Smoke Detection in Stationary Video Using Wavelets

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The Problem:

VIDEO:

Standard techniques for fire or smoke detection:

- Indoor smoke detectors
  - ionization
  - photoelectric
  - air-sampling
  - CO or CO_2 sensors
- Infra-red sensors/cameras

Techniques for fire/smoke detection with stationary video:

- Fourier analysis - using the flickering of flames
- Luminance/chrominance energy measurements (for color videos)
- A wavelet technique - high frequency energy measurements

Prerequisites for students are quite minimal:

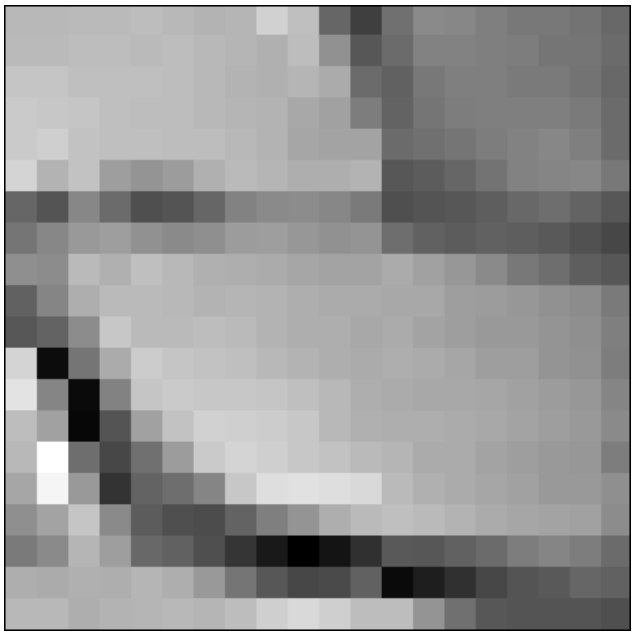
- Basics of Digital Signal Processing
- Some knowledge of the basic wavelet transforms and their application to digital images
- Familiarity with *Mathematica* or *MatLab*

Expected Student Outcomes:

- Students will get a flavor of the ideas and issues involved in applying mathematics to a relevant engineering problem.
- Students will develop a deeper understanding of wavelet transforms and their applications.
- Students will improve their programming skills.

Each pixel in a gray-scale image is represented by an integer between 0 and $255 = 2^8 - 1$ (8 bit = 1 byte)

0=black, 255=white



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136	136	132	134	135	136	135	138	145	149	145	138	138	122	108	98	97	97	97	95

A color image consists of three color channels: Red, Green and Blue

R

G

B

The Red, Green and Blue color channels can be thought of as grayscale images:

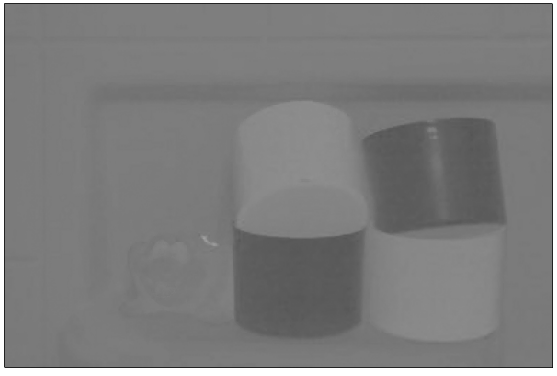
R

G

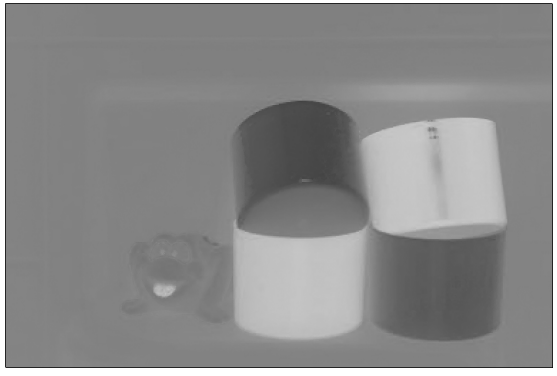
B

For many applications it is more useful to split the color information into a **luminance** channel (Y) and two **chrominance** channels (Cb and Cr) instead:

Y



Cb



Cr

Energy is a measurement of the brightness of a grayscale image.
For a matrix $A = (a_{ij})$, its energy $E(A)$ is defined as

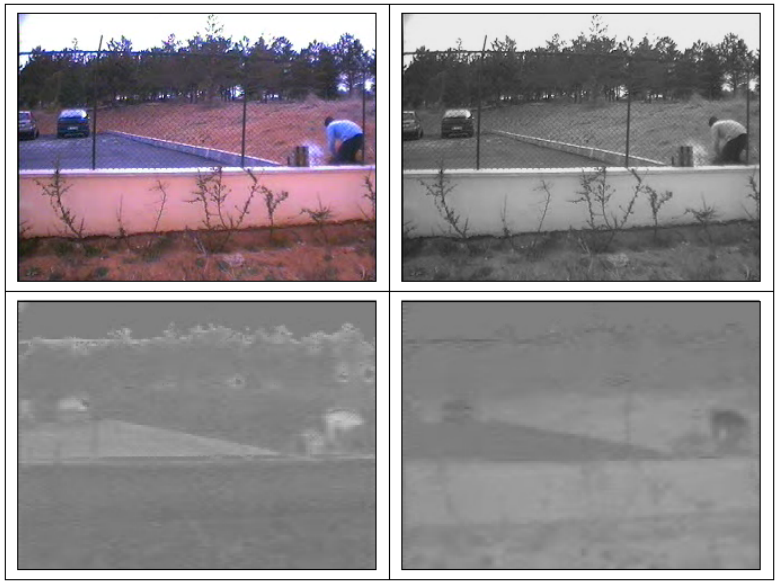
$$E(A) = \sum_i \sum_j a_{ij}^2.$$

(This is just the square of the 2-norm of A.)
A brighter image will have higher energy than a darker one.

Smoke Detection Idea #1:
Smoke makes an image grayer and less colorful.

Thus an increase in the ratio between the energy of the luminance channel and the combined energy of the chrominance channels should be an indicator for the presence of smoke.

VIDEO: Luminance vs. Chrominance Energy Ratio:



Our next technique works for grayscale videos. In case of a color video, we will use its luminance channel.
Wavelet transforms separate the low-frequency content of an image from the high-frequency content.

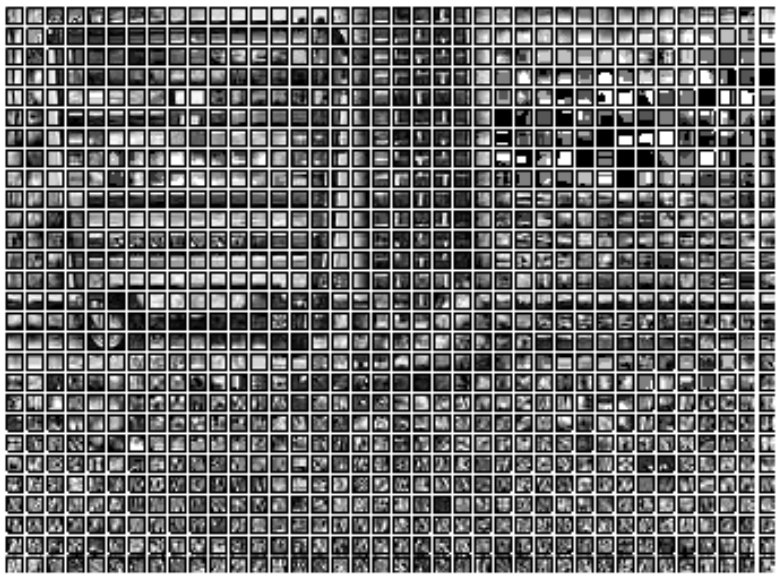
Smoke Detection Idea #2:
Smoke obscures edges.

Thus a decrease in the combined energy of the high-frequency portions of an image should be an indicator for the presence of smoke.
(Note that this will detect smoke only if edges are present.)

VIDEO: High-frequency Energy:

This technique can be refined to identify smoke regions within the video images.

1. Each image is partitioned into sub-images of size 8×8 pixels each.



2. The wavelet transform is computed for each sub-image.
3. The energy of the high-frequency portions is computed for each sub-image.
4. The first (smoke-less) frame of the video is now used as a reference frame.

5. The energies computed are subtracted from the corresponding energy values of the reference frame.
6. The result is visualized.
   - If the high-frequency energy of a region decreases, a positive value will result in Step 5, leading to a bright pixel.
   - If the high-frequency energy of a region increases or remains unchanged, a non-positive value is computed in Step 5, leading to a black pixel.

VIDEO: High-frequency Energy:

References

- B. Ugur Toreyin, Yigithan Dedeoglu & A. Enis Cetin: *Contour Based Smoke Detection In Video Using Wavelets.* Proceedings of the 14th European Signal Processing Conference (EUSIPCO 2006).
- Videos: http://signal.ee.bilkent.edu.tr/VisiFire/Demo/SampleClips.html
- Video frame extraction program: VirtualDub-1.9.11

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