The Fast TracKer upgrade for the ATLAS Trigger and Data Acquisition system, and FTK applications for early Alzheimer’s disease detection.

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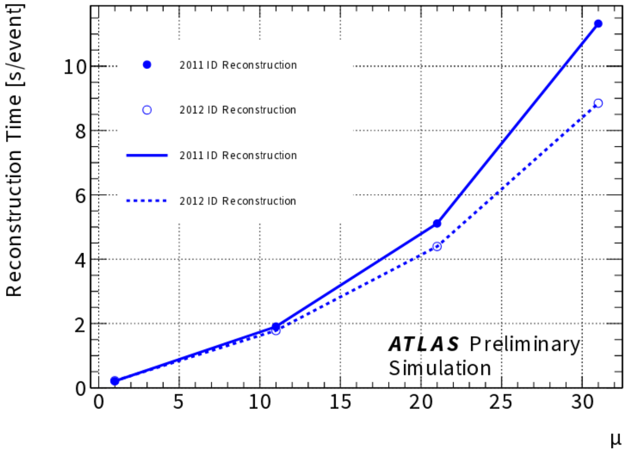
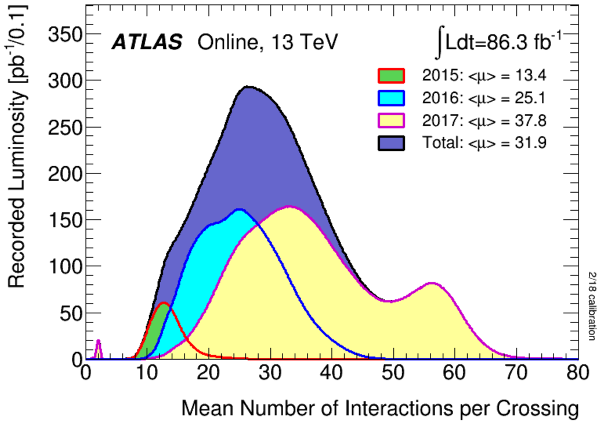
Introduction

- Efficient tracking is essential for many analyses.
  - b-tagging, lepton isolation.
- As overlapping collisions increase, tracking becomes more challenging.
  - Simultanteously, the reconstruction time per event increases as well.
- The Fast TracKer aims to offload this task from the High Level Trigger, moving tracking to a separate hardware processing unit.

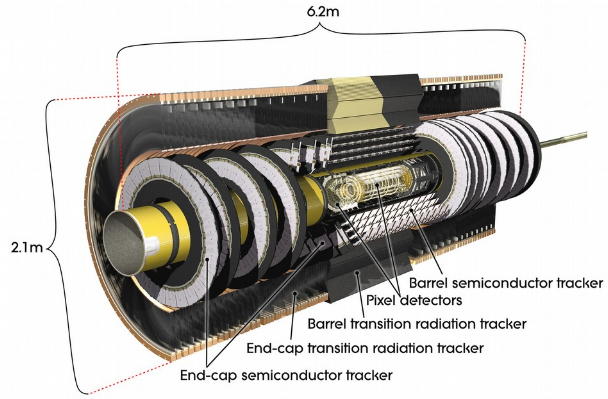


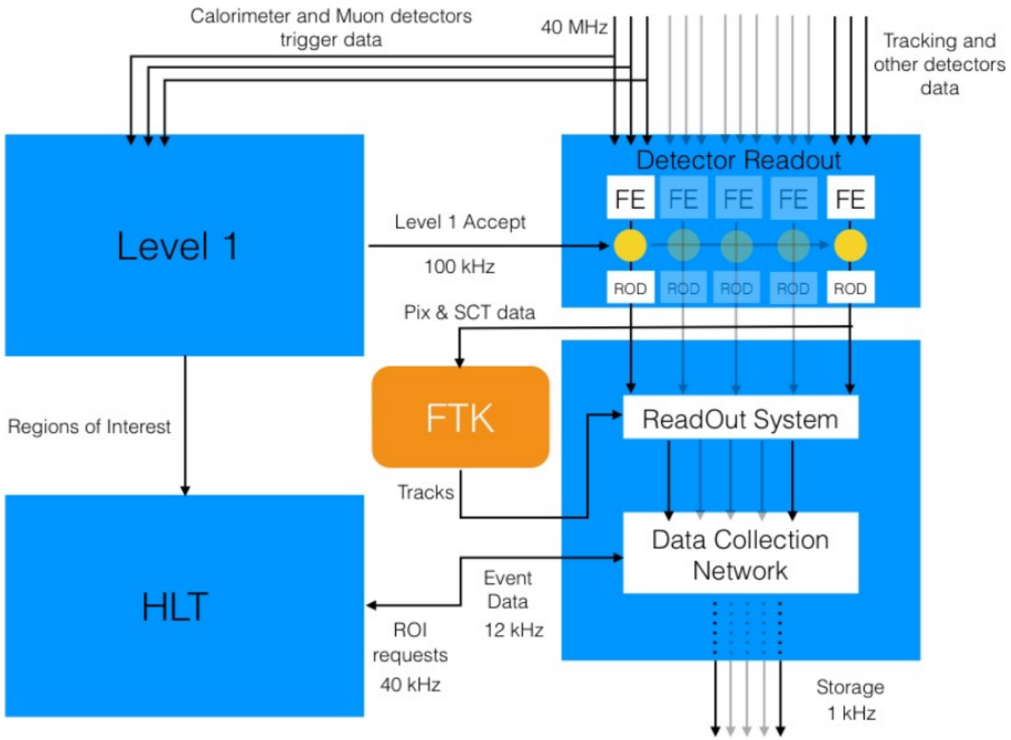
Certain components developed for FTK can also be used in other applications, e.g. for image processing.



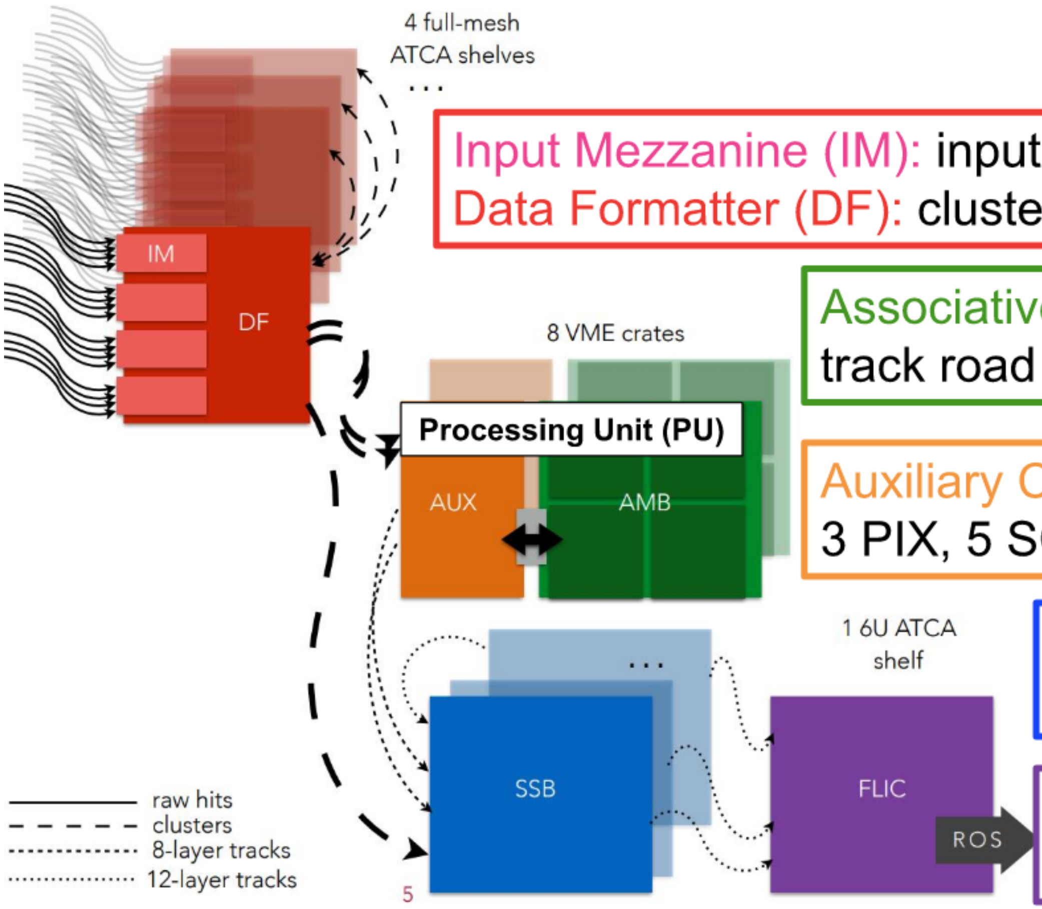
FTK Overview

- FTK is a hardware-based tracker, finding all tracks in the Inner Detector with p_T>1GeV within 100ms for each event passing the Level 1 trigger.
- Massively parallel system, consisting of 450 boards, 8000 ASICs and 2000 FPGAs.
- Receives a copy of the data sent from the Read-Out Drivers to the Read-Out System for the 3 pixel layers, the IBL and the 5 SCT layers.





FTK Architecture



Input Mezzanine (IM): input from ID + hit clustering
Data Formatter (DF): clustering data organisation

Associative Memory Board (AMB): ~instant track road finding (Crude, low resolution tracking)

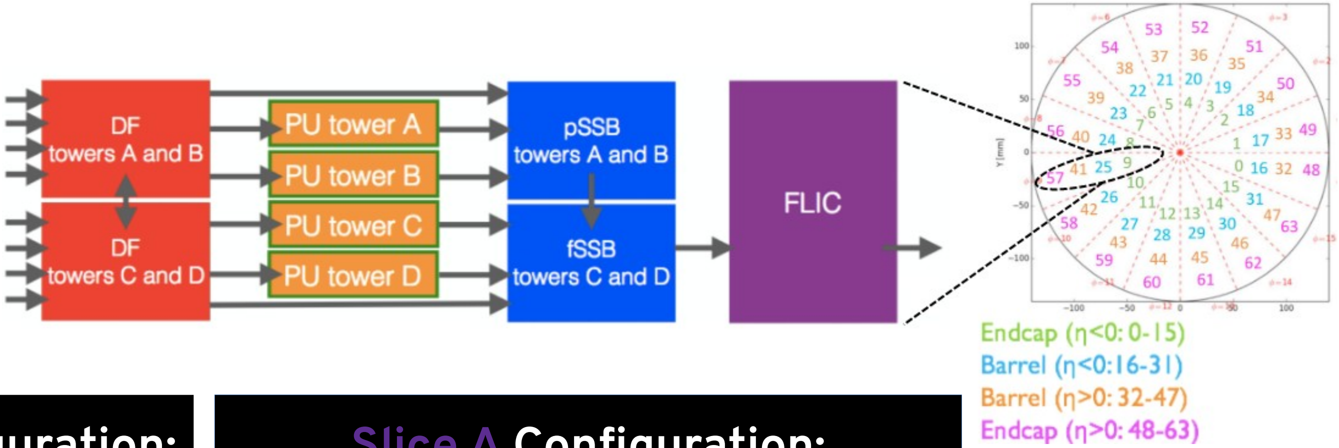
Auxiliary Card (AUX): first-stage fit; 8 Layers: 3 PIX, 5 SCT

Second Stage Board (SSB): 8L → 12L extrapolation + 12L fit

FTK to Level-2 Interface Card (FLIC): data formatting for HLT

FTK Run 2 Configuration

- 32 DFs (2 η-adjacent towers: barrel & endcap) send data to 2 AUX and 1 SSB.
- 64 PUs (AUX, AMB) receive the data from one tower (128 in Run 3).
- 32 SSBs receive 2 η-adjacent towers from 1 DF and 2 AUX.
- 16 FLIC on 2 FLIC boards receive 4 towers each and send their data to HLT.

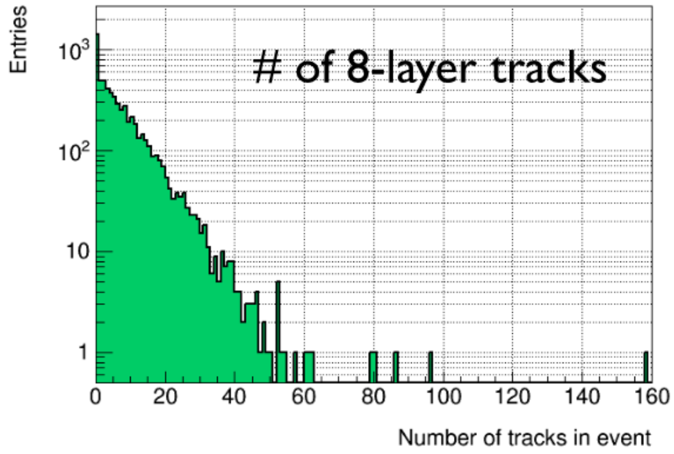


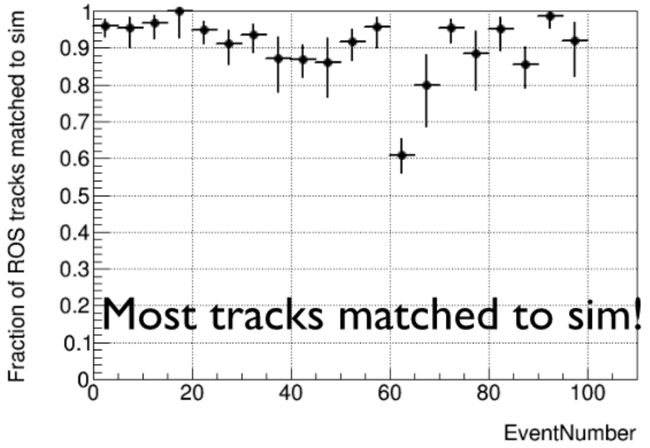
Slice 2 Configuration:
IM→ DF→ PU → HLT
Produces 8L tracks

Slice A Configuration:
IM→ DF→ PU → SSB → FLIC→ HLT
Produces 12L tracks

First FTK Data

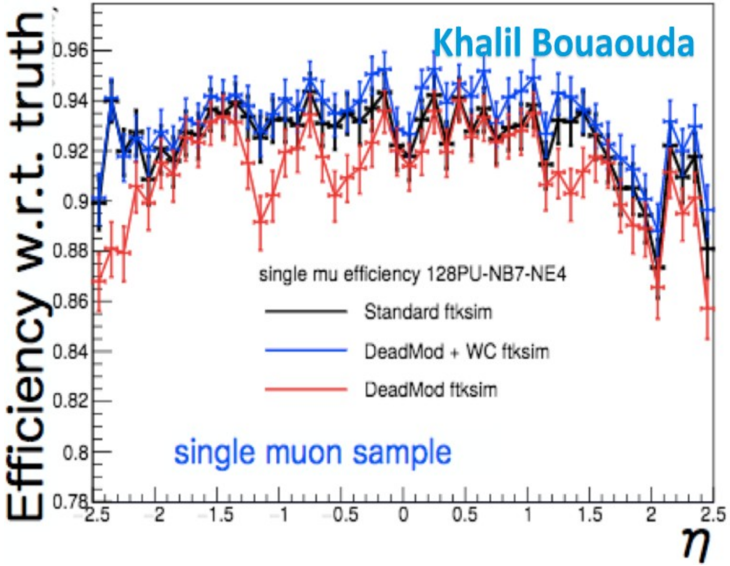
- Many tests spying on ID data (localy & on ATLAS Bytestream).
- AUX→ROS (Slice 2) tests on 25/10/2017.
  - First time with 8L tracks from real data.
- Many bugs fixed from this experience.
- Data taken from many runs, including
  - 13TeV run on 9/11/2017.
  - Low-μ run on 15/11/2017.
- 13TeV run for approximately 7 hours
  - More than 1 billion events recorded.





FTK Software

- A lot of work done on various parts of the software.
- Produced Pattern Banks with 2017 data.
  - Pattern Banks are necessary for the operation of the Associative Memory chip (AM).
  - Essential for the real-time pattern matching capabilities of the AM: Find .
- Implemented wildcards in patterns to account for dead modules.
- Validation of FTK simulation using bit-level comparisons to hardware outputs.



FTK Milestones

A) Bit-level comparisons of test vectors.
B) Slice 2 integrated into ATLAS.
C) Slice A integrated into ATLAS.
D) Multiple DFs feeding 1 AUX/AMB pair with pseudo data.
E) Multiple DFs feeding 1 VME shelf (AUX+AMB).
F) Demonstration of usage of L1 Trigger Type for prescaling.
G) Validate refactored DF code with ID data.
H) Stress vector library.
I) Test with ID on cosmics readout.
J) Test handling of ID error bits.
K) FW release packet handler + sync in all boards.
L) Monitoring Sprint 1.
M) FW release with all boards including common error word filling.

FTK Goal for 2018

Run the full Run 2 system.

Green: completed

AUTh & HOU Contributions to FTK

- FTK_IM
  - Board development, general firmware, hit clustering firmware & software (N. Kimura, C.L. Sotiropoulou, S. Gkaitatzis)
  - Commissioning and integration (C.L. Sotiropoulou, N. Kimura, M. Ntogramatzi)
- AMBoard
  - Test and commissioning at CERN (I. Maznas, A. Marantis)
  - Firmware (I. Xiotidis, C. Gentsos)
- Second Stage Board: firmware, test & commissioning at CERN (C. Gentsos)
- Simulation
  - Bit accurate simulation (S. Gkaitatzis)
  - Impact of final implementation on performance (S. Gkaitatzis)
  - Timing emulation (N. Kimura)
  - Pattern Bank validation (G. Bourlis)
- System control & monitoring
  - Detector Control System: software, test & commissioning (I. Maznas)
  - High-level Online Monitoring: data vs. simulation (A. Marantis)

Green: Active (6 persons)
Black: Inactive (3 persons)

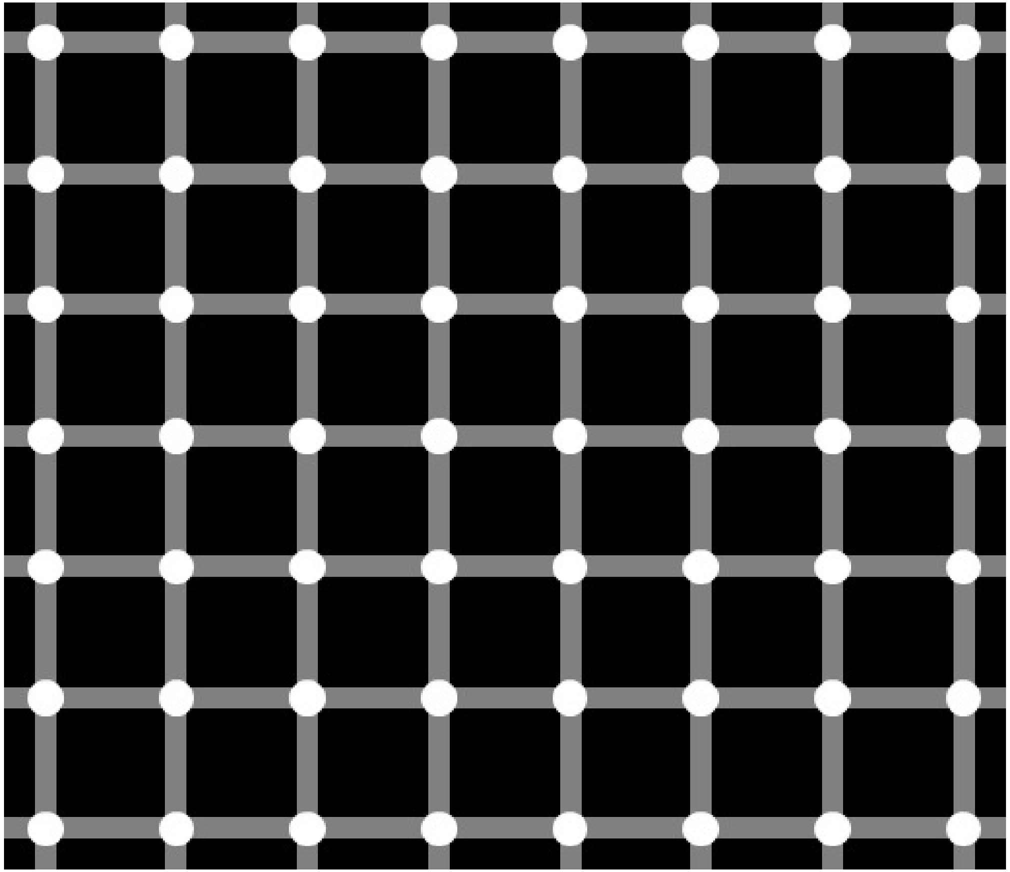
Image Processing with FTK

- FTK components can also be used outside HEP.
- The Associative Memory performs real-time pattern matching.
  - In FTK it matches tracks, but any kind of pattern matching is possible!
  - The important patterns are saved in a Pattern Bank and then they are compared to the input.
- How could we use these pattern matching capabilities to perform real-time image processing? We would need
  - A model able to select the important patterns (i.e. salient features).
  - To perform a simulation optimizing the results.
  - Modify the hardware to perform the required activity.

Cognitive Image Processing

- The visual system needs to extract the most important environmental features for survival purposes.
- The capacity of transmission of photoreceptors is 20 Gb/s per eye.
- The above is reduced to 4 Gb/s at the level of optic nerve fibers.

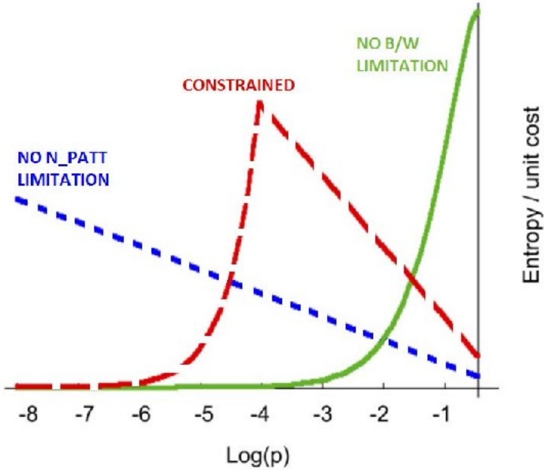
The human brain performs some early stage data reduction.



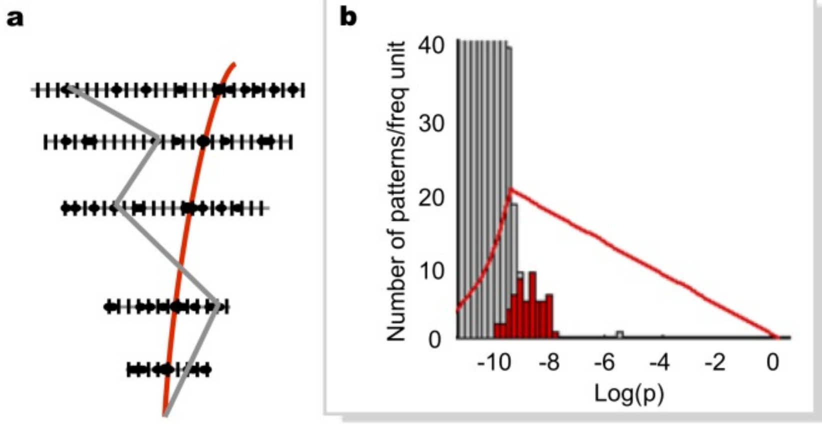
Del Viva Model

- The goal is the maximization of information entropy.
- Let p be the probability of a pattern matching an input pattern.
- Without constrains, we would use the classic formula of information entropy but…
- The total entropy of the system is bound by
  - N: The maximum number of distinct patterns stored in the system.
  - W: Pattern acceptance rate (Bandwidth).
- Thus, the entropy yield per unit cost is given by

$$f(p) = \frac{-p\log(p)}{max(1/N, p/W)}$$



Application in HEP



Example of model applied on MRI slices

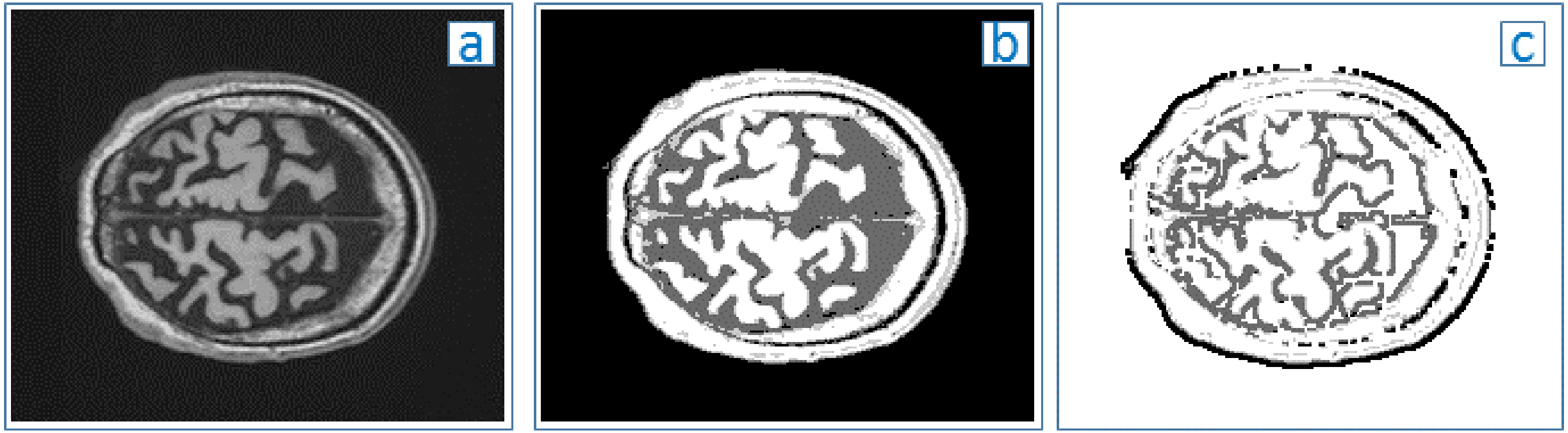
a) Input image – Normal MRI.

b) Downsampled image – Input to the simulation has to be either B/W or with 4 levels of grey.

c) Filtered image – The result after the simulation. Acts as an edge detector.

Thresholds chosen in proximity with three different brain compartments:

- White matter.
- Grey matter.
- Celebrospinal fluid.



Detecting Alzheimer’s Disease in MRIs

- A particular network within the grey matter links most of the higher order functions of the brain.
- Potential alterations in the grey matter could damage the network, leading to various disorders.
- Mild cognitive impairment (MCI) is a disorder that has been associated with risk for Alzheimer's disease.
  - MCI is an intermediate stage between the expected cognitive decline of normal aging and the more-serious disorders.
- Decision-making systems have demonstrated their ability in the prediction of the conversion of MCI to Alzheimer’s Disease (AD).
- The algorithm studied is based on Support Vector Machines (SVM) classifiers.
- Applying an edge-enhancement filter before the classification could lead to an enhancement of the salient features.

Procedure

- Run the same analysis twice:
  - Train SVM with the original MRI scans.
  - Train SVN with the filtered MRI scans.
  - Compare!
- Del Viva filter inserted after SPM preprocessing.

Results:

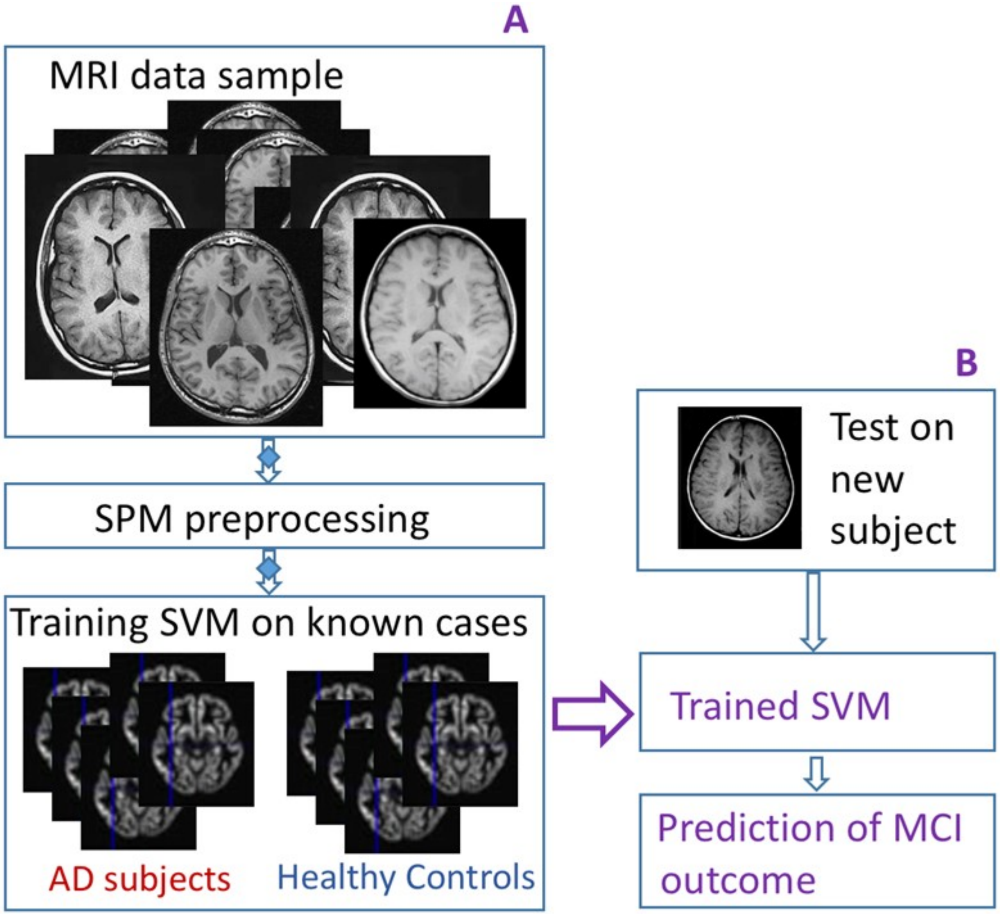
- Running with original MRIs:

  70.9% AUROC (Confidence indicator for decision-making systems).

- Running with filtered MRIs:

  77.6% AUROC.

- No optimization of classification of the SVM parameters has been performed.



Conclusions

- Very big process on FTK integration.
  - First 8L and 12L tracks have been found.
  - Active development moving rapidly – Manpower however needed.
  - Accurate results.
- Associative Memory successfully used for image processing.
  - Real-time enhancement of boundaries between grey & white matter has many potential applications.
  - Promising increase in the early detection of Alzheimer's Disease conversion.