



# Material Classification Using Frequency- and Depth-Dependent Time-of-Flight Distortion

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### Introduction

#### Material classification

May be difficult from an image.

#### Contribution

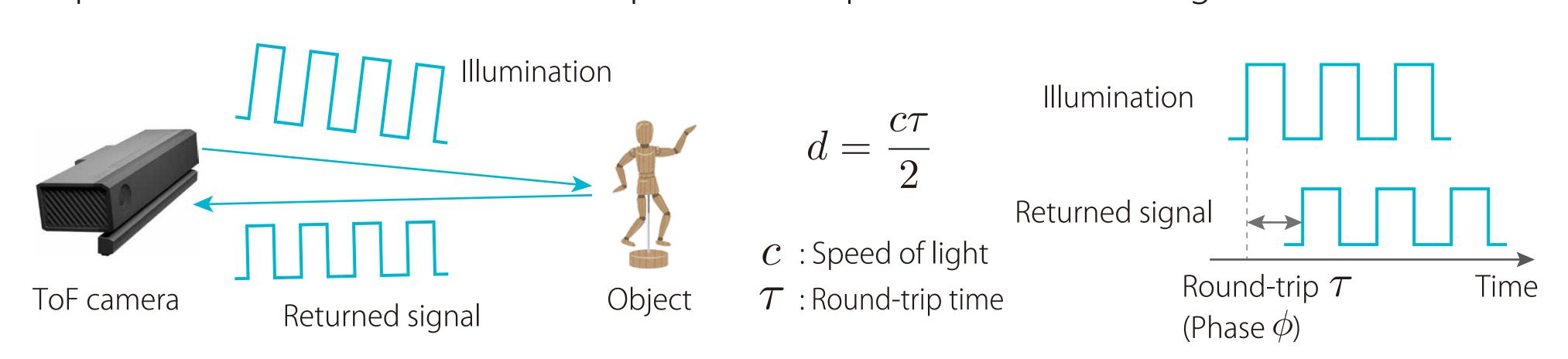
- We propose a new modality for material classification.
- Off-the-shelf ToF camera is used.
- Cause of measurement distortion is revealed.



# Key Observation

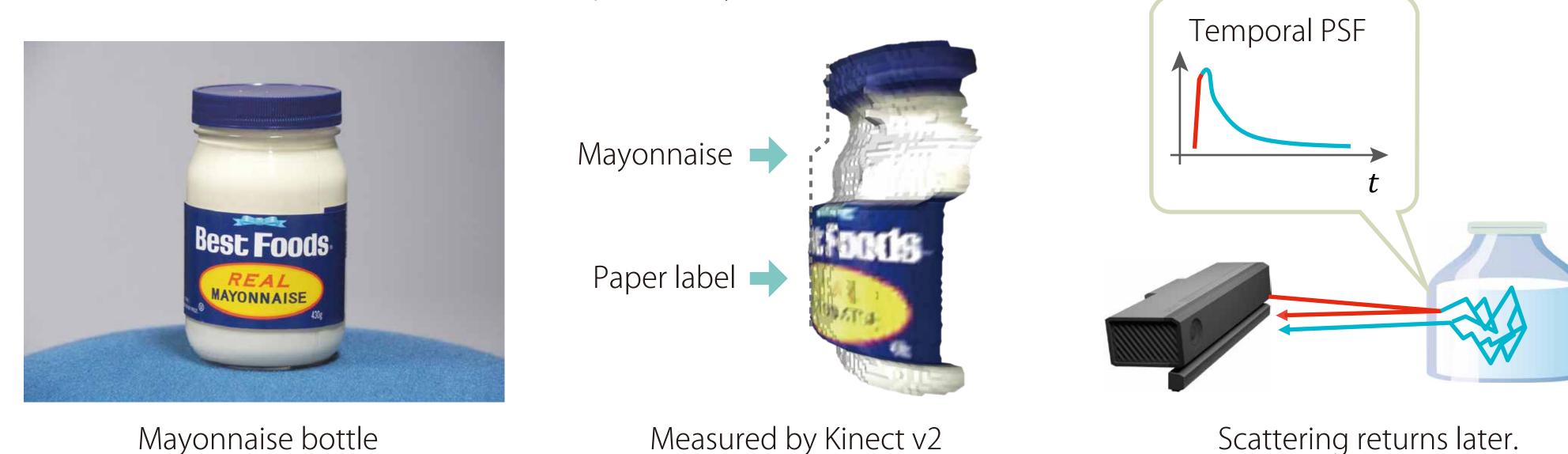
#### Time-of-Flight (ToF) Camera

• Depth measurement from round-trip time of amplitude modulated light.

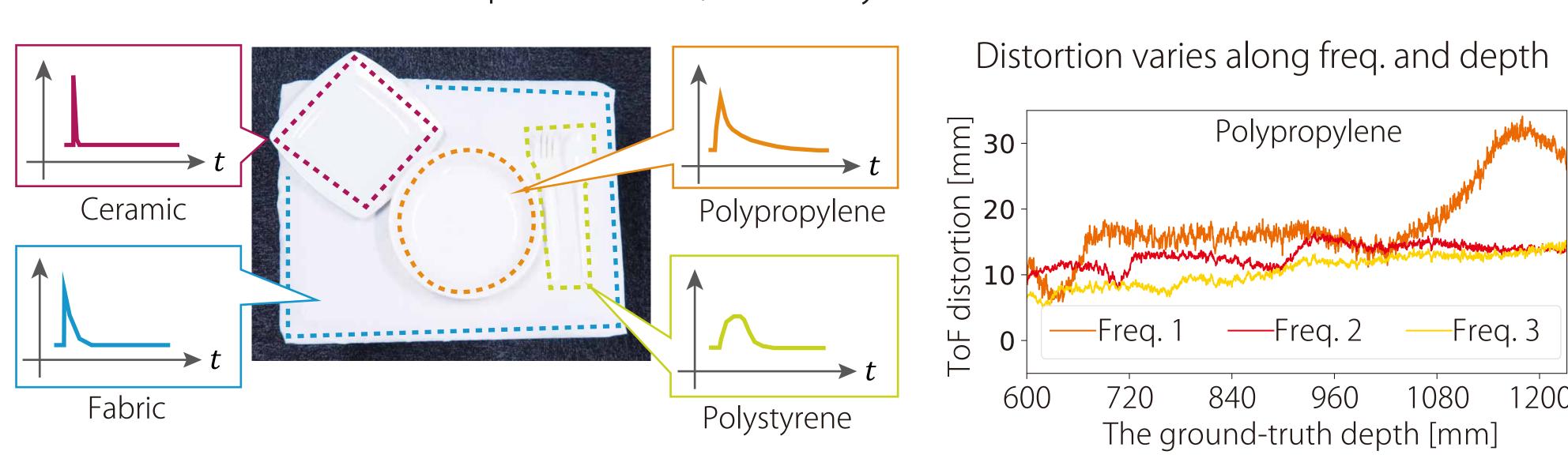


#### Time-of-Flight Distortion

• Measurement of translucent object may be distorted.



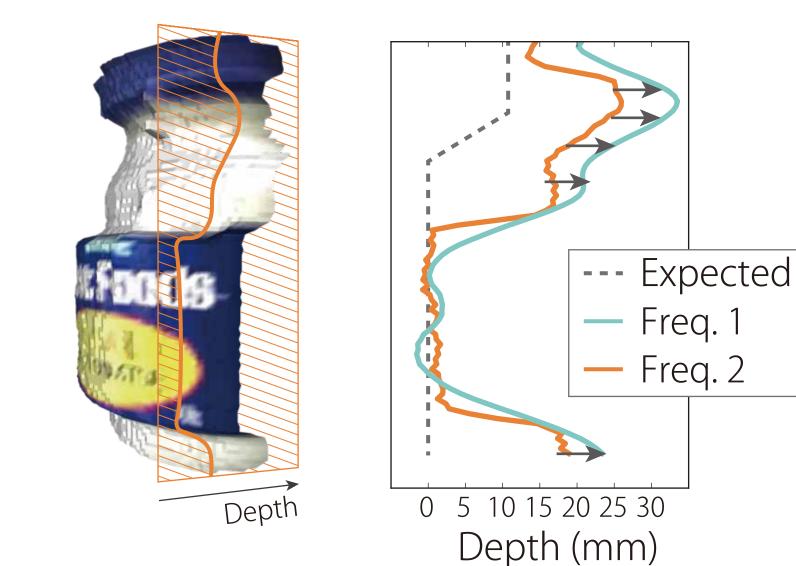
- Mayonnaise bottle
  - Measured by Kinect v2
- → This distortion inherits material information of the object.
- Different materials have respective PSFs, thus they have different ToF distortions.

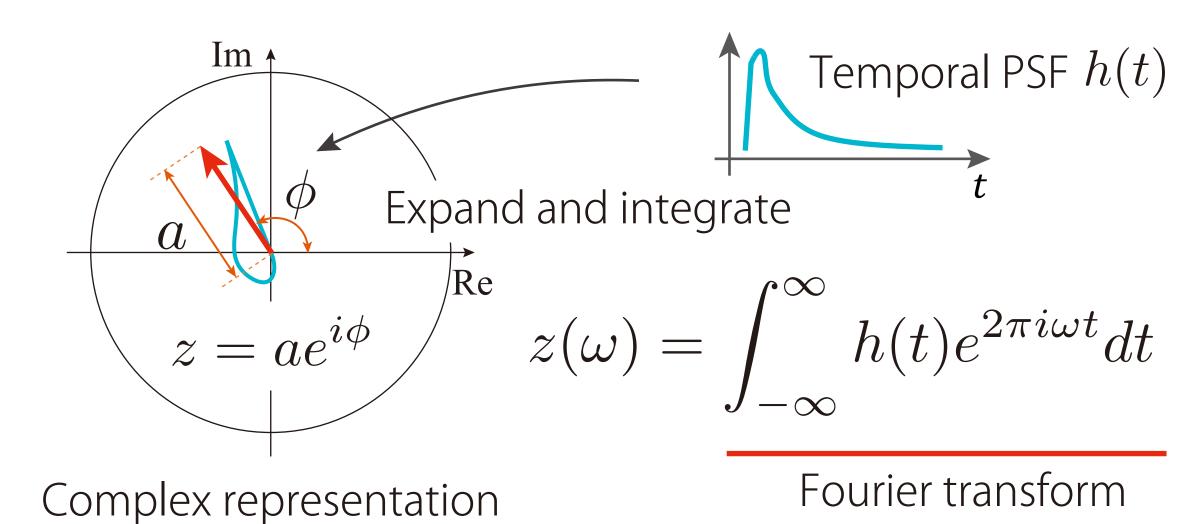


## Frequency and Depth-Dependent Distortions

#### Frequency-dependent distortion

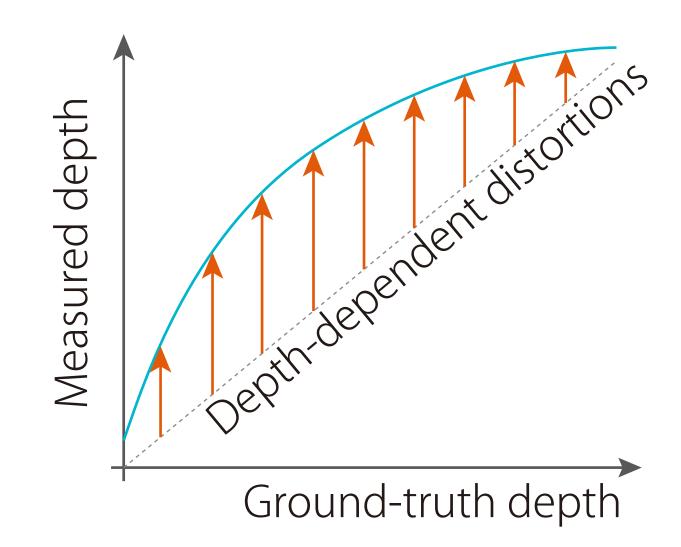
• Distortion is frequency-dependent. • ToF observation is equivalent to Fourier coefficient.





#### Depth-dependent distortion

Distortion is depth-dependent.



• Irregular phase correspondence between waves. = Depth distortion varies along depth.

3. Align all depth distortions

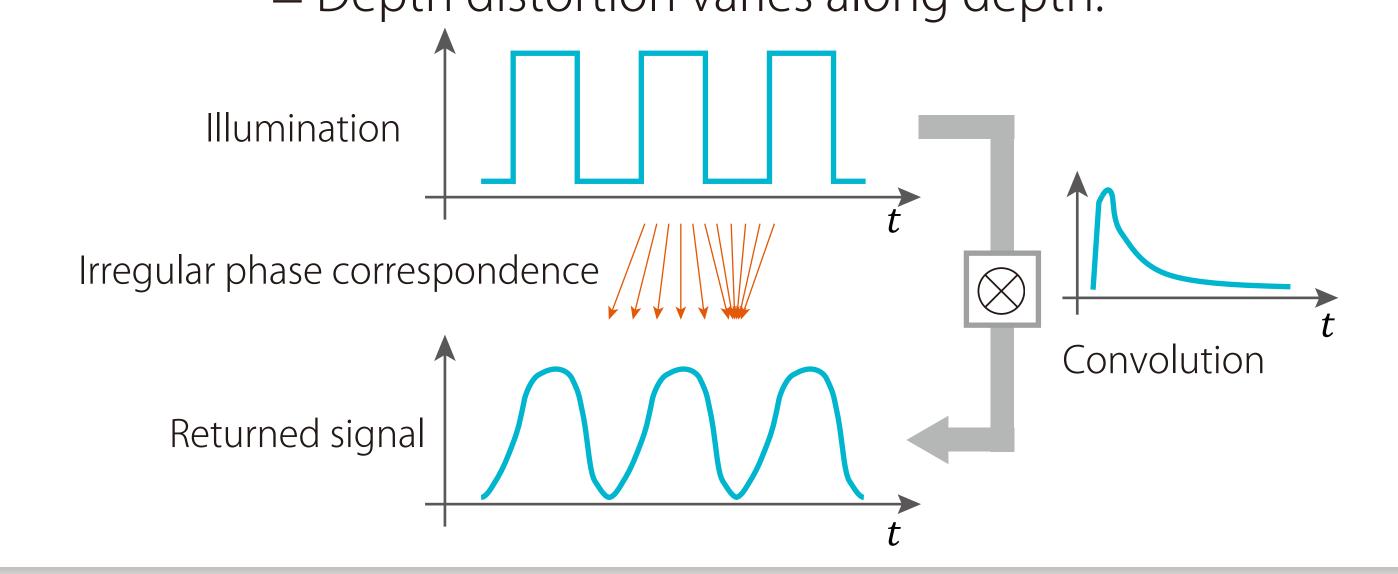
Absolute distortion feature

Relative distortion feature

m(n-1)-length vector

n-th frequency as reference

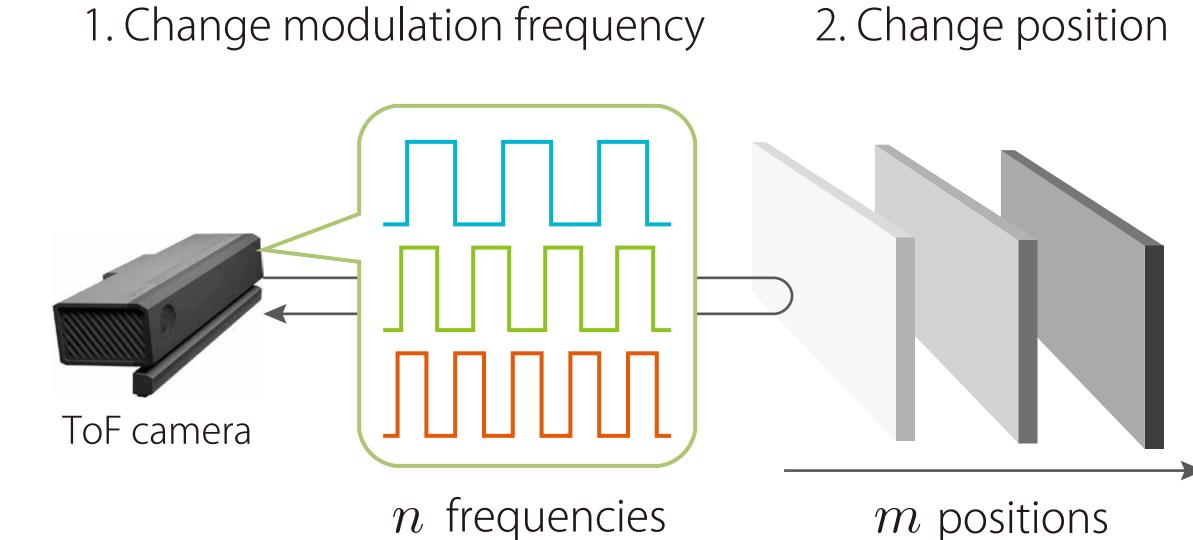
mn -length vector treq 1 / treq n



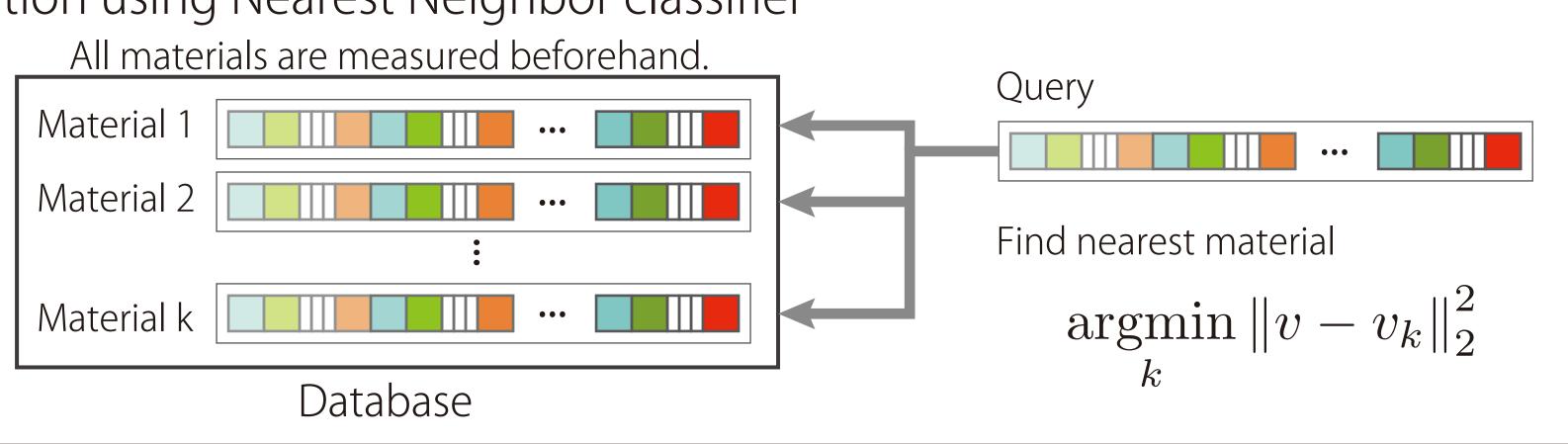
## Classification Method

#### Material classification using distorted depths

 Feature vector construction 1. Change modulation frequency



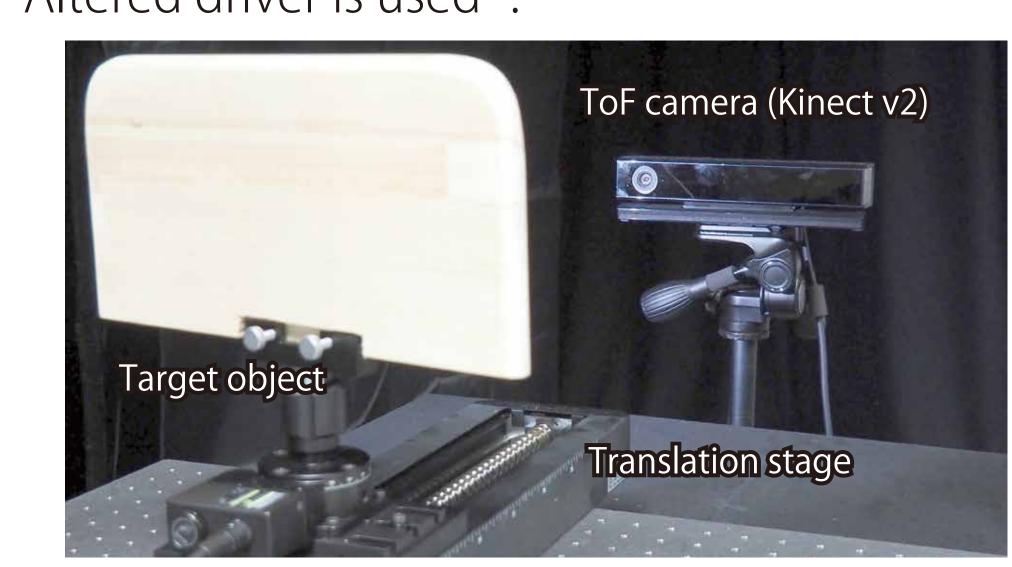
Classification using Nearest Neighbor classifier



#### Results

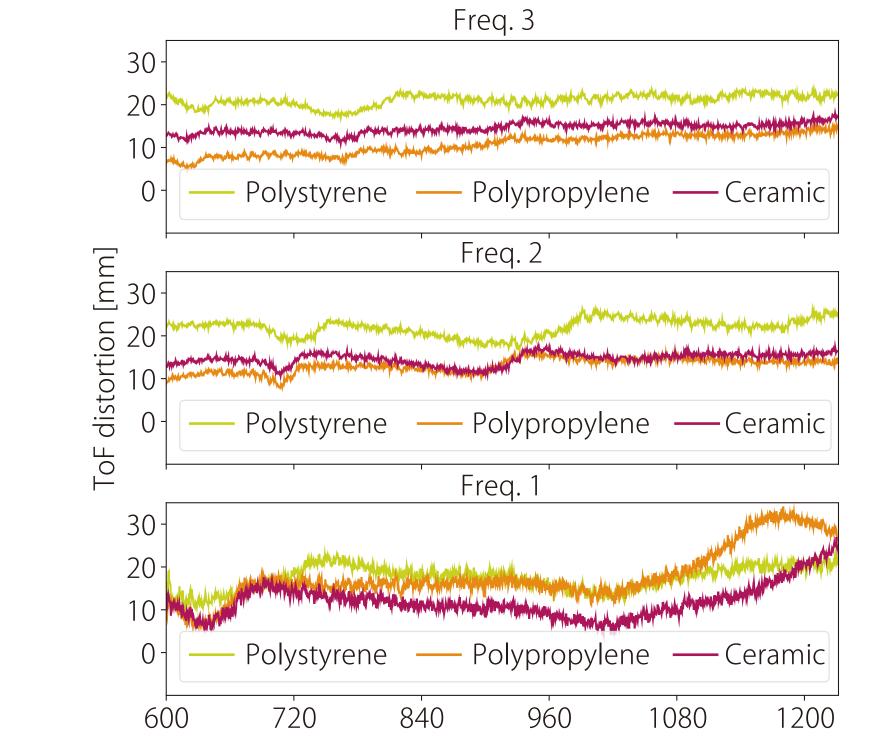
#### Measurement System

• Kinect v2, which has 3 modulation frequencies. Altered driver is used\*1.



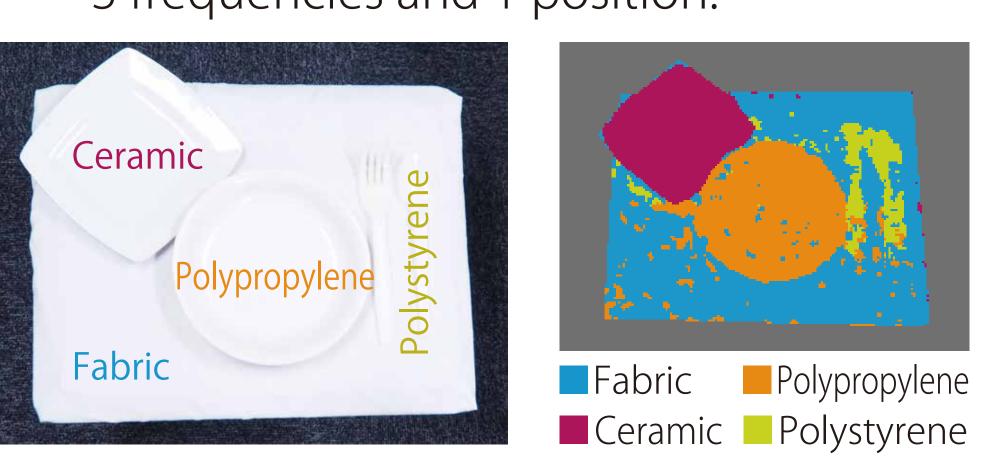
## Measured ToF distortions

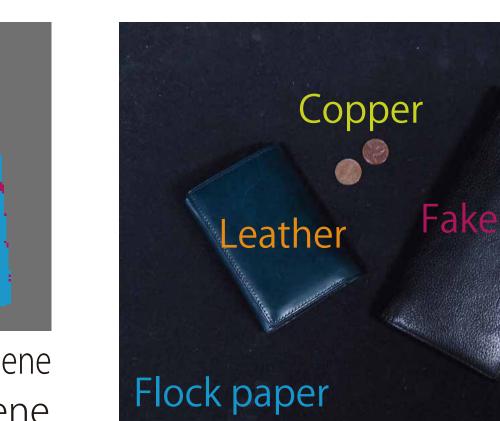
Different pattern is observed.

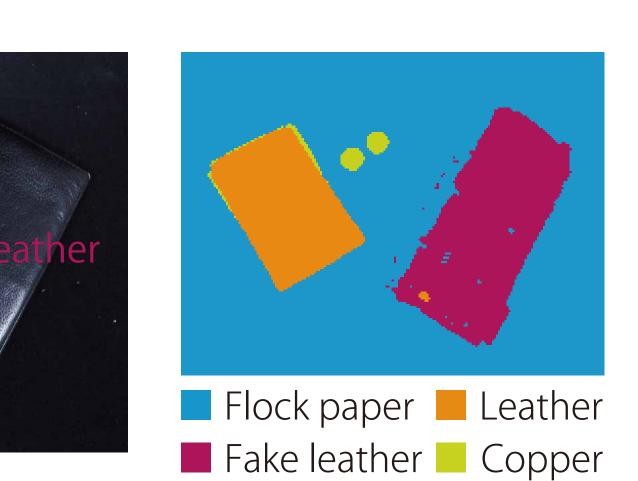


#### Qualitative Results

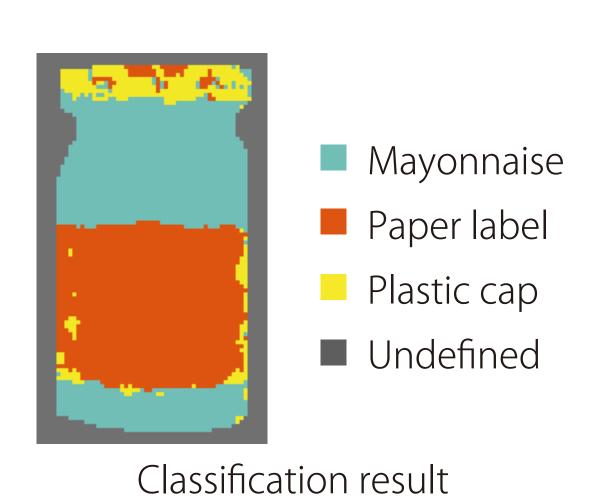
3 frequencies and 1 position.









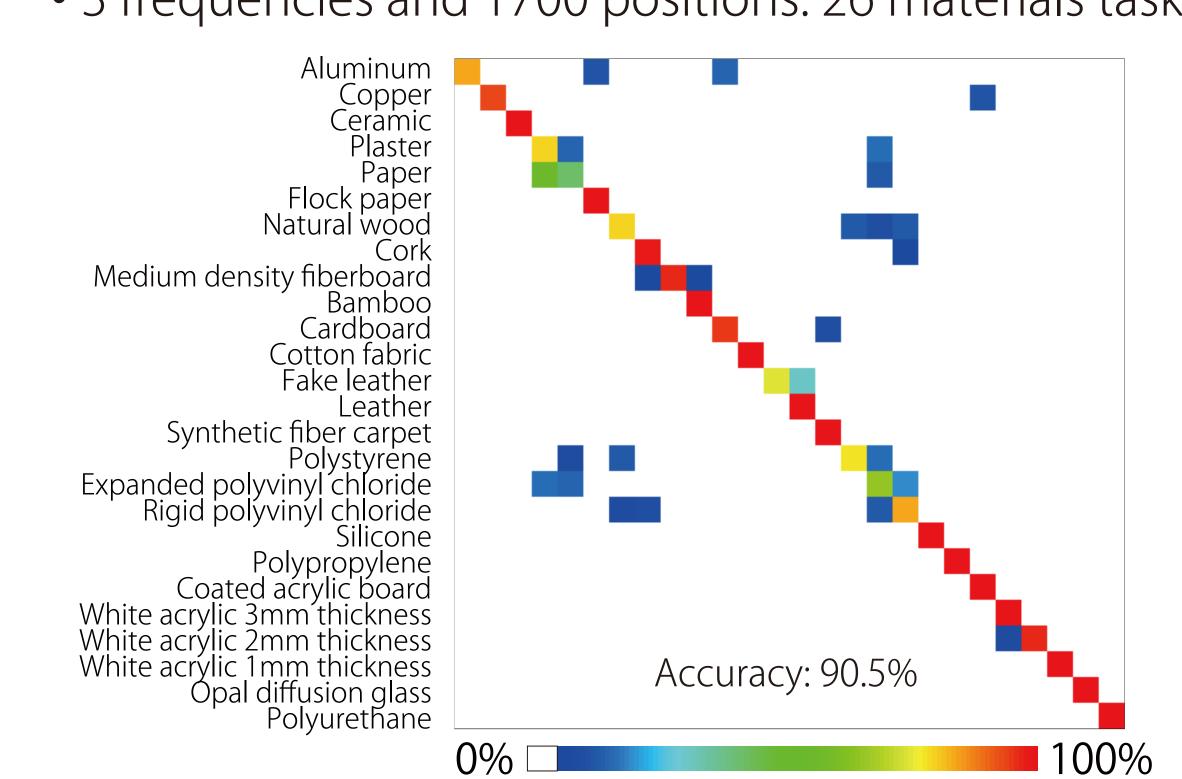






Quantitative Evaluation

• 3 frequencies and 1700 positions. 26 materials task.







<sup>\*1</sup> Code available online: http://k-tanaka.me/projects/material-tof.html