Introduction

Objective
Design a low-cost, non-destructive system to estimate the Soluble Sugar Content (SSC) of fruits using the millimeter-wave (mmWave) wireless technology in 5G-and-beyond devices.

Motivation
1) Fruit’s SSC indicates ripeness, making it a valuable tool for quality control in the fruit production and consumption chain.
2) Existing systems require mostly lab-grade hardware and destroy the fruits in the process.

Challenge
Developing a fruit-agnostic SSC estimation system is hard due to the varied shapes, sizes, and ranges of SSC in different types of fruits.

Estimating SSC in Fruits

Estimating SSC in fruits using sugar solution data
• Collect reflections from multiple pairs of Tx and Rx.
• Extract time domain and frequency domain features such as mean amplitudes and signal strengths from the reflection profiles.
• Train regression models using these features and ground truth SSC.
• Test the models on real fruits.

How to use mmWave reflection signals for SSC estimation?
• Direct relationship between the strength of the reflected signals ($A_r$) and reflection coefficient ($r$).
  \[
  \frac{A_r}{A_t} \propto G_r G_t \frac{\lambda}{4\pi(2d) \cdot r}
  \]
• Inverse relationship between $r$ and SSC.
• Assessed this relationship using sugar solutions.
  • Single antenna pair inadequate for estimating SSC.

Preliminary Results

SSC estimation performance
• Train Linear Regression (LR), Support Vector Regression (SVR), and Random Forest Regression (RF) with 360 sugar solution samples.
  • Testing with LR on 90 sugar solution samples yields an average error of 0.54 °Bx.
  • Testing with LR on 130 samples of apples, oranges, and kiwis yields an error of 1.43 °Bx.

Conclusion and Future Work
• SSCense estimates SSC in a non-destructive manner.
  • Exploration of Generative Adversarial Networks to map fruit reflected signals to similar sugar reflected signals for improving performance.