VIII International Conference on Information Technology and Nanotechnology

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Automatic dominant orientation estimation of texture images using the scattering ellipse of the gradients

Автоматическое оценивание доминантной ориентации текстурных изображений с применением эллипса рассеяния градиентов

23 - 27 May 2022, Samara, Russia

RUSSIAN-ARMENIAN UNIVERSITY

INSTITUTE FOR INFORMATICS AND AUTOMATION PROBLEMS
NATIONAL ACADEMY OF SCIENCES OF ARMENIA

PLAN

Introduction
Mathematical models
- Weibull distribution
- Similarity assessment measure

Parameters estimation
- Blur assessment measure
- Scattering Ellipse
- Dominant Orientation Estimator
- Sharpness Estimator

Results of experiments

Mathematical model-1

Image I={I(m,n)}, I(m,n)∈{0,1,...,255}, m = 0,1,..., N −1, n=0,1,…,M-1

Gradients components: G_V – vertical, G_H - horizontal

$M = \sqrt{G_V^2 + G_H^2}$ - Gradient magnitude

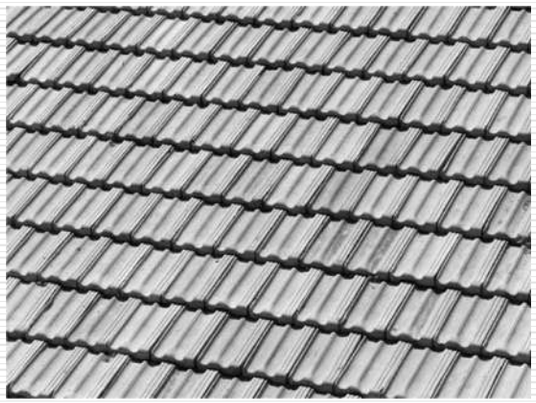
$f(x;\lambda,\eta) = \frac{\eta}{\lambda}\left(\frac{x}{\lambda}\right)^{\eta-1} \exp\left[-\left(\frac{x}{\lambda}\right)^{\eta}\right], x \geq 0,$ - Weibull distribution for M

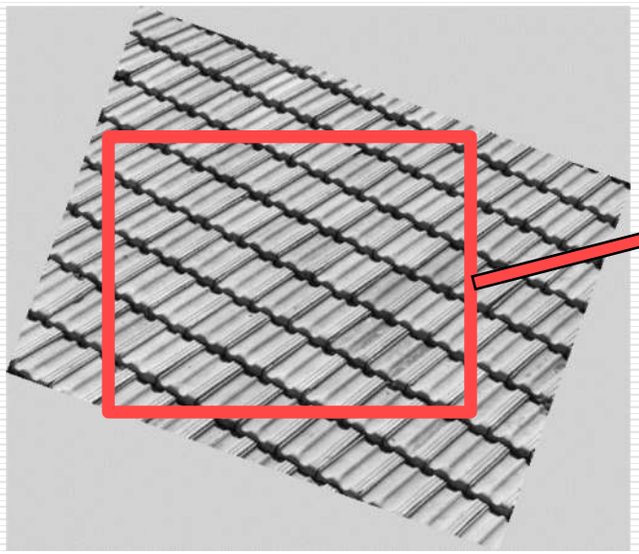
Similarity of two images

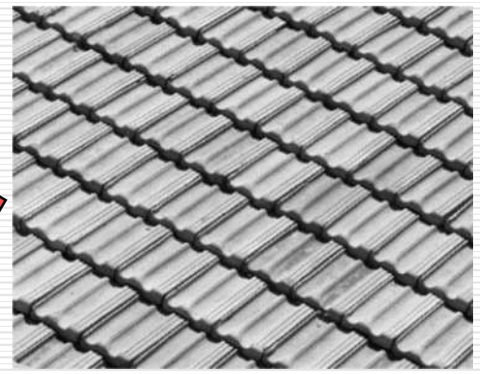
$$W^2 = \frac{\min(\eta_1,\eta_2)\min(\lambda_1,\lambda_2)}{\max(\eta_1,\eta_2)\max(\lambda_1,\lambda_2)}, \qquad 0 < W^2 \leq 1,$$

where $\eta > 0$ is the shape parameter, $\lambda > 0$ is the scale parameter of Weibull distribution, applied to the gradient magnitudes of the tested images.

Similarity assessment (example)

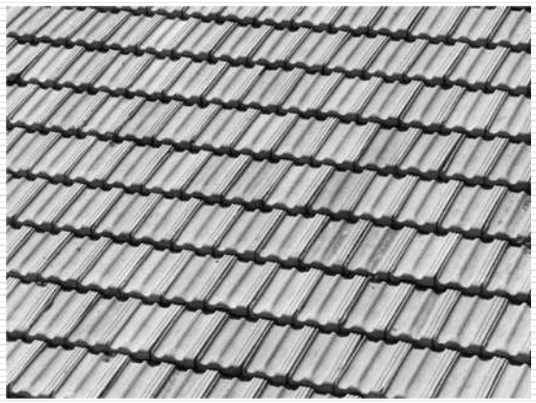




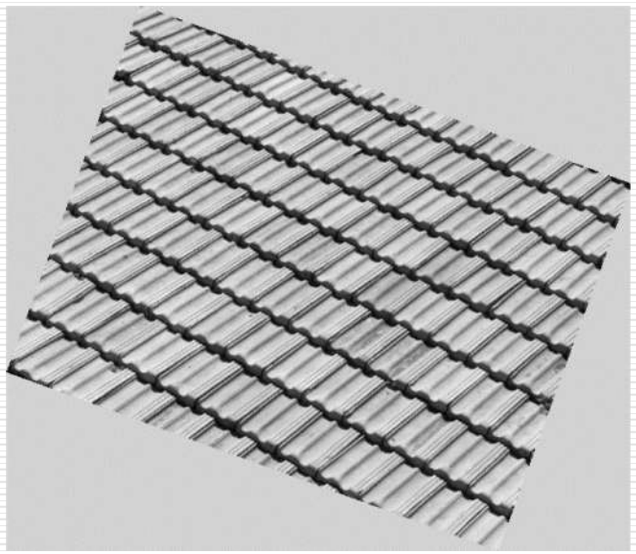


Original Rotated Fragment

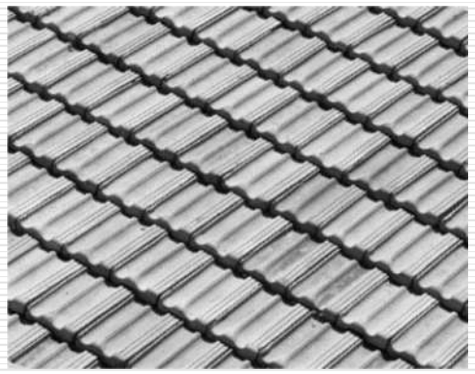
Similarity assessment (example)



Original



Rotated



Fragment

Similarity measure W^2

Original – Rotated	-	0.297
Original – Fragment	-	0.879
Rotated – Fragment	-	0.315

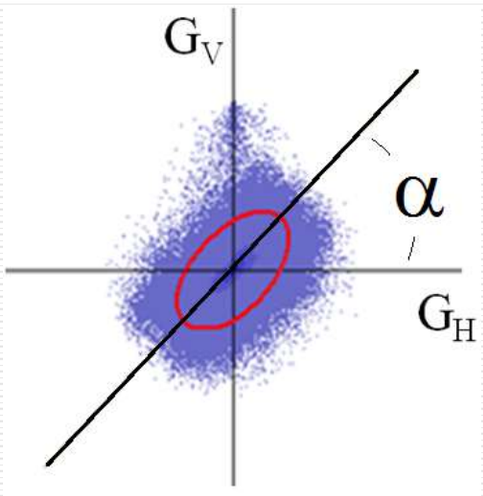
Mathematical model-2 (Scattering Ellipse)

$$\frac{1}{1-\rho_{HV}^2}\left[\frac{(g_H-\mu_H)^2}{\sigma_H^2}-\frac{2\rho_{HV}(g_H-\mu_H)(g_V-\mu_V)}{\sigma_H\sigma_V}+\frac{(g_V-\mu_V)^2}{\sigma_V^2}\right]=C^2$$

Where $\mu_H, \mu_V, \sigma_H, \sigma_V$ - the means and MSE of the gradient components,

ρ_{HV} - the correlation coefficient between gradient components

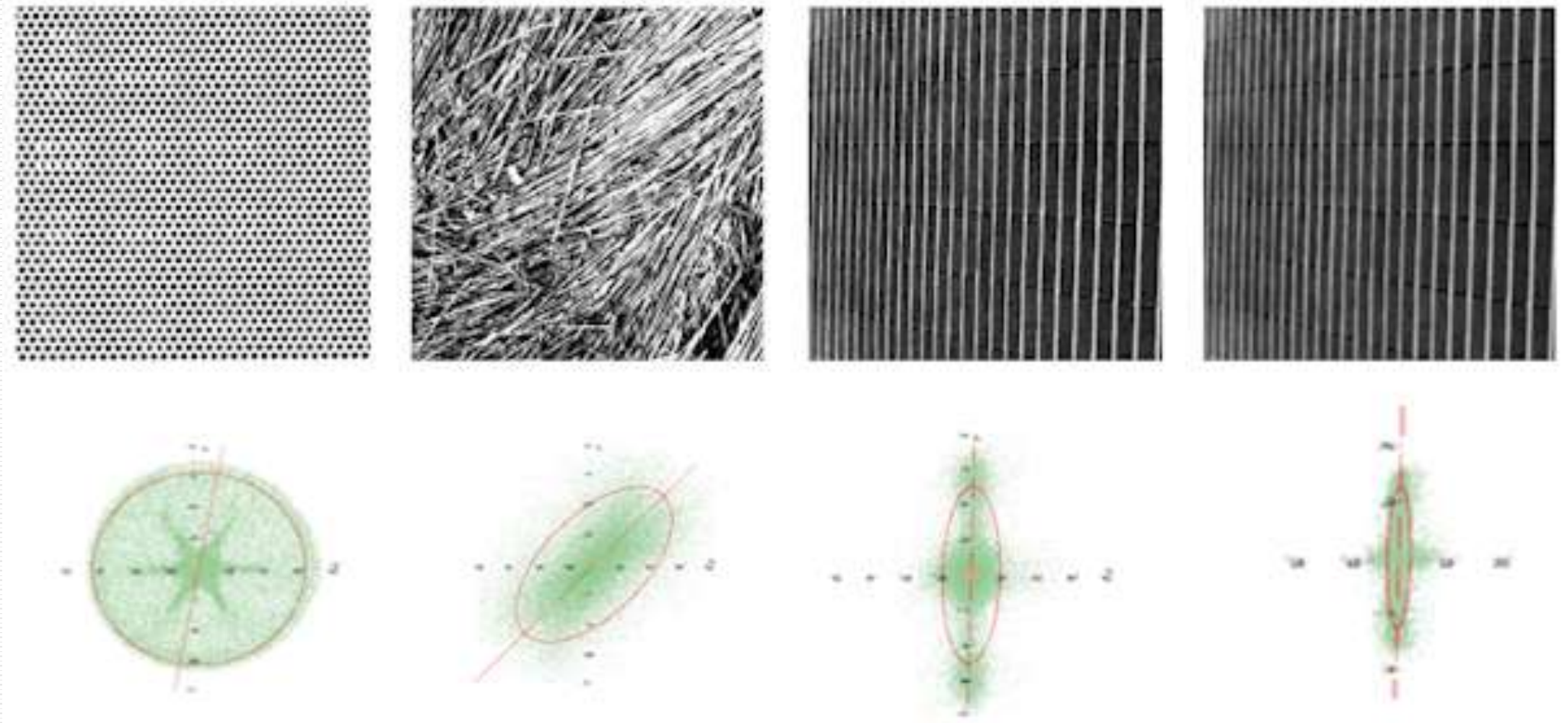
$$tg\alpha=\frac{2*\sigma_H\sigma_V\rho_{HV}}{\sigma_H^2-\sigma_V^2-\sqrt{(\sigma_H^2-\sigma_V^2)^2+4\sigma_H^2\sigma_V^2\rho_{HV}^2}}$$ - Angle of dominant orientation



$$\beta=\frac{\max(E_1,E_2)}{\min(E_1,E_2)}$$ - Sharpness Estimate

E_1, E_2 – Axes of the ellipse

Angle α and Sharpness β of the Dominant orientation (Examples)

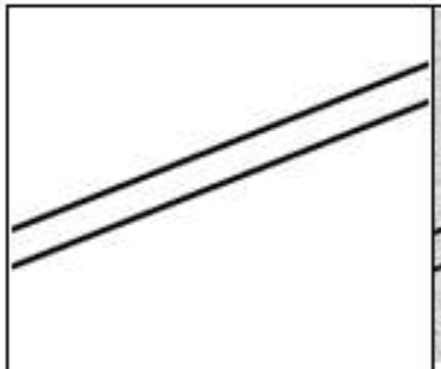
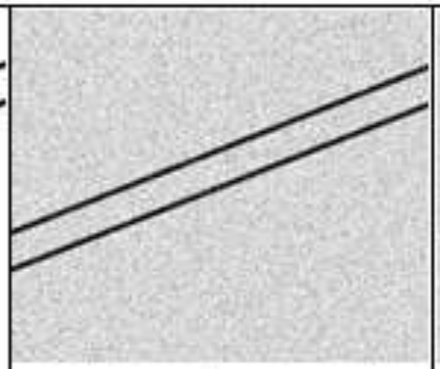
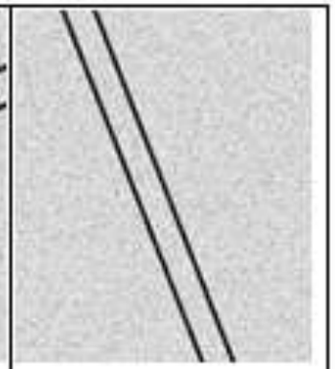


$\alpha = 80°$	$\alpha = 43.6°$	$\alpha = 88.5°$	$\alpha = 88.5°$
β=1.02	β=1.96	β=3.03	β=5.88

Sharpness β is the ratio of major and minor axes
of the scattering ellipse

Experiments

Experiment 1. Noise addition and rotation. Quality evaluating parameters

IDO=20°	20°	110°
		
a	b	c
α=20.26°	α=20.32°	α=110.32°
β=14.9	β=1.07	β=1.07
η =0.26	η =1.69	η =1.69

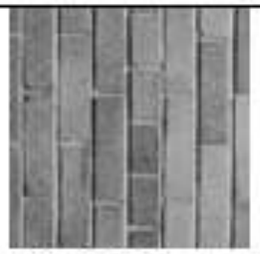
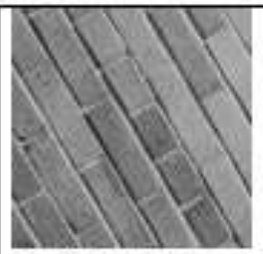
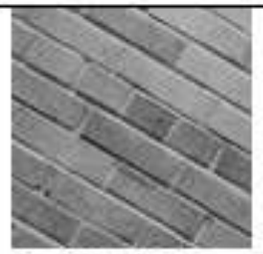
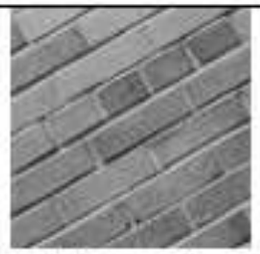
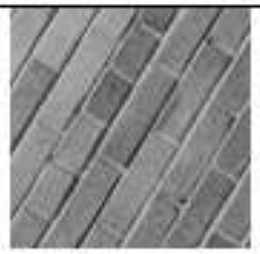
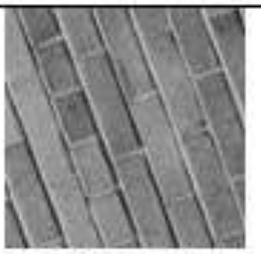
Parameters

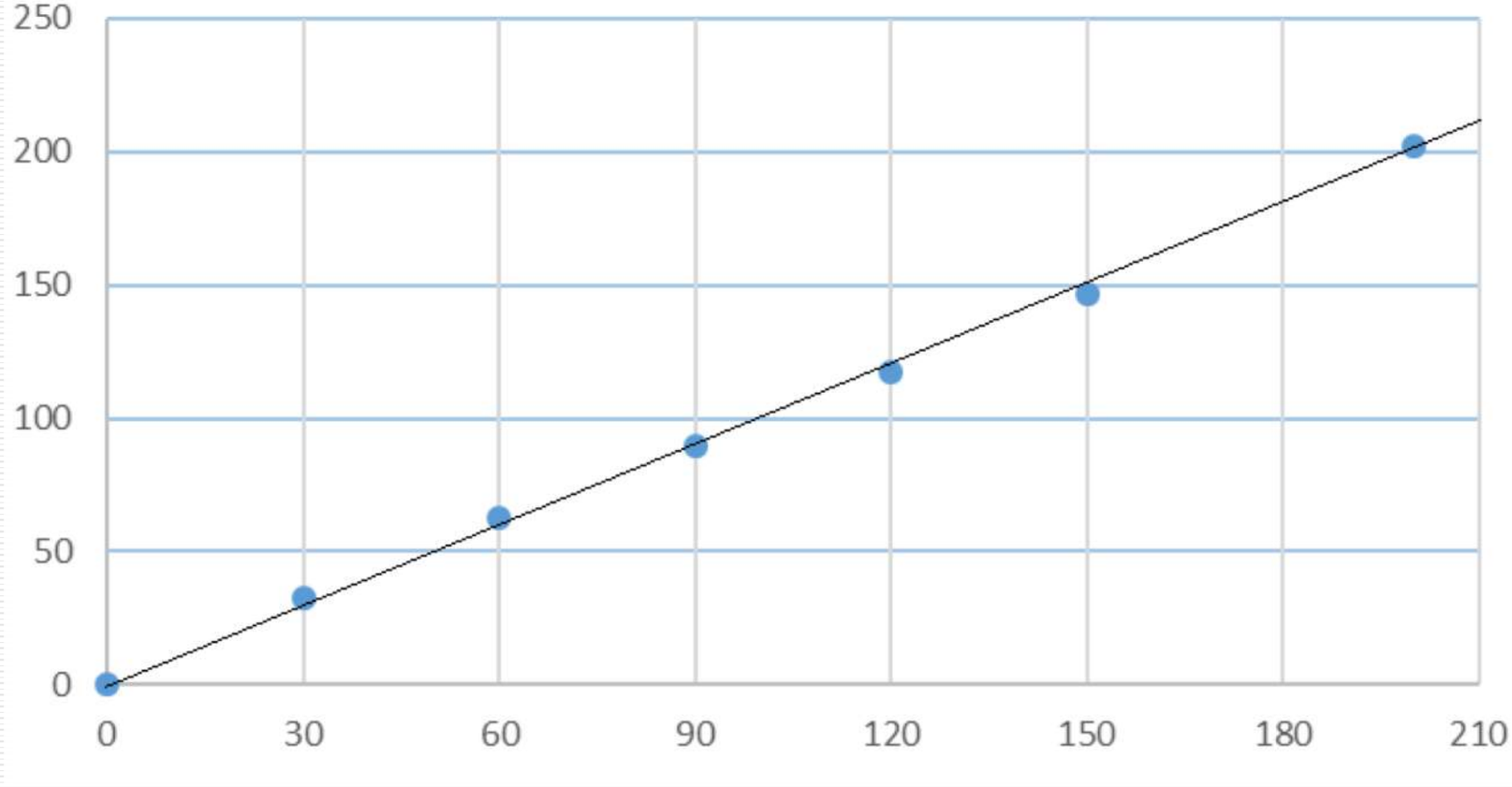
α – Dominant orientation angle (DOA), deg.

β – Sharpness of DOA estimate

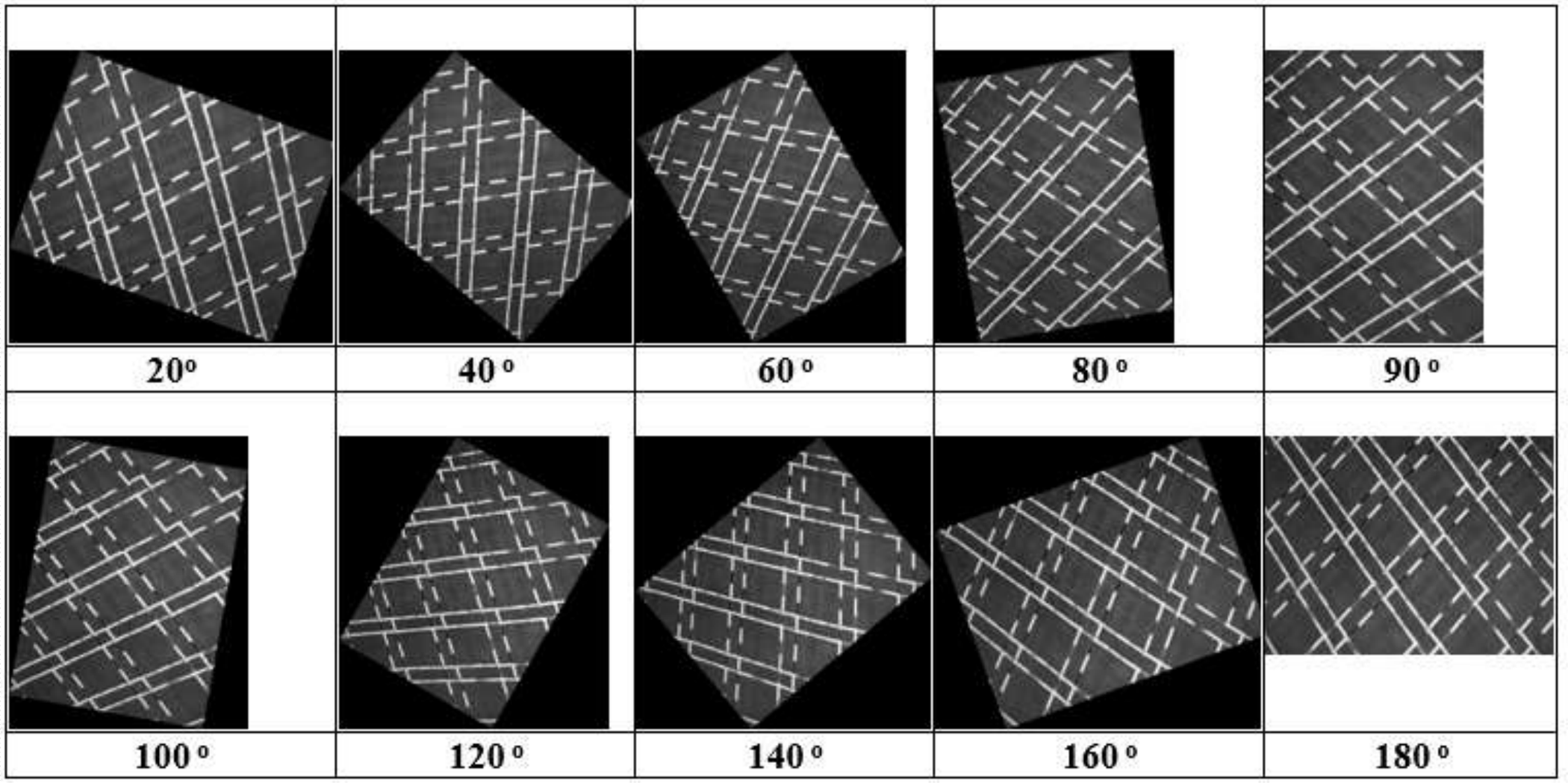
η – Blur estimate (Shape parameter of Weibull distribution)

Experiment 2. Rotation of a texture image.

 brick00.bmp	 brick30.bmp	 brick60.bmp	 brick90.bmp	 brick120.bmp	 brick150.bmp	 brick200.bmp
$\hat{\alpha}$ = 0°	$\hat{\alpha}$ =32.7°	$\hat{\alpha}$ = 62.8°	$\hat{\alpha}$ =89.8°	$\hat{\alpha}$ =117.1°	$\hat{\alpha}$=146.8°	$\hat{\alpha}$ =202.3°
$\hat{\beta}$ =1.61	$\hat{\beta}$ =1.63	$\hat{\beta}$ =1.75	$\hat{\beta}$ =1.80	$\hat{\beta}$ =1.72	$\hat{\beta}$=1.59	$\hat{\beta}$ =1.55
$\hat{\eta}$ =1.22	$\hat{\eta}$=1.22	$\hat{\eta}$ =1.21	$\hat{\eta}$ =1.21	$\hat{\eta}$ =1.22	$\hat{\eta}$=1.25	$\hat{\eta}$ =1.28

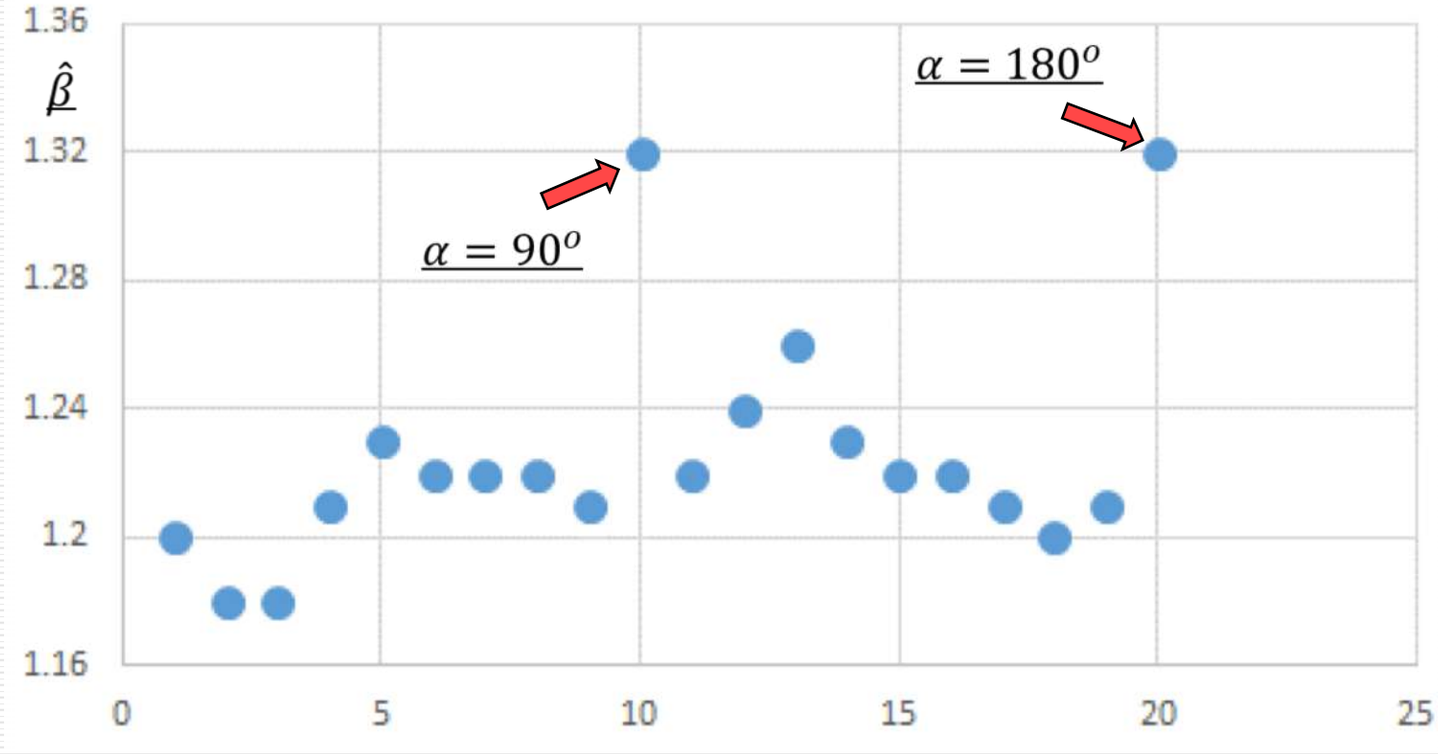


Experiment 3. Rotation by usual method.

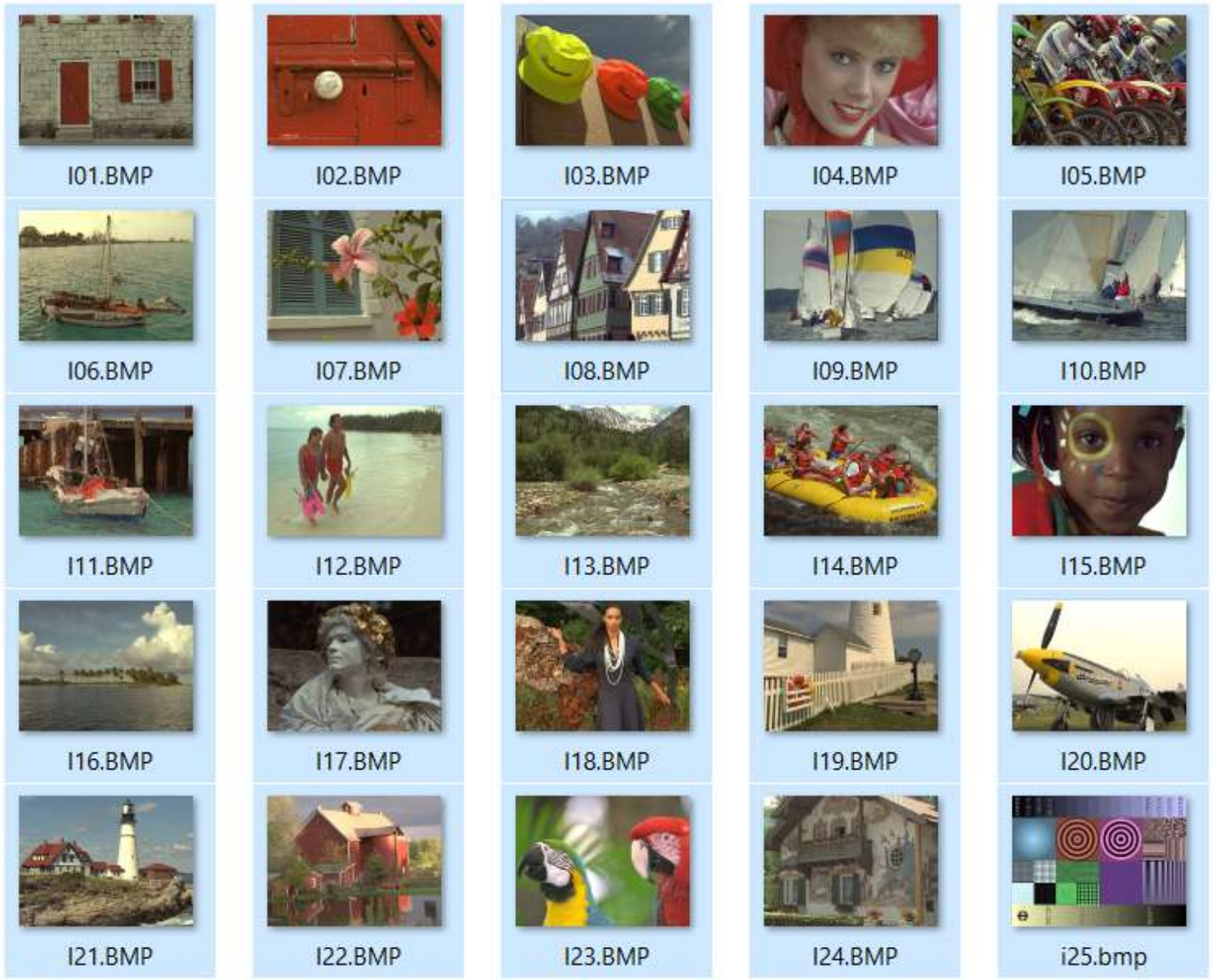


Experiment 3. Results

Parameters				Parameters			
α	$\hat{\alpha}$	$\hat{\beta}$	$\hat{\eta}$	α	$\hat{\alpha}$	$\hat{\beta}$	$\hat{\eta}$
20	14.5	1.18	0.57	100	97.5	1.22	0.56
40	36.0	1.21	0.47	120	117.0	1.26	0.48
60	60.0	1.22	0.48	140	135.3	1.22	0.47
80	76.9	1.21	0.56	160	153.6	1.20	0.51
90	90.8	**1.32**	0.66	180	180.2	**1.32**	0.66



Experiment 4. Reference images from Database TID_2013

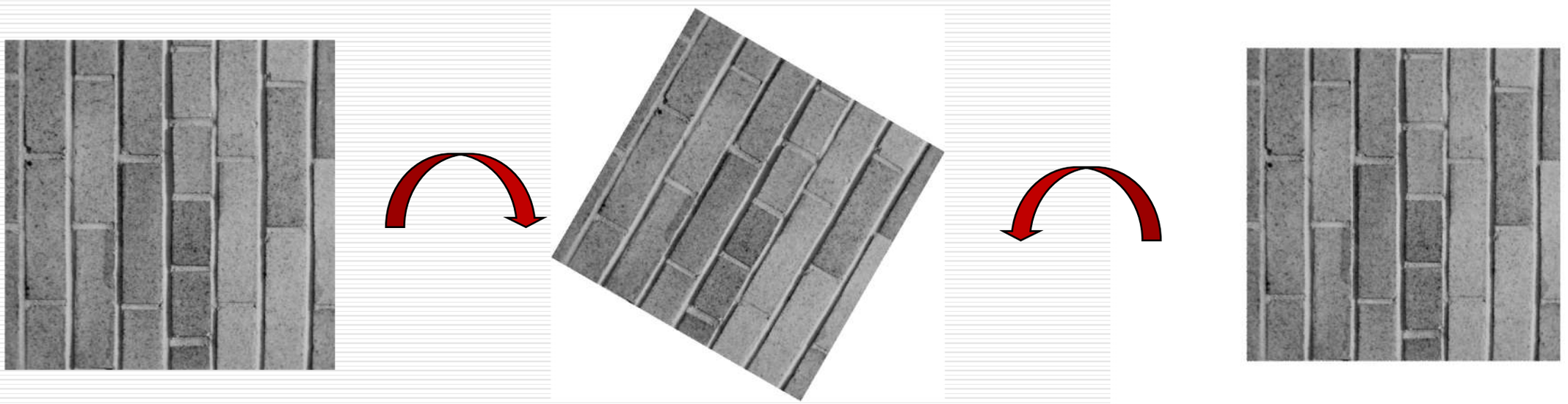


All images were rotated by the same angle of 60° and estimated the angular displacement of the dominant orientation.

Results:

- The standard deviation of the DIO estimate error - 2.1°, $\bar{\beta} = 1.23$

Experiment 5. “Backlash” as quality assessment measure for rotation procedure



$\hat{\alpha} = -0.7$ $\hat{\alpha} = 28.7$ $\hat{\alpha} = 0.2$

$$\text{Backlash} = 0.2 - (-0.7) = 0.9$$

Experiment 5. “Backlash” as measure for rotation procedure quality assessment

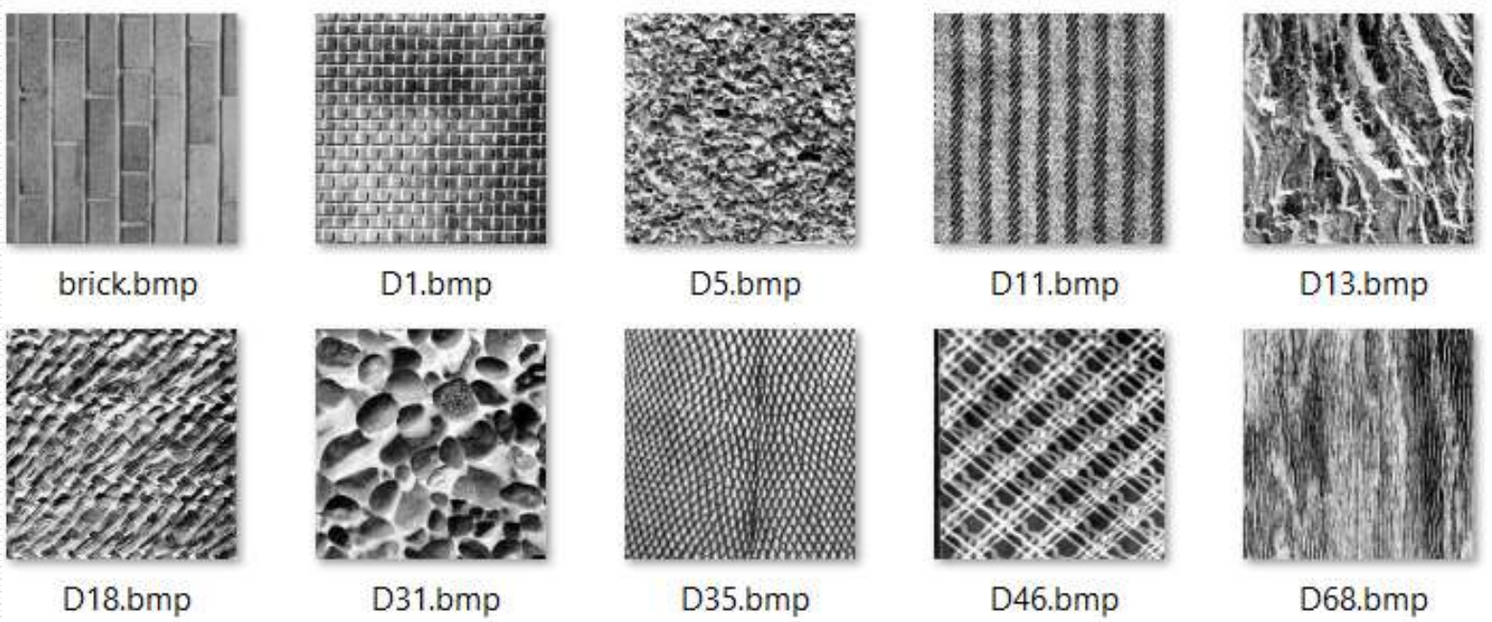
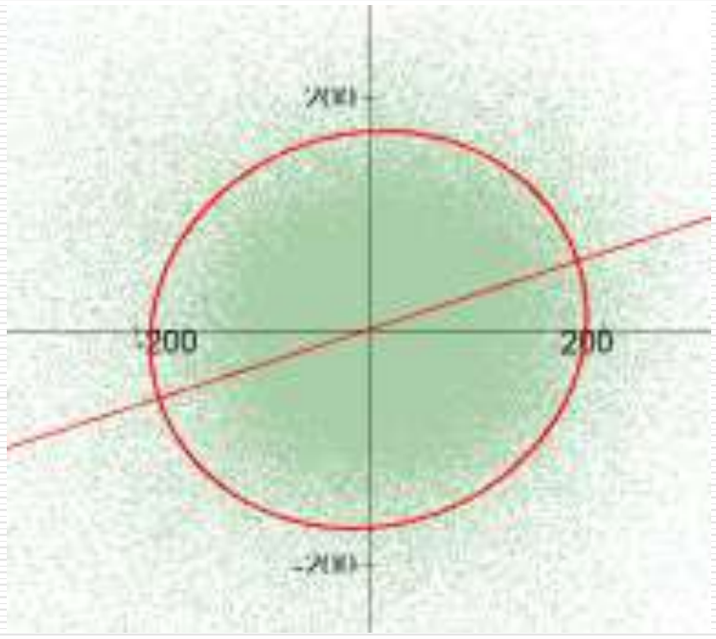
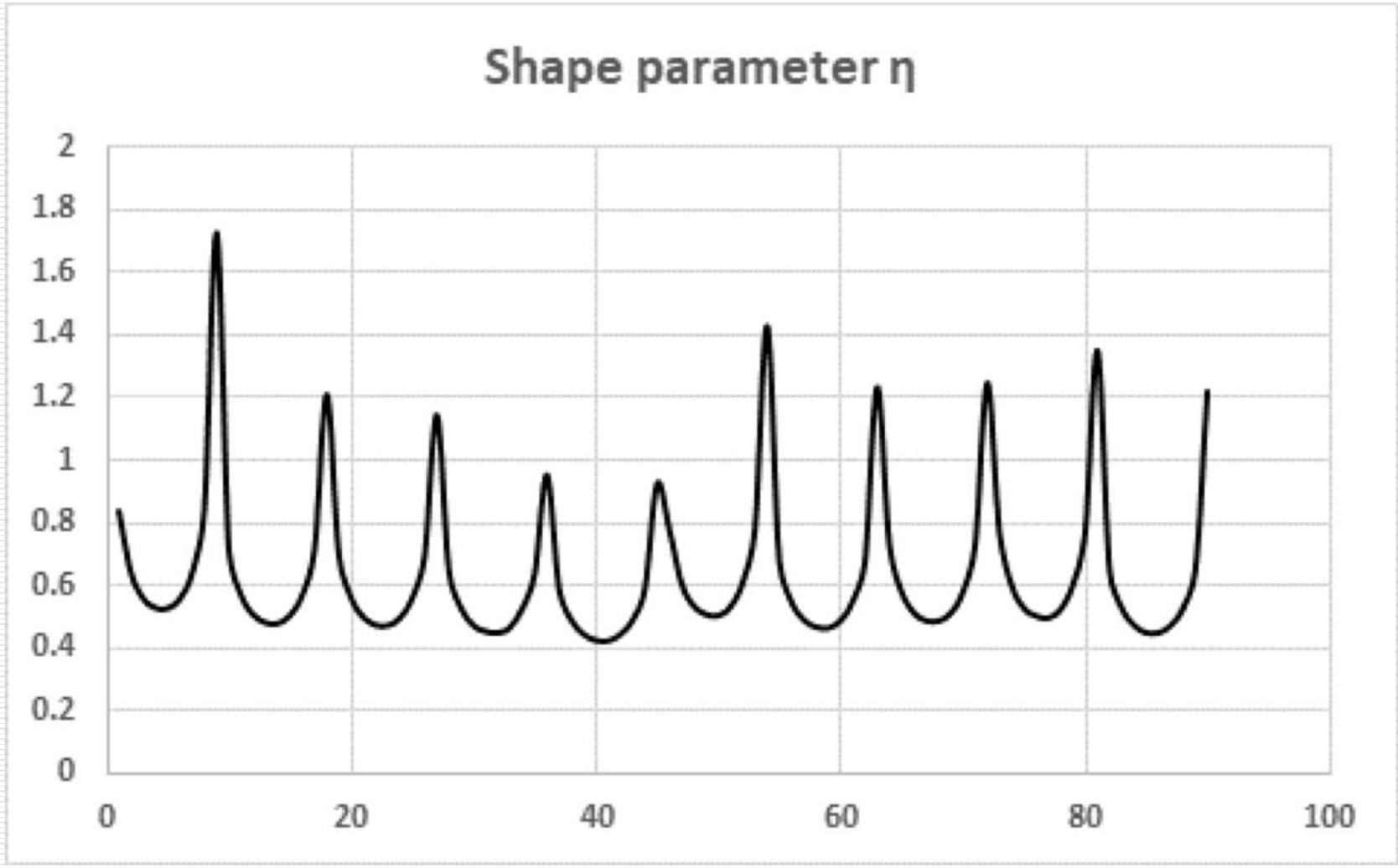


Image	$\bar{\beta}$	MSE of β	Average backlash	MSE of backlash
1	1.15	0.056	6.44	3.52
2	1.25	0.045	3.56	2.73
3	1.37	0.066	2.22	1.38
4	1.16	0.064	1.33	1.51
5	1.1	0.034	6.45	4.76
6	1.44	0.094	0.84	0.98
7	1.07	0.031	26.7	16.4
8	1.15	0.043	3.16	2.63
9	2.92	0.81	0.16	0.21
10	1.44	0.122	0.61	0.56



Experiment 5. Dependence of an image blur on shape parameter η



THANK YOU
FOR ATTENSION