Intelligent Sensor systems

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Intelligent surveillance system (our old definition)

- The system solves different tasks **automatically**;
- System is **adaptive** to the changes;
- System allows **fast reorganization** and **tuning**;
- System doesn't require **permanent human monitoring** and **control**.

Open problems to be solved

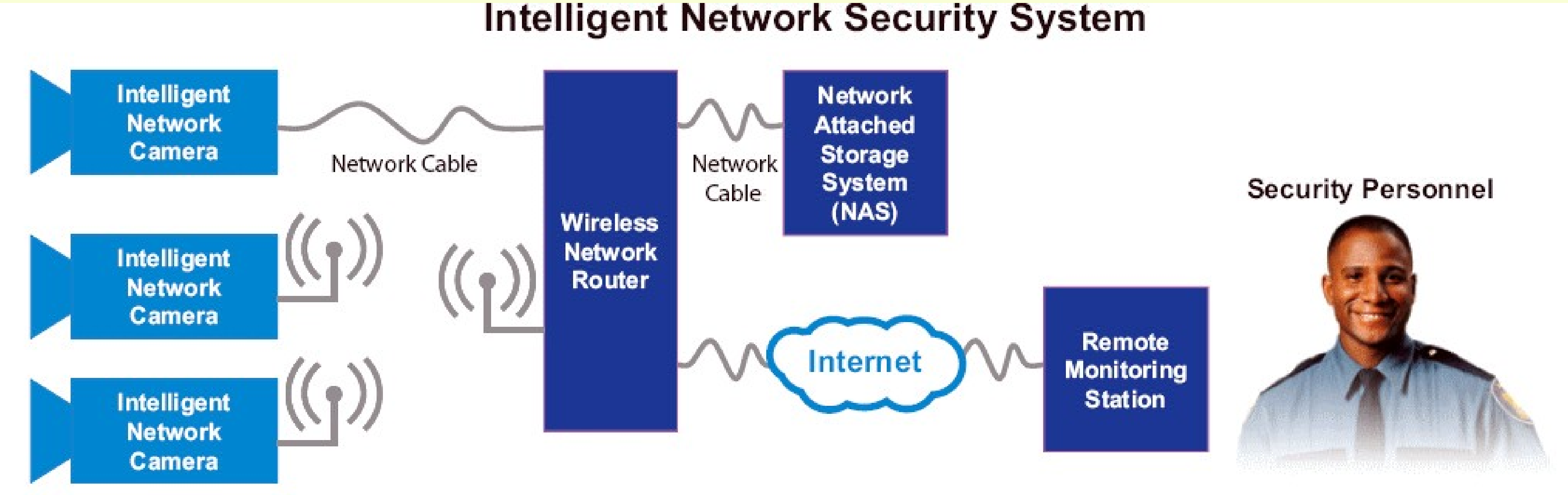
1. Unique feature selection.
2. 3D scene reconstruction.
3. Image registration.
4. Extended object tracking.
5. Dynamic camera calibration.
6. Optimal sensor control for multi-target tracking.
7. Face localization in human silhouette.
8. Image and multimedia data bases.
9. Face recognition.
10. Abnormal behavior detection.
11. Optimal resource allocation.
12. Object selection.

Open problems (after 3 years)

OK	1. Unique feature selection.
Near to OK	2. 3D scene reconstruction.
Some results	3. Image registration.
Some results	4. Extended object tracking.
Negative res.	5. Dynamic calibration.
Next year	6. Optimal sensor control for multitarget tracking.
Several meth.	7. Face localization in human silhouette.
Some results	8. Image and multimedia data bases.
Some results	9. Face recognition.
Next year	10. Abnormal behavior detection.
Some results	11. Optimal resource allocation.
Next year	12. Object selection.

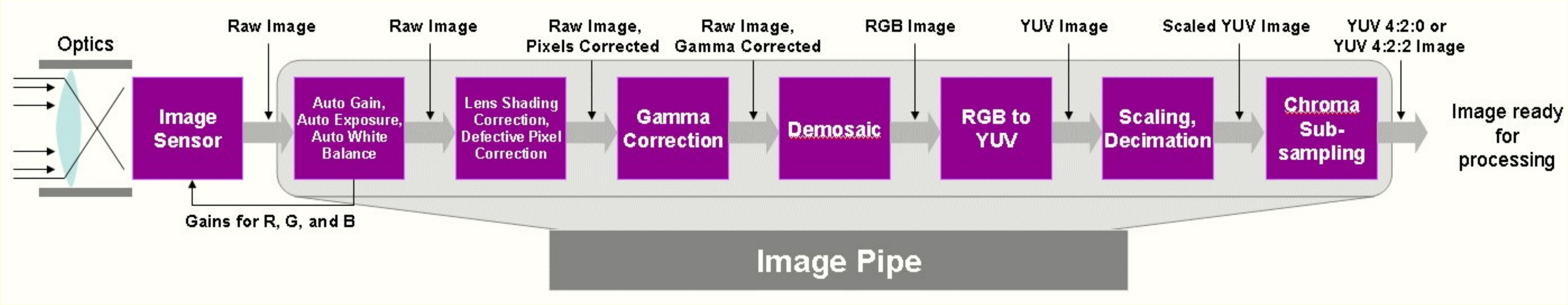
Where we are?

John Weber, Avnet   Classical security systems



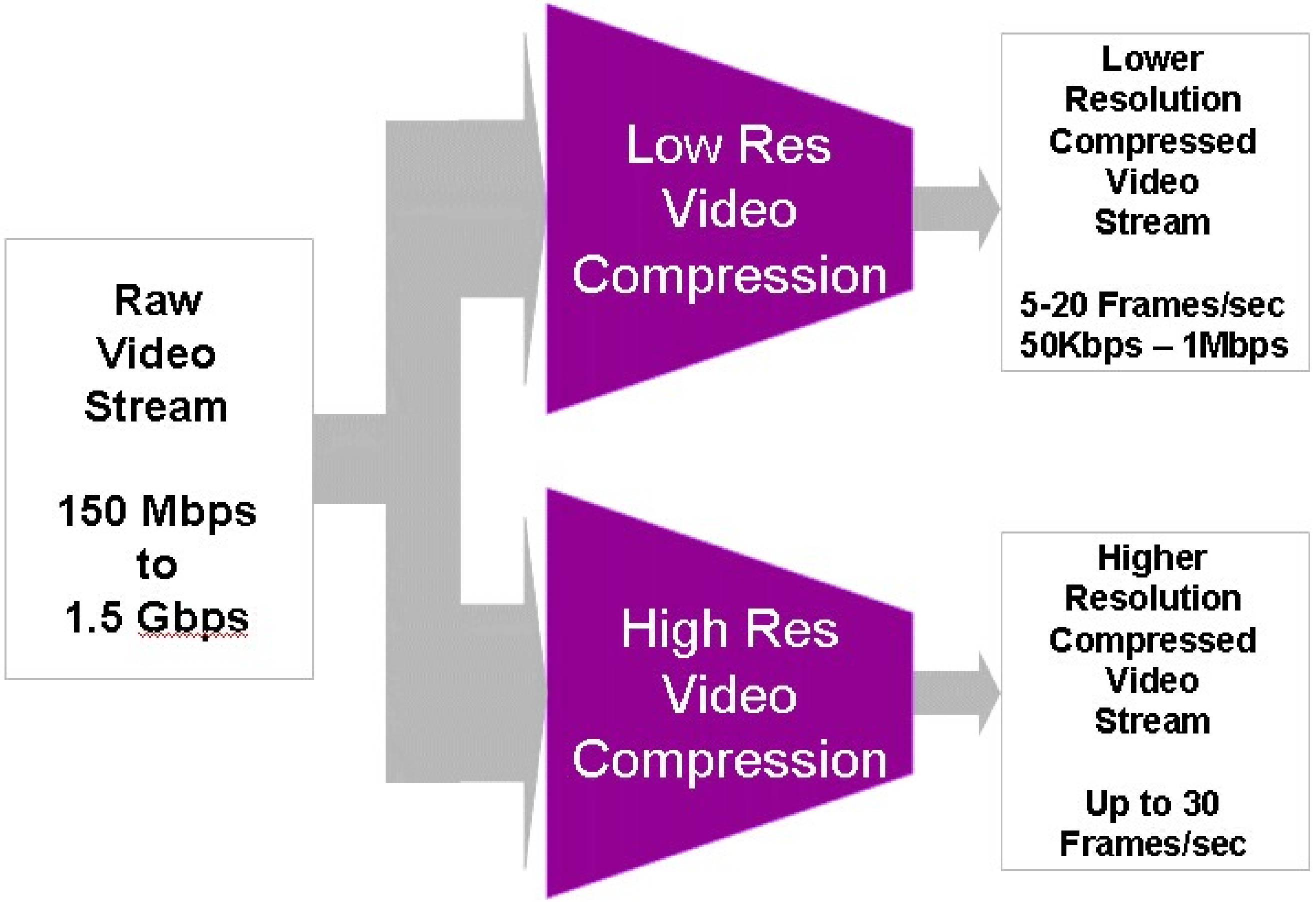
John Weber, Avnet , Smart camera basics

The image pipe



John Weber, Avnet , Smart camera basics

Compression

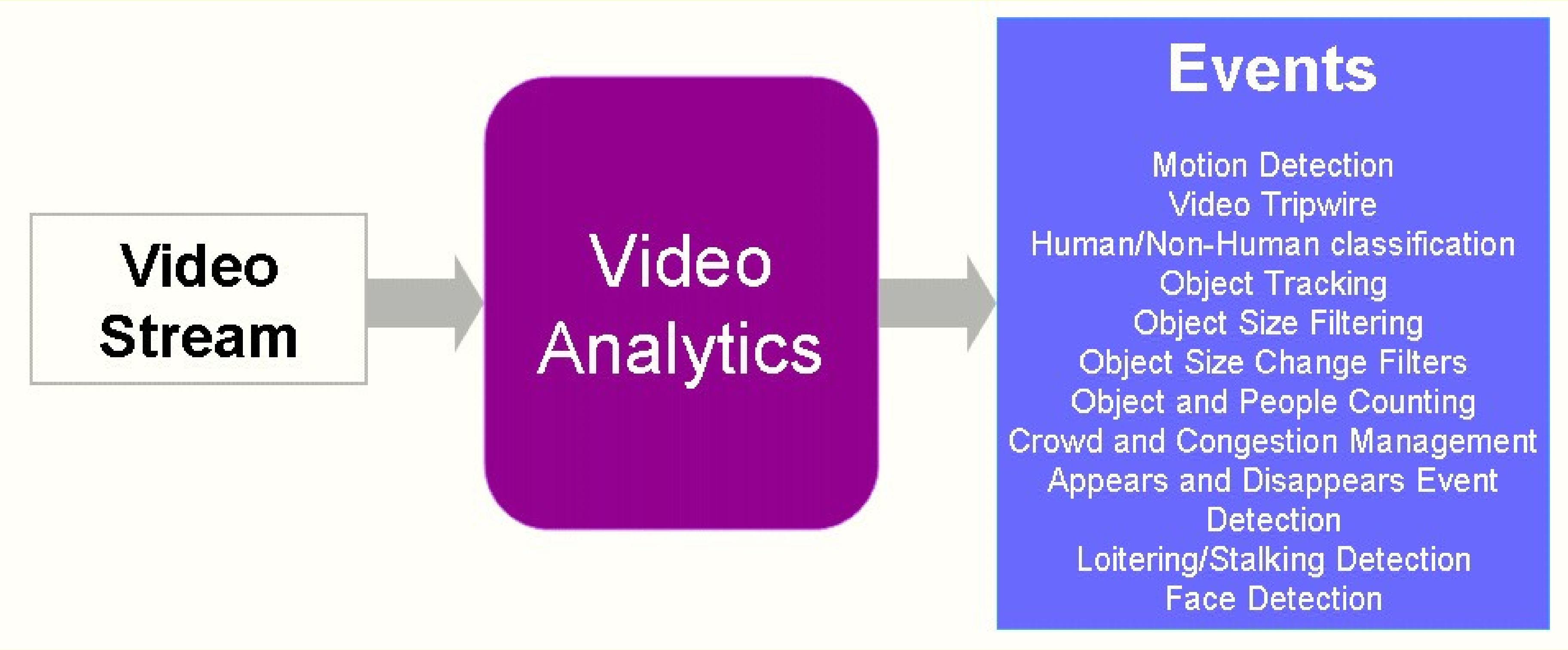


Lower bandwidth stream can be sent over wired telephone lines using a modem or via a cell phone modem. Used to save bandwidth in times of little to no activity

Higher bandwidth stream is stored locally and transmitted only when events occur.

John Weber, Smart camera basics

Information processing



1. Super-resolution
2. Depth recovery

N.B. Using one only controllable IP camera

Let denote signal by $f \in R_n$. This signal can be decomposed in an arbitrary orthonormal basis $\Psi = [\psi_1 \psi_2 \ldots \psi_n]$ as follow:

$$f(t) = \sum_{i=1}^{n} x_i \psi_i(t)$$

,

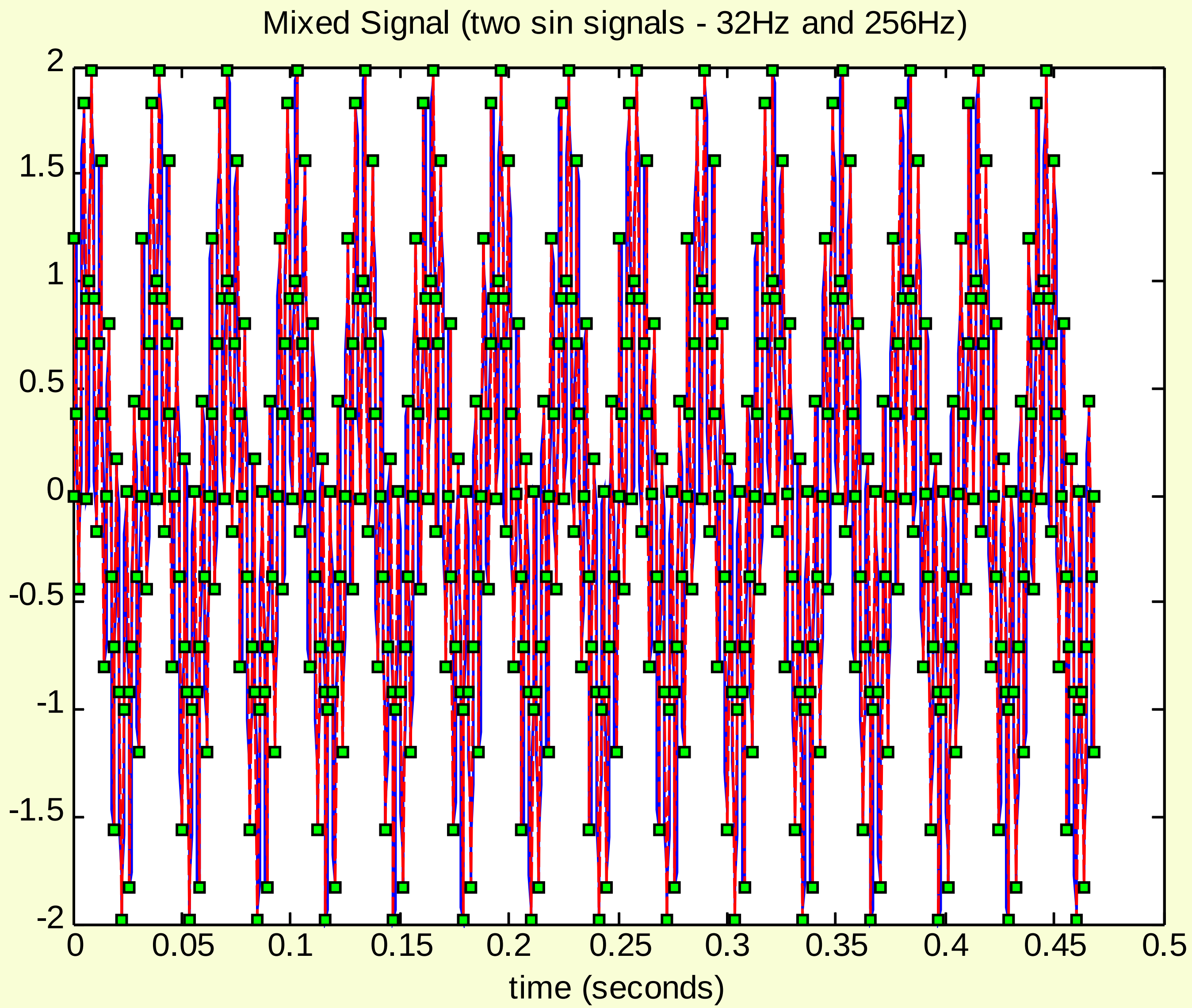
$$x_i = \langle f, \psi_i \rangle$$

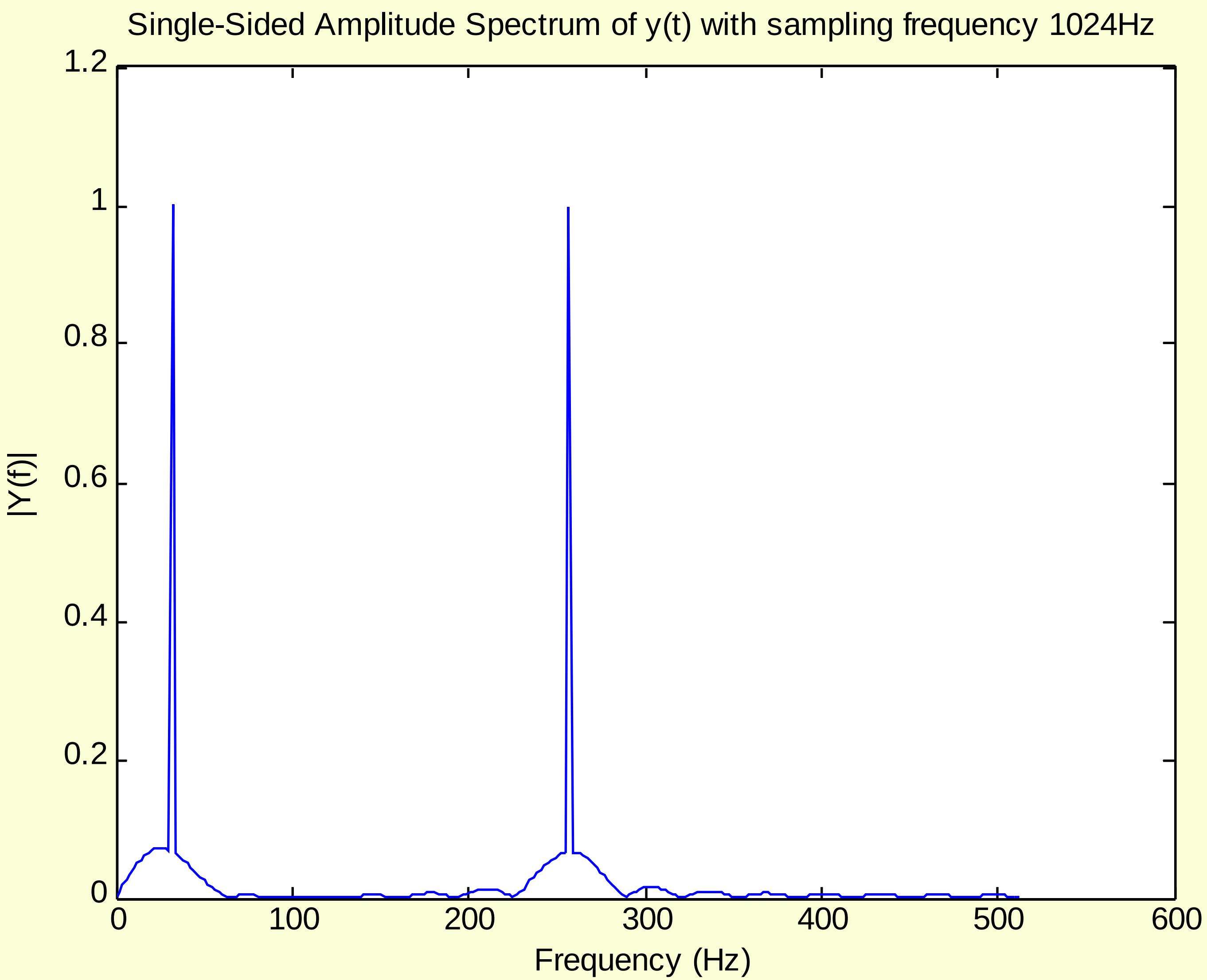
where are the coefficients of the corresponding orthonormal functions.

„Sparse" signals are signals for which almost all coefficients are small or zero and relatively small quantity of coefficients may restore almost ideally the signal. Let the restored signal is presented as a sum of the S **biggest coefficients in decomposition:**

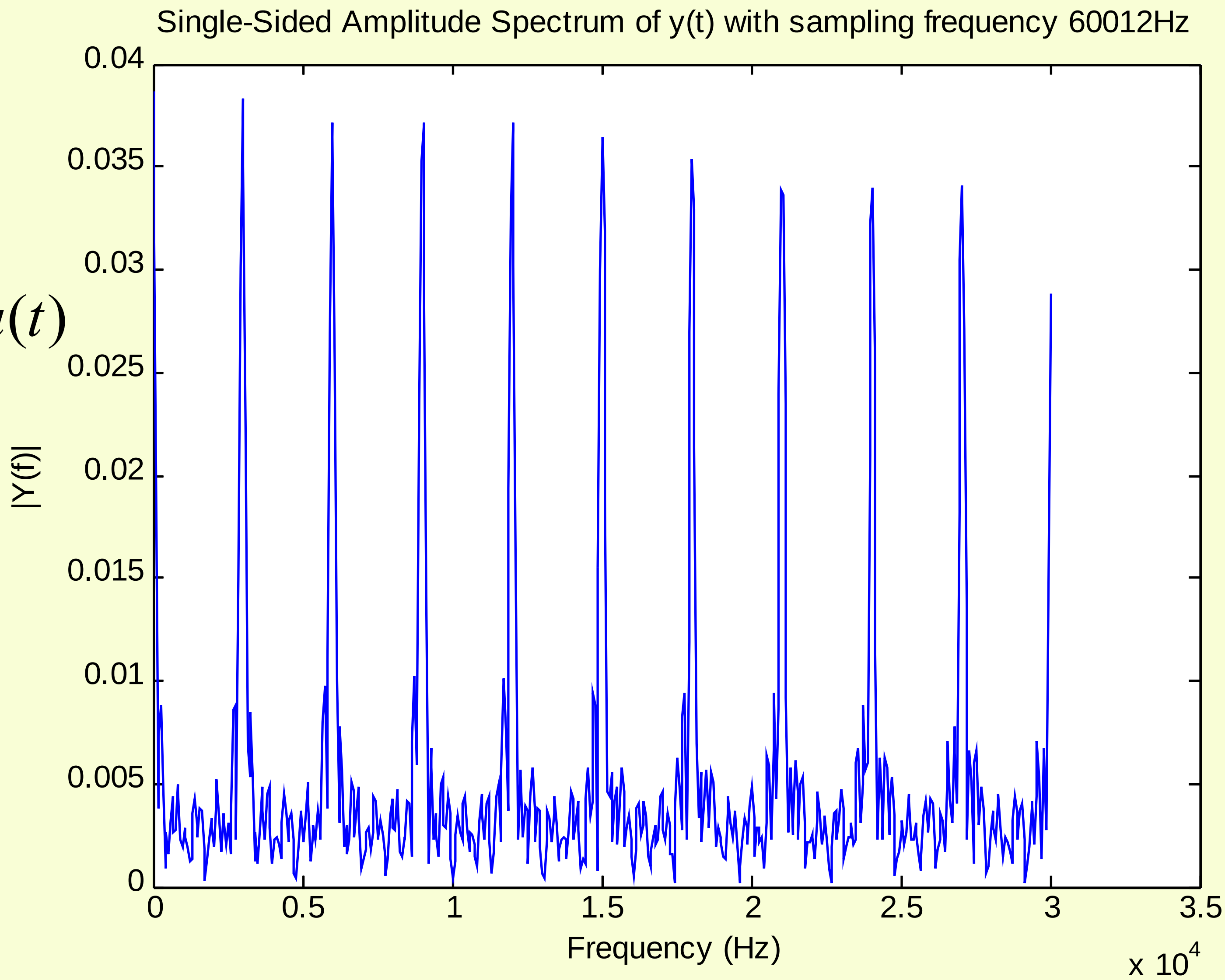
$$f_S(t) = \sum_{i \in S} x_i \psi_i(t)$$

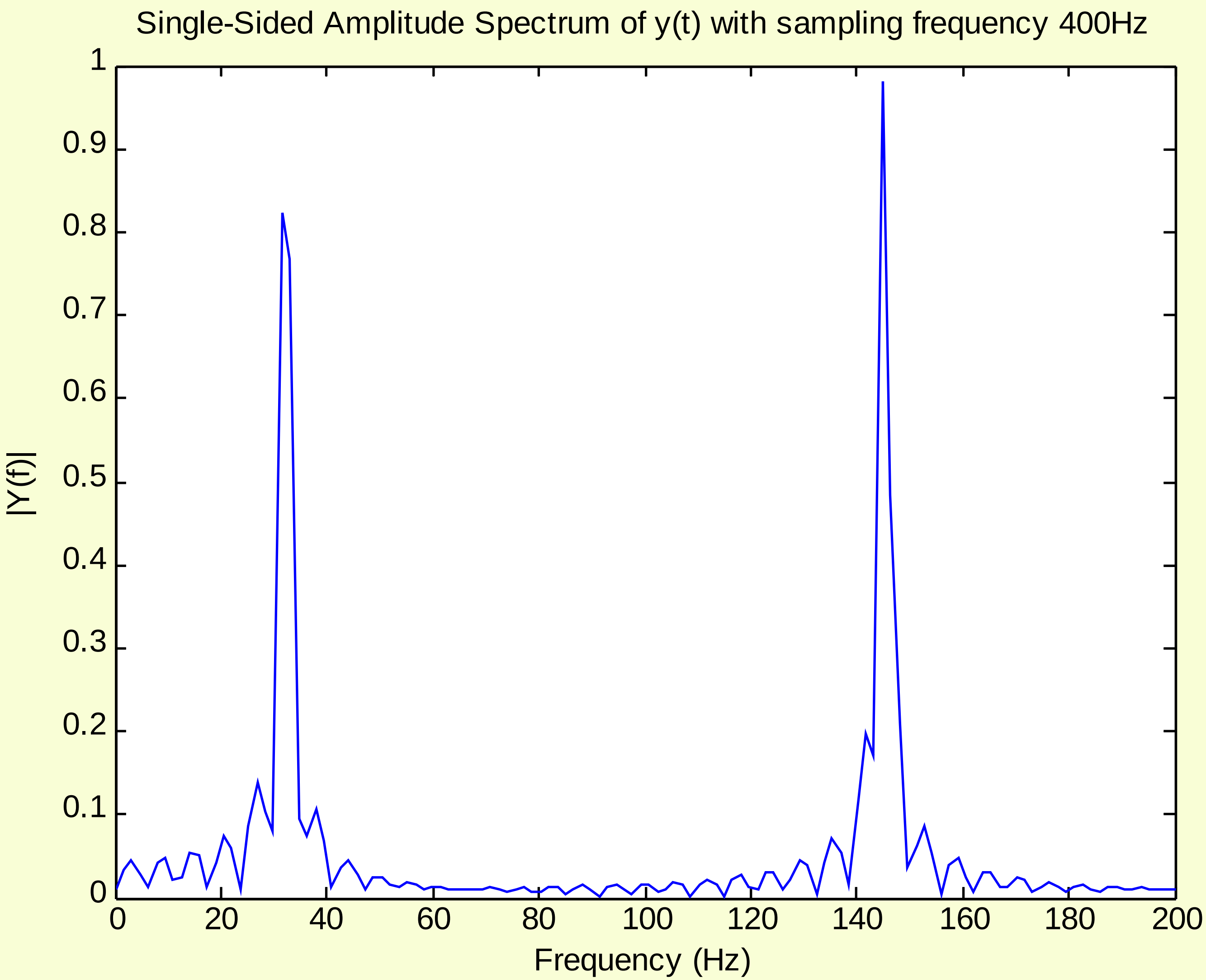
The signal $f \in R_n$ **will be called** S **sparse, if** f_S **approximate very good** f **and the approximation error** $\varepsilon = \left\| f - f_S \right\|_{l_2}$ **is small enough. For audio- and video-signals it is well-known that only about 2.5% of the biggest coefficients may be used for signal recovery and the discrimination between the restored signal and the original one can not be easily found.**

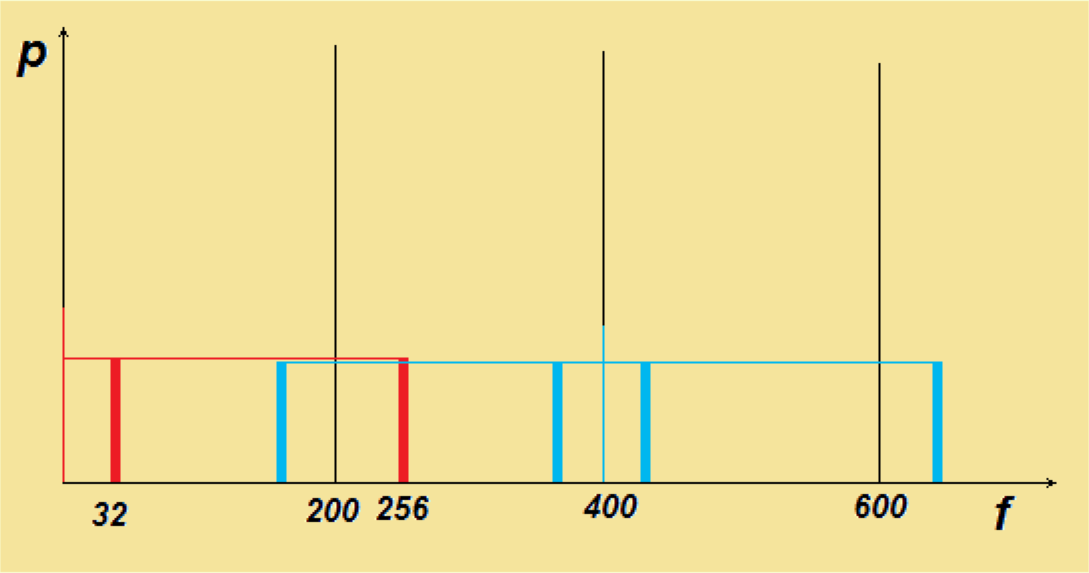

Mixed Signal (two sin signals - 32Hz and 256Hz)
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
time (seconds)


Single-Sided Amplitude Spectrum of y(t) with sampling frequency 1024Hz
1.2
1
0.8
0.6
0.4
0.2
0
|Y(f)|
0
100
200
300
400
500
600
Frequency (Hz)

$$\sum_{i=-\infty}^{\infty} \delta(t - iT) = u(t)$$



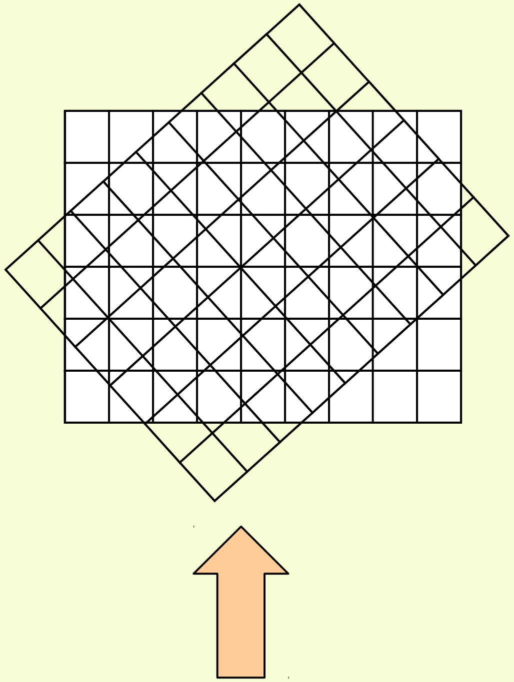

Single-Sided Amplitude Spectrum of y(t) with sampling frequency 400Hz
|Y(f)|
Frequency (Hz)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
20
40
60
80
100
120
140
160
180
200


p
32
200
256
400
600
f

How to use alias information?

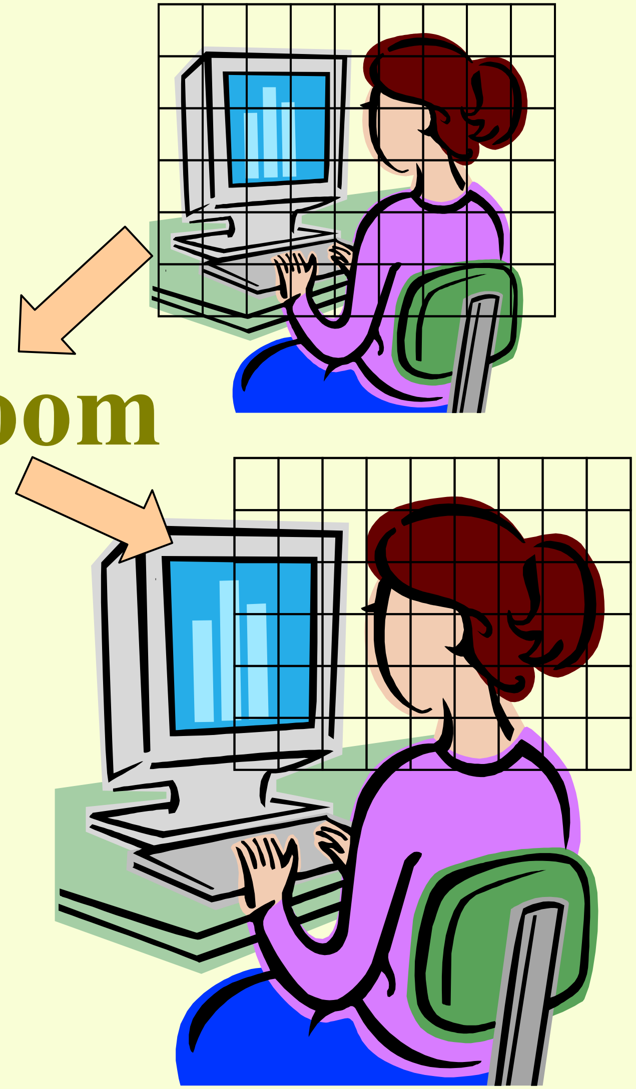
1. Generate „in plane" camera rotation on random angle (angle $\neq k\dfrac{\pi}{2},\quad k=1,2,\ldots$). When such images are registered, the sampling rate is changed.

2. Using camera "zoom". The change of zoom rescale the scene in the same sampling rate, hence the sampling rate of one and same scene element is changed.

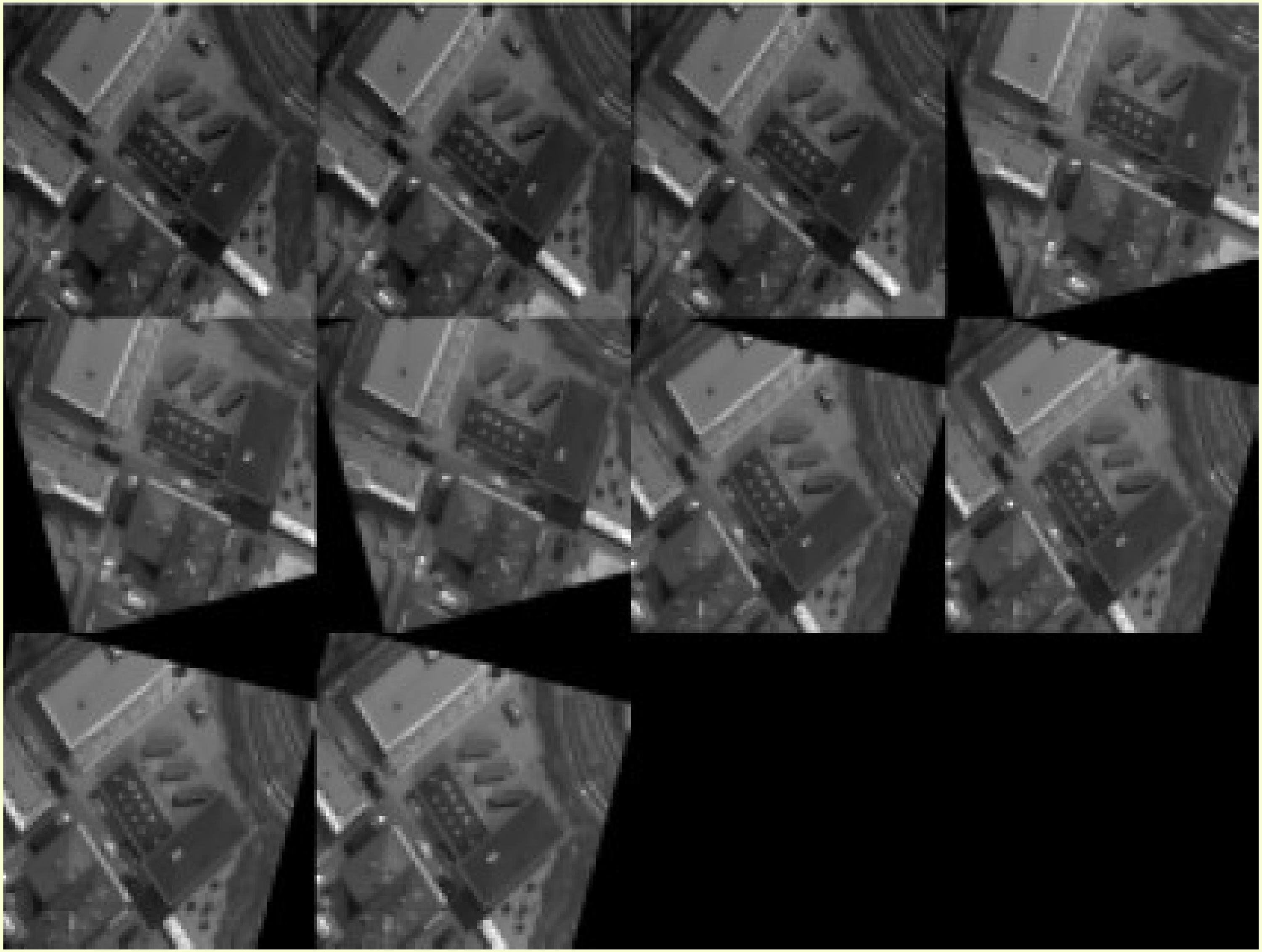


In plane rotation

zoom



Low-resolution images



Enhanced image

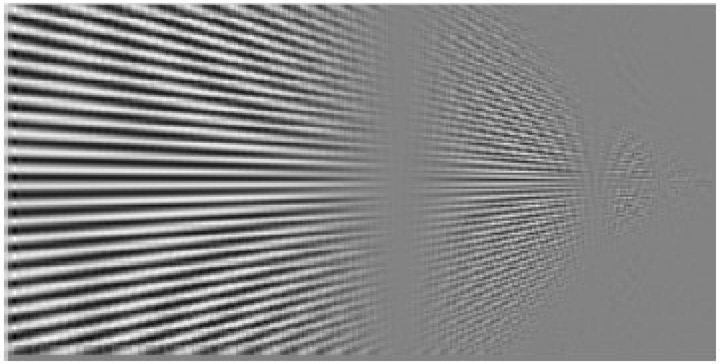


Figure 7: Restored 400x200 HR resolution test target image, no camera rotation

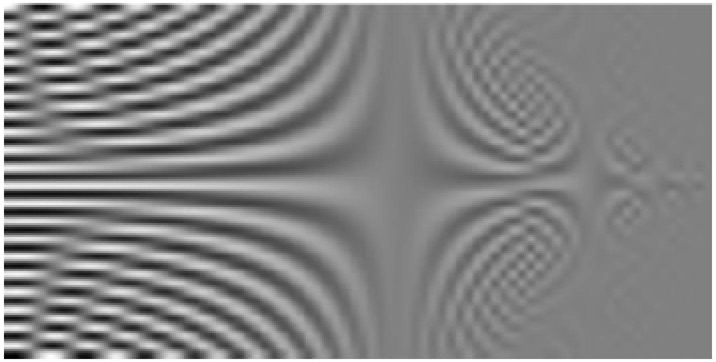


Figure 5: An 80x40 simulated LR resolution test target image

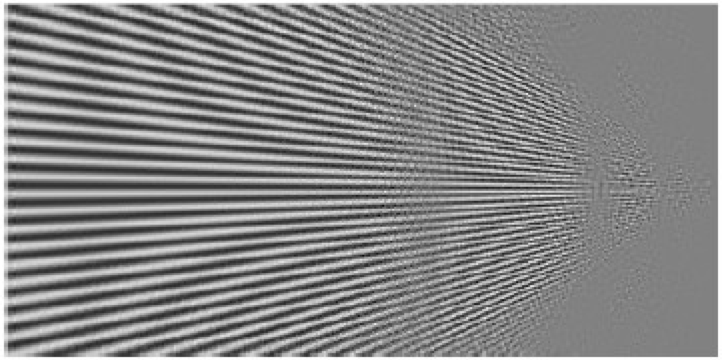


Figure 8: Restored 400x200 HR resolution test target image with camera rotation

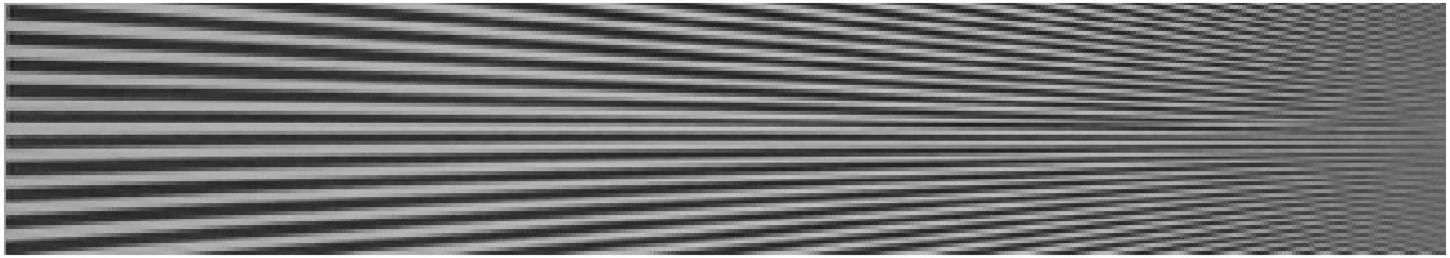


FIGURE 4. Very high resolution photo of a resolution test target (detail)

FIGURE 5. Same detail of one of the 357 by 263 pixel low-resolution photos of the resolution test target

FIGURE 6. Same detail of the 892 by 657 super-resolved image, using 10 images taken using the same zoom

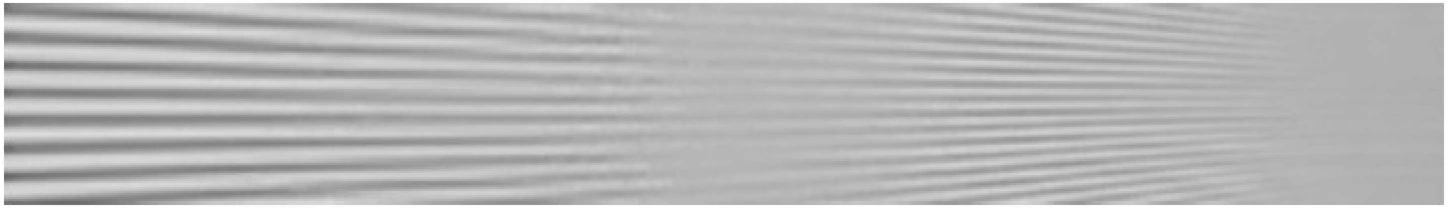


FIGURE 7. Same detail of the 892 by 657 super-resolved image, using 10 images taken under two different zooms

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Technology News

Compressed sensing ups data acquisition resolution, cuts cost

August 19, 2010 | R. Colin Johnson | 222903295

Compressed sensing has been a laboratory curiosity for several years, but now the technology has been cast in an inexpensive hardware prototype that could enable ultrasound, radar and other data-acquisition applications to increase resolution while reducing costs.

Compressed sensing can let lower-speed hardware acquire data just as accurately as existing systems or can be used to make systems more accurate at the same sampling speed. Defense contractors are working with Technion to increase the resolution of existing radar systems; medical contractors are seeking to downsize their hardware at the same resolution.

RELATED NEWS

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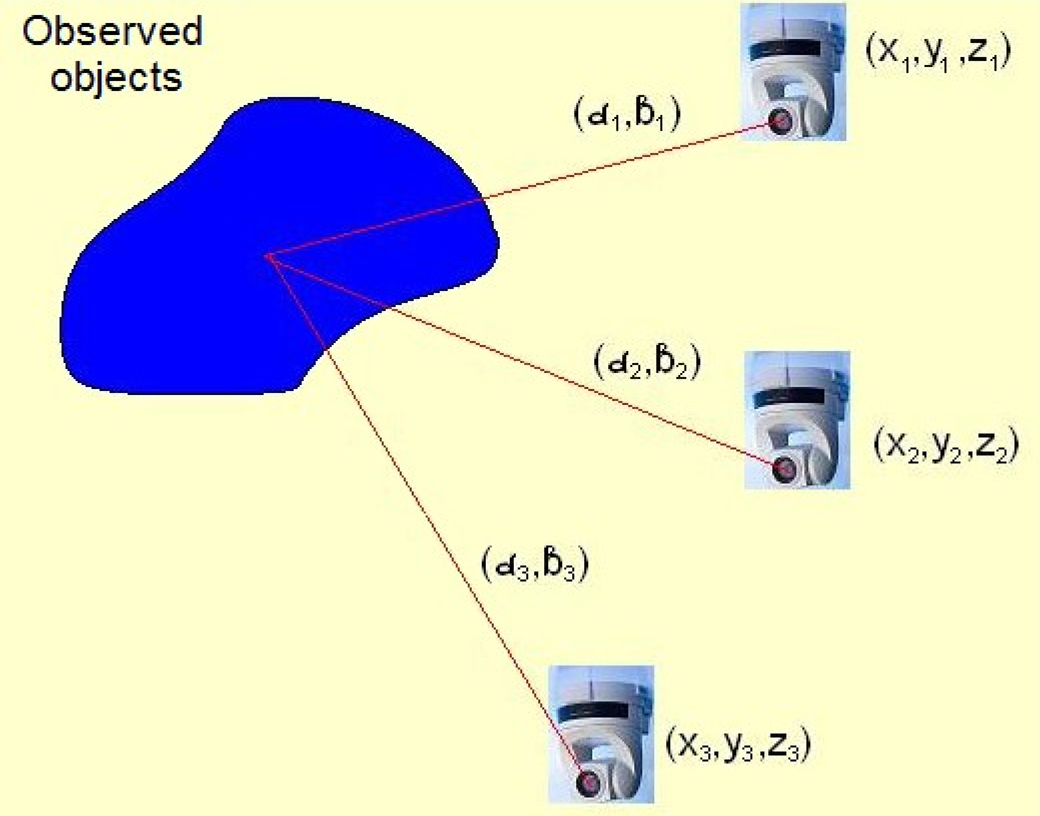
- Hitachi, Seagate, WD forge hard drive research group
- Compact 6-GHz RMS power detector provides fast, accurate RF power

"We are creating aliasing—just what we teach EEs not to do," said Eldar. "We are folding the high-frequency signal into the lower-frequency domain, all aliased, but modulated by a known high-frequency signal. The key to the post-processing step is to recognize that all the information is still there, just aliased into a low-frequency domain, [and that] by using all four channels together, the original [signal] can be reconstructed.“

3D scene reconstruction is important for:

- Object localization;
- Object tracking;
- Discovering space-time relations between participants in the scene;
- Object behavior estimation;
- Future events prediction.

Miltisensor (stereo) approach stereopsis/depth perception



Depth recovering by focusing

Today, all cameras use different auto-focusing systems and algorithms. The auto-focus system, established in most PTZ IP cameras is based on one of the approaches of the passive focus.

Usually they use the fact that the accurately focused image has the highest contrast among all images in the same scene.

Depth from defocus

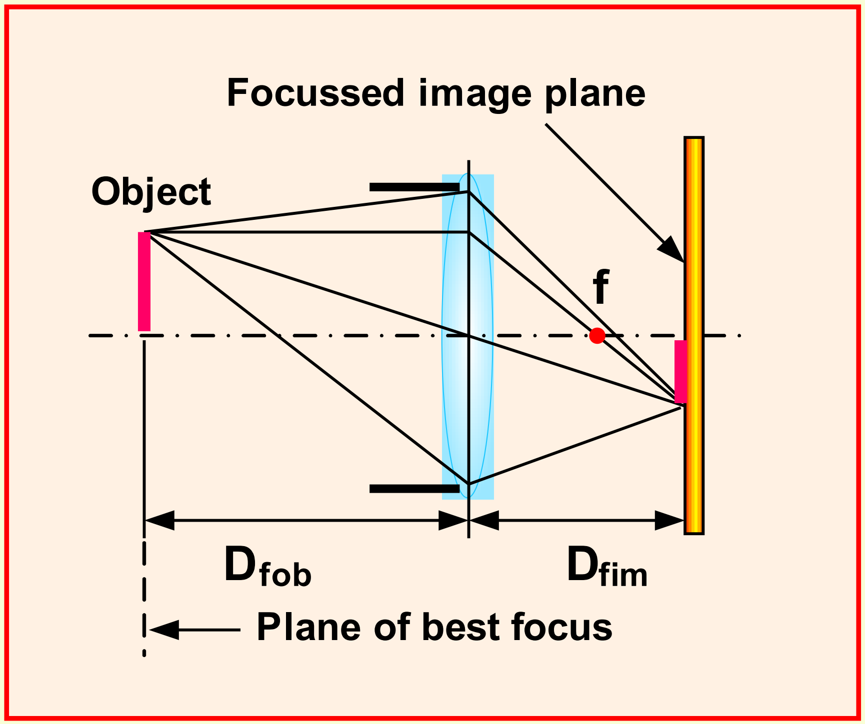
The algorithm steps:

- **Several frames (2-8) are required from camera on one and same scene. In every frame a different camera focus is set;**
- **Edge detection algorithm is applied (Canny);**
- **The blur spot diameter is estimated for every line of interest in the processed frames;**
- **The estimates for blur diameter for a particular line from all processed frames are input parameters for an optimization procedure for line fitting (Levenberg–Marquardt).**

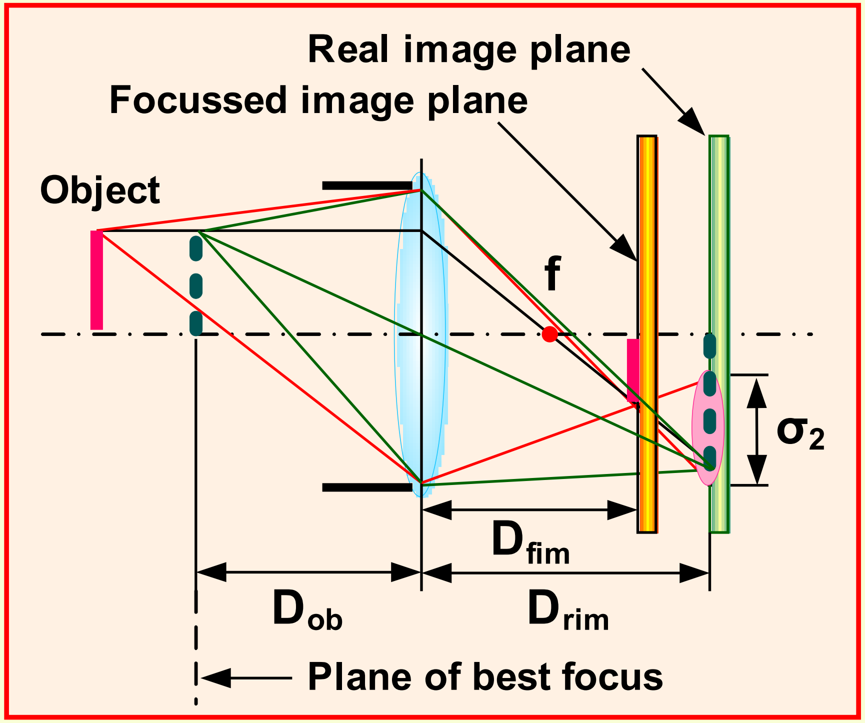
Blur spot diameter estimation

Blur spot estimation is carried out onto detected edges. This reduces the number of analyzed image fields. The brightness profile on the processed edge is built and blur width is estimated. The integration of results for many points is applied to reduce the influence of Gaussian additive noise. Also, it is considered the gradient of intensity, not the intensity itself to diminish the role of intensity.

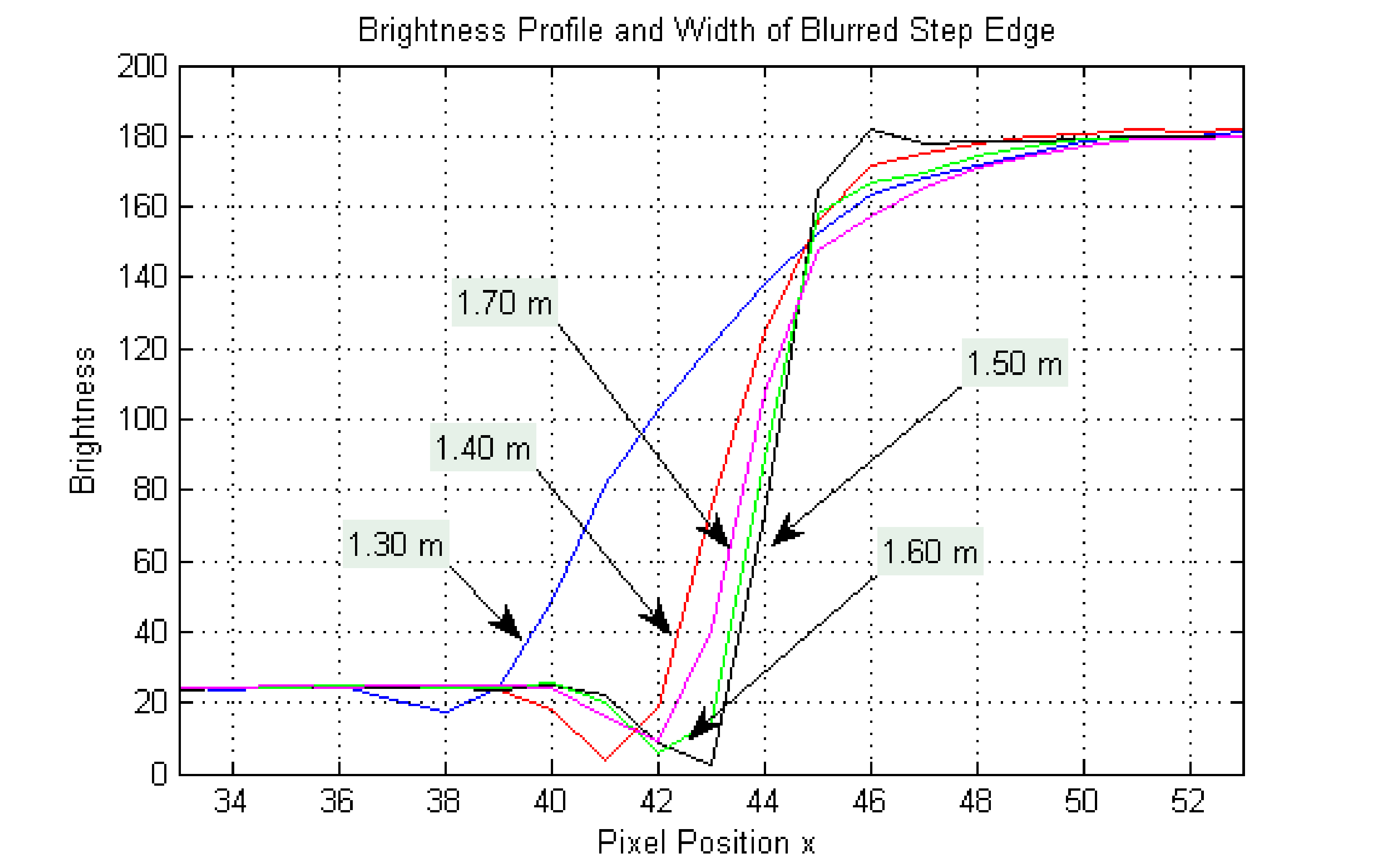
Focused object



Object out of focus



Blur spot diameter estimation – cont.



Mathematical model of defocus blur

The main equation describing dependencies in this model is based on the Gaussian lens law:

$$\frac{1}{f} = \frac{1}{D_{fob}} + \frac{1}{D_{fim}}$$

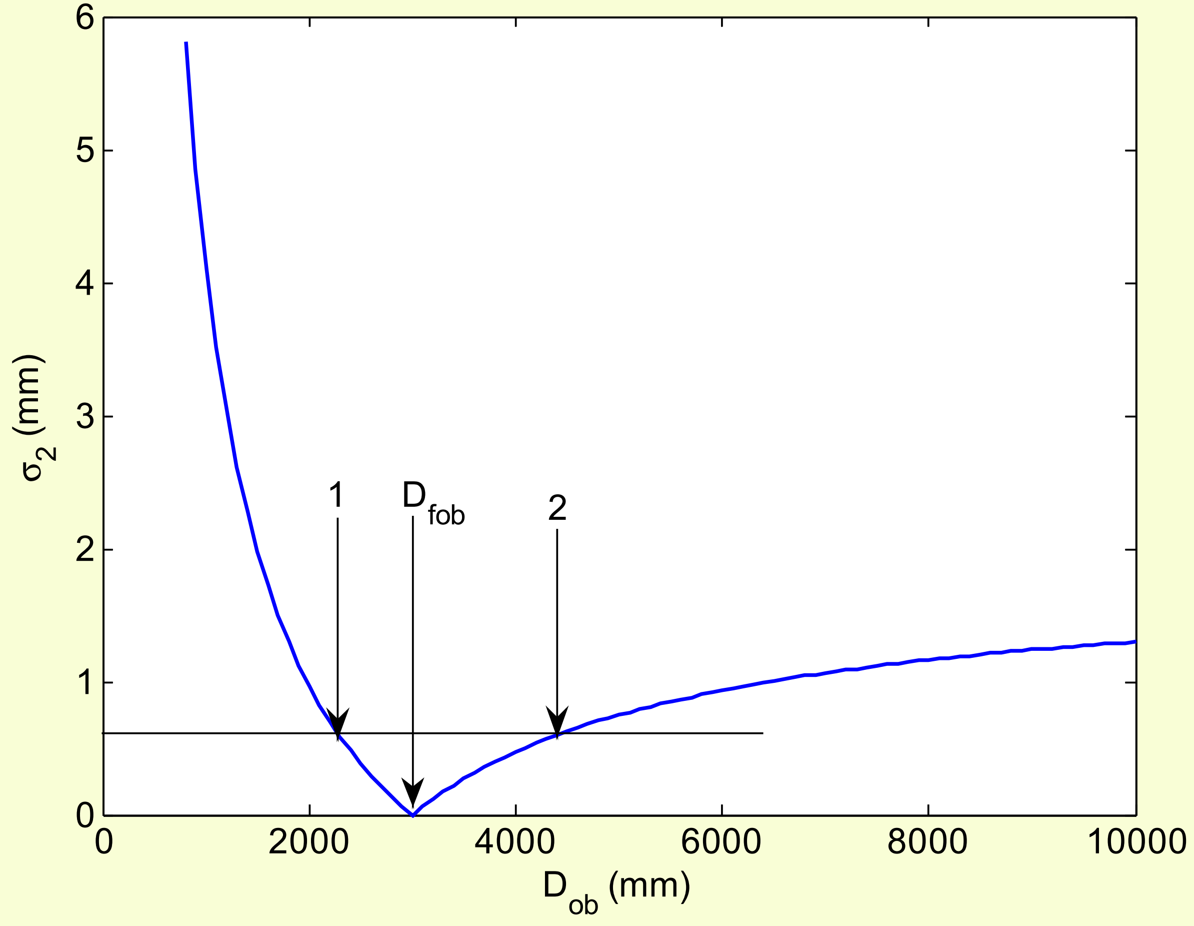
$$D_{fim} = \frac{fD_{fob}}{D_{fob} - f}$$

$$\sigma_2 = \frac{B_2}{D_{fim}} abs(D_{rim} - D_{fim})$$

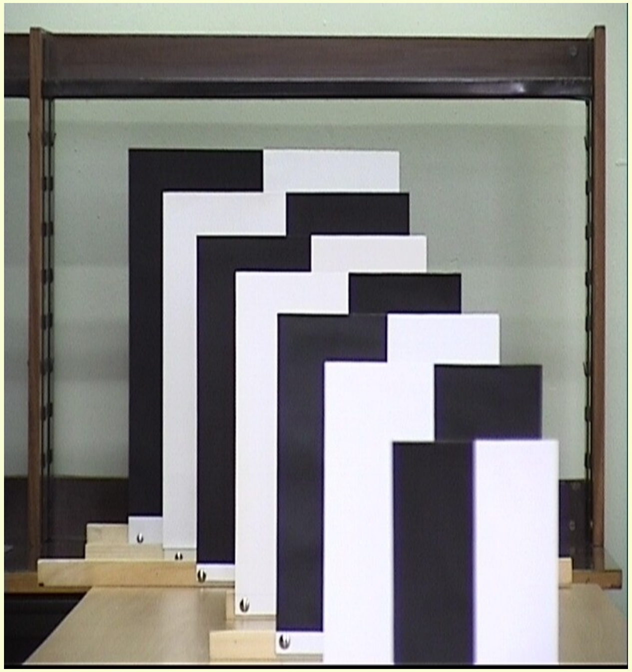
$$D_{rim} = \frac{fD_{ob}}{D_{ob} - f}$$

$$\sigma_2 = \frac{B_2}{D_{fim}} abs\left(\frac{fD_{fob}}{D_{fob} - f} - \frac{fD_{ob}}{D_{ob} - f} \right)$$

Mathematical model of defocus blur



Experimental results



Scene 1 – templates

Scene 2 – real scene

Scene 3 – real scene

Experimental results

Test templates – scene 1 Zoom 9x			**Real Scene 2 Zoom 6x**		**Real Scene 3 Zoom 6x**	
	Inside Edges	**Outside Edges**				
Real distance [m]	Estimated distance [m]	Estimated distance [m]	Real distance [m]	Estimated distance [m]	Real distance [m]	Estimated distance [m]
3.0	3.16	2.67	1.37	1.30	3.78	1.64
3.5	3.20	3.27	1.77	1.68	3.22	1.20
4.0	3.65	3.72	2.43	1.49	2.81	2.50
4.5	3.91	4.02	2.04	1.99	2.47	1.75
5.0	4.54	4.68	2.04	1.62	1.69	1.65
5.5	4.83	5.04	1.91	1.92	1.65	1.49
6.0	5.27	4.91	2.06	1.86		

Plane depth recovery

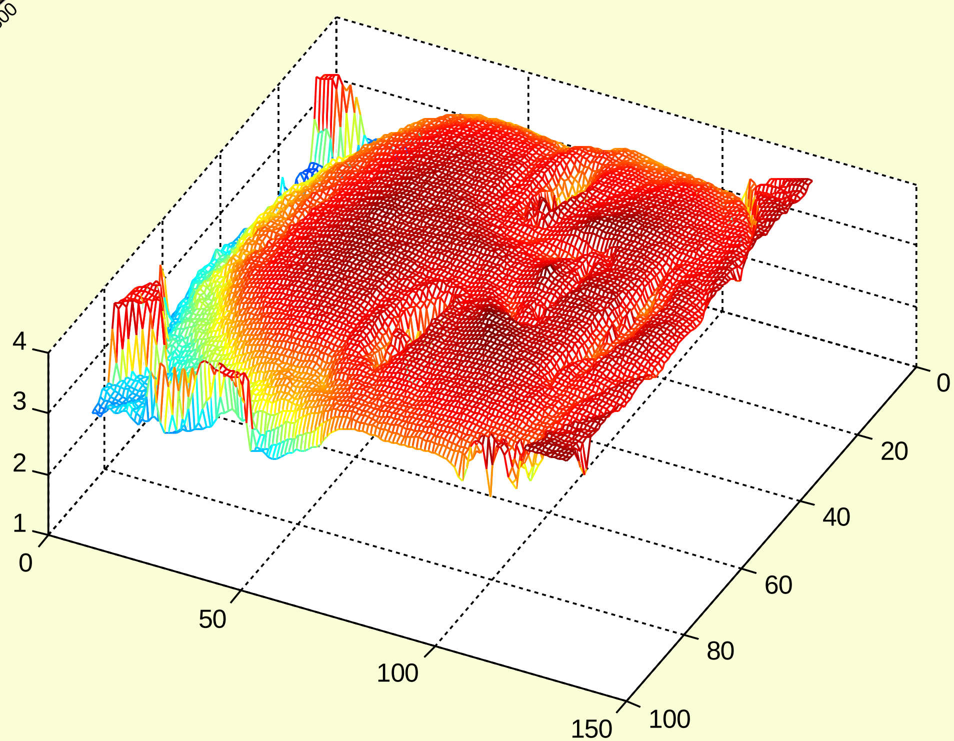
$$P \approx I = K \frac{1}{D_l^2} \frac{1}{D_c^2} \approx K \frac{1}{\left(Depth\right)^4}$$

where

D_l -Distance between object and light source

D_c - Distance between object and camera


200
400
600
800
1000
1200
100
200
300
400
500
600
700
800
900


4
3
2
1
0
50
100
150
0
20
40
60
80
100


100
200
300
400
500
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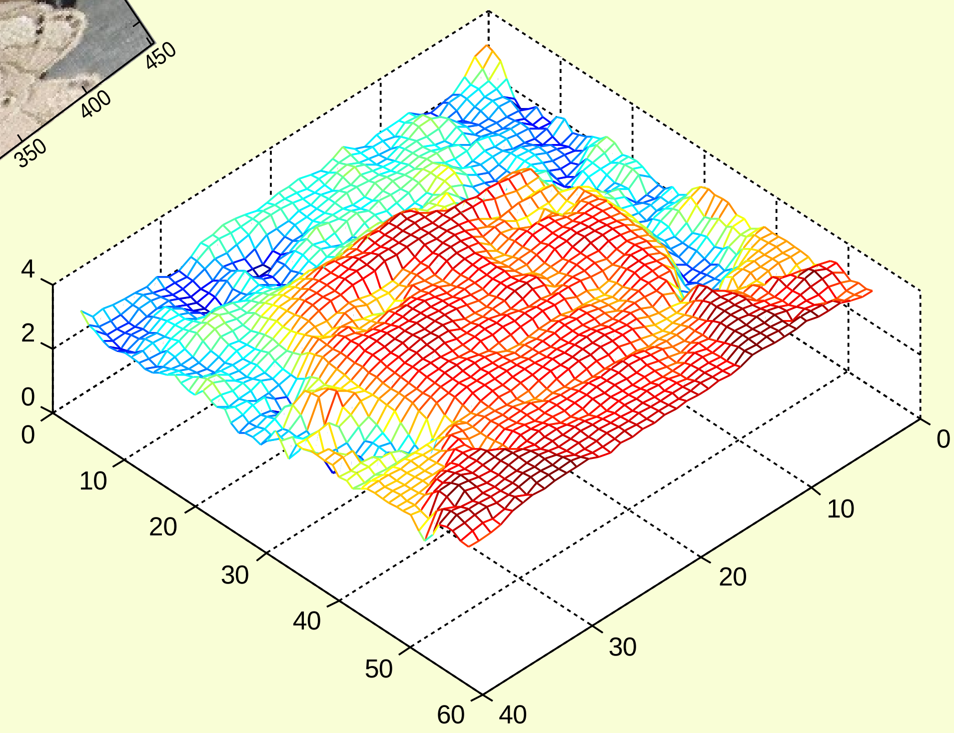
50
100
150
200
250
300
350
400
450


4
2
0
0
10
20
30
40
50
60
40
30
20
10
0

Acknowledgments

1. I’m much obliged to the organizers of the conference and personally to Dr. Reinaldo Rosa for opportunity to be here, to participate in the conference and to see this wonderful country!

2. This presentation is partially supported by the Bulgarian Ministry of Education and Science under grants VU-MI-204/06