Smoke Detection in Compressed Video

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Outline–Part 1 (Compressed Domain Analysis)

- Motivation
  - Fire Detection
  - State-of-the-art Methods/Techniques
    - Point vs. Volumetric Detection
    - Computer Vision based Detection
    - Compressed Domain Video Analysis
    - Possible Implementation on Memristor Cross-Bar Arrays

- Proposed Method
  - Smoke Detection in Wavelet Domain
    - Motion Detection
    - High-band Energy Fluctuation
  - Initial Results

Outline – Part 2 (SP4CING at İTÜ)

- Istanbul Technical University
- Institute of Informatics
- Signal Processing for Computational Intelligence Group
  - Projects
  - Collaborations

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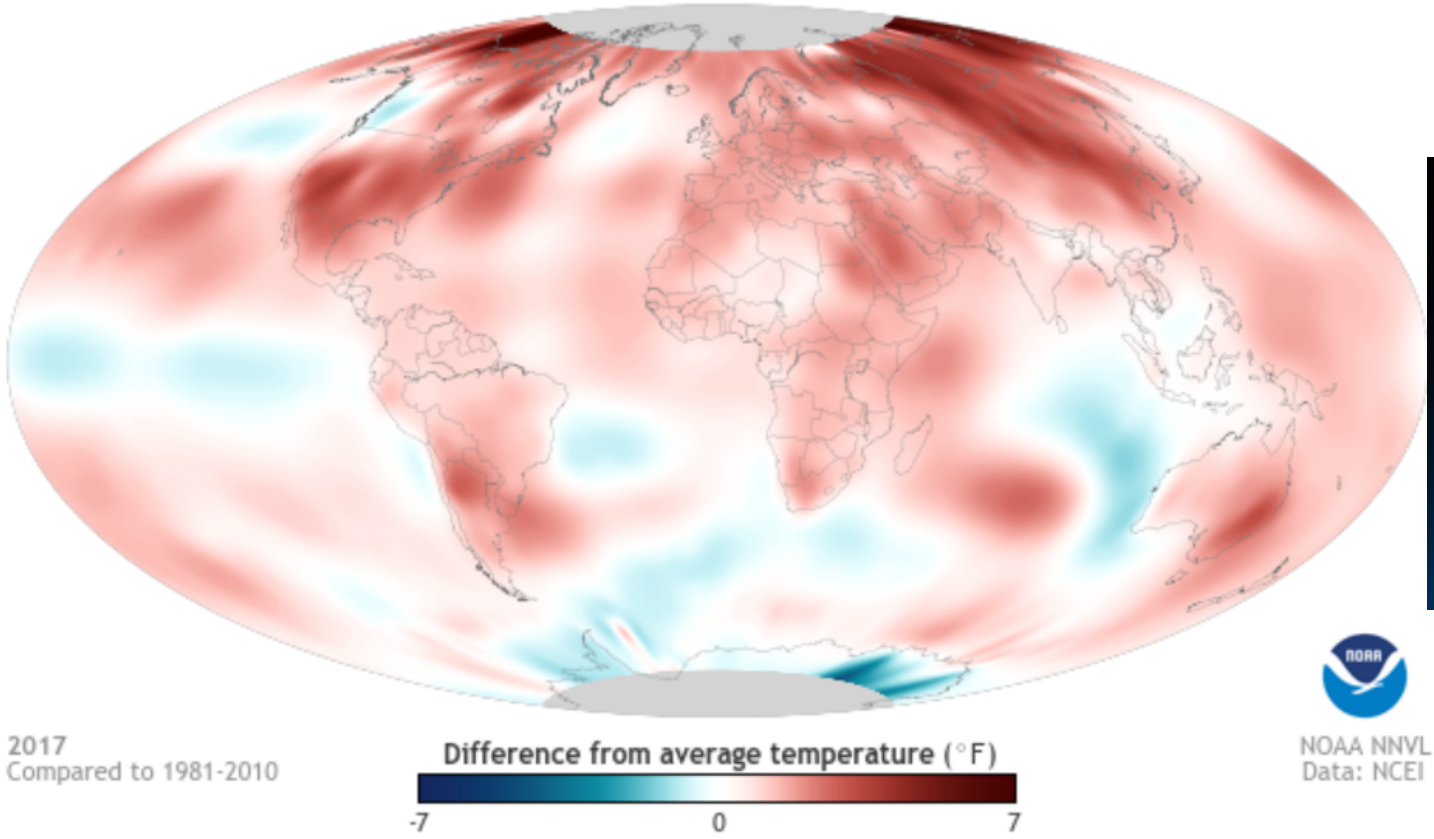
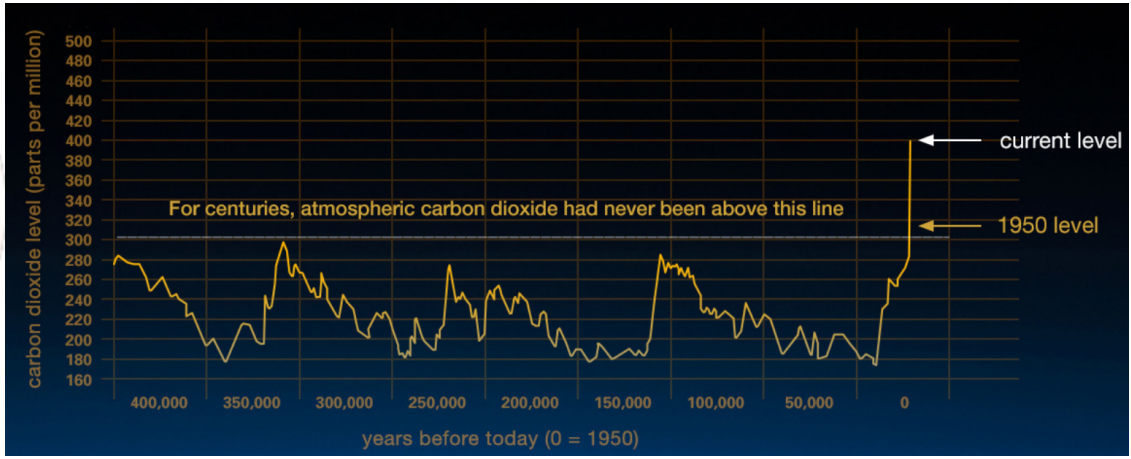
Motivation – Fire Detection

- Expecting to have a much more number of fire outbreaks each year



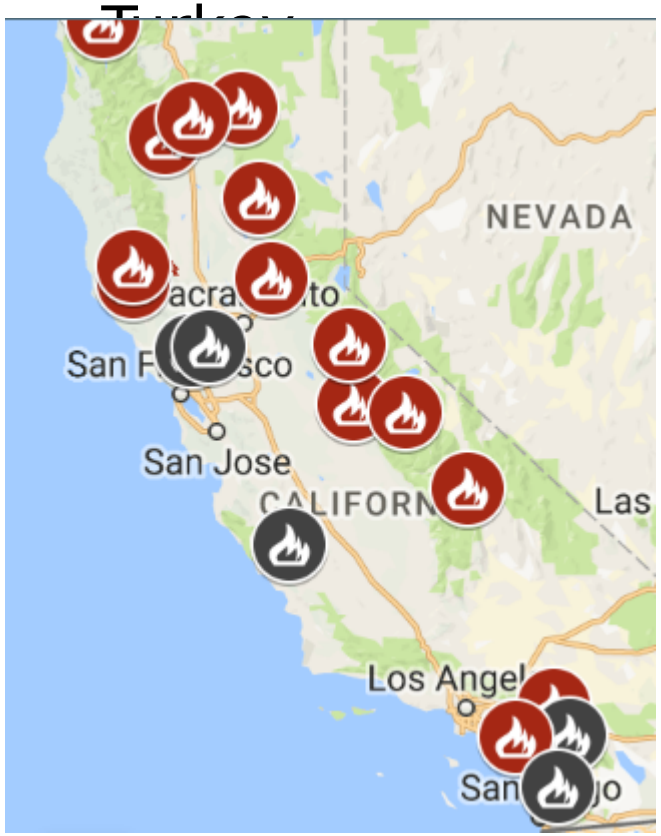


Atmospheric CO2 Levels (ppm)

2017 compared to ave(1981:2010) [NOAA]

Spread of Wildfires

- Not only in CA
  - Turkey
  - Greece



[USFS]

[EPA – European Press Photo Agency]

[Orman Genel Müd.]

Wildfires – All Around the World

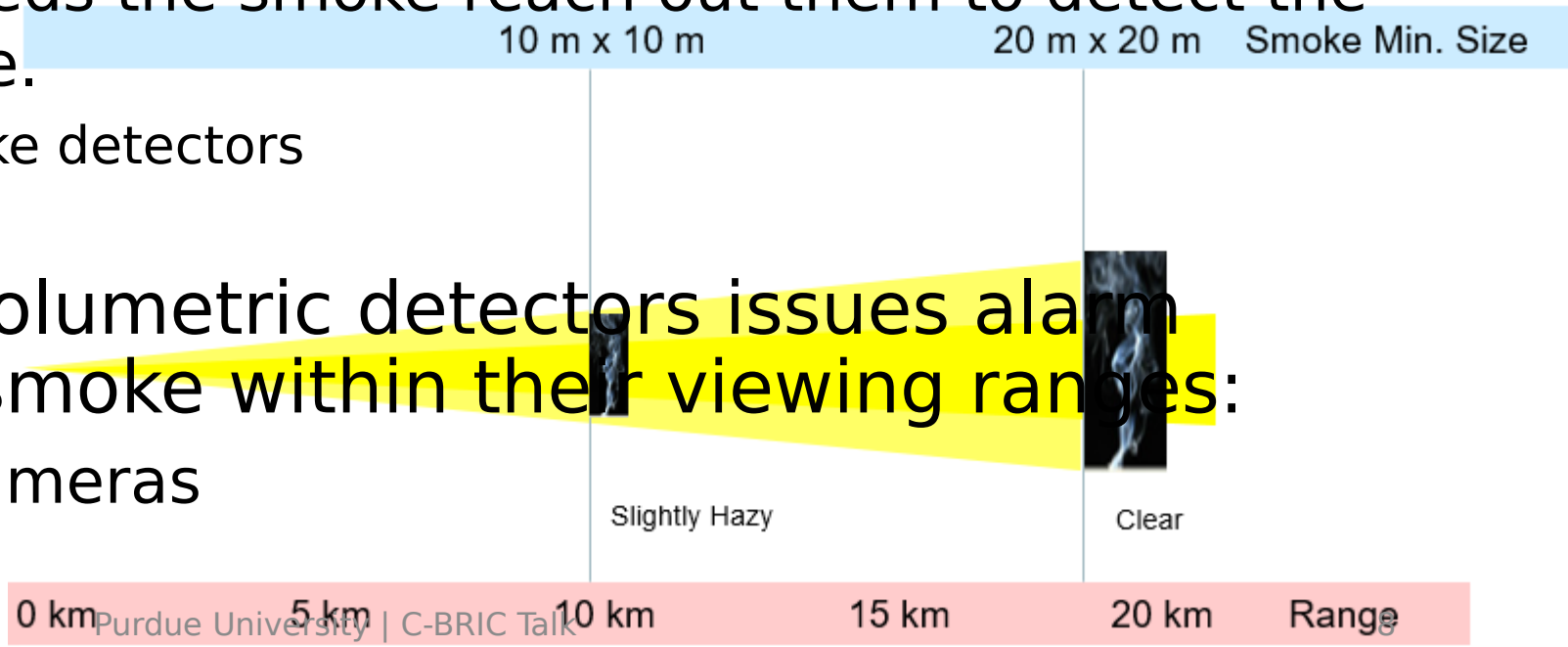
- But also, in Sweden, and Norway

[REUTERS] [NTB - Scanpix]

Point Detectors won’t Help Outdoors

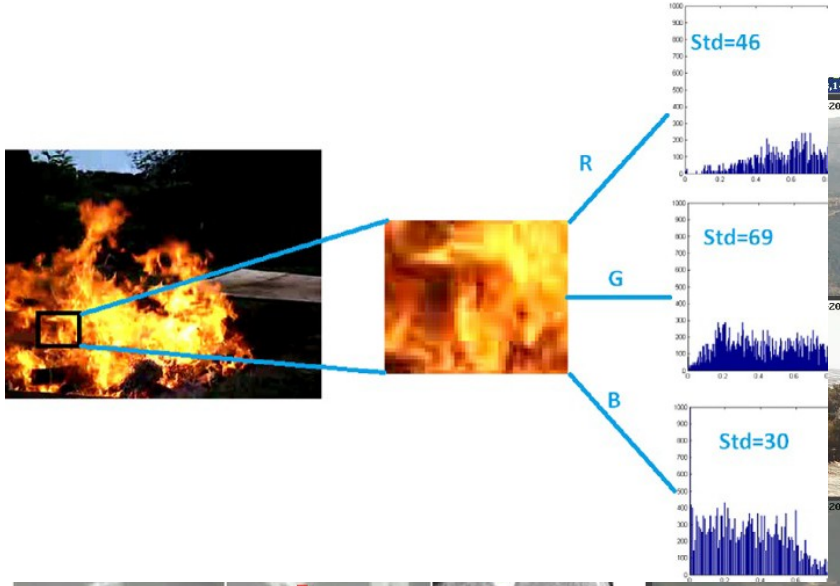
- - and, they don’t help in large and spacious covered places, as well:
- Plane hangars, Concert Halls, Museums, etc.
  - Point detectors needs the smoke reach out them to detect the existence of smoke.
    - Conventional smoke detectors

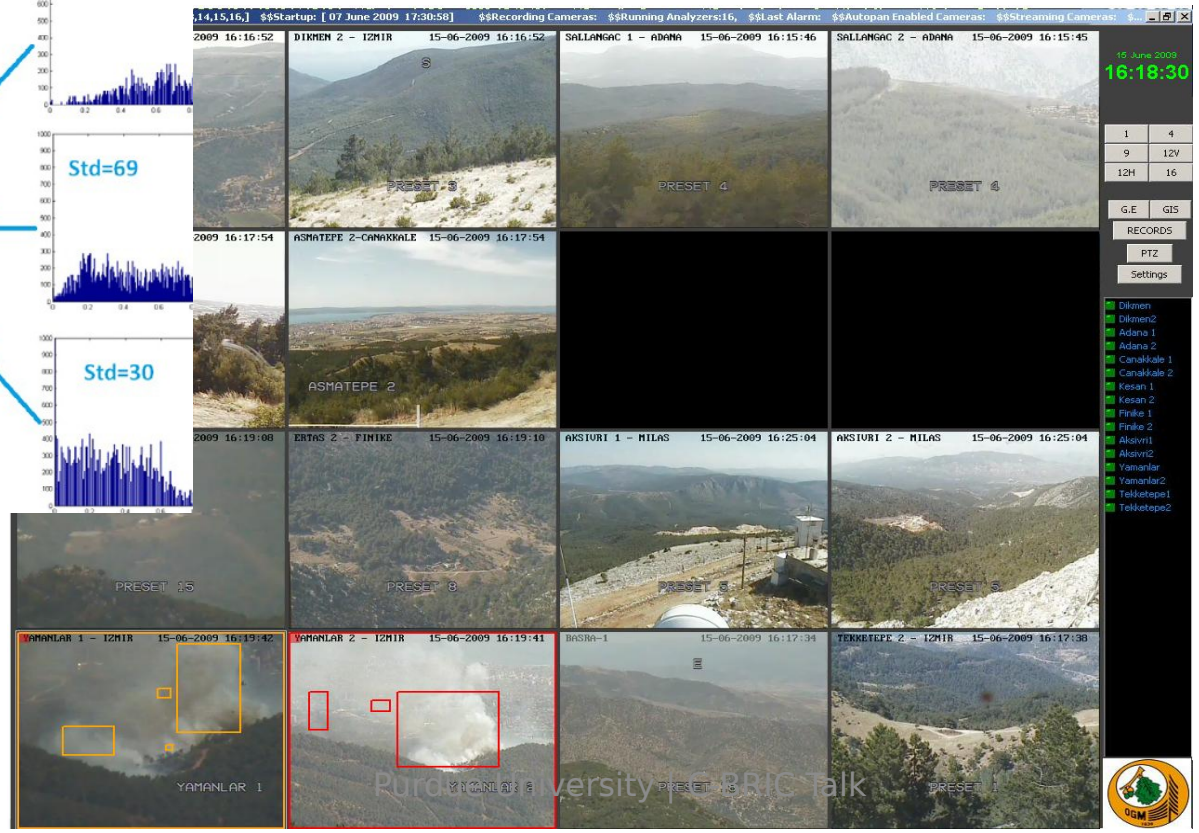
- On the contrary, volumetric detectors issues alarm when they «see» smoke within their viewing ranges:
  - PIR sensors and cameras

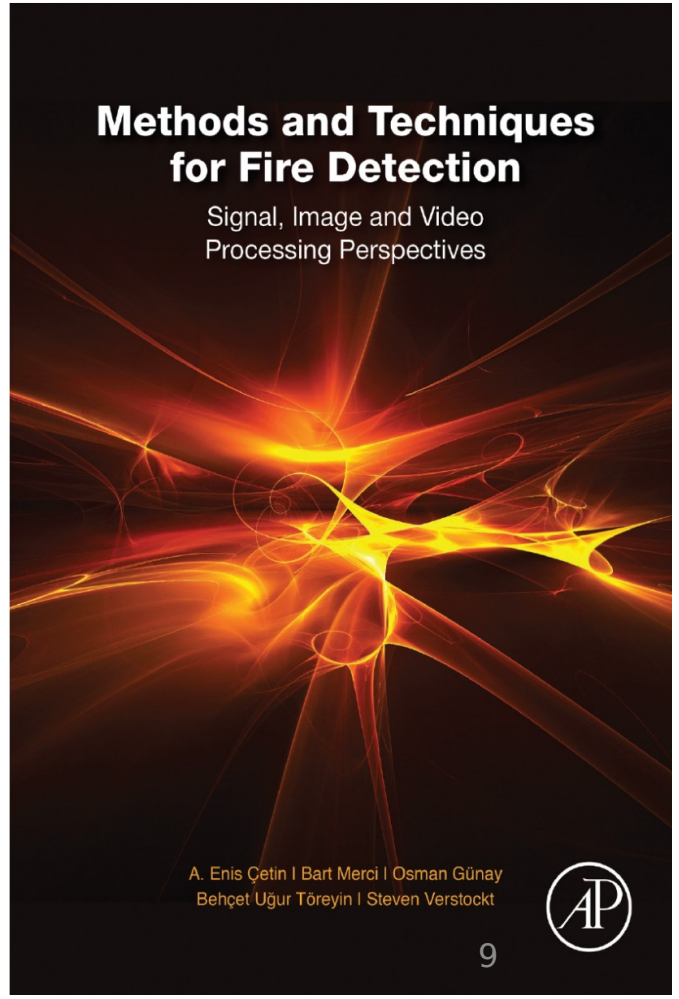


Computer Vision Based Fire Detection

- Flame Detection (Visible / Infrared)
- Smoke Detection (< or > 30 m)







Computer Vision Based Fire Detection

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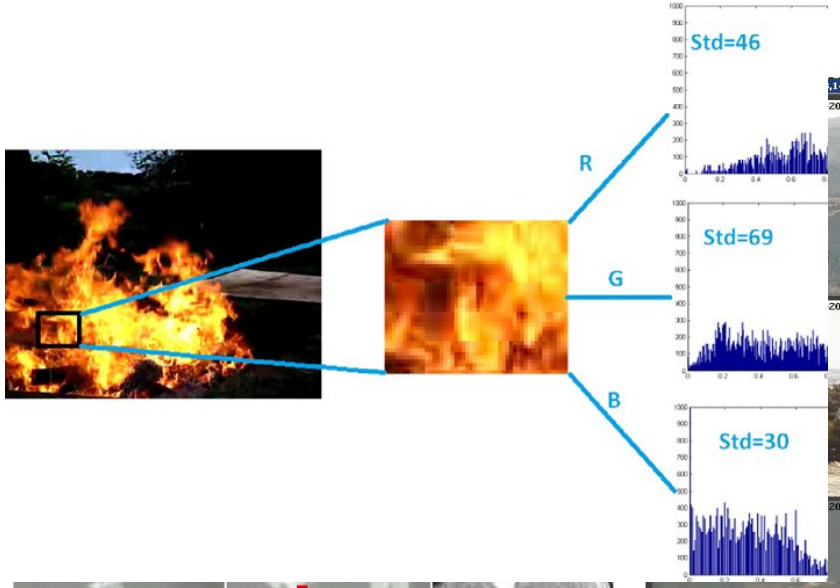
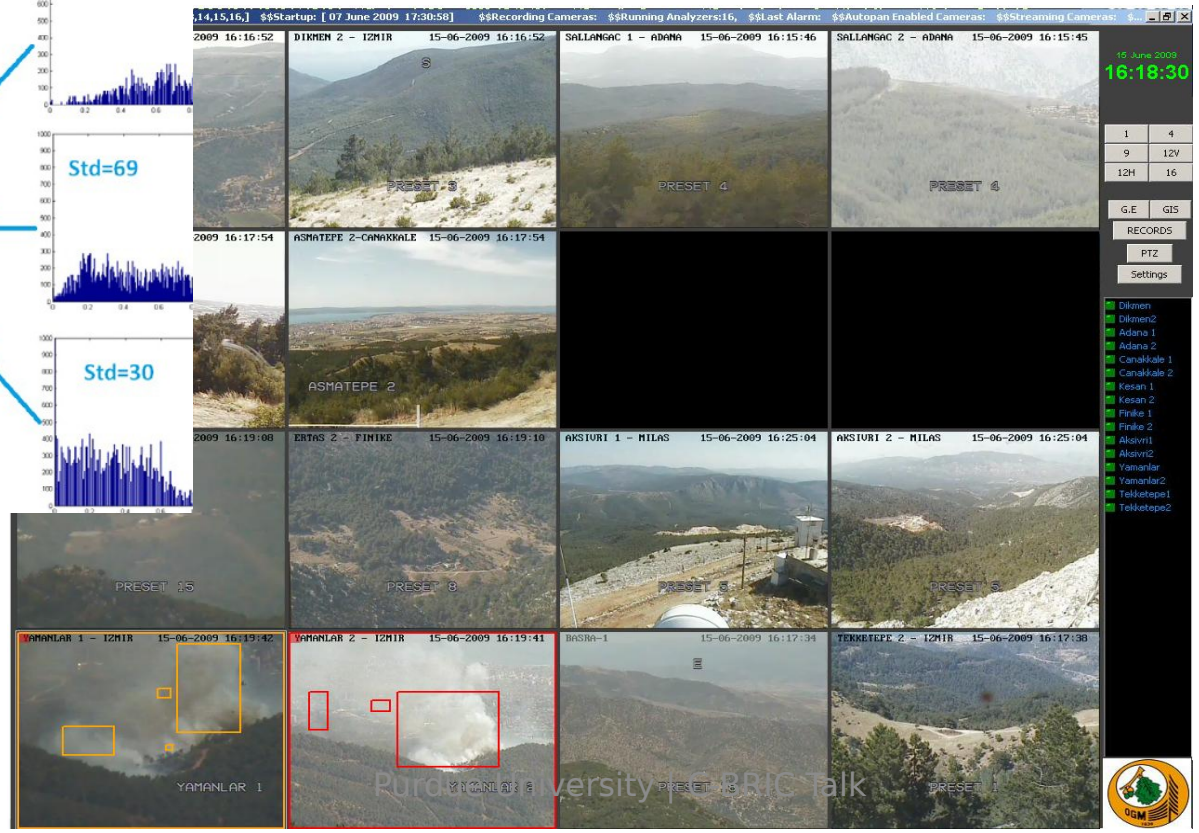
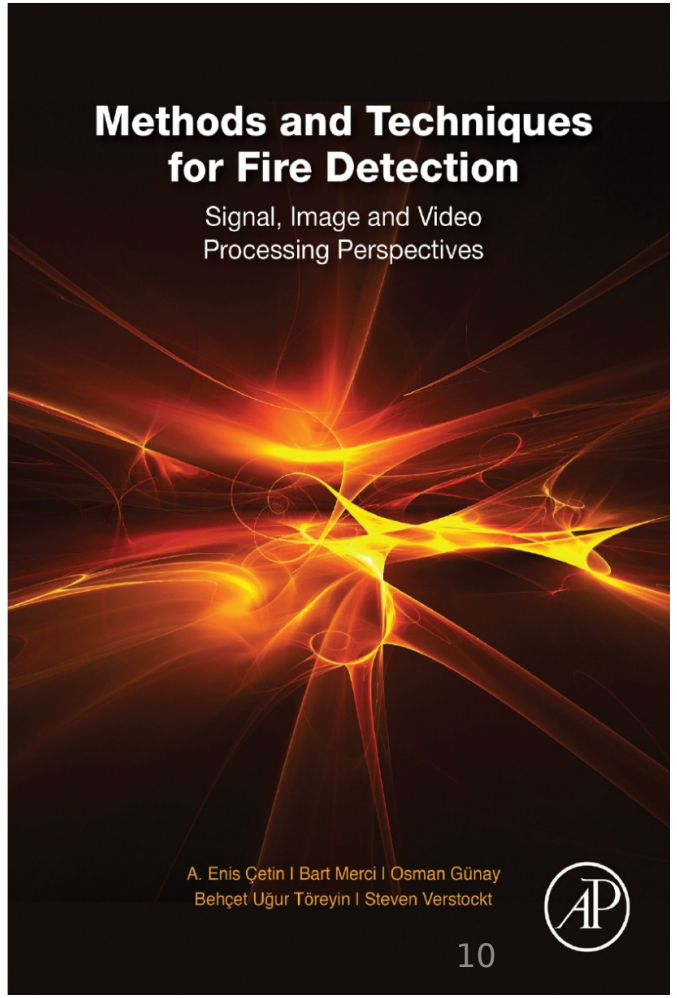
- Smoke Detection (< 30 m)

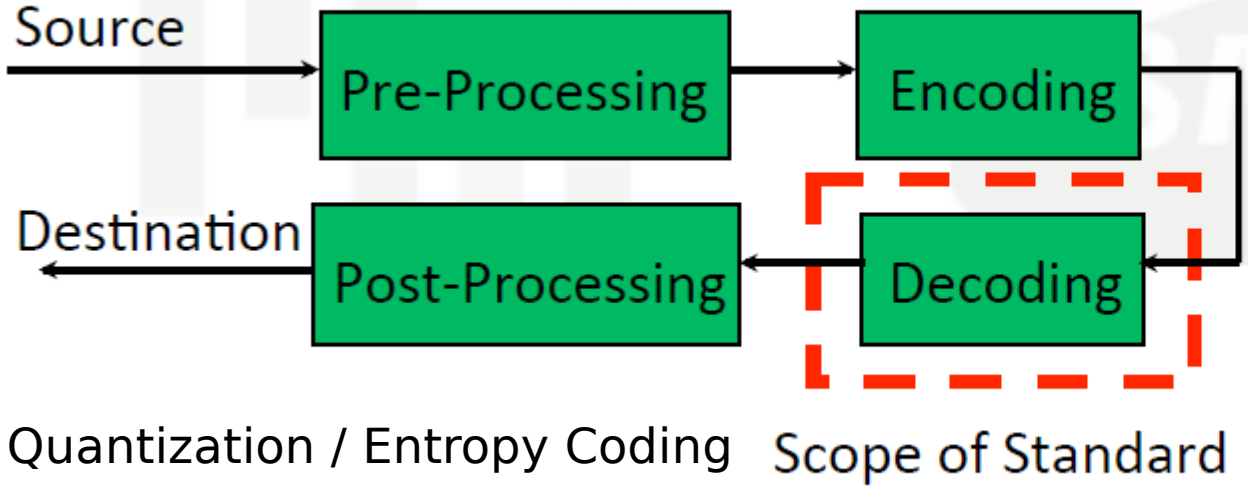


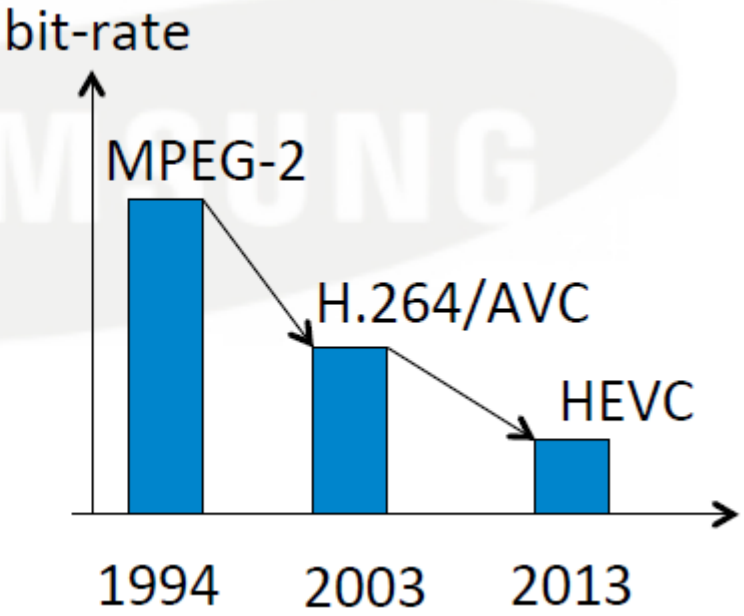




Compressed Domain Video Analysis

- Acquired video is readily available in compressed format, most of the time!
  - Decorrelates the data in all possible ways
    - Color / Temporal (Inter-) / Spatial (Intra-) Prediction
  - Makes use of transforms
    - DCT, Wavelet, DST, Fractal





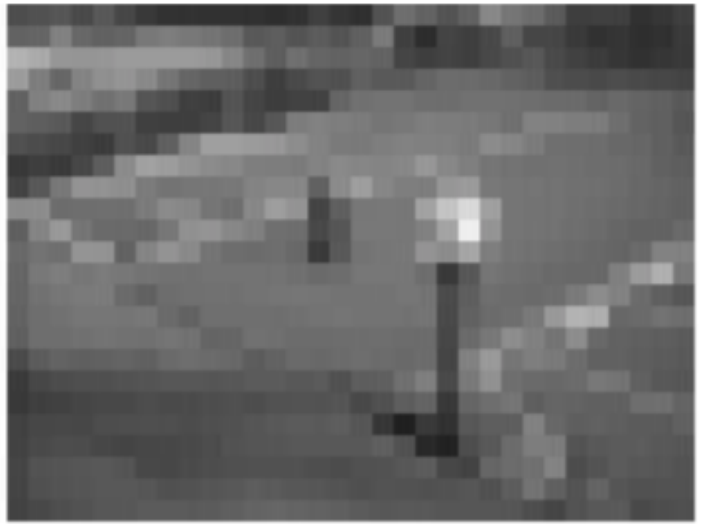
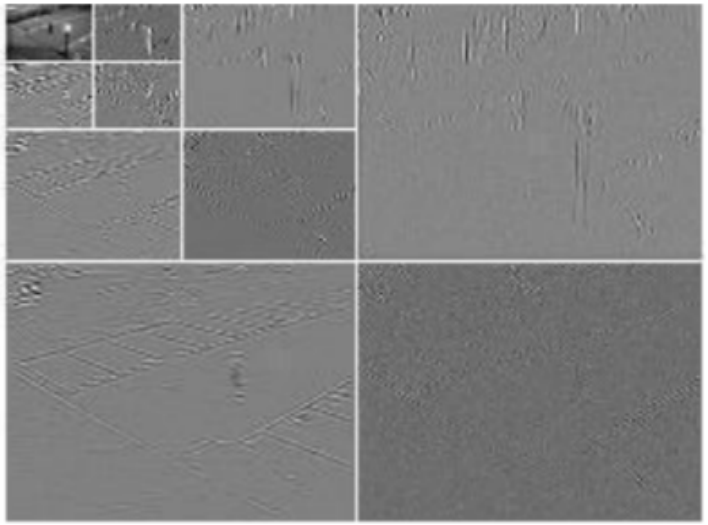
  - Vector Quantization / Entropy Coding

- Standards (MPEG – (1-4), H.264, H.265, MJPEG, MJPEG2000)
  (High-Efficiency Video Coding)

[Image Credit: Samsung/MIT Tutorial – ISCAS 2014]

Compressed Domain Video Analysis

- Why not analyze the data in compressed domain, then?
  - Moving Region Detection in Compressed Video [Toreyin et al., 2003] –
  - Compressed Domain Video Classification with Deep NN [Chadha et al., 2017]

  - Dealing with less number of coefficients
  - Paves the way for real-time processing
  - Suitable for parallel-processing
  - Edge computing / Embedded computer vision

Implementation on Crossbar Memristor Arrays?

- In contrast to CMOS technology, memristor arrays exhibit brain-like non-volatility
- Thanks to the inherent parallelism, O(1) time complexity matrix-vector multiplication may be performed [S. Liu, Y. Wang, M. Fardad and P. K. Varshney, "A Memristor-Based Optimization Framework for Artificial Intelligence Applications," in *IEEE Circuits and Systems Magazine*, vol. 18, no. 1, pp. 29-44, Firstquarter 2018]
- Possible implementation of compressed domain video analysis algorithms on memristor arrays may further enable edge-/pervasive- computing

- CV based smoke detection is a practical candidate to showcase the efficacy of memristor crossbar arrays

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Smoke Detection in Wavelet Domain

- Assumptions:
  - MJPEG2000 codec
    - Intra-frame coding based on wavelet transform (no inter-frame coding / motion compensation)
  - Fixed camera
    - Background image is estimated

- Compressed Domain Algorithm consists of two steps:
  - Motion detection using Hybrid Background Subtraction
  - Subband energy analysis

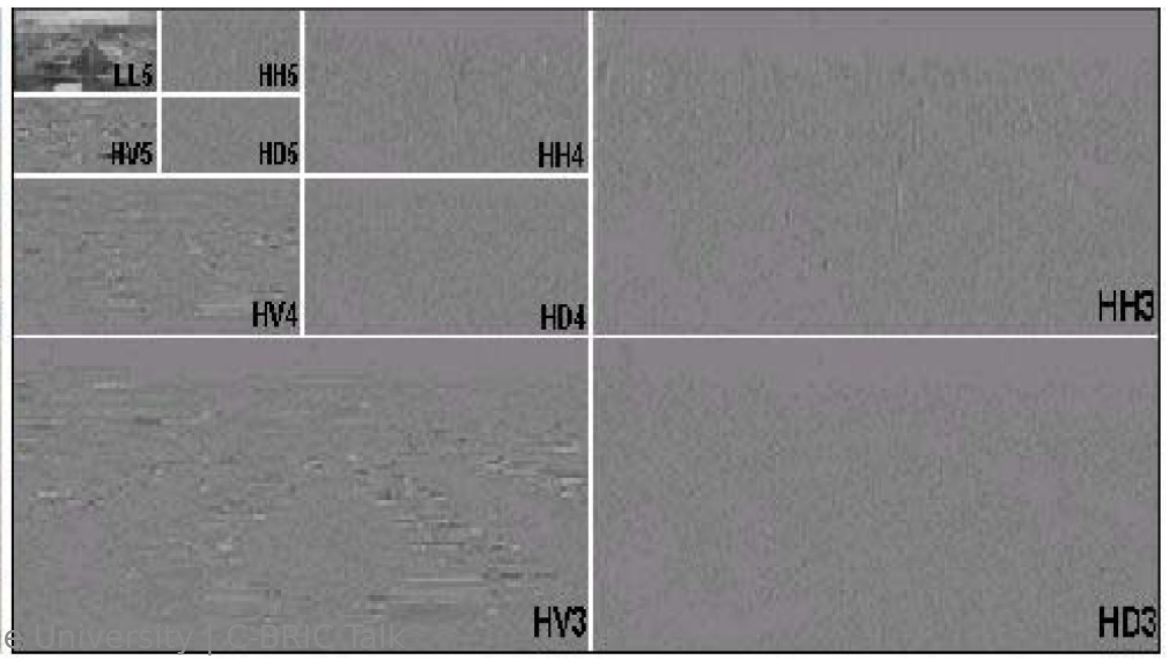
Motion Detection in Compressed Domain

$$D_{n+1}(i,j) = \begin{cases} aD_n(i,j) + (1-a)J_n(i,j) & \text{if } (i,j) \text{ is non-moving} \\ D_n(i,j) & \text{if } (i,j) \text{ is moving} \end{cases}$$

$$T_{n+1}(i,j) = \begin{cases} aT_n(i,j) + (1-a)(b\,|\,J_n(i,j) - D_n(i,j)\,|) & \text{if } (i,j) \text{ is non-moving} \\ T_n(i,j) & \text{if } (i,j) \text{ is moving} \end{cases}$$

$$|J_n(i,j) - J_{n-1}(i,j)| > T_n(i,j)$$

$$|J_n(i,j) - D_n(i,j)| > T_n(i,j)$$



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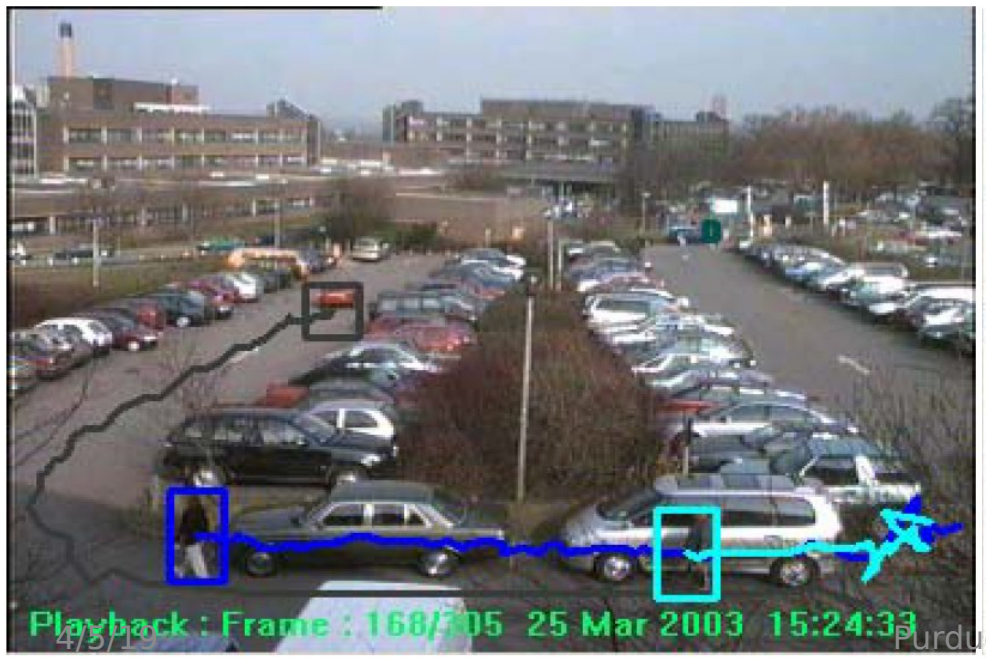
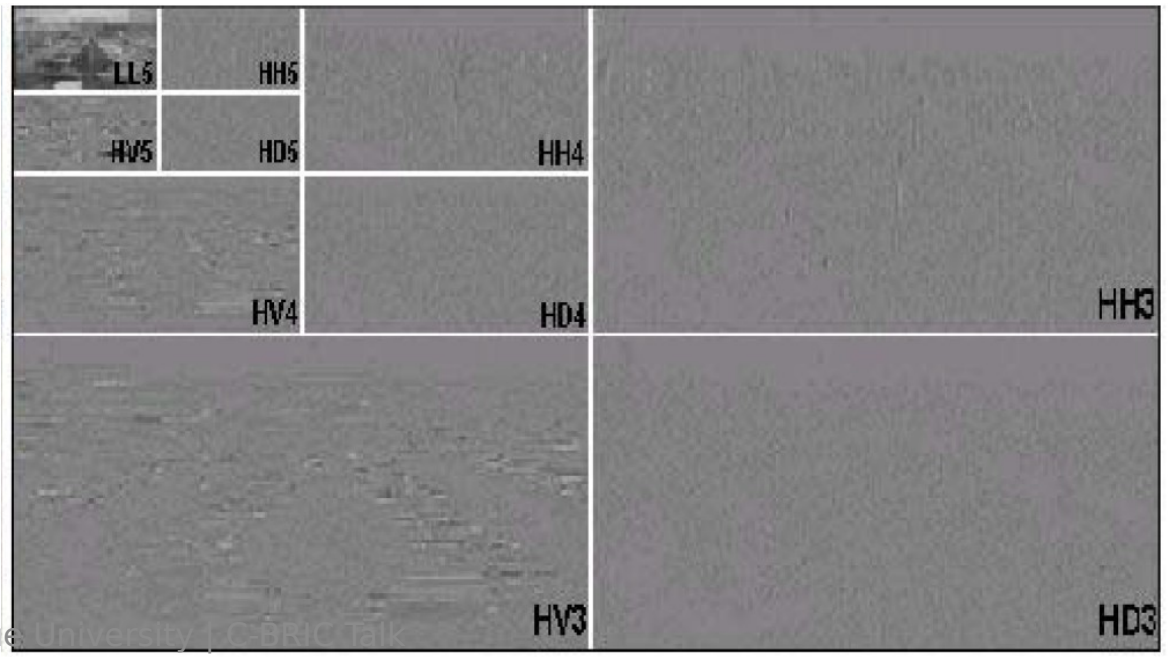
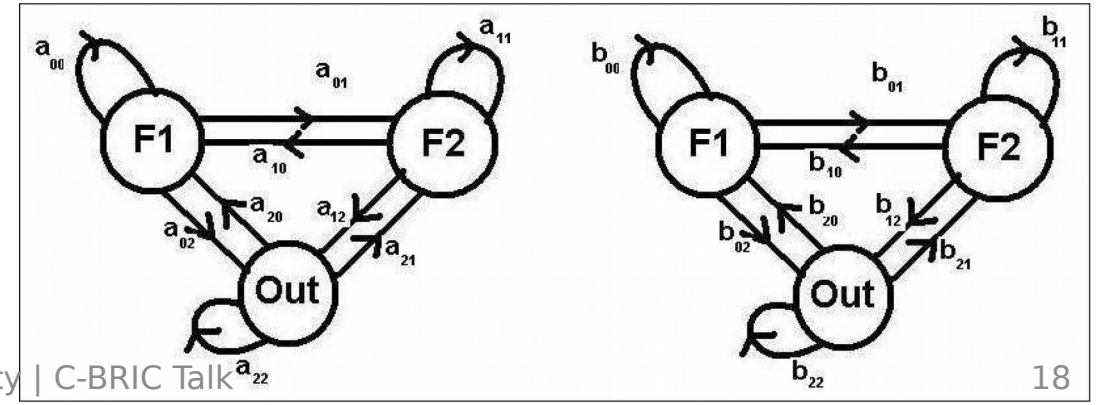




Subband Energy Analysis

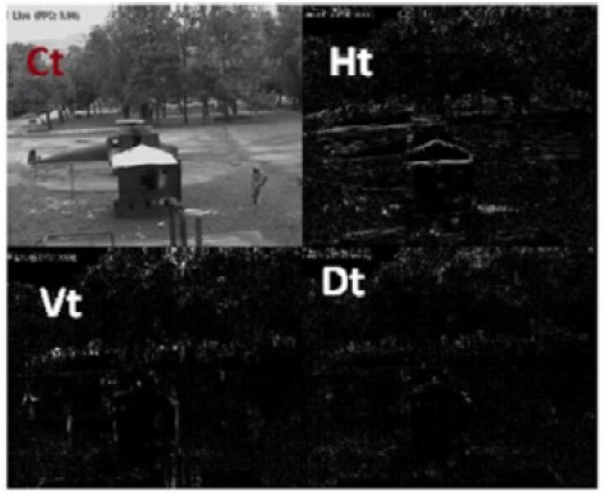
- Wavelet coefficients corresponding to Background and Current Image frames are further investigated
  - Observations:
    - «Smoke video object» degrades local subband energies
    - Fire flicker results in «random oscillations» in energy-ratio of wavelet coefficients corresponding to background and current image frame
  - Method:
    - Calculate high-subband energies: $E(I_t, b_k) = \sum_{i,j \in b_k} H_t^2(i,j) + V_t^2(i,j) + D_t^2(i,j)$
    - Represent oscillations using three-state Markov Chains
    - Transition probabilities are estimated using smoke and non-smoke moving video objects.



Smoke Video Object Causes Oscillations in High-based Energy

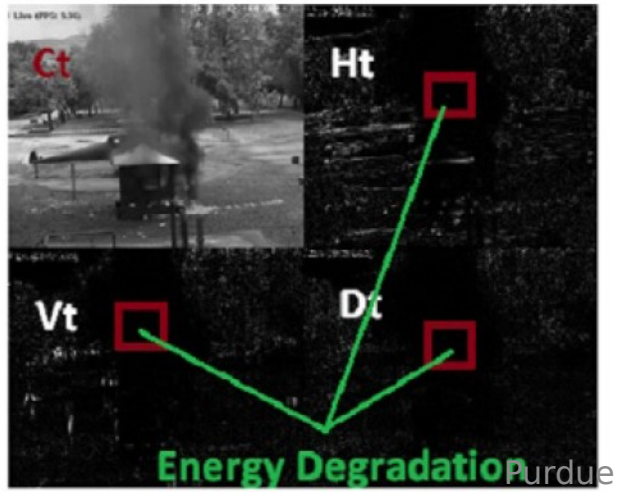
$$E(I_t, b_k) = \sum_{i,j \in b_k} H_t^2(i,j) + V_t^2(i,j) + D_t^2(i,j)$$

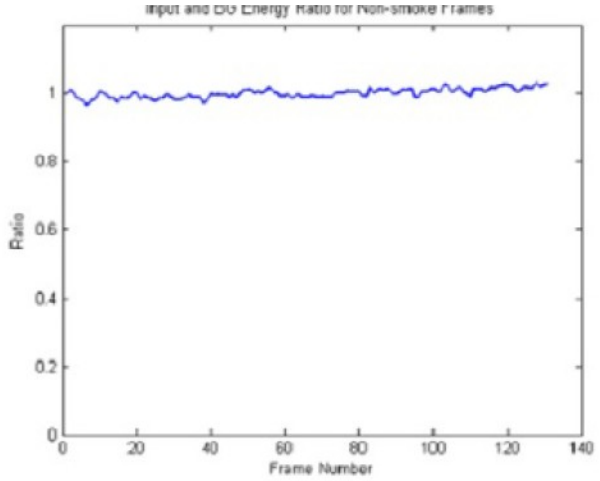
BG MODEL

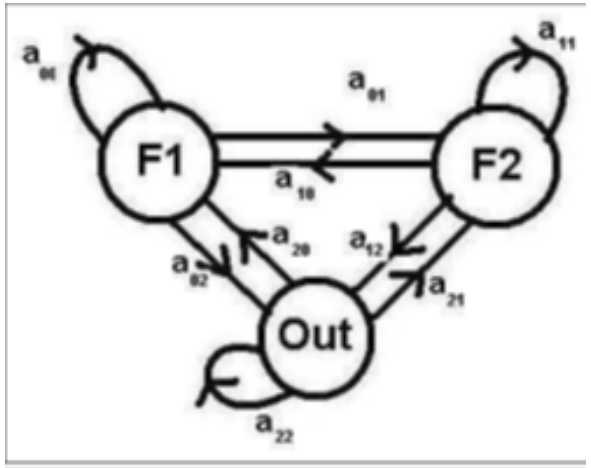


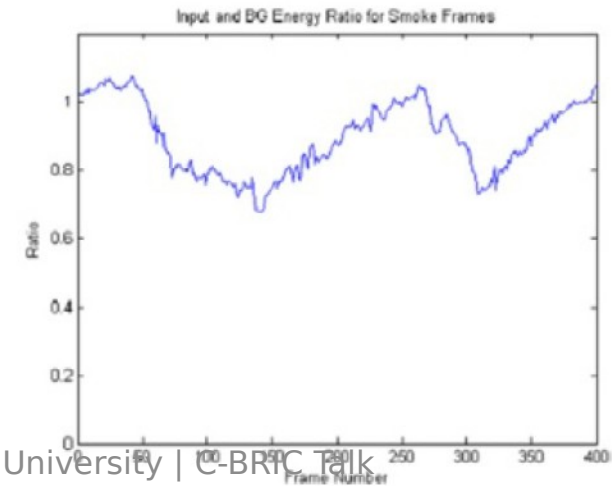
DWT Decomposition

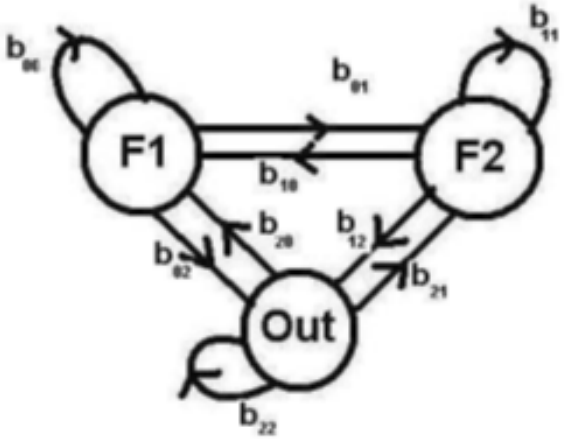
SMOKE FRAME









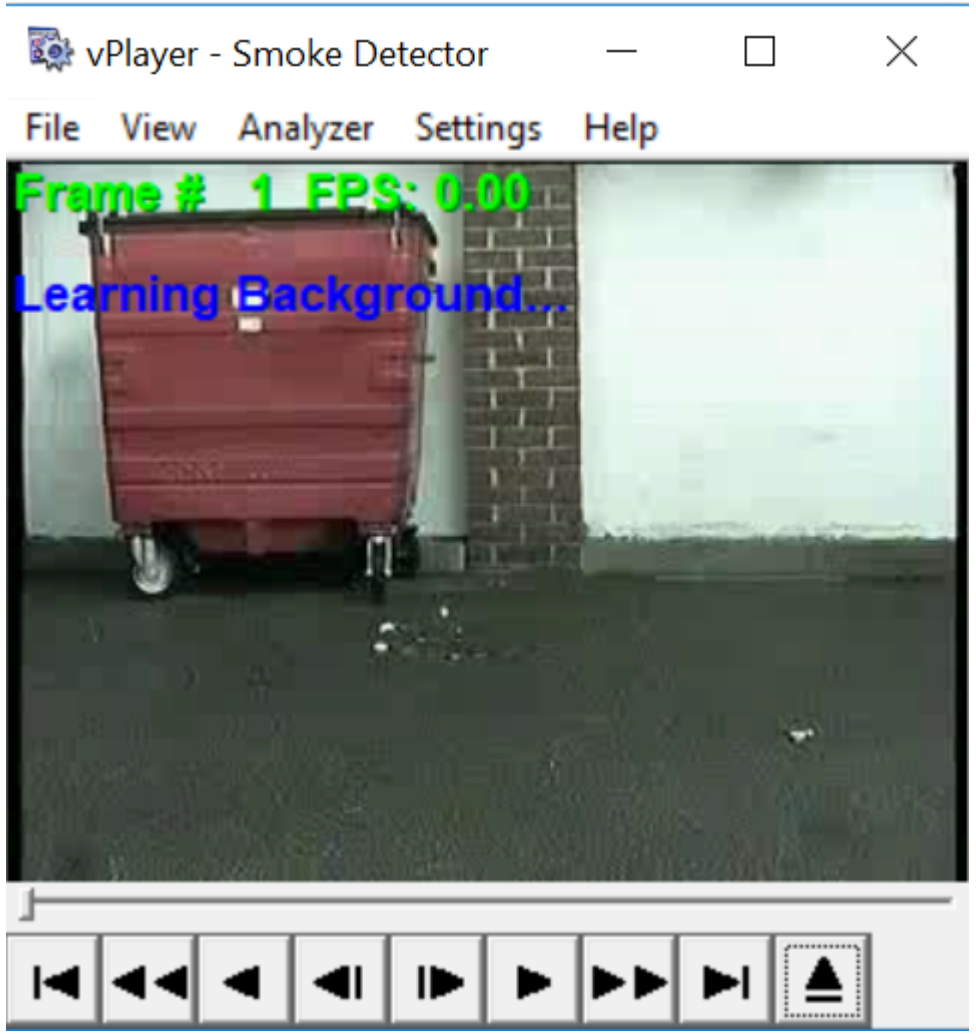


Initial Results

- Run mostly on home-made sequences.

- Tests on a larger dataset will be carried out.

- Measure of accuracy is an issue.



Outline – Part 2 (SP4CING at İTÜ)

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İstanbul Technical University – Pioneer Through the Ages

- One of the oldest engineering schools in the world
  - Dates back to 1773, Imperial School of Naval Engineering (for the Ottoman Army).
  - State – Technical University
  - 35,000+ (hard-working) Students (more than 1/3 graduate students)
  - 2,500+ (productive) Academic Staff
  - Times Higher Education Engineering & Technology Ranking 2018: 401-500
  - QS 2019 Electrical Engineering Ranking: 151-200

  - 5 (picturesque) campuses (views of which are among the best in the world :-)

Institute of Informatics

- Offers MS and PhD degree programs in different disciplines of informatics:
  - Computer Science
  - Applied Informatics
  - Cyber-security and Cryptology
  - Remote sensing and Satellite Communications
  - Computational Science and Engineering
- Number of full-time faculty members (PhD holders): 14
- Number of students: 700+

Signal Processing for Computational Intelligence Group (SPACING)

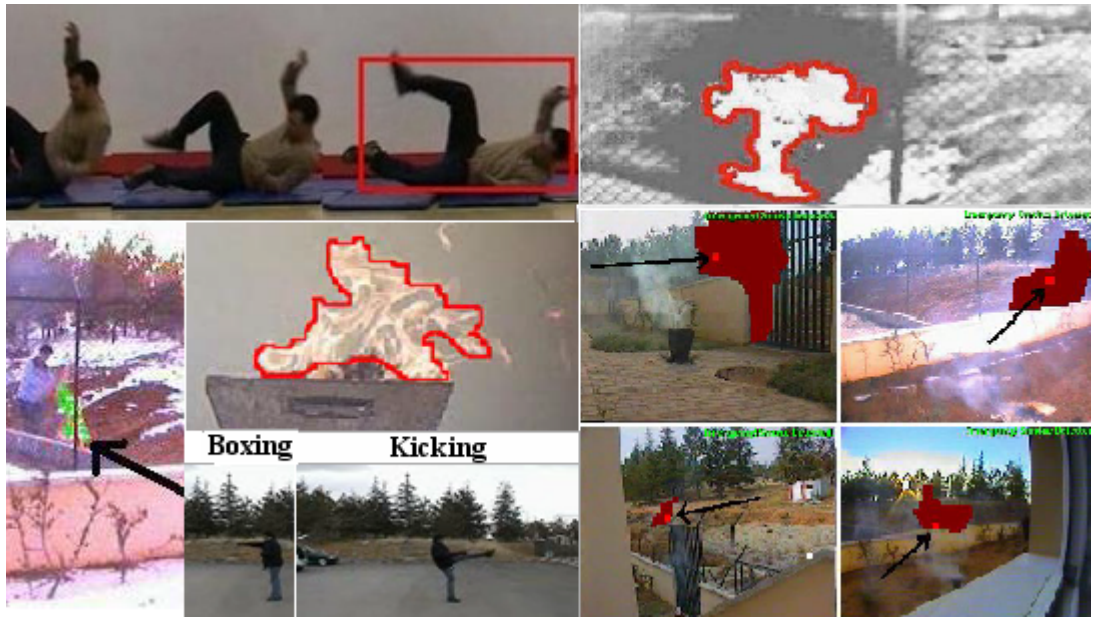
- Founded in Feb. 2018 | 20+ Members (PhDs/ Grad. Students)
- Research Focus:
  - Design novel and/or apply existing signal processing tools/techniques for computational intelligence applications

- Applications/Directions:
  - Multi-modal Surveillance [Compressed Domain Analysis, Video/Audio/PIR sensor analysis]
  - Bioimage analysis [Digital Pathology, Myelin Quantification, Karyotyping/super resolution]
  - Environmental Monitoring [Forest Fire Detection, Fish Tracking, Soil Moisture Monitoring, Wind Speed/Turbulence Estimation]
  - Remote Sensing [Hyperspectral Data Compression, Anomaly Detection]
  - UAVs [Image Analysis based Autonomous Landing]
  - Superconductor Sensor Analysis [Seismic Signal Analysis]

Unusual Event Detection Research Experience

· Develop algorithms to analyze contents of and compress signals from multitude of sensors such as

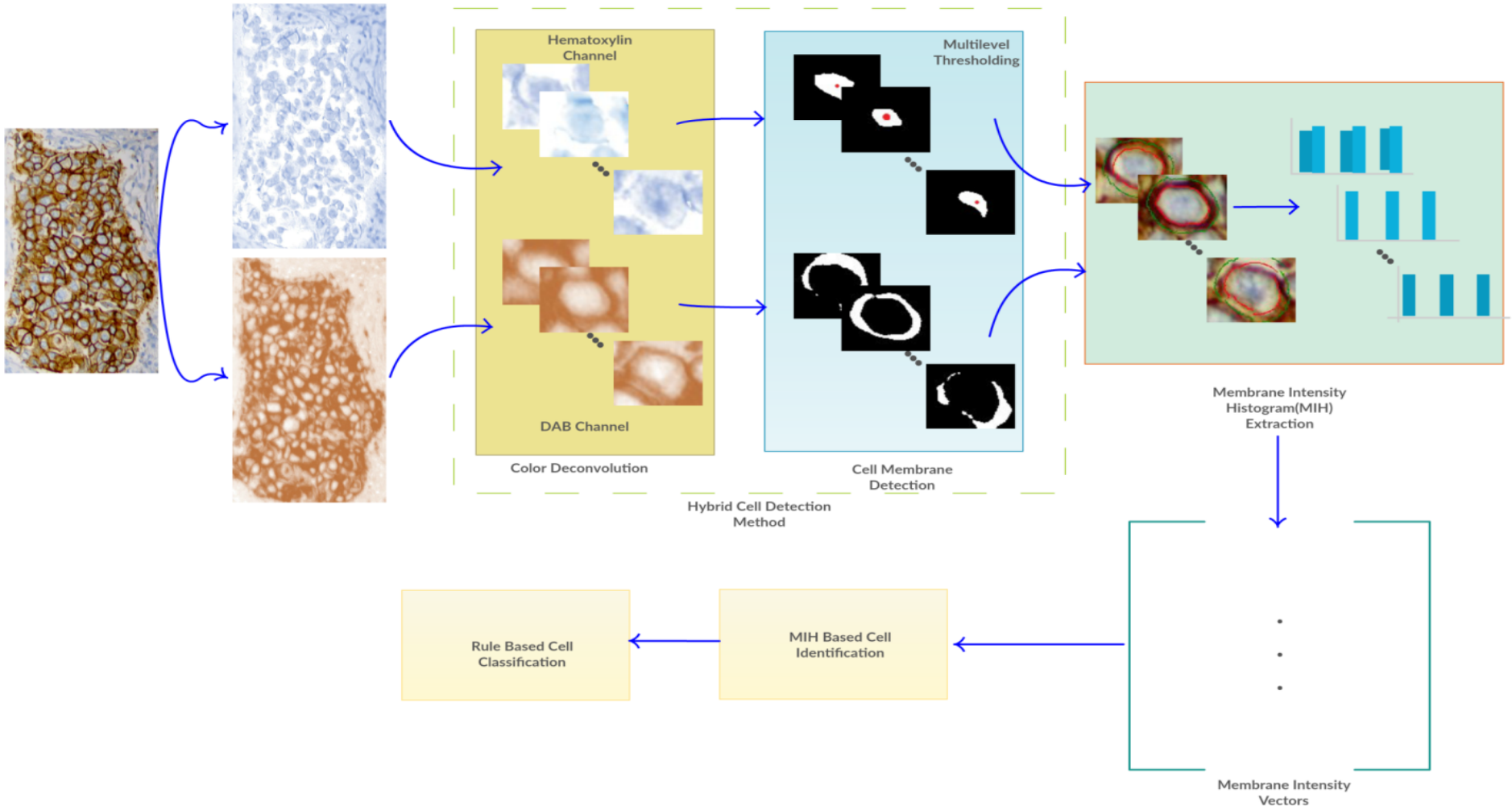
•Visible/IR/hyperspectral cameras
•microphones
•passive IR sensors
•vibration sensors
•spectrum sensors.



· Developed signal processing algorithms for hyperspectral data compression, forest fire, flame/smoke, volatile organic compound, falling person detection in video and using other sensing modalities.

· Serving as PI, researcher and consultant for projects funded by TÜBİTAK, EU FP6/FP7, NSF, Qatar Foundation,
Türk Telekom, surveillance and intelligent building companies for 17 years.

Digital Pathology



- In order to mitigate the inter-observer discrepancy, novel image analysis methods are developed to determine the **score** of the cerbB2 tissue sample.
- For this purpose, tissue samples are analyzed on a **cellular basis** where each cell is identified using membrane based **feature**

Hyperspectral Data Analysis / Compression

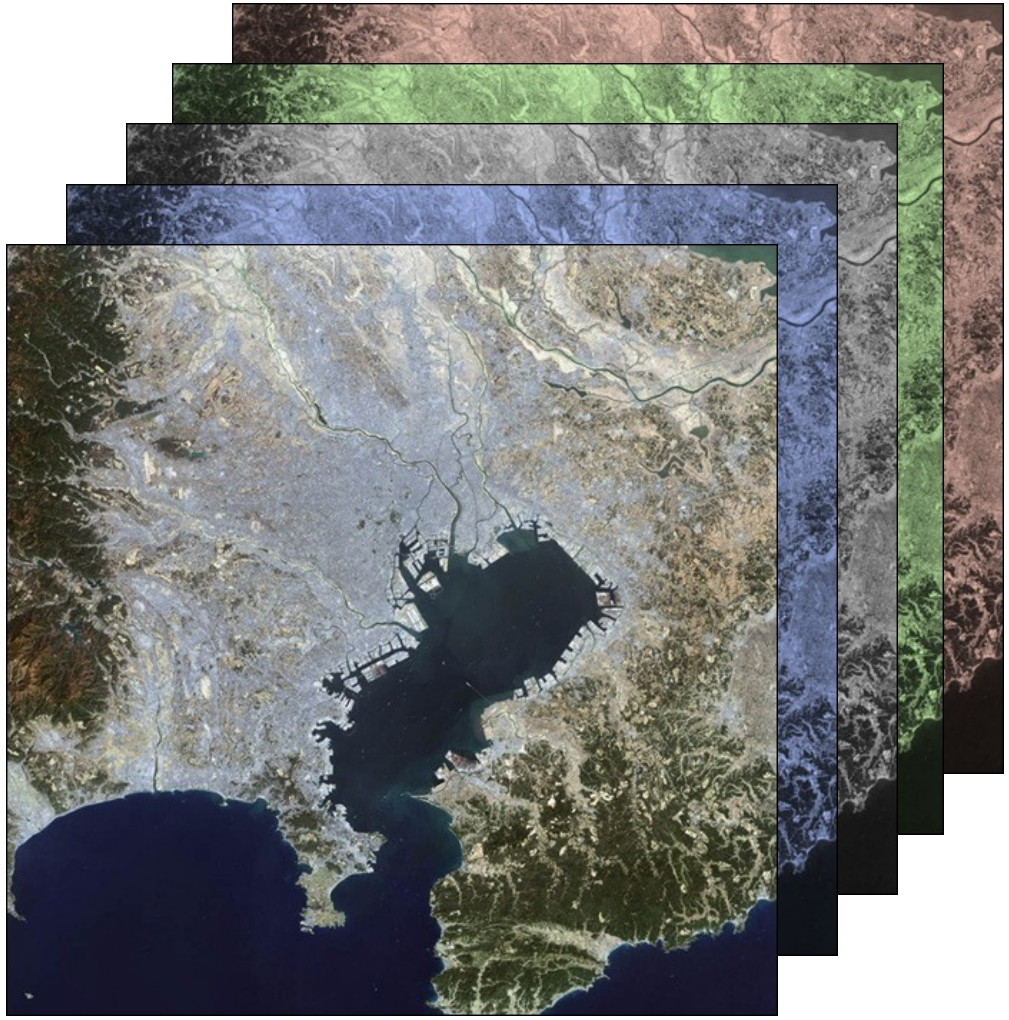
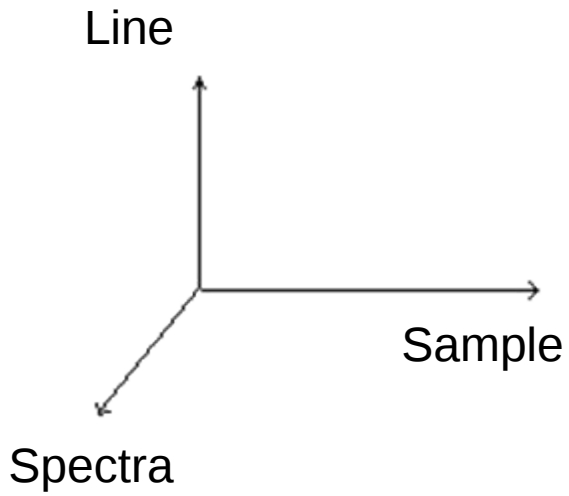
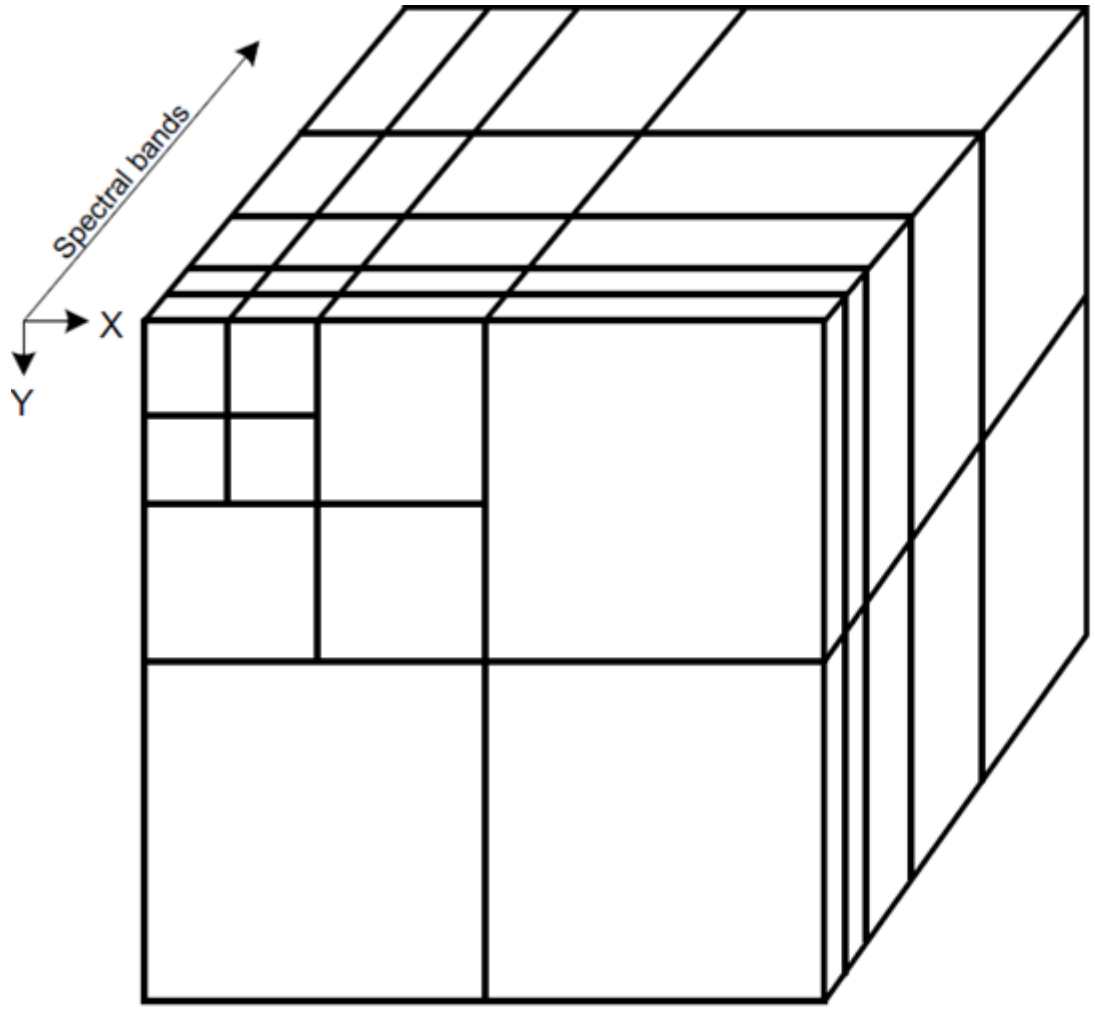
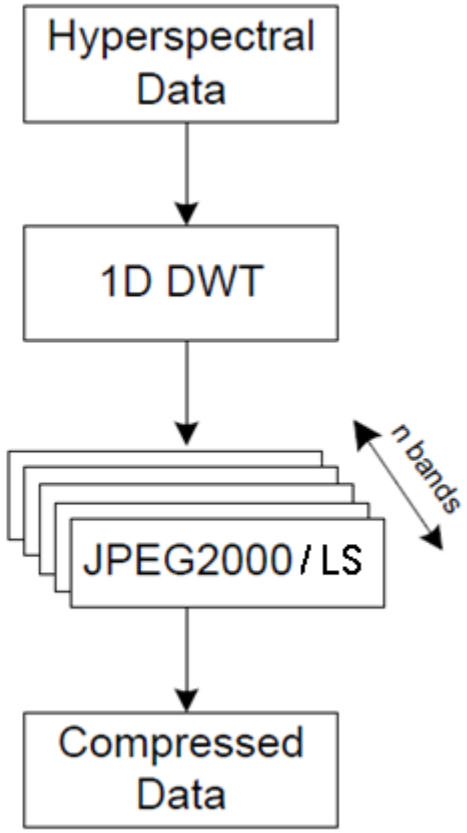


Image Credit:
NASA's Goddard Space Flight Center, Tokyo Metropolitan Area



Lossless : Spatial (2D) + Spectral Compression





Lossy : Sparse Coding Based Compression

Express data in terms of;

- Few number of dictionary elements

x_t : Training sample vector
α_t: Sparse coefficient vector
D_{t-1}: Dictionary Matrix

t=1,..., T.

- Basis Pursuit Approach

$$\alpha_t = \arg\min_{\alpha \in R^k} \|\alpha\|_1 \quad \text{subject to} \quad x_t = D_{t-1}\alpha$$

Force coefficients α;
To be as sparse as possible

Force coefficients α;
To satisfy the value of the training sample x_t

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- It is also part of a project that has received funding from the European Union's H2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 691178.