Ls-liquid:Towards Container-irrelevant Liquid Sensing on Smartphones

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INTRODUCTION

Background. Liquid sensing is essential to our life and health, which has recently garnered significant research attention[1–3, 5, 6]. A ubiquitous and mobile liquid sensing system could have a significant impact on ensuring food security and in-home health monitoring, i.e., detecting the food additives in beverages, and tracking protein concentration in the urine.

Key idea. To sense a liquid, we leverage a fact that different liquids have different acoustic impedances [4], which lead to the reflected signals from liquids have different energy distribution at each frequency.

Result. Our experimental evaluations demonstrate that Ls-liquid is able to identify one kind of food additive in four different beverages with over 90% accuracy, and can measure protein concentration under 1 mg/100 mL in the urine.

Figure 1: Visualization of Ls-liquid.

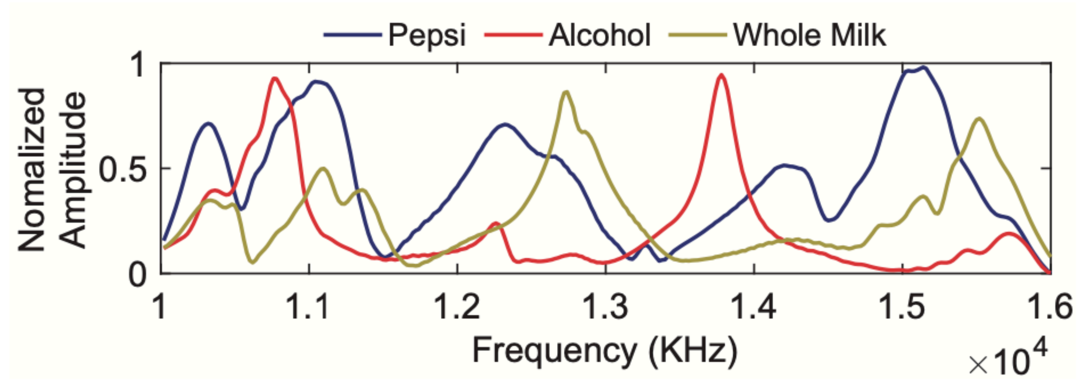

Figure 2: Amplitude-frequency patterns of different liquids.

DESIGN

Identification method. In Ls-liquid, the basic idea arises from the fact that acoustic signals experience distinct strength variation when reflected by a liquid, manifesting in the amplitude and frequency of the reflected signals. To illustrate this, we take three liquids (Pepsi, Alcohol, Whole Milk) as an example. We then extract the amplitude-frequency patterns from the reflected signals. The result is shown in Fig. 2, we discover that the energy distribution in the frequency domain differs between the reflected signals, and the different liquids have the significant amplitude-frequency patterns. Since the containers with different materials have different reflection coefficients, it will also lead to the reflected signal variations. We employ a Siamese network-based model with a specific training sample selection strategy to reconstruct the extracted feature to container- irrelevant feature.

Figure 3: The experimental setup.

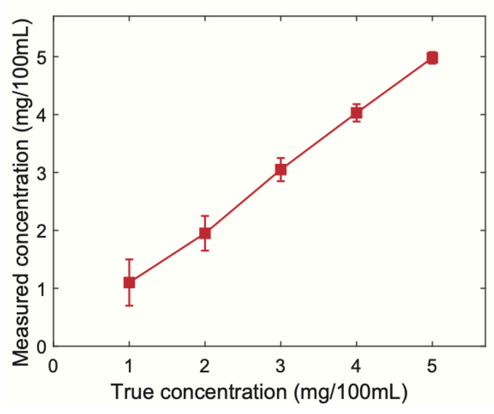

Figure 4: Detection protein concentration in urine.

Table 1: Performance of detecting the food additive (sorbate) in beverages.

	Water	Coca	Pepsi	Juice	Average
Precision	94.48%	91.76%	93.30%	97.00%	93.13%
Recall	90.97%	90.48%	92.57%	96.76%	93.10%

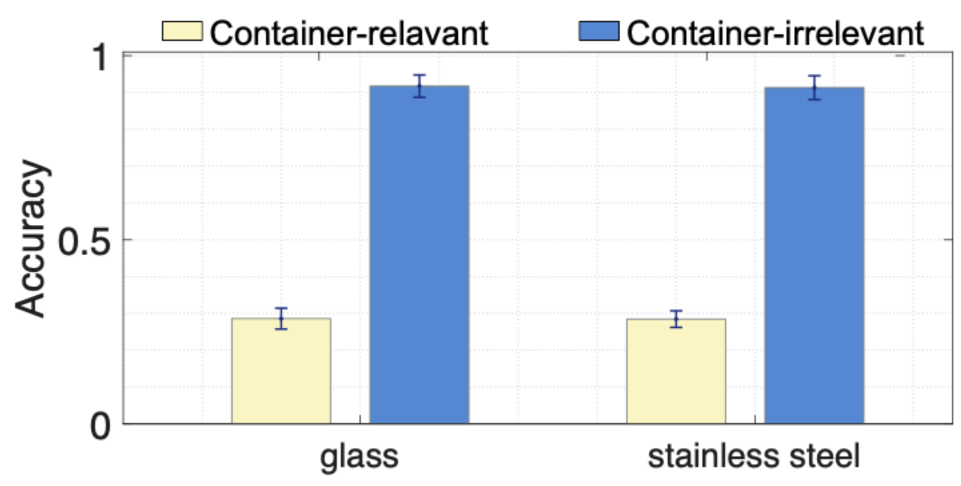

Figure 6: The performance across different containers.

PRELIMINARY RESULTS

Hardware setup: The system setup is shown in Fig 3. Ls-liquid utilizes a smartphone placed on a glass container, and leverages the top-speaker of the smartphone to transmit acoustic signals, and the front-microphone of the smartphone to receive the reflected signals.

Tracking the protein in the urine: We first evaluate our system to track the protein concentration in the urine. The result is shown in Fig. 4, we can measure protein concentration under 1 mg/100 mL in the urine.

Detecting the food additives in the beverages: We experimented with three common food additives (i.e., sorbate, citric acid and cyclamate). The result is shown in Tab. 1. We can detect one food additive (sorbate) in four different beverages with an average 93% accuracy.

Impact of different containers: The result is shown in Fig. 6, we can discover that the accuracy is low when testing on new container without the training sample selection.

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