E9 205 Machine Learning for Signal Processing

Feature Extraction

08-08-2016

Established
1911

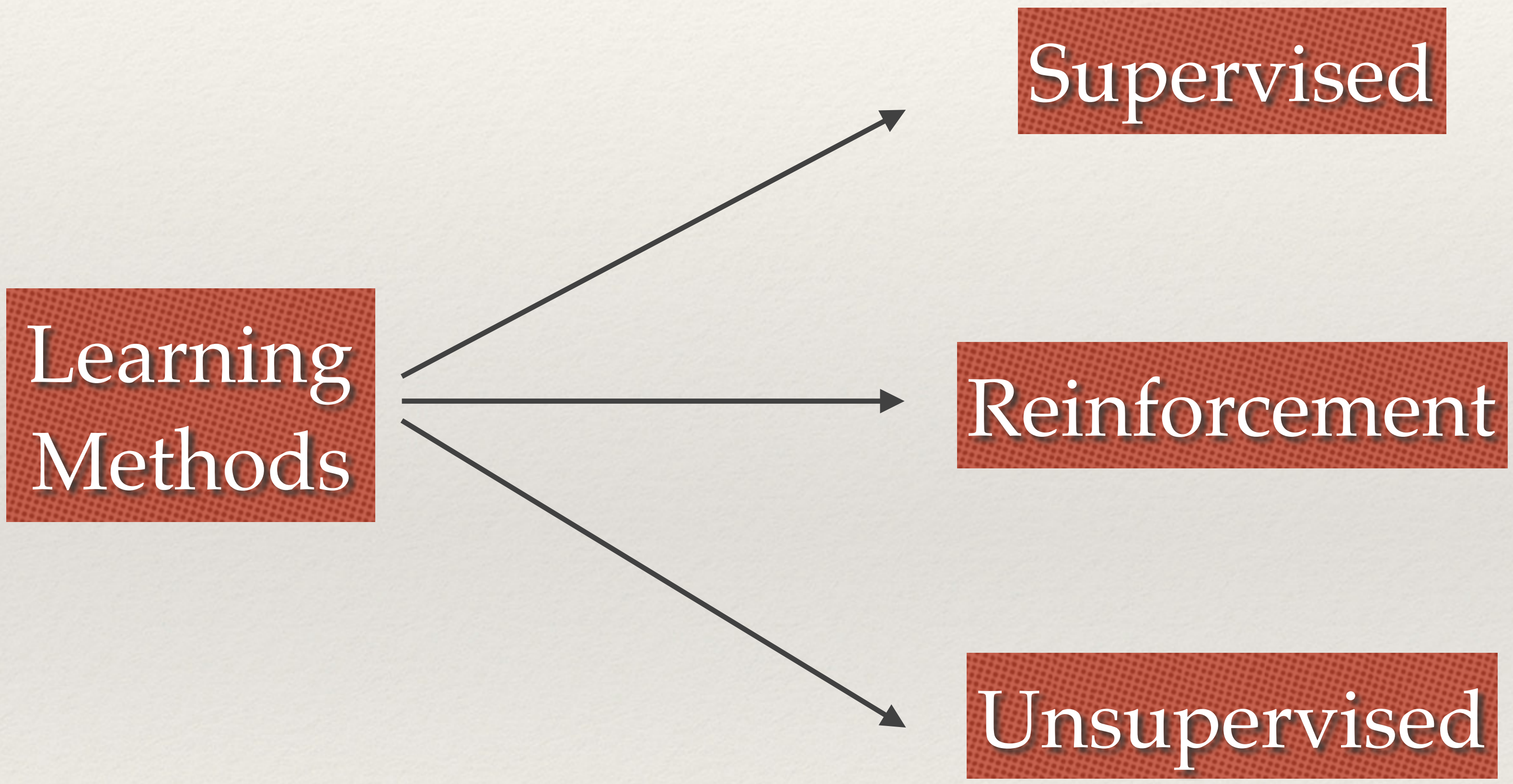
INDIAN INSTITUTE OF SCIENCE
भारतीय विज्ञान संस्थान

Recap

- Real-world signals
  - Patterns in signal
- Learning - uncovering the underlying patterns
- Roadmap of the course

Established
1911

Types of Learning



Camstra, Vinciarelli, “Machine Learning for Audio, Image and Video Analysis” 2007.

Unsupervised Learning

- Data is presented without associated output targets
  - Extracting structure from the data.
  - Examples like clustering and segmentation.
  - Concise description of the data - dimensionality reduction methods.

Reinforcement Learning

- Dynamic environment resulting in triplets - state/action/reward.
  - No optimal action for a given state
  - Algorithm has to learn actions in a way such the expected reward is maximized over time.
  - May also involve minimizing punishment.
  - Reward/punishment could be delayed - learning based on past actions.

Sutton, Barto, "Reinforcement Learning: An Introduction." MIT Press, 1998.

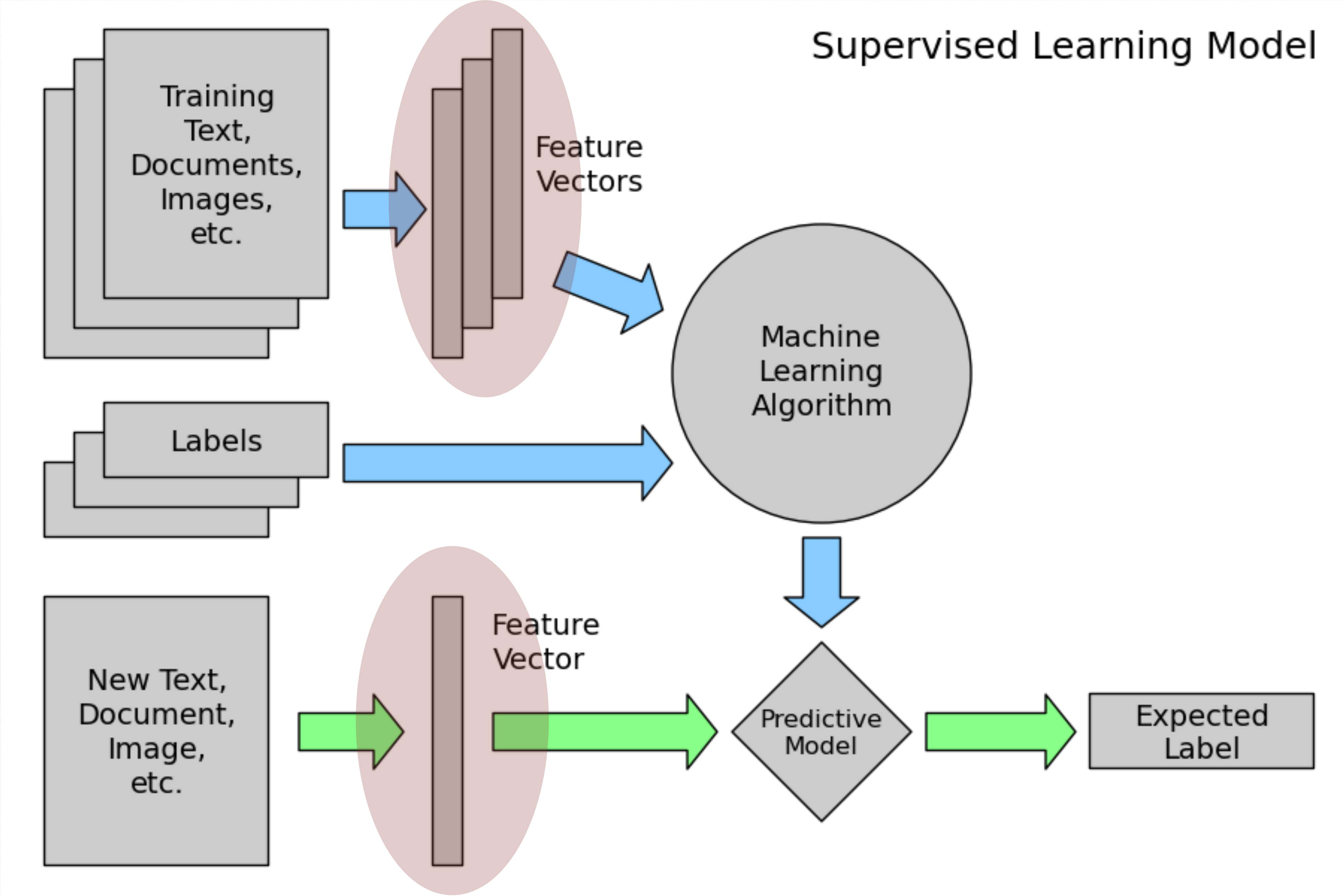
Supervised Learning

- Training data is provided with along with target values (ground truth).
  - Goal - to learn the mapping function from data to targets.
  - Use the mapping function to predict unseen/test data samples.
- Two types based on the structure of the labels.
  - Classification - discrete number of classes or categories.
  - Regression - continuous output variables.

Established 1911

INDIAN INSTITUTE OF SCIENCE
भारतीय विज्ञान संस्थान

Supervised Learning



http://www.astroml.org/sklearn_tutorial/auto_examples/plot_ML_flow_chart.html

Established 1911

INDIAN INSTITUTE OF SCIENCE
भारतीय विज्ञान संस्थान

Feature Extraction

- Feature Extraction
  - Using measured data to build desirable values.
  - Attributes of the data that are informative and non-redundant.
  - Resilience to noise/artifacts.
  - Facilitating subsequent learning algorithm.

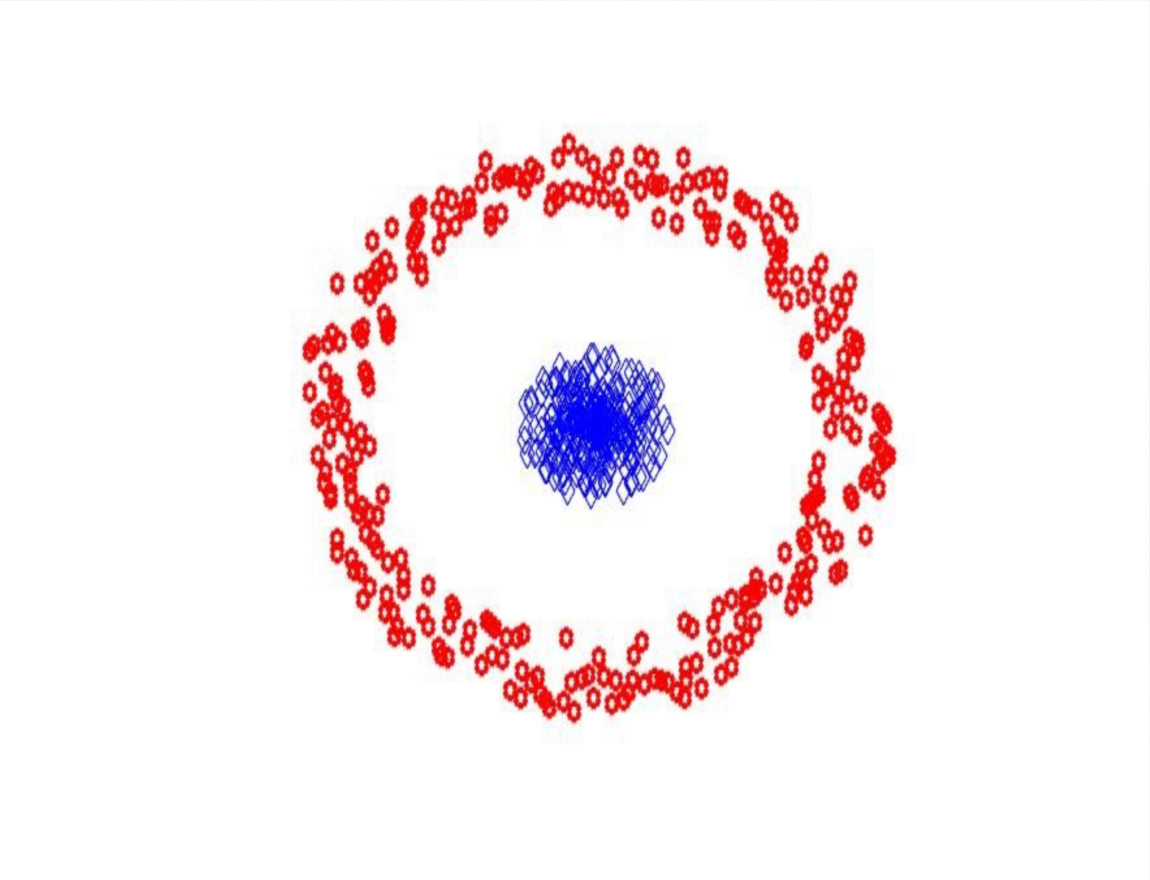
Established 1911

INDIAN INSTITUTE OF SCIENCE
भारतीय विज्ञान संस्थान

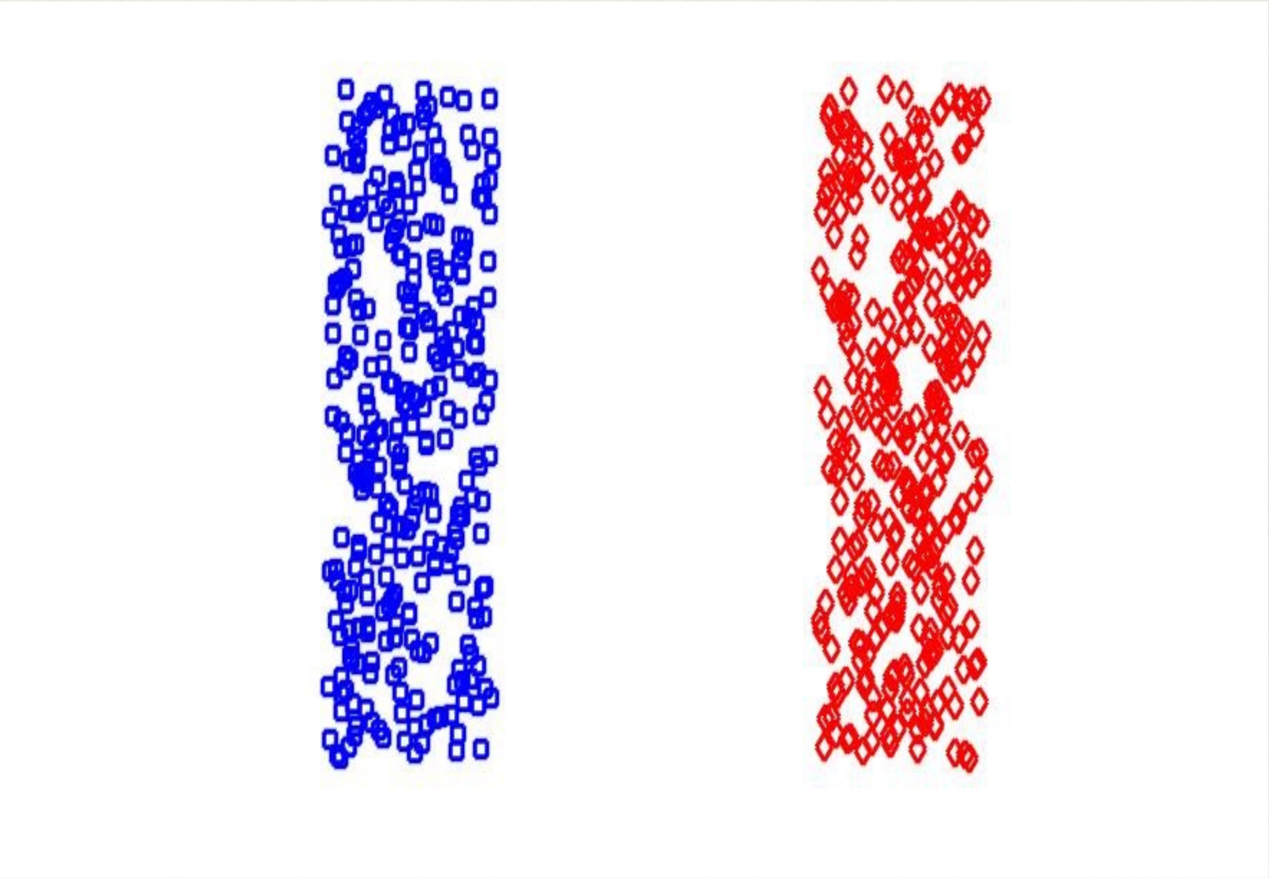
Feature Extraction

- Representation Problem

Cartesian Coordinates



Polar Coordinates



Feature Extraction

Scope for this course

I. Feature Extraction in Speech and Audio signals.

II. Feature Extraction Methods for Images.

III. Brief Introduction to Feature Extraction in Text.

Established 1911

INDIAN INSTITUTE OF SCIENCE
भारतीय विज्ञान संस्थान

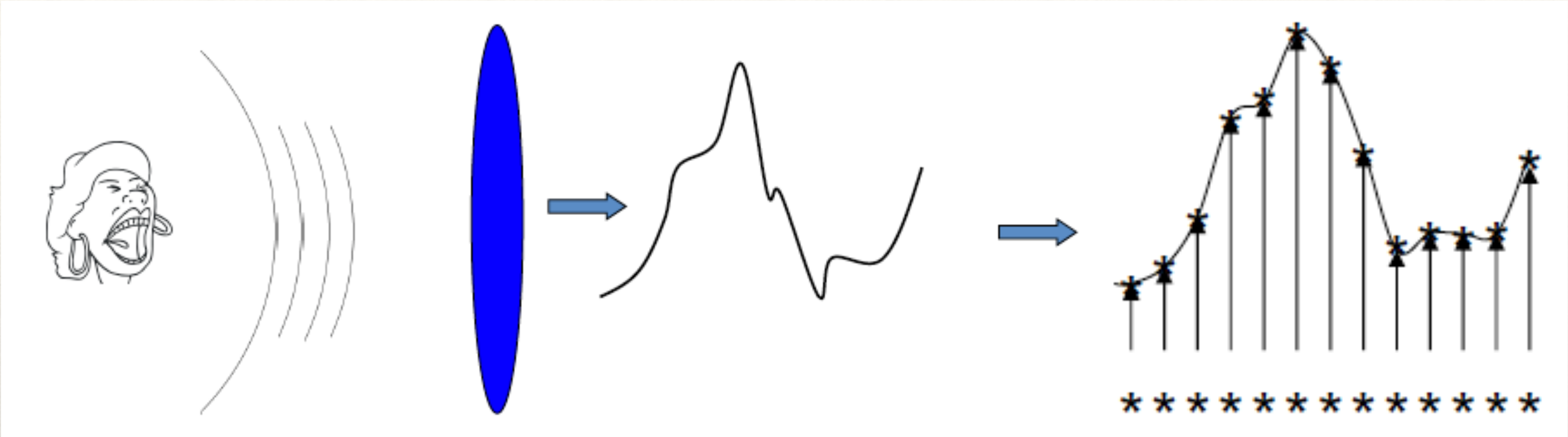
Speech and Audio

- Speech/Audio - 1D signals
  - Generated by pressure variations producing regions of high pressure and low pressure.
  - Travels through a medium of propagation (like air, water etc).
  - Human sensory organ - eardrum.
    - Converting pressure variations to electrical signals.
    - Action mimicked by a microphone.

Established 1911

INDIAN INSTITUTE OF SCIENCE
भारतीय विज्ञान संस्थान

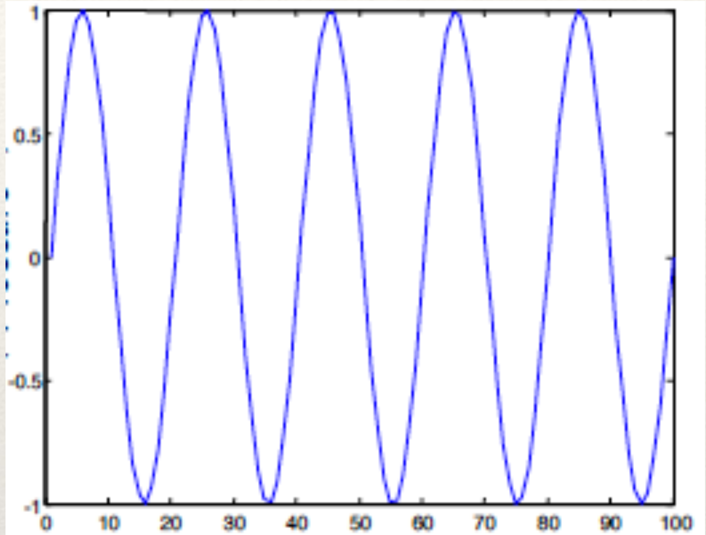
Sound waves in a computer



- Analog continuous signal from the microphone
  - Discretized in time - sampling.
  - Digitized in values - quantization.

Sampling

- Signals like speech/audio - analyzed in terms of sinusoids.



  - Can be considered as a set of basis functions.
  - Complex sinusoid - $ae^{-j2\pi f_0 t}$
  - Signal expressed as weighted sum (integral) of sinusoids.
  - Continuous Time Fourier Transform

$$x(t) = \frac{1}{2\pi} \int X(f) e^{j2\pi f t} df$$

$$X(f) = \int x(t) e^{-j2\pi f t} dt$$

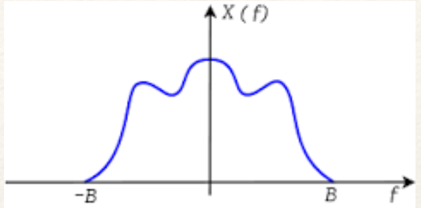
Established 1911

INDIAN INSTITUTE OF SCIENCE

भारतीय विज्ञान संस्थान

Sampling

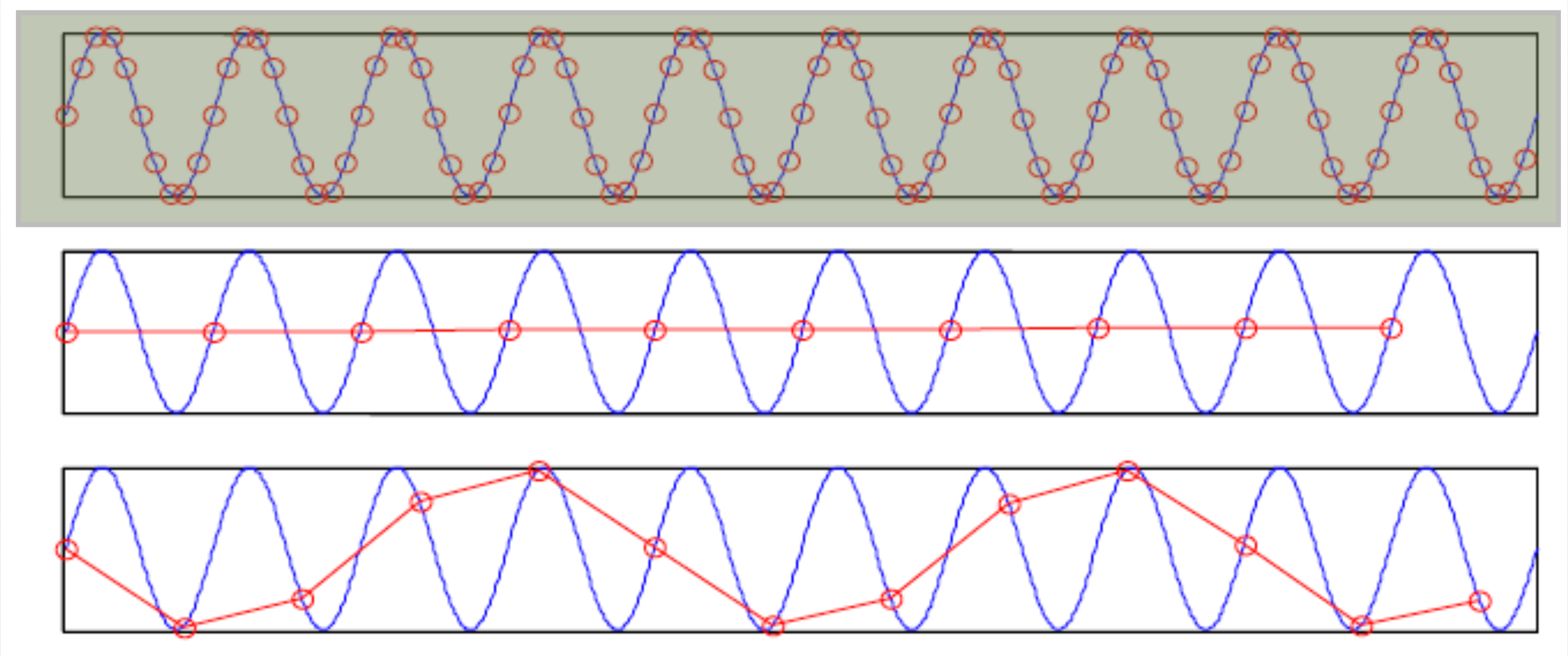
- Band limited signals $X(f) = 0 \quad |f| > B$



- Nyquist theorem - sampling frequency $f_s \geq 2B$

Oversampling

Undersampling

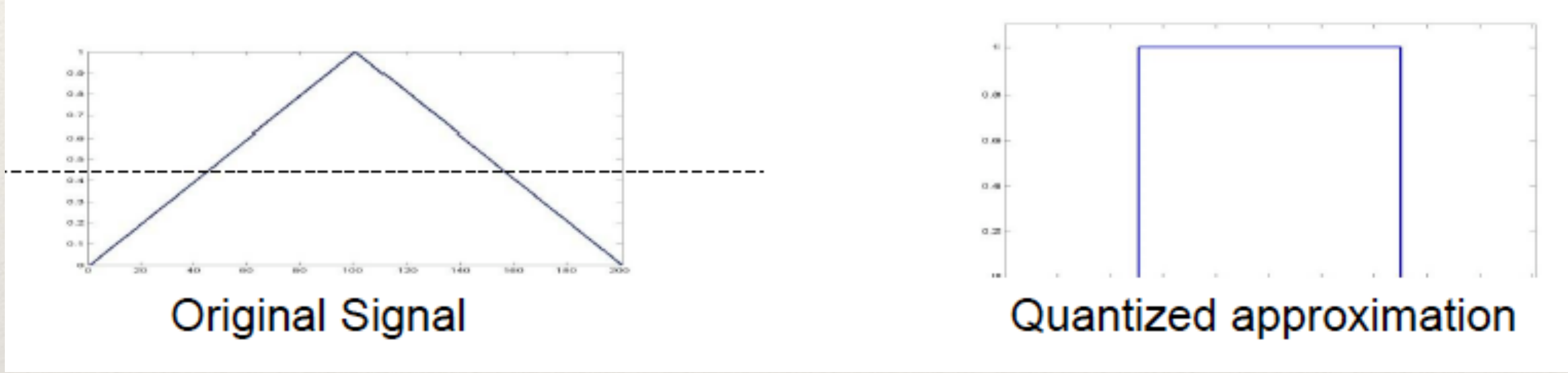


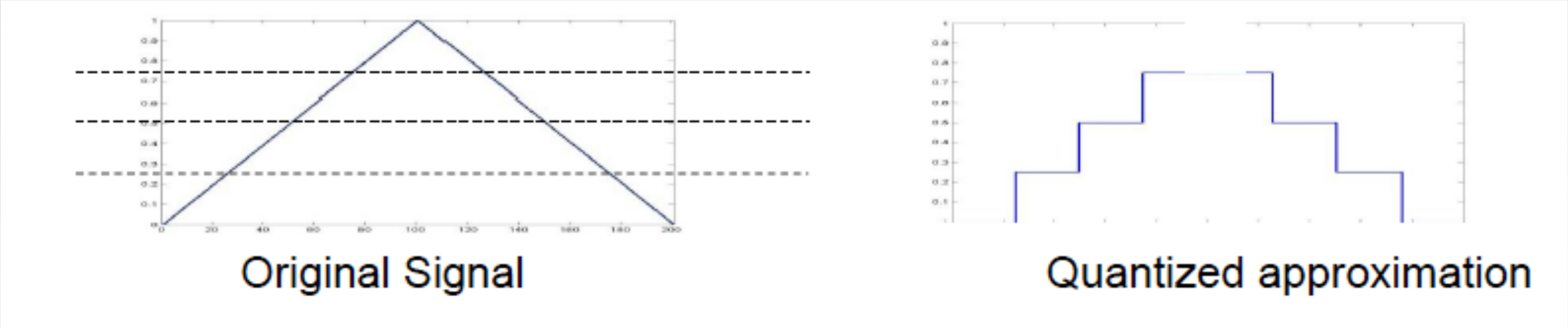
- Speech signals
  - maximum frequency ~ 4 - 8 kHz, typical sampling frequency - (8/16 kHz).

http://mlsp.cs.cmu.edu/courses/fall2014/lectures/slides/Class1.Introduction.pdf

Quantization

- Storing real values using finite number of bits



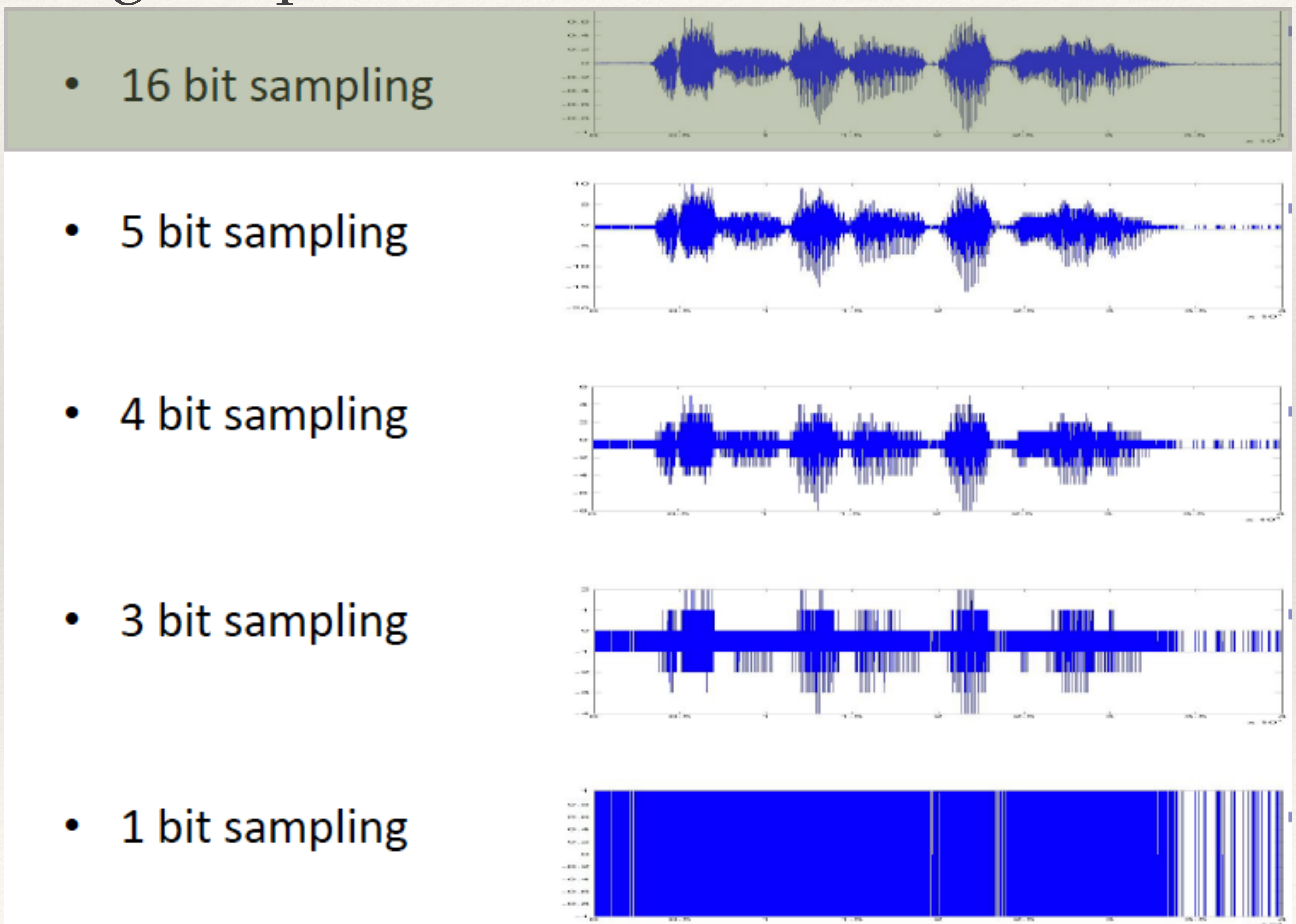


http://mlsp.cs.cmu.edu/courses/fall2014/lectures/slides/Class1.Introduction.pdf

Established 1911

Quantization

- Speech signal quantization

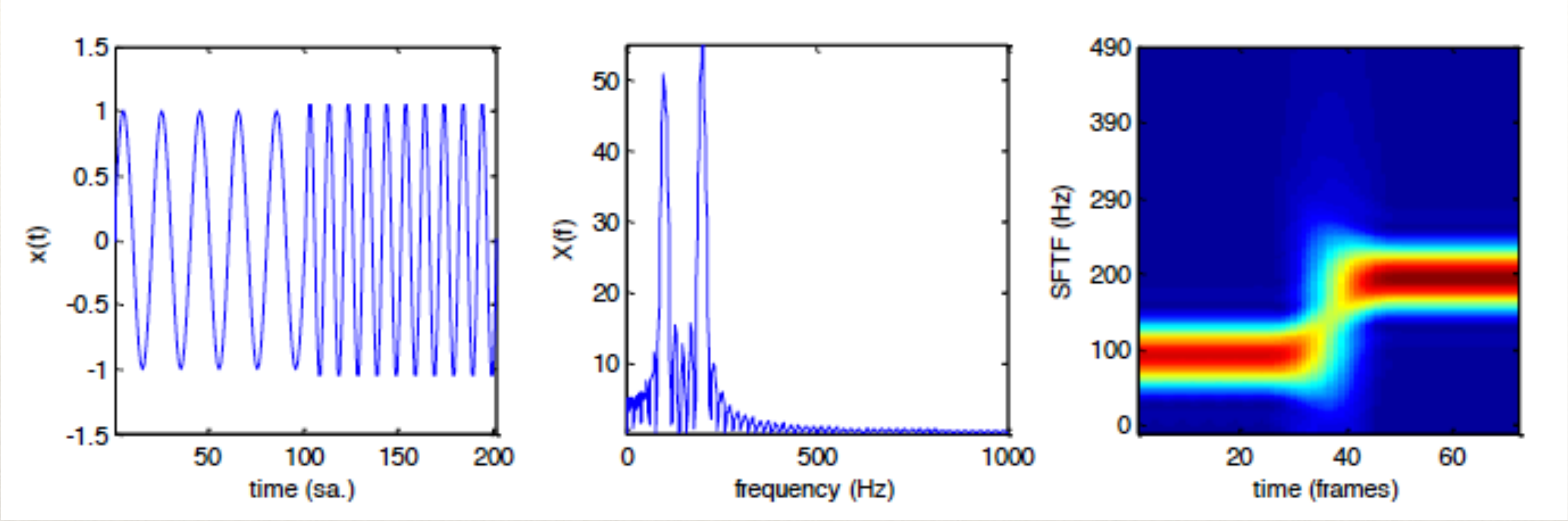


Established 1911

INDIAN INSTITUTE OF SCIENCE
भारतीय विज्ञान संस्थान

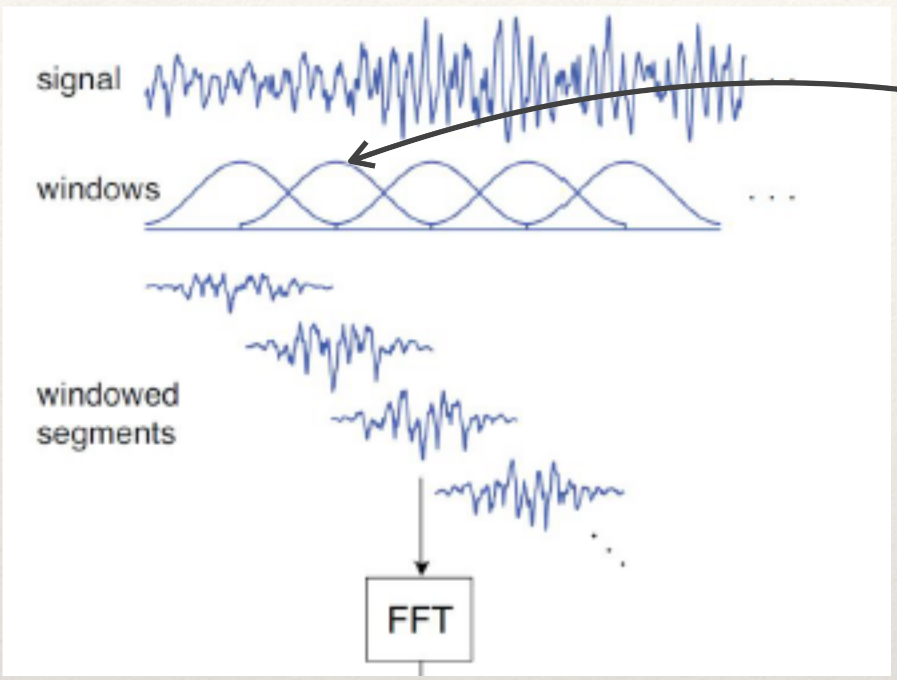
Short-term Fourier Transform

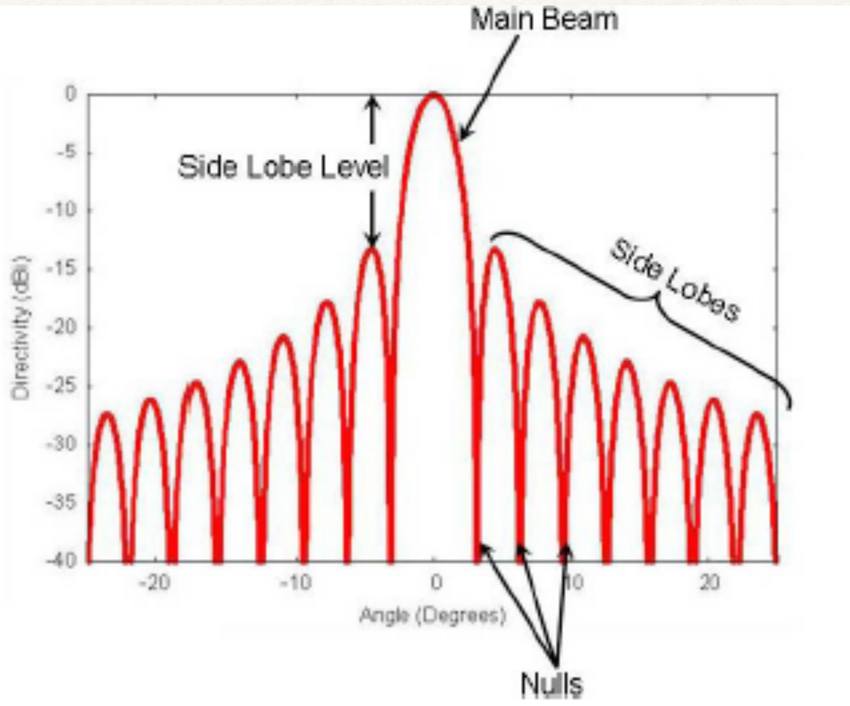
Why do we need time varying Fourier Transform



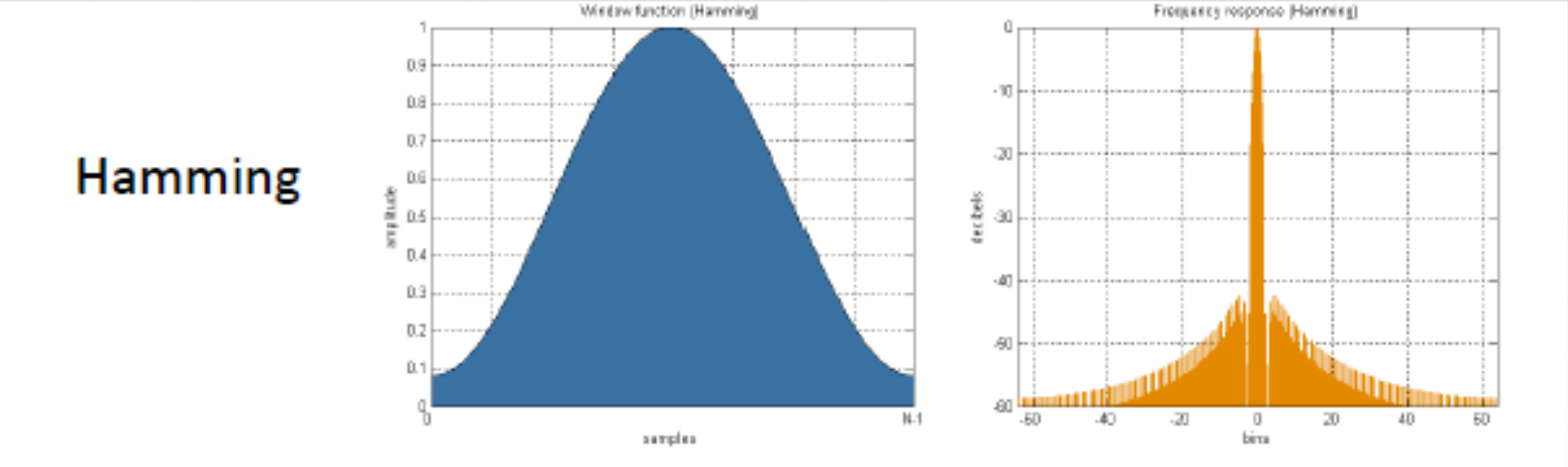
- When the signal properties change in time
  - DFT will only capture the average spectral character
  - Short-window analysis can indicate the change in spectrum.

Summary of STFT Properties





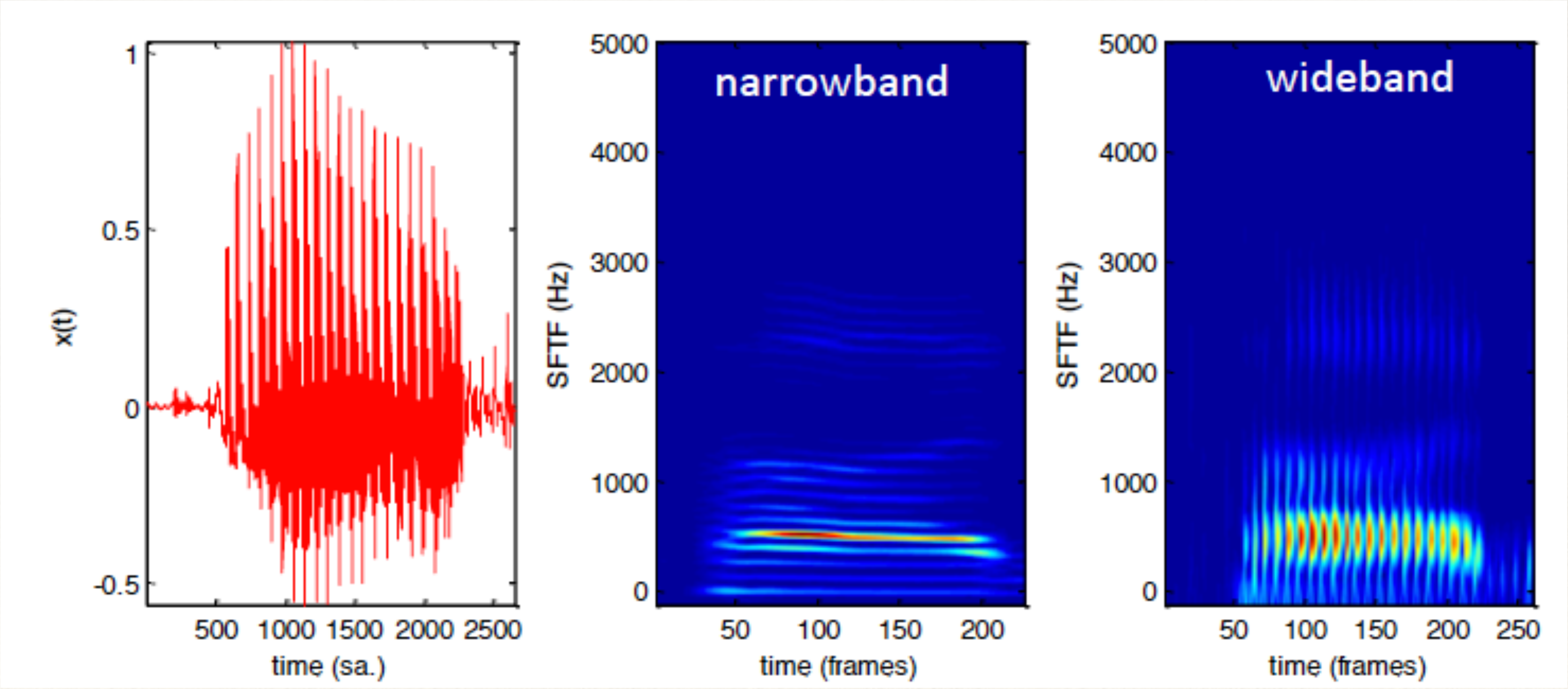
$X[k, n_0]$



http://en.wikipedia.org/wiki/Window_function

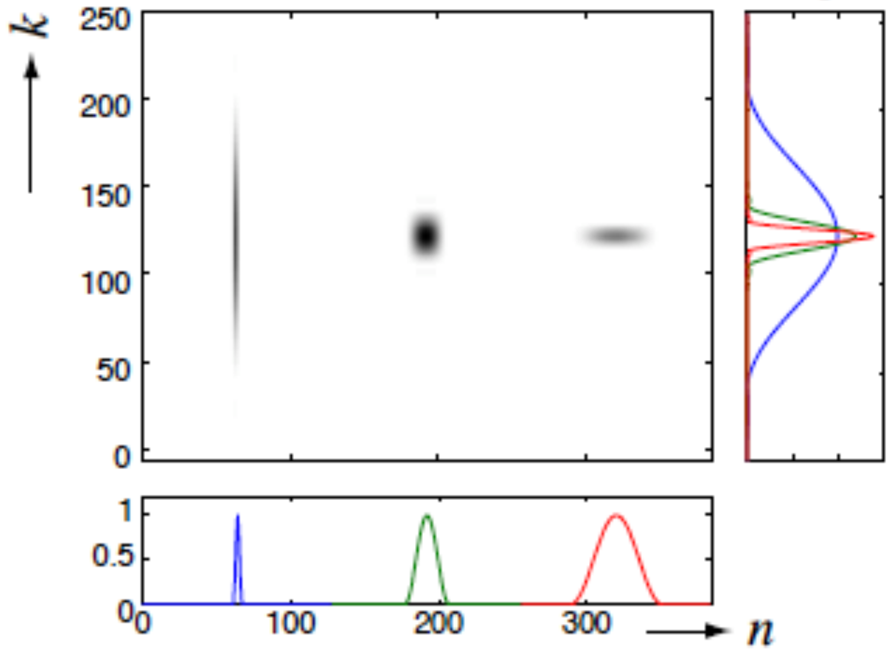
Narrowband versus Wideband

- Short windows - poor frequency resolution - wideband spectrogram
- Long windows - poor time resolution - narrowband spectrogram



Narrowband versus Wideband

- Can illustrate time-frequency tradeoff on the time-frequency plane:

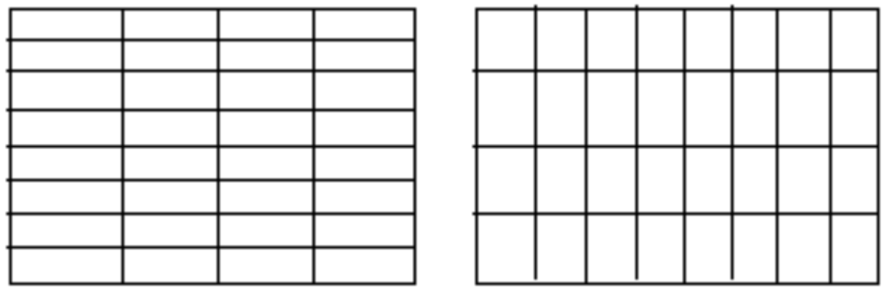


disks show 'blurring' due to window length; ***area** of disk is constant*

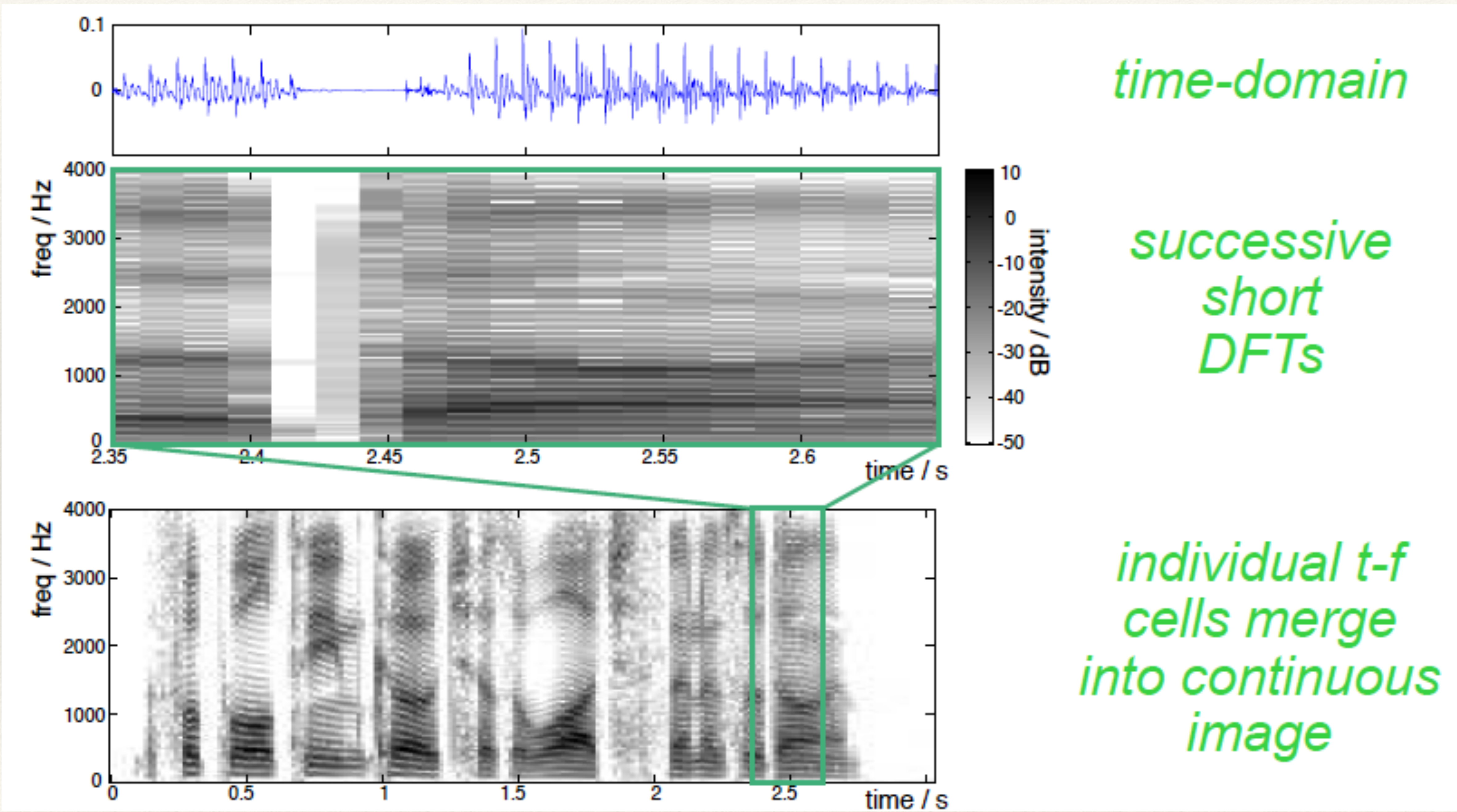
→ ***Uncertainty principle**:*

$$\delta f \cdot \delta t \geq k$$

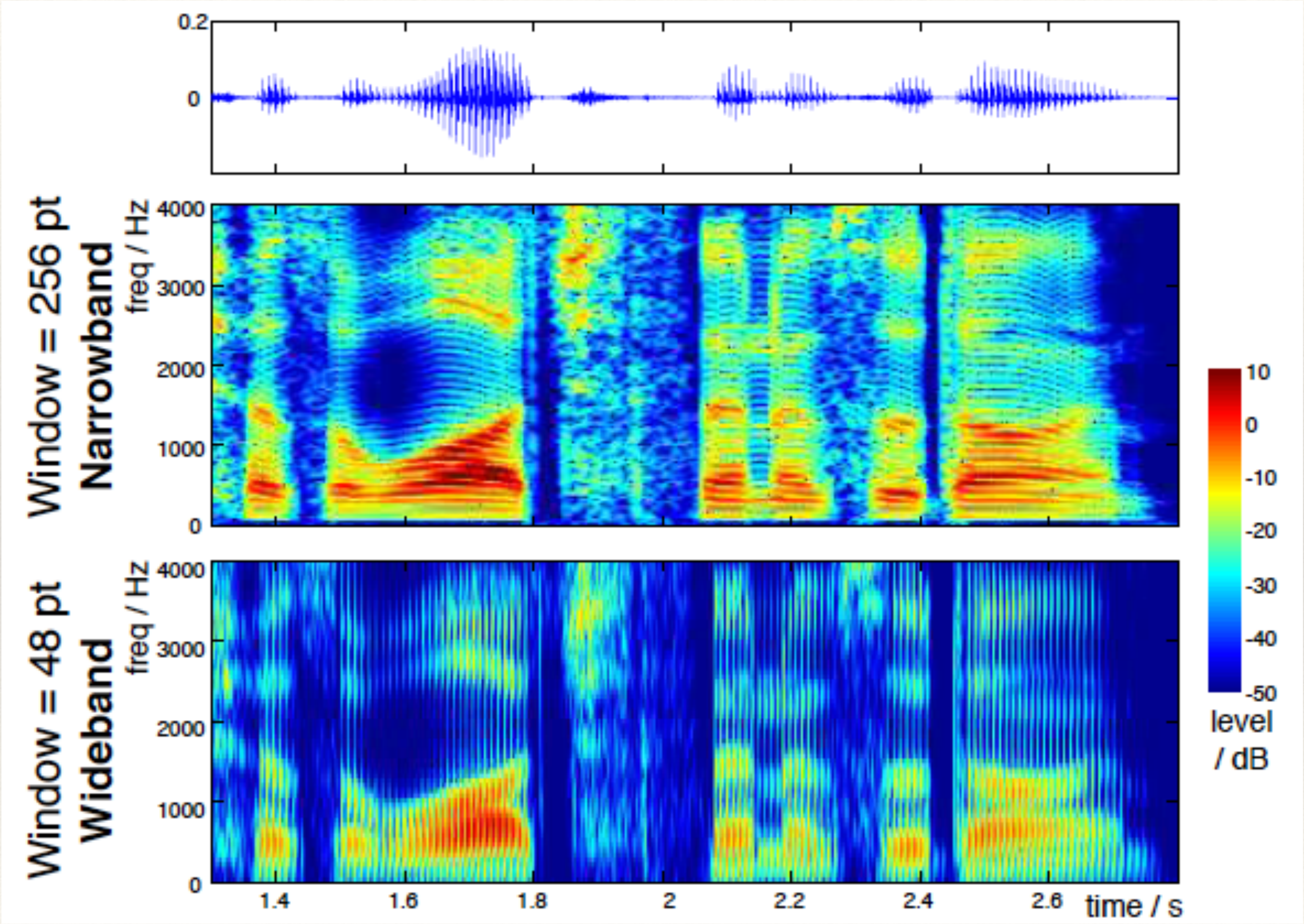
- Alternate tilings of time-freq:



Spectrogram of Real Sounds



Narrowband versus Wideband



Dan Ellis, "STFT Tutorial"

Spectrogram in Matlab

```
>> [d,sr]=wavread('mpgr1_sx419.wav');
>> Nw=256;
>> specgram(d,Nw,sr)
>> caxis([-80 0])
>> colorbar
```

(hann) window length

actual sampling rate (to label time axis)