Combining Ultrasonic Measurement and Machine Learning to Assess Baked Product Quality

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Why is it important?

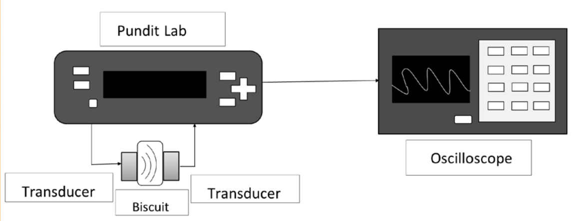
Baked products are one of the most popular ready-to-eat snacks in the world[1].

Food manufacturers have begun integrating digital technologies such as IoT and ML into their processes to provide many benefits related to food quality, food safety and process optimisation[2].

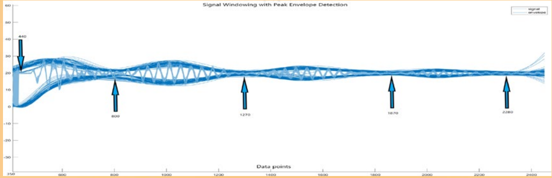
Ultrasonic sensors have many advantages such as low-cost, non-destructive and can operate online in challenging production environments.

The aim is creating a non-invasive, online, smart sensor system using ultrasonic sensors to detect changes in the texture of baked products such as biscuits and then converting ultrasonic signals into useful information for appropriate machine learning methods to meet the expectation of consumers and food industry.

The typical ultrasound set-up for experimental measurement is similar to the diagram below.



Machine Learning Results



The speed of sound (SOS) through biscuits was calculated by the distance and time-of-flight (TOF) of an ultrasonic wave propagating through the biscuit sample. The amplitude and energy of the recorded signals was calculated from the received of waveform.

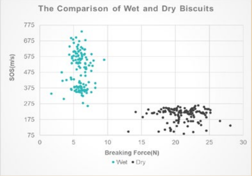
The energy and amplitude of windowed waveforms were used as feature for the ML algorithms.

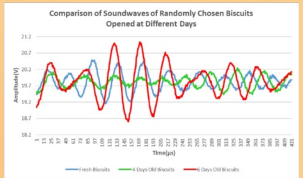
Methodology

This project combines ultrasonic measurements and machine learning methods to determine physical parameters of baked food products.

- Baked Product Preparation
- Experimental Setup- Ultrasonic System
- Acquire & Explore Data
- Choose and Build a Machine Learning Model
- Training and Evaluation of the Model
- Comparing Result of Machine Learning Algorithm

Results





A clear difference in terms of SOS vs Breaking Force was identified for the wet and dry biscuits.

The difference of dry and wet biscuits in terms of breaking force, amplitude, energy and SOS values is shown below. The results are based on a small number of samples yet still show differences in the ultrasonic results.

Machine Learning Results

	Classification Accuracies to Predict Wet and Dry Biscuit			Regression Accuracies to Predict Moisture Content in Biscuit		
Features	Support Vector Machines	Decision Trees	Artificial Neural Network	Support Vector Machines	Decision Trees	Artificial Neural Network
	Correct Classification Rate (%)			R-Squared Value		
SOS, Energy(E)	99.2	99.5	100	0.93	1	0.9965
Amplitude(A), E	77.6	95	100	0.72	0.71	0.959
SOS, E, A	98.1	99.2	100	0.95	0.81	0.9982
A1, E1	85	90	99	0.51	0.40	0.999
A2, E2	87.5	92.5	100	0.76	0.70	0.9995
A3, E3	95	87.5	99	0.85	0.67	0.9993
A1, E1, A2, E2	82.5	82.5	99	0.74	0.63	0.999
A1, E1, A2, E2, A3, E3	92.5	95	99	0.81	0.67	0.997

A1- Amplitude of windowed waveform datapoints from 440 to 800; E1- Energy values of windowed waveform datapoint from 440-800; A2,E2- Datapoints from 800 to 1270; A3,E3- Datapoints from 1270-1870

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