AI & Machine Learning

© Dr. Anthony Menicucci, PhD. 20210108
amen@unm.edu
anthony@armatech.us

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A Technical Overview of Current Machine Learning Architectures;
&
Quantifying Some Interesting Applications.

What INPUTS facilitate the ability to learn?

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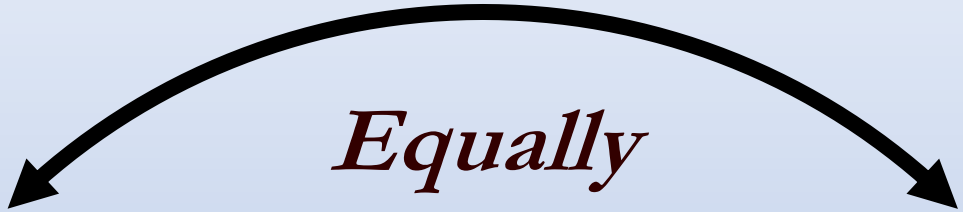
What INPUTS facilitate the ability to learn?

Basics of Mammalian Neurons



Neurons that Fire Together, Wire Together

Neurons that Wire Together, Fire Together

Ex: Improving at sports & musical instruments with practice grows neurons

Ex: Remembering eating chocolate, dreaming & *nightmares

'fight or flight' reinforcement; "training" without consequences?

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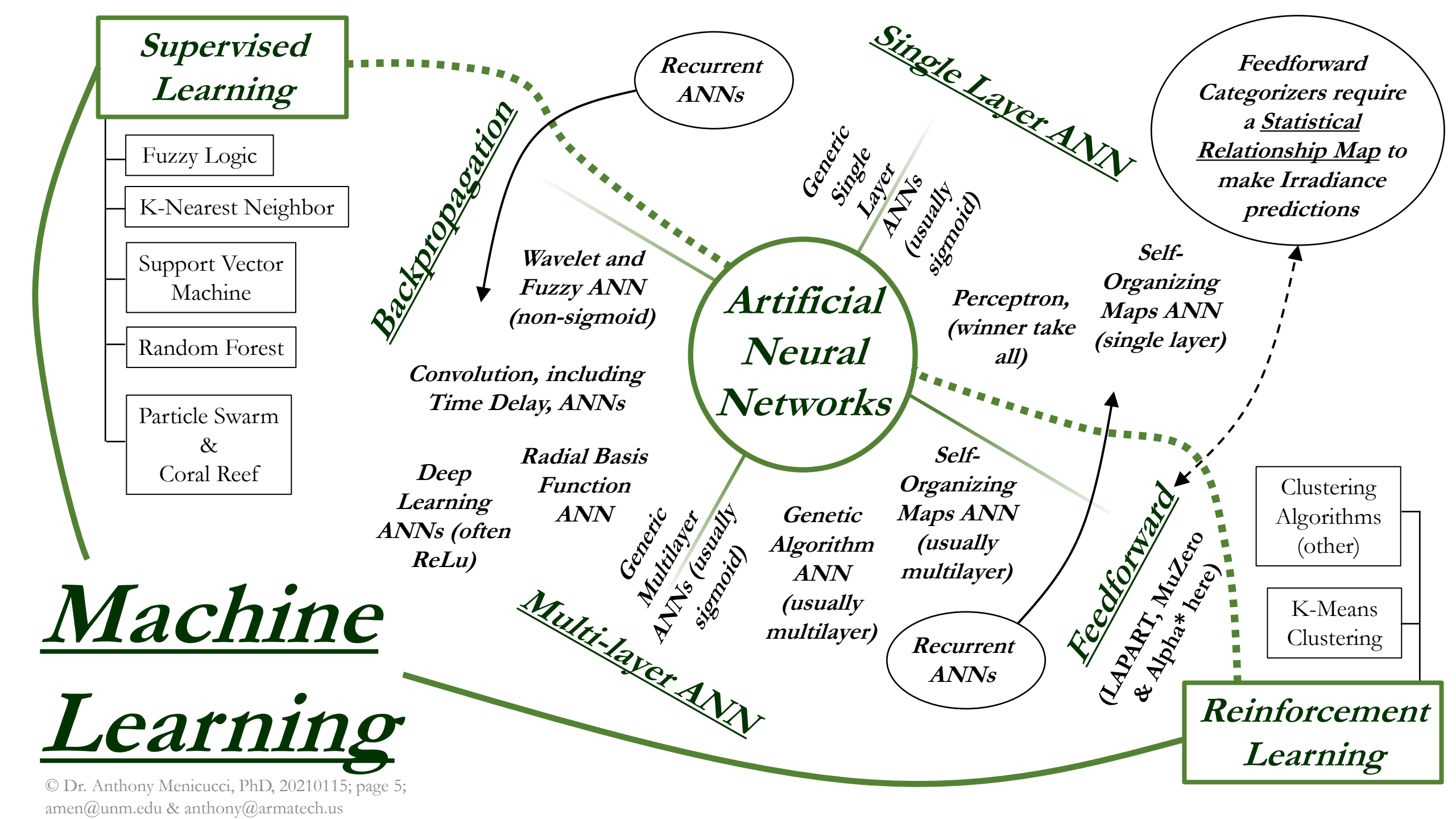
Basics of Neural Networks, Two Types

Cost Function (Gravity) Methods, including GPT-3 & others

1. Self-organizing, Competitive learning;
2. Rosenblatt's Perceptron (model) with varied activation functions;
3. Use Cost Functions as a basis of convergence and update;
4. Have elegant and complete convergence proofs;
5. Slow to "learn" or converge;
6. Always "predict" in the context of "memory";
7. Novelty is quantified as a "low probability" prediction.

Map Methods, including Clustering, ART, LAPART, Markov Chain Search Tree & Others

1. Self-organizing, Reinforcement Learning algorithms, with map updates;
2. Different Methods (fuzzy complement coded, proximity);
3. Rule Based;
4. Have no elegant & complete convergence proof;
5. Some (like LAPART) are Fast at "learning" in relative and absolute terms;
6. Only predict in the context of a "learning" threshold, otherwise flags as "novel";
7. Novelty is quantified as unknown & can produce "low probability" predictions.



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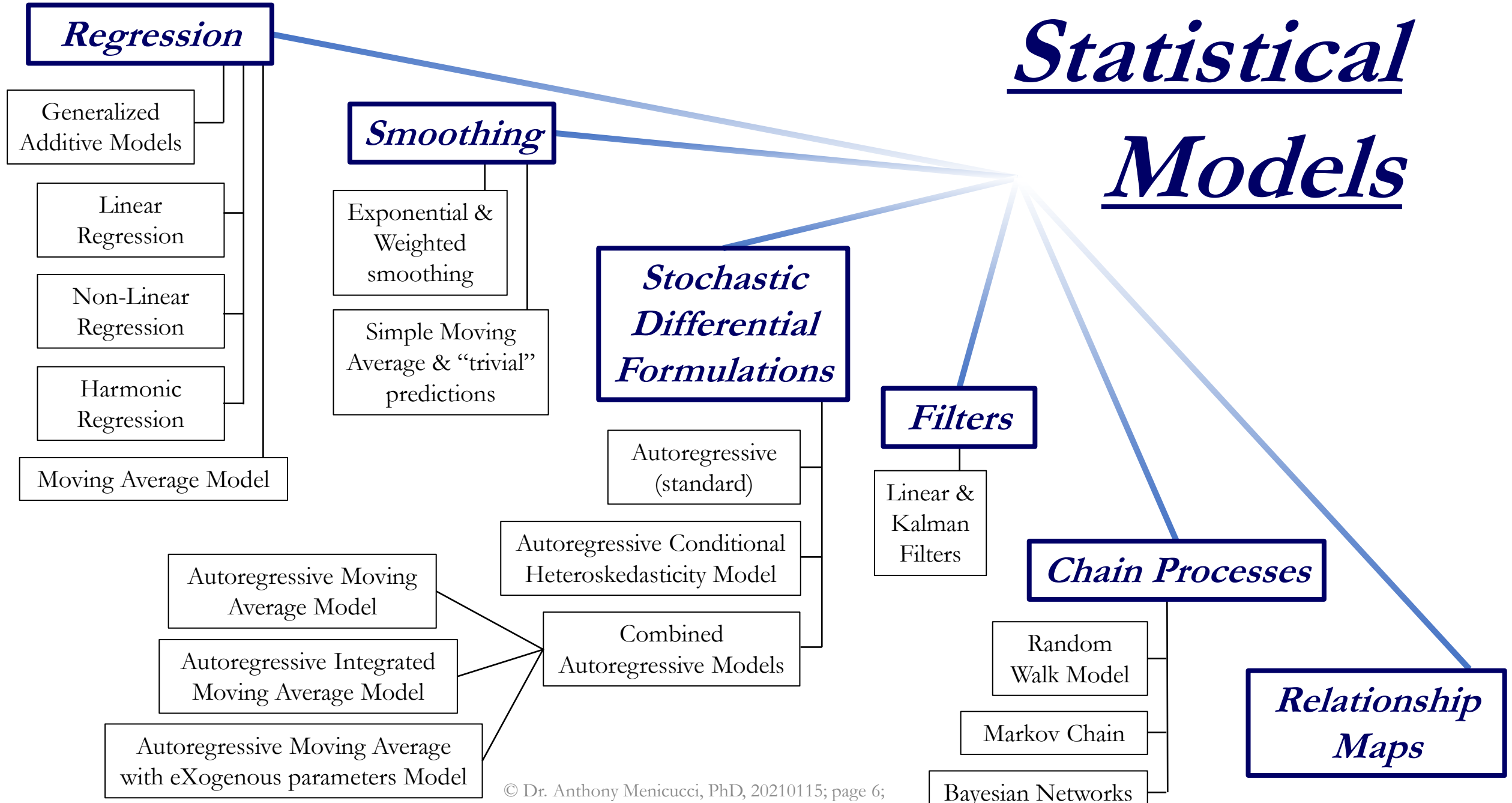
Statistical Models



Fuzzy LAPART;

In the range [0,1];
exA.: 0.3 compliment coded = 1.0 - 0.3 = 0.7
exB.: 0.9 compliment coded = 1.0 – 0.9 = 0.1

In the fuzzy form, the normalized input must be complement-coded as follows:

$$I = (a, a^c) = (a_1, a_2, 1 - a_1, 1 - a_2)$$

The weight update follows the equation: $W_J^{new} = \beta\left(I \wedge W_J^{old}\right) + (1 - \beta)\left(W_J^{old}\right)$

Fuzzy ART then solves these two equations to find a category:

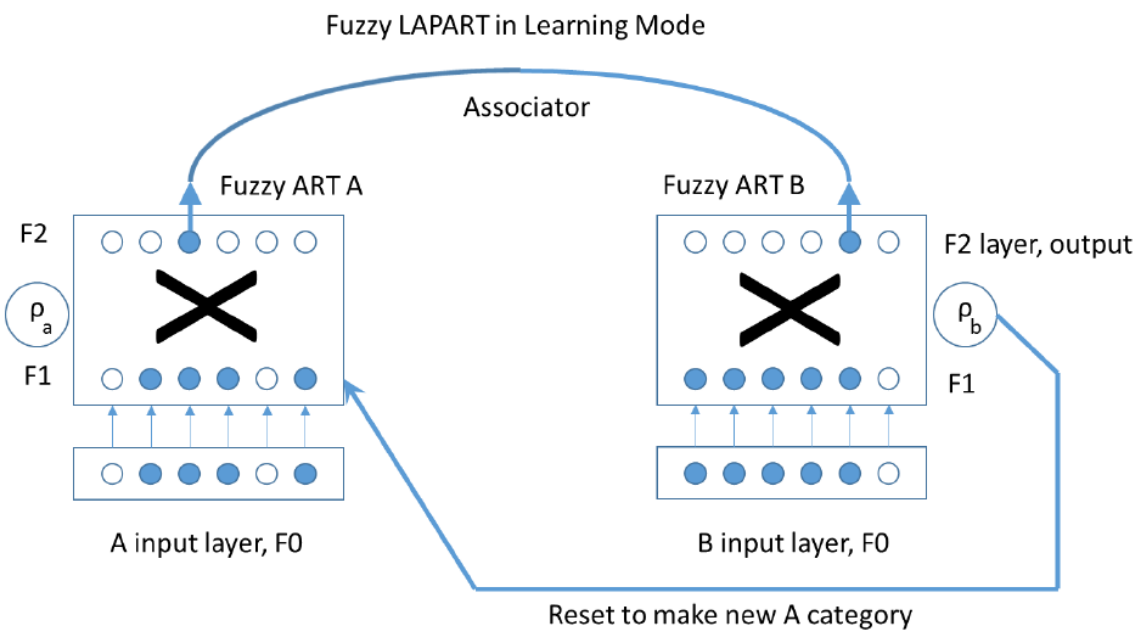
$$T_J = \frac{\|I \wedge W_J\|}{\alpha + \|W_J\|} \qquad \|D\| = \sum_{g=1}^{m} |D_i| \qquad \alpha \leq \frac{1}{n-1}$$

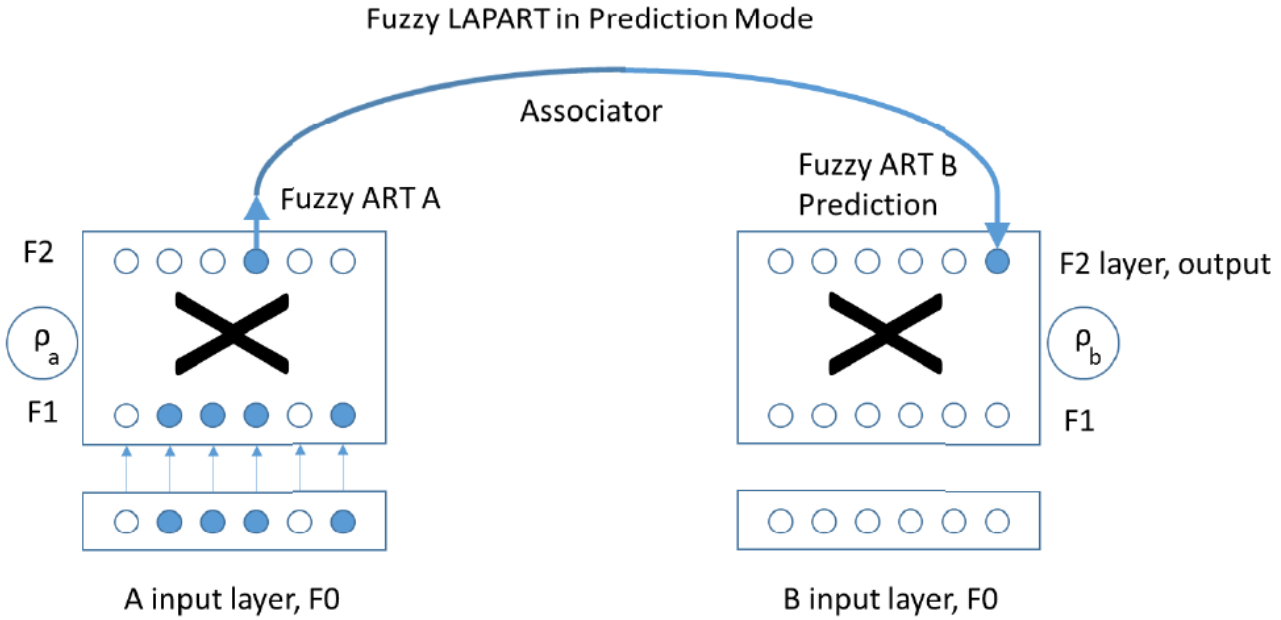
Best Choice

Subject to vigilance: $\rho \leqq \frac{\|I \wedge W_J\|}{\|I\|}$

(this is the anomaly detection aspect)

Fuzzy LAPART;

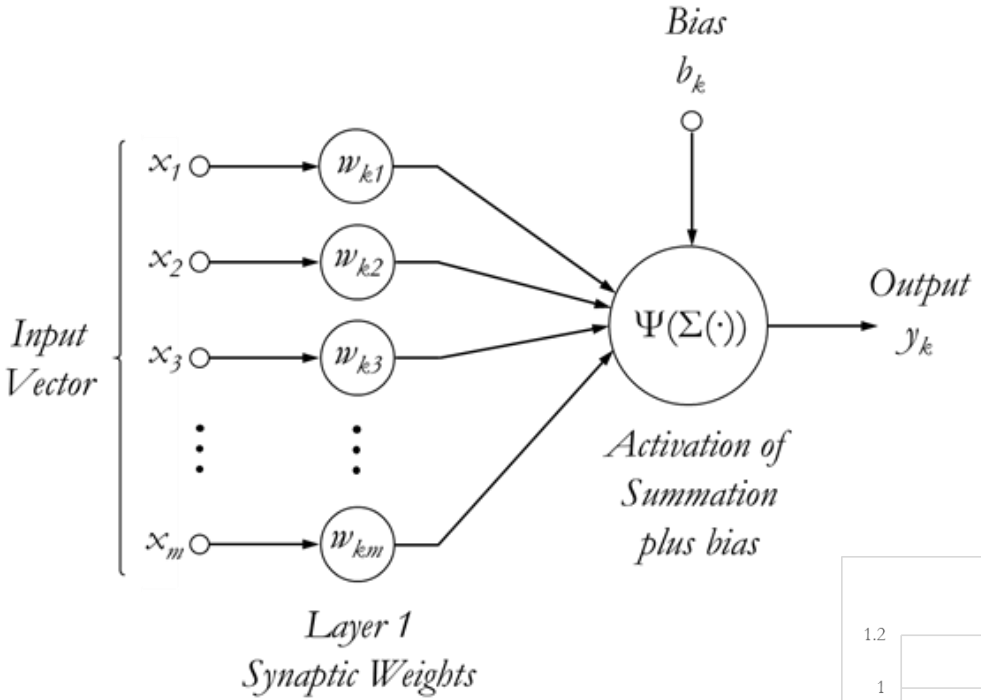




LAPART Learning Stage

LAPART Prediction Stage

Neuron Model;



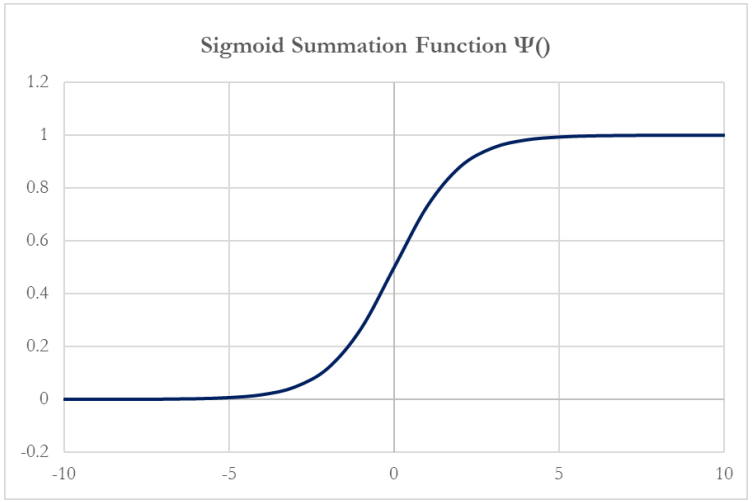
The neuron output y_k can be written as follows:

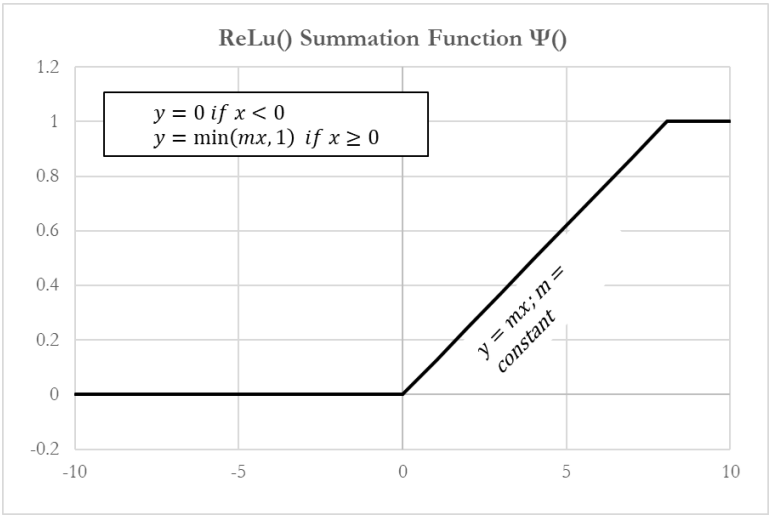
$$y_k = \varphi(u_k + b_k)$$

$$u_k = \sum_{j=1}^{m} w_{kj} x_j$$

The bias b_k has the effect of moving the activation function

The effect is that neurons that fire get amplified and neurons that are not firing as much get suppressed.





Cost Function;

With general ANNs, the output function of layer *j* and row *i* is defined as: $a_i^j = \sigma\left(\sum_{i=1}^{n} w_i^j * x_i^{j-1} - b^j\right)$

Our Cost Function is: $c_i^j = \left(a_i^j - y_i^j\right)^2$

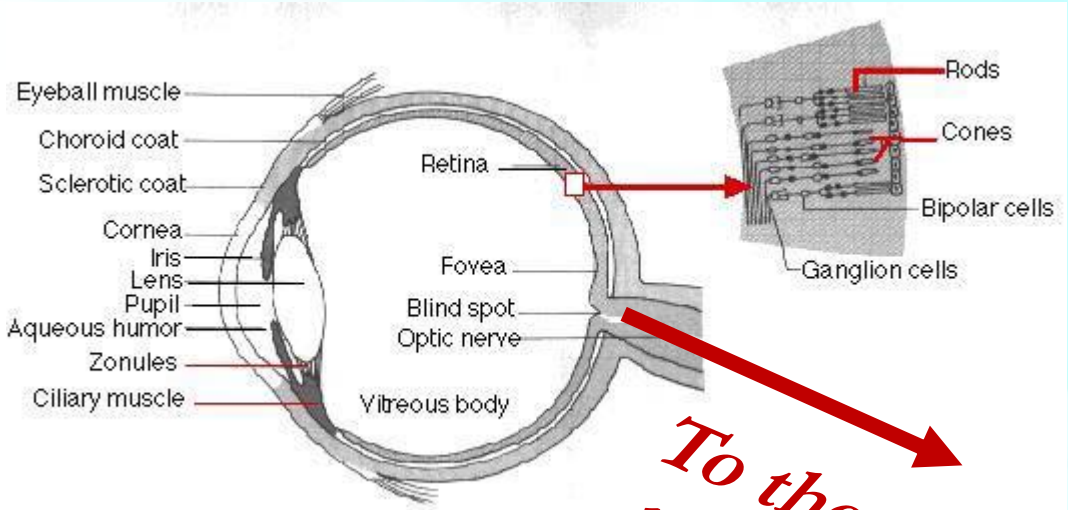
Where a_i^j is the output activation from the previous layer and y_i^j is the expected output.

The cost function derivative follows $\frac{\delta c^j}{\delta w^j} = \frac{\delta z^j}{\delta w^j}\frac{\delta a^j}{\delta z^j}\frac{\delta c^j}{\delta a^j}$

Backpropagation updates with the gradient descent formulation: $\Delta w = -\eta \frac{\delta c^j}{\delta w^j}$

Inputs: What Transmits from the eye?

A. Retina bipolar cells connect both rods & cones (photoreceptors) to ganglion (closer to the brain) and horizontal cells.
B. Horizontal cells increase contrast by lateral inhibition. (decrease our neighbor neuron activation unless the neighbor is large)



Firing happens when one and/or the other occurs from the rod/cone eye network:

We shutter our eye back & forth to generate an artificial contrast. That generates a signal to the brain.

$$\left|\frac{dI(x,y)}{dt}\right| > T_1$$

&, ||

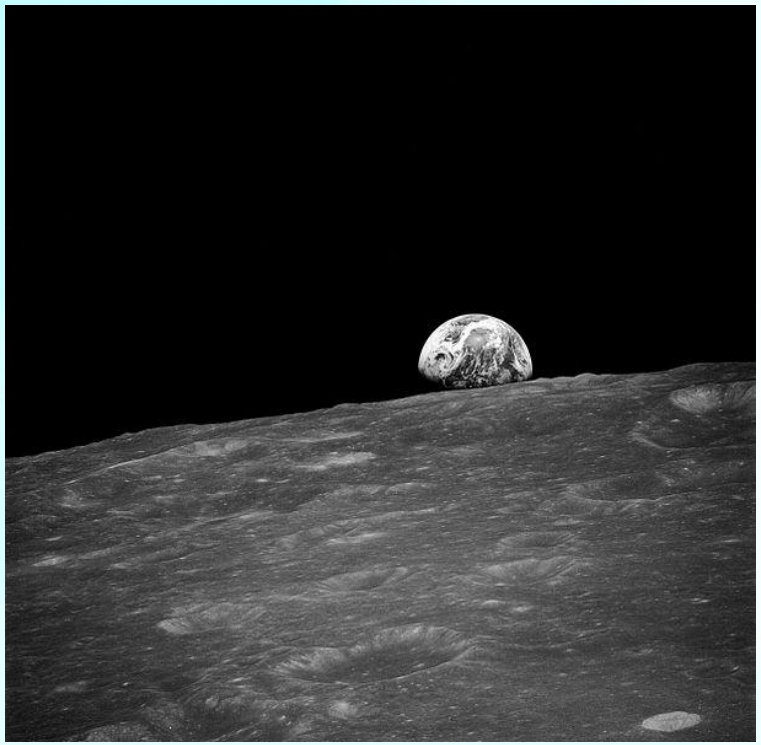
$$\left|\frac{I(x,y) - I(x+\Delta x, y+\Delta y)}{(\Delta x, \Delta y)}\right| > T_2$$

There is large image contrast & that generates a signal to the brain.

The input is not the direct intensity value like it would be from a camera.

where:* T_1 & T_2 *are Thresholds
&* I *is the intensity of the rod/cone activation in the eye

Inputs: What Transmits from the eye?



What your camera "processes"

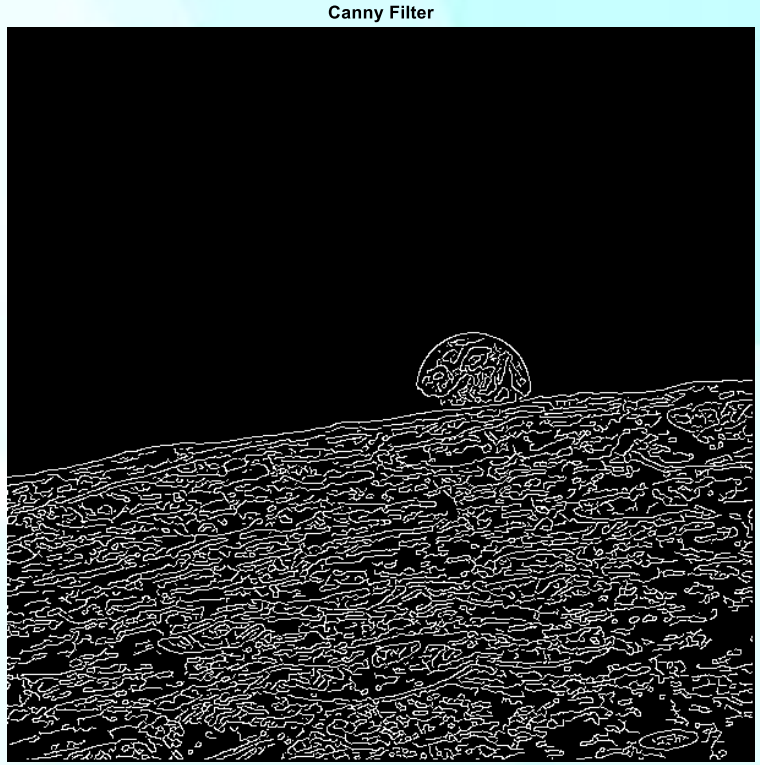
Original Apollo 8 picture, Left

'Canny' edge detection filter in Matlab, **Right:** A more accurate depiction of what the brain receives as an INPUT from the eye.

We apply the following:

$$\text{If } \left|\frac{dI(x,y)}{d(x,y)}\right| > T;\ I_{new}(x,y) = 1$$

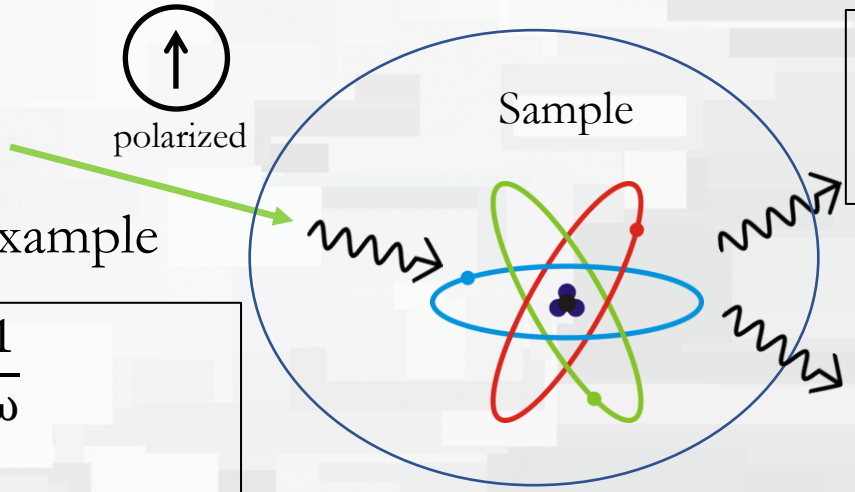
$$else;\ I_{new}(x,y) = 0$$



What your brain "processes"

Principles of Stokes Raman Spectroscopy

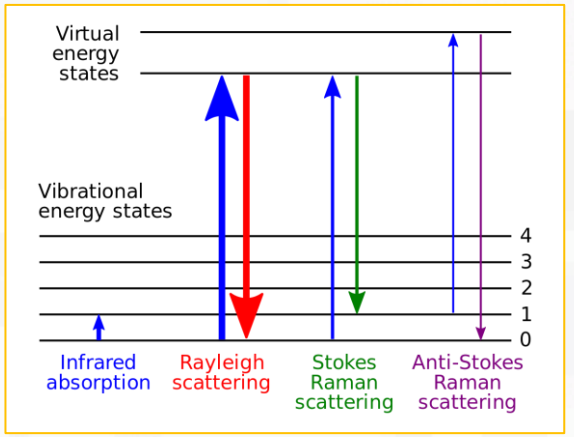
Polarized Laser Source, various frequencies, 532 (nm) this example



$\gamma_{reflected}$ (532 nm) polarized

Raman (532 nm High Pass Filter) Signal

γ_{new} (less than 532 nm) occurs ~ 0.0001% polarized



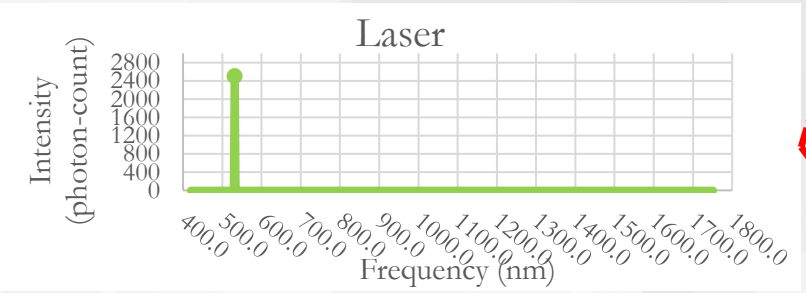
$$\lambda = \frac{c}{\nu} = \frac{1}{\omega}$$

&

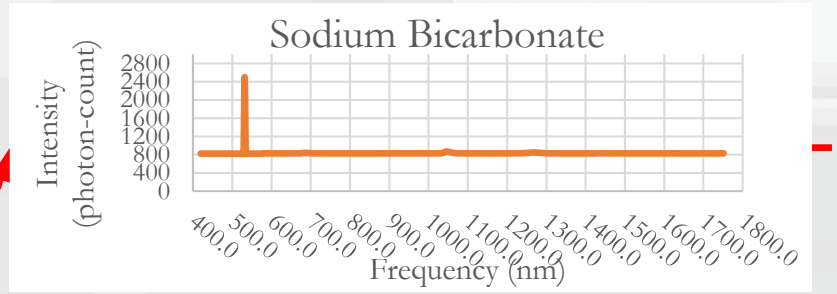
$$E = h\,\nu$$

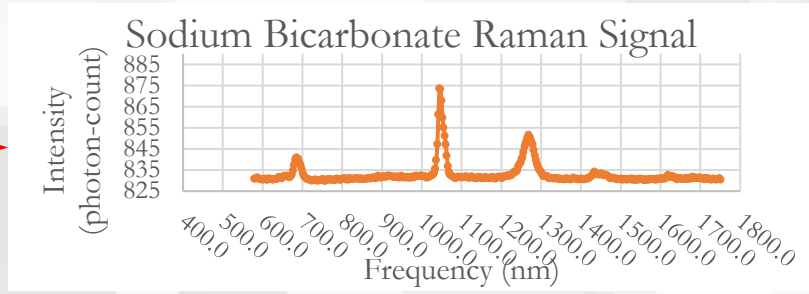
Frequency, speed of light, Wavelength & Energy are related

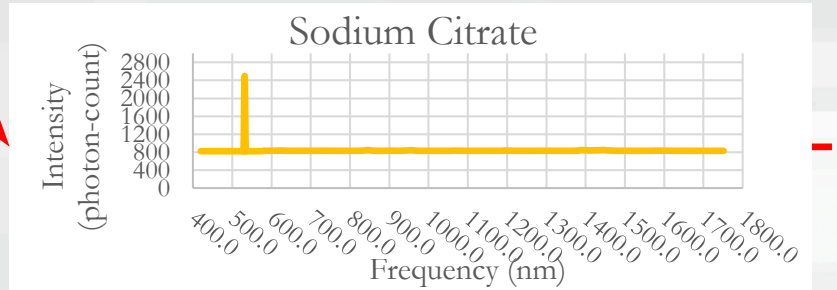
Laser Signal

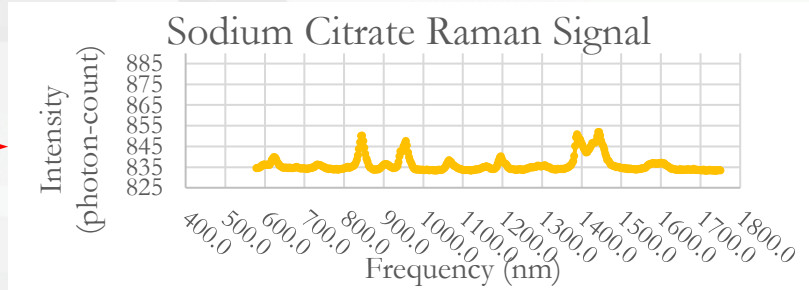


Isolated Raman Signature









Total Reflected Photon Signal

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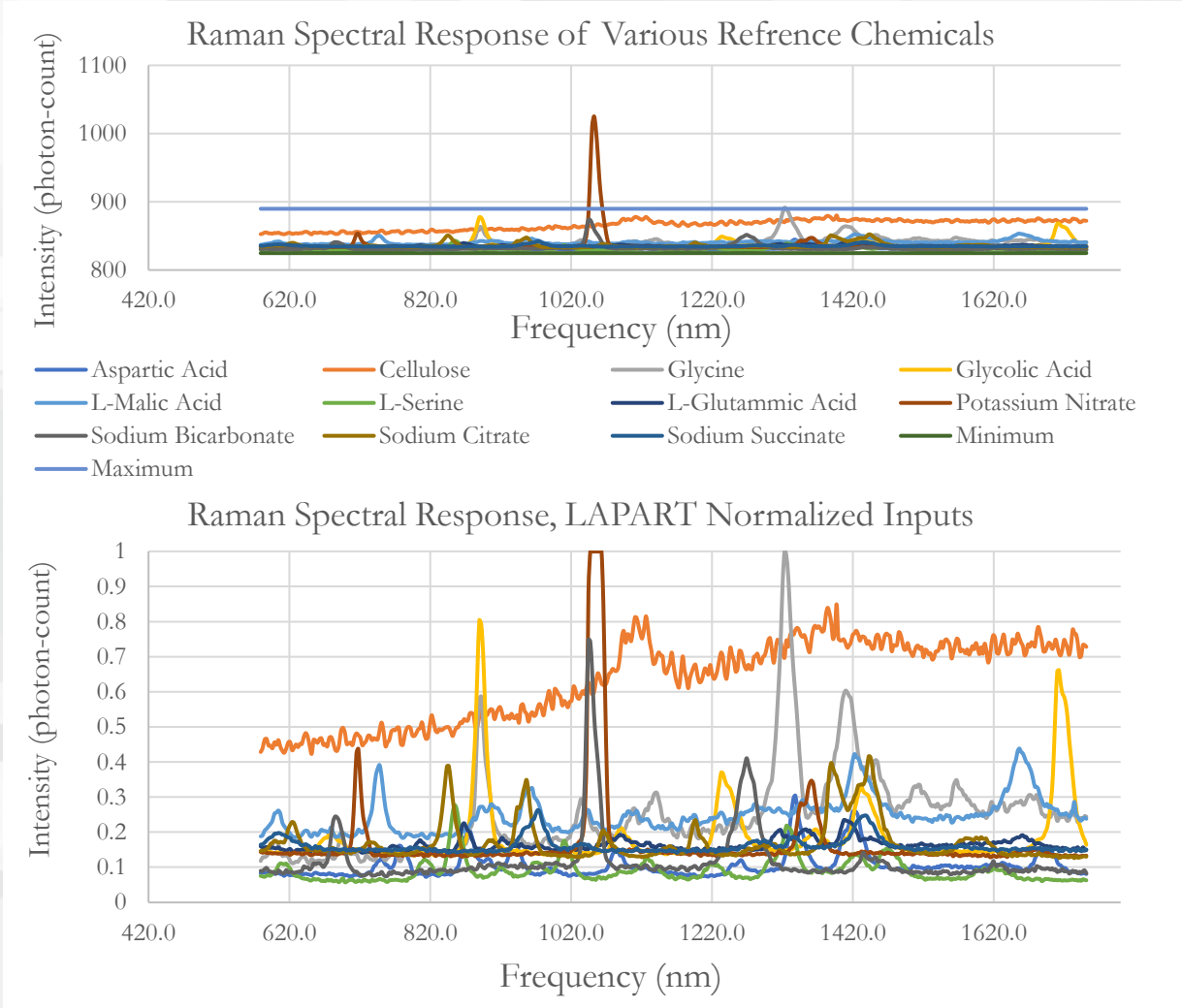
LAPART Inputs: Raman Spectroscopy

A Side Input is:
1x451, Raman Spectral Response

B Side Input/Prediction is:
1x11, Chemical binary ID

LAPART input is discretized into 451 frequency bands

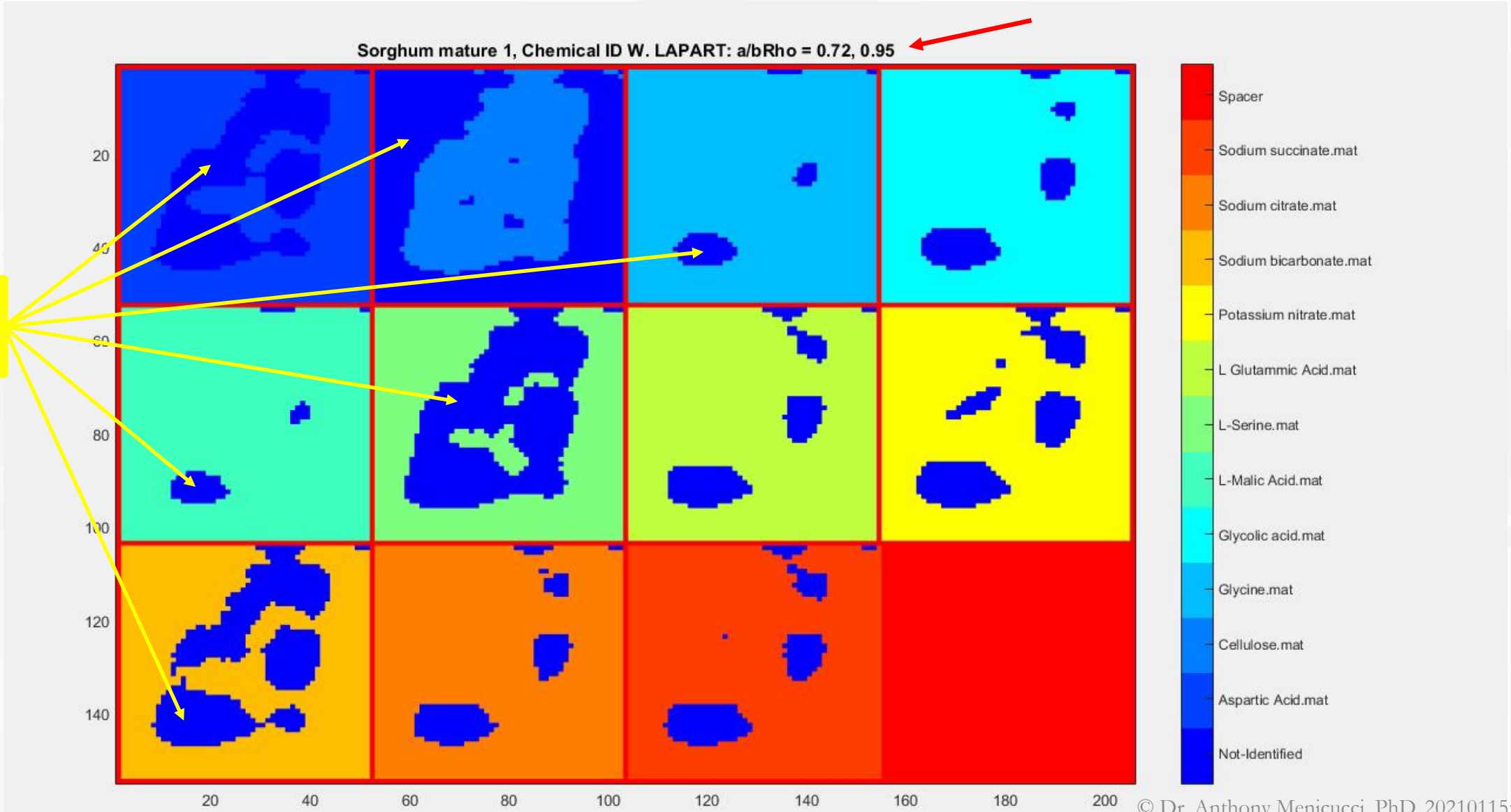
	Frequency (nm) & Normalized Response for LAPART		
Compound	579.2	582.0	584.8
Aspartic Acid	0.083	0.084	0.084
Cellulose	0.428	0.439	0.463
Glycine	0.118	0.128	0.129
Glycolic Acid	0.147	0.146	0.145
L-Malic Acid	0.188	0.191	0.204
L-Serine	0.075	0.074	0.072
L-Glutammic Acid	0.159	0.156	0.156
Potassium Nitrate	0.143	0.141	0.142
Sodium Bicarbonate	0.090	0.089	0.095
Sodium Citrate	0.146	0.148	0.148
Sodium Succinate	0.164	0.166	0.170



Aspartic Acid	1	0	0	0	0	0	0	0	0	0	0
Cellulose	0	1	0	0	0	0	0	0	0	0	0
Glycine	0	0	1	0	0	0	0	0	0	0	0
Glycolic Acid	0	0	0	1	0	0	0	0	0	0	0
L-Malic Acid	0	0	0	0	1	0	0	0	0	0	0
L-Serine	0	0	0	0	0	1	0	0	0	0	0
L-Glutammic Acid	0	0	0	0	0	0	1	0	0	0	0
Potassium Nitrate	0	0	0	0	0	0	0	1	0	0	0
Sodium Bicarbonate	0	0	0	0	0	0	0	0	1	0	0
Sodium Citrate	0	0	0	0	0	0	0	0	0	1	0
Sodium Succinate	0	0	0	0	0	0	0	0	0	0	1

LAPART Results: Raman Spectroscopy

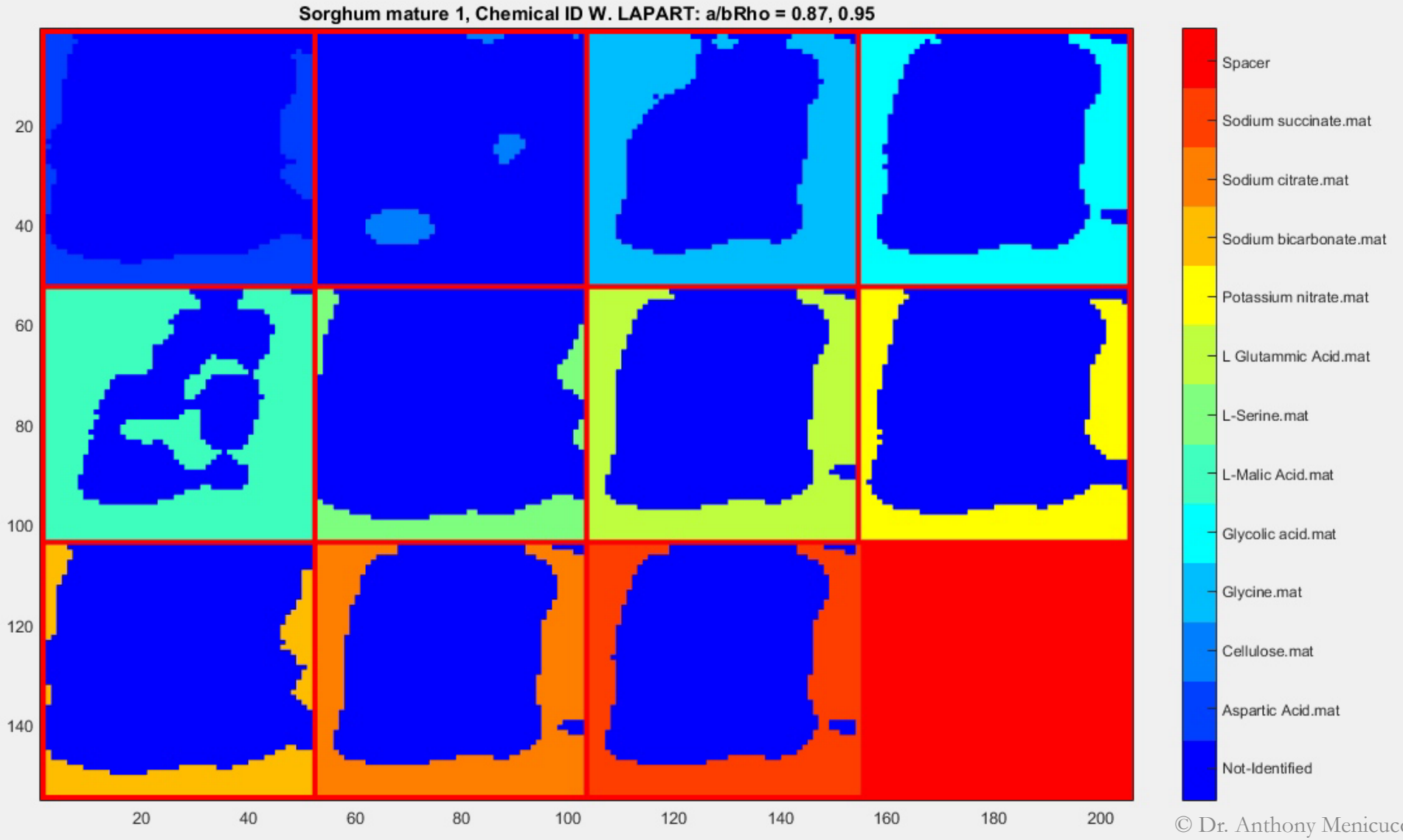
Each of the 11 panels is the same scan of a mature sorghum cell, with LAPART identifying one reference chemical.



nothing identified

LAPART Results: Raman Spectroscopy

Note that some chemicals are identified better with different LAPART rho values.



LAPART Inputs: Direct Vs Fourier

If we change our input to the frequency space, what do we need to ask about the system?

$$f(x) = \int_{-\infty}^{\infty} \hat{f}(\xi) e^{2\pi i x \xi} \, d\xi$$

Fourier Transform

Does:

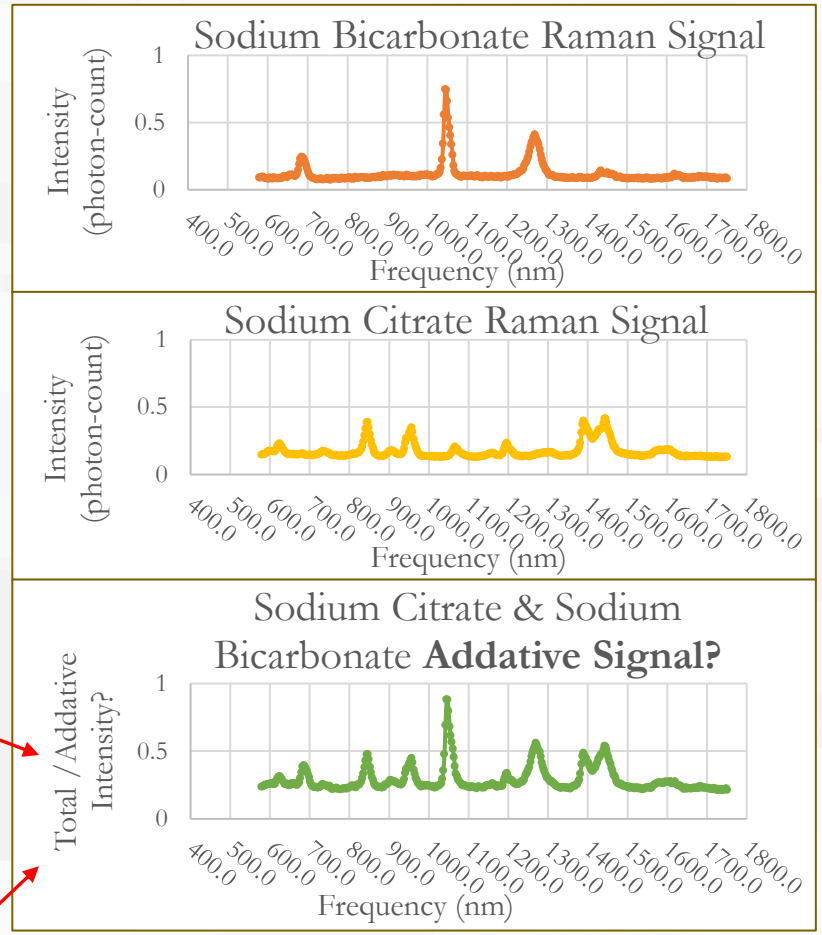
Sodium Bicarbonate

+

Sodium Citrate

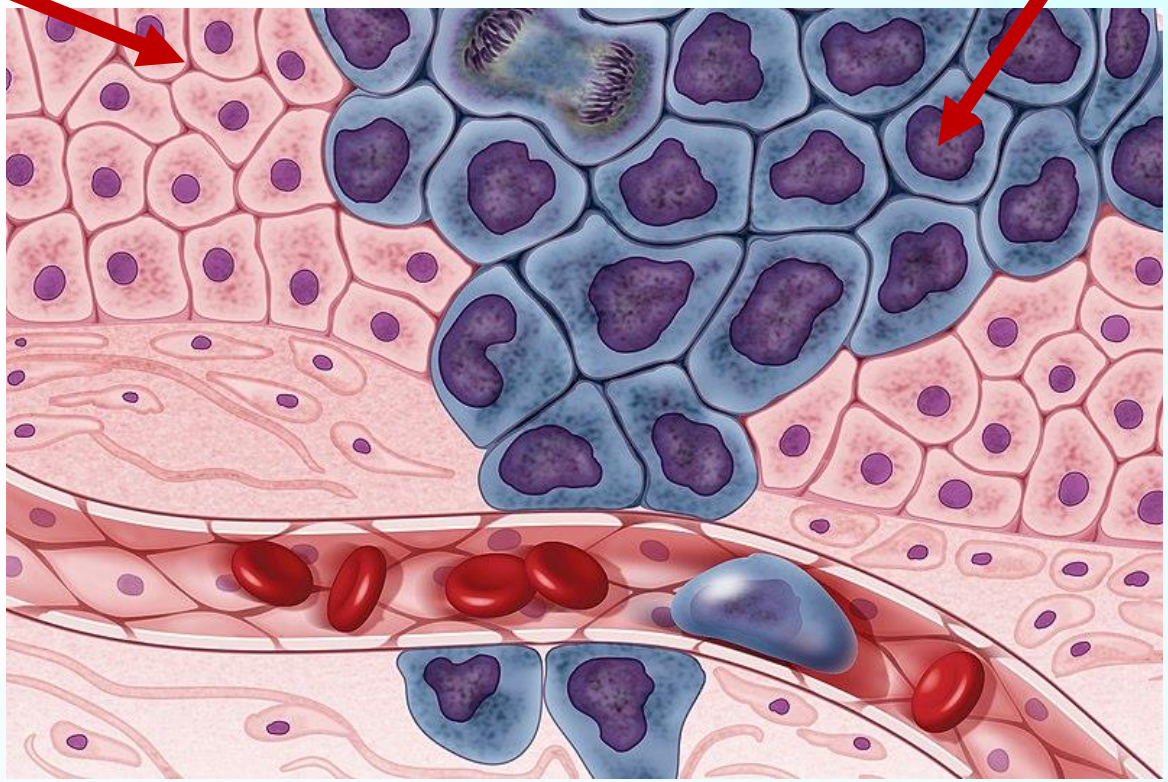
=

Both Raman Signals?



1. ***Do multiple Raman signal intensities add?***
2. ***How would that affect our normalization bounds?***
3. ***Other _____ ?***

Inputs: Brainstorming Section

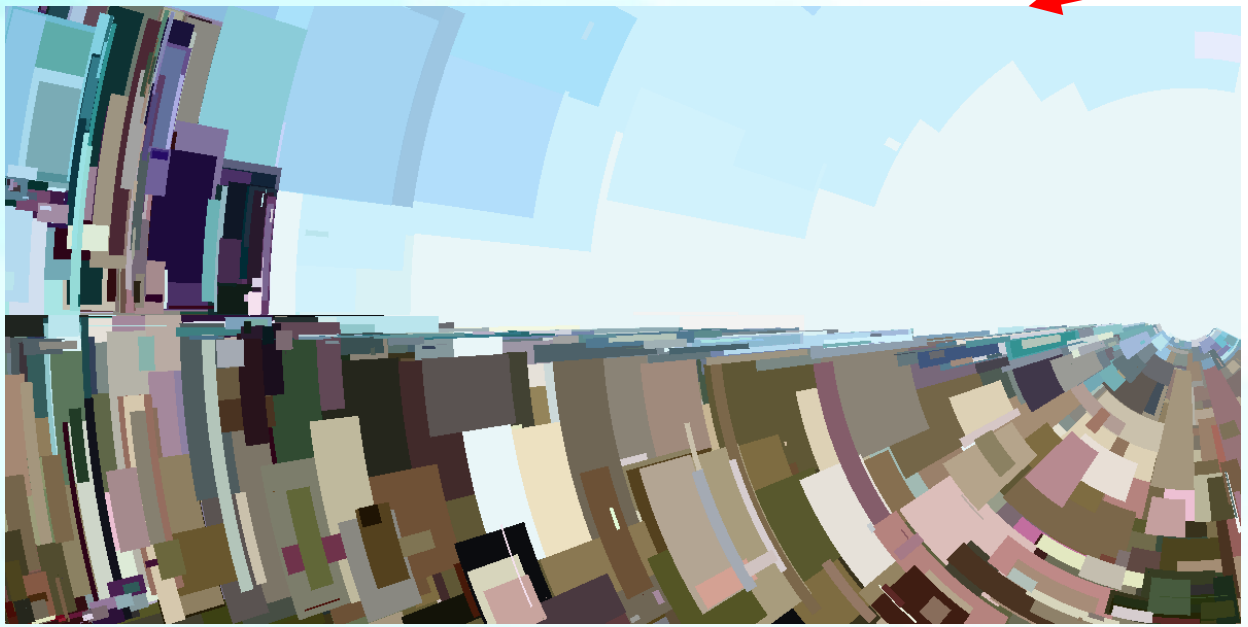


File:Cancer cells illustration (40379829875).jpg, National Institute of Health

Cancer Cell Identification Inputs

1. Color, artificially dyed or not, including RGB values &/or hyperspectral frequency response (Raman or IR Spectroscopy)
2. Uniformity of roundness:
   center & $\frac{dr}{d\theta} > \text{threshold}$
3. Volume differences: $\frac{\text{d Volume}}{\text{d cell}} > x * \sigma$
   where x is Real Number
4. $\frac{\text{d Replication}}{dt} >$ threshold
5. Others _____?

Inputs: LAPART Paint from memory



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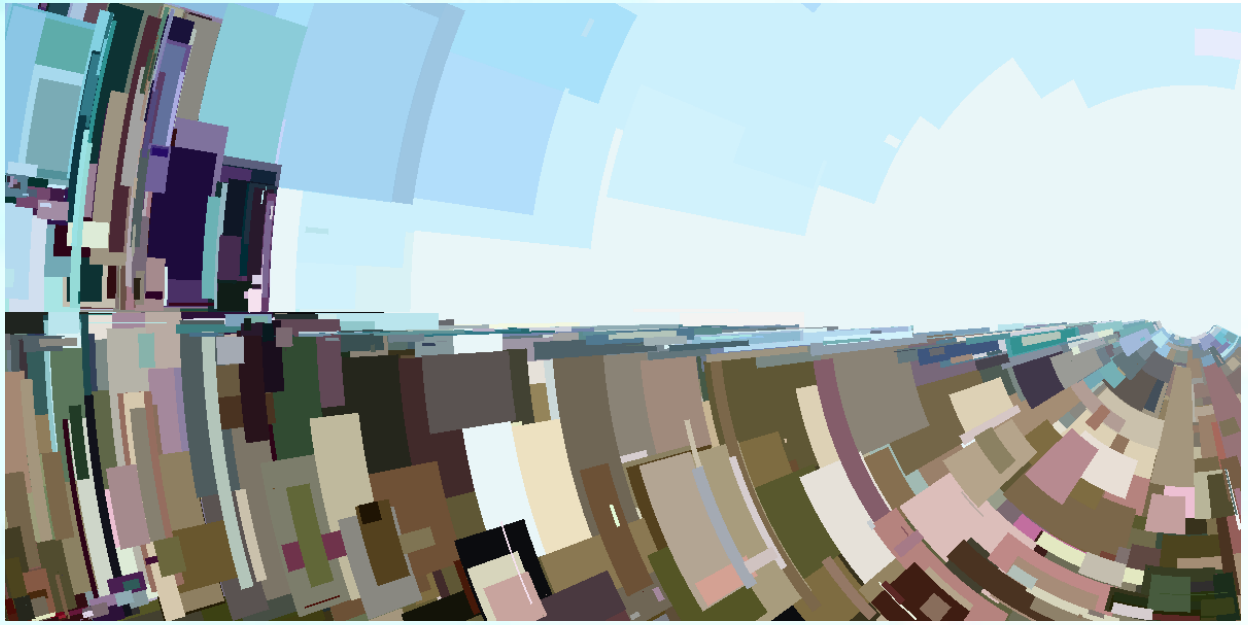
Quiz on inputs:

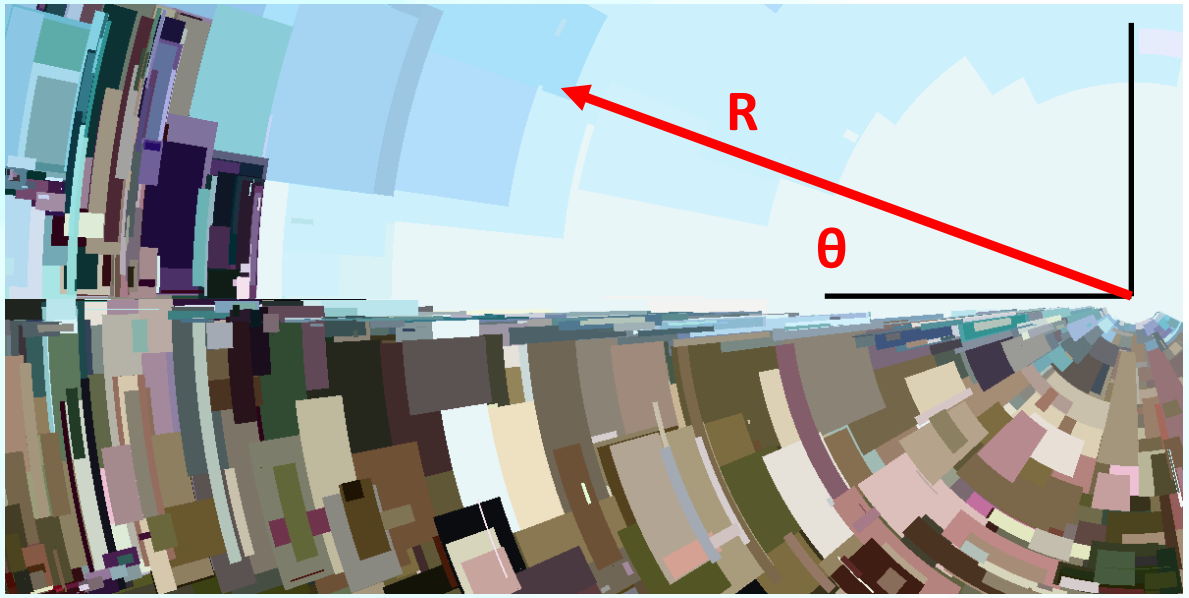
A-Side inputs: _____?
B-Side inputs: _____?

A-Side inputs: _____?
B-Side inputs: _____?

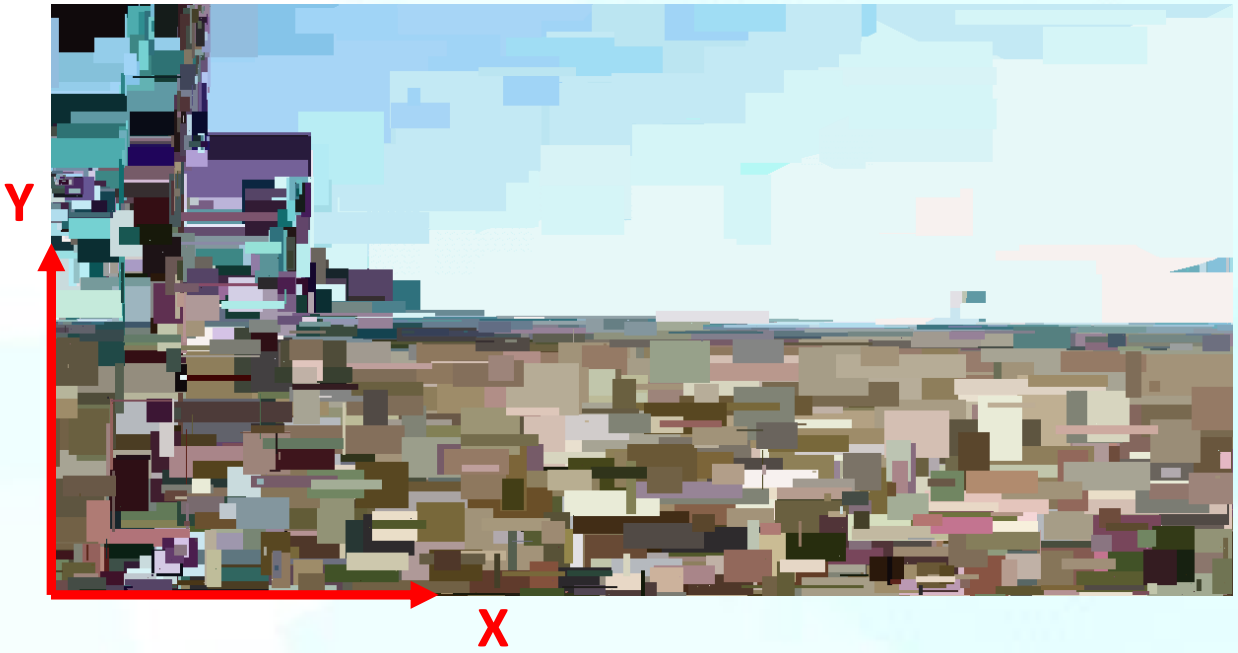


Quiz on inputs:

A-Side inputs: R & θ (normalized from center)
B-Side inputs: Red, Green, Blue (normalized)



A-Side inputs: X and Y (normalized, lower left)
B-Side inputs: Red, Green, Blue (normalized)



Thank You

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