FROM IMAGERY TO DIGITAL REALITY: ERS & Photogrammetry
19th International Scientific and Technical Conference

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СИБИРСКИЙ ГОСУДАРСТВЕННЫЙ
УНИВЕРСИТЕТ ГЕОСИСТЕМ
И ТЕХНОЛОГИЙ

Forest space image decoding using the structural-statistical approach

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Natural object decoding

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The main goal

- ✓ to form feature vectors that are capable to detect objects and their characteristics in a unique manner

The way to solve a goal

- ✓ To creating a model linking features and measurements carried out in a model space;
- ✓ Features have to define objects uniquely;

The structural-statistical approach

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The structural-statistical approach has to determine unique links when changing spectral brightness of pixels.

(based on a joint analysis of a neighboring pixel group forming a feature vector).

The essence of the non-parametric approach

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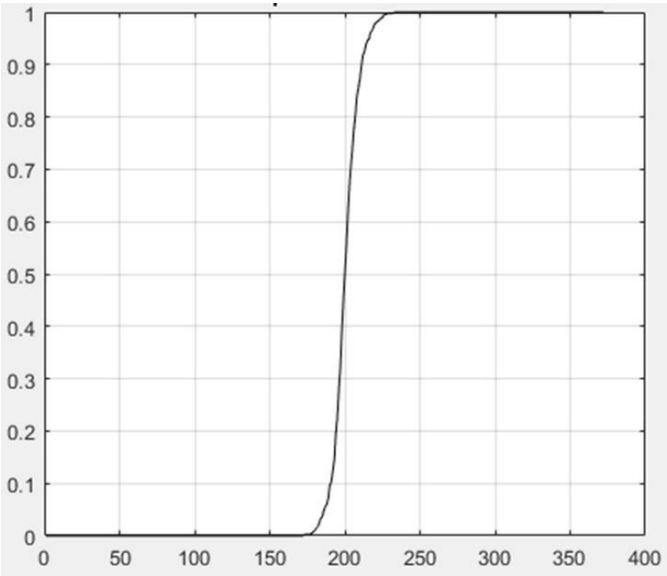
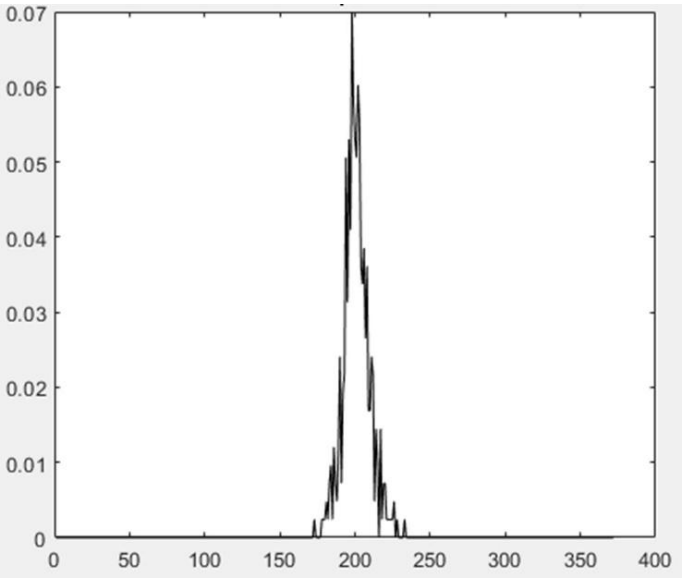
- ✓ reference features in the form of probability density and the cumulative distribution functions are generated with samples for all object classes required for recognition;
- ✓ measurements are performed according to images of reference objects;
- ✓ Application of decision rules.



Cumulative distribution function



Probability density function

The decision rule for comparing functions

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For probability density functions

Pearson's correlation coefficient K_{xy} between two functions of images x, y.

$$K_{xy} = \frac{\sum_{i=0}^{n}((x_i - \overline{X})(y_i - \overline{Y}))}{\sqrt{\sum_{i=0}^{n}(x_i - \overline{X})^2 \sum_{i=0}^{n}(y_i - \overline{Y})^2}}$$

x_i – the probability, that brightness pixel value of the image *x is equal to the value i* at brightness range [0, n];

y_i – the probability, that brightness pixel value of the image *y is equal to the value i* at brightness range [0, n];

$\overline{X}$ – mean value of probability density function for image *x*;

$\overline{Y}$ – mean value of probability density function for image *y*.

For cumulative distribution functions

Minimum Distance between two functions of images (for each spectral band)

$$r = \frac{\sum_{j=1}^{10}|f[j] - f_i[j]|}{10}$$

f – brightness vector of the size 1x10 corresponding to the tested cumulative distribution function;
f_i – brightness vector of the size 1x10 corresponding to the reference cumulative distribution function;
r – distances between functions.

For the whole image:

$$r = \frac{\sum_{j=1}^{10}\sqrt{\sum_{k=1}^{n}(f[j]_k - f_i[j]_k)^2}}{10}$$

n – number of spectral bands;
k – the number of a spectral band.

Source data

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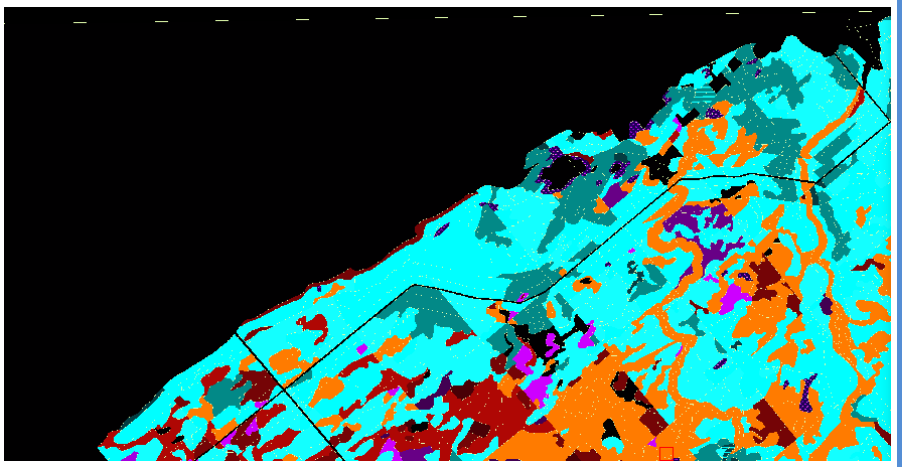
A four-channel Ikonos space image for the area of Karakan forest near Berdsk in Novosibirsk region.



The thematic map for species composition of forest

Creation of reference samples

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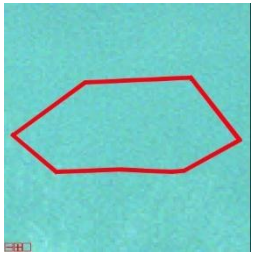
Birch

aspen

pine



water

ground

The example of generating probability density functions in an infrared band

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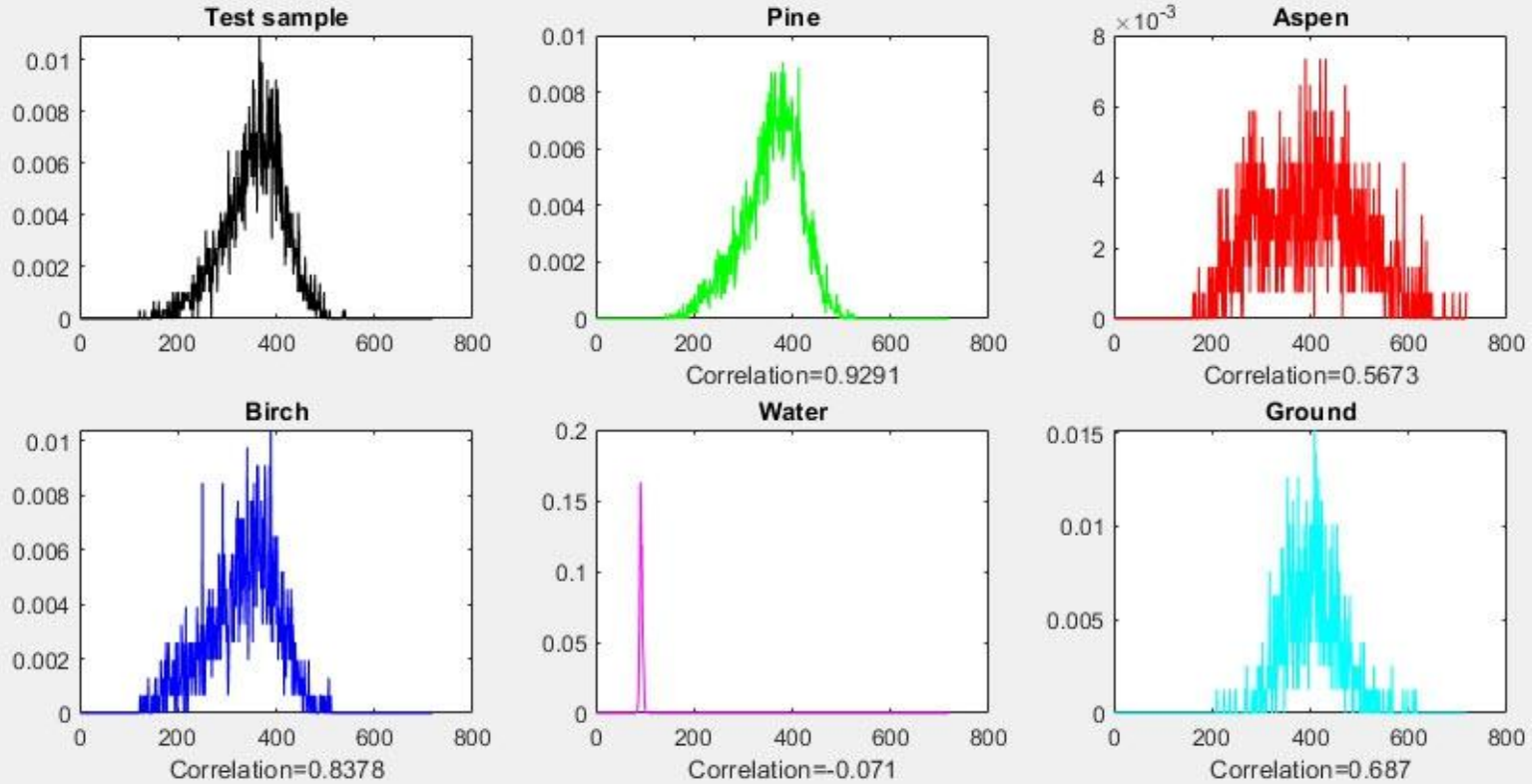

Test sample – a part of pine forest

The example of generating cumulative distribution functions in all spectral bands

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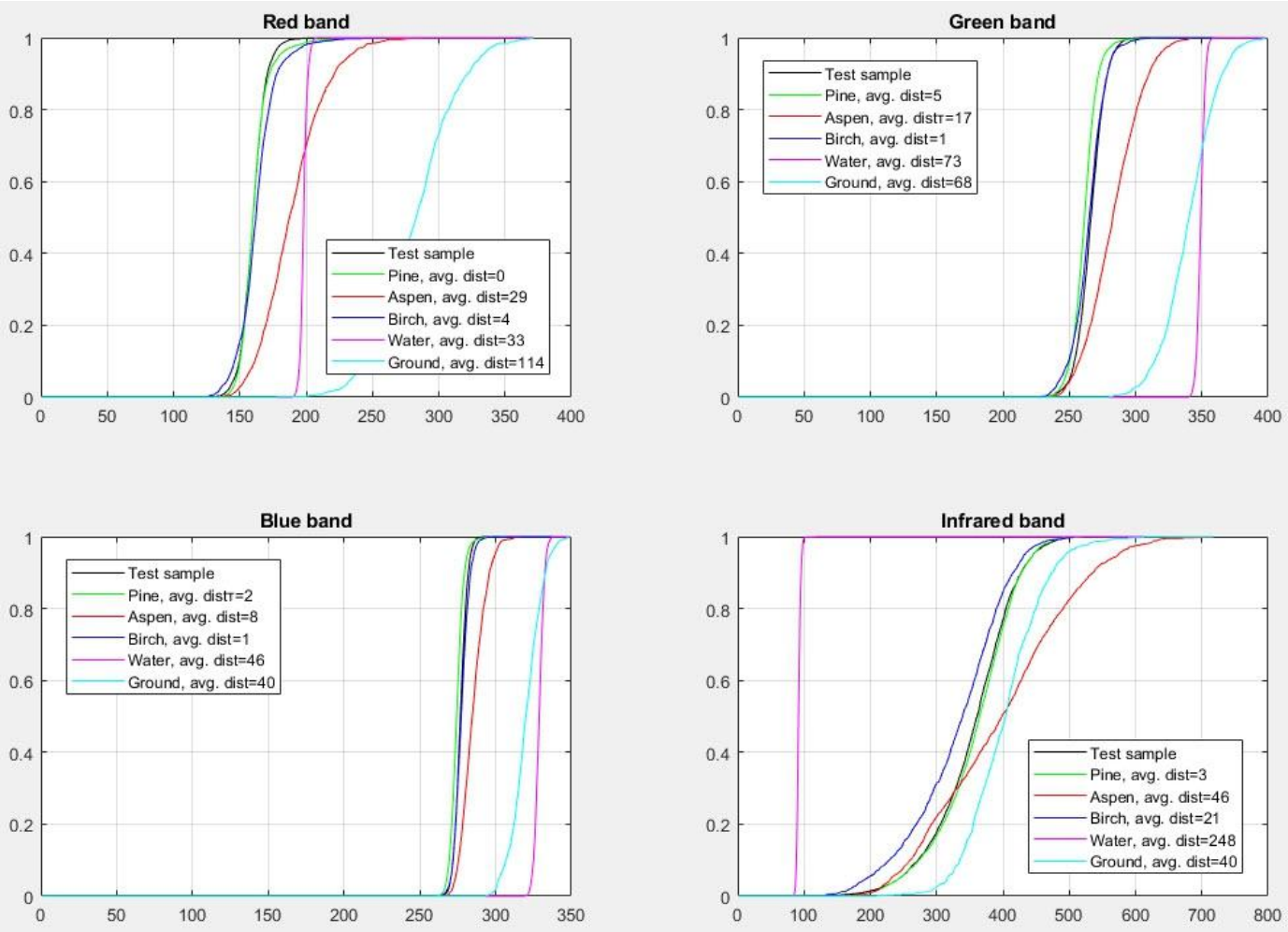

Test sample – a part of pine forest

Results of decoding

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Test sample	Band	Number of matches by cumulative distribution function	Number of matches by cumulative distribution function in 4D	Number of matches by probability distribution function
Pine	Red	8 из 8	8 from 8	8 from 8
	Blue	8 from 8		7 from 8
	Green	8 from 8		7 from 8
	Infrared	8 from 8		8 from 8
Birch	Red	1 from 9	0 from 8	1 from 9
	Blue	1 from 9		1 from 9
	Green	1 from 9		1 from 9
	Infrared	0 from 9		0 from 9
Aspen	Red	5 from 9	8 from 9	8 from 9
	Blue	8 from 9		8 from 9
	Green	8 from 9		8 from 9
	Infrared	5 from 9		2 from 9
Water	Red	7 from 9	9 from 9	3 from 9
	Blue	3 from 9		1 from 9
	Green	3 from 9		2 from 9
	Infrared	9 from 9		9 from 9
Ground	Red	0 from 5	0 from 5	0 from 5
	Blue	0 from 5		0 from 5
	Green	0 from 5		0 from 5
	Infrared	0 from 5		0 from 5
Deciduous forest	Red	13 from 18	17 from 18	18 from 18
	Blue	18 from 18		18 from 18
	Green	18 from 18		18 from 18
	Infrared	16 from 18		12 from 18

Reliability of decoding for bands and the type of function

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Classes for comparison / Bands	Classes: pine, birch, aspen, ground, water		Classes: pine, deciduous forest, ground, water	
	Cumulative distribution function	Probability density function	Cumulative distribution function	Probability density function
Red	53%	50%	70%	73%
Blue	50%	48%	73%	65%
Green	50%	45%	73%	68%
Infrared	55%	48%	83%	73%
4D space	63%	–	85%	–

The example of generating new probability density functions in infrared band

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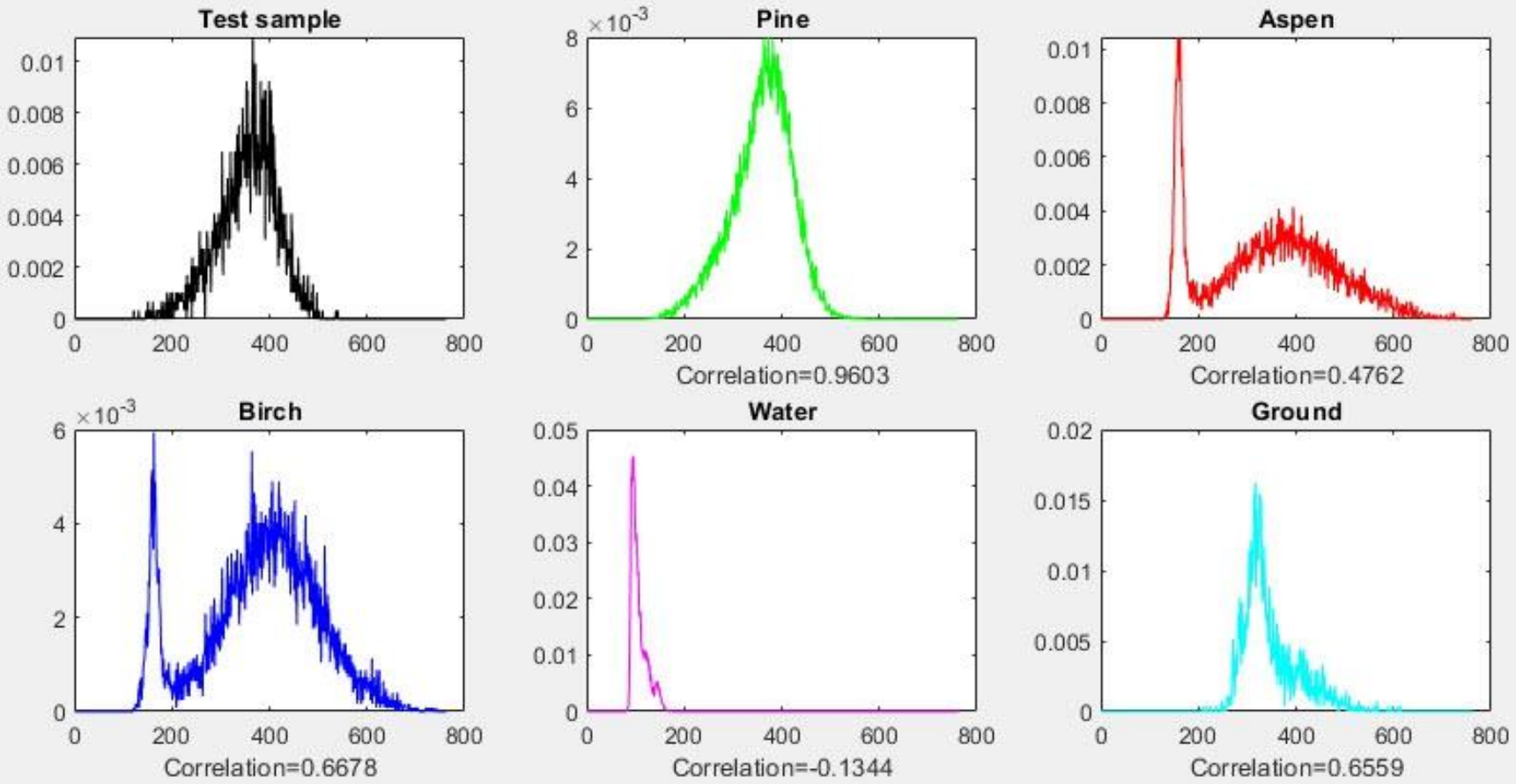

The functions constructed with using a greater number of samples

The example of generating new (common) cumulative distribution

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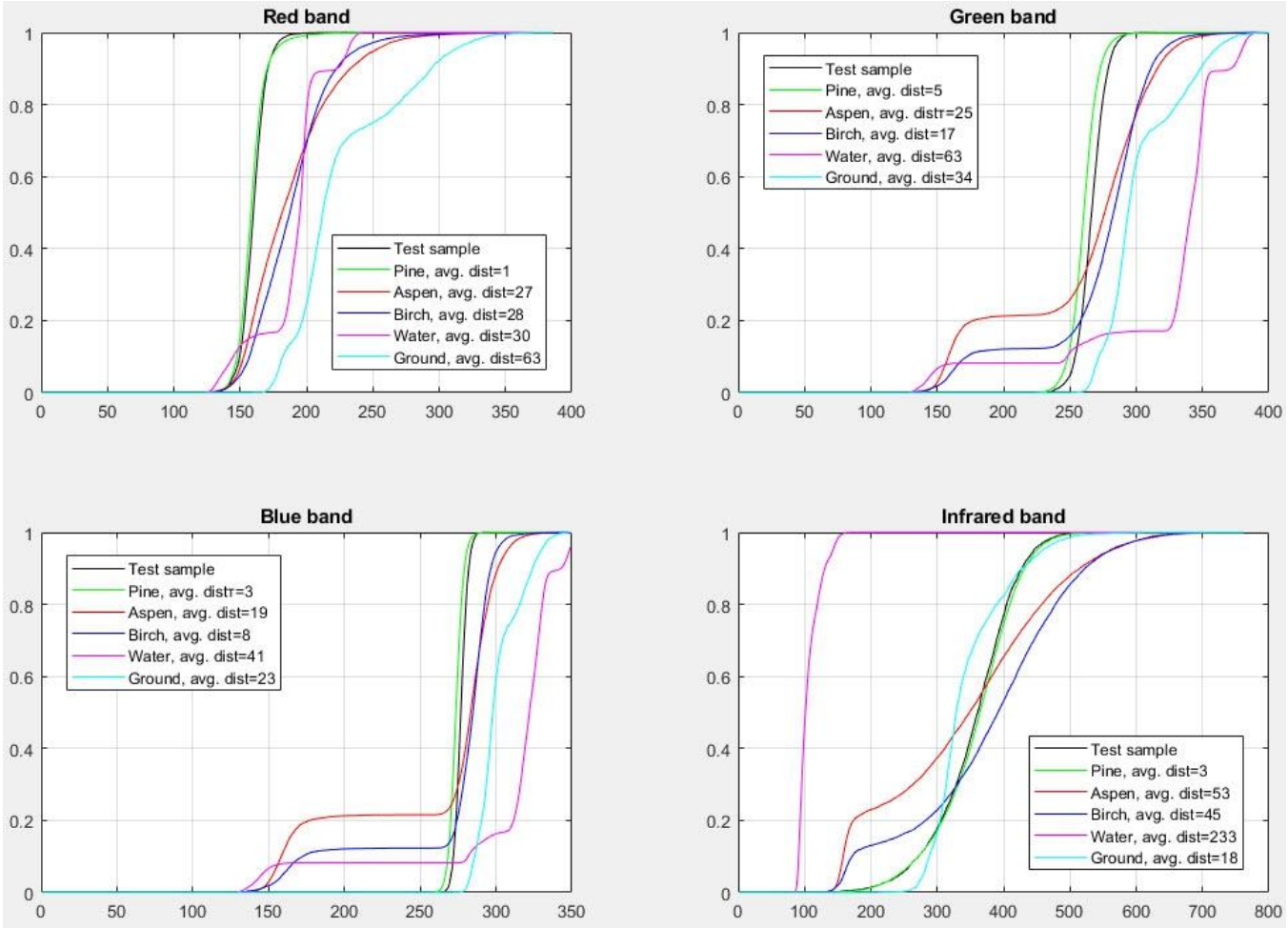

The functions constructed with using a greater number of samples

Results of decoding using the common functions

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Test sample	Band	Number of matches by cumulative distribution function	Number of matches by cumulative distribution function in 4D	Number of matches by probability distribution function
Pine	Red	8 from 8	8 from 8	8 from 8
	Blue	8 from 8		8 from 8
	Green	8 from 8		8 from 8
	Infrared	8 from 8		8 from 8
Birch	Red	3 from 9	7 from 9	5 from 9
	Blue	8 from 9		7 from 9
	Green	8 from 9		7 from 9
	Infrared	9 from 9		7 from 9
Aspen	Red	0 from 9	0 from 9	1 from 9
	Blue	0 from 9		2 from 9
	Green	0 from 9		1 from 9
	Infrared	0 from 9		0 from 9
Water	Red	7 from 9	9 from 9	7 from 9
	Blue	7 from 9		7 from 9
	Green	7 from 9		7 from 9
	Infrared	9 from 9		9 from 9
Ground	Red	0 from 5	4 from 5	3 from 5
	Blue	0 from 5		4 from 5
	Green	0 from 5		4 from 5
	Infrared	0 from 5		5 from 5
Deciduous forest	Red	9 from 18	16 from 18	11 from 18
	Blue	16 from 18		12 from 18
	Green	15 from 18		15 from 18
	Infrared	15 from 18		11 from 18

Reliability of decoding for bands and the type of function

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Classes for comparison / Bands	Classes: pine, birch, aspen, ground, water		Classes: pine, deciduous forest, ground, water	
	Cumulative distribution function	Probability density function	Cumulative distribution function	Probability density function
Red	45%	60%	60%	73%
Blue	58%	70%	78%	78%
Green	58%	68%	75%	85%
Infrared	62%	73%	80%	83%
4D space	70%	–	93%	–

Comparison of the probability density functions

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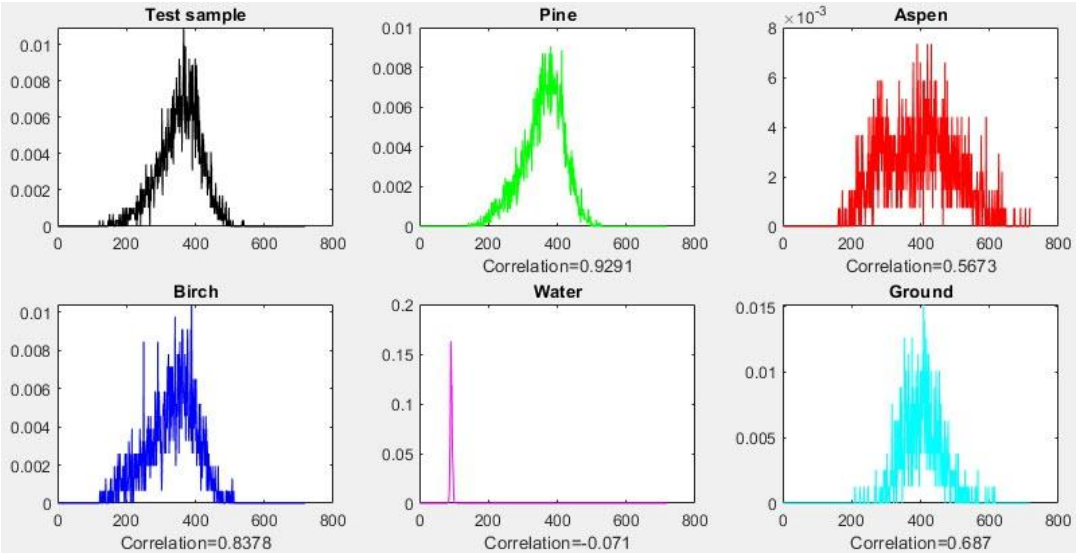
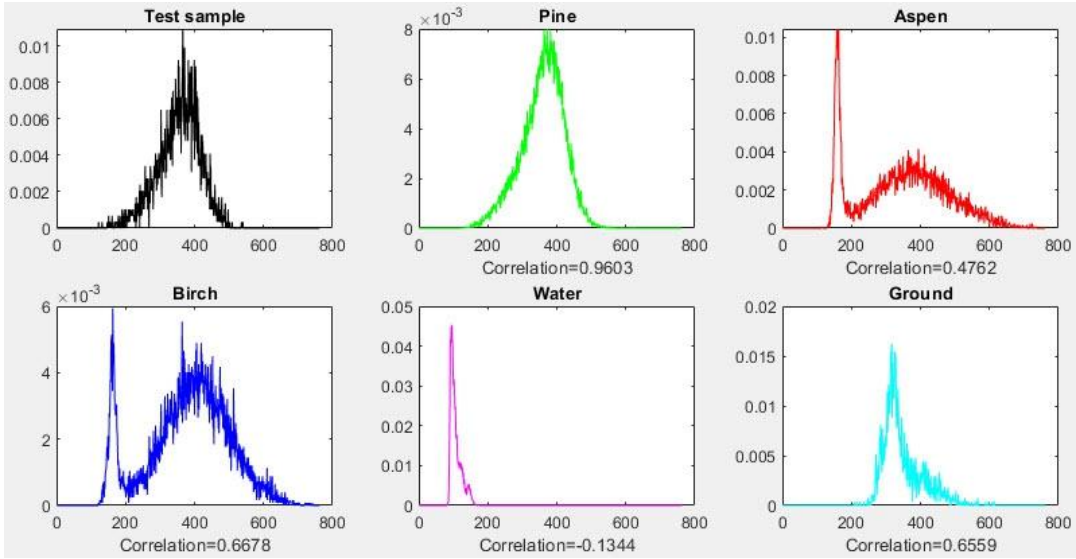


Reference functions constructed on the basis of 1 sample.



Reference functions constructed on the basis of several samples.

Comparison of the cumulative distribution functions

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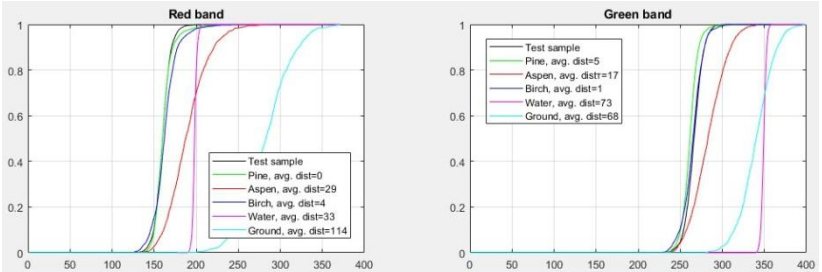

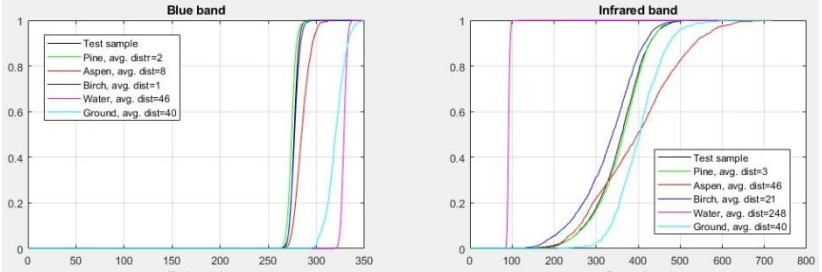

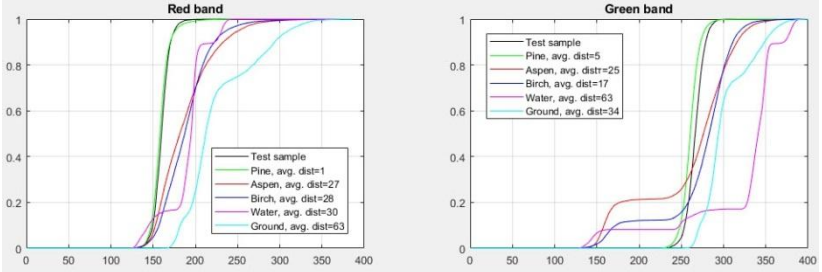

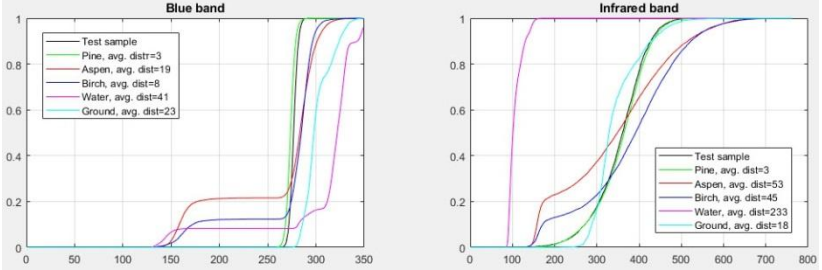

Reference functions constructed on the basis of 1 sample.

Reference functions constructed on the basis of several samples.

Conclusions

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- ✓ Application of the structural-statistical approach when decoding space images is capable to significantly increase the results of various object class recognition;
- ✓ The offered decision rules allow estimating differences between cumulative distribution functions and the probability density ones;
- ✓ The use of reference functions created over several test sites allowed significantly increasing the reliability of space image decoding;
- ✓ Fragments of conifer forest and deciduous forest were reliably identified;
- ✓ The decision rule based on determining the minimum distance between cumulative distribution functions in a four-dimensional space demonstrated the best results of decoding;
- ✓ The recognition reliability of individual species of deciduous forest turned out to be low;
- ✓ To increase the decoding reliability of individual forest species, the generation of cumulative distribution and probability density functions can be carried out using not the original bands of space images, but using transformed ones on the basis of various algorithms.

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Thank you for attention!