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Título da Dissertação	FPGA accelerated spectrogram generator for applications predictive maintenance applications based on CNN techniques.

1. Enquadramento / descrição problema

Nowadays, artificial intelligence (AI) and machine learning (ML) allow us to automatically solve complex tasks and problems that erstwhile could only be solved by Human. There are many applications for AI, like object detection and identification, voice assistance, autonomous vehicles, predictive maintenance, among others. The Convolutional Neural Networks (CNN) are a type of artificial neural networks algorithms that has been emerging in recent years, being the most suitable for image and video processing.

A spectrogram is a way of representing a signal's strength in the time domain, in its various frequencies, creating a visual representation of the signal using a colour gradient. So, spectrograms show a signal's variations in frequency over a certain period of time. In the Figure 1, one can see three spectrograms from three different locations where an earthquake occurred. The vertical axis shows the frequency domain, while the horizontal axis shows the time domain. The intensity of the signal is computed by a grey scale or colour intensity, where the red colour represents high intensity and the blue colour represents low intensity. Therefore, a CNN algorithm can be applied to the signal's spectrogram to detect and identify certain variations in the captured signal.

This project intends to investigate, design and implement a Field Programmable Gate Array (FPGA) accelerated system capable of sampling an input signal, generate the respective spectrogram and send it to other system to be analysed by a CNN algorithm. The study case for this dissertation is predictive maintenance, that allows to detect anomalies in a specific operation and possible defects in equipment and processes. Therefore, one can get an anticipated warning of a system's faults, making it possible to fix them before they result in failure, which may lead to serious consequences in production and losses in revenue.

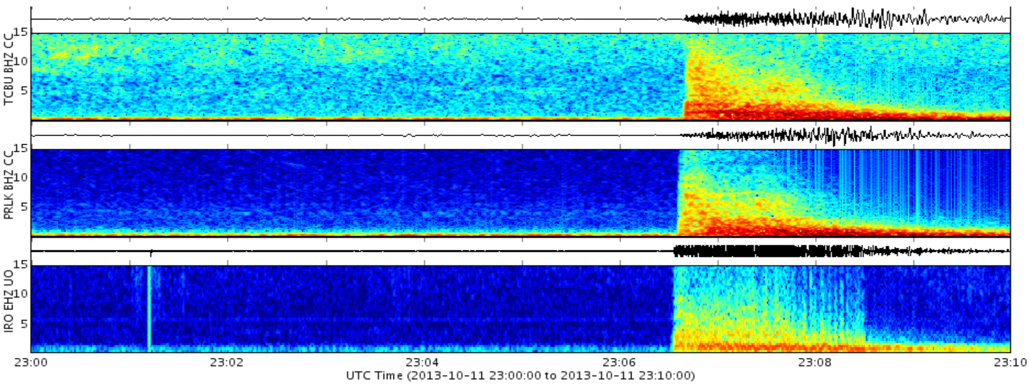

Figure 1 - Earthquake Spectrogram obtained from 3 different locations.

2. Requisitos

The system must sample two signals: one from an accelerometer and one from a microphone. The sample frequency needs to be adequate to the type of signals to be studied. For the microphone, the sample rate may be 2500 Hz, that corresponds to ten times the typical human voice frequency. For the accelerometer, the sample rate can be...

It is required to apply a filter or a bank of filters to the signal, in order to obtain the desired spectrogram. The obtained spectrogram needs to be dispatched to other system using a communication protocol.

3. Relevância técnico-científica

Spectrograms can be used in the context of many applications. For the study case of this project, predictive maintenance, one can obtain a spectrogram from the sound pressure signal that comes from a microphone, or the vibration signal captured by an accelerometer. These applications intend to ensure that faults can be detected, diagnosed and predicted. When the predictive maintenance system detects an error, the production line can be stopped, allowing a much faster repair, than it was compared to a forced stopping. The targeting faults may include low bearing condition, pressure leaks and too much load, for example.

There are other important applications for spectrograms such as audio processing applications, for example a bird species tracker, in which one can identify and geographically locate them, in order to protect them. It can also be used to do speech recognition in voice assistants or to help in the process of teaching blind students. Furthermore, as seen above, the seismology is another area where one can apply spectrograms to detect earthquakes and tectonic movements.

4. Motivação

One can emphasize the constant evolution of technology and industry for motivation. As the number of machines increases in industry, it is desirable to have a mechanism that prevents faults in order to repair it quickly. A spectrogram can be applied to whatever analogic sensor, making it easy for an industry to replicate this solution and apply it to all the different sensors.

Moreover, the advance of ML algorithms facilitates its implementation and adaptation to different datasets and types of signals captured by different sensors, facilitating the adaptation of the solution to other signals.

5. Passos para a solução

The project is divided into five phases: analysis, design, implementation, tests and validation, and thesis writing.

Firstly, in the analysis phase, one must understand the problem, define its requirements and the topics of the state of the art that will be necessary throughout the design and implementation of the solution. These topics may involve the architectures to be used in the sample of the signal, the generation of the spectrograms, standard algorithms related to the matter, and others. In addition, one can go through a market study.

In the design, implementation and tests phases, one must define the most suitable sensors for the solution, considering its communication interface. They should be tested using a simple microcontroller program to configurate its registers and understand how they work. It is needed to implement and validate a block diagram as well as its individual blocks. In order to better test and validate the system, it will be implemented a PCB. Moreover, one has to define the protocol interface to be used to send the spectrogram for other system to apply the ML model.

At last, it is necessary to integrate all the individual architectures and test all the system.