Computer Vision Algorithms applied on AHCAL Data

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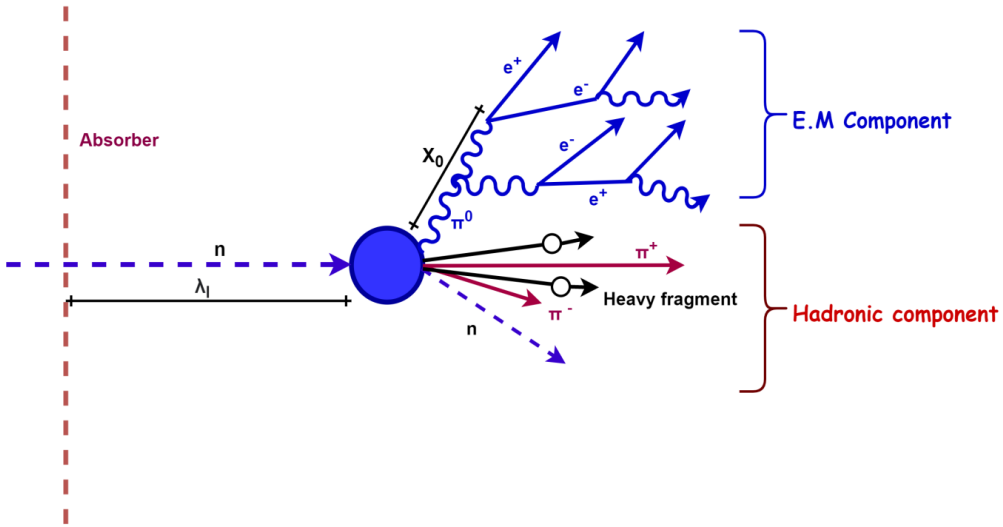
Overview

Hadronic showers



- Hadronic - EM Showers comparison
- Less compact
- More invisible energy
- More delayed

Image source: 'Study of shower shapes recorded with the CALICE-AHCAL in 2018 Test Beam Data' by Olin Pinto

From Event to Energy

- Each event may contain different EM fraction, a different size and timing
- Nevertheless in average they should be similar or show a similar behaviour in data
- Idea: Use well-known Computer Vision (CV) Algorithms to calculate the EM-fraction
- Aim: Finding the EM fraction of every event - Software compensation
- Benefits: Different method for particle identification
- Benefits: Might be more robust against angle variations and differences from training data

Computer Vision Algorithms

- Gaussian Blur - smoothen edges and hot/cold pixel/voxel
- Edge Detection - find edges and surfaces
- Floodfill - find areas and blobs
- Marching Cubes - find fitting curve and mesh
- k-Means - relates voxel to center of gravity of blobs

Gaussian Blur, Edge Detection, Floodfill

Original

Edgedetection

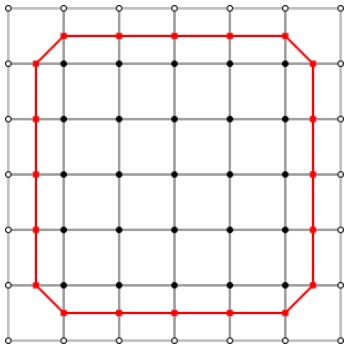
Gauss, Edgedetection

Contrast, Gauss, Edgedetection

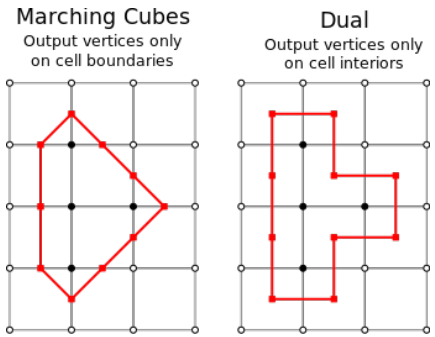
Contrast, Gauss, Edgedetection, Floodfill

Contrast, Gauss, Edgedetection, Floodfill

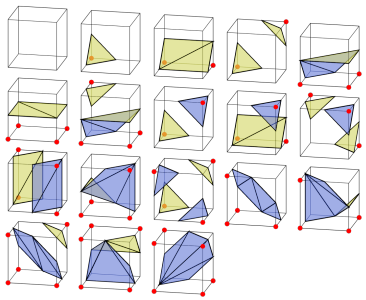
Marching Cubes



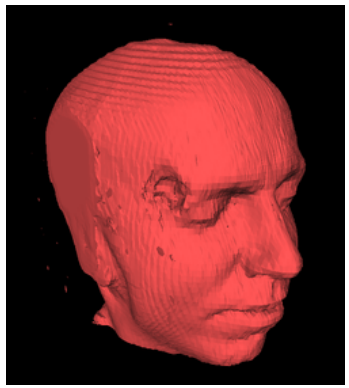
Marching Cubes example of a 2d square



Comparision between MC Cubes and trivial example



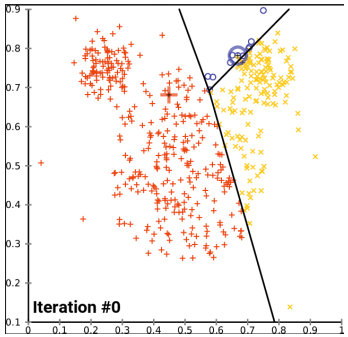
All 18 possible cases of 3d Marching Cubes



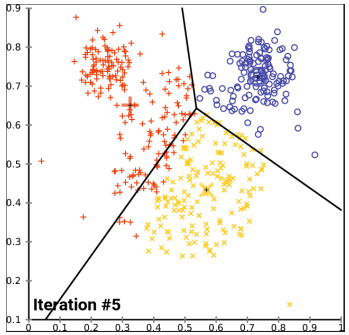
Mesh of a head with Marching Cubes

Source: http://www.boristhebrave.com/2018/04/15/dual-contouring-tutorial/ and Wikipedia

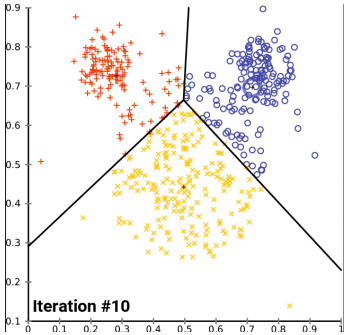
k-Means Algorithm



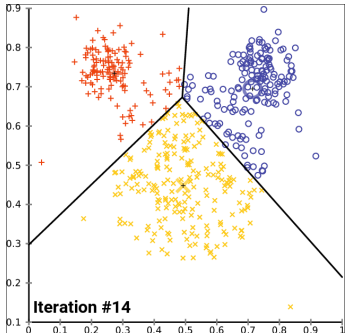
Iteration-0



Iteration-5



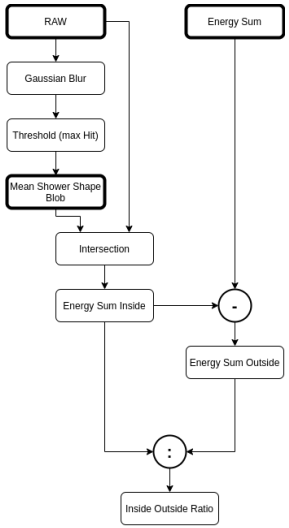
Iteration-10



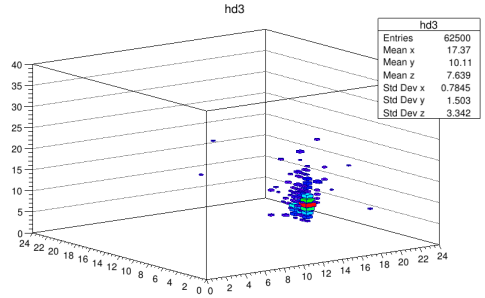
Iteration-14

Source: https://de.wikipedia.org/wiki/K-Means-Algorithmus

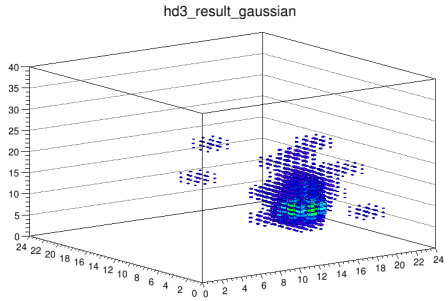
Particle Identification



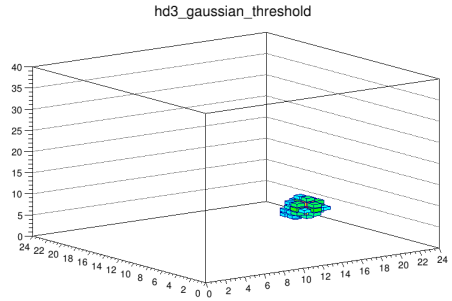
Sequence of inside-outside-ratio



10GeV Electrons Eventdisplay



Eventdisplay with applied Gaussian Blur



Eventdisplay with Gaussian Blur and threshold

Calculation sequence of the inside to outside ratio for hadronic showers to estimate the energy concentration in EM

Particle Identification

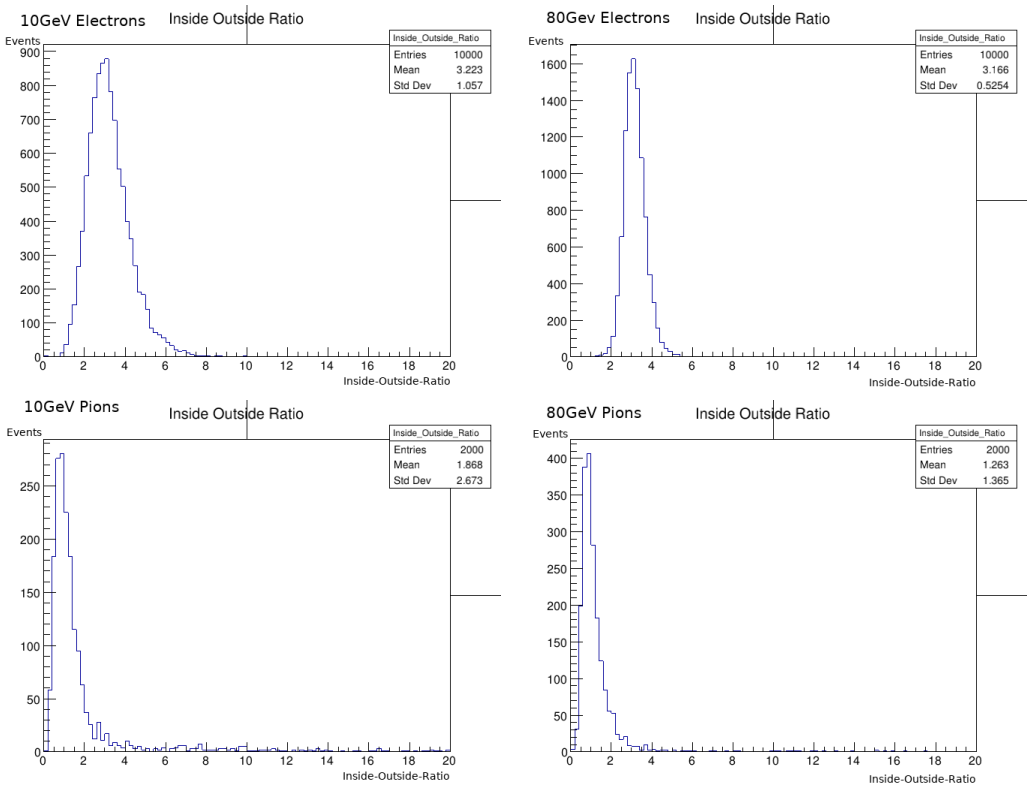
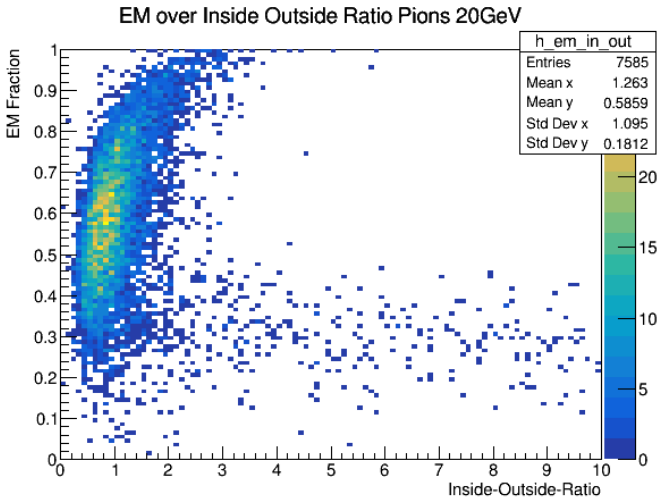
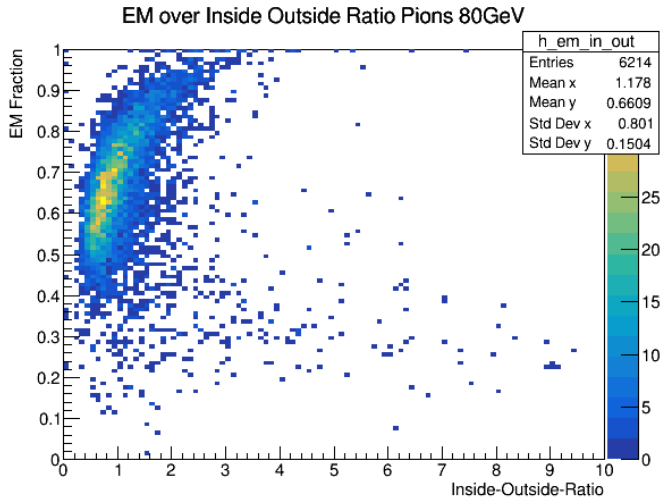
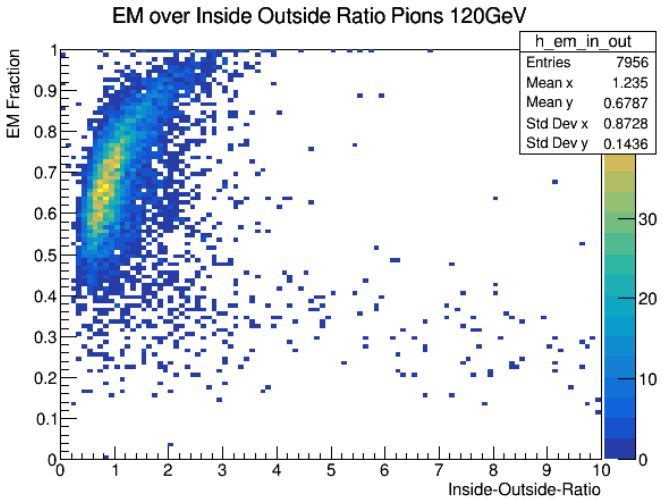


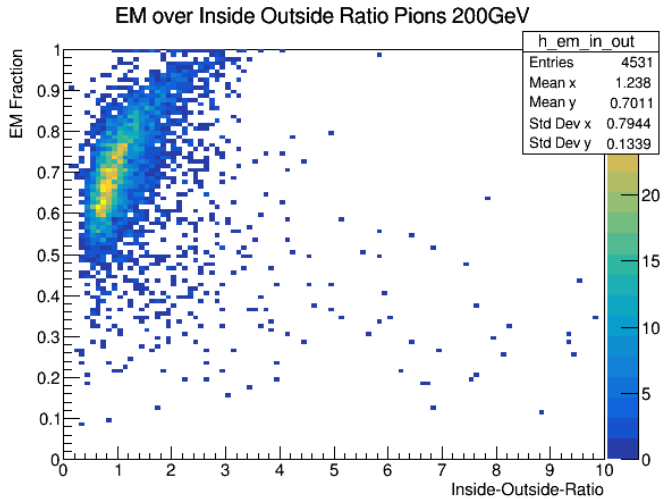
Figure: Number of event vs. inside-outside-ratio of 10 and 80GeV electrons and pions, respectively, after applying gaussian blur and threshold on it

Particle Identification MC Truth

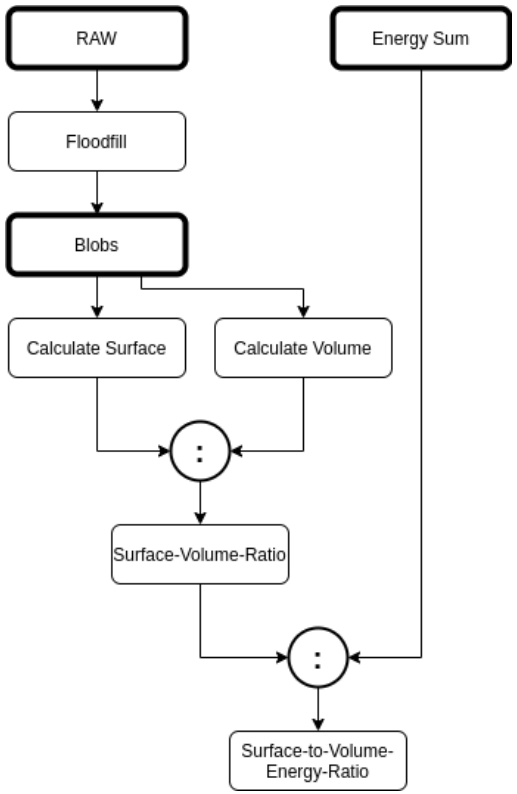






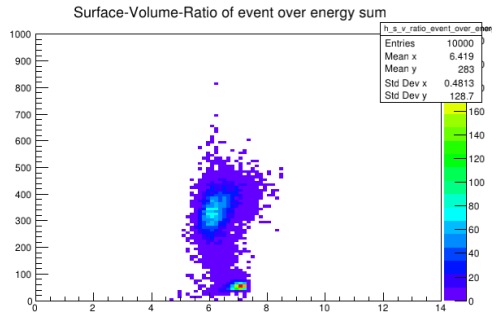


Surface-to-Volume Ratio

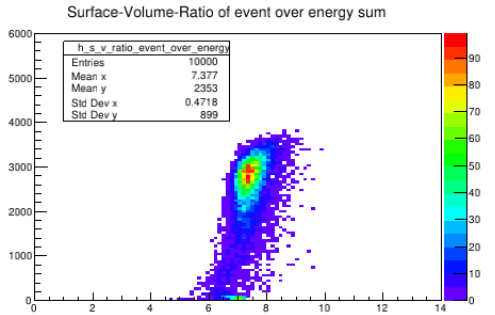


Calculation sequence of the volume to surface ratio for hadronic showers to estimate the compactness of the event

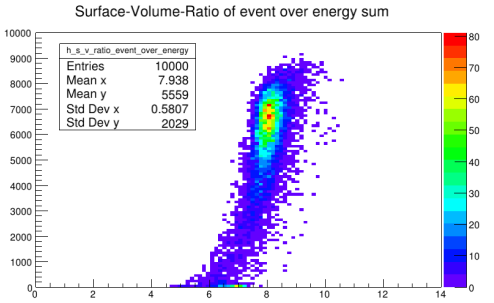
Surface-to-Volume Ratio



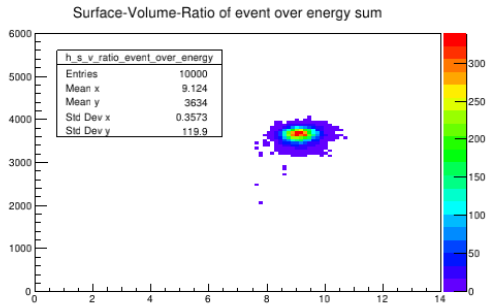
MC-Pions_10GeV



MC-Pions_80GeV



MC-Pions_200GeV



MC-Electrons_80GeV

X-Axis: Surface-to-Volume-Ratio Y-Axis: Energy Sum

Surface-to-Volume Ratio over EM Fraction

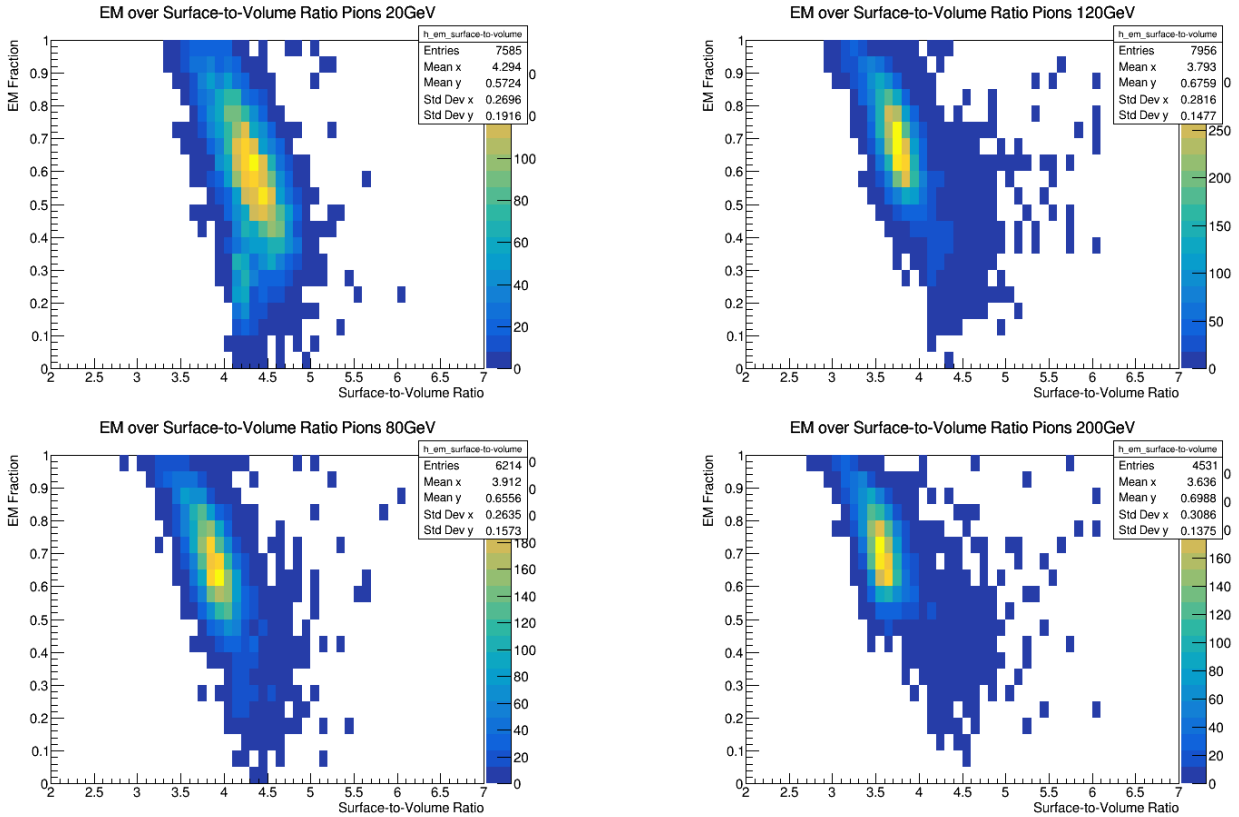


Figure: Correlation Factors: -0.53 (20GeV), -0.68 (80GeV), -0.66 (120GeV), -0.65 (200GeV)

Comparison between Computer Vision Algorithms and Maschine Learning

- The presented algorithms should be nearly independent from the incident angle (all coordinates are treated equally)
- There is no training data, thus there is no dependence from it (nevertheless there should be validation for different conditions)
- No cuts were applied (!)
- Even it might be less efficient, it is well defined and thus comprehensible (E.g.: FastCaloSim – Geant4)
- Should be as fast as or faster than a machine learning approach

Outlook

- Diving deeper into the algorithms
- See how far I can get
- Compare and then combines the results with the other (e.g. machine learning) approaches

Questions?

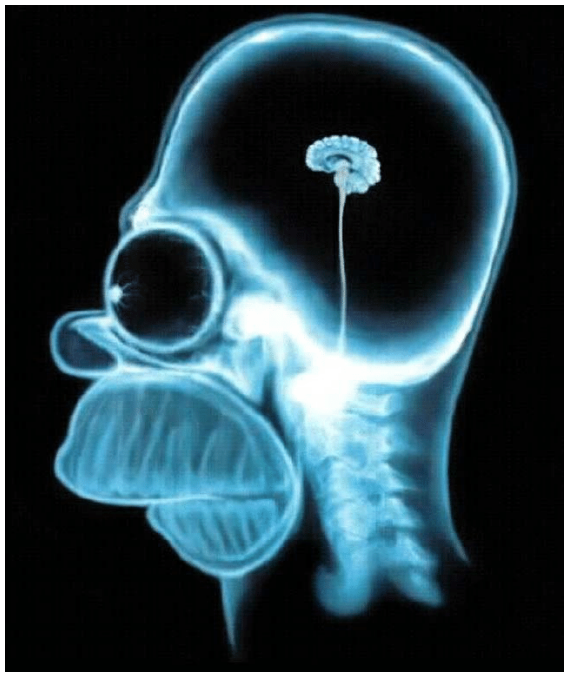


Figure: Me, myself and I, missing a crayon