Artificial Intelligence & Infrared Technologies for quick diagnosis of spinal diseases

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Introduction

Based on the statistical analysis of the global disease database 266 million individuals (3.63%) worldwide have degenerative spine disease, from which 39 million individuals (0.53%) were found to have spondylolisthesis, 403 million (5.5%) individuals with symptomatic disc degeneration, and 103 million (1.41%) individuals with spinal stenosis annually [1].

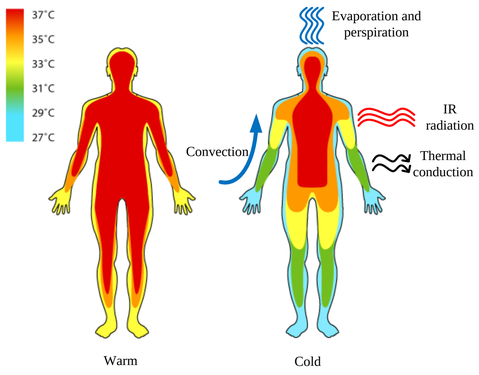

***Figure 2**. Heat transfer mechanisms from human body*

Spinal disorders significantly limit mobility and agility, increasing the disability and leading to early retirement, lower well-being levels, and reduced ability to participate in society. Degenerative spine conditions (DSC) are characterized by the progressive loss of normal spine structure and function over time, i.e. treatment varying depending on the type and severity of the disorder [2]. The treatment process began at a later stage leads to a long rehabilitation process or painful operation treatment. Early detection of spinal problems is not only more likely to continue a healthy human lifestyle but is also essential for better care and a lower treatment period.

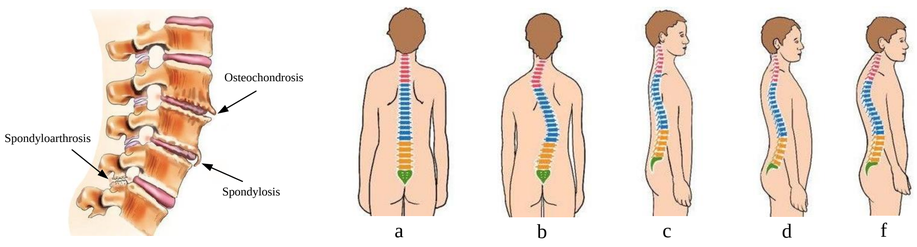

***Figure 1.** Examples of vertebral column deforming dorsopathies: coronal plane (a – normal, b – scoliosis), sagittal plane (c – normal, d – lordosis, b – kyphosis).*

Nowadays, the medical infrared thermal imaging (MITI) techniques can provide a good quality images in real time for monitoring and pre-clinical diagnostic of the diseases caused by inflammatory processes by showing the thermal abnormalities present in the body. MITI allows specify of the functional changes in the normal temperature distribution on the surface of the body, as well as enables refinement the localization of functional changes, the activity of the process, its prevalence and the nature of the changes – inflammation, stagnation, malignancy, etc. Due to its non-contact, non-invasive and non-destructive way of using, this technology has a distinct advantage among other diagnostic methods.

Medical applications based on AI algorithms have been successfully implemented in monitoring and pre-clinic diagnostics of complex medical data. Consequently, the present research study aimed to develop an AI algorithm for the classification of infrared images database of patients with spinal disorders to healthy and unhealthy classes which were not done before.

Materials and Methods

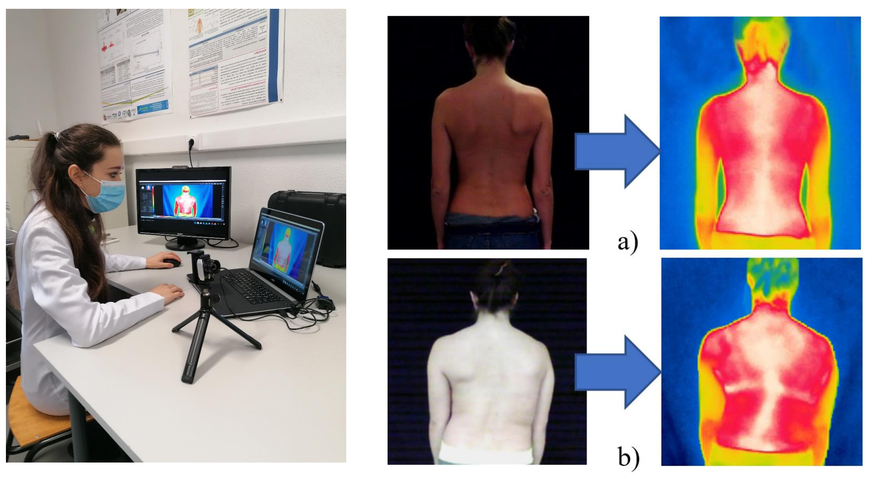

***Figure 3.** Data acquisition using thermal camera FLIR E6 a) healthy and b) with scoliosis patients*

The infrared (IR) images (figure 3.) were obtained in the laboratory room with a constant temperature of 21°C and humidity of 50%, approximately, using IR camera FLIR® E6 (320x240), with thermal sensitivity of <0.06°C (Table 1). The emissivity parameter on the camera was set for the skin ε = 0.98. Before the acquisition, the camera was switched on for 15 minutes, as well as each volunteer had to stay at the ambient temperature for accommodation. The black matte curtain was used as a background. During the measurements, each participant was in the same standing position, facing the wall with the head straight ahead, and the arms down.

Before measurement, each participant has to stay undressed for accommodation to the ambient temperature. During the measurements each participant stood in the same position, facing the wall with head straight ahead and the arms down. All volunteers were asked to complete a questionnaire regarding general information and agreement to be involved in measurements.

Medical applications based on AI algorithms have been successfully implemented in monitoring and pre-clinic diagnostics of complex medical data. Advances in AI development seem to make it possible to move from the days of misdiagnosis and treating only disease symptoms. These will continue to change the way both doctors and researchers approach clinical problem-solving.

To construct an effective AI algorithm, firstly computer systems need to fed data that is typically structured (each data point has a label that is recognizable to the algorithm). After the CNN is exposed to enough data sets and their labels, the performance results are dissected to ensure precision. The algorithm generally involves data input to which already know the answers, allowing to evaluate the algorithm capacity to find out the correct solution. Based on the testing results, CNN can be modified or fed more data to improve outcoming results.

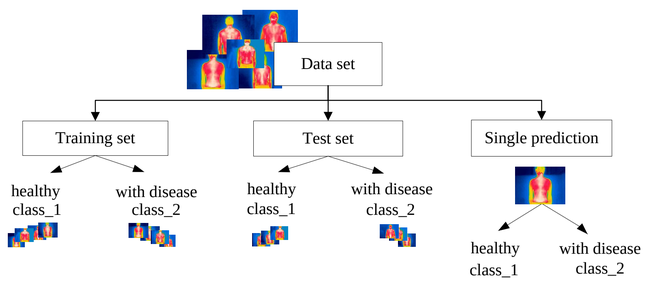

***Figure 4.** The schematic of dataset pre-processing*

Before an AI-based classification algorithm was implemented, all database images were treated by our previously developed algorithm [3]. Using pre-processed infrared images, CNN was trained and tested on selected regions-of-interest (ROI) of the human body. The thermal images to classify the patients with spinal disorders into healthy or with spinal disease. The entire dataset was split into three subsets: the training set, the test set, and the validation set, as shown in figure 4. The main algorithm steps for thermal images classification using a CNN, as shown in figure 5.

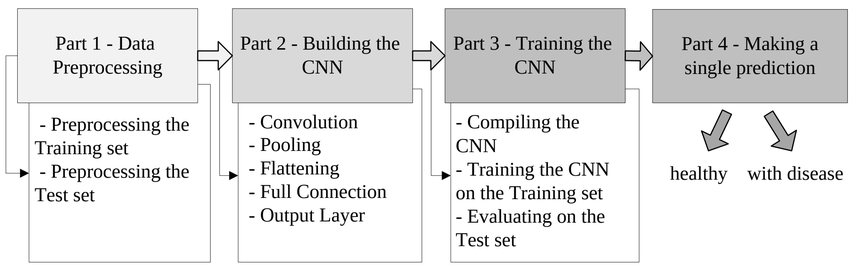

***Figure 5.** The algorithm steps for thermal images classification using a CNN*

***Table 1.** Specifications of Infrared camera FLIR®E6*

Nº	Attribute	Value
1	Thermal Sensitivity	<0.06°C
2	Temperature range	-20 → +250 °C
3	Accuracy	±2 %
4	Field of view	45x34°
5	Image frequency	9Hz
6	Detector Resolution	160 x120pixel
7	Focus Type	Focus-Free
8	Display Size	3in
9	Display Resolution	320x240pixel
10	Weight	575g
11	Spectral Range	7.5–13 µm

In the proposed architecture, it was used two Convolutional Layers with the size of 5x5 and 32 outputs, followed by two Max Pooling Layers. The Rectified Linear Activation Function was used to prevent the exponential growth in the computation required to operate the neural network. The output layer is a fully connected layer and classifies the data into two classes: healthy and with the disease. Also was use cross-validation to guarantee that every image is evaluated in test and train sets.

Results

The results of descriptive statistical analysis of developed methodology for the classification of infrared images database of patients with spinal disorders based on a CNN is shown in Table 2. The obtained results showed a good outcome with 95% accuracy and 94% specificity, which is a significant impetus to continue work on the classification of infrared images database of patients with spinal disorders based on a CNN algorithm. Meanwhile, the reported results show the potential for implementing IR thermal imaging of patients with spinal disorders based on a CNN algorithm.

Table 2. Our results using a pre-proceed infrared image database

Experim.	Accuracy	Sensibility	Specificity	PPV	NPV
1.	0.96	0.93	0.94	0,93	0,93
2.	1	1	1	1	1
3.	0.94	0.93	0.94	0.95	0,96
..	...	...	...	...	...
Mean	**0.95**	**0.94**	**0.93**	**0.94**	**0,95**

Conclusions and Perspectives

The development of medical applications based on AI algorithms using infrared image data is a growing and promising research worldwide. These applications have great potential for medical imaging technology, medical data analysis, and medical diagnostics. Medical applications based on AI algorithms using infrared image data can be successfully used for spinal disease classification. The first obtained results allow assuming that our methodology can be easily generalized for much more data, conducting even more precise results.

In future works, we expect to increase the database of the spine thermograms to classify them not only by two classes (healthy and with the disease) but specify by the type of disease to which it belongs, as well as to use different CNN architectures to compare results.

Acknowledgments

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