Introduction to detection systems

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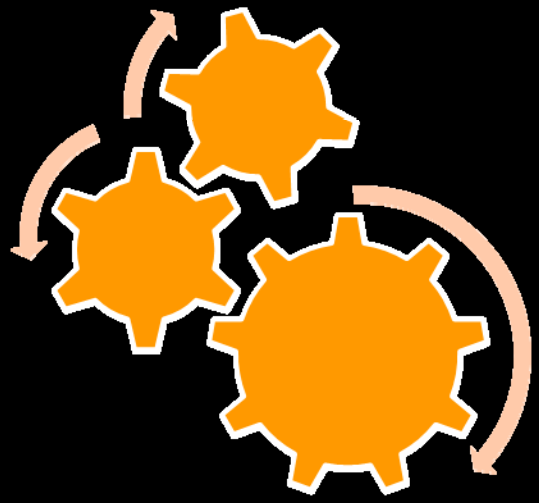
Objectives

- To provide insight into some of the issues in information processing and detection systems
- To facilitate the discussion



the good solution requires a cross-disciplinary effort

Outline

- The information processing pipeline
- Example: detecting a signal in noise
- Discussion of the issues in detection
- Exercise
- Wrap up

Information processing pipeline

Physical domain

object

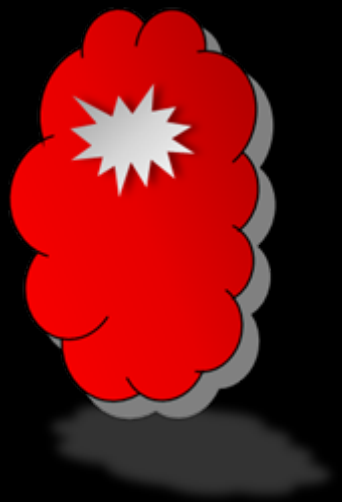
environment

Technical/detection domain

User /cognitive domain

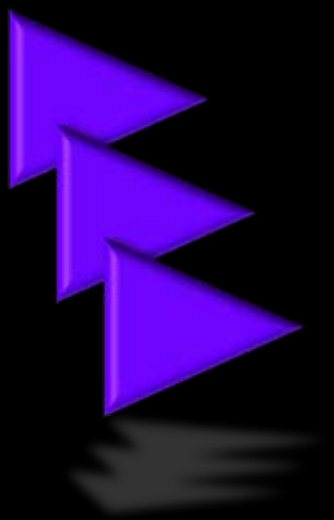
HCI
perception
interpretation

Physical environment



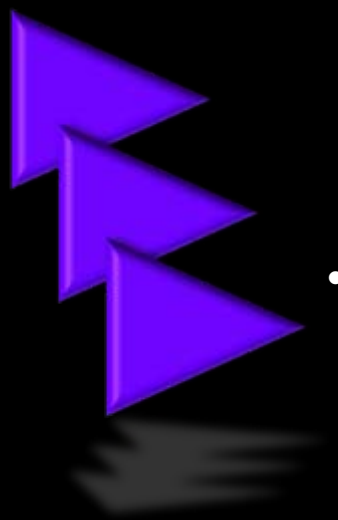
- Influential environmental factors change in number and strength over time
- Number, type and other properties of objects change over time

Sensing



- Sensing specific primary property of the object (e.g. odor component)
- Sensing a related property (e.g. reflected light)
- Sensing a mixture of properties – maybe only one is relevant
- Multiple sensors can sense different aspects

Sensing errors



- Various factors and other objects in the environment disturb the sensing
  - masking of related or primary property
  - other properties might be too strong
  - the environment is different from the environment in which the sensor was designed to work
- Errors and faults in the sensors
  - electrical noise
  - drift
  - degradation
  - malfunction

Data processing

Data processing

- Extracting relevant features from sensor data
- Suppressing noise and error
- Segregation of relevant components from a mixture
- Integration of sensor data
- Prediction:
  - Presence of object
  - Classification of object type
  - Quantification of properties of the object (e.g. amount, size)
  - Description of object

Data processing errors

Data processing

- The sensed expression is too weak to make a reliable prediction of objects presence or quantification of an object property
- The sensed expression is strong but not related to an object of interest (false alarm)
- The processing device misinterprets the sensed expression (missed detection)
  - Maybe an unknown object in the environment
  - Not able to sufficiently suppress noise and errors

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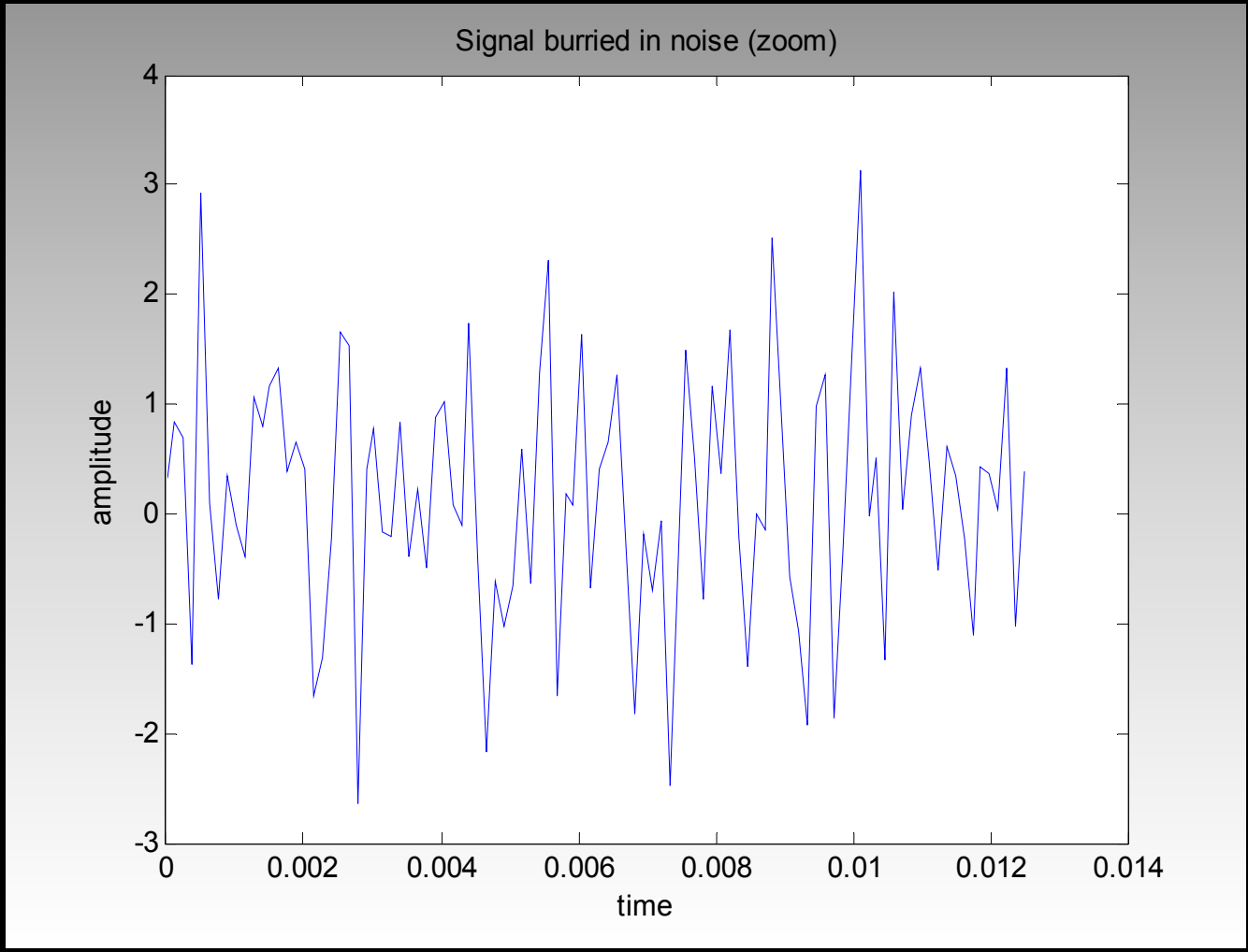
Signal in noise demo

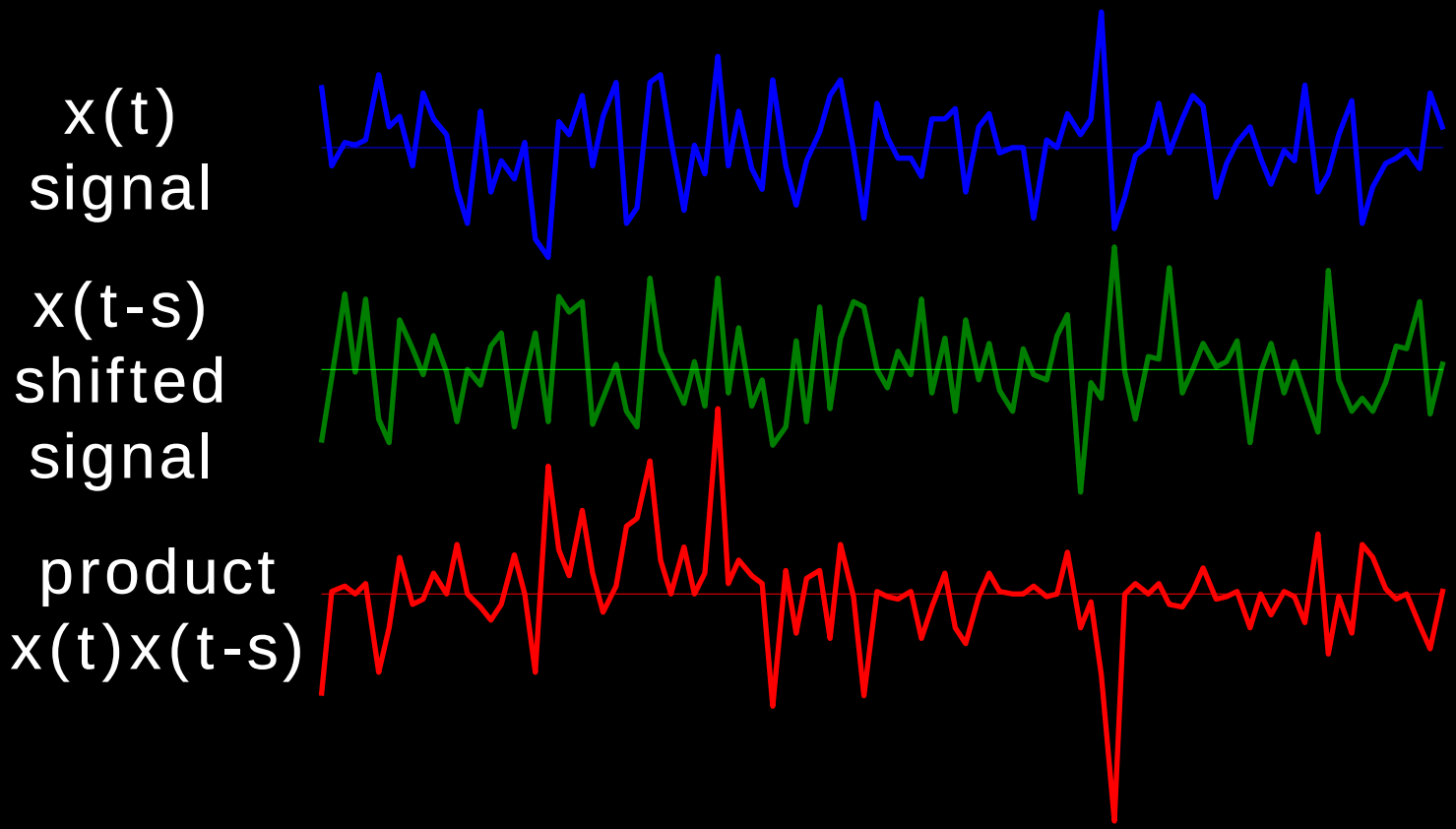
```
Matlab: s_in_noise(-8,1)

SNR=-8
```

Human visual and auditory sensors are not good enough – data processing makes the difference!

Signal in noise - time course



Autocorrelation for white noise

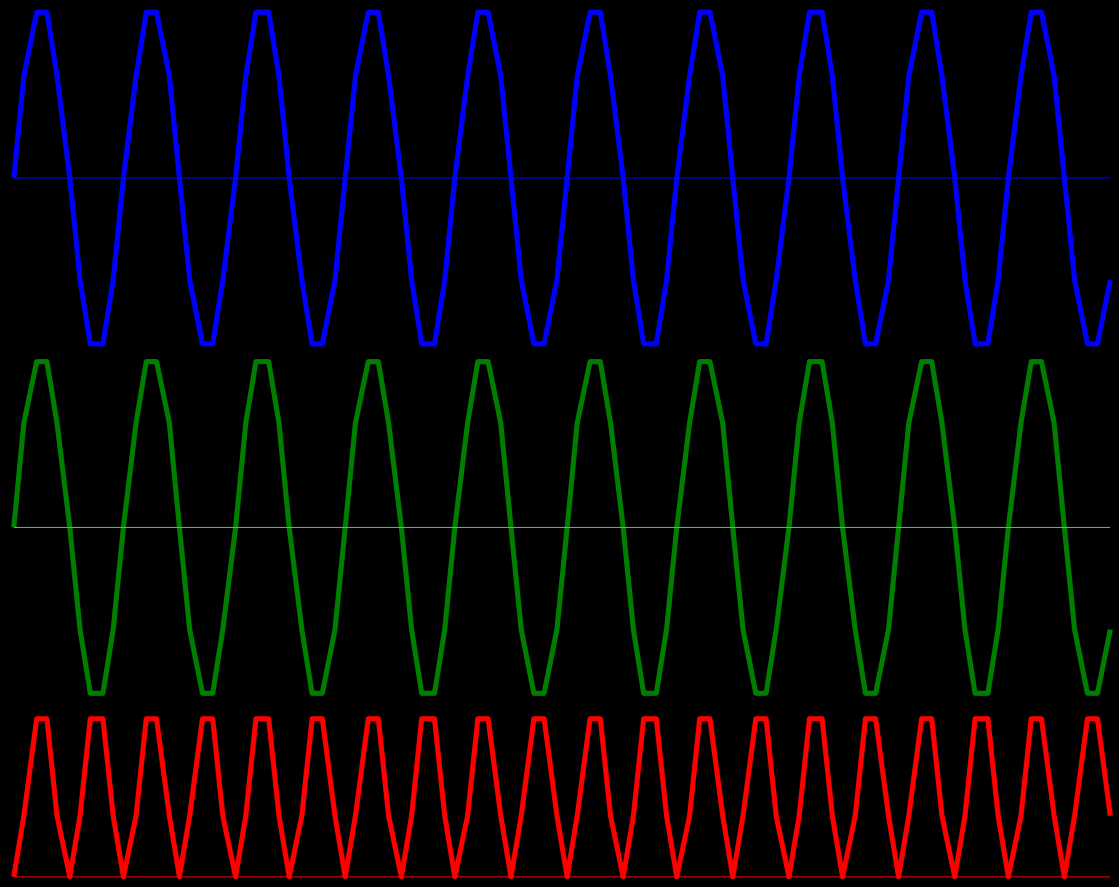


Autocorrelation for a tone sigal

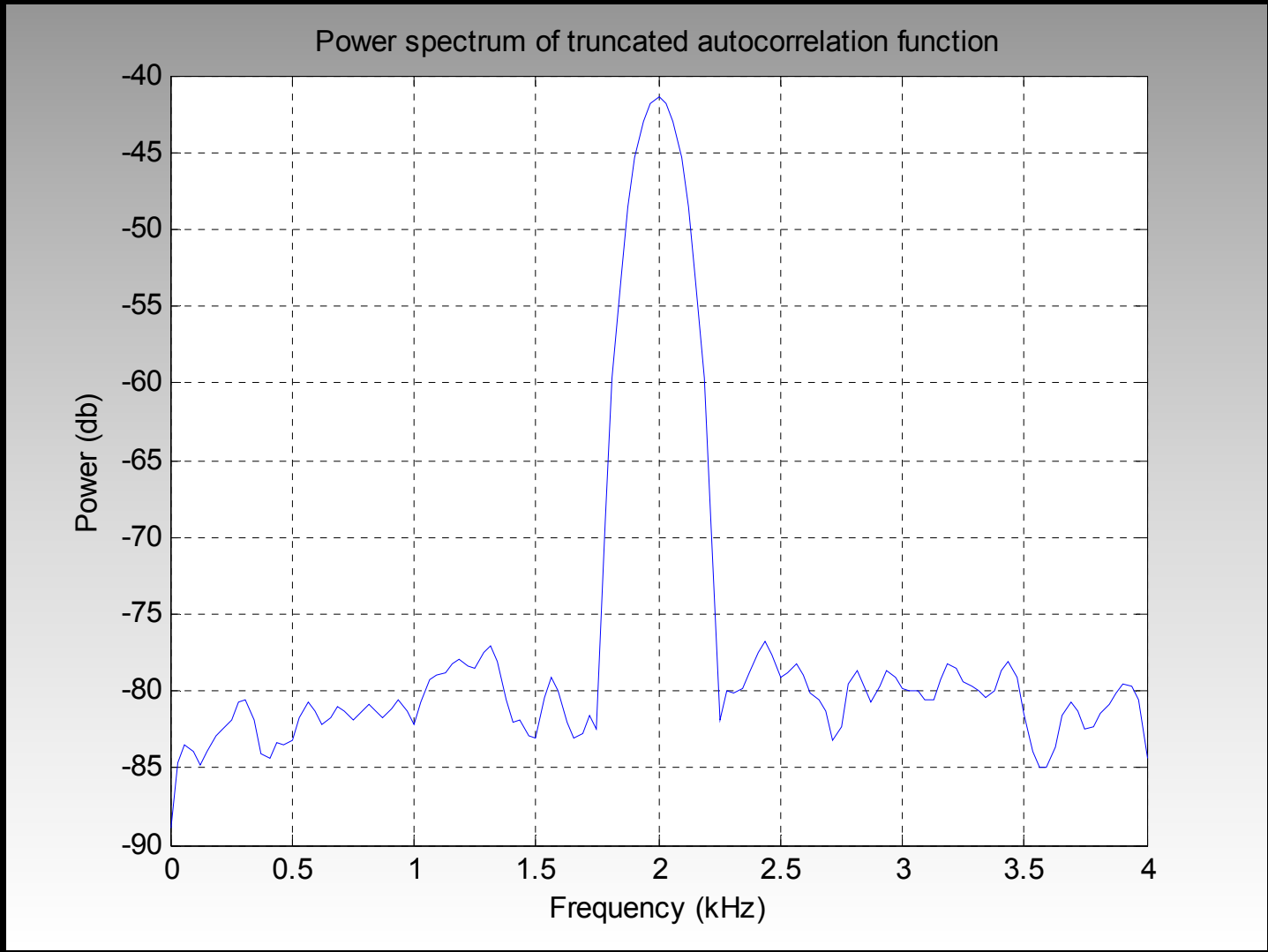
x(t)
signal

x(t-s) signal
shifted number of
periods

product
x(t)x(t-s)



Autocorrelation is the right processing tool



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Issues in detection

- Suppose that you are to detect objects in a sound stream by simple listening

- What are the issues in relation to reliable detection?

5 min

Issues identified

- Human factors
- Knowledge about what to identify
- Experience
- Interference
- Problem with the sensor – ear
- Training

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Auditory detection exercise

- In each experiment you will be presented by 10 sound clips of 3 seconds duration and in-between pause of 3 seconds
- We will conduct 12 experiments
- Report the identified object on the results chart

```
Matlab: playobjects('all');
```

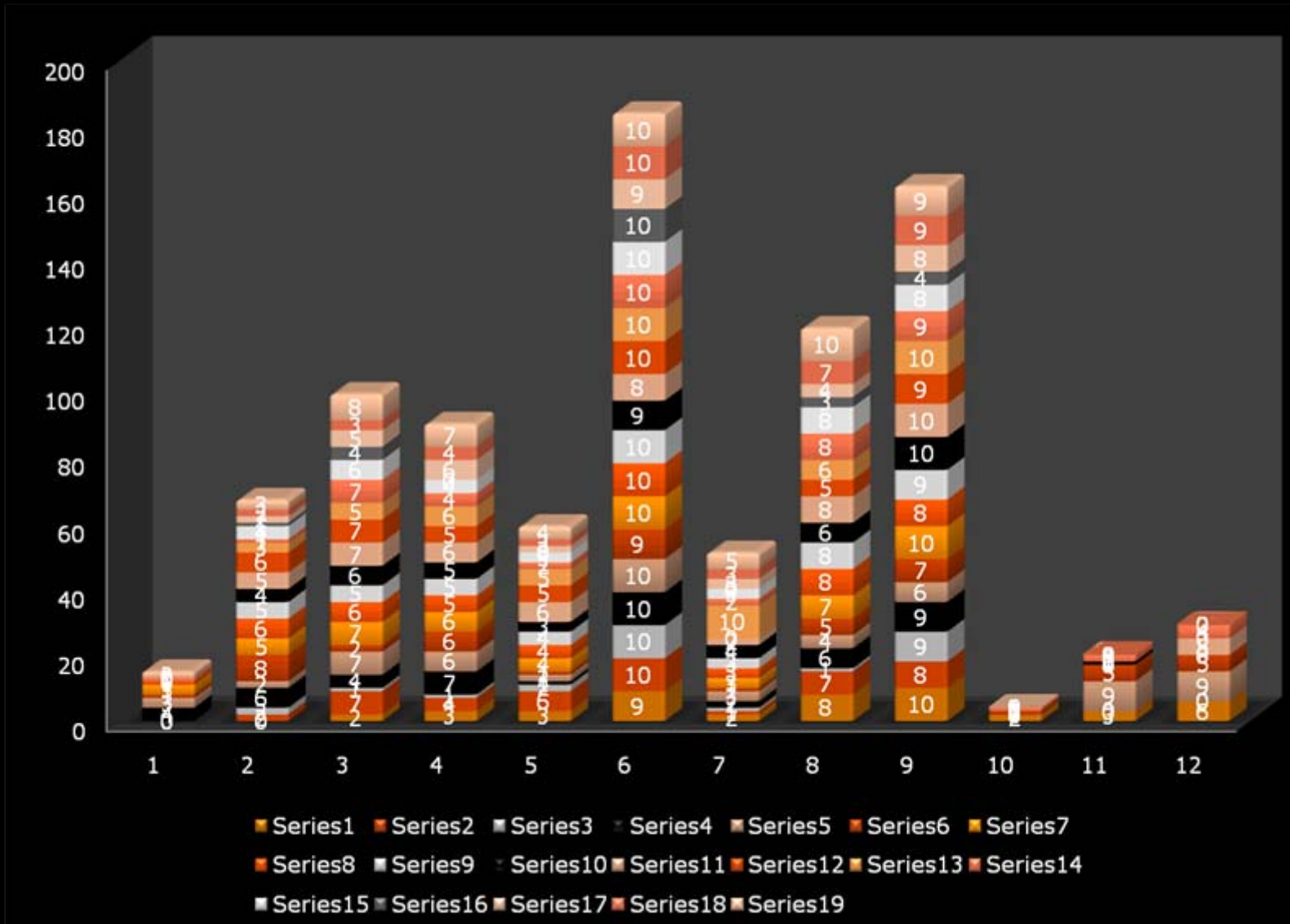
Summary of the twelve experiments

	Objects		Interference (Weak, Med, Strong)		
Experim. number	English numbers	Czech numbers	White noise	Music	Speech
1	√		S		
2	√		M		
3	√		W		
4	√		S		
5	√			S	
6	√			W	
7	√				S
8	√				M
9	√				W
10		√	S		
11		√	W		
12		√		W	

Results 27.09.08 of the twelve experiments

	Objects		Interference (Weak, Med, Strong)			Scores	Median Scores
Experim. number	English numbers	Czech numbers	White noise	Music	Speech	Max. score was 190	Max. is 10
1	√		S			15	0
2	√		M			67	3
3	√		W			99	6
4	√		S			90	5
5	√			S		59	3
6	√			W		184	10
7	√				S	51	3
8	√				M	119	7
9	√				W	162	9
10		√	S			3	0
11		√	W			20	0
12		√		W		29	0

Summary of results 27.09.08



Summary of results 27.09.08

	1	2	3	4	5	6	7	8	9	10	11	12
MIN	0,0	0,0	1,0	0,0	0,0	8,0	0,0	1,0	4,0	0,0	0,0	0,0
LQ	0,0	2,0	4,0	4,0	2,0	9,5	1,5	5,0	8,0	0,0	0,0	0,0
MEDIAN	0,0	3,0	6,0	5,0	3,0	10,0	3,0	7,0	9,0	0,0	0,0	0,0
HQ	1,0	5,0	7,0	6,0	4,0	10,0	3,0	8,0	9,5	0,0	0,5	2,0
MAX	4,0	8,0	8,0	7,0	6,0	10,0	10,0	10,0	10,0	2,0	9,0	9,0

Issues of detecting auditory objects

- Known vs. unknown object types
  - knowledge about the number, type and other properties of objects helps the detection
- Some interferences are easier than others - similar interference similar is harder
- Interference strength is crucial
- A learning effect is present
  - the second time you identified objects under strong interference you probably did better
- Exposure time is crucial (not tested in the experiment)
- Other issues:
  - Perceptual disabilities such as hearing loss

Wrap up

- Elements of the information processing pipeline was presented
  - you need to model all steps for reliable detection!
- Math modeling can be used detect hidden objects
  - autocorrelation was used to detect invisible and inaudible signal in noise
- Issues in detection were discussed
- Auditory exercise demonstrated many relevant issues in detection