The Abdus Salam
International Centre
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United Nations
Educational, Scientific and
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2384-16

ICTP Latin-American Advanced Course on FPGADesign for Scientific Instrumentation

19 November - 7 December, 2012

Advanced topics in signal processing

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advanced topics in signal processing
lecture 1

introduccion al procesamiento biologico de señales: que oímos?

marcelo magnasco
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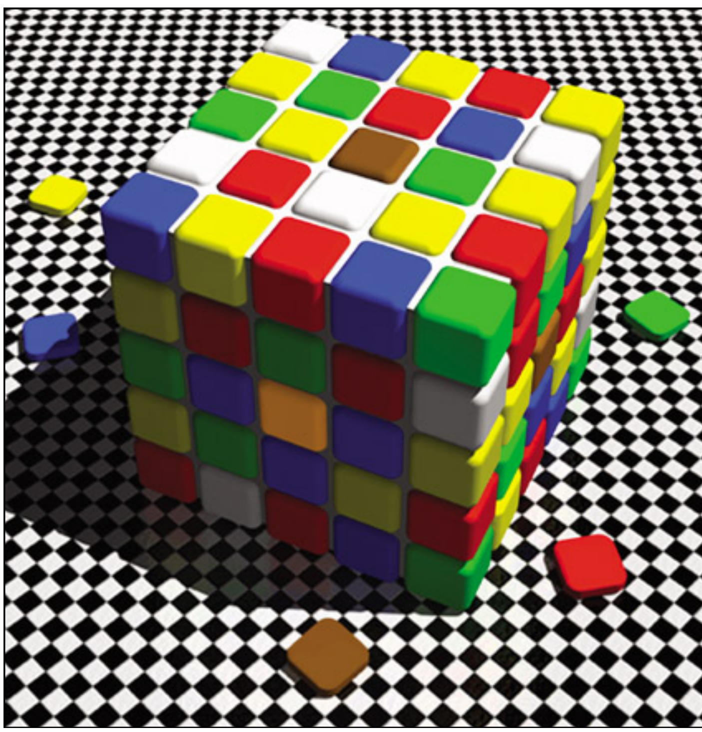
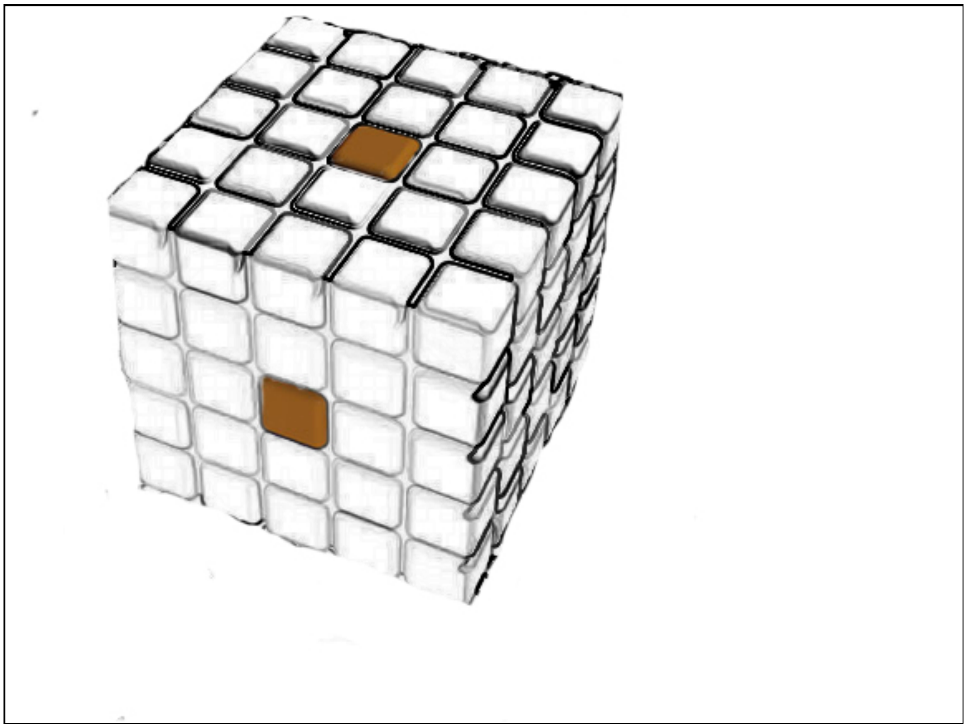
universidad de las ciencias informaticas, havana, cuba, noviembre 2012

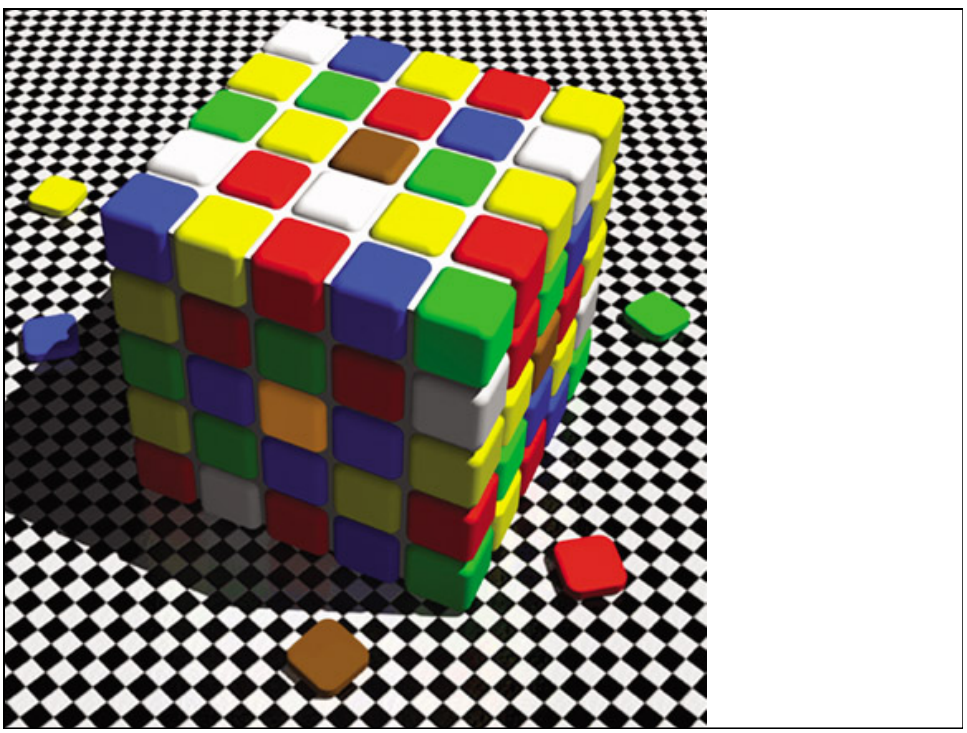
sopranos

- cheryl studer
- edita gruberova
- florence foster-jenkins

what exactly is the color "brown"?







our senses parse entire scenes at a time, separating attributes of the objects being looked at (albedo of surfaces) from the attributes of the scene (direction of incident light) from the attributes of our own relationship to the scene ("shiny" reflectivity) into separate percepts.

therefore concepts such as "color" end up being extremely complex because they are anchored in the relationship of an object to an entire scene to the viewer

important: most modern display systems do not change with relationship to viewer --- "immersive" technologies do change with viewer's motions.

we mix audio and video

- localization of simultaneous click and flash (which are displaced from one another) show we trust hearing ~ 1/3 and vision ~ 2/3
- manipulation of video stream of human vocalization shows we "hear" different syllables when the video and audio are mismatched

a rich auditory world

I hear the rain pattering on the roof above me, dripping down the walls to my left and right, splashing from the drainpipe at ground level on my left, while further over to the left there is a lighter patch as the rain falls almost inaudibly upon a large leafy shrub. On the right, it is drumming, with a deeper, steadier sound upon the lawn. I can even make out the contours of the lawn, which rises to the right in a little hill. The sound of the rain is different and shapes out the curvature for me. Still further to the right, I hear the rain sounding upon the fence which divides our property from that next door. In front, the contours of the path and the steps are marked out, right down to the garden gate. Here the rain is striking the concrete, here it is splashing into the shallow pools which have already formed. Here and there is a light cascade as it drips from step to step. The sound on the path is quite different from the sound of the rain drumming into the lawn on the right, and this is different again from the blanketed, heavy, sodden feel of the large bush on the left. Further out, the sounds are less detailed. I can hear the rain falling on the road, and the swish of the cars that pass up and down. I can hear the rushing of the water in the flooded gutter on the edge of the road.

John Hull, *Touching the Rock*

numbers don't lie

- 200'000'000 photoreceptors in two retinas
- 100'000'000 olfactory receptors
- 20'000'000 tactile- noci- and propio- receptors

- 7'000 inner hair cells

very different density of information in bits/sec/cell

what's in a voice?

the text
the volume of the utterance
the emotional stance
the identity of the speaker
the speaker's accent
the distance to the speaker
the position of the speaker
the orientation of the speaker
an impression of the room

a multitude of percepts!

we hear things that move

I can tell when other things are moving by the sounds they make. Cars swish past, feet patter along, leaves rustle, but a silent nature is immobile. So it is that, for me, the clouds do not move.

John Hull, Touching the Rock

why sounds wake us up

many sounds have survival and evolutionary importance: we perceive things that make noise

that includes *living beings*, especially predators, prey, offspring and mates,

and many *inanimate things* on which our survival hinges, such as fire, water, wind and earth.

we can even hear things that do not make sounds

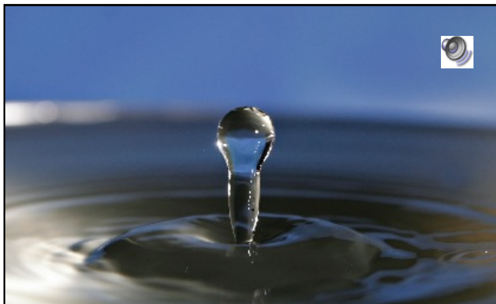
a current project: sound textures

sounds such as rain, fire crackling,
brook babbling, windblown leaves

they are important because:
- they have great survival (ecological) value,
- we inattentively recognize them extremely fast,
- they are powerful modulators of emotional state.

scale changes

/4 /2 normal speed *2 *4



$r_{i,1} \quad r_{i,2} \quad r_{i,3}$

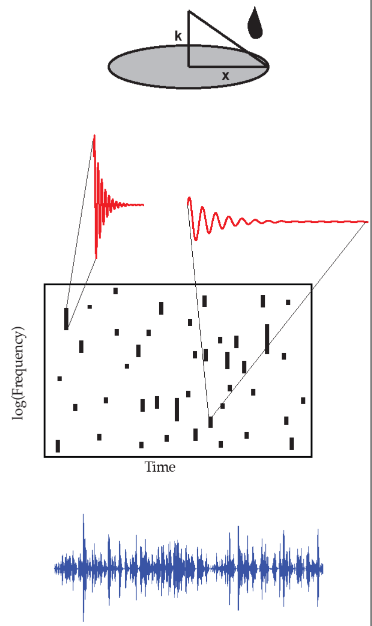
$t_i = a r_{i,1}$

$\omega_i = \exp(r_{i,2})$

$x_i = \sqrt{r_{i,3}}$

$$s_i(t) = \frac{1}{\sqrt{k^2 + x_i^2}} t \exp\left(\frac{-\omega_i t}{Q}\right) \sin\left(2\pi\omega_i t\right)$$

$$S(T) = \sum_{i, t_i < T} s_i(T - t_i)$$



the uncertainty principle

$$P(t) = \frac{|x(t)|^2}{\int_{-\infty}^{\infty} |x(t')|^2 dt'}$$

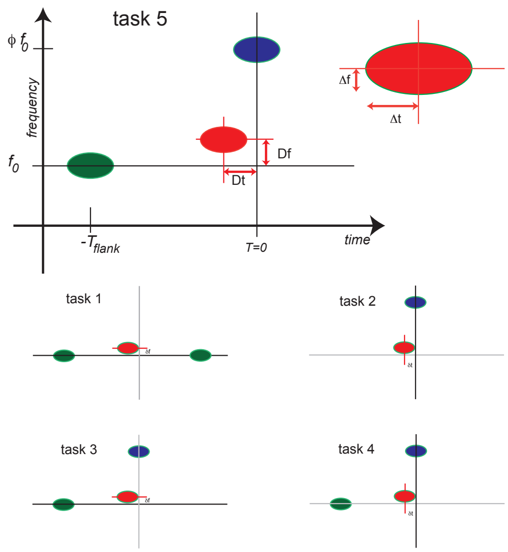
$$P(f) = \frac{|\tilde{x}(f)|^2}{\int_{-\infty}^{\infty} |\tilde{x}(f')|^2 df'}$$

$$4\pi \Delta t \, \Delta f \geq 1$$

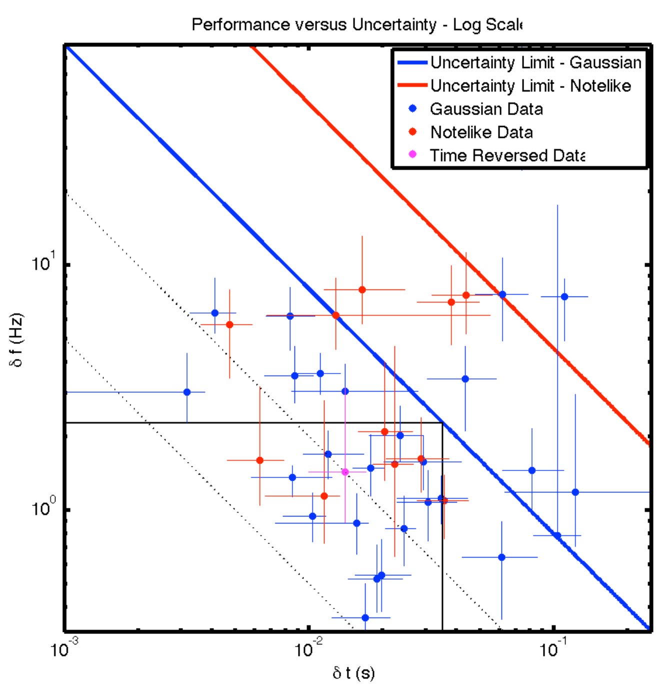
refers to individual time or frequency representations. as far as time-frequency representations are concerned, it only needs to be obeyed by first-order operators. cohen's class operators, as well as more nonlinear representations (spectral derivatives, huang-hilbert, reassigned) do not need to observe this

in this setting the uncertainty principle limits *resolution* as opposed to *accuracy*

time-frequency uncertainty



Distinguish between
Δt and Δω (physical)
δt and δω (psychological)



phases and amplitudes

Consider a signal x(t) contained in a Python or Matlab variable x[i], and create two new signals

```
xw = ifft(  fft(x) ./ abs(fft(x)) )

eta = exp(2j*pi* rand( length( x ), 1 ) )

xs = real( ifft( fft(x) .* eta ) )
```