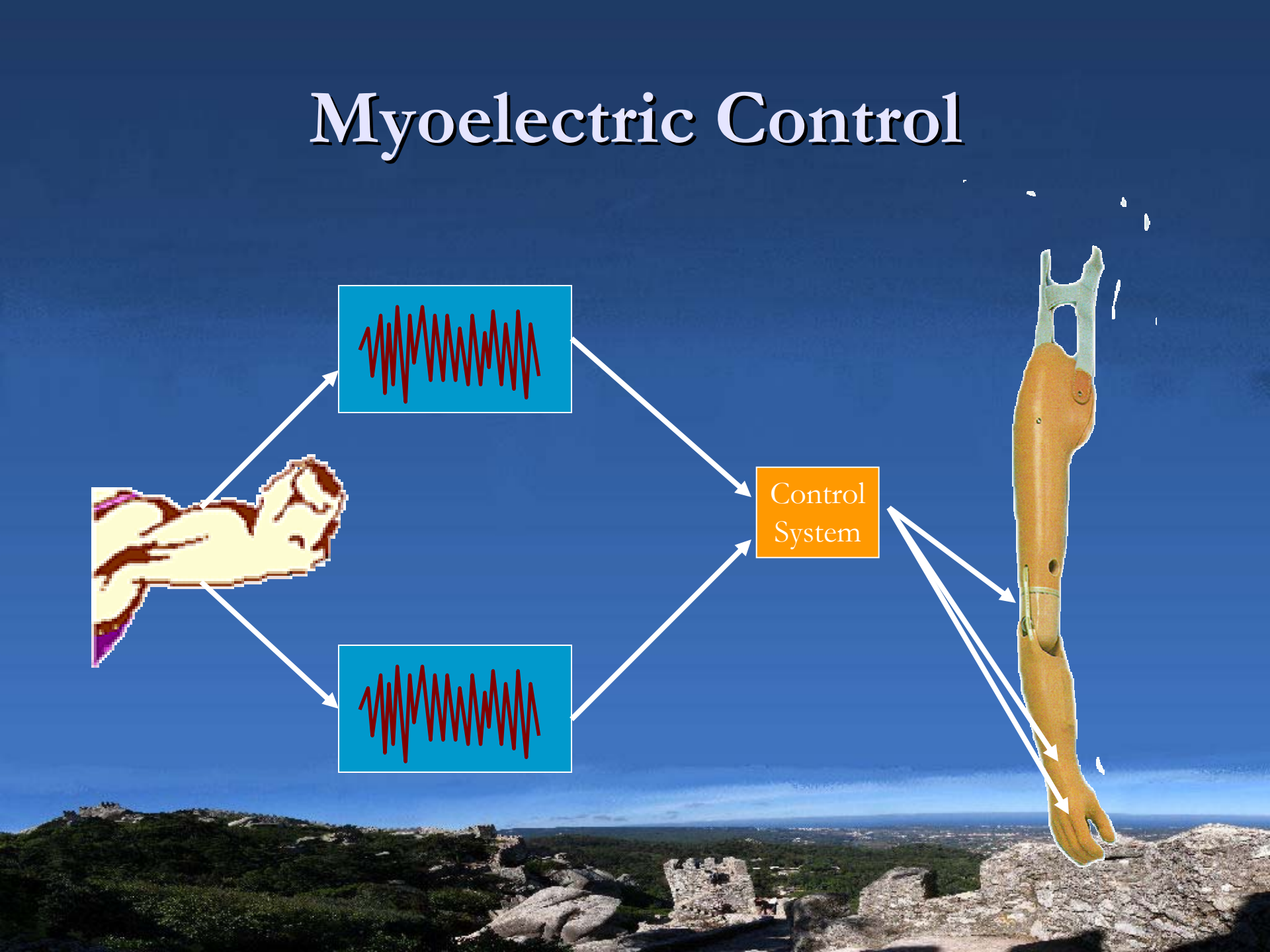


Myoelectric signals are electrical signals associated with the contraction of a muscle.

Myoelectric Signals

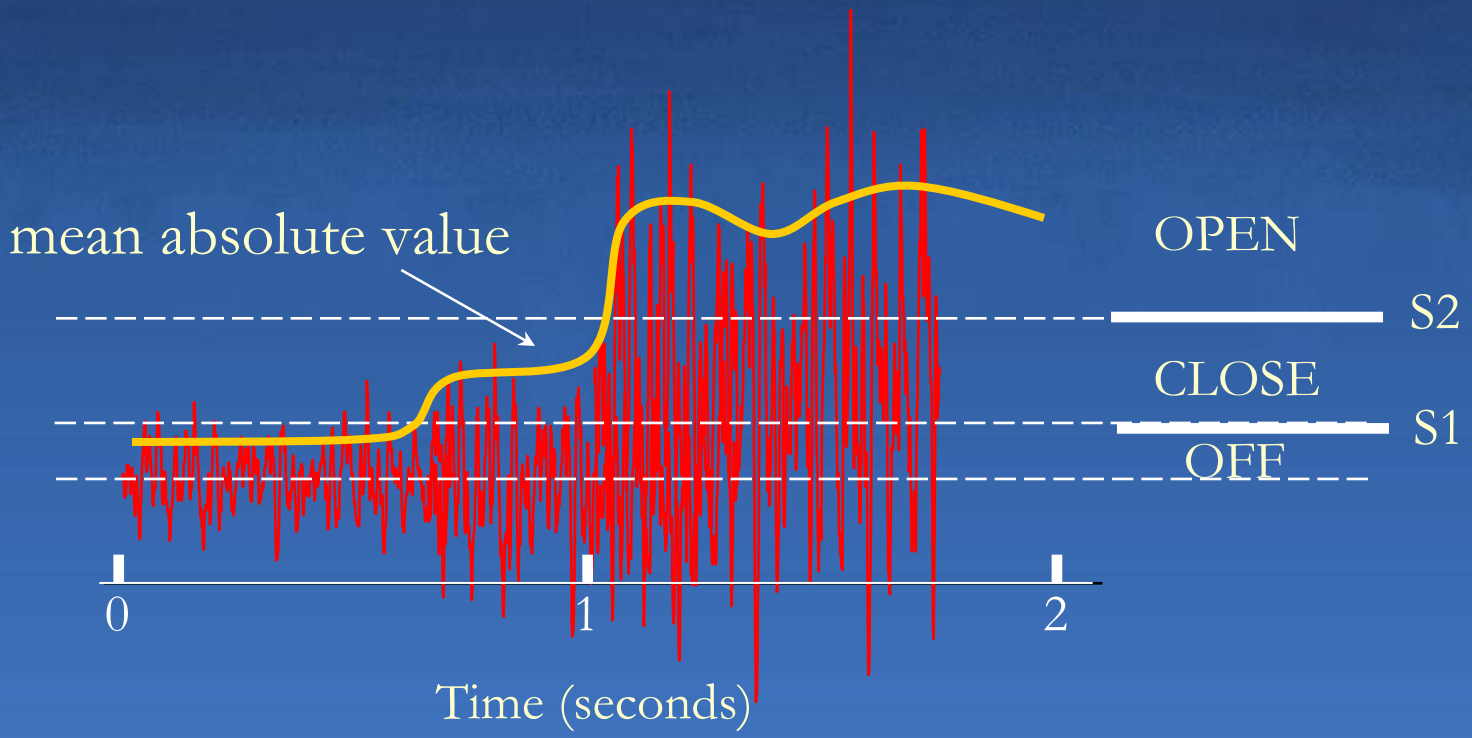
- Muscle activation
- Contraction force

Myoelectric Control



Conventional Myoelectric Control

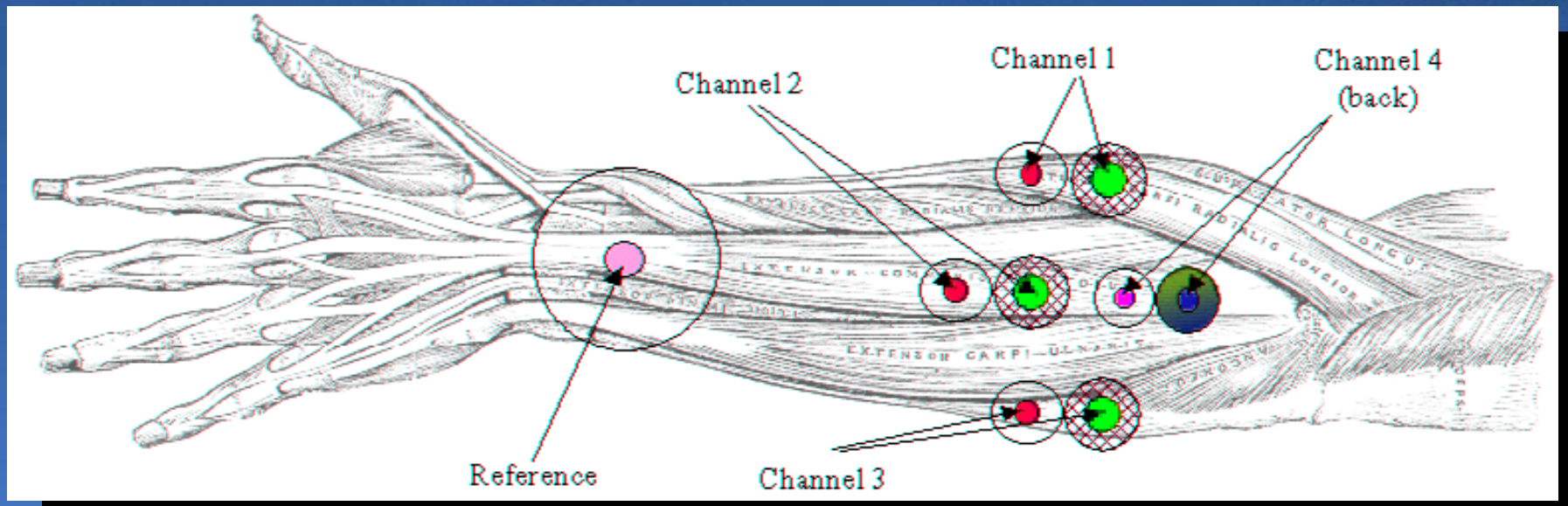
Level-coded scheme



Limitations

- Limited Function
  - Level-coding scheme allows only one or two classes of motion to be reliably controlled
  - Multifunctional control would require more myoelectric control sites
- Awkward Interface
  - Contrived muscle contractions are used to select functions

Continuous Myoelectric Control



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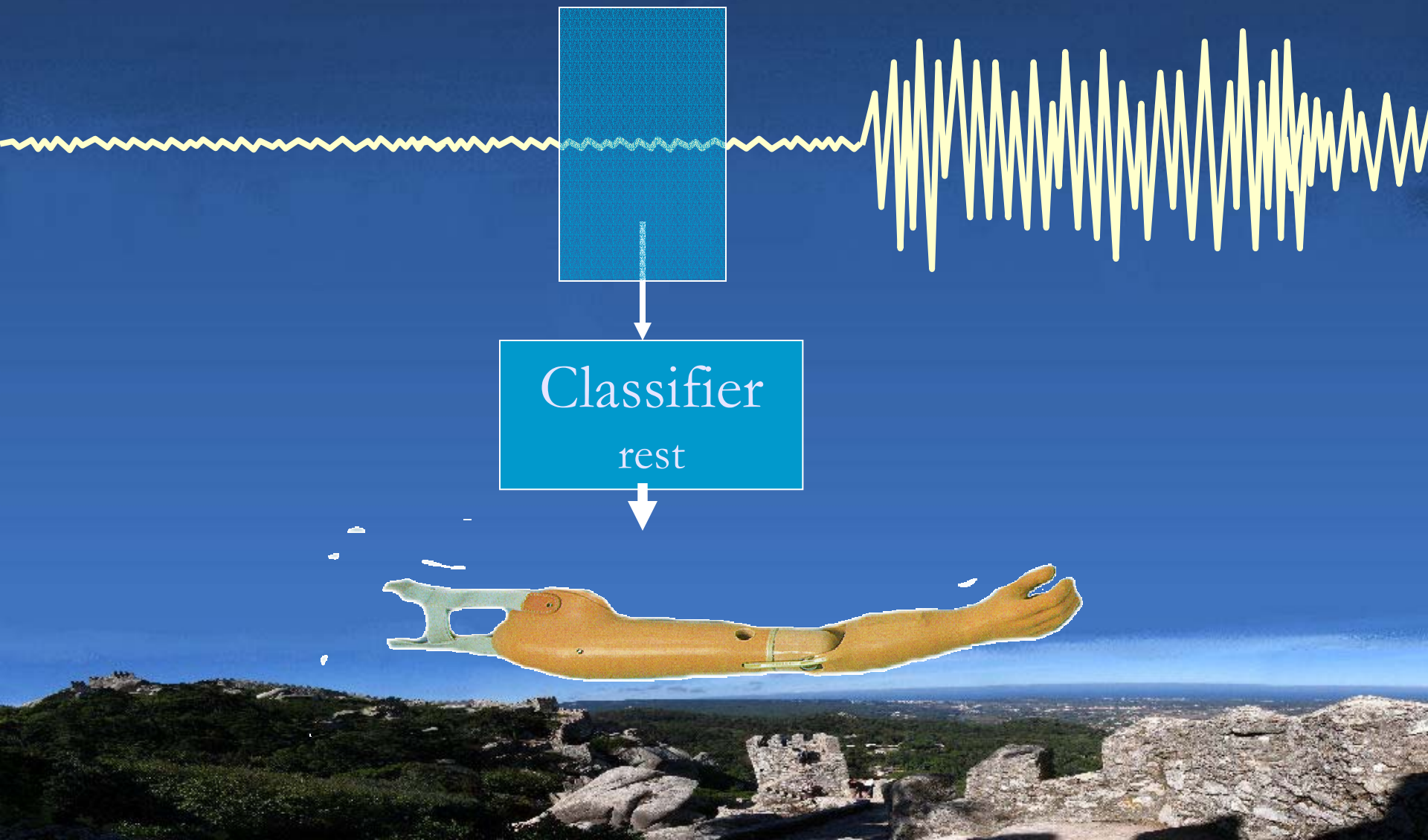

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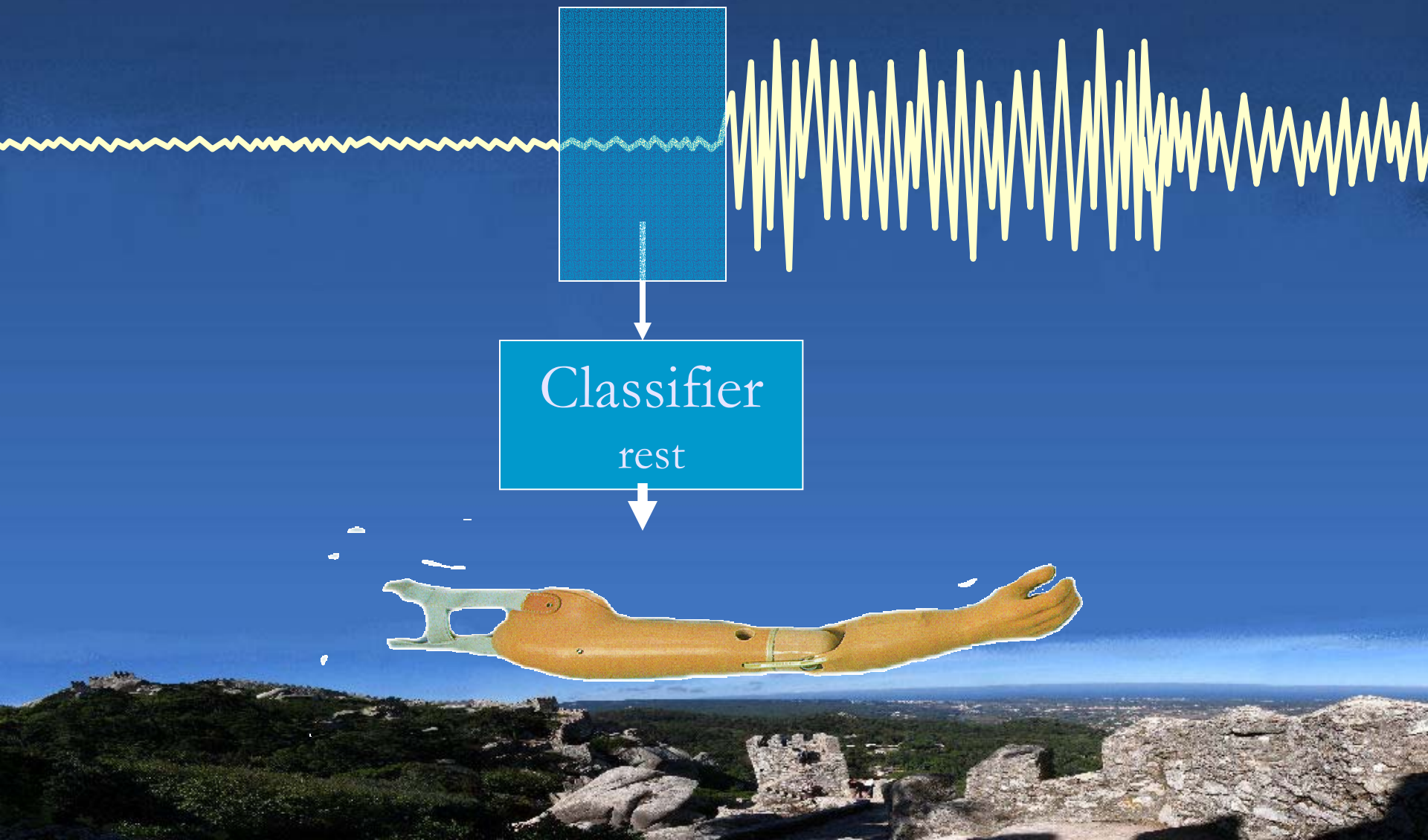

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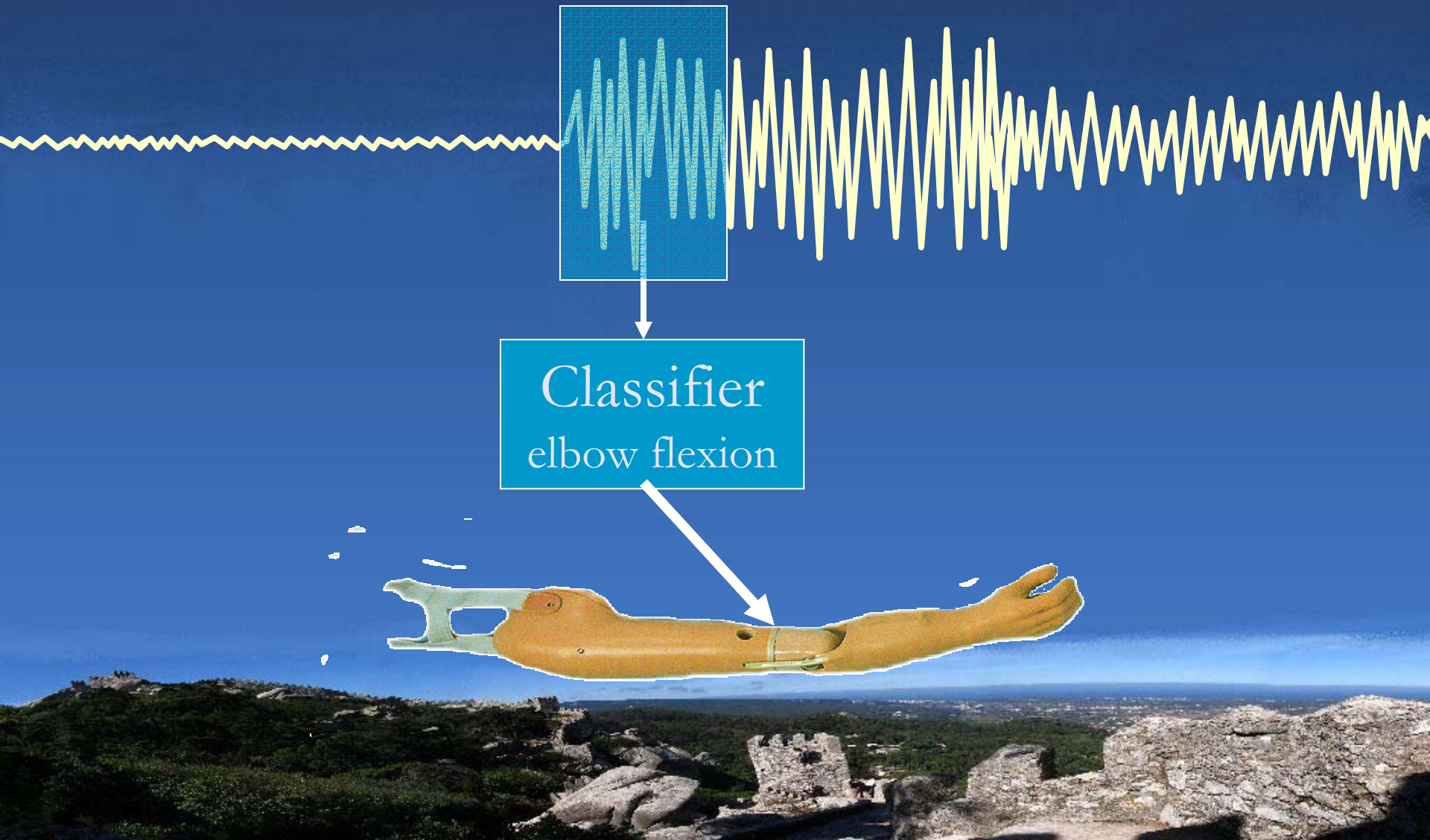

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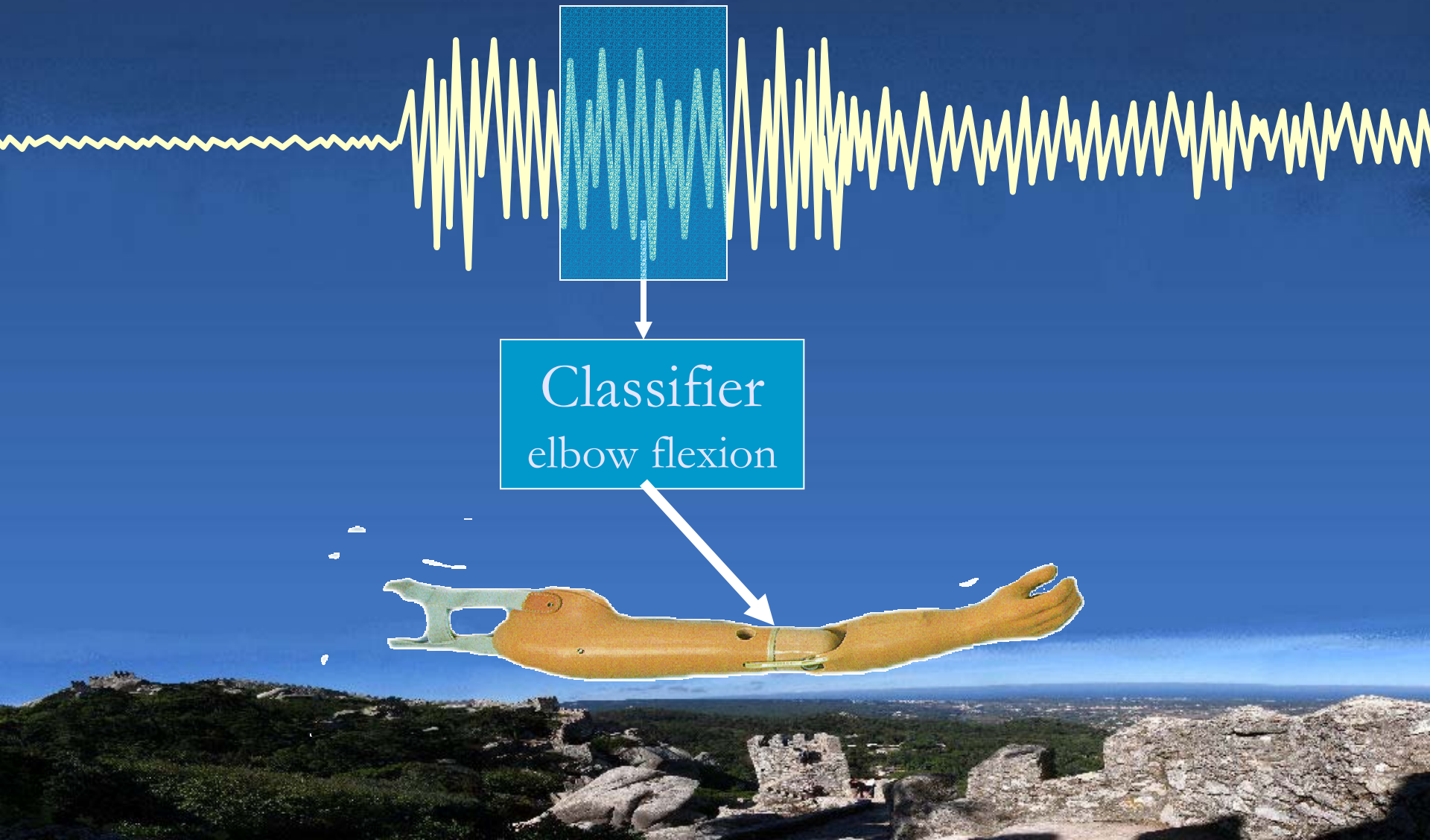

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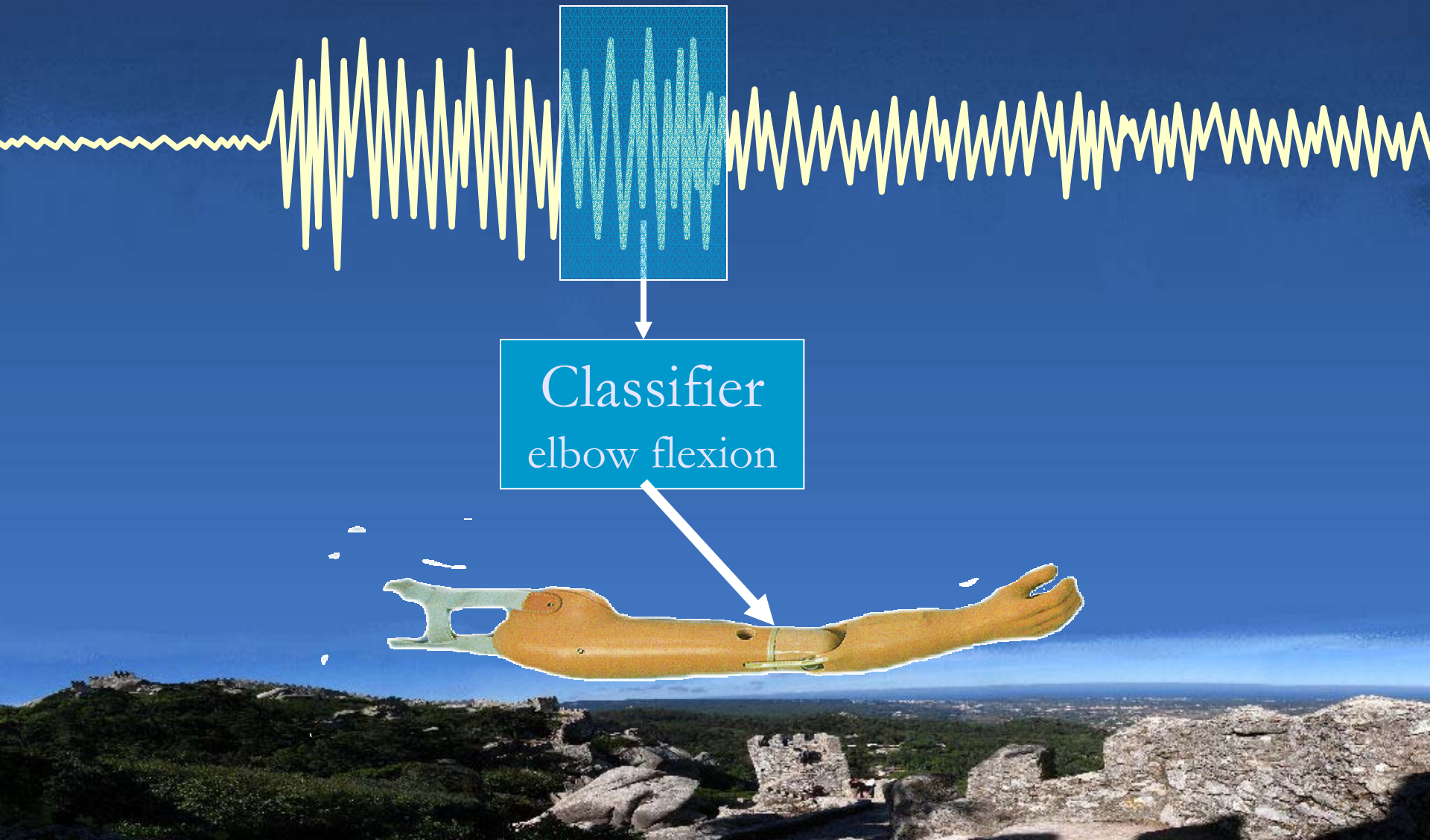

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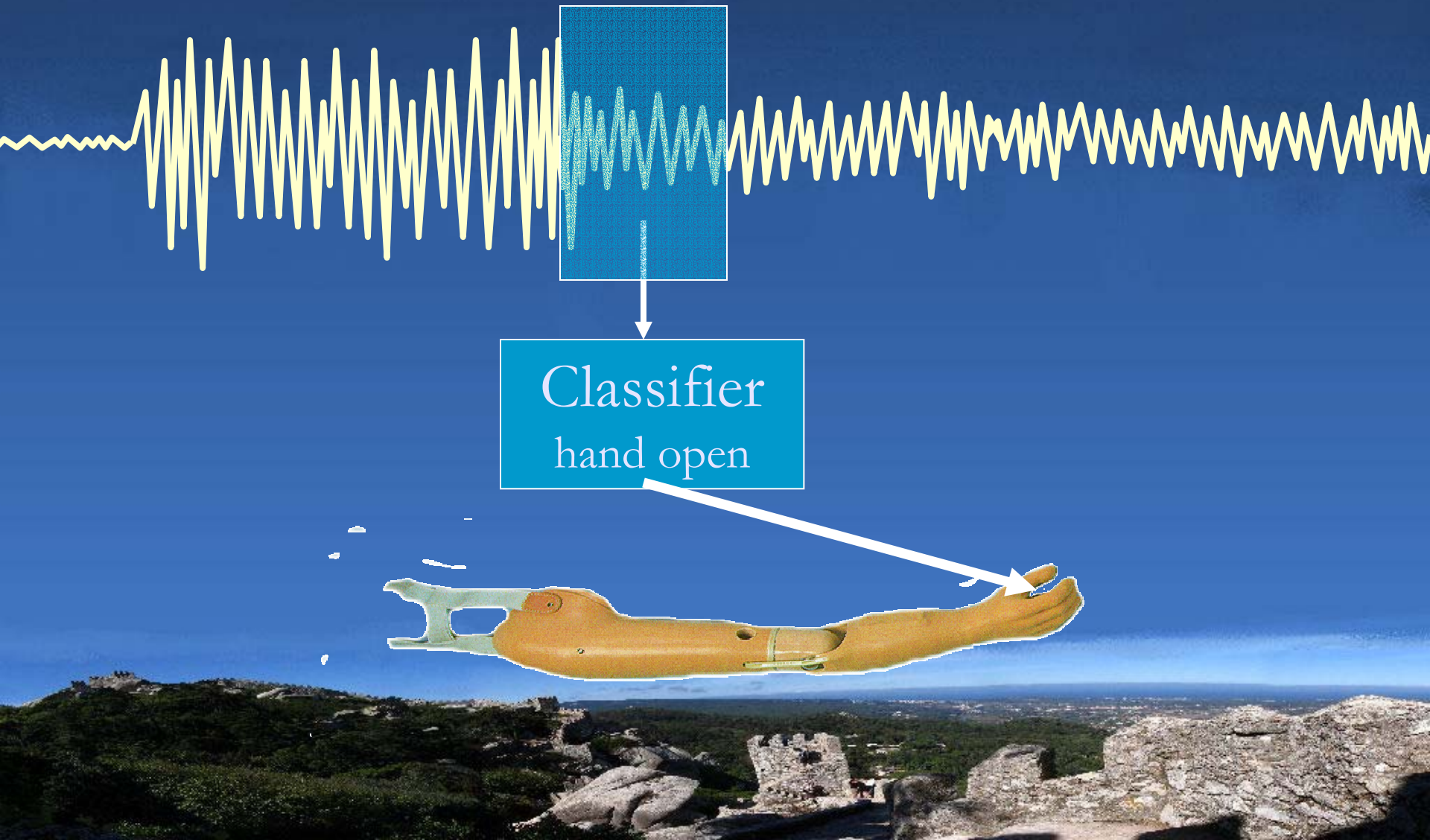

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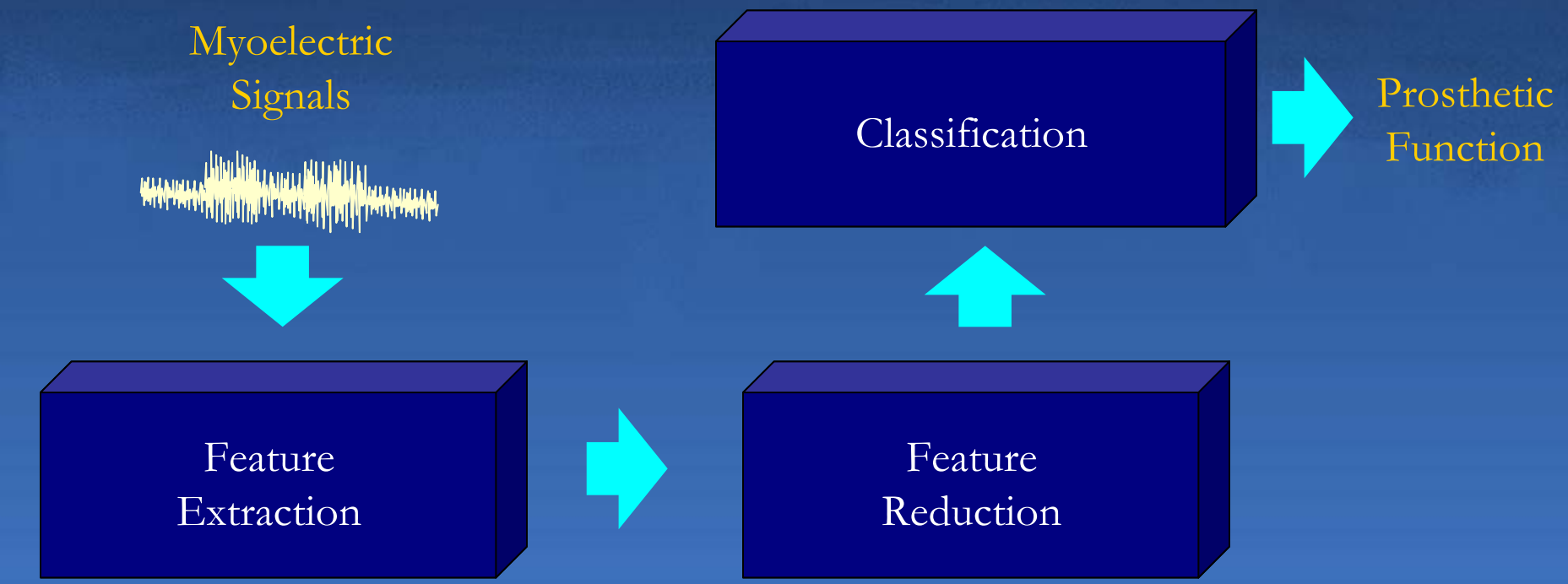


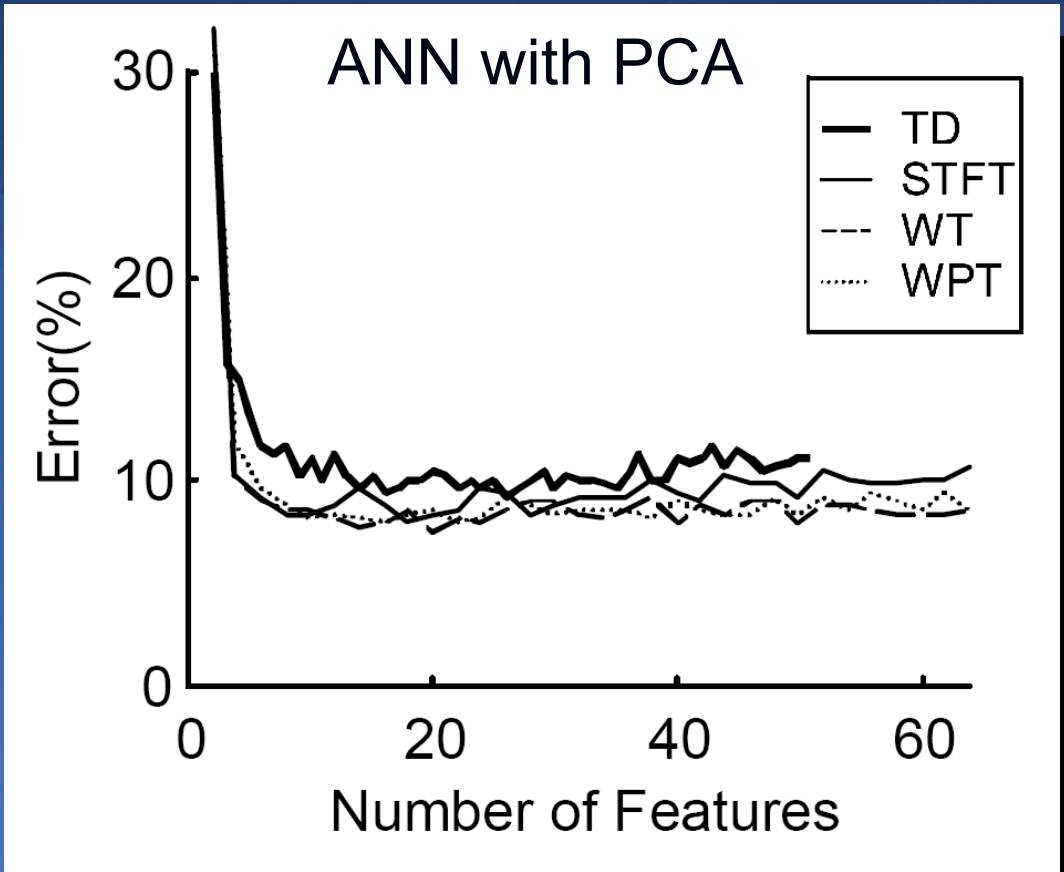
Englehart K, Hudgins B, Parker PA, Stevenson M, "Classification of myoelectric signal using time-based representations, Med. Eng. Phys., 21: 431-438, 1999.

Feature Reduction

- Improve classification accuracy
- Reduce the training time

Haykin S, Neural Networks: A Comprehensive Foundation, Maxwell MacMillan Canada, Inc., DonMills, Ontario, 1994.

Feature Reduction



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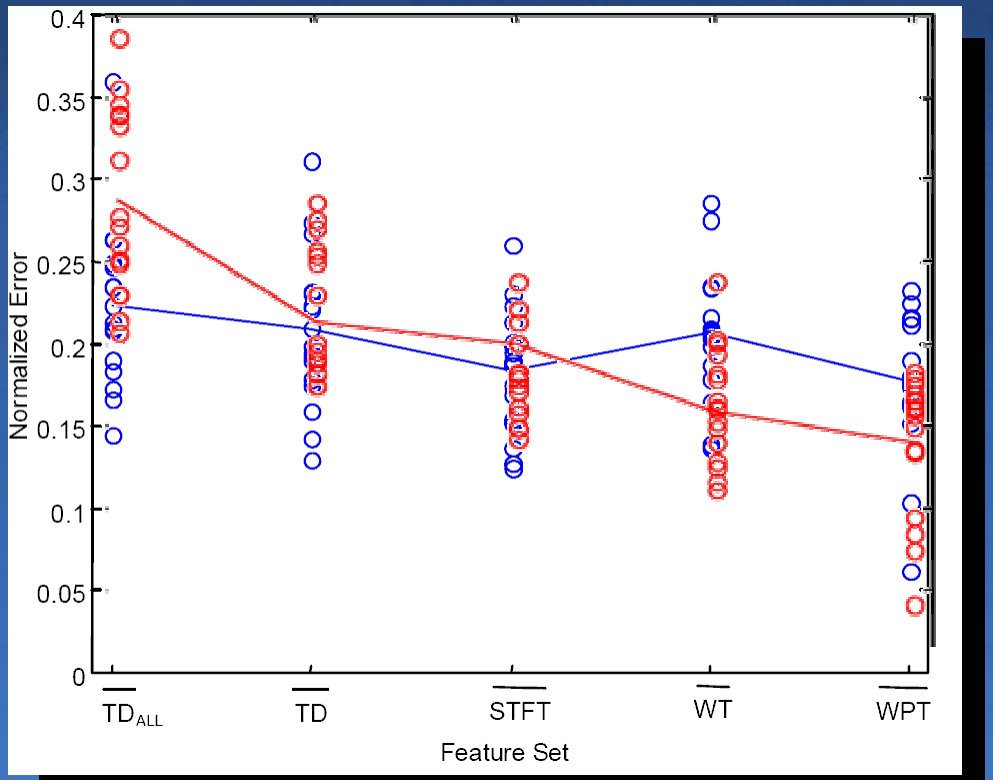
ANN versus LDA



ANN

LDA

ANN versus LDA

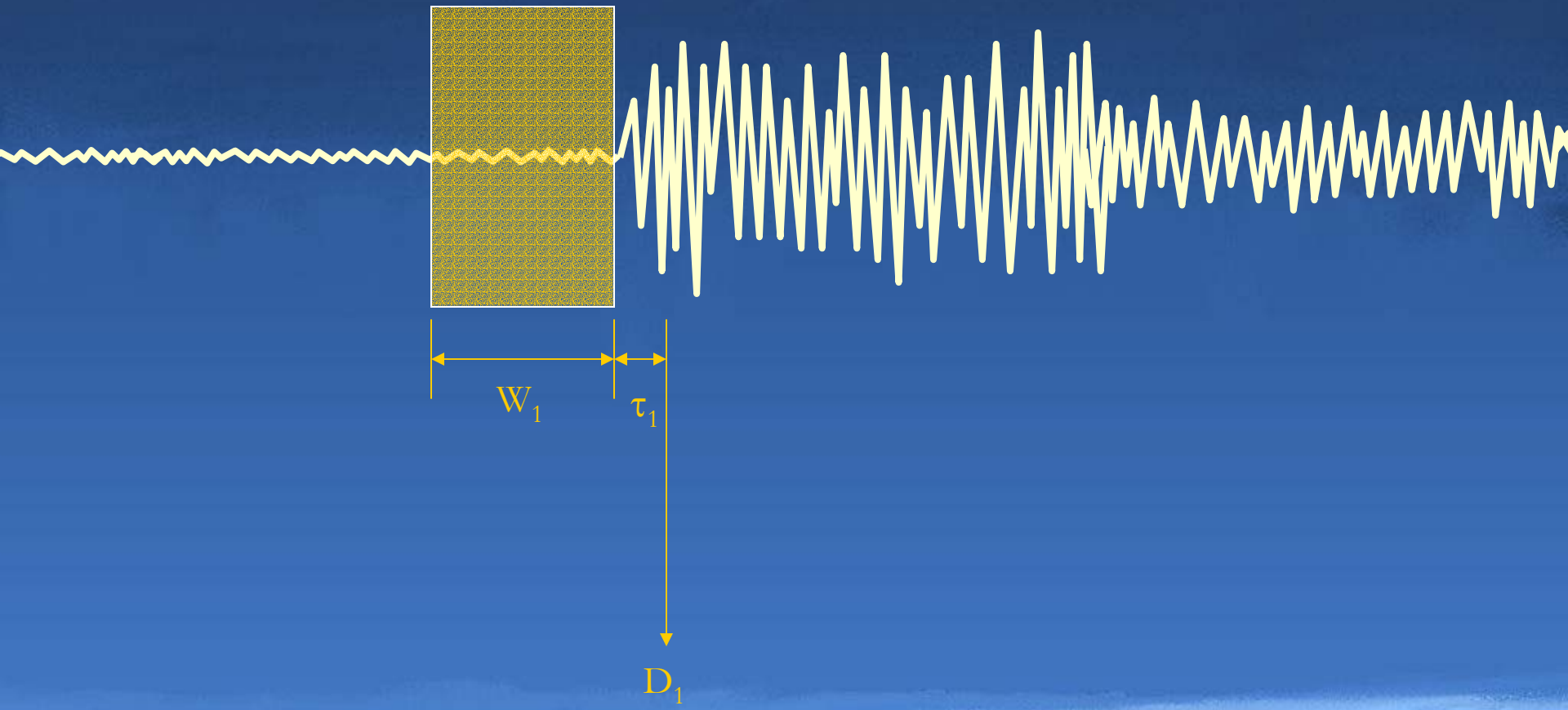
- ANN has the advantage of prescribing nonlinear class boundaries
- In an ideal situation, ANN will always be able to match or outperform LDA

ANN versus LDA

- Feature set dimensionality increases
- Class boundary nonlinearity decreases

- LDA avoids over- and under-training

Windowing



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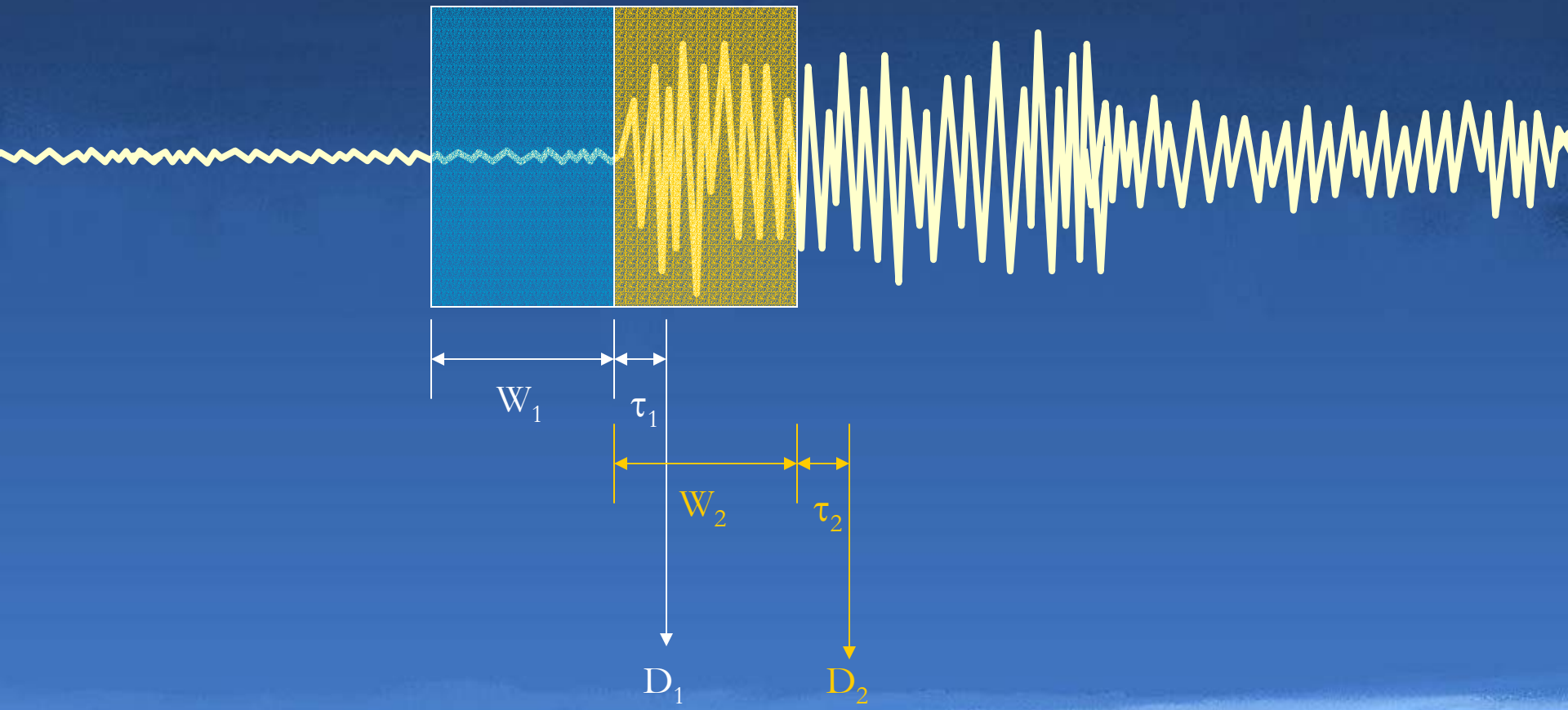

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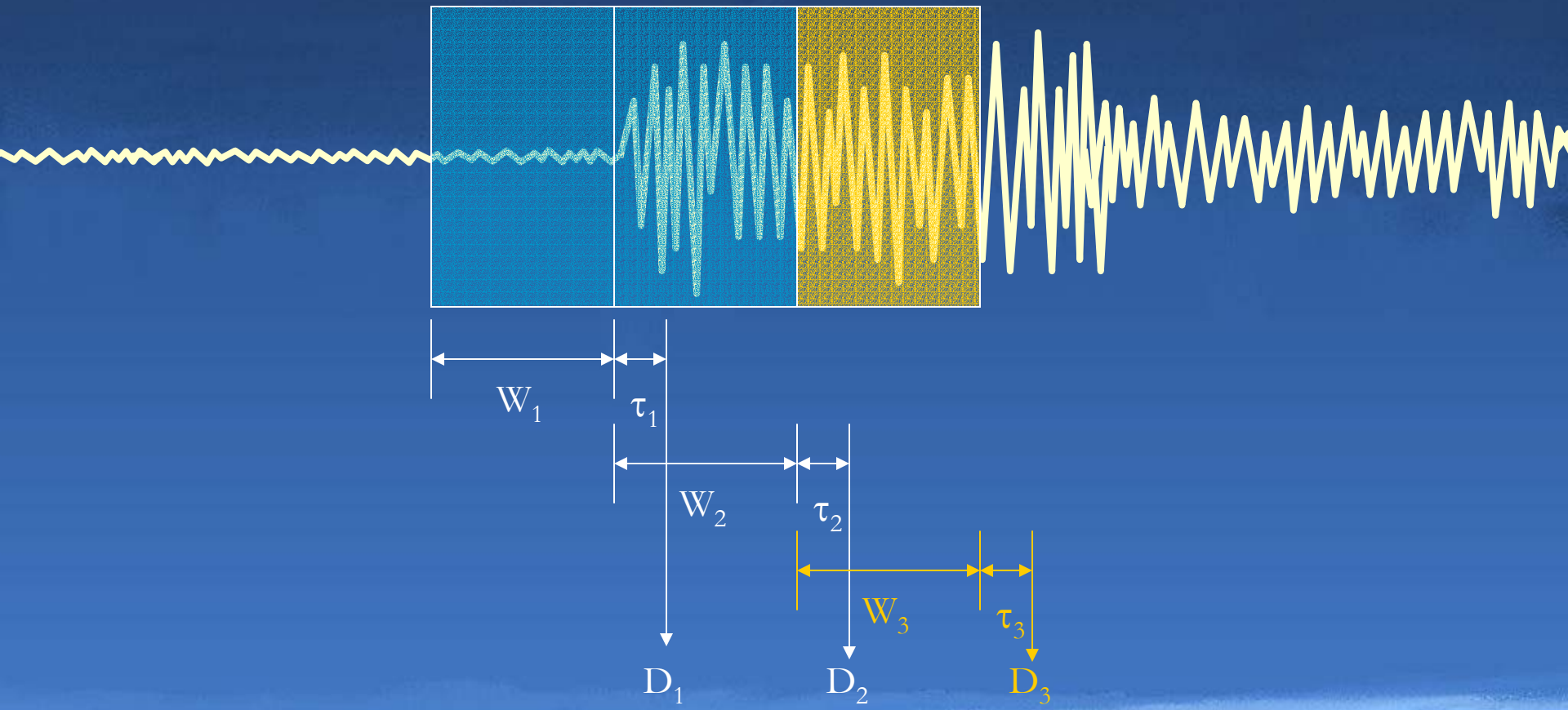

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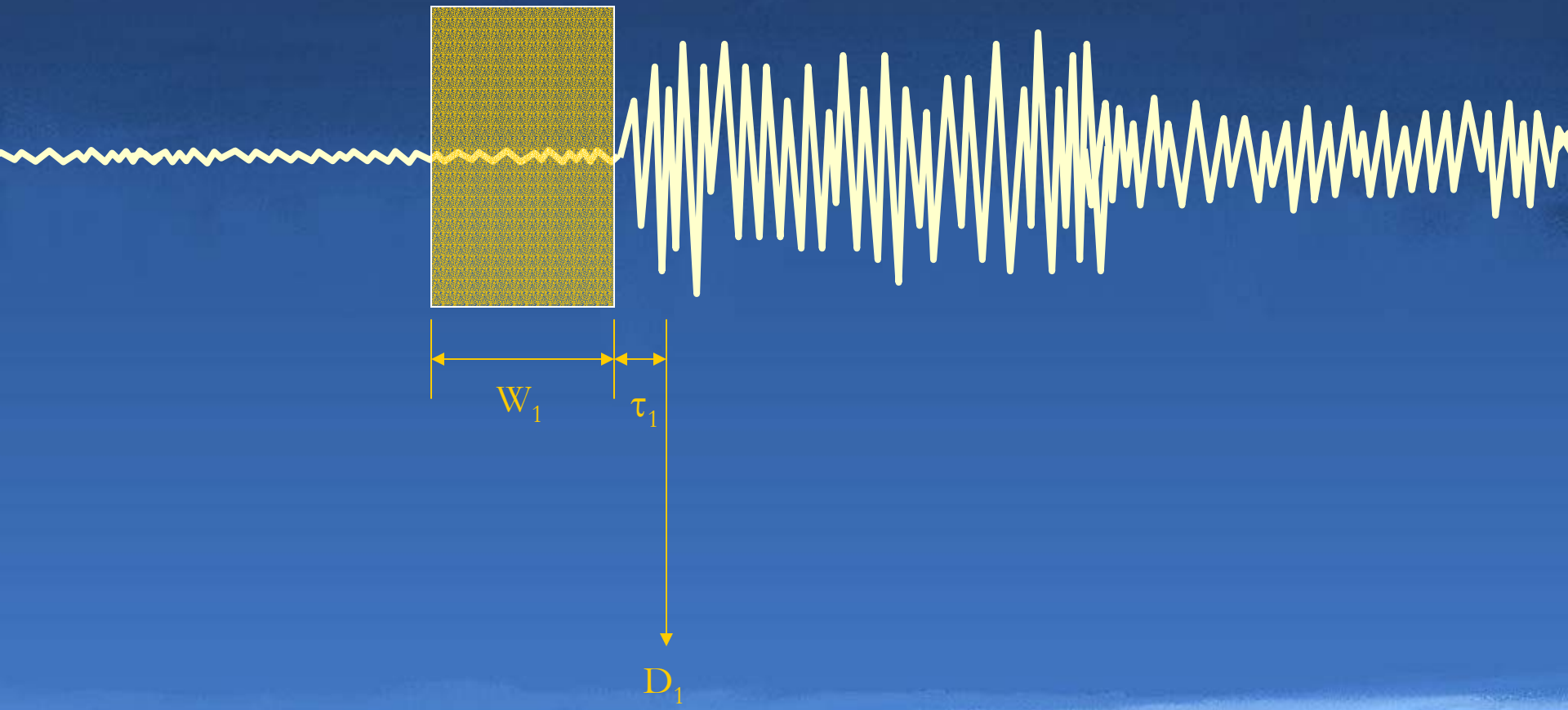

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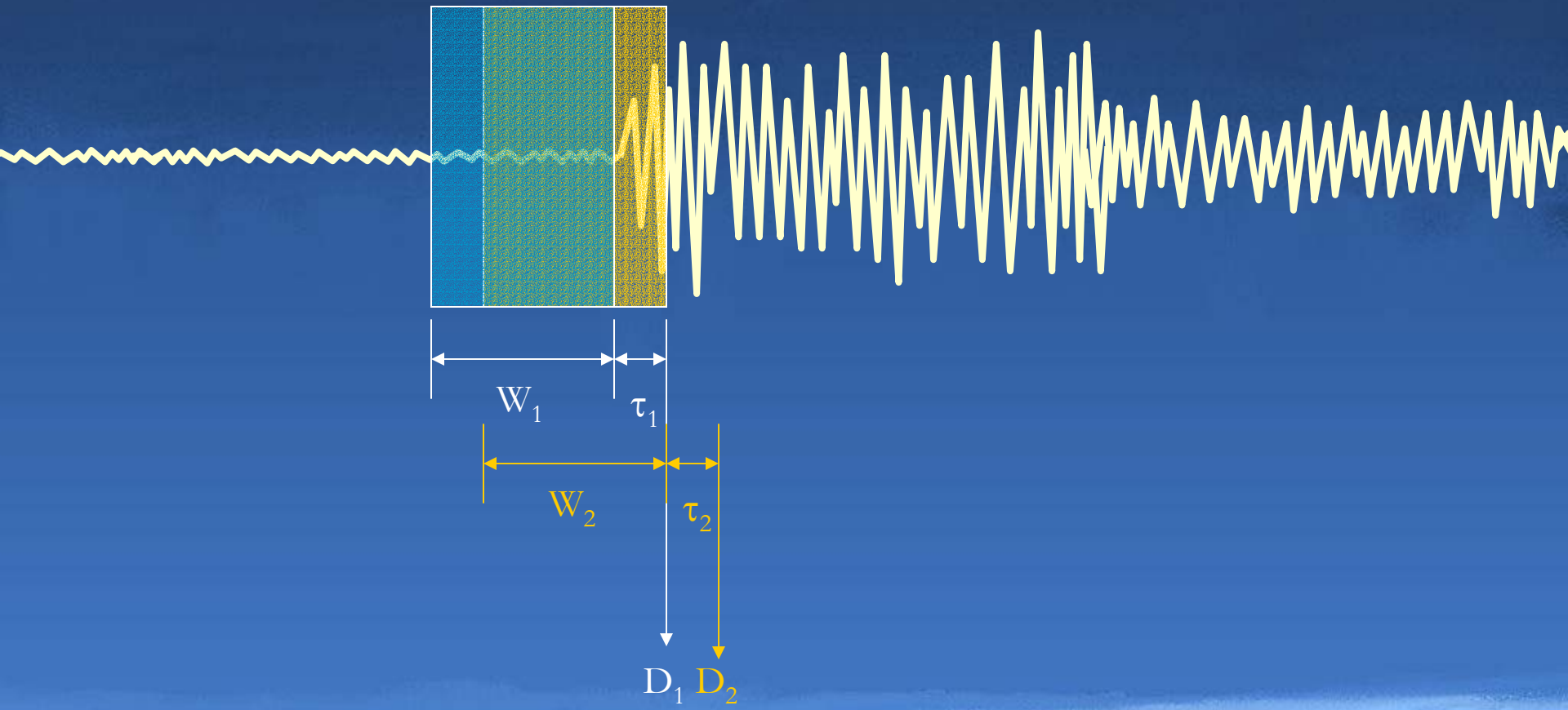

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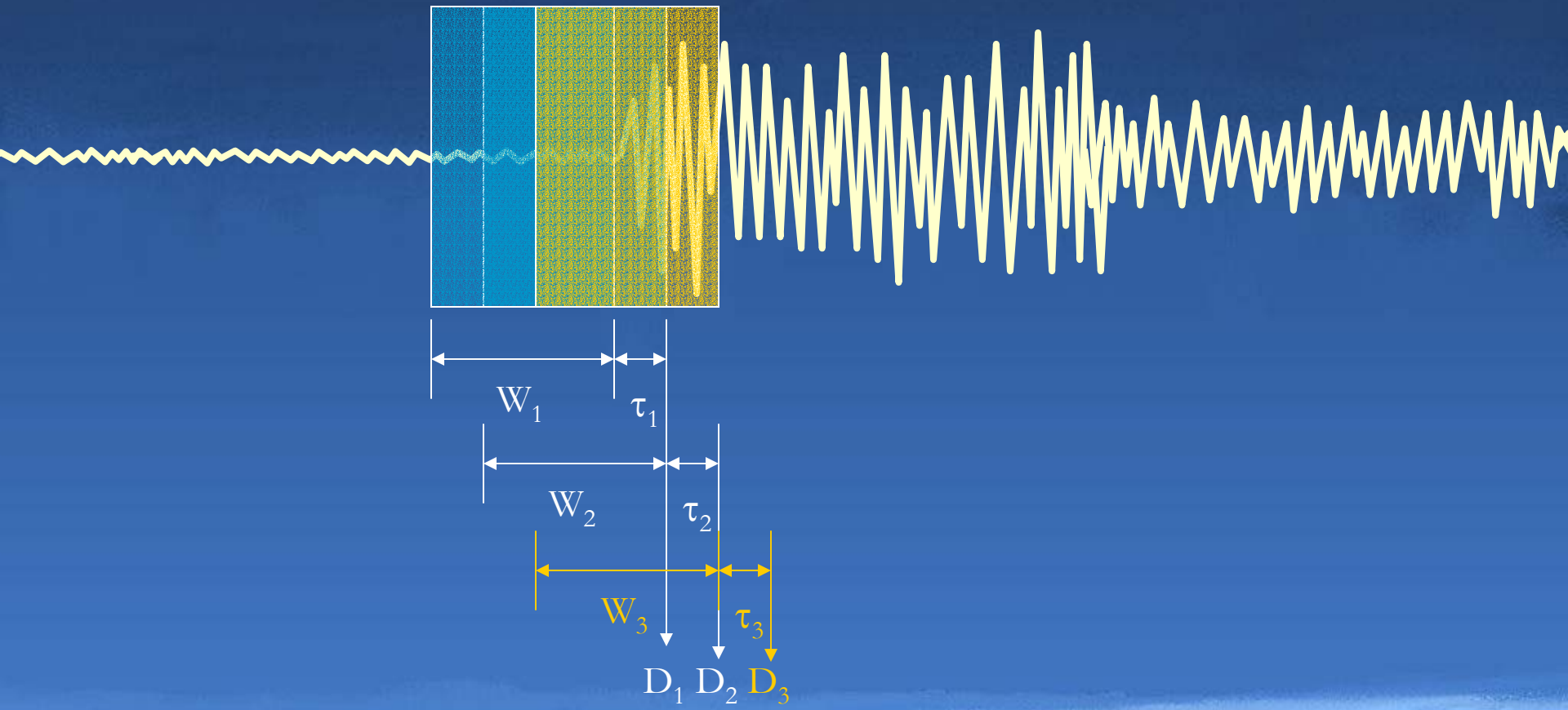
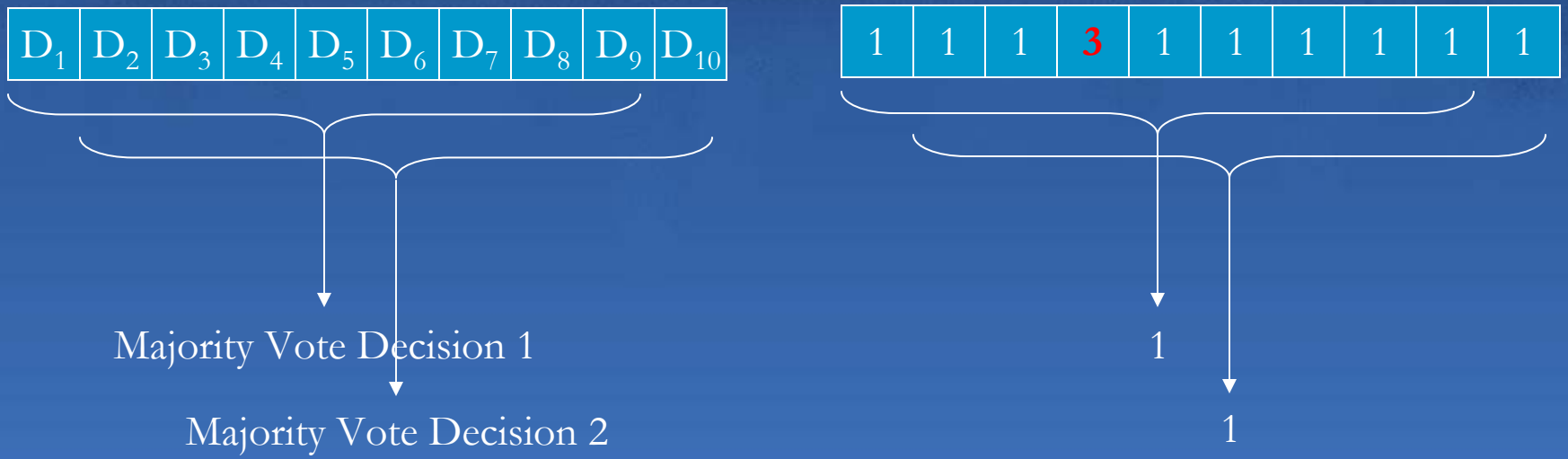
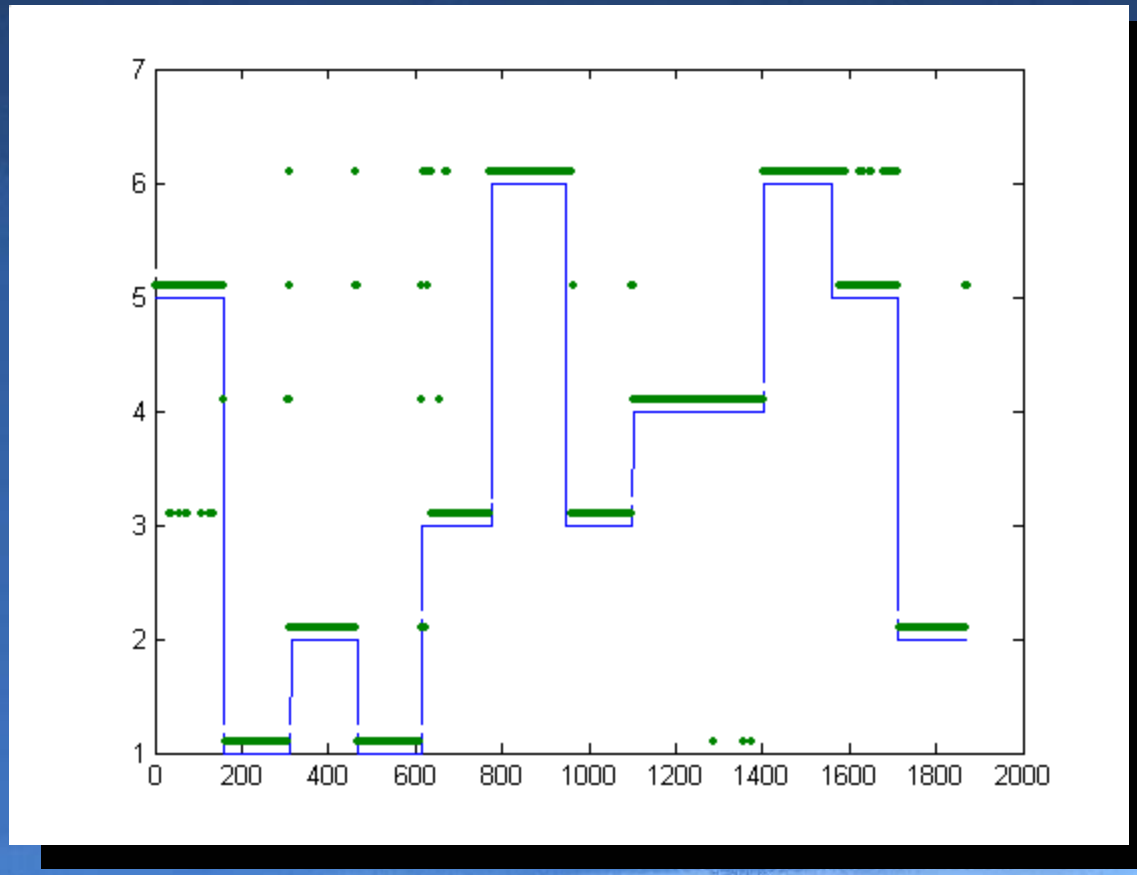


Majority Vote



Majority Vote

Target Class
No MV
MV



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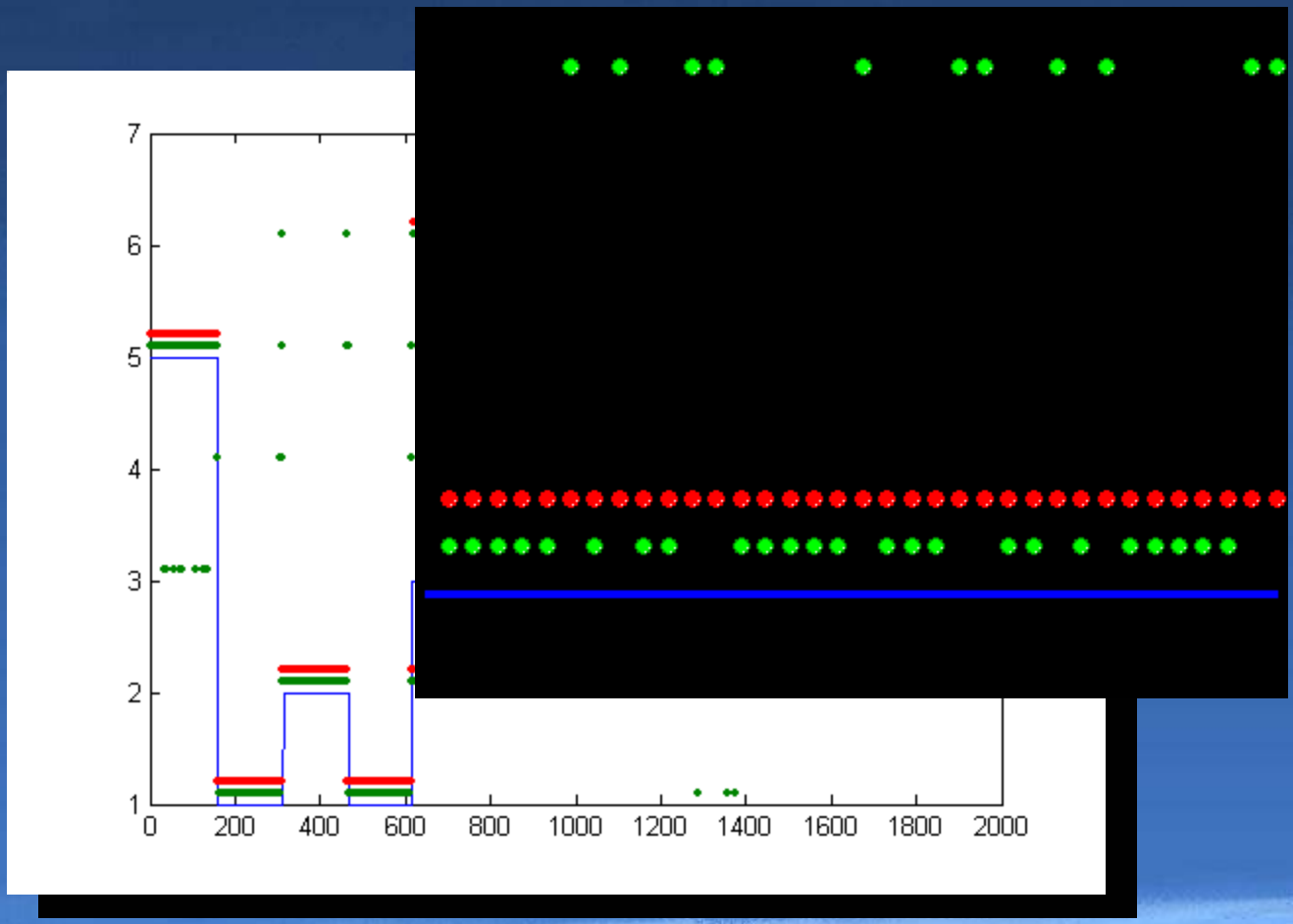
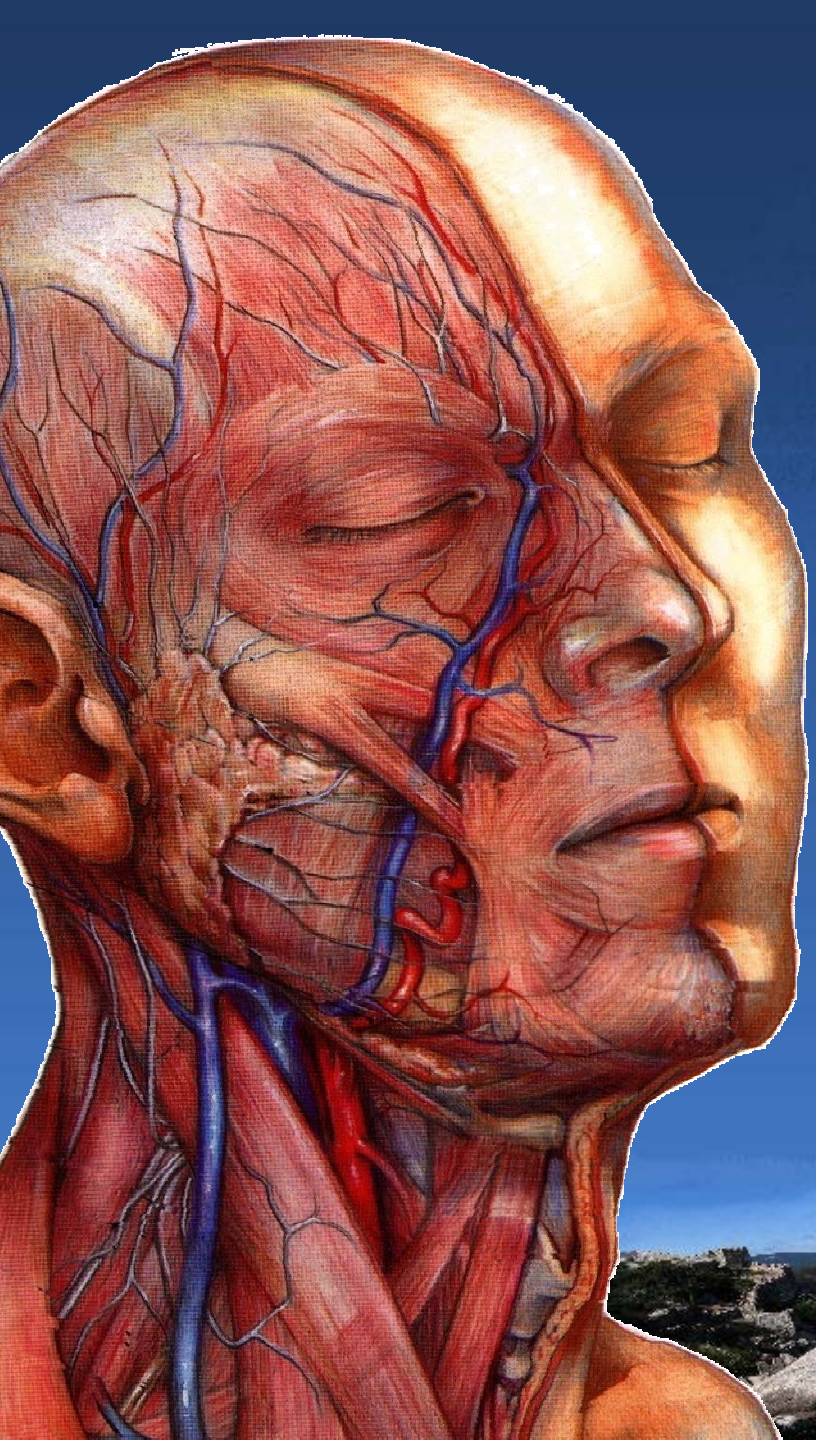


Majority Vote

- Classification accuracy improvements of approximately 2%
  - Significant improvement considering accuracies are already above 90% classification accuracy

Other Classifiers

- Hidden Markov Models
- Gaussian Mixture Models
- Fuzzy Logic Systems



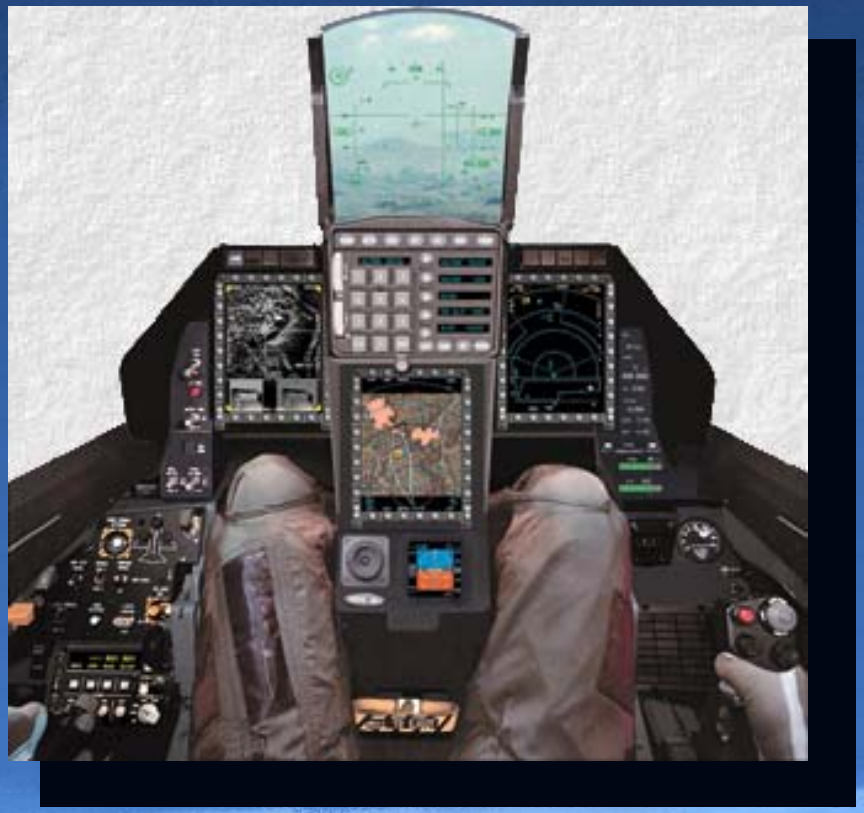
Myoelectric Speech Recognition

Myoelectric Speech Recognition

Complex Instrumentation

Alternative Control Methodologies

Automatic Speech Recognition



Conventional Speech Recognition

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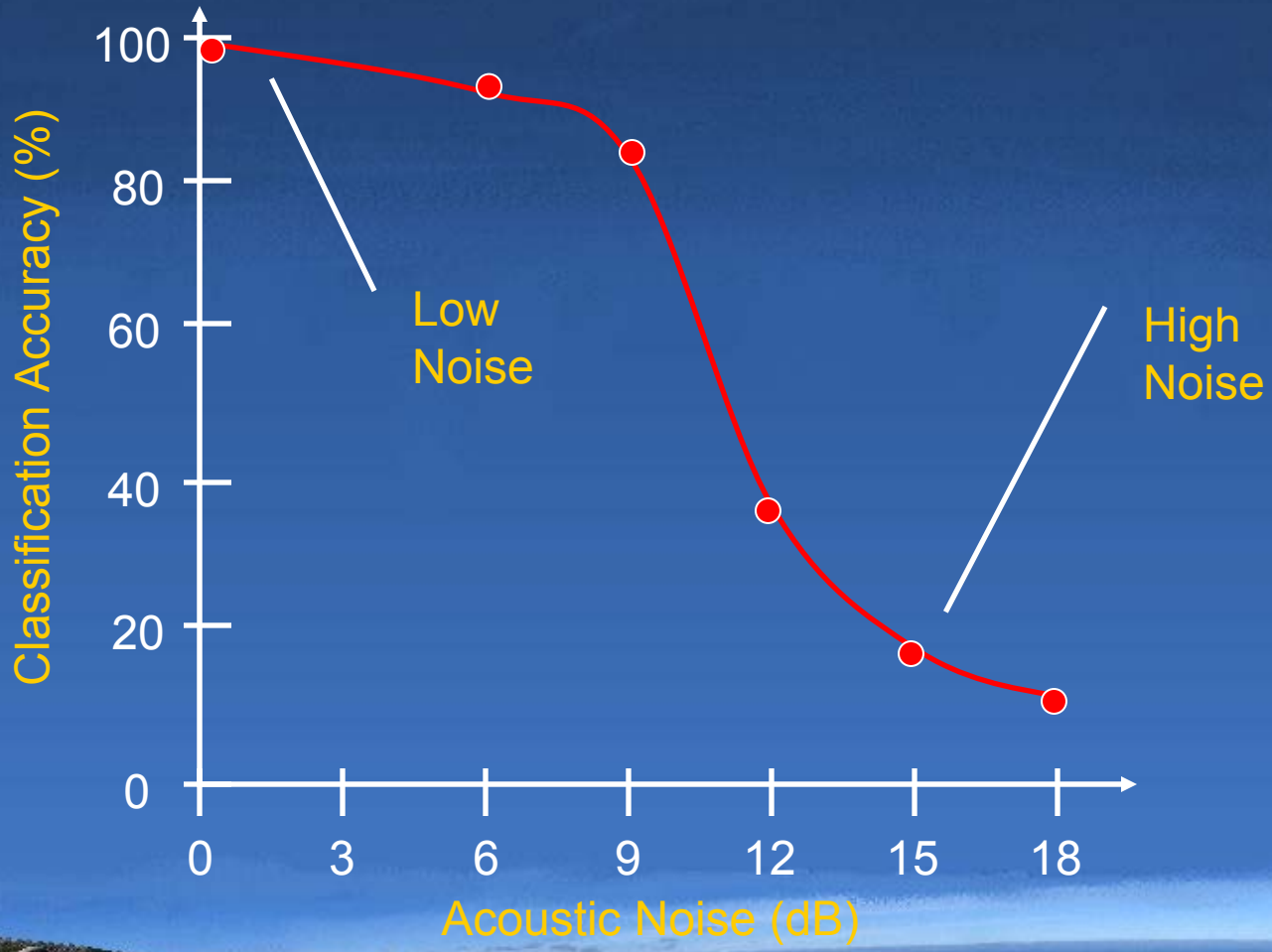
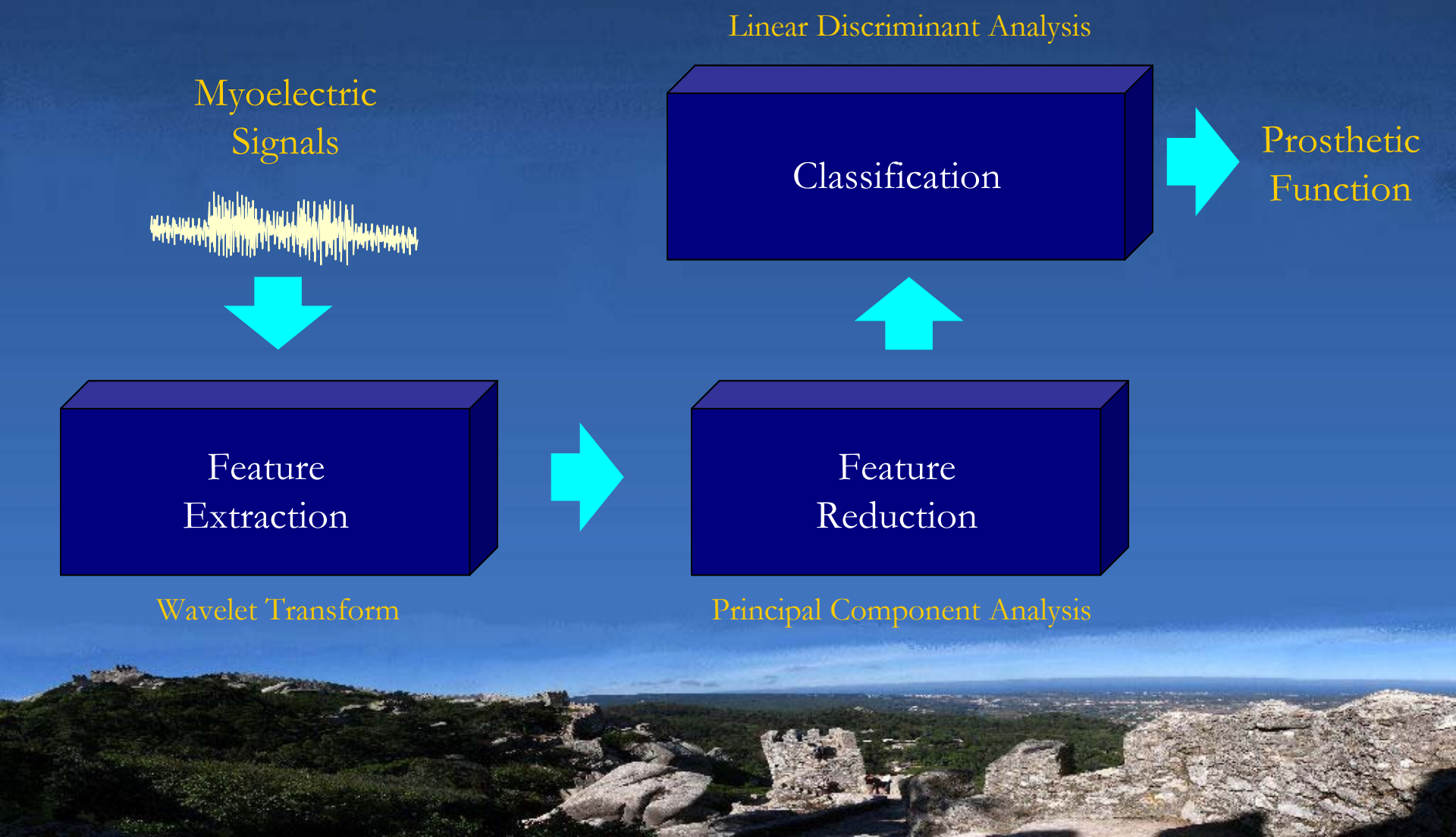


Myoelectric Speech Recognition

- not corrupted by audio noise
- there are similar sounding words with unique mouth positions implying unique myoelectric signals

  Example: "**sign**" and "**fine**"

Myoelectric Speech Recognition



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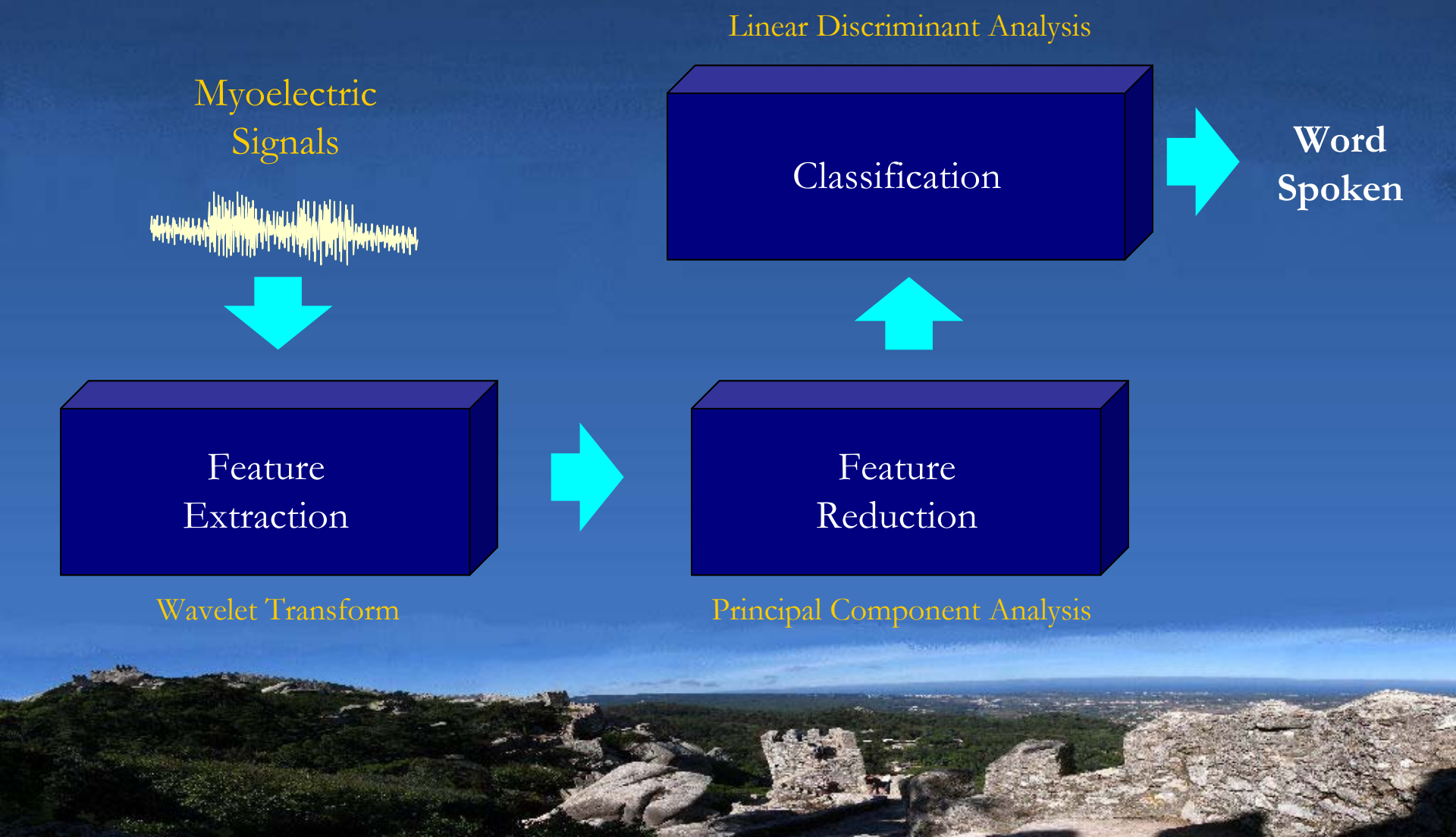
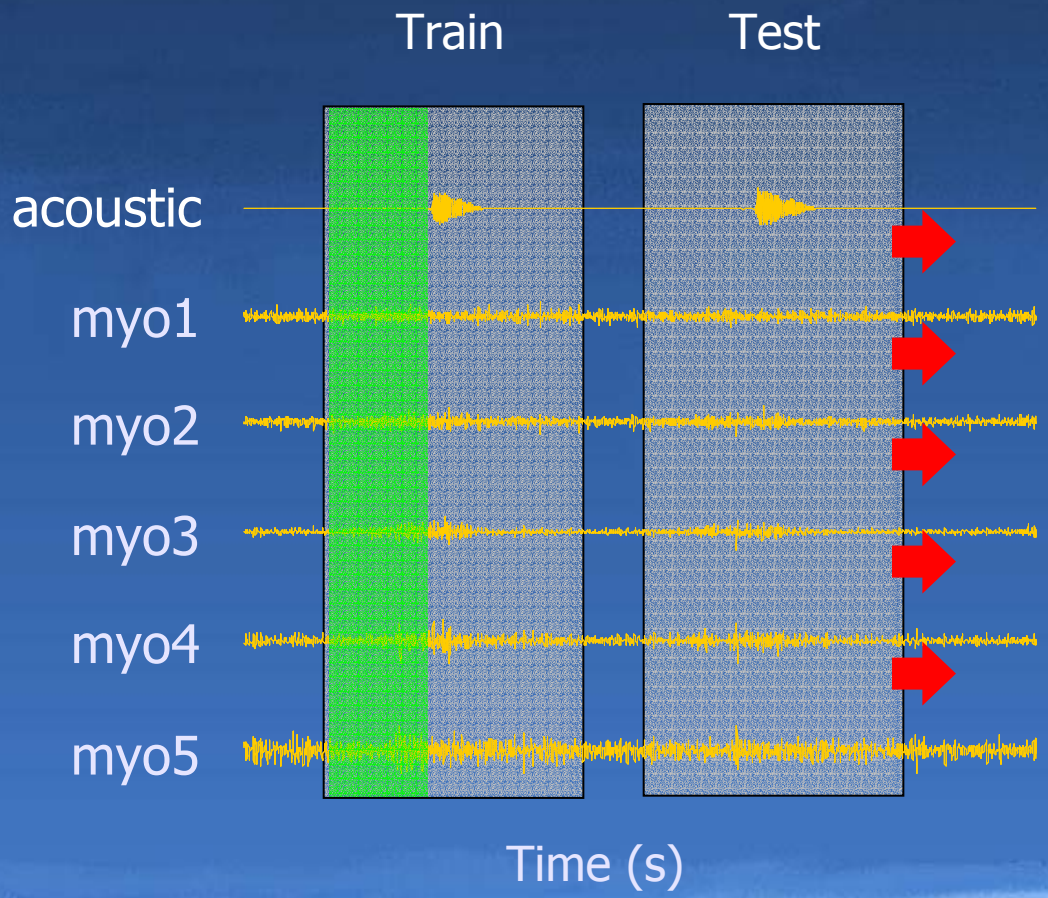


Data Collection

- 2 subjects
- 5 myoelectric signals
- 10 word vocabulary
  - "zero" through "nine"
  - Random order

"six",	"four",	…,	"three"
"one",	"zero",	…,	"five"
:	:		:
"eight",	"six",	…,	"two"

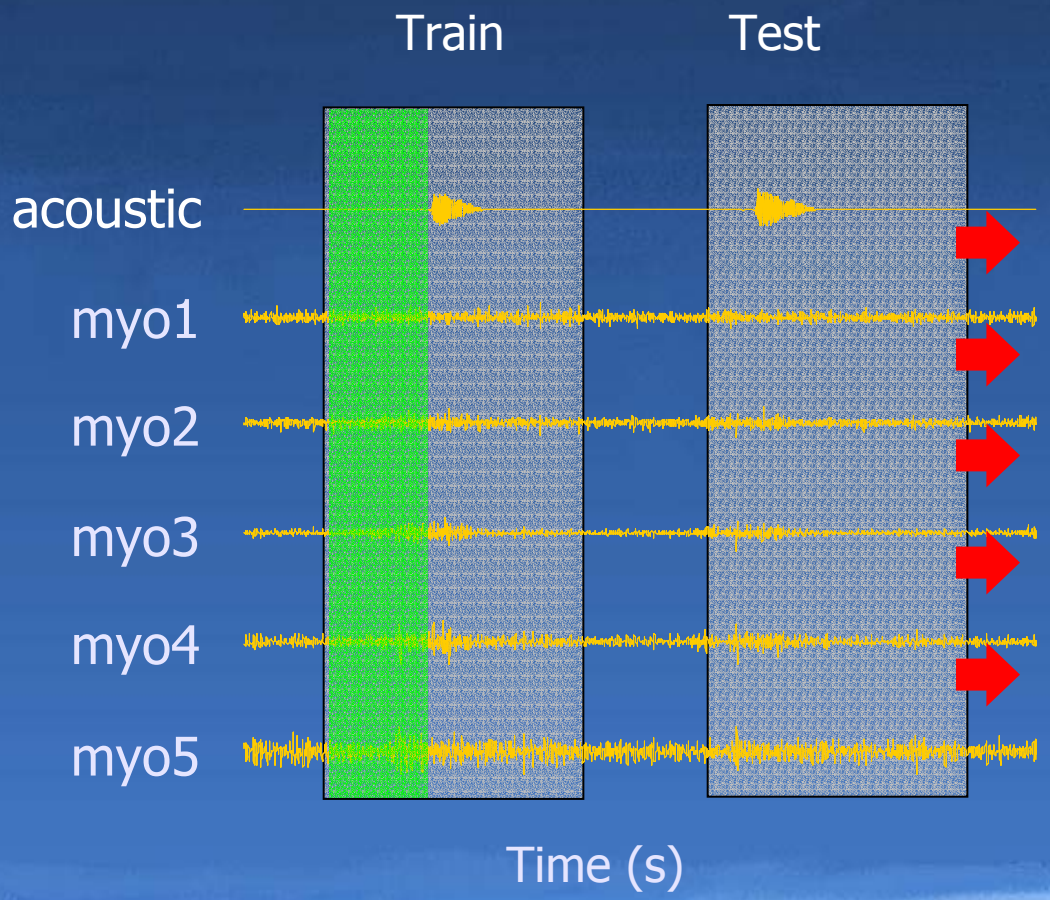
Temporal Variance



Training set uses a fixed pre-trigger of 500 ms

Temporal variance introduced by varying the pre-trigger of the test set

Temporal Variance



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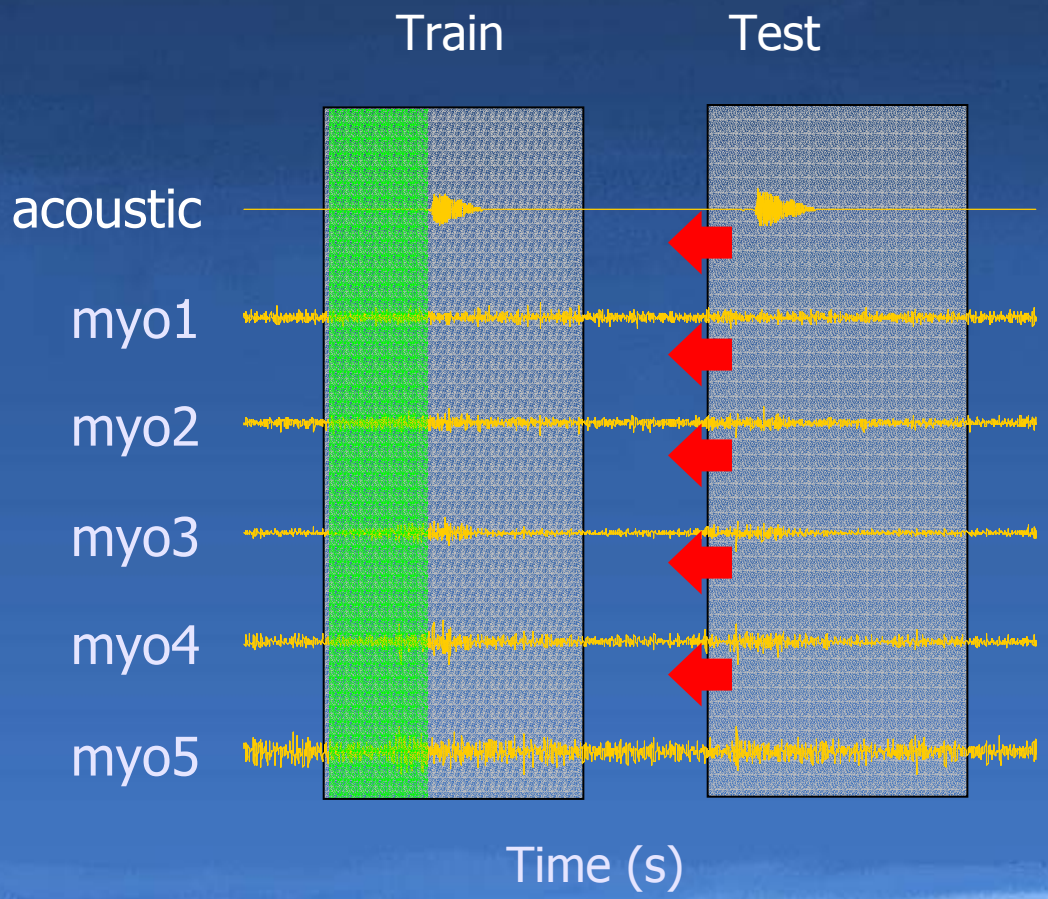

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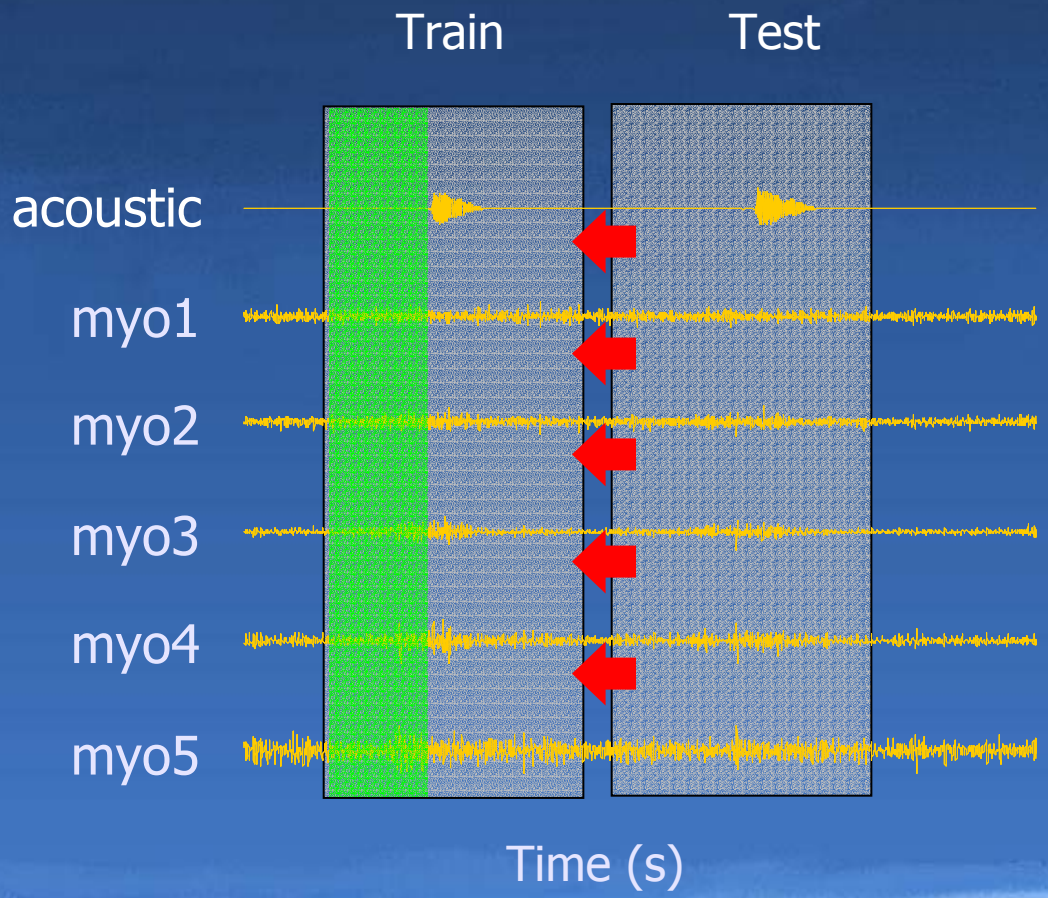

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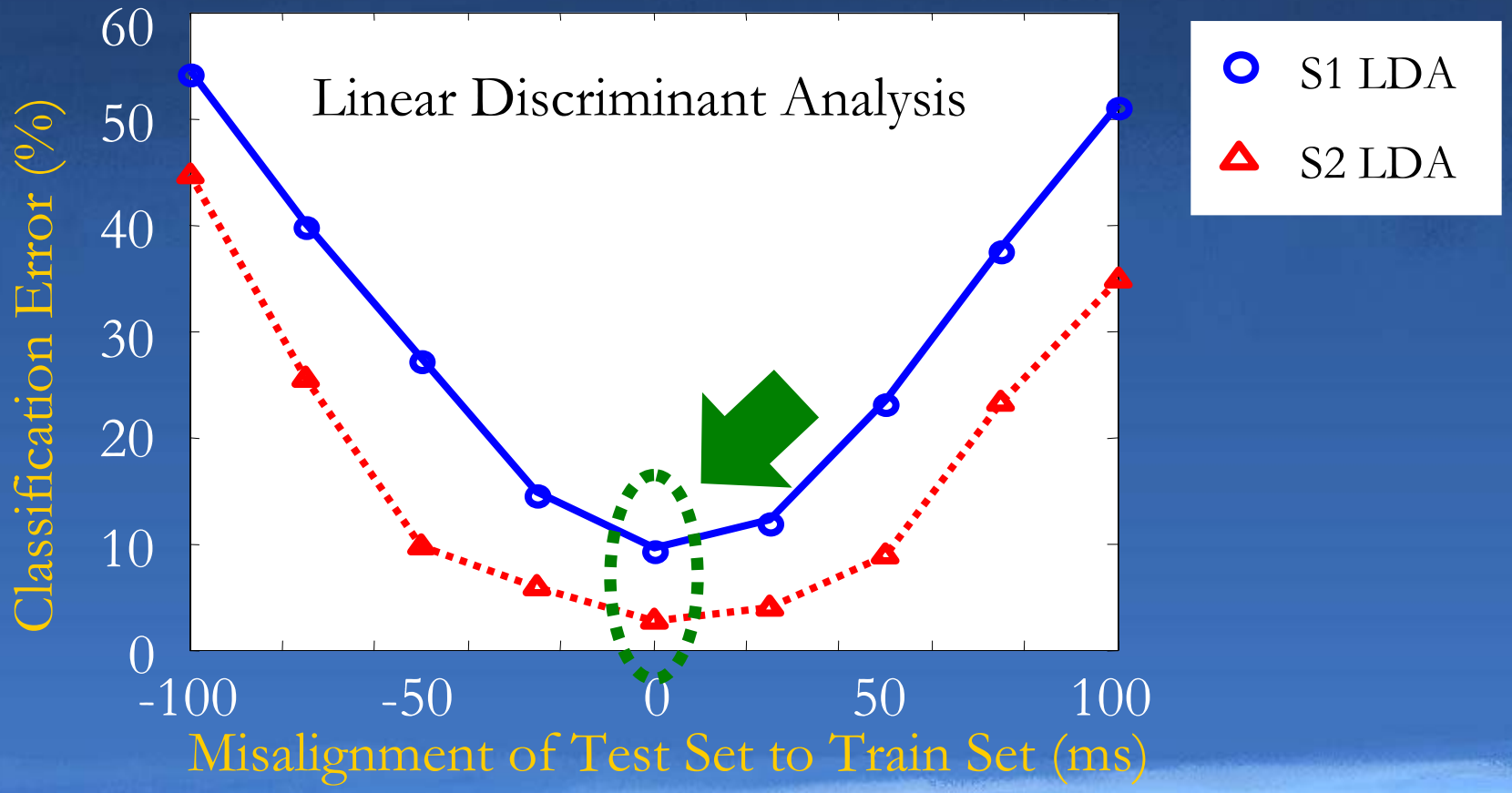
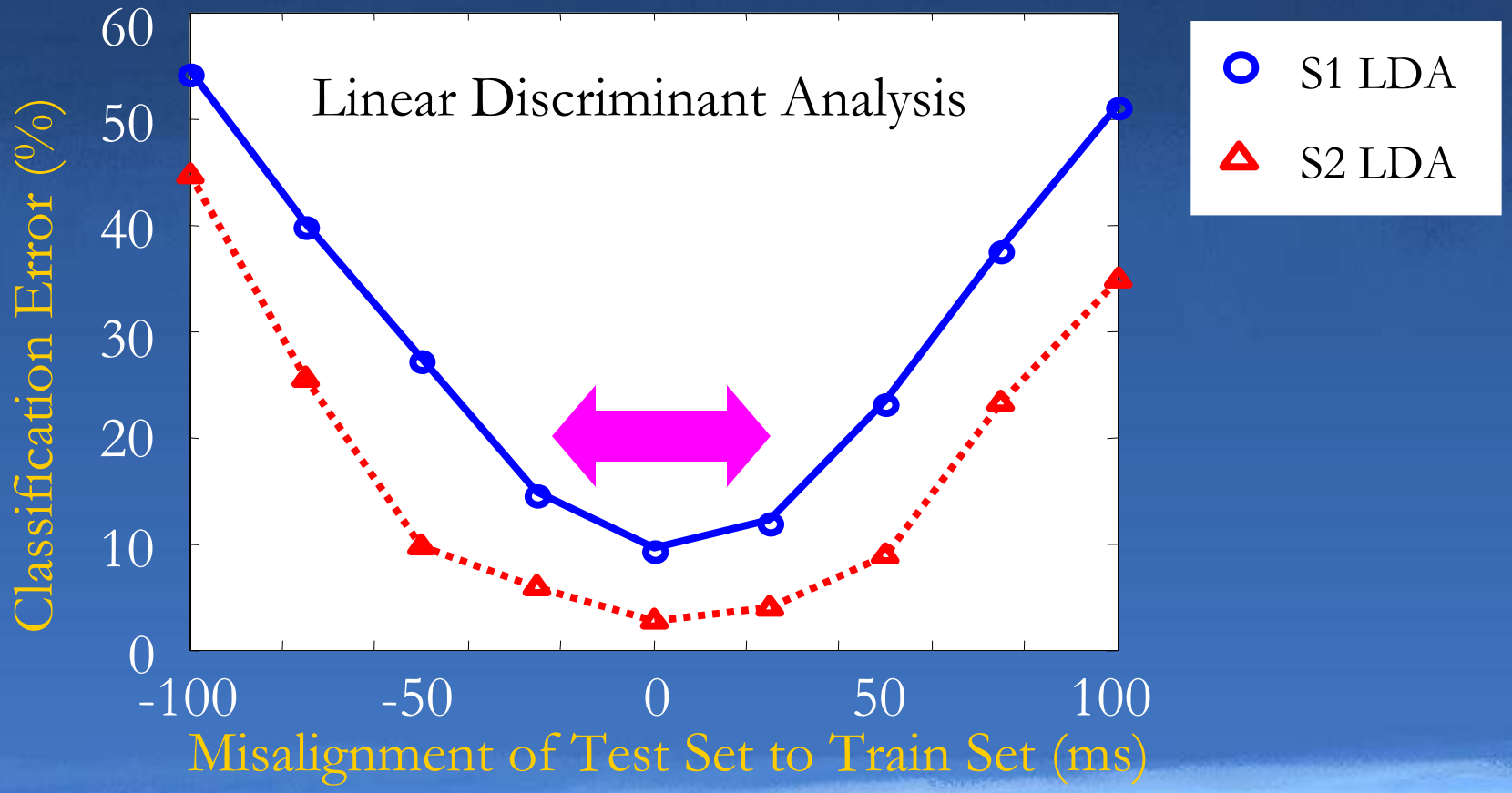
Results


Linear Discriminant Analysis
Classification Error (%)
60
50
40
30
20
10
0
-100
-50
0
50
100
Misalignment of Test Set to Train Set (ms)
S1 LDA
S2 LDA

Results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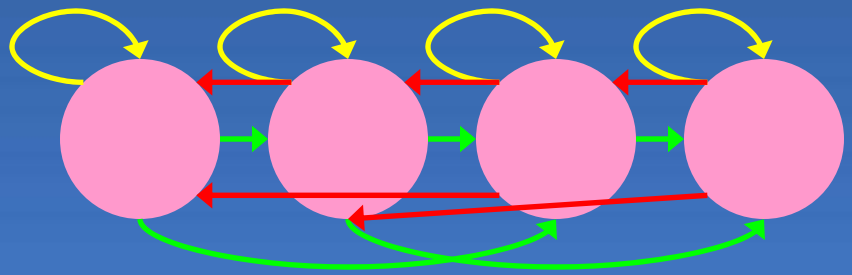
Hidden Markov Models

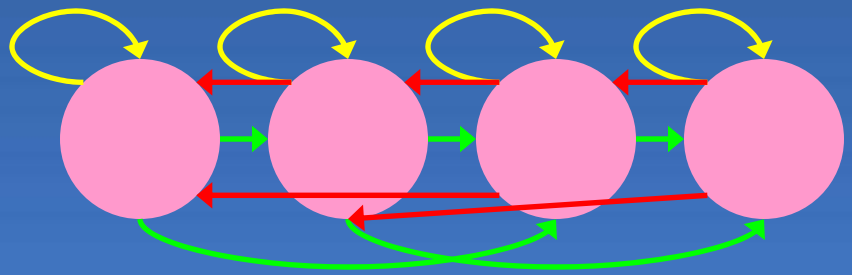
- States
  - Observation probabilities
- State transitions
  - State transition probabilities



Hidden Markov Models

- Hidden Markov model structure enables it to cope with time-scale variance and shape variance

- Used extensively in acoustic speech recognition



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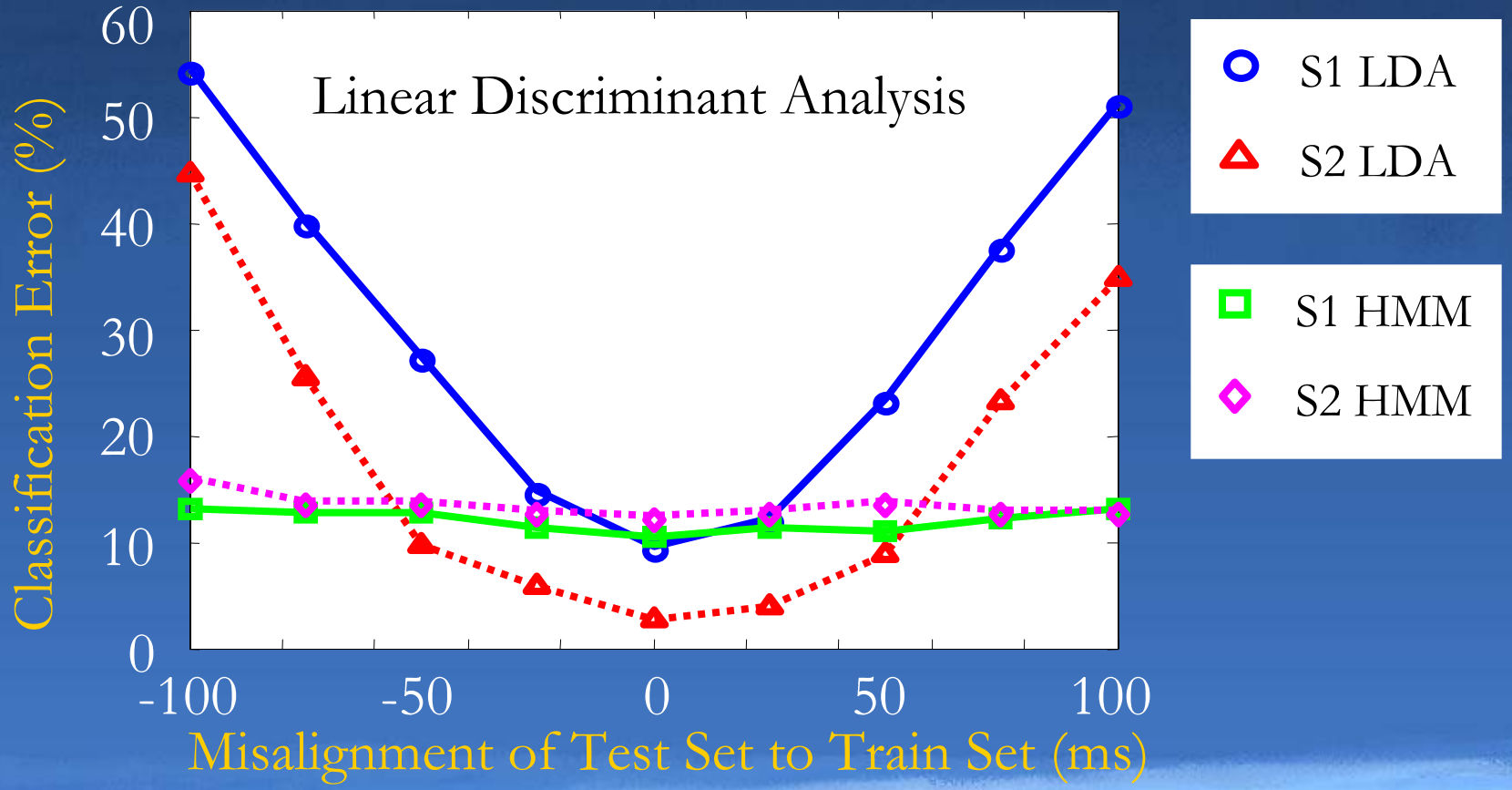
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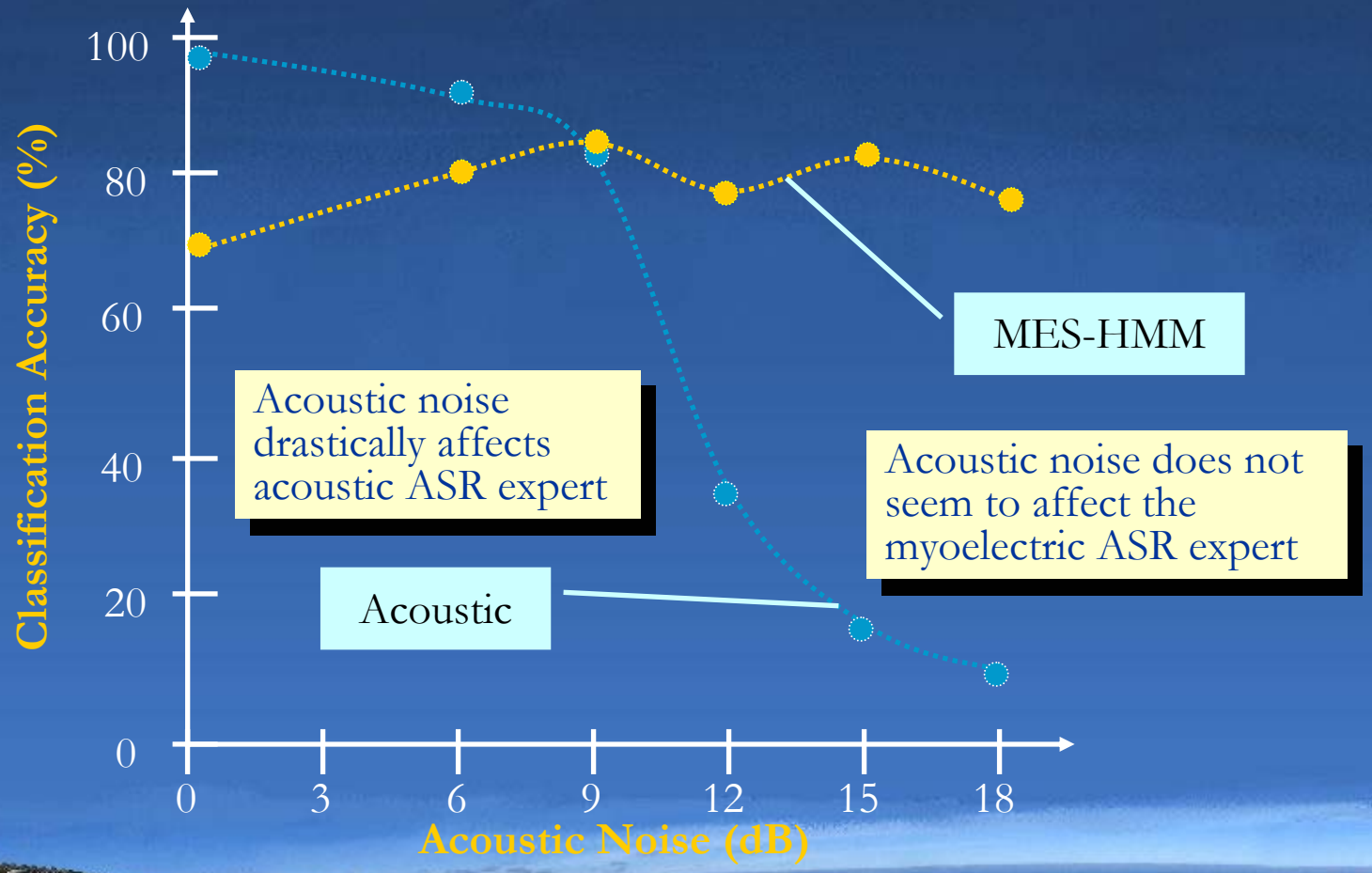
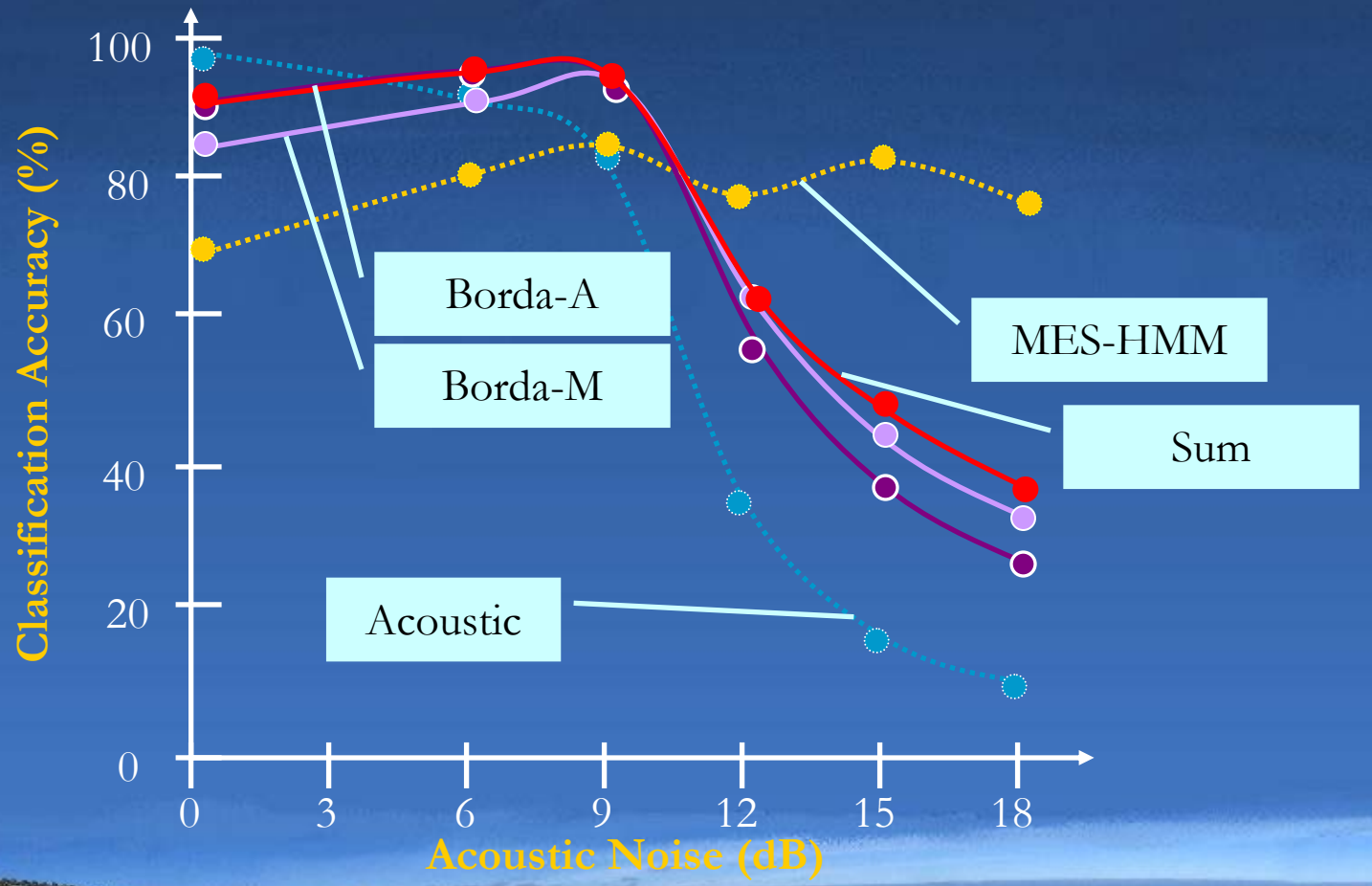


Multi-Expert System



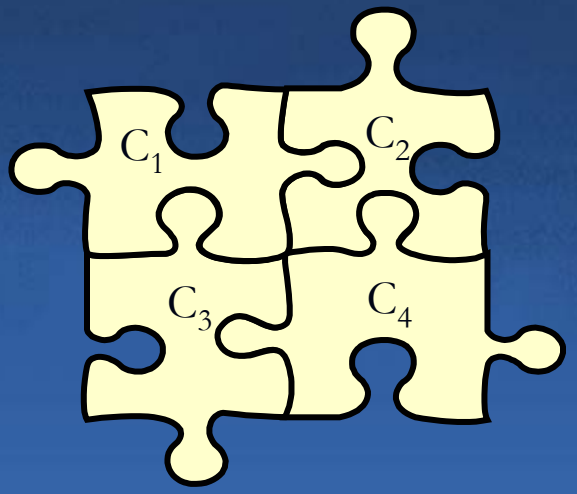
Evidence Theory

- Enables precise assignment of partial beliefs
- Provides method of combining partial beliefs from multiple bodies of evidence

Klir GJ, Yuan B, *Fuzzy sets and fuzzy logic: theory and applications*, Prentice-Hall, Upper Saddle Creek NJ, 1995.

Evidence Theory

- Frame of discernment Θ
  - Set of mutually exclusive classes C_i
  - Includes the empty set $\varnothing$
- Basic probability assignment
  - m(A) assigns a portion of belief to the set A



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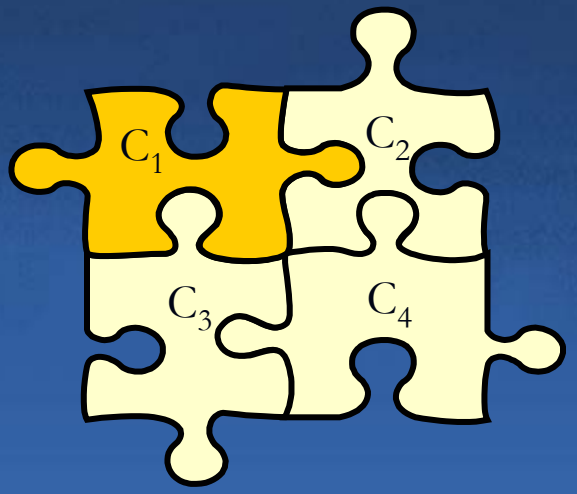

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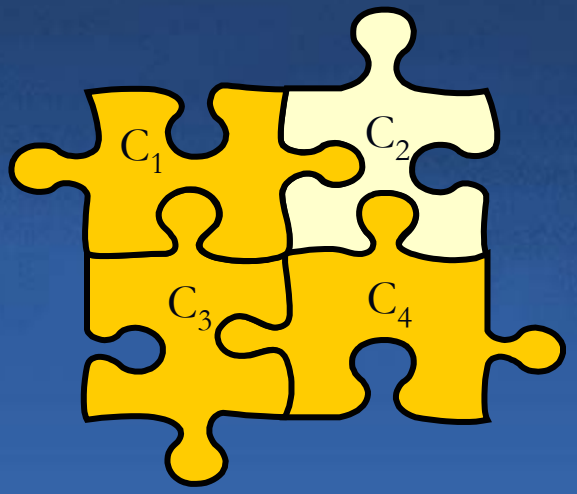
  - Set A can include multiple classes



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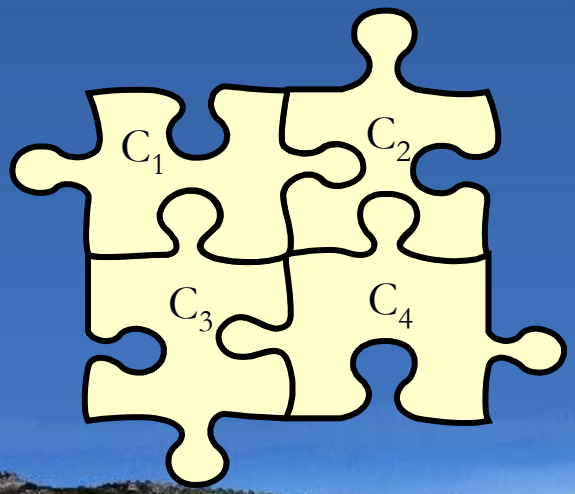
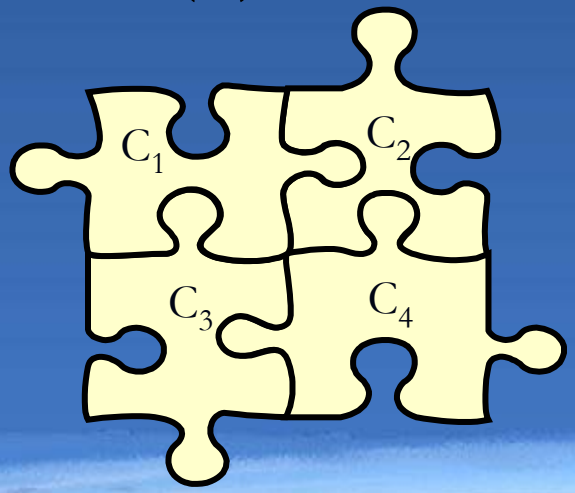
Evidence Theory

- Bayesian theory
  - No evidence:
    $Pr(C_i) = 1/N$



- Evidence theory
  - No evidence:
    $m(\Theta) = 1$



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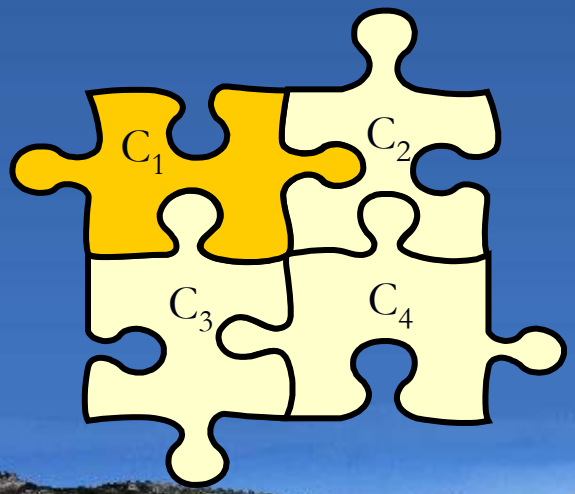

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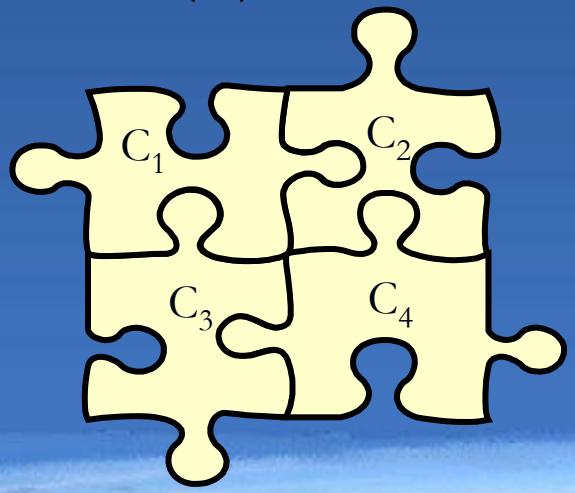

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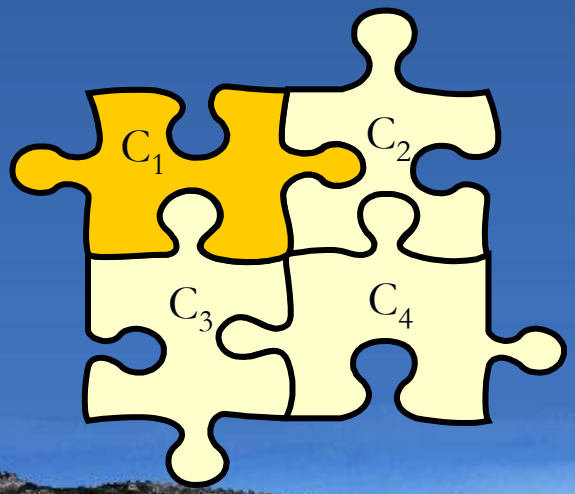

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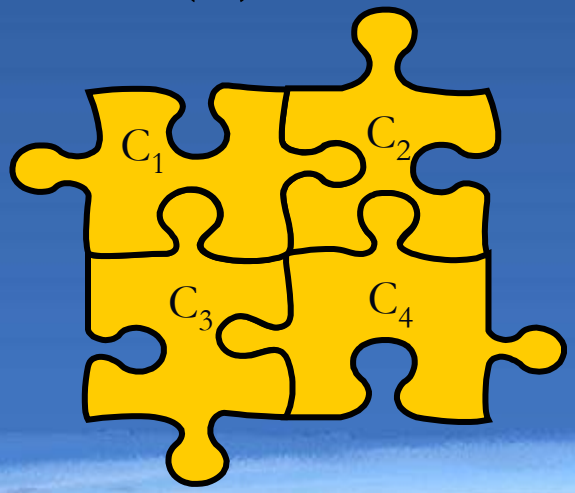
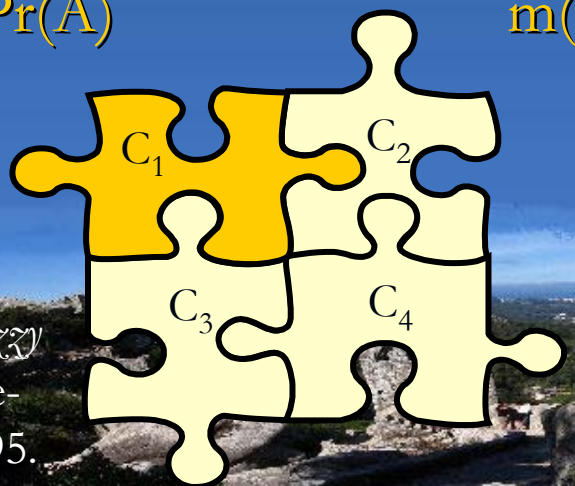


Klir GJ, Yuan B, *Fuzzy sets and fuzzy logic: theory and applications*, Prentice-Hall, Upper Saddle Creek NJ, 1995.

Evidence Theory

- Bayesian theory
  - No evidence:
    $Pr(C_i) = 1/N$
  - Pr(A) implies
    $Pr(\neg A) = 1 - Pr(A)$
- Evidence theory
  - No evidence:
    $m(\Theta) = 1$
  - m(A) does not imply
    $m(\neg A) = 1 - m(A)$



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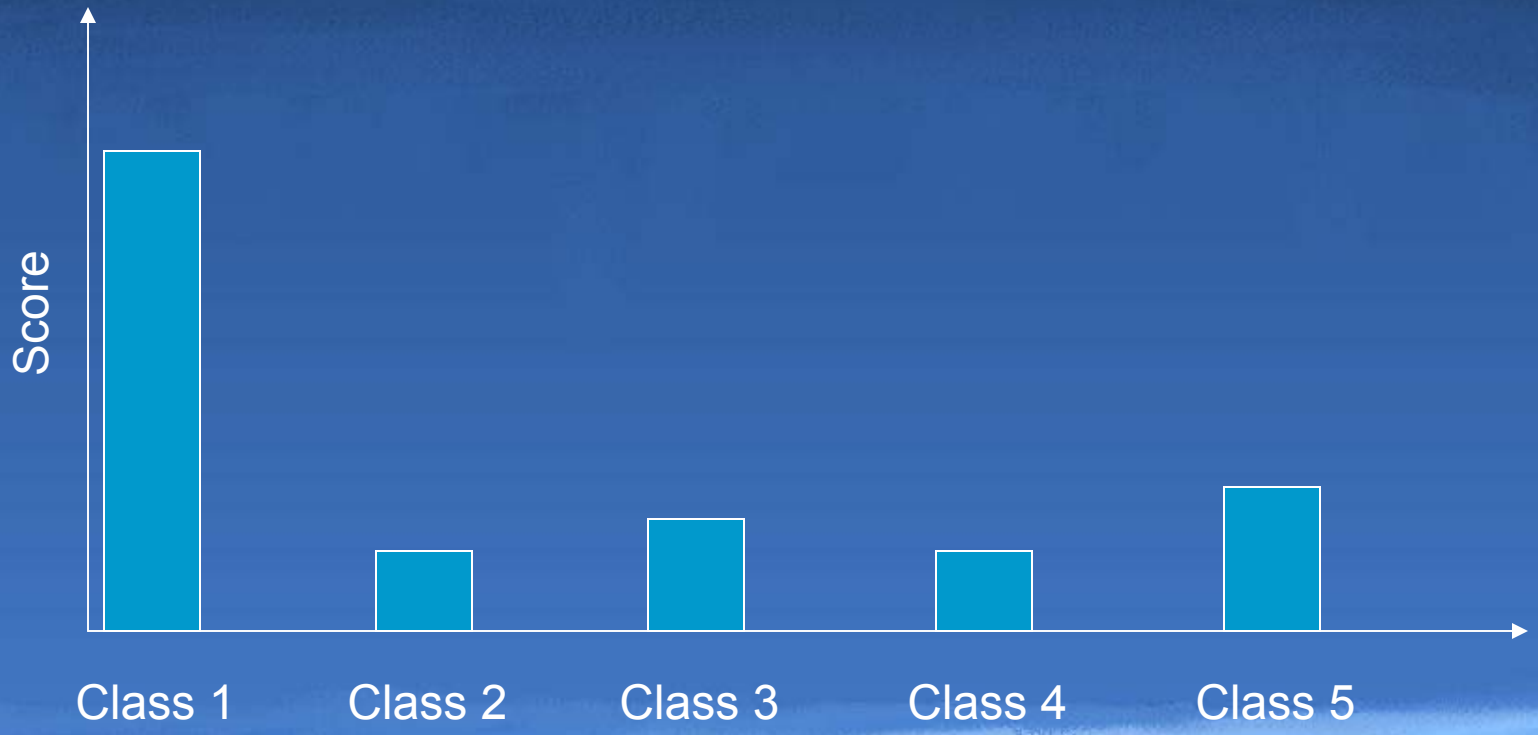
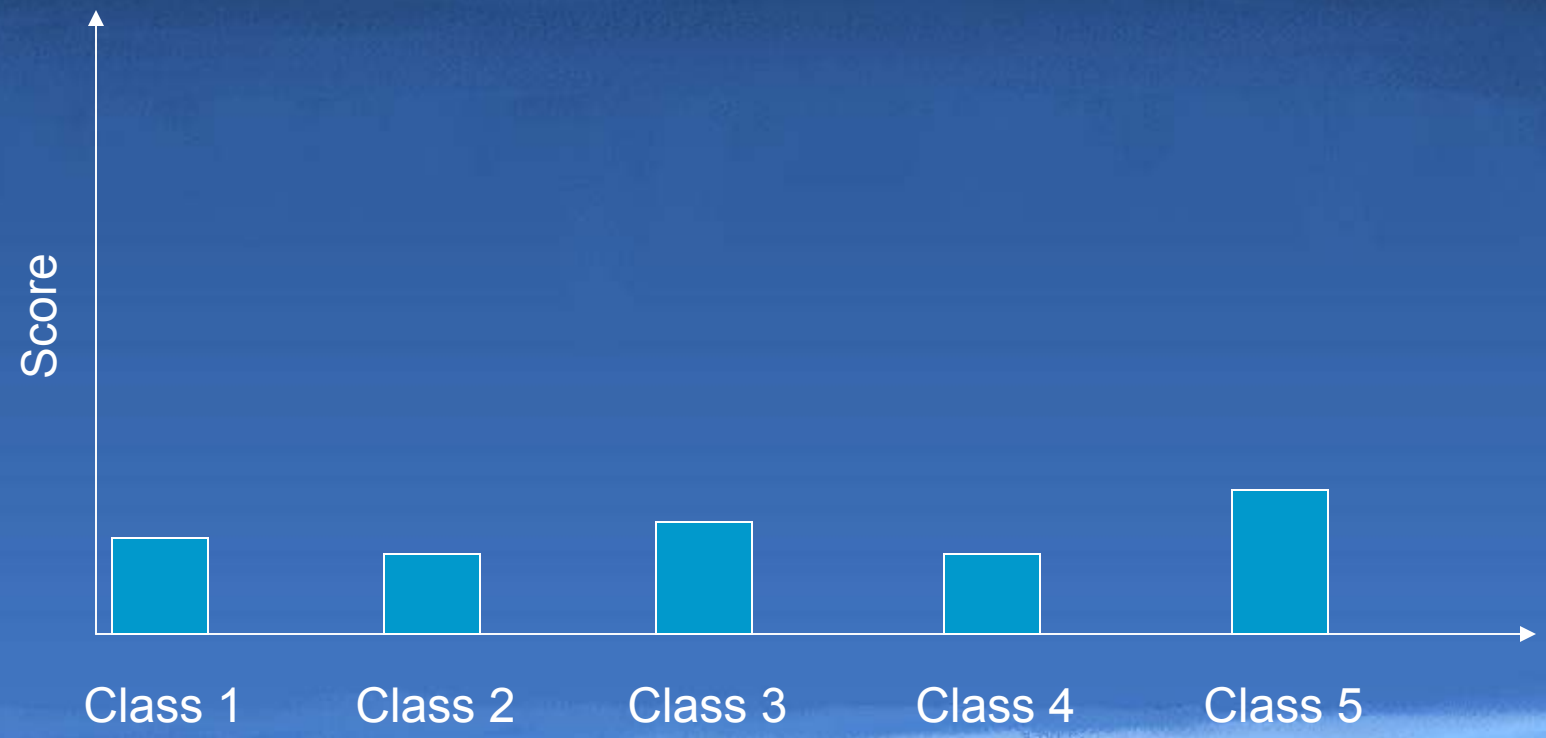
Plausibility Method

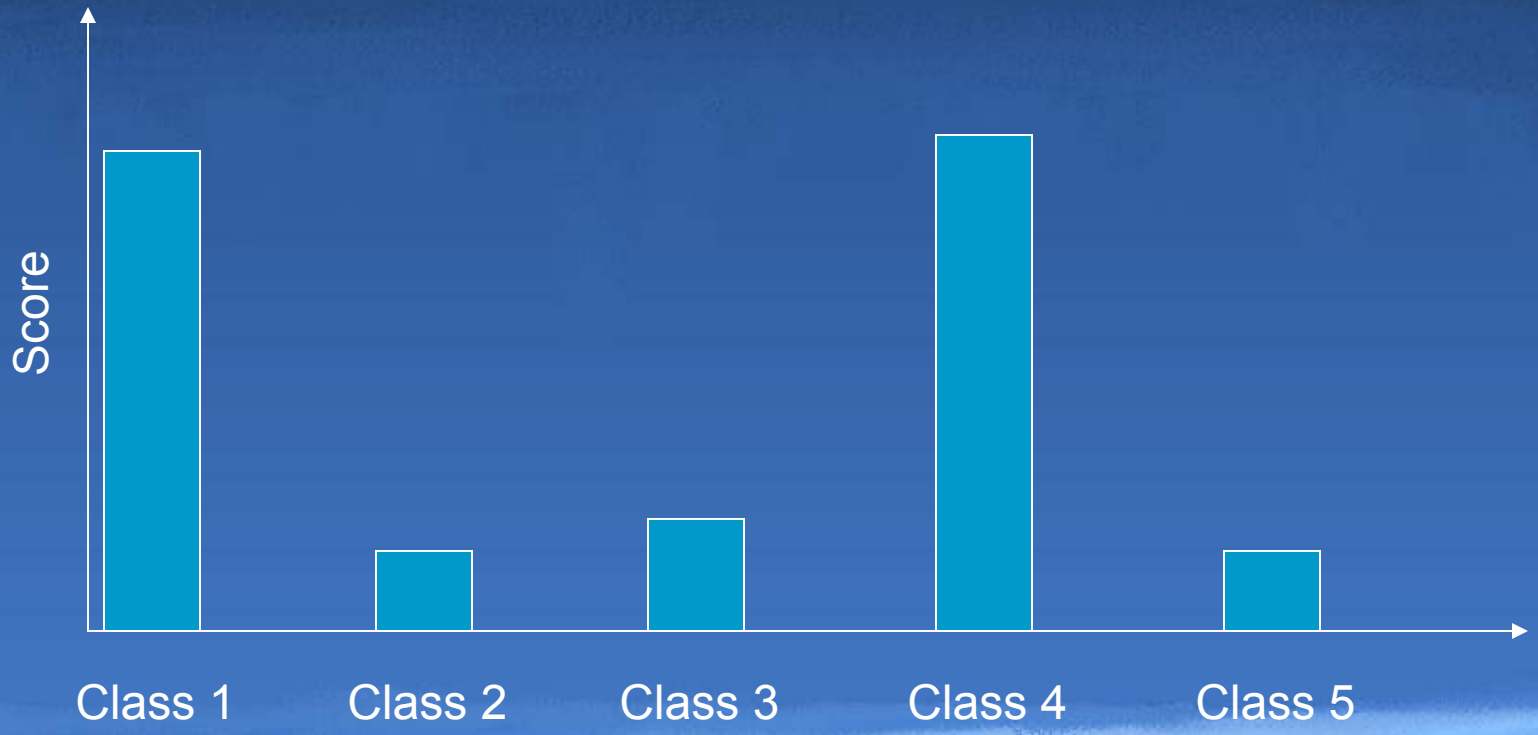


Plausibility Method



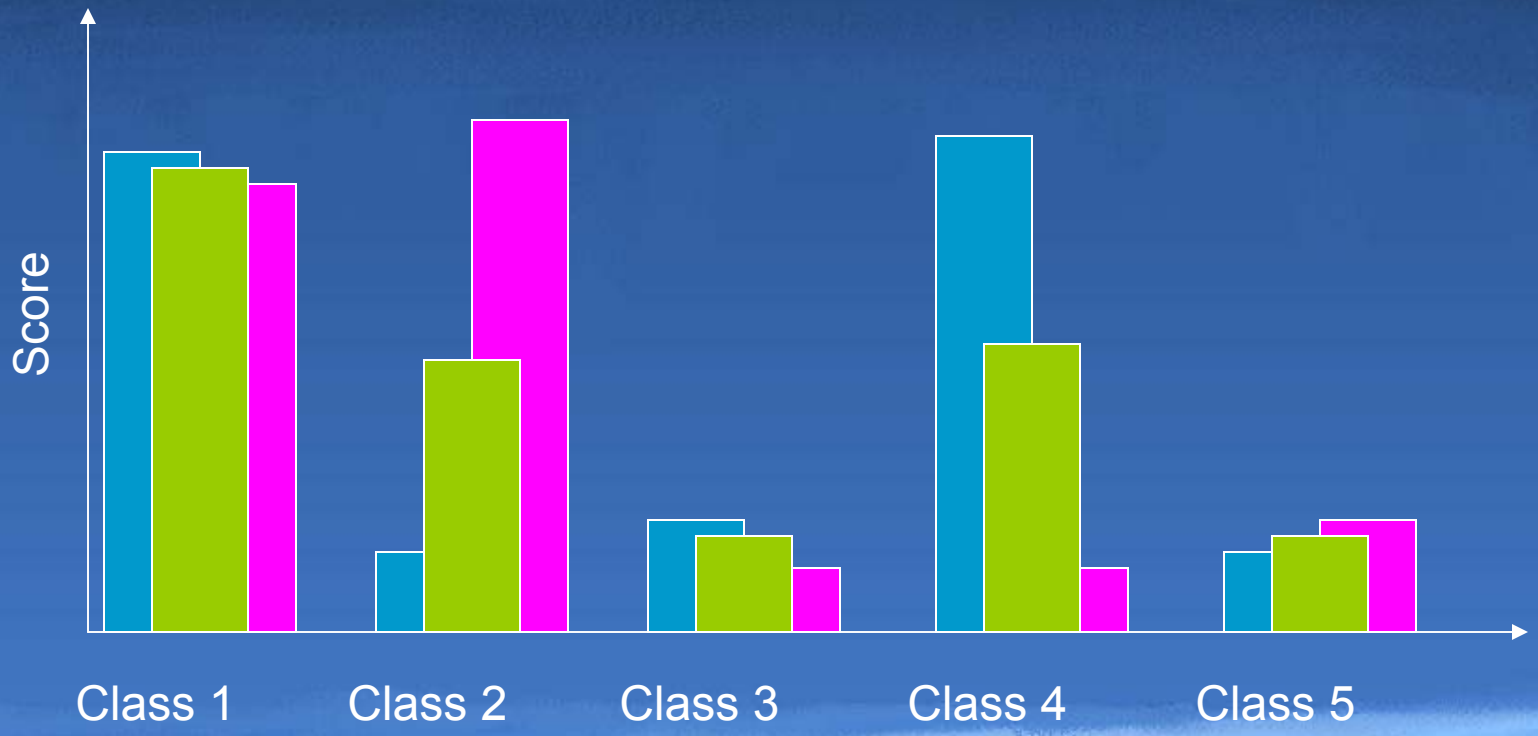
Plausibility Method

Plausibility Method

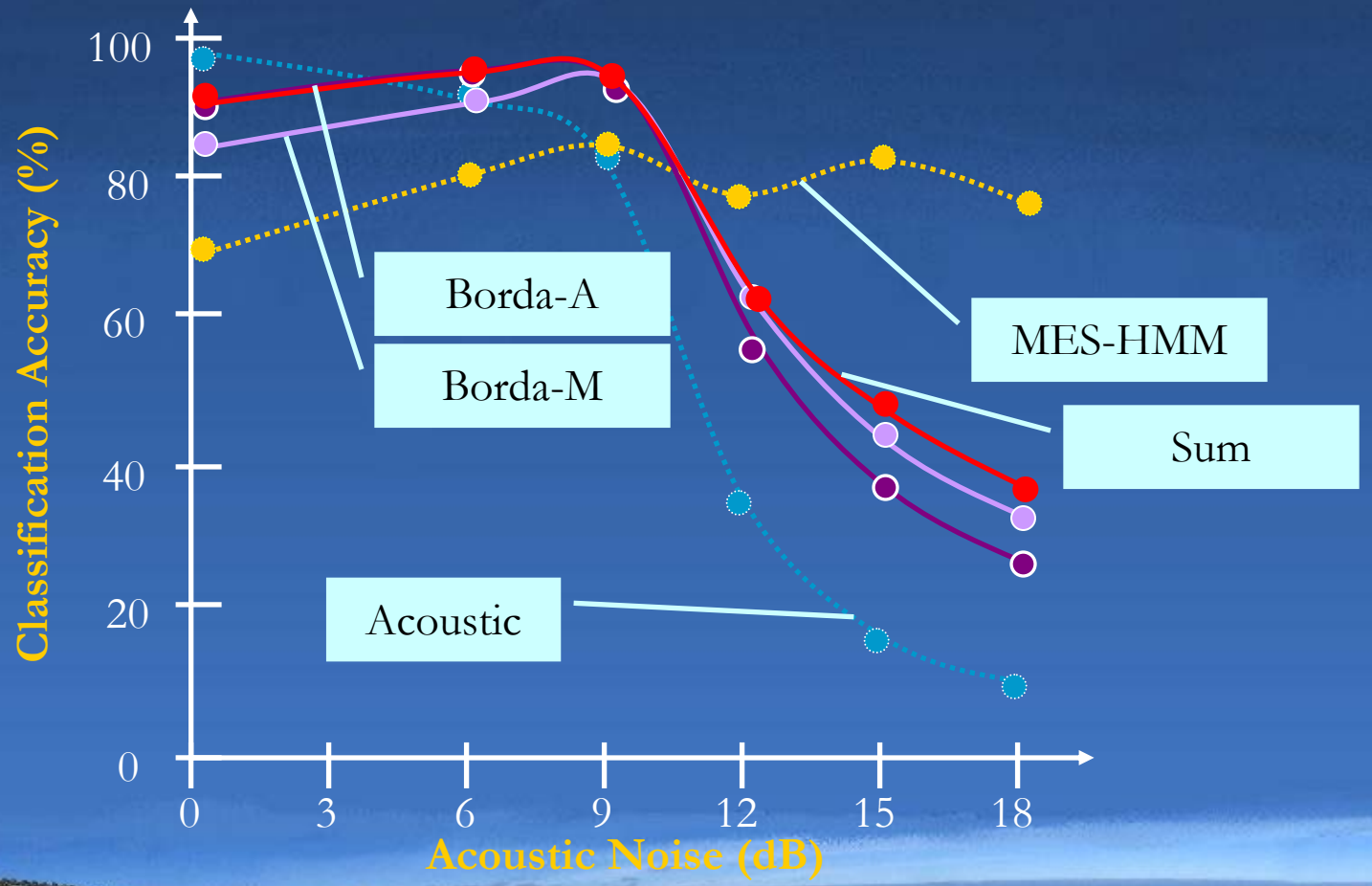


Plausibility Method

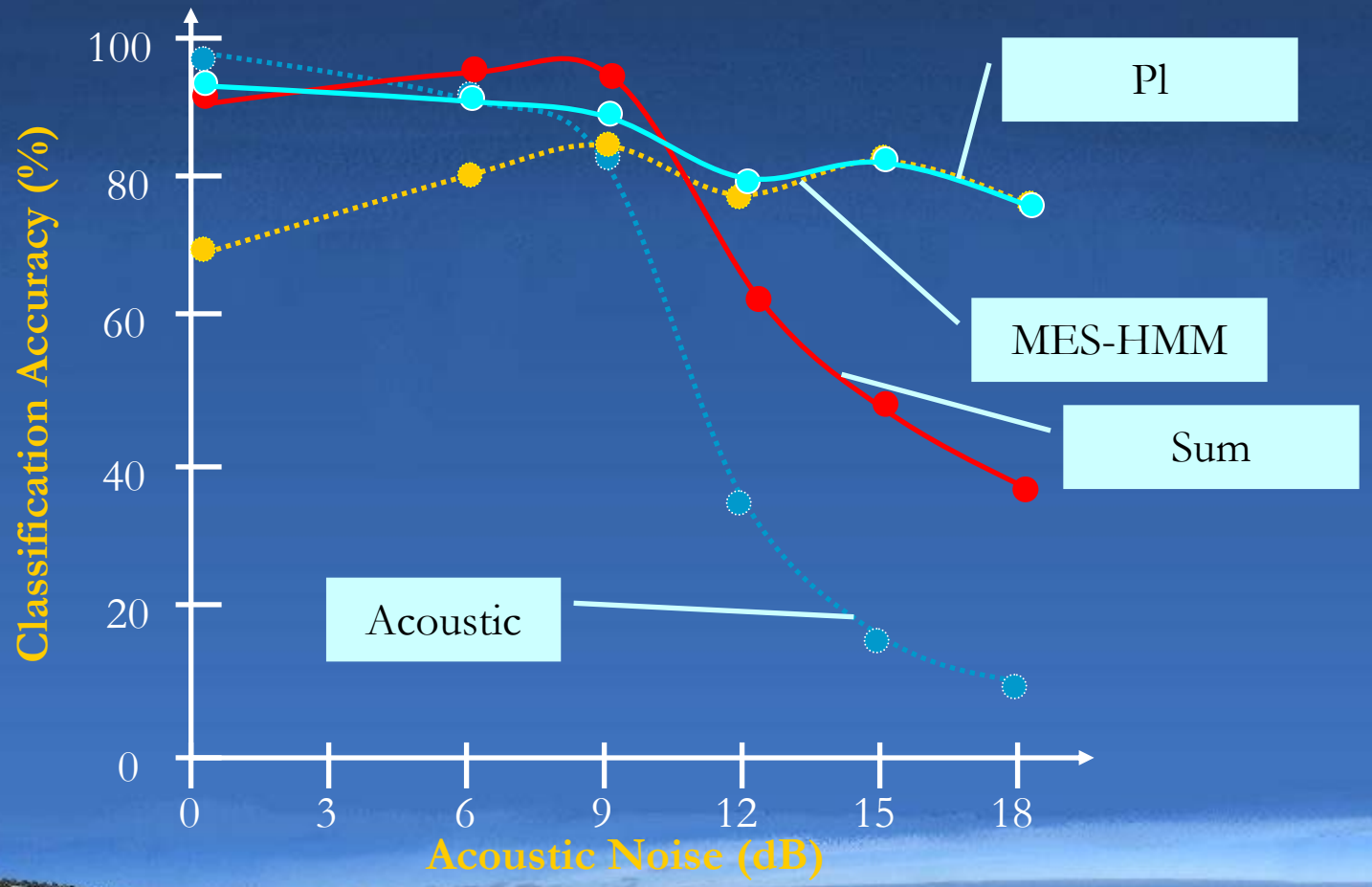
Plausibility Method



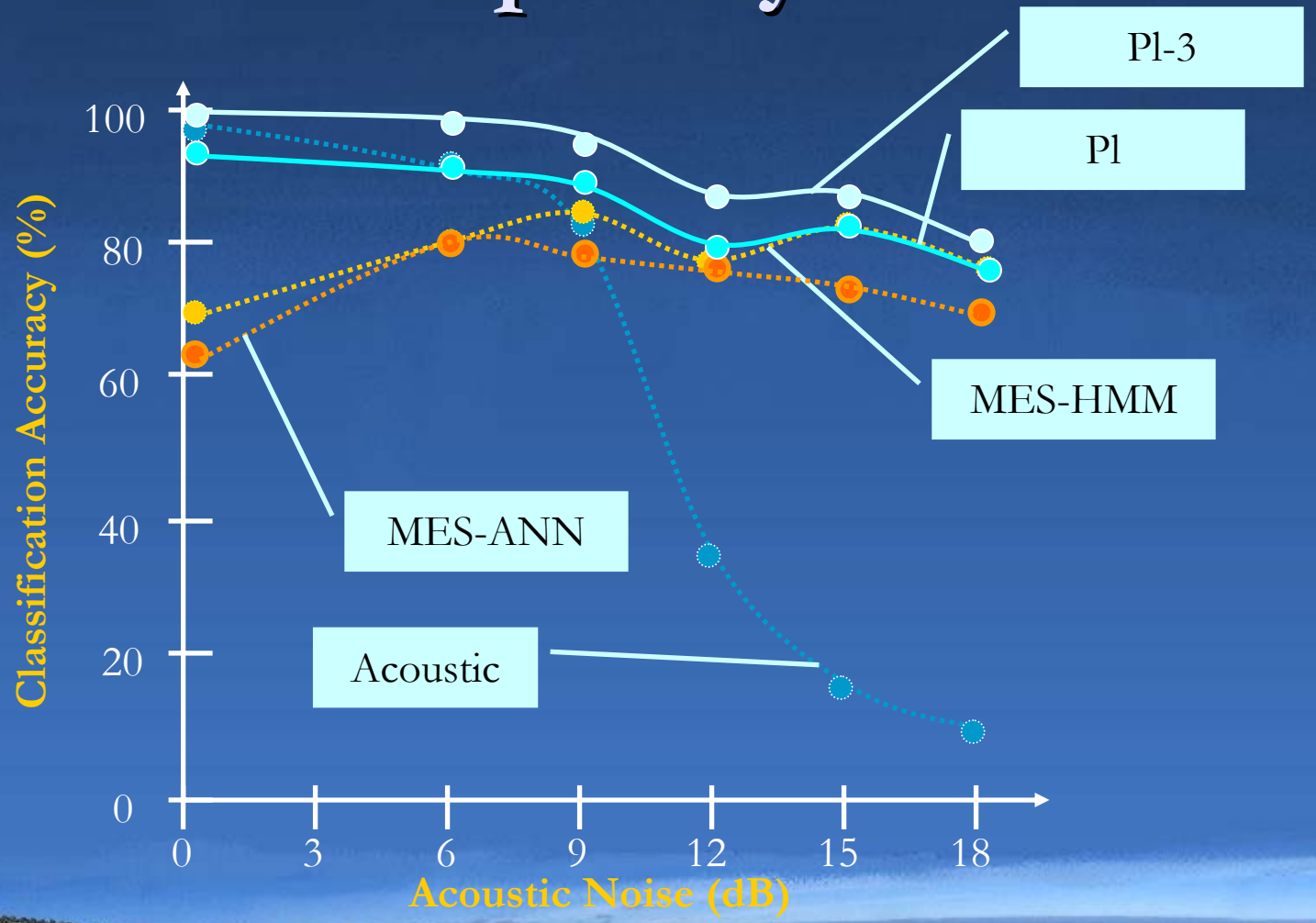
Multi-Expert System



Multi-Expert System



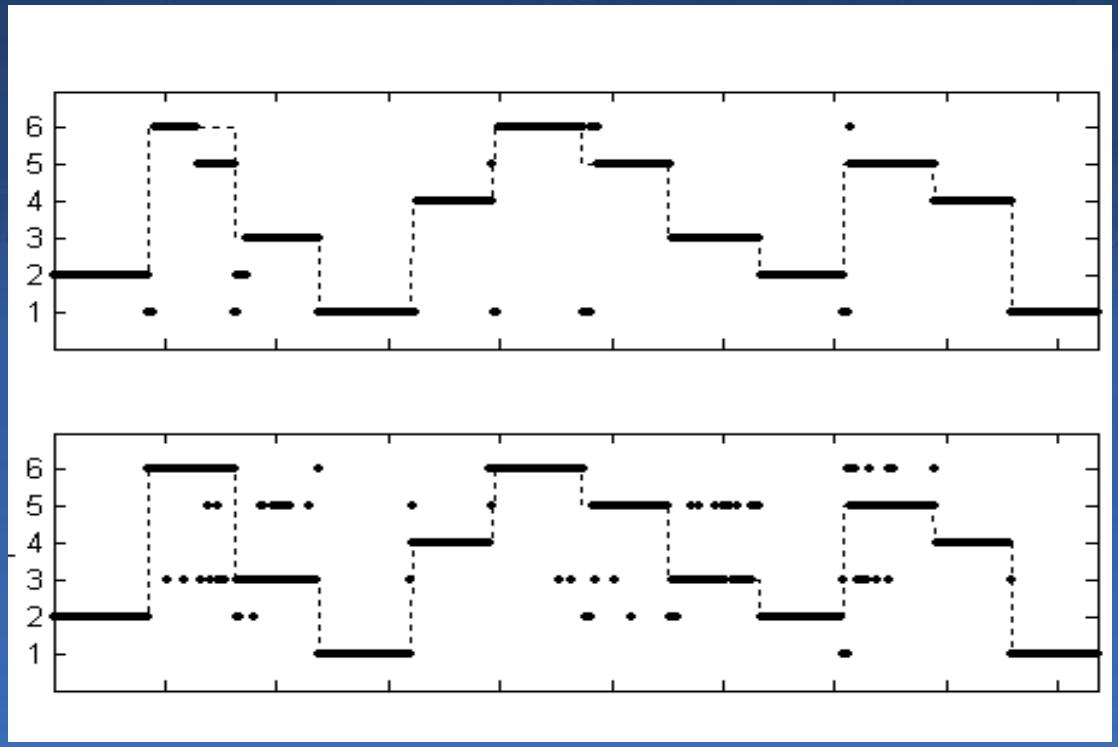
Multi-Expert System



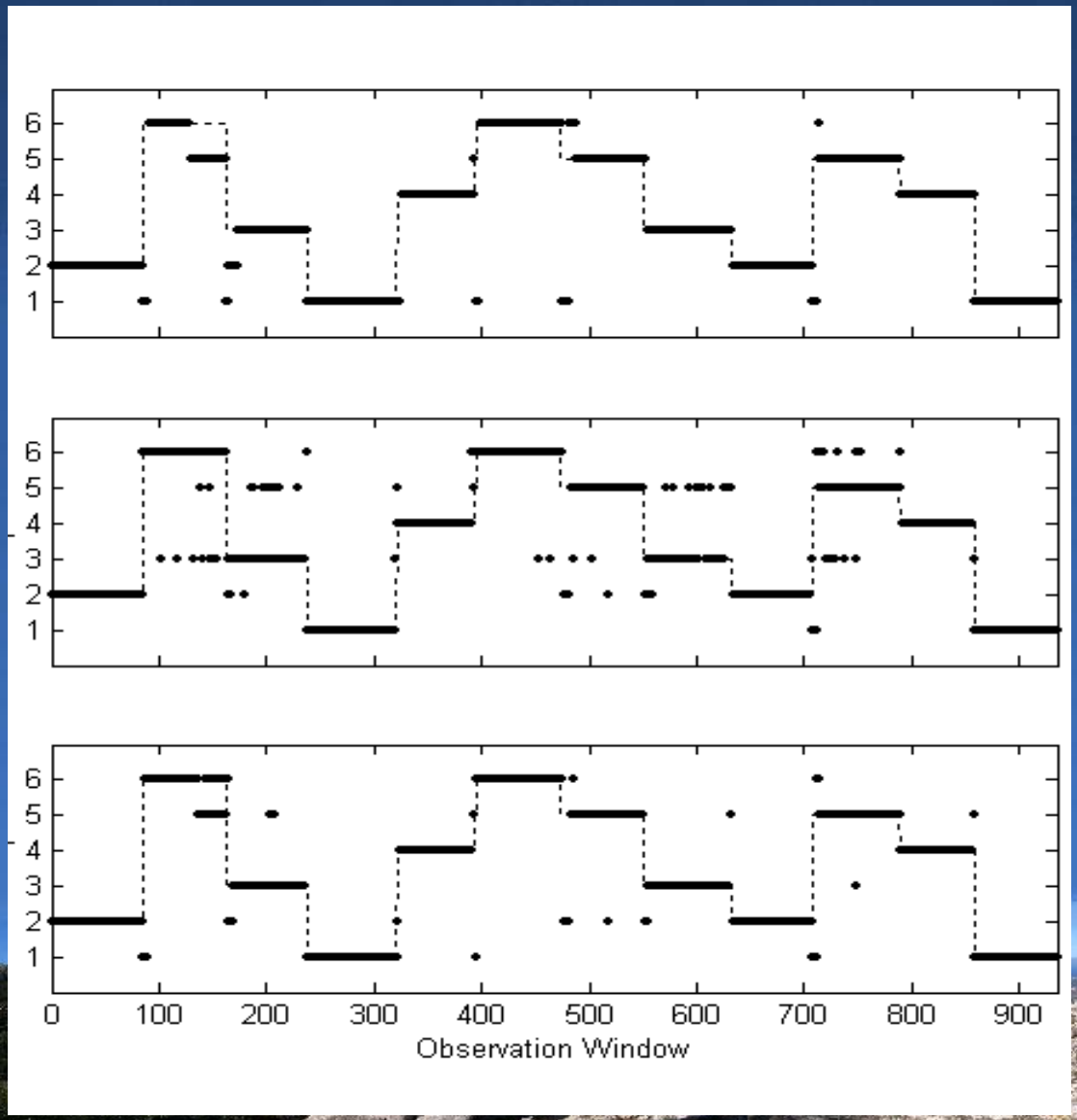
Discussion

- A multi-expert system can be applied in a variety of applications
  - Speech recognition (acoustic, visual, myoelectric)
  - Person identification (fingerprint, voice)
- As mono-modal approaches saturate in performance, a multi-modal system provides a means of significantly improving performance and robustness
- Performance can also be enhanced by multiple channels

Continuous Prosthetic Control



Continuous Prosthetic Control



Continuous Prosthetic Control

	HMM	ANN	Multi-expert
Subject 1	84%	88%	91%
Subject 2	94%	91%	95%
Subject 3	90%	86%	92%
Average	89%	88%	93%

Let Your Muscles Do the Talking

Myoelectrically Controlled Prostheses

to

Myoelectric Speech Recogntion

Carleton UNIVERSITY

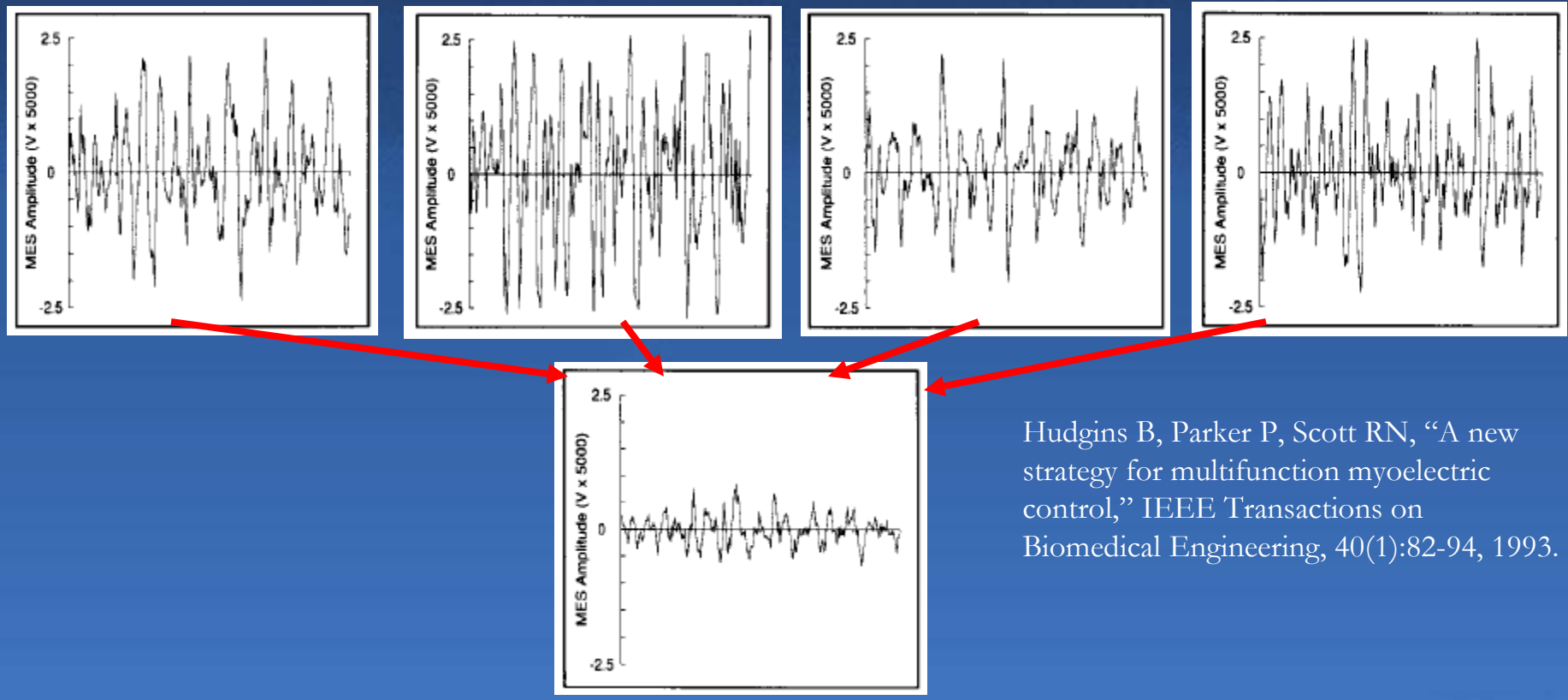
Adrian D. C. Chan

Department of Systems and Computer Engineering

Advanced Myoelectric Control

Static Contractions

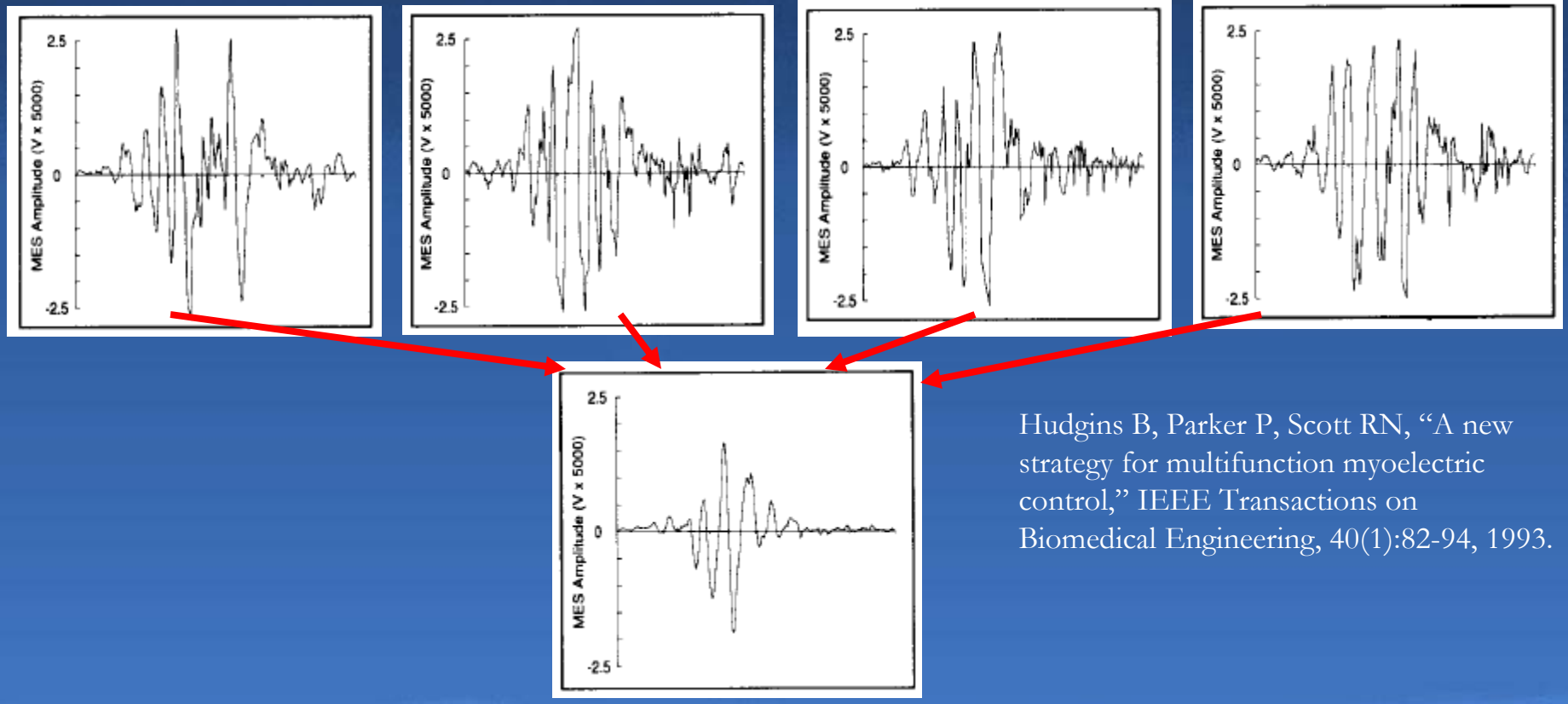
Elbow Flexion



Hudgins B, Parker P, Scott RN, "A new strategy for multifunction myoelectric control," IEEE Transactions on Biomedical Engineering, 40(1):82-94, 1993.

Dynamic Contractions

Elbow Flexion



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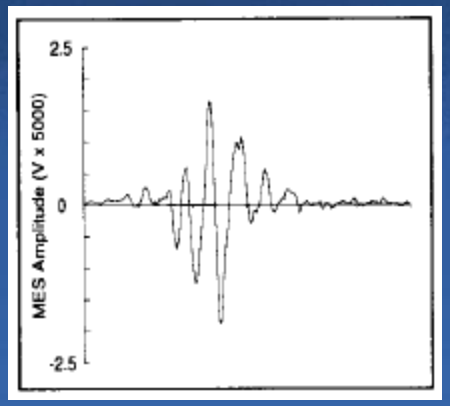
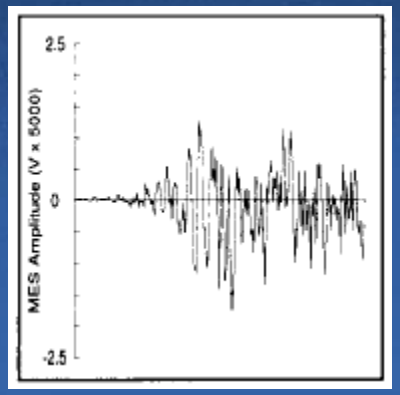
Dynamic Contractions

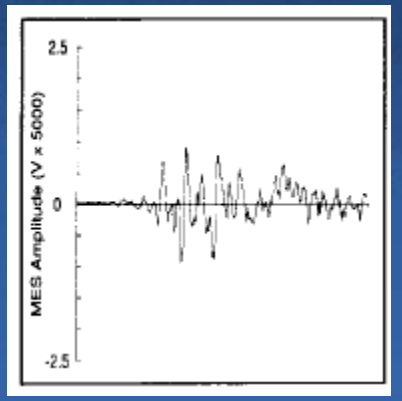
Elbow Flexion



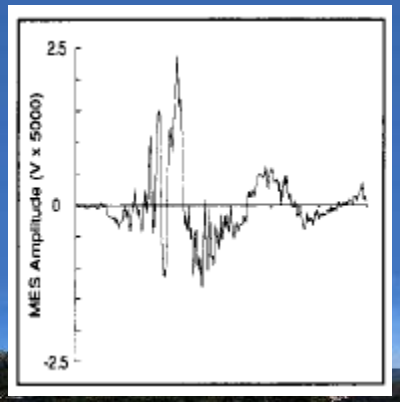
Elbow Extension



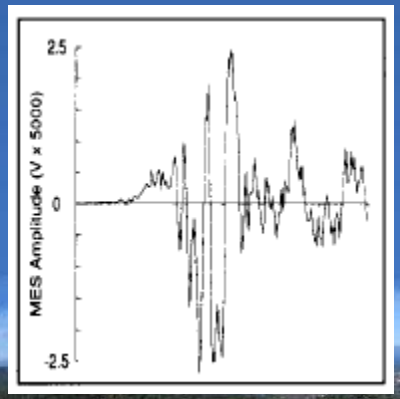
Pronation



Wrist Flexion

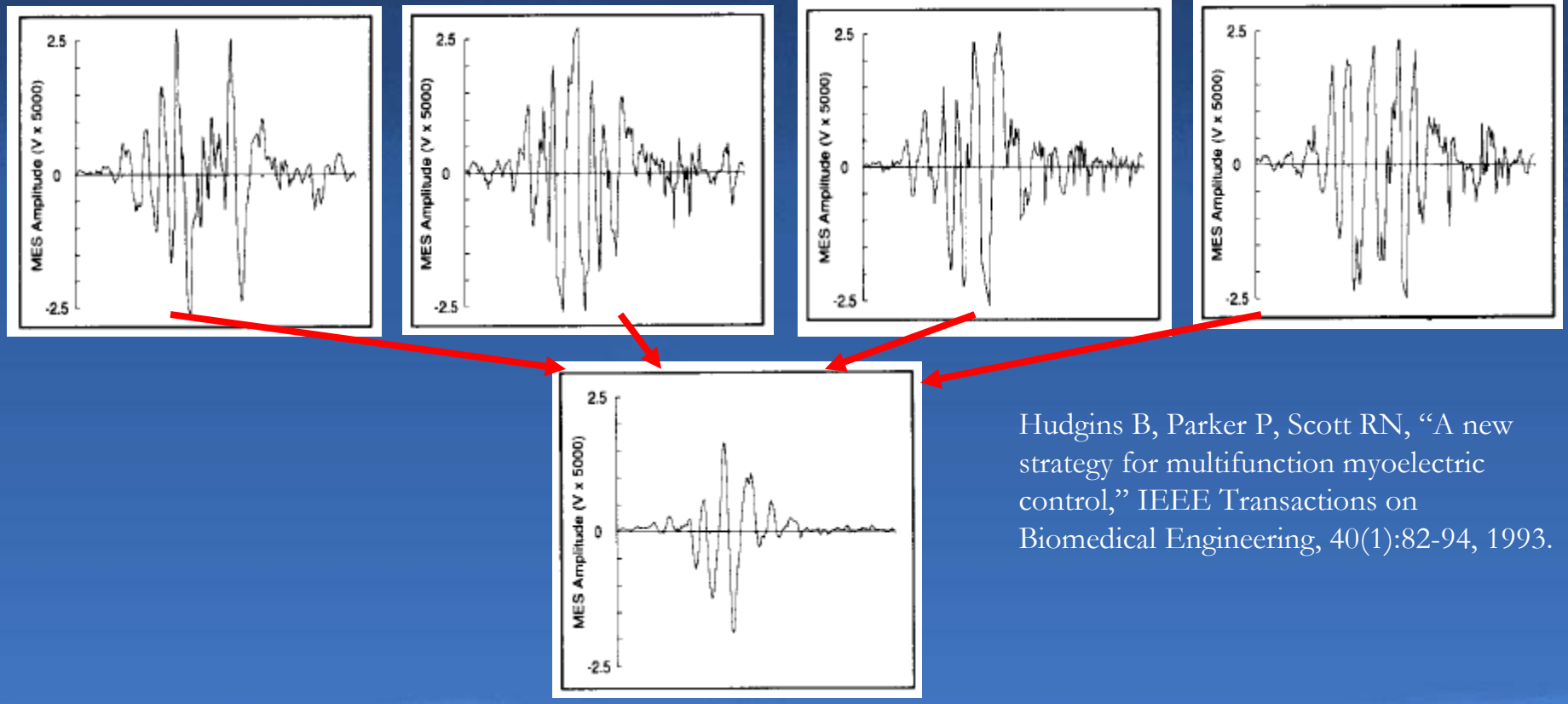


Supination



Dynamic Contractions

Elbow Flexion



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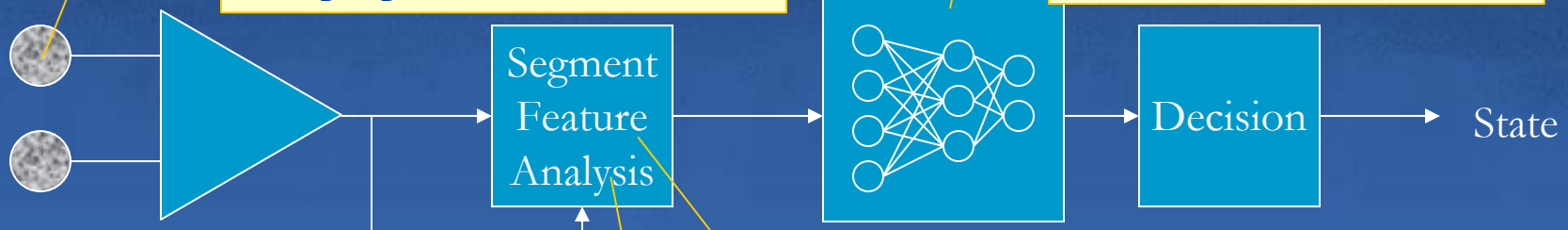
Control System



Two myoelectric control sites:
- Bicep brachii
- Tripcep Brachii

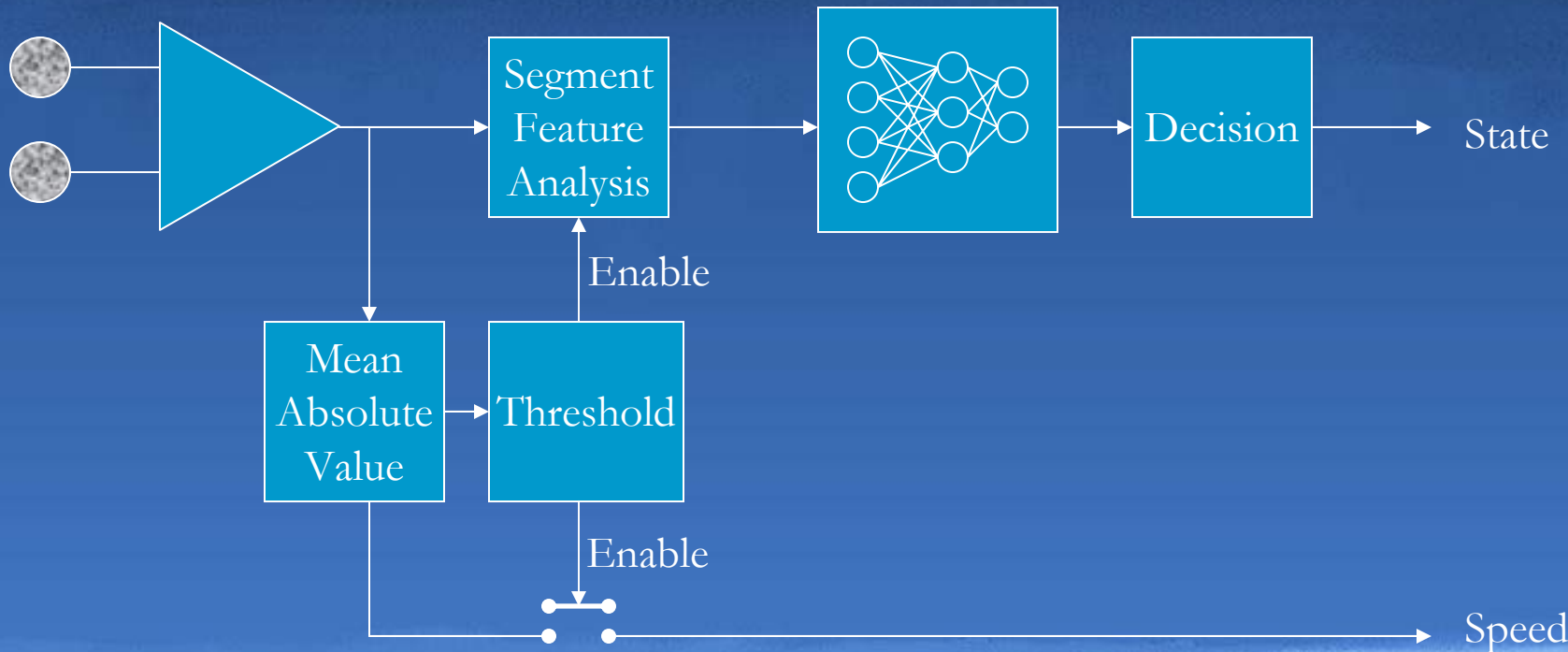
Artificial Neural Network
- Full connected
- 2-layer
- Backpropagation training

Time domain features:
- Mean Absolute Value
- Mean Absolute Value Slope
- Zero Crossings
- Slope Sign Changes
- Waveform Length

Detect Muscle activity

200ms analysis window

Control System



Results

- 90% accuracy for 4 limb motions
- Non-intuitive interface
  - Selection of prosthetic function required an initiation of contraction from rest
  - Imagine picking up a cup

Evidence Theory

- Belief: $\mathrm{Bel}(A) = \sum_{B|B\subseteq A} m(B)$
  - Sum of all partial beliefs assuming all uncertainties do not support proposition A
- Plausibility: $\mathrm{Pl}(A) = \sum_{B|B\cap A\neq\varnothing} m(B)$
  - Sum of all partial beliefs assuming all uncertainties do support proposition A