Introduction. Malignant melanoma (MM) is not common but highly metastatic tumour having poor prognosis and high resistance to treatment. Early stage diagnosis of MM is very important for patient survival. Histological evaluation is the “golden standard” of diagnosis of MM. Biopsy specimen or complete excision of the lesion is required for histological procedure. In vivo differentiation between benign and malignant melanocytic skin lesions (MSL) is one of the most important issues in clinical dermatology.

Diagnostic accuracy of the melanoma is related to the experience of dermatologist [1]. The accuracy achieved with unaided eye is only slightly higher than 60%. Dermatoscopy can increase the accuracy by 10-27% [2]. Unfortunately, dermatoscopic images do not provide information about thickness, which is important for the prognosis of the lesion and surgery planning. Ultrasound is non-invasive, harmless and provides the information in a real time. However, there are only a few works related to the MM characterization and differentiation from benign pigmented skin lesions (melanocytic nevus, MN) possibilities by using ultrasonography [3, 4].

The purpose of this study was to evaluate parameters for tissue characterization and to develop the algorithm for automatic MM recognition from MN by using ultrasonic data.

Materials and methods. In this study broadband mechanically scanned single element focused transducer with 22 MHz central frequency (DUB-USB, Taberna pro medicum, Luneburg, Germany, 22 MHz, bandwidth 12-28 MHz at -6 dB, focused on the surface of the skin at 11 mm) was used for ultrasonic data collection of pigmented skin lesions. No non-linear processing (such as log-compression, envelope detection or time-gain compensation) has been applied. The data were acquired during clinical examination by an experienced dermatologist before excision for histopathological examination. The study was approved by Lithuanian bioethics committee.

79 patients with clinically suspected MM and dysplastic MN were involved in this study. The diagnosis was confirmed for 35 patients, 44 patients having diagnosed MN (from which 15 has dysplastic or atypical nevi, which appear very similar to MM on dermatoscopic analysis). Forty-eight patients had single, 23 had two, 6 had three and 2 had four datasets (B-scans consisting of
Lesion segmentation. We have developed the segmentation algorithm based on time-frequency analysis of ultrasonic data recently [5]. Segmentation of the lesion was performed using threshold on the parametric integrated backscattering (IBS) signals. IBS served as RF data spectrum parameter, evaluated from power spectral density (PSD). PSD is obtained via short-time Fourier transform. The results of automated thickness estimation using proposed segmentation technique are presented in our previous work and published in the [5, 6]. The example of segmented lesion is presented in Fig. 1.

Feature extraction and selection. Twenty-three parameters were evaluated for each segmented lesion. Machet and colleges [7] found that the shape of a MM frequently differs to compare with MN. Shape parameters are also used for ultrasonic diagnosis of breast and prostate tumours [8-10]. As the shape parameters we used perimeter, area and circularity of the segmented lesion.

Acoustical parameters (attenuation and backscattering coefficients) are related to collagen and water content in the tissues [11] and have a potential to be an informative features for melanoma diagnosis. The frequency-dependent ultrasound attenuation was estimated by using Fourier analysis of the reflections from the surface and bottom at the mid A-scan line of the tumour [12]. Attenuation trends were linearly approximated over the bandwidth of the transducer using the least squares fitting. Three parameters were estimated by using linear fit: mid-band value, slope and intercept. The backscattering was estimated as the ratio of power spectrum of signal reflected from the thickest place of melanoma and reference PSD (reflection from flat surface at the focal distance of the transducer). Linear fit was used for estimation of slope and intercept of backscattering. Backscattering coefficient was estimated, as described in [11]. Peak value of average spectrum of segmented ROI signals was also included into feature set.
Harland and colleagues found that mean echogenicity of melanomas are significantly greater in comparison to nevi [13]. Differences in echo pattern may be detected by first-order statistical analysis of echogenicity. The first order statistics was evaluated by using envelope of echo signals in ROI. Eight parameters of the first order statistics were used for the tissue evaluation: maximal, minimal and average amplitude values, variance, kurtosis, signal-to-noise ratio, entropy and full width at half maximum (FWHM) of the histogram.

The parameters of the grey level co-occurrence matrix (GLCM) are successfully used for texture analysis and tissue characterization [9, 14, 15]. The co-occurrence matrix parameters used in this study were contrast, correlation, energy, homogeneity and entropy.

The feature vectors were normalized, in order to get the features at the same scale according to equation:

\[
x_j = \frac{x_j - \mu_j}{\sigma_j},
\]

where, \(\mu\) is the average of input feature vector \(x\), and \(\sigma\) is the standard deviation of \(x\). \(X\) is the normalized feature vector, \(j=1, 2...m\) is the number of features for a sample.

Mahalanobis distance (MD) was used as feature selection criterion in order to select near-optimal set of parameters for the two classes under analysis.

The MD was evaluated according to equation:

\[
MD_j = \frac{2}{n} \sum_{i=1}^{n} \sqrt{(N_j - \mu_j)S^{-1}(N_j - \mu_j)^T},
\]

where, \(\mu_j = \frac{1}{N} \sum M_j\), and \(S\) is covariance matrix, the superscript \(T\) denoting matrix transposition, \(M\) is the normalized feature vector of MM (\(X\) of the MM class) and \(N\) is the normalized feature vector of MN and \(j=1, 2...n\) is the number of samples. The two data sets are more similar and difficult to distinguish if the MD value is smaller. We selected the parameters, which MD was more than 2 and 7 features from 23 were selected as possibly informative: perimeter of ROI boundaries, area of ROI, variance, kurtosis and entropy of ROI envelope, homogeneity and entropy of GLCM of ROI.

**Classification.** The linear regression classifier was applied to differentiate malignant skin tumours from benign. The optimal vector of feature weights is found in the case of linear regression. This classifier is based on simple “neuron” model, which is described as:

\[
Y = w^T \cdot X,
\]

where, \(Y\) is the output vector which is closer to one of two classes, \(w\) is the weights vector for each selected feature and \(X\) is the testing sample matrix. Optimal weight vector is found by iterative gradient descent method.

**Results.** By using parameters selected by using MD and linear regression classifier it is possible to differentiate MM from benign lesions. Classification
performance was assessed using analysis of receiver operating characteristic (ROC). The results were obtained by changing the training and testing data by using \(k\)-fold cross-validation method (\(k\) was 5, each group had 24 datasets). Averaged (20 iteration) ROC curve is presented in Fig. 2.

![ROC curve](image)

**Fig. 2.** ROC curve of the linear regression classification (averaged area under the ROC curve 0.84±0.028)

**Conclusions.** There is no single parameter, which can reliably discriminate melanoma and non-melanoma skin lesions. Perimeter, area and homogeneity had a greatest classification weights. Multi-feature ultrasonic data analysis is required for melanoma recognition from other melanocytic skin lesion. The results showed that it is possible to differentiate malignant and benign MSL by using ultrasonic data. Automatic classification based on ultrasonic data can supplement existing diagnostic methods in clinical dermatology.

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**References**

5. Andrekute K., Valiukeviciene S., Raisutis R., Linkeviucyte G., Makstiene J., Kliunkiene R. Automated Estimation of Thin Melanocytic Skin Tumour Thickness by
The Classification of Melanocytic Skin Lesions Using Ultrasonic Data

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The purpose of this study was to evaluate parameters for tissue characterization and to develop the algorithm for automatic recognition of malignant melanoma from melanocytic nevi by using ultrasonic data. The shapes, acoustical and textural parameters of melanocytic skin lesions were tested. The linear regression classifier was applied in order to differentiate malignant skin tumours from benign. The most informative features were selected using Mahalanobis distance. The averaged area under the ROC curve was 0.840±0.028. The results showed that it is possible to differentiate malignant and benign melanocytic skin lesions by using ultrasonic data. Automatic classification based on ultrasonic data can supplement existing diagnostic methods in clinical dermatology.