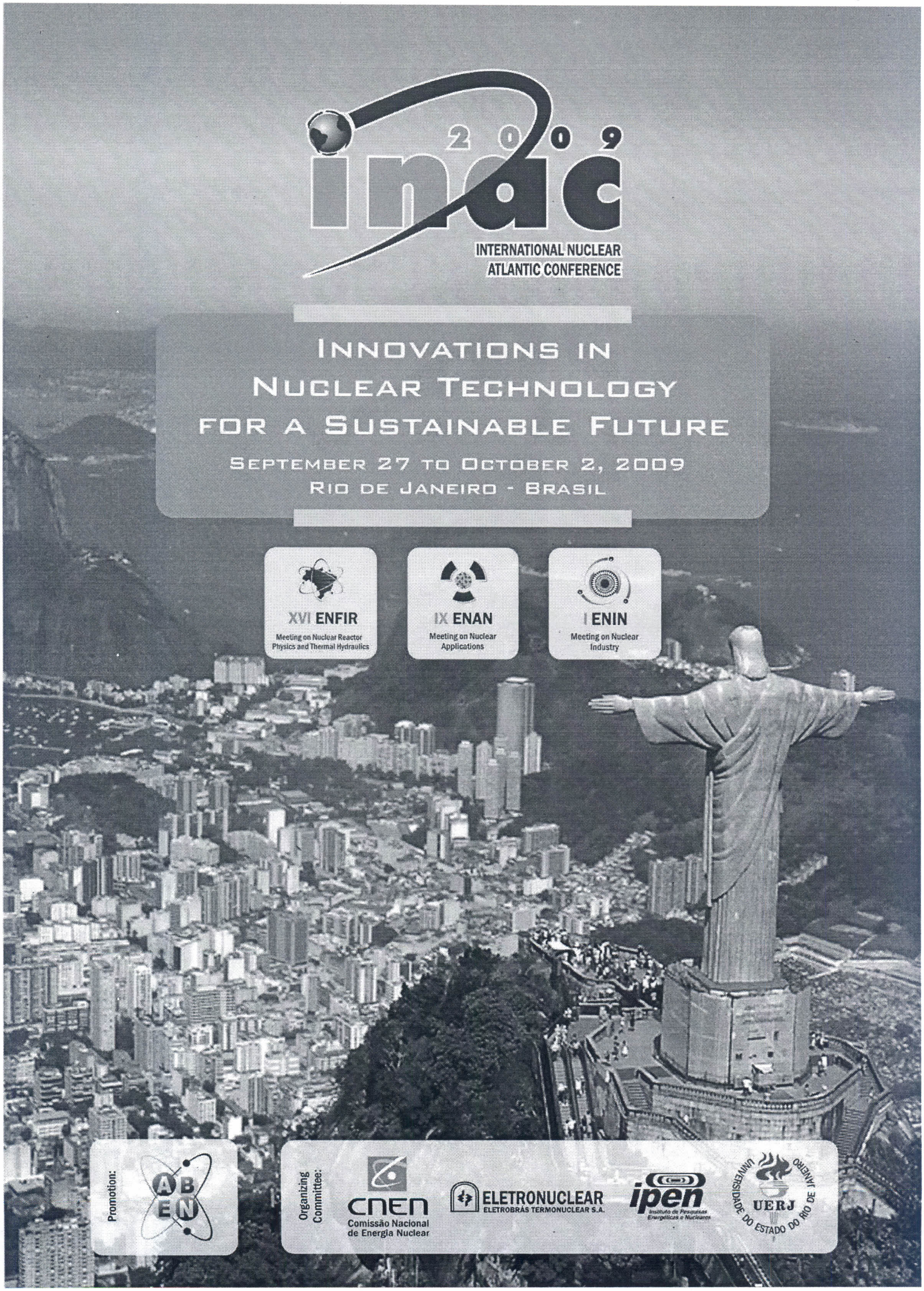
2009
inac
INTERNATIONAL NUCLEAR
ATLANTIC CONFERENCE
INNOVATIONS IN
NUCLEAR TECHNOLOGY
FOR A SUSTAINABLE FUTURE
SEPTEMBER 27 TO OCTOBER 2, 2009
RIO DE JANEIRO - BRASIL
XVI ENFIR
Meeting on Nuclear Reactor Physics and Thermal Hydraulics
IX ENAN
Meeting on Nuclear Applications
I ENIN
Meeting on Nuclear Industry
Promotion:
ABEN
Organizing Committee:
CNEN
Comissão Nacional de Energia Nuclear
ELETRONUCLEAR
ELETROBRÁS TERMONUCLEAR S.A.
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KEY DATES TO REMEMBER

Set-up dates

- 26th September, 2009 from 08:00 am to 18:00 pm

Exhibition opening hours

- 27th September 2009 from 15:00 pm to 23:00 pm
- 28th September 2009 from 08:00 am to 19:00 pm
- 29th September 2009 from 08:00 am to 19:00 pm
- 30th September 2009 from 08:00 am to 19:00 pm
- 01st October 2009 from 08:00 am to 19:00 pm
- 02nd October 2009 from 08:00 am to 19:00 pm

Dismantling / Move-out

- 03rd October, 2009 from 08:00 am to 18:00 pm

THE EVENT

In the beginning of the 21st century, nuclear technology presents itself as an efficient alternative to guarantee a sustainable future for the planet, bringing together safe energy supply with respect for the environment. Besides being an energy source that helps to reduce greenhouse gas emissions, nuclear applications benefit areas like medicine, industry and agriculture. Nuclear energy will have an important role to play in the world's energy expansion and technological innovations in the next decades.

In this context, the Brazilian Nuclear Energy Association (Aben) is promoting the International Nuclear Atlantic Conference (Inac 2009), which will be held at the Windsor Barra Hotel, in Rio de Janeiro, from September 27th to October 2nd, 2009. With the theme "Innovations in Nuclear Technology for a Sustainable Future", the conference pretends to discuss the contribution that innovations in the nuclear sector can give to contemporary society in order for it to develop in a sustainable manner. To achieve this goal, Brazilian and foreign specialists will be invited to debate and analyze technological perspectives, as well as questions involving the environment and energy security.

Inac 2009 will be promoted alongside the XVI Meeting on Nuclear Reactor Physics and Thermal Hydraulics (Enfir) and the IX Meeting on Nuclear Applications (Enan). The event will also host the I Meeting on Nuclear Industry.

Also a part of the event's official program is ExpoInac, an exhibition in which public and private companies, nuclear and non-nuclear, will take part, offering products and services in various areas of application. ExpoInac 2009 will present tendencies, alternatives, studies, projects and accomplishments developed in areas directly or indirectly linked to the conference's central theme. Taking part in the exhibition will be engineering, consulting and technological innovation companies and service providers. Equipment and machine manufacturers and companies that work with management software, research and development, energy generation, transmission and distribution, fuels and lubricants, infrastructure, sanitation and energy efficiency will also be present. Educational institutions and technical and scientific, business and technological associations will likewise participate in Inac 2009.

Bring your company to this event!

2009 International Nuclear Atlantic Conference - INAC 2009
Rio de Janeiro,RJ, Brazil, September27 to October 2, 2009
ASSOCIAÇÃO BRASILEIRA DE ENERGIA NUCLEAR - ABEN
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PATTERN RECOGNITION OF NUCLEAR TRACES PRODUCED BY ALPHA PARTICLES IN SOLID STATE DETECTORS

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ABSTRACT

A great concern about the spread of radon gas in human living environments requires an improvement of the detection techniques used nowadays and the development of new technologies that provides greater reliability, accuracy and agility in the process of analyzing the results generated by emission of radon. Aiming to increase the analytical capacity of Radon Laboratory, unit of Brazilian Commission of Nuclear Energy, located in Poços de Caldas, the automation of the XY table of the optical microscope was proposed and implemented and also a new technique of nuclear traces analysis generated by alpha particles from radon using digital imaging processing and artificial neural networks as pattern classifiers.

1. INTRODUCTION

Radon and its decay products contribute to the majority of ionizing radiation received by worldwide population. Studies carried out a long of the years confirmed the association between exposure to radon and lung cancer. Radon when inhaled is eliminated almost immediately, however, its decay products are deposited in the lungs which emits alpha particles that interact with the lung tissue and may also reach the bloodstream, affecting other organs like the bone marrow.

According to UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation), radon contributes approximately 50% of the natural radiation dose received by the worldwide population annually. Outdoors concentrations of radon are very low, however, high concentrations are observed in underground mines, particularly in uranium mines. Considerable concentrations of radon are also found in homes depending on the characteristics of the building materials, underground and ventilation.

Thus, this work presents an automated technique for obtaining images produced by alpha particles in solid-state detectors through a digital optical microscope coupled with a digital camera CCD and motors capable of moving it along the X and Y axes, which guarantees a complete scan of the detector, increasing agility in the process of capturing images and also the development of an algorithm to analyze those images, based on techniques of digital image processing using Hough transform to identify traces and Artificial Neural Networks as patterns classifiers and indicators that qualify the alpha particle in terms of its angle of incidence and energy.

2. NUCLEAR TRACES PRODUCED BY NUCLEAR PARTICLES

2.1. Radon

Radon was discovered by Owens and Ernest Rutherford in 1899 and it is the product of alpha decay of ^{226}Ra, result the alpha decay of radioactive series of ^{238}U. It is a colorless, odorless, tasteless and has half life of 3.823 days and for being a noble gas is easily disseminated to human living environments through building materials, soil and water.

2.2. Radon detection techniques

The most widely used techniques for radon detection can be divided into two groups: active detection and passive detection, where each of these techniques can be used to detect ^{222}Rn and its decay products [1].

Active techniques detection consists of a few liters of air samples which are placed in a radiation detection system. The main techniques used are the Lucas cells and ionizations chambers. In the passive techniques detections solid state nuclear track detectors (SSNTD) are exposed to the environment for a certain period of time, with a diffusion chamber, which are permeable only for ^{222}Rn [1].

2.3. Tracks formation and etching process

Tracks formation occurs when a heavy particle (alpha particles, protons, etc.) incises on a SSNTD causing damage in the material. This damage is named latent track, Figure 1, and each one has different characteristics according to their energy and angle of incidence

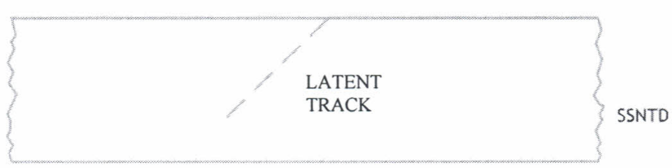


Figura 1. Latent track on a SSNTD.

To the latent tack be observed, the SSNTD must go through a process of etching, which consists of a chemical attack that etches its surface, increasing the diameter of the latent track. This method is called EPC (Chemical Pre Etching). There is also another process of etching called ECE (Electro Chemical Etching). The difference between then is that the ECE during the chemical process of etching applies a voltage in SSNTD [2]. The most used chemical reagents are potassium hydroxide (KOH) and sodium hydroxide (NaOH).

The appearance of an alpha particle incident on a SSNTD after chemical etching process can be seen in Figure 2, which illustrates the surface of CR-39 detector exposed to an environment with high radon concentrations.

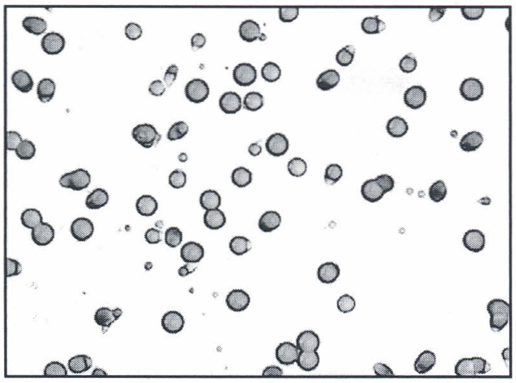


Figura 2. Surface of an SSNTD exposed to an environment with a high radon concentration after chemical etching process in NaOH solution.

3. DIGITAL IMAGES PROCESSING AND ARTIFICIAL NEURAL NETWORKS

In the last 30 years, considerable advances have been developed in patterns recognition, and image processing with applications to vision systems. These advances have led to a great need to develop methods, software and hardware.

From the initial concepts of signal processing and systems theory, image processing depends mainly on linear filters and convolution masks. Recently, image processing has been developed mainly in areas of frequency analysis, nonlinear analysis, space-variant filtering and analysis based on methods that provide better results than the traditional techniques.

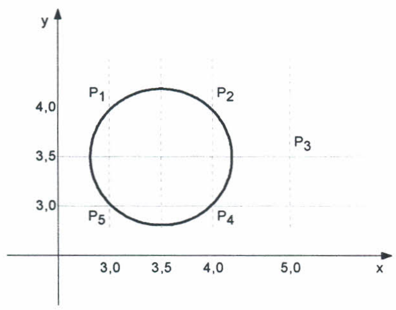
Digital image processing can be used in several applications in various levels of knowledge, as geoprocessing, medicine, X-ray images or MRI, astronomy, recognition of celestial bodies or applications for facial and retina recognition and also as a form of classification and patterns recognition.

3.1 Hough transform

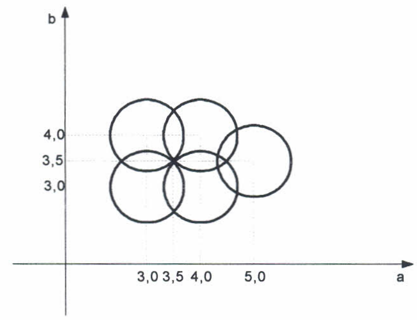
Duda and Hart [3] suggested the use of the Hough Transform for straight adapted to circles. Using the circle equation given by Equation 4, where a and b are its center coordinates and c its radius, it is possible to use the Hough Transform. The implementation of the Hough Transform consists to change the image from the Cartesian plane in a parameter space, i.e. each pixel on the Cartesian plane is converted into a circle in the parameter space. The intersection of circles in the parameter space will define the center coordinates of a circle and the total radius of the circle [4].

$$(x-a)^2+(y-b)^2=c^2 \tag{4}$$

Figure 6 (a) illustrates a circle with five pixels and radius equal to $1/\sqrt{2}$ in the Cartesian plane (x, y). Figure 6 (b) illustrates image mapping from the Cartesian plane to a parameter space.



(a)



(b)

Figura 6. (a) Circle in a Cartesian plane x, y; (b) parameter space *a* and *b*.

Each pixel, Figure 6 (a) creates a circle in the parameter space, Figure 6 (b). Thus, points *a* and *b* generated in the parameter space are stored in an accumulator array. The intersection of circles in parameter space indicates the circle center coordinates and its sum indicates the pixels belonging to the circle. The circle equation is given by Equation 5.

$$(X-3,5)^2+(Y-3,5)^2=\left(1/\sqrt{2}\right)^2 \quad (5)$$

For this approach, where the radius is known, the size of the accumulator array should have the dimensions shown in Equation 6.

$$ACC[X_{max}+2.raio][Y_{max}+2.raio] \quad (6)$$

However, when you want to detect a circle with radius value is unknown is necessary to use a three dimensional accumulator array with the dimensions shown in equation 7.

$$ACC(X_{max}+2.raio).(Y_{max}+2.raio).(r_{max}-r_{min}+1) \quad (7)$$

3.2 Artificial neural networks

An artificial neural network is a mathematical model or computational model that tries to simulate the structure and functional aspects of biological neural networks. It consists of an interconnected group of artificial neurons and processes information using a connectionist approach to computation.

Neuron has a structure represented by Figure 7. Neurons receives input signals, x1, x2 ,..., xm and are equipped with synapses, which modulate the received signal, represented by the synaptic weight w_{ji}.

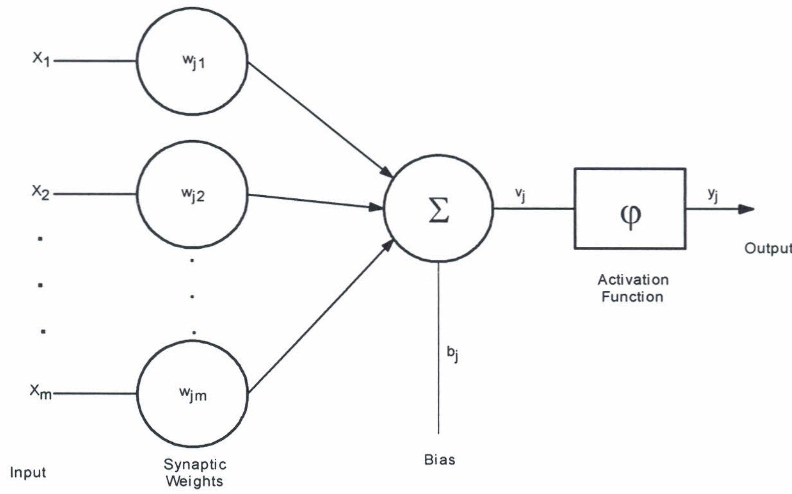


Figura 7. Artificial neuron or artificial neuron network.

The activation function process the stimuli weighted sum by the synaptic weights and is defined by Equation 8, where y_j is the output generated by each neuron in the layer above.

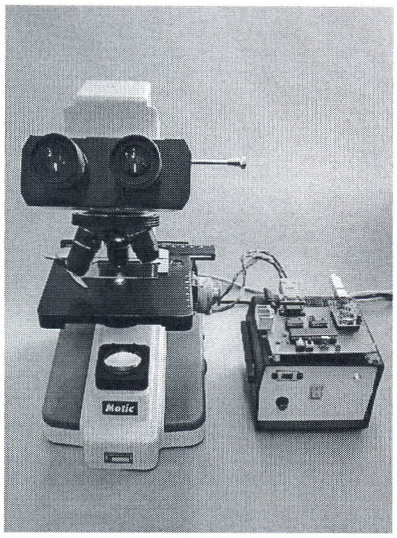
$$y_j = \sum_m \omega_{jm} \cdot x_m \tag{8}$$

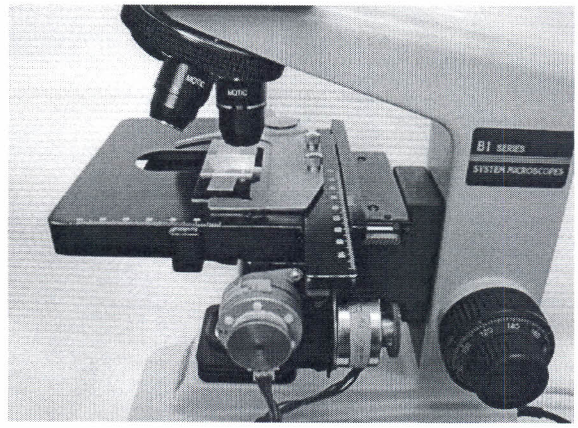
With the multilayer perceptron networks was possible to solve non-linear problems, ending with the limitations of single-layer perceptron networks. The supervised learning process consists to adjust the weights of the network so that they achieve a configuration that is capable of mapping entries in the desired outputs. Backpropagation is the most popular algorithm to make these weight adjustments and to minimize errors.

Backpropagation uses a sequence of two steps, where the first consists in the patterns presents to the input layer and that cover the entire network until a response is obtained by the output layer. In the second step, the output obtained is compared with the desired response and its error is calculated and then propagated from output layer to input layer and the weights are adjusted and modified [6].

4. IMAGE ACQUISITION

To image acquisition is used an automatic capture system of images which consists of a digital optical microscope, Figure 8 (a), which has motors capable of moving it along the X and Y axes, Figure 8 (b). The motors are controlled by a programmable microcontroller PIC type 16F877A, Figure 9.





(a) (b)

Figura 8. (a) Digital optical microscope used to automatic capture images. (b) Digital optical microscope and its motors capable of moving it along X and Y axes.

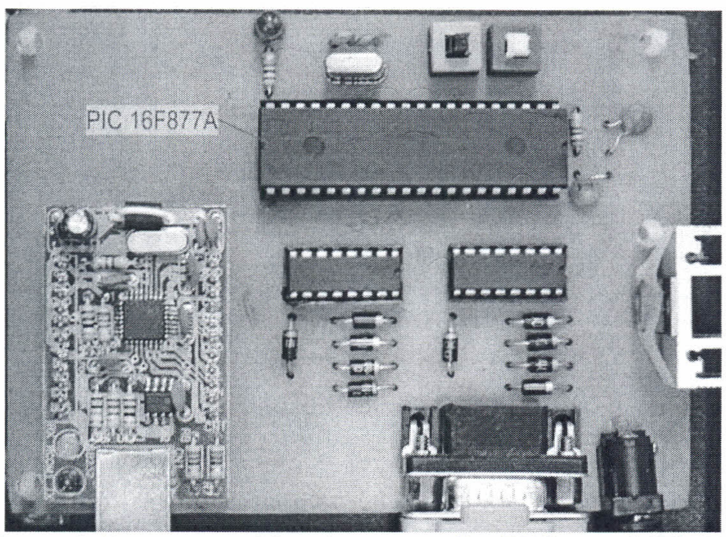


Figura 9. Programmable microcontroller PIC type 16F877A.

The algorithm developed for the management of the system is able to send instructions to the microcontroller device in the hardware and perform reading of the current situation. This algorithm is also responsible for the process of capturing images from the microscope to be analyzed later.

For perfect control of the X and Y axes, were developed two algorithms, which the first one is installed on a computer and the other one recorded in a microcontroller. The software installed on a computer is responsible for positioning the X and Y axes in an initial position and adjust all the settings necessary to start the process of image acquisition. After the initial setup, the system begins to acquire images. When the first image is acquired, the software in the microcontroller sends a control sign indicating a new position for the X and Y axes, and acquired a new image. This process is repeated until all images are captured. The software recorded in the microcontroller receives from serial port commands from computer and send signals that will put the motors in motion.

5. PATTERNS

To create a database, which consists of images and the bank's standards, were carried out a series of experimental studies to determinate the behavior of the alpha particles incident on CR-39 due to its energy and angle of incidence. The objective of these studies was to obtain traces of alpha particles of known energy and incident angles. The experiments were performed using a radioactive source of ^{241}Am, which emits alpha particles with energy of 5.486 MeV, restricting the angle of incidence at 30 °, 45 °, 60 °, 70 ° and 90 ° with respect to the normal surface. To restrict the angles were used collimators made of acrylic and with central holes of 1 mm with pre-determined angles. Figure 10 shows collimators with incidence angles of 90 °, 75 °, 60 °, 45 ° and 30 °.

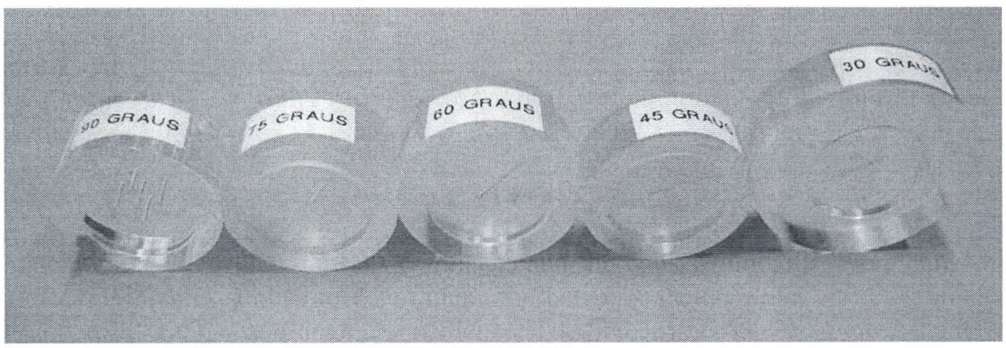


Figura 10. Collimators with incidence angles of 90°, 75°, 60°, 45° e 30°.

To avoid the energy loss of alpha particles emitted by radioactive sources, a vacuum camera was used, Figure 11 Therefore, we can ensure that particle's energy wont decrease until reaches detector surface. For each experiment performed in the vacuum camera, a similar was performed in the air using the same radioactive source and collimator.

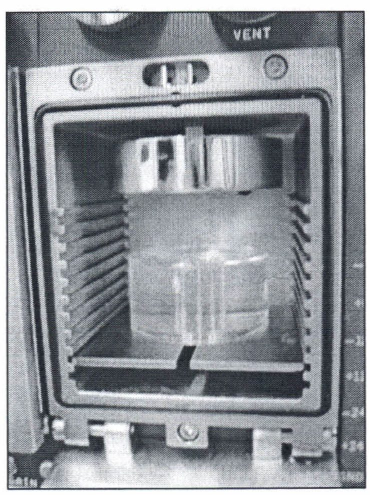


Figura 11. Vacuum camera.

6. ACQUIRE PROCESSING AND IMAGE ANALYSIS

The project under development is based on three steps consisting of: acquisition (image digitization), processing and analysis (pattern classification).

The step of image acquisition involves: microscopy, XY table, control signals and acquiring images. This stage of processing consists on image acquisition from a plastic detector using the automatic control of the XY table and the camera attached to the microscope.

The next step is image processing which includes noise correction and focus from the acquired images of the microscope and preparing it to analysis step.

Image analysis, consists to identify patterns in image using the Hough transform, which is able to identify circular and elliptical patterns, providing the largest and smallest diameters of each event. Pattern recognition uses an artificial neural network that receives as parameters data obtained from patterns identification and classifies them according to their energy and angle of incidence.

A bank of images was designed with the purpose of storing images at all stages of processing, i.e., the original images, pre-processed images and images with patterns identified.

7. CONCLUSIONS

The automation process based on capturing and analysis of traces in images produced by alpha particles in solid-state detectors can increase the analytical capacity of the Radon Laboratory, CNEN unit, installed in Poços de Caldas. Therefore, based on this presented work it will be possible improve the efficiency to determinate the radon concentration in indoor environments, reducing errors and risk of false positives comparing with the manual method used routinely.

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