HOST 2018 Hardware Demo Proposal

Authentication and Traceability of Food Products using NQR Spectroscopy

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Motivation and Significance:

The global food supply chain has been becoming more complicated and less secure; fraud in food and food substances has been estimated to be a 40 billion dollar problem per year. Customers are increasingly concerned about food quality but cannot entirely trust the food they eat due to the limited information provided by food producers to guarantee the provenance of their products. One of the biggest challenges preventing traceability is the fragmented form of the supply chain. While several Internet of Things (IoT)-enabled technologies, e.g., RFID tags and optical barcodes, can provide more accurate and detailed information to the supply chain than earlier methods, they are also prone to new vulnerabilities and failures.

Description of the Experiment:

To address the pressing need for checking the integrity of diverse food and dietary supplement products as they move through the supply chain, we will present a novel hardware-enabled authentication method. It relies on applying nuclear quadrupole resonance (NQR) spectroscopy to authenticate the contents of packaged food products based on intrinsic signatures of its chemical composition. NQR is a non-invasive, non-destructive, and quantitative radio frequency (RF) spectroscopic technique. It is sensitive to subtle features of the solid-state chemical environment such that signal properties are influenced by the manufacturing process, thus generating a manufacturer-specific watermark or intrinsic tag for the product. Such tags enable us to uniquely characterize and authenticate products of identical composition but from different manufacturers based on their NQR signal parameters. These intrinsic tags can be used to verify the integrity of a product and trace it through the supply chain. We apply a support vector machine (SVM)-based classification approach that trains the SVM with measured NQR parameters and then authenticates food products by checking their test responses. Measurements of several example substances using semi-custom hardware shows promising results (95% classification accuracy) which can be further improved with improved instrumentation.

Demo model:

The proposed hardware demo will concentrate on authentication of food and dietary supplements using NQR spectroscopy through the supply chain. An unknown sample will be tested at a specific resonant frequency using the experimental setup and its unique intrinsic signature based on its manufacturer-specific watermark consisting of three parameters: amplitude, decay time, and linewidth will be obtained. This signature will be tested with an existing SVM classifier to trace the unknown sample to its manufacturer.

Experimental Setup:

1. Kea 2 Benchtop Nuclear Magnetic Resonance (NMR) spectrometer.
2. Sample coil and tunable impedance-matching network.
3. Prospa graphical user interface (GUI) to collect data from the spectrometer.
4. MATLAB for chemometric data analysis and SVM classification.
5. Laptop to display the classification results.

Related References:

[1] Fengchao Zhang, Naren Masna, Cheng Chen, Soumyajit Mandal, and Swarup Bhunia, "Authentication and Traceability of Food Products Through the Supply Chain Using NQR Spectroscopy", *IEEE BioCAS, FoodCAS Lecture session*, Italy, October 2017.

[2] Cheng Chen, Fengchao Zhang, Jamie Barras, Kaspar Althoefer, Swarup Bhunia, and Soumyajit Mandal. , "Authentication of medicines using nuclear quadrupole resonance spectroscopy", *IEEE/ACM Transactions on Computational Biology and Bioinformatics (TCBB)*, 13.3 (2016): 417-430.

[3] Cheng Chen, Fengchao Zhang, Swarup Bhunia, and Soumyajit Mandal. "Broadband quantitative NQR for authentication of vitamins and dietary supplements", *Journal of Magnetic Resonance*, 278 (2017): 67-79.

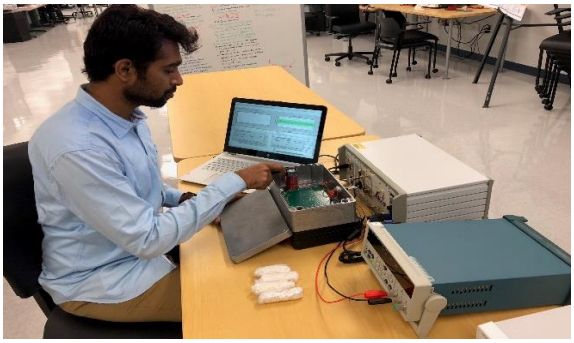


Fig.1: Experimental Setup for the food product authentication.

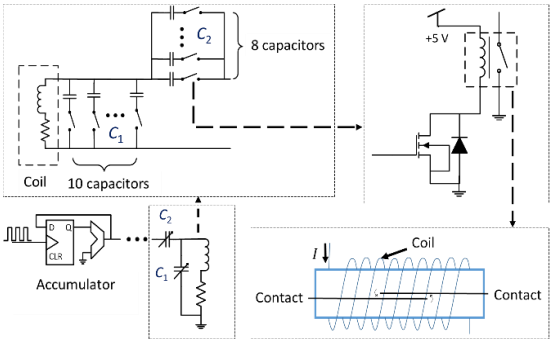


Fig.2: Schematic diagram for the hardware modules.

Fig.3: Kea 2 NMR Spectrometer used for pulse generation.

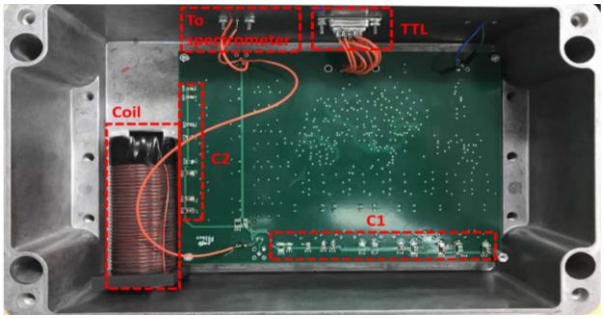
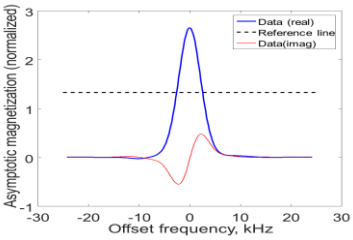


Fig.4: Sample coil and tunable matching. network.

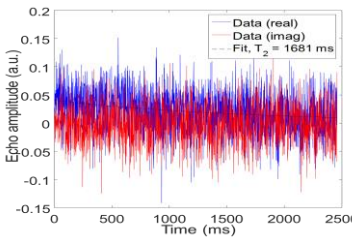
Observables:

1. A graphical representation of the three-parameter signature of the sample.
2. SVM classification and manufacture identification.

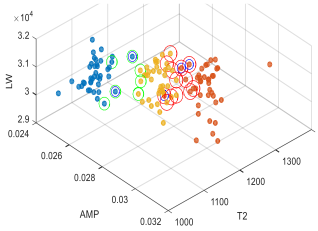
Normalized frequency domain spectrum



Time-domain echoes after matched filtering

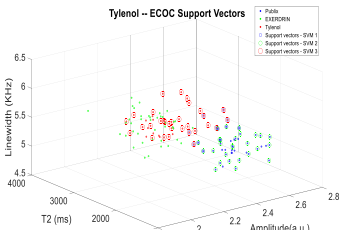


Classification of L-Histidine



Accuracy: 97.5%

Classification of Acetaminophen



Accuracy: 95%

Goal: We will present a novel non-invasive chemometric approach for verifying the integrity of food products and tracing them through the supply chain using Nuclear Quadrupole Resonance spectroscopy.