Available online at www.sciencedirect.com
ScienceDirect
Information Sciences 177 (2007) 1543–1557
INFORMATION SCIENCES
AN INTERNATIONAL JOURNAL
www.elsevier.com/locate/ins

An intelligent hybrid approach for industrial quality control combining neural networks, fuzzy logic and fractal theory

Patricia Melin *, Oscar Castillo

Department of Computer Science, Tijuana Institute of Technology, Mexico

Abstract

The application of type-2 fuzzy logic to the problem of automated quality control in sound speaker manufacturing is presented in this paper. Traditional quality control has been done by manually checking the quality of sound after production. This manual checking of the speakers is time consuming and occasionally was the cause of error in quality evaluation. For this reason, by applying type-2 fuzzy logic, an intelligent system for automated quality control in sound speaker manufacturing is developed. The intelligent system has a type-2 fuzzy rule base containing the knowledge of human experts in quality control. The parameters of the fuzzy system are tuned by applying neural networks using, as training data, a real time series of measured sounds produced by good sound speakers. The fractal dimension is used as a measure of the complexity of the sound signal.

Keywords: Neural networks; Fuzzy logic; Fractal theory; Quality control

1. Introduction

In this paper, we present the use of an intelligent hybrid approach, combining type-2 fuzzy logic and neural networks, to the problem of quality control in the manufacturing of sound speakers. The quality control of the speakers was done manually by checking the quality of sound achieved after production [4]. A human expert evaluated the quality of sound of the speakers to decide if production quality was achieved. Of course, this manual inspection of the speakers was time consuming and occasionally resulted in errors in quality evaluation [8]. For this reason, it was necessary to consider automating the quality control of the sound speakers using intelligent techniques and fractal theory. The problem of measuring the quality of the sound speakers can be outlined as follows:

* Corresponding author.
E-mail address: pmelin@tectijuana.mx (P. Melin).

doi:10.1016/j.ins.2006.07.022

(1) First, we need to extract the real sound signal of the speaker during the testing period after production.
(2) Second, we need to compare the real sound signal to the desired sound signal of the speaker, and measure the difference with some appropriate metric.
(3) Third, we need to decide on the quality of the speaker based on the difference found in step 2. If the difference is small enough then the speaker can be considered of good quality, otherwise it is of bad quality.

The first part of the problem was solved by using a multimedia kit that enables us to extract the sound signal as a file, which basically contains 108,000 points over a period of time of 3 s (this is the time required for testing). We can consider that the sound signal is expressed as a time series [3], which captures the basic characteristics of the speaker. The second part of the problem was addressed by using a neuro-fuzzy approach to train a fuzzy model with the data coming from the good quality speakers [9]. We used a neural network [6] to obtain a Sugeno fuzzy system [22] with the time series of the ideal speakers. In this case, a neural network [5,17,21] is used to adapt the parameters of the fuzzy system with real data of the problem. With this fuzzy model, the time series of other speakers can be used as checking data to evaluate the total error between the real speaker and the desired one. The third part of the problem was solved by using another set of type-2 fuzzy rules [13], which basically are fuzzy expert rules to decide on the quality of the speakers based on the total checking error obtained in the previous step. Of course, in this case we needed to define type-2 membership functions for the error and quality of the product, and the Mamdani reasoning approach was used. We also use as input variable of the fuzzy system the fractal dimension of the sound signal. The fractal dimension [9] is a measure of the geometrical complexity of an object (in this case, the time series). We tested our fuzzy-fractal approach for automated quality control during production with real sound speakers with excellent results.

2. Basic concepts of sound speakers

In any sound system, ultimate quality depends on the speakers [4]. The best recording, encoded on the most advanced storage device and played by a top-of-the-line deck and amplifier, will sound awful if the system is hooked up to poor speakers. A system's speaker is the component that takes the electronic signal stored on things like CDs, tapes and DVD's and turns it back into actual sound that we can hear.

To understand how speakers work, the first thing you need to do is understand how sound is processed by the human brain. Inside your ear there is a very thin piece of skin called the eardrum. When your eardrum vibrates, your brain interprets the vibrations as sound. Rapid changes in air pressure are the most common thing to vibrate your eardrum.

An object produces sound when it vibrates in air (sound can also travel through liquids and solids, but air is the transmission medium when we listen to speakers). When something vibrates, it moves the air particles around it. Those air particles in turn move the air particles around them, carrying the pulse of the vibration through the air as more and more particles are pushed farther from the source of the vibration. In this way, a vibrating object sends a wave of pressure fluctuation through the atmosphere. When the fluctuation wave reaches your ear, it vibrates the eardrum back and forth. Our brain interprets this motion as sound. We hear different sounds from different vibrating objects because of variations in:

- *sound wave frequency* – a higher wave frequency simply means that the air pressure fluctuates faster. We hear this as a higher pitch. When there are fewer fluctuations in a period of time, the pitch is lower.
- *air pressure level* – the wave's amplitude – determines how loud the sound is. Sound waves with greater amplitudes move our ear-drums more, and we register this sensation as a higher volume.

A speaker is essentially the final translation machine – the reverse of the microphone. It takes the electrical signal and translates it back into physical vibrations to create sound waves. When everything is working as it should, the speaker produces nearly the same vibrations that the microphone originally recorded and encoded on a tape, CD, LP, etc. Traditional speakers, do this task with one or more drivers. A driver produces sound waves by rapidly vibrating a flexible cone, or diaphragm. Fig. 1 shows a typical speaker driver.