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Classification of raw meat based on their sensory and mechanical features by multispectral images coupled with multi-layer feed-forward neural network trained with back-propagation algorithm

L. Lakhal, A. Listrat, A. Aït Kaddour

Institut Polytechnique UniLaSalle (site de Beauvais)

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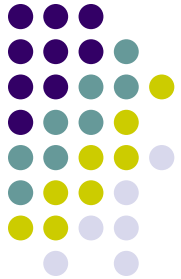

- Motivations
- Samples and analyses
- Multispectral images acquisition
- Artificial Neural Networks (ANN)
- Results
- Conclusions

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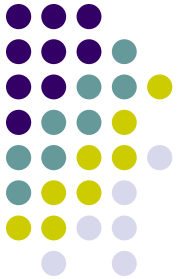

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Motivations

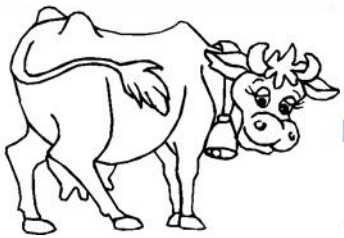
Beef tenderness…

A tender meat = a meat easy to chew

- Organoleptic characteristic: the most important for consumer, should be constant
- Will influence his decision to repurchase

Several factors of variation

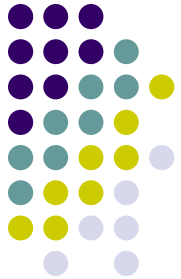
Breeding conditions



Muscle characteristics

Transformation

Motivations



It is important to predict tenderness for beef sector and consumer

Easy, fast, non-destructive method, usable online

- Classification of carcasses or meat

  payment of meat to the producer according to quality

- Authentication of meat

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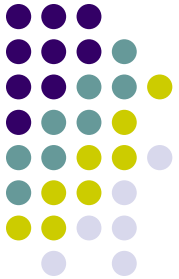

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Samples and analyses

Three breeds , two muscles

Limousine

Aberdeen Angus

Blonde d'Aquitaine

n=12

Longissimus thoracis
(noix d'entrecôte)

Tenderness
AA<Lim<BA;
SM<LT

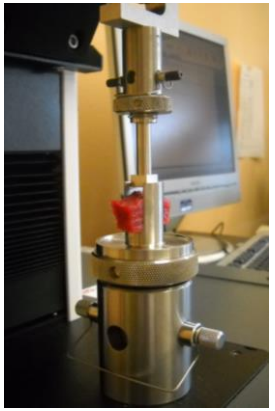
n=14

Semimembranosus
(tende de tranche)

Samples and analyses

- Tenderness measurements

Cooked meat at 55°C, aged at 4°C, 14 days

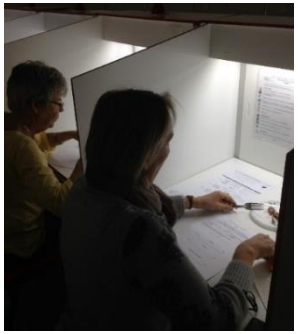


- Two methods:

- Mechanical measurements: shear force with Warner-Bratzler instrument

- Sensory analyses by expert panel: overall liking, beef flavour, total tenderness, residues after chewing

- 4 sensory attributes and 1 mechanical attribute



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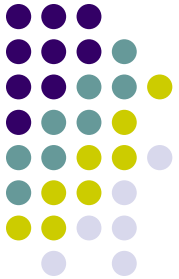

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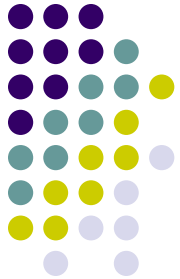
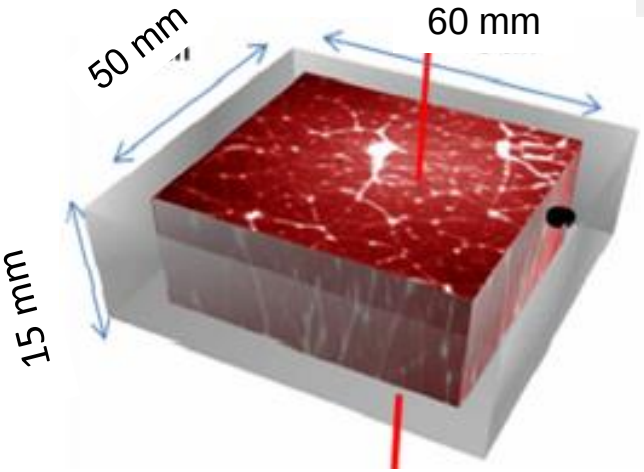
Multispectral images acquisition



- Muscle size: 50 mm x 60 mm x 15 mm
- Muscles taken parallel to the direction of muscle fibres
- Samples frozen in pure ethanol at -20°C, then kept at -20°C
- Samples thawing at 5°C (12h)
- Temperature of MSI acquisition : 25°C

Multispectral images acquisition

- Camera: Scorpion SCOR-20SOM
- Spatial resolution :1200 x 1200 pixels
- 19 LEDs (UV, Visible and NIR)
- At least 4 images recorder on 2 parts the muscle
- 189 images measured



Adapted from El Jabri et al. (2010)

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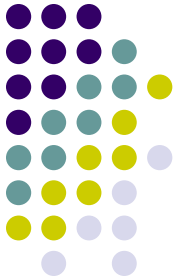

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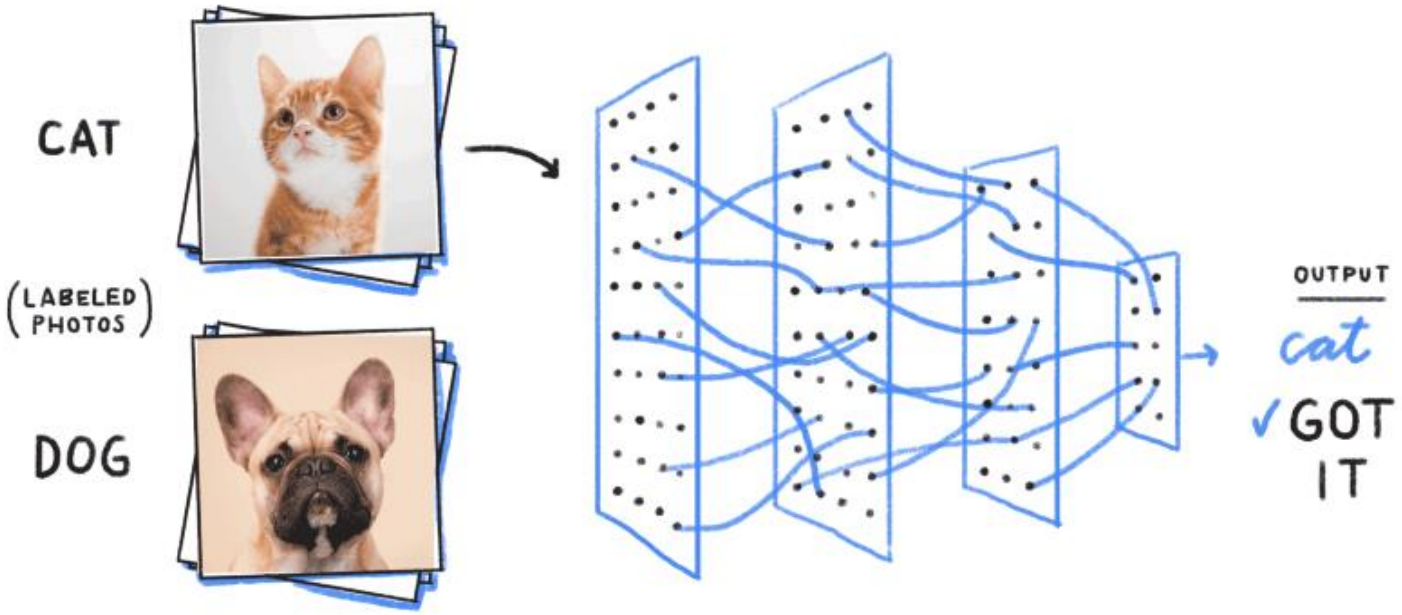
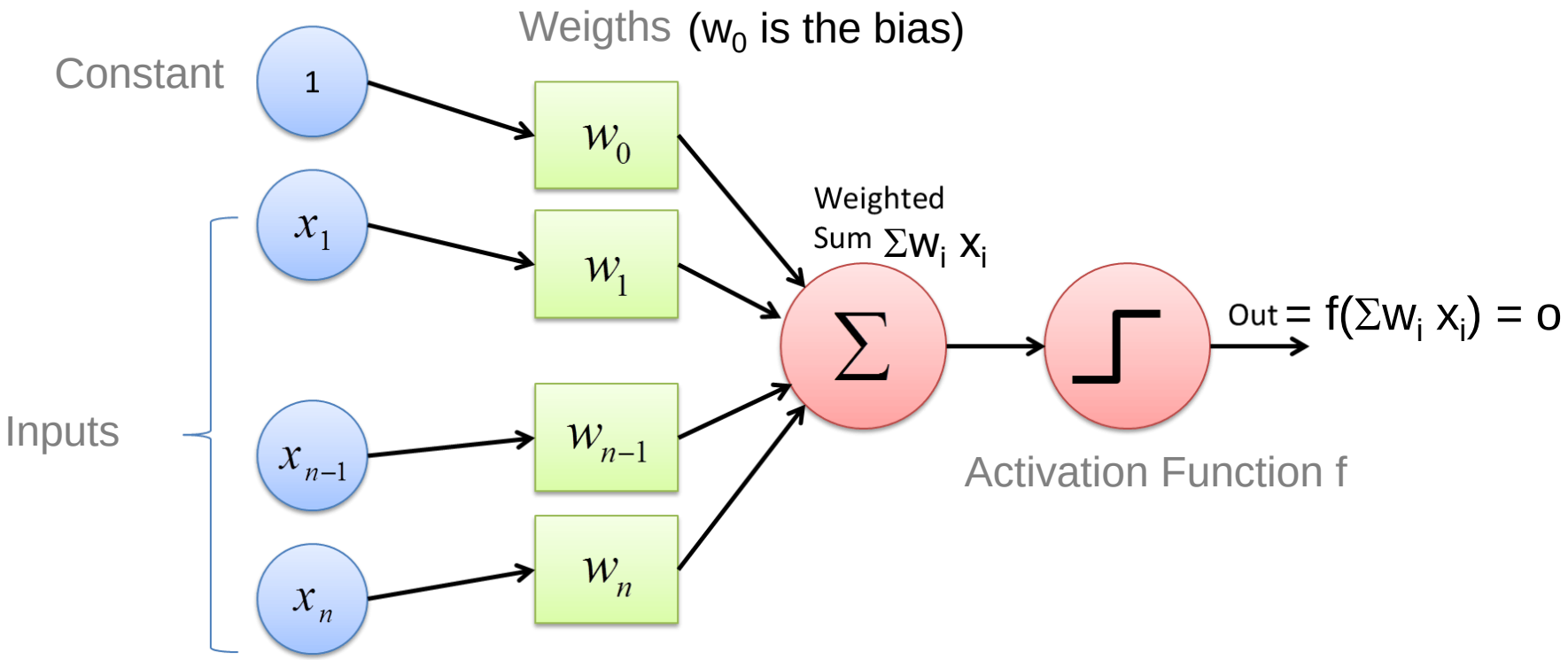
Perceptron, Neural Networks



Perceptron = single layer neural network
Multi-layer perceptron = neural networks

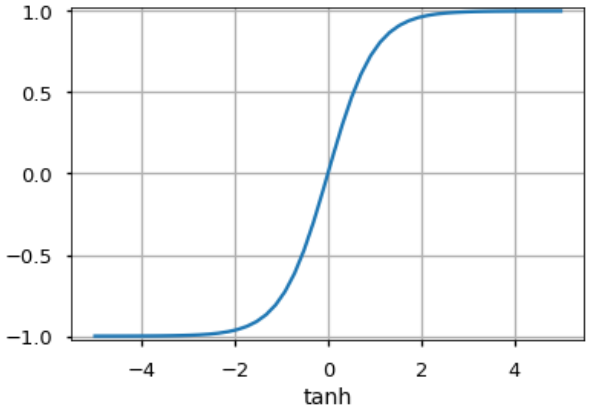
How does Perceptron work ?

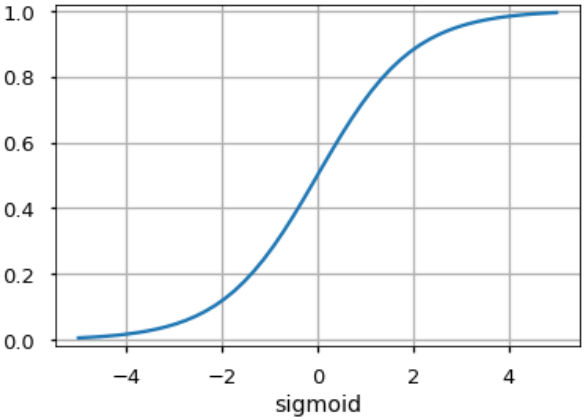
The perceptron consists of 4 parts

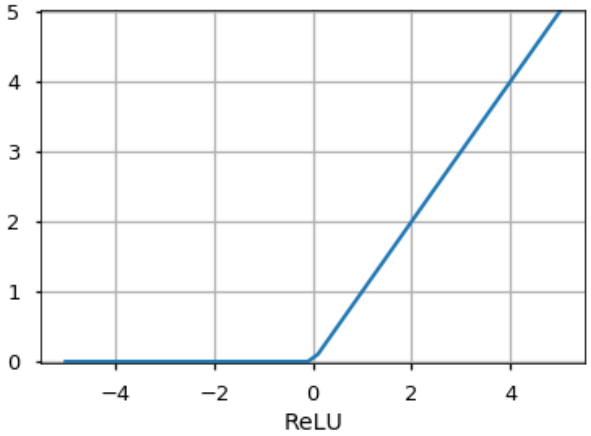


Activation functions

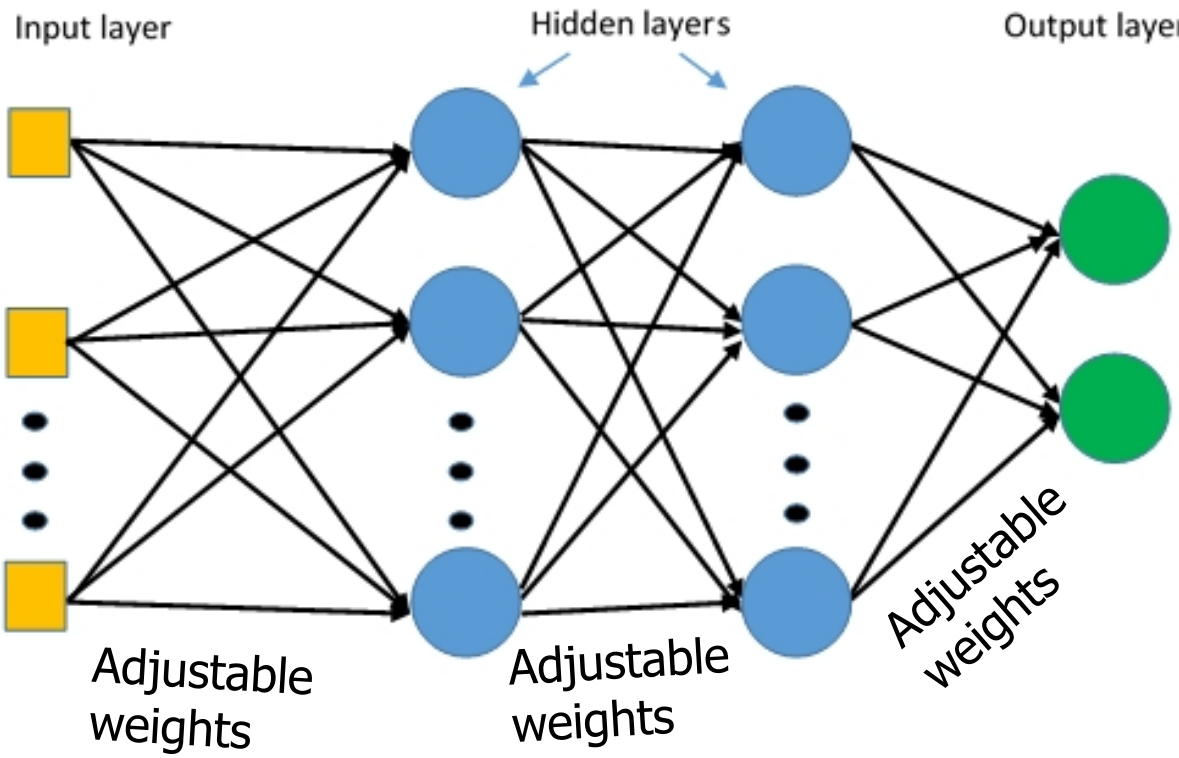
The activation functions are used to map the input between the required values like (0, 1) or (-1, 1).



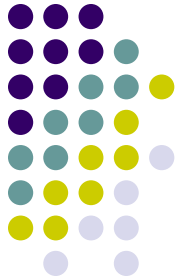




Types of Layers

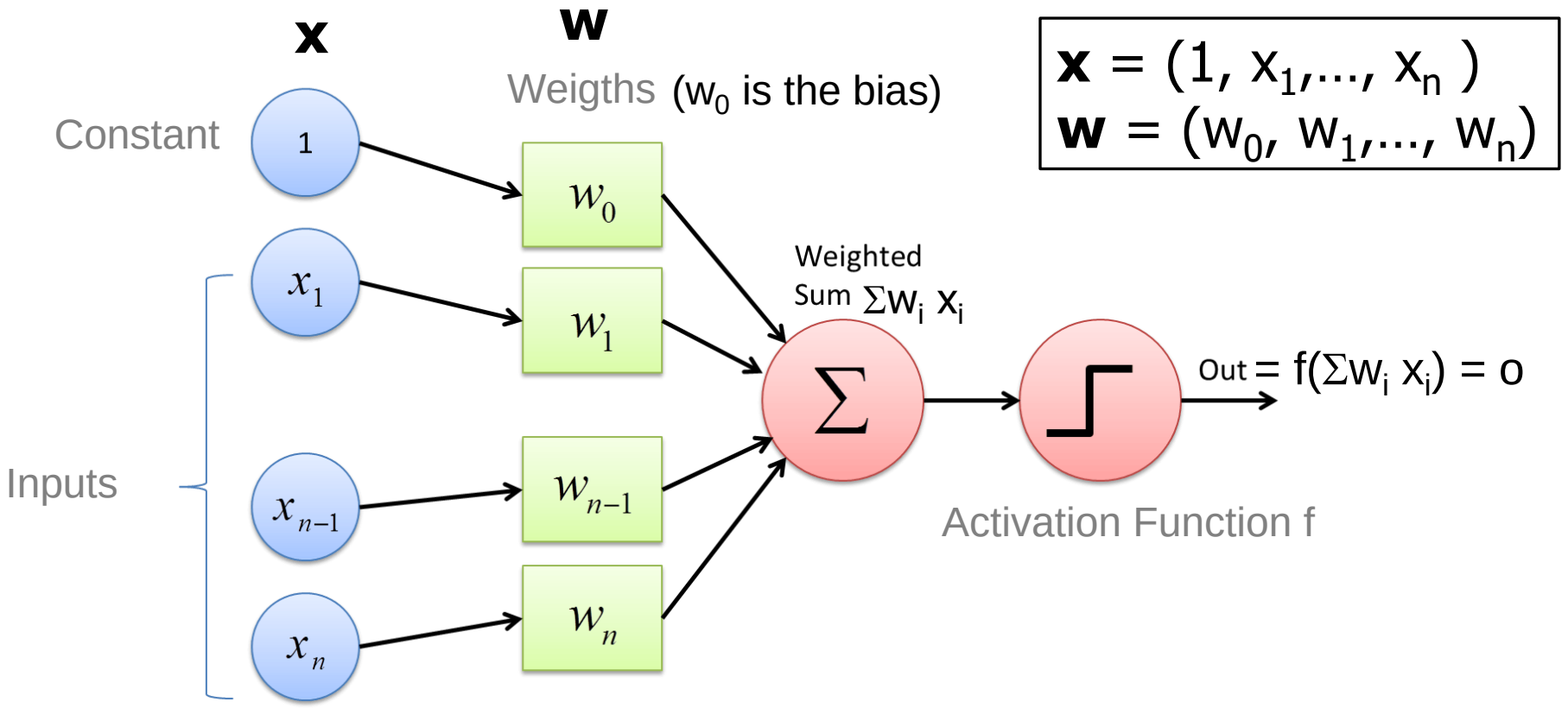


Back-Propagation



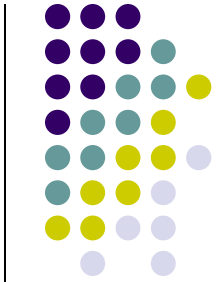
- A training procedure which allows multi-layer feedforward Neural Networks to be trained;
- Can theoretically perform “any” input-output mapping;
- Can learn to solve linearly inseparable problems.

Gradient Descent



Parameters stored in **w** are optimised by minimising an error function, called perceptron criterion:

Gradient Descent

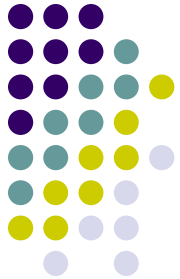


- Consider linear unit without threshold f(s) = s and continuous output o (not just –1,1)
  - $o = f(w_0 + w_1 x_1 + \ldots + w_n x_n) = w_0 + w_1 x_1 + \ldots + w_n x_n$
- Train the w_i's such that they minimize the squared error
  - $E[w_0, w_1, \ldots, w_n] = \frac{1}{2} \sum_{d \in D} (t_d - o_d)^2$

where D is the set of training examples

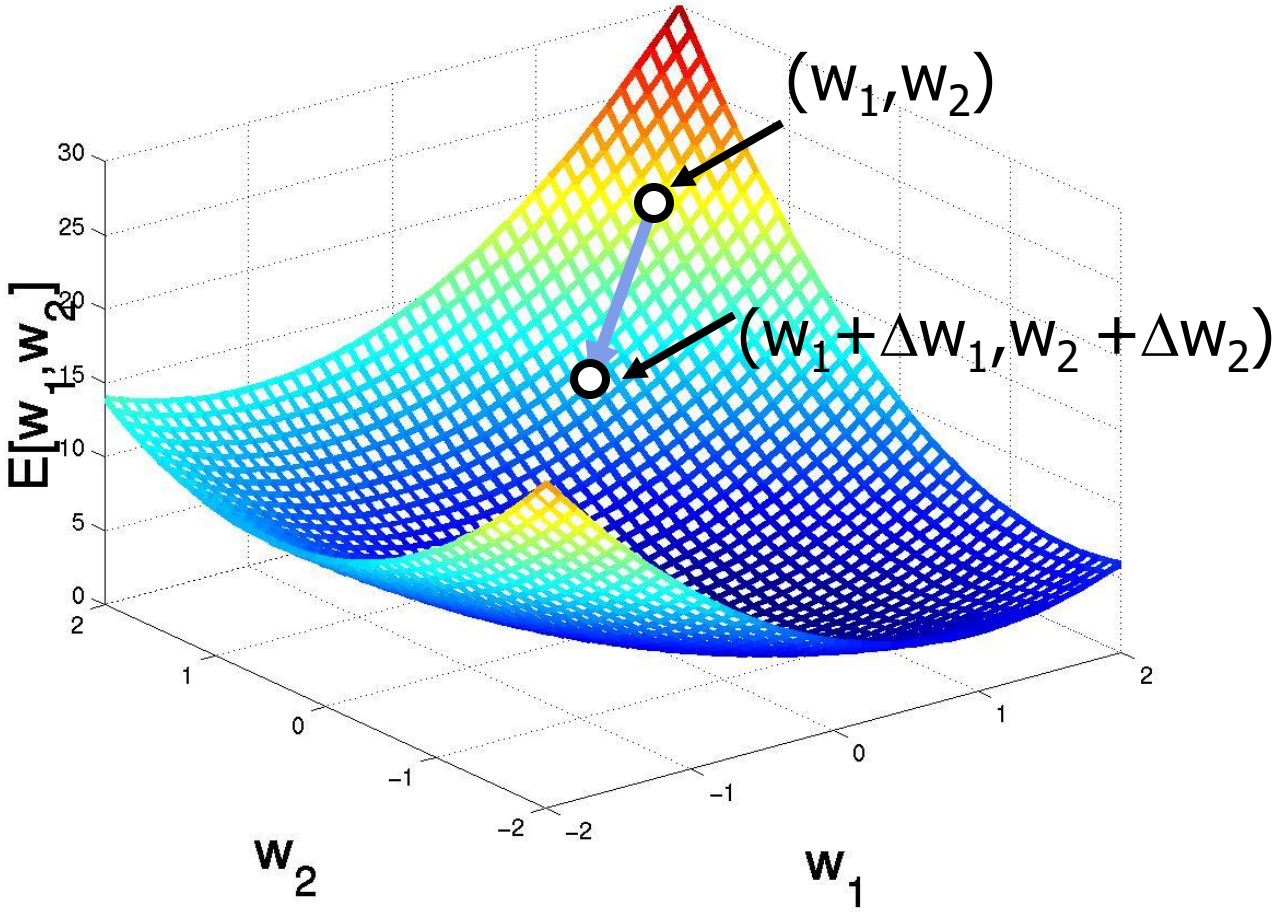
- Each training example is a pair of the form $(\mathbf{x_d}, t_d)$, $\mathbf{x_d}$ the d^{th} vector of input values, t_d target output value

Gradient Descent

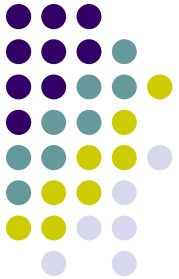


- Initialize each w_i to some small random value
- Until the termination condition is met, Do
  - Initialize each weigth increment Δw_i to zero
  - For each < **x**, t > in D, Do
    - Input the instance (**x**) to the linear unit and compute the output o
    - For each linear unit weight w_i , Do
      - $\Delta w_i = \Delta w_i + \eta\ (t\text{-}o)\ x_i$, η learning rate (e.g 0.1)
  - For each linear unit weight w_i, Do
    - $w_i = w_i + \Delta w_i$

Gradient Descent



Parameter setting



- Number of layers
- Number of neurons
    - too many neurons, require more training time
- Learning rate
    - from experience, value should be small ~ 0.1
- Number of training epochs
- Momentum term
- ..

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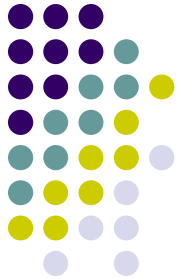

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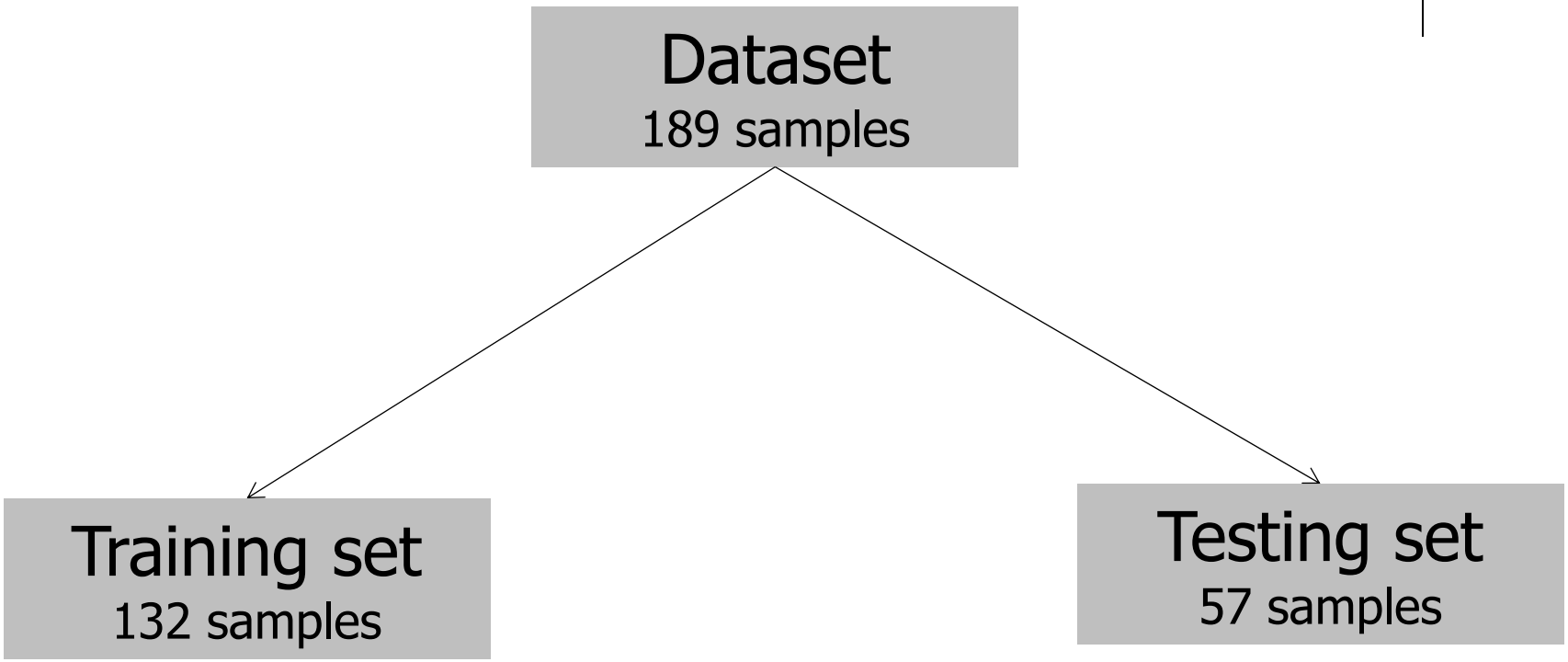
Training set / testing set

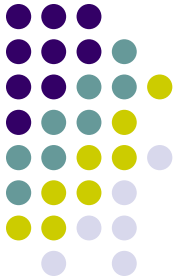


Testing set : Confusion matrix

Shear force – NER = 80,7%

		Predicted class		
		Class 1	Class 2	Class 3
True class	Class 1	**17**	2	2
	Class 2	1	**14**	3
	Class 3	3	0	**15**

Testing set : Confusion matrix



Overall liking - NER = 84,2%

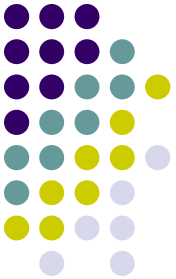
		Predicted class		
		Class 1	Class 2	Class 3
True class	Class 1	**15**	2	3
	Class 2	2	**20**	0
	Class 3	2	0	**13**

Testing set : Confusion matrix

Beef flavor - NER = 82,4%

		Predicted class		
		Class 1	Class 2	Class 3
True class	Class 1	**14**	2	3
	Class 2	0	**17**	0
	Class 3	2	1	**16**

Testing set : Confusion matrix



Total tenderness – NER = 86, 7%

		Predicted class		
		Class 1	Class 2	Class 3
True class	Class 1	**20**	2	1
	Class 2	1	**17**	2
	Class 3	2	3	**13**

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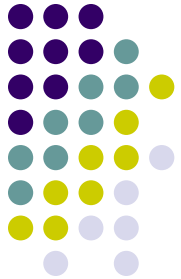

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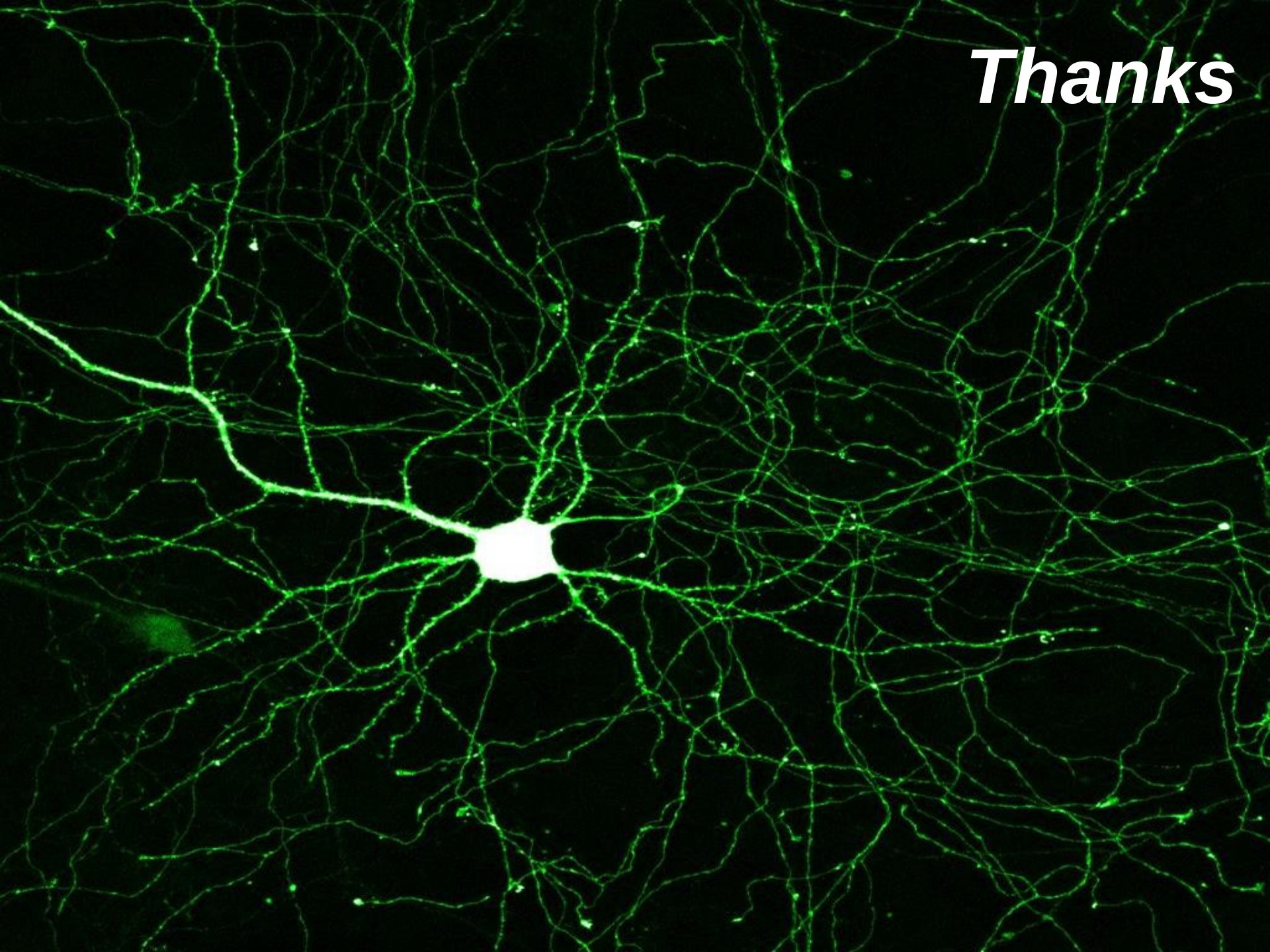
Conclusions

A Multilayer perceptron classifier incorporating MSI was designed for rapid prediction of mechanical and sensory attributes of beef meat.

Good prediction performance (81% - 86%) were achieved with limited number of learning samples (132) and poor spectral resolution.

The prediction performances will be improved by using larger amount of training samples

The classifier can be trained to predict other meat characteristics


Thanks