

Testing Masks and Air Filters with Your Smartphones

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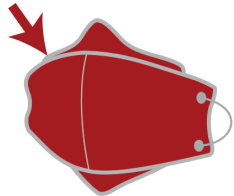


Masks and Air Filters are Pervasive

- **High demand** for masks and air filters with **effective filtration**
- Protect users from inhaling **air pollutants** and **hazardous particles**



Disposable
Face Mask



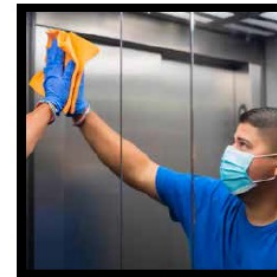
Reusable
Face Mask



Gas Mask

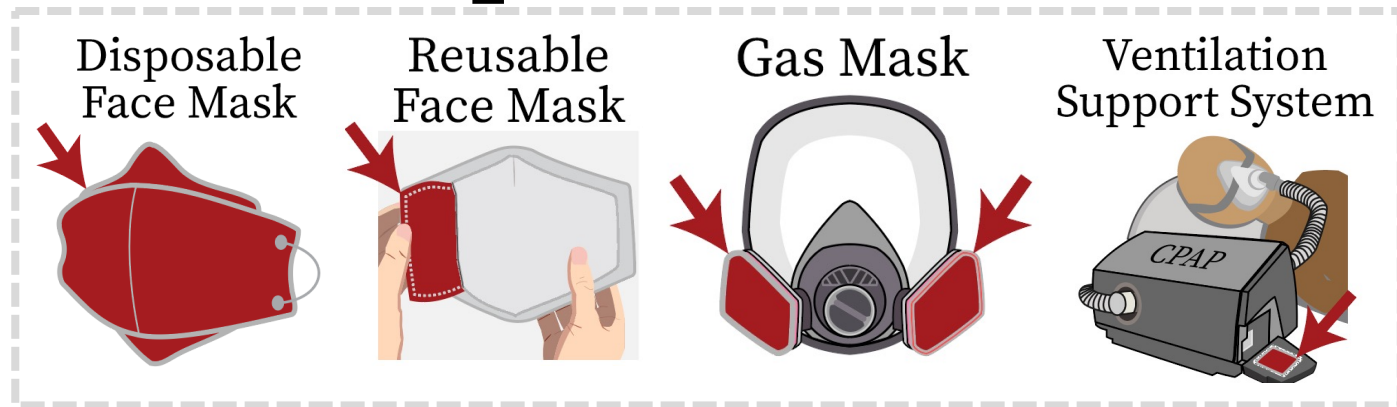
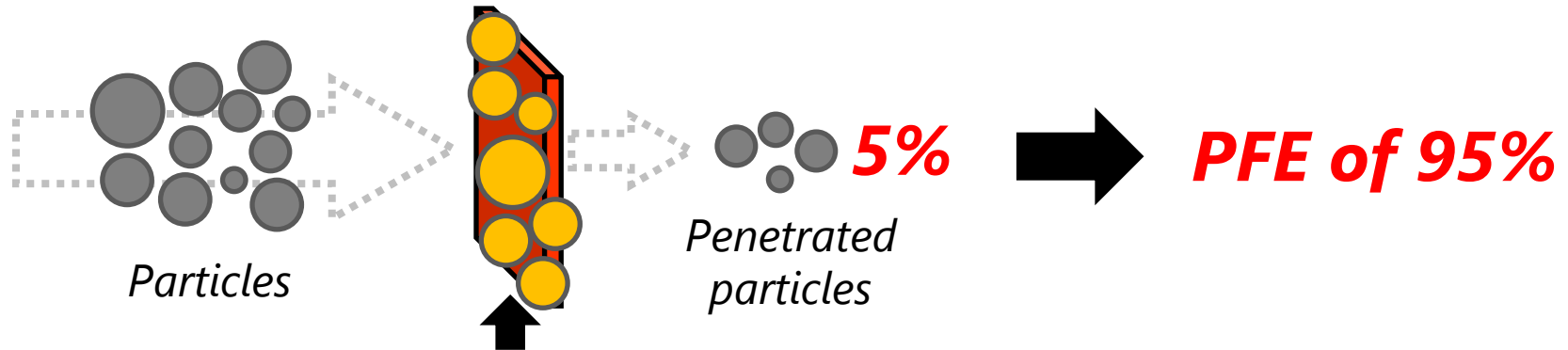


Ventilation
Support System



Particulate Filtration Efficiency (PFE) is Critical

- PFE is **percentage of particles blocked** by masks and air filters



Risks and Difficulties

- **Diverse standards** and different **expressions of filtration efficiency**, leading to user confusion



Alice



Face Mask

VS.



Respirator

Risks and Difficulties

- **Counterfeit, substandard** and/or **mislabeled** products

Millions of counterfeit N95 masks distributed to health care workers in the U.S.

Masks imitating the real thing are flooding U.S. ports, and



Forbes

FORBES > INNOVATION > HEALTHCARE

CORONAVIRUS

Almost 70% Of Chinese KN95 Masks Don't Meet Minimum Safety Standards

Robert Glatter, MD Contributor


I cover breaking news in medicine, med tech and public health

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Sep 25, 2020, 09:20pm EDT

Counterfeit Respirators / Misrepresentation of NIOSH Approval

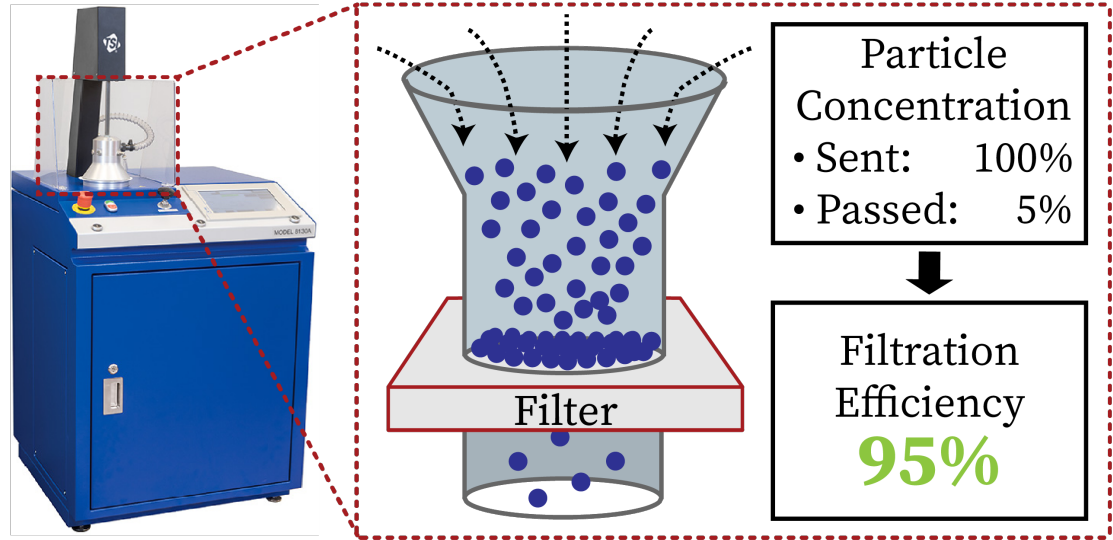
Promoting productive workplaces through safety and health research 



Breath Buddy is NOT a NIOSH approval holder. They are falsely indicating product can be used with half and full facepieces made by other NIOSH approval manufacturers. The Breath Buddy Particulate Filter is NOT a component associated with a NIOSH approval. Users cannot use this filter in place of the filter component associated with the NIOSH Approved respiratory protective device. If so, it will void the NIOSH approval. (1/26/2022)

Risks and Difficulties

- Lack of filtration efficiency **verification** method for **average users**



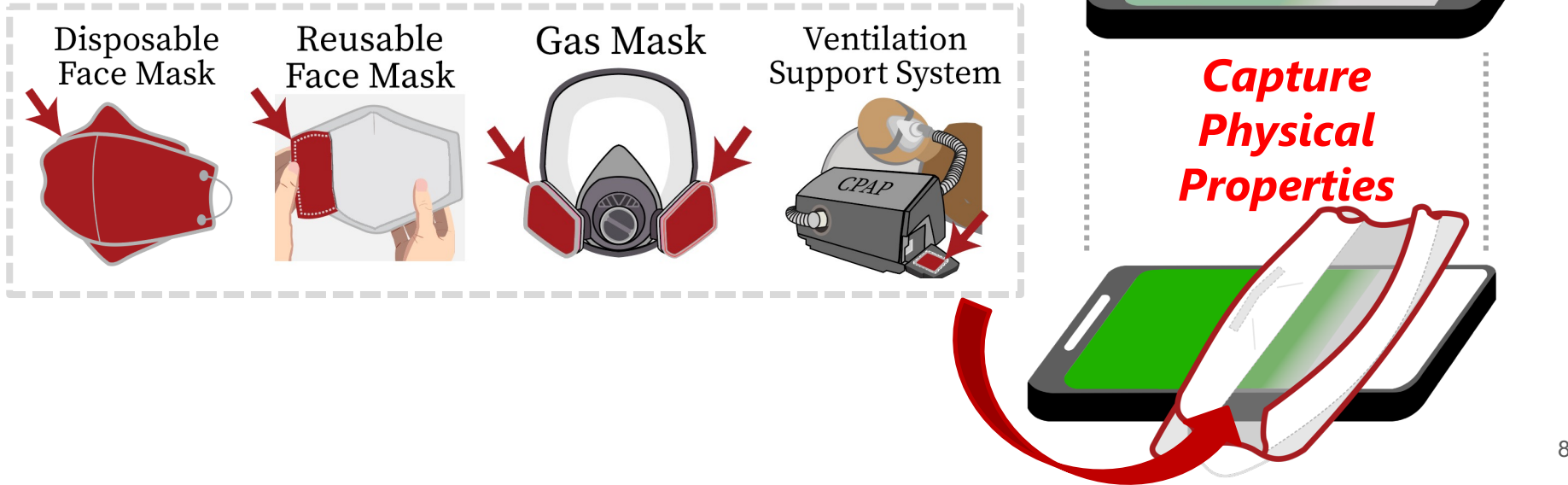
Disadvantage:

- Require **costly** and **bulky** equipment
- **Contaminate** each mask/filter

***Can we empower average users to
test masks and air filters using only
commodity smartphones?***

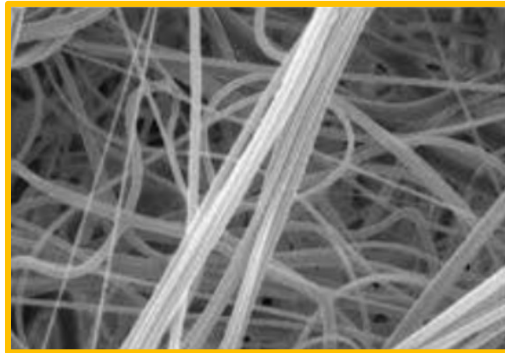
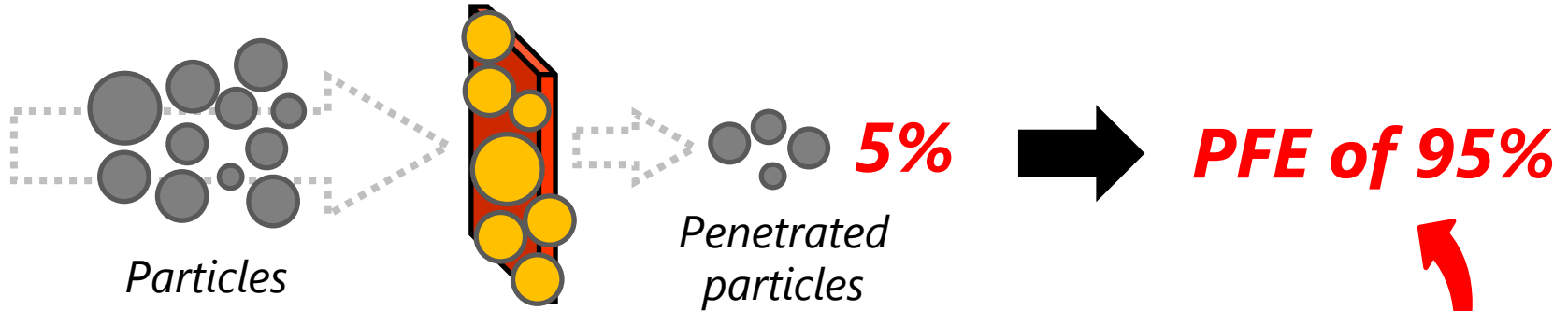
Our Work: *FilterOp*

- Test filtration efficiency utilizing only a **smartphone camera** and another **display device**



Background: Filtration Efficiency

- Filtration efficiency can be determined by **three fiber properties**:

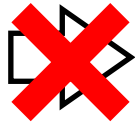
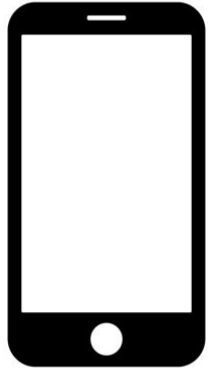


Microfibers in the filter

- Fiber diameter
- Volume fraction
- Filter thickness

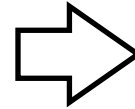
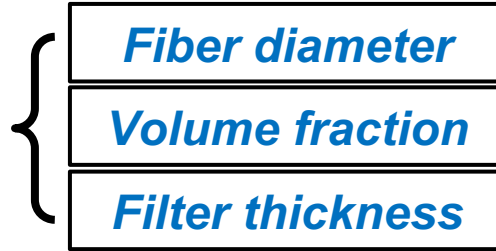
When these values increase, more particles can be **blocked**

Core Idea of *FilterOp*



Fiber Properties

Smartphones have limited hardware capabilities

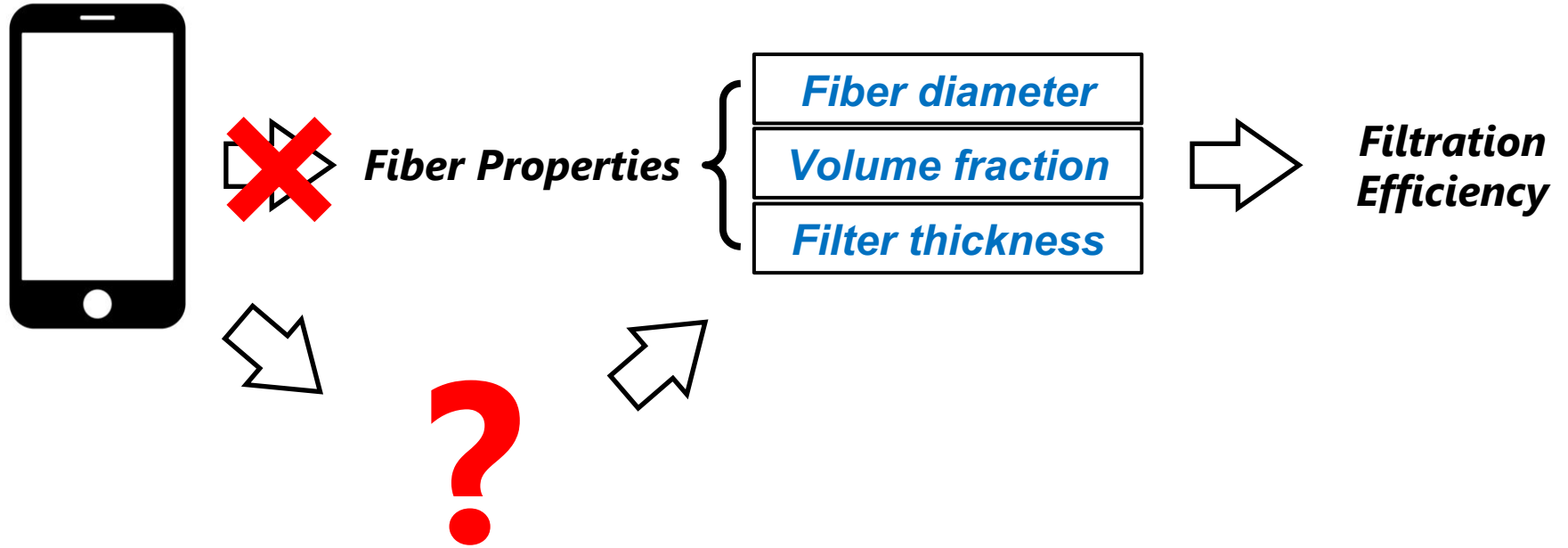


Filtration Efficiency



Scanning Electron
Microscope

Core Idea of *FilterOp*

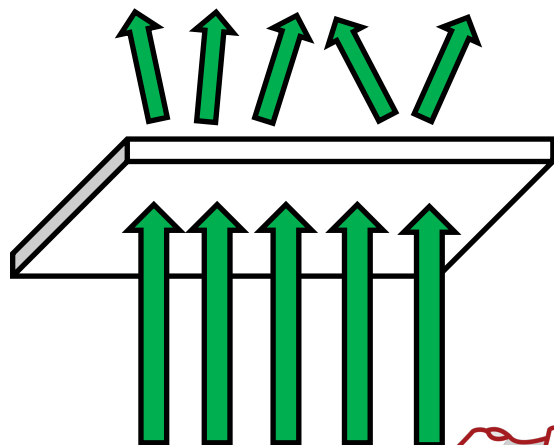


Core Idea of *FilterOp*: Optical Properties

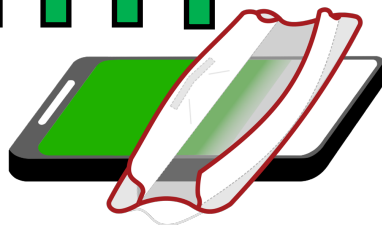
Light Pattern
Captured by Camera



Air Filter

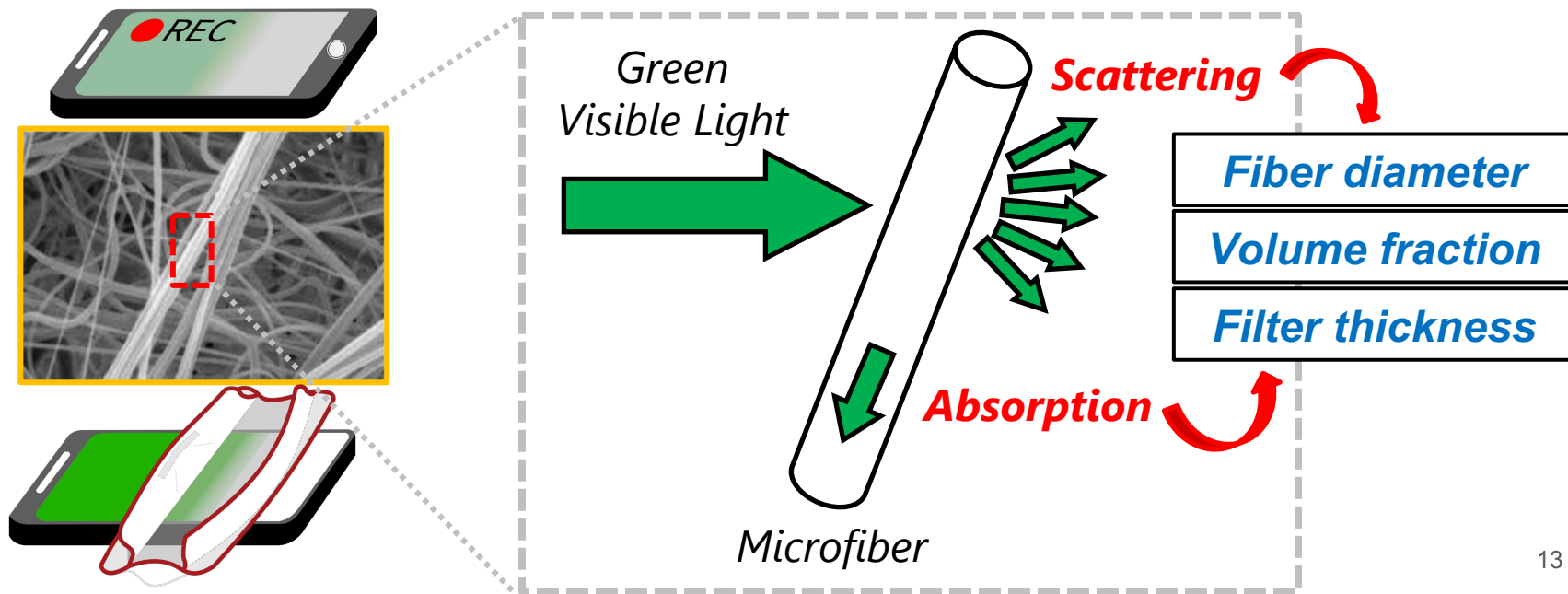


Visible Light
Emitted by Display

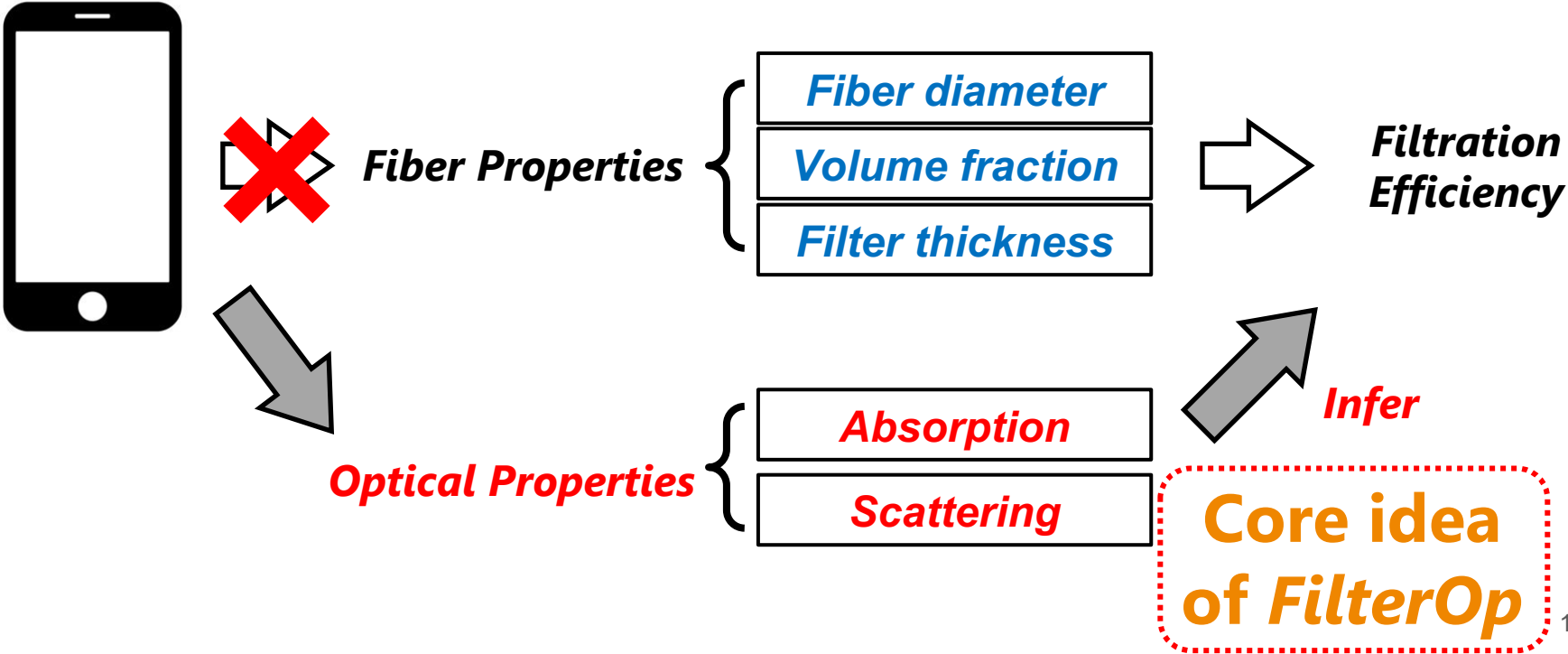


Core Idea of *FilterOp*: Optical Properties

- These **fiber properties** also affect optical properties, namely light **absorption** and **scattering** effects

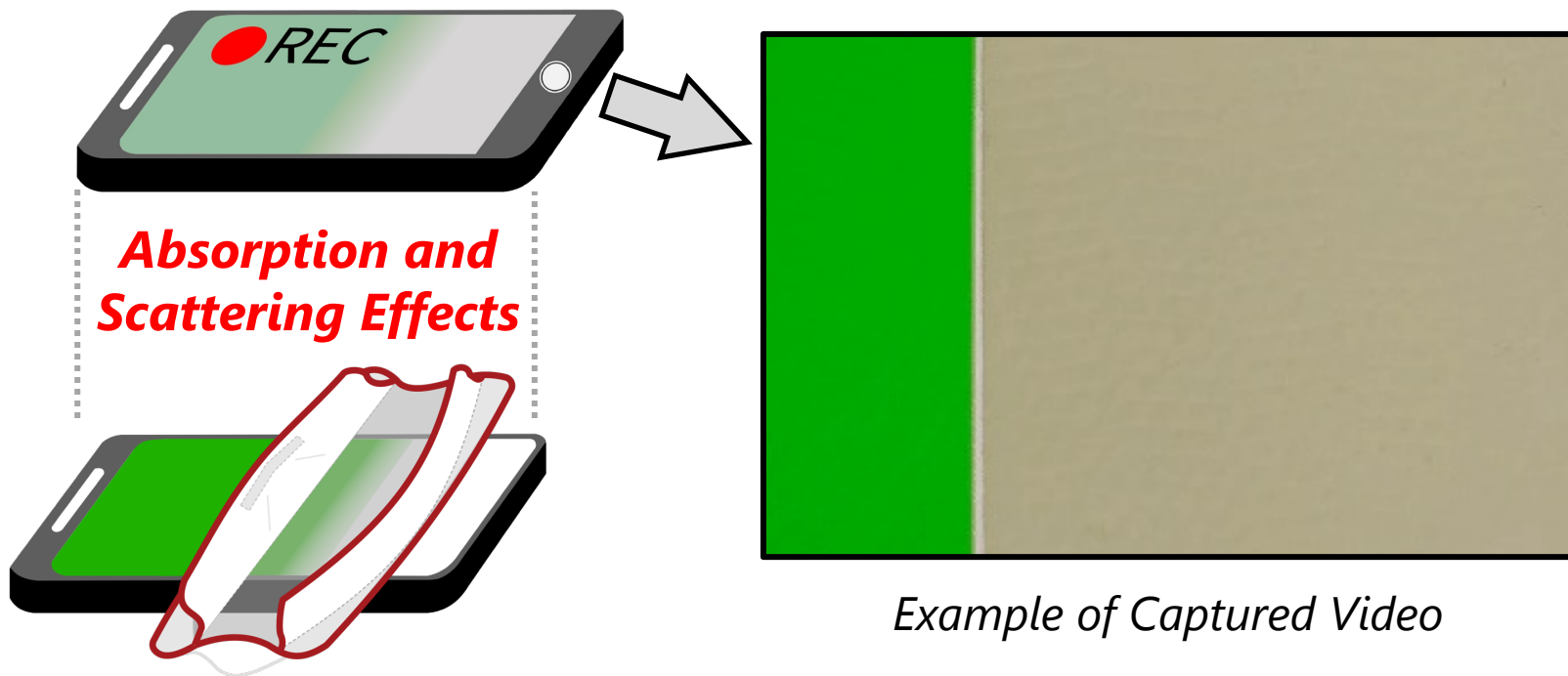


Core Idea of *FilterOp*: Optical Properties



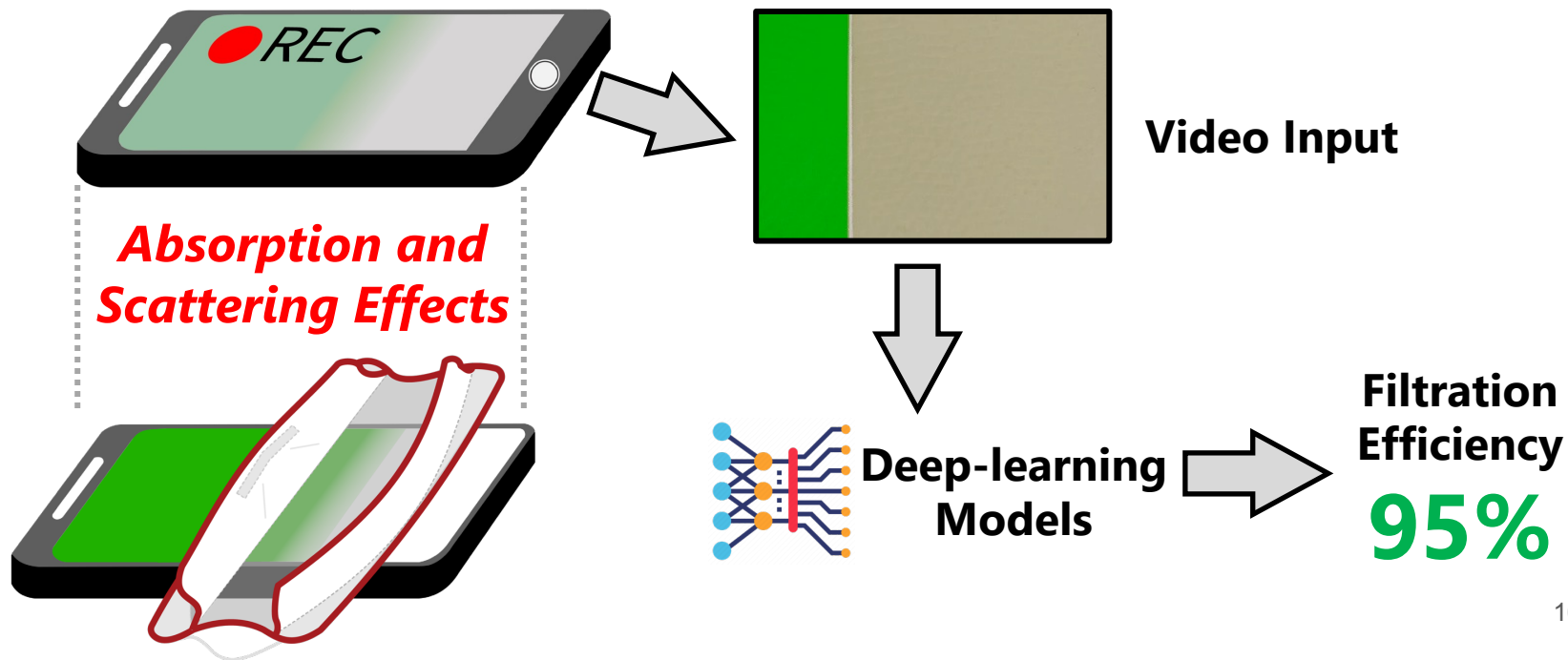
Our Work: *FilterOp*

- **Core idea** of *FilterOp* is to analyze the **optical properties** of filters when visible light propagates through the filter



Our Work: *FilterOp*

- **Core idea** of *FilterOp* is to analyze the **optical properties** of filters when visible light propagates through the filter



Challenge (1): Environmental Noise

- Noise arise from environmental and experimental conditions

① Device



② Lighting Condition

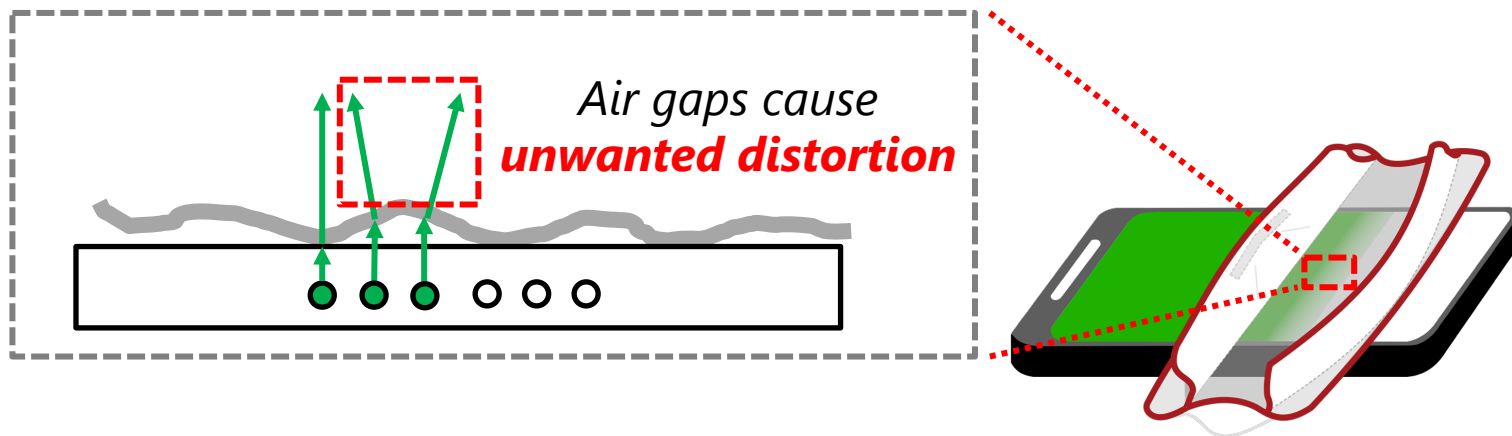


③ Screen Protector



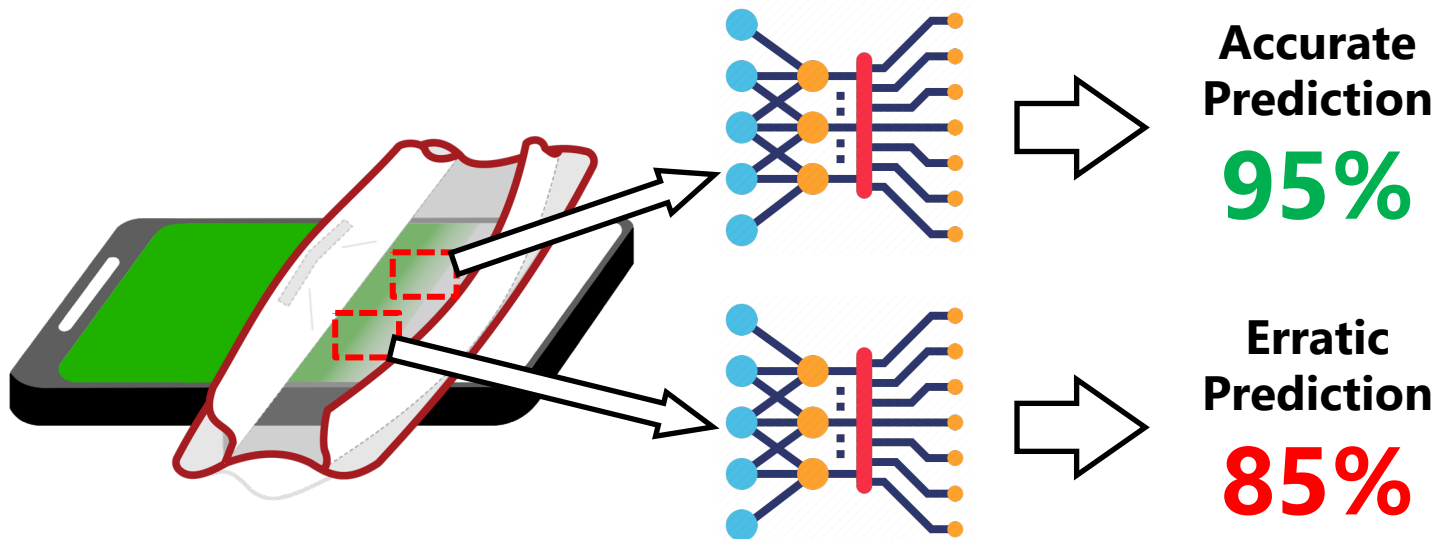
Challenge (2): Filter Noise

- Uneven mask and air filter surfaces create air gaps



Challenge (2): Filter Noise

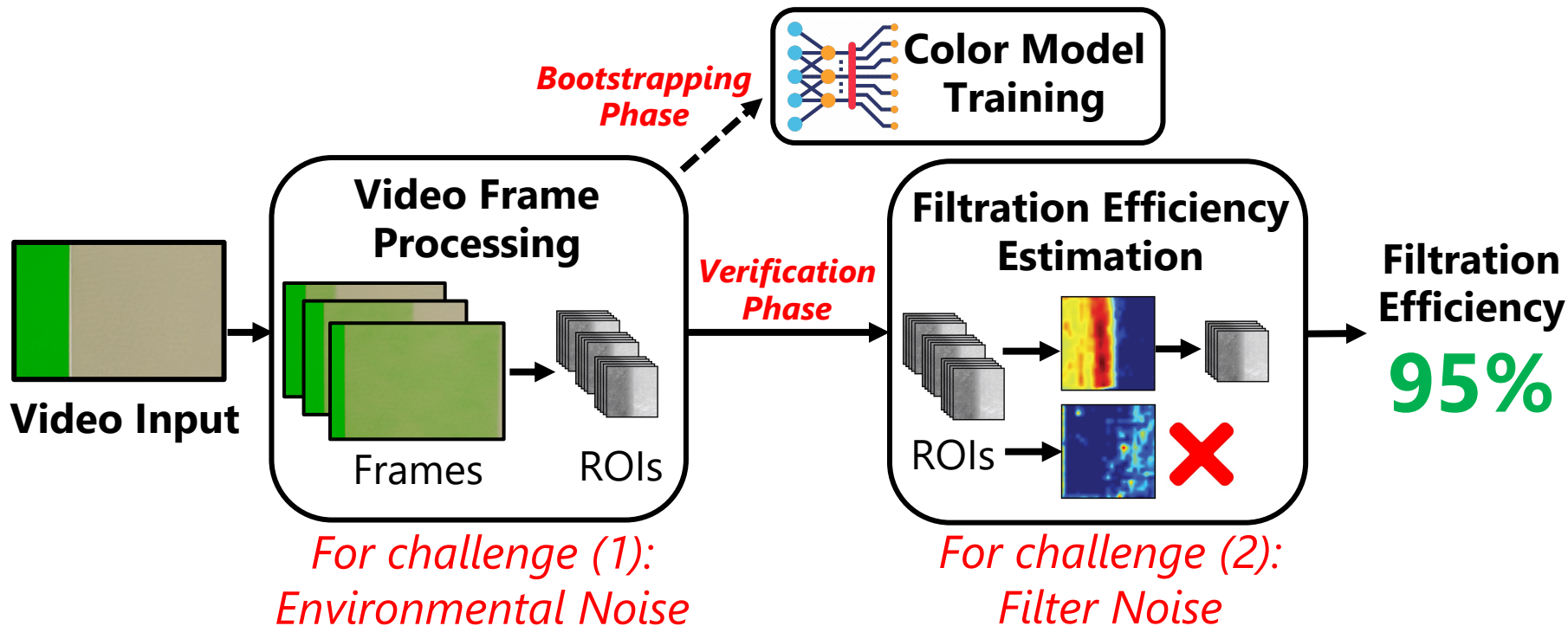
- Uneven mask and air filter surfaces create air gaps
- Convolutional Neural Network (CNN) may yield **inconsistent and unreliable** predicted filtration efficiencies



**How can we solve the combined challenges of
(1) environmental noise
and *(2) filter noise*?**

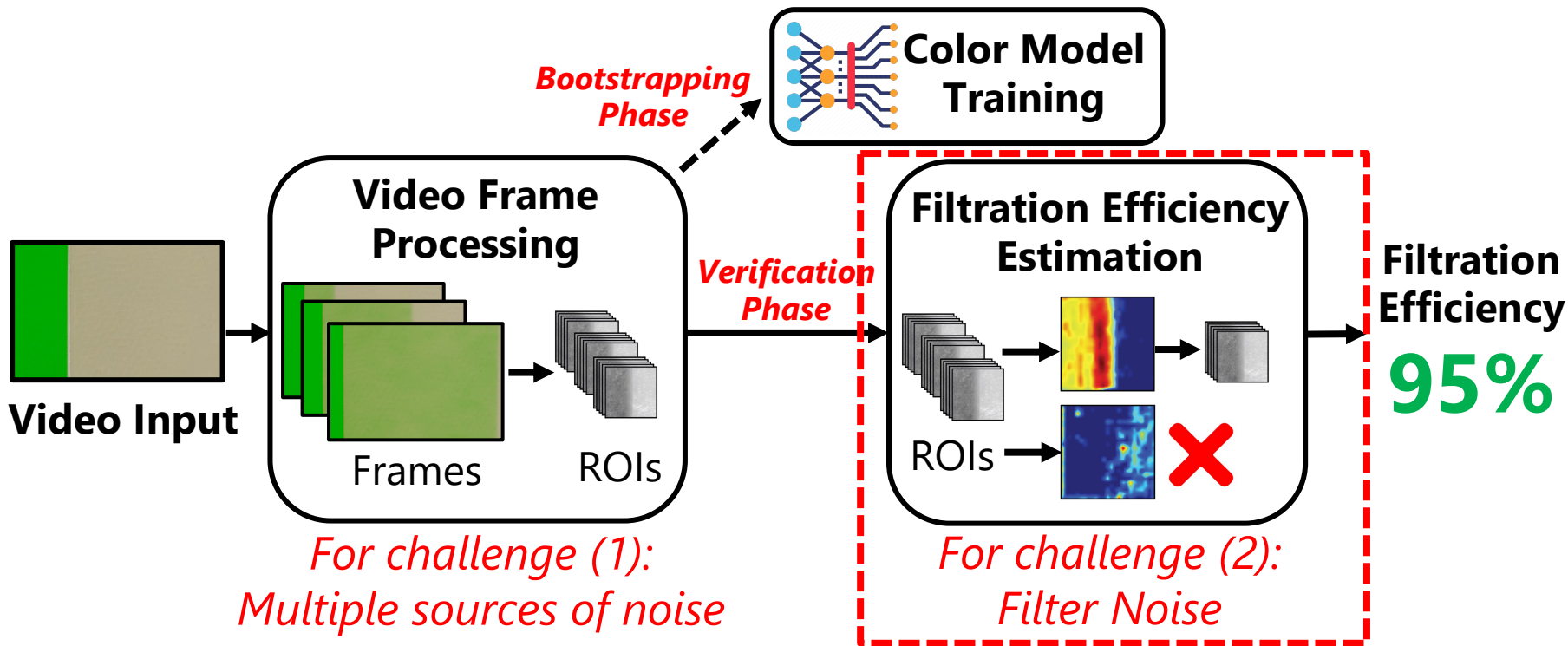
System Design of *FilterOp*

Goal: To test the filtration efficiency of masks and air filters

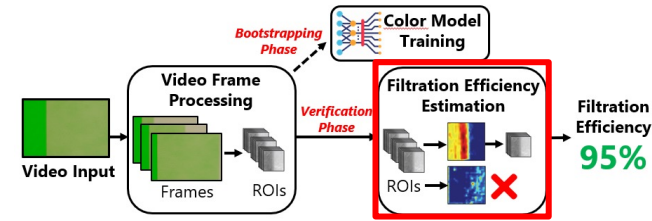


System Design of *FilterOp*

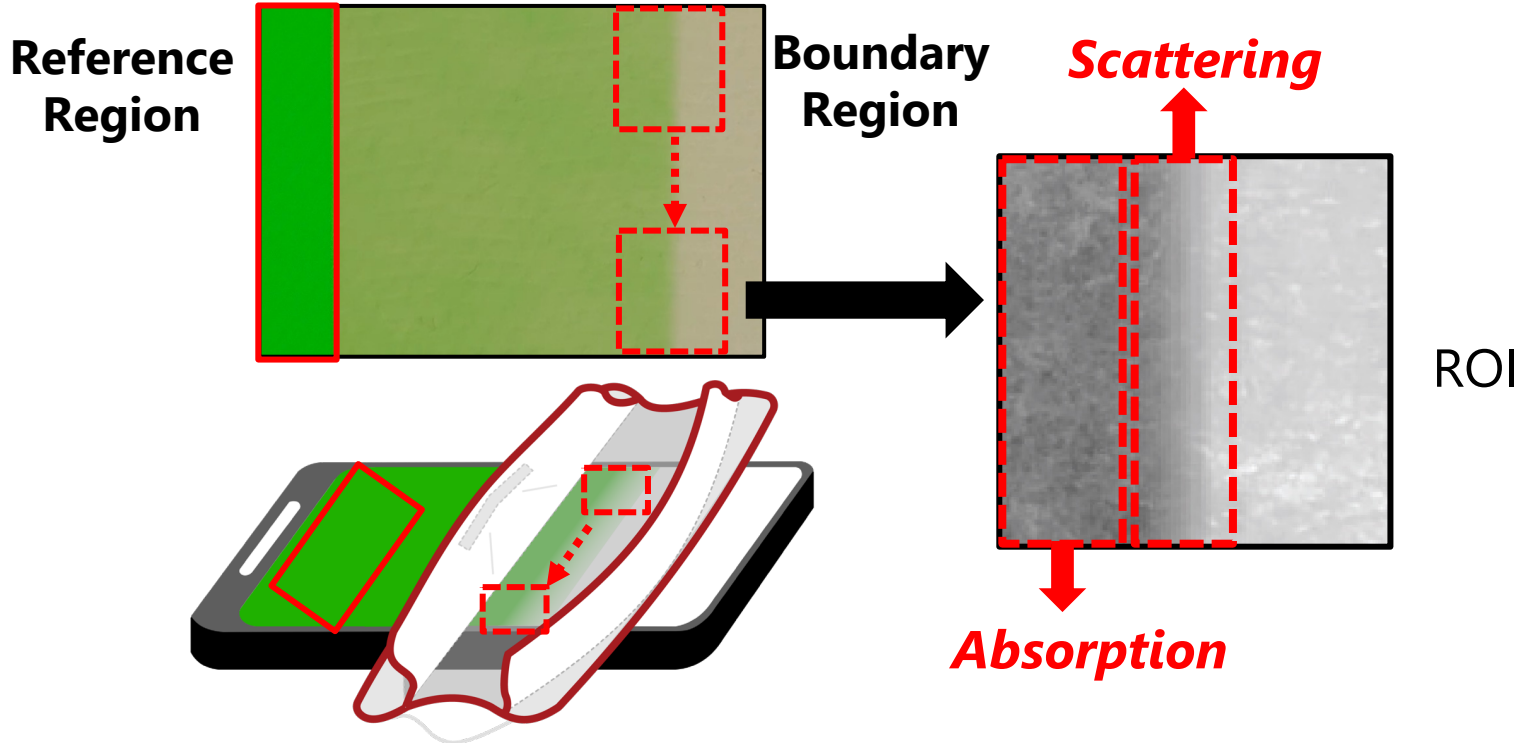
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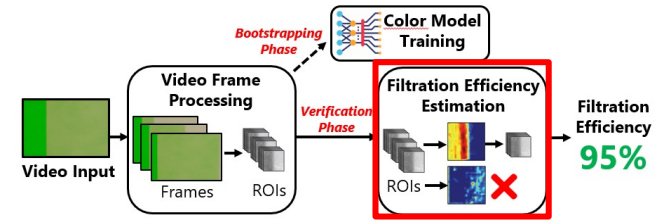
Filtration Efficiency Estimation



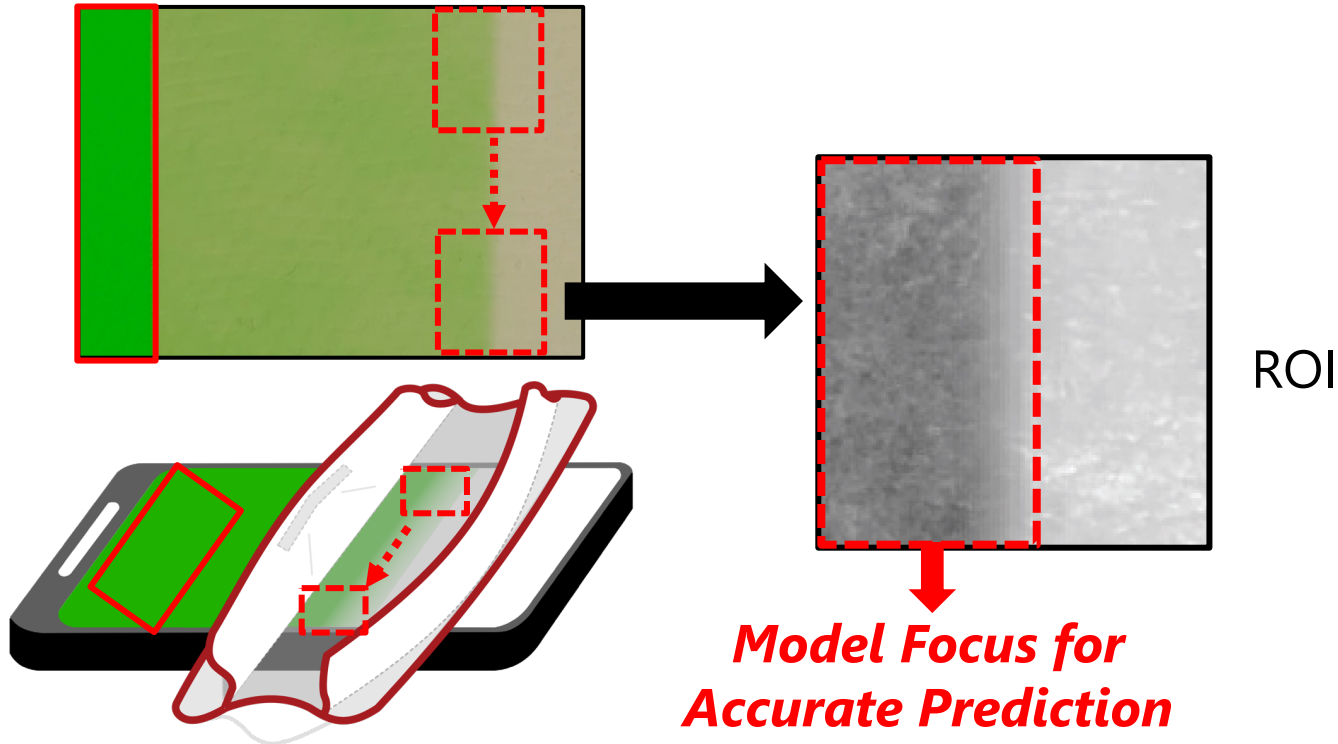
Goal: To predict filtration efficiency **accurately and reliably** from ROIs



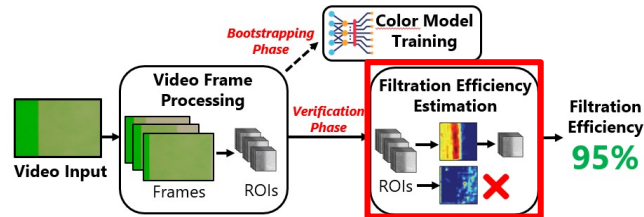
Filtration Efficiency Estimation



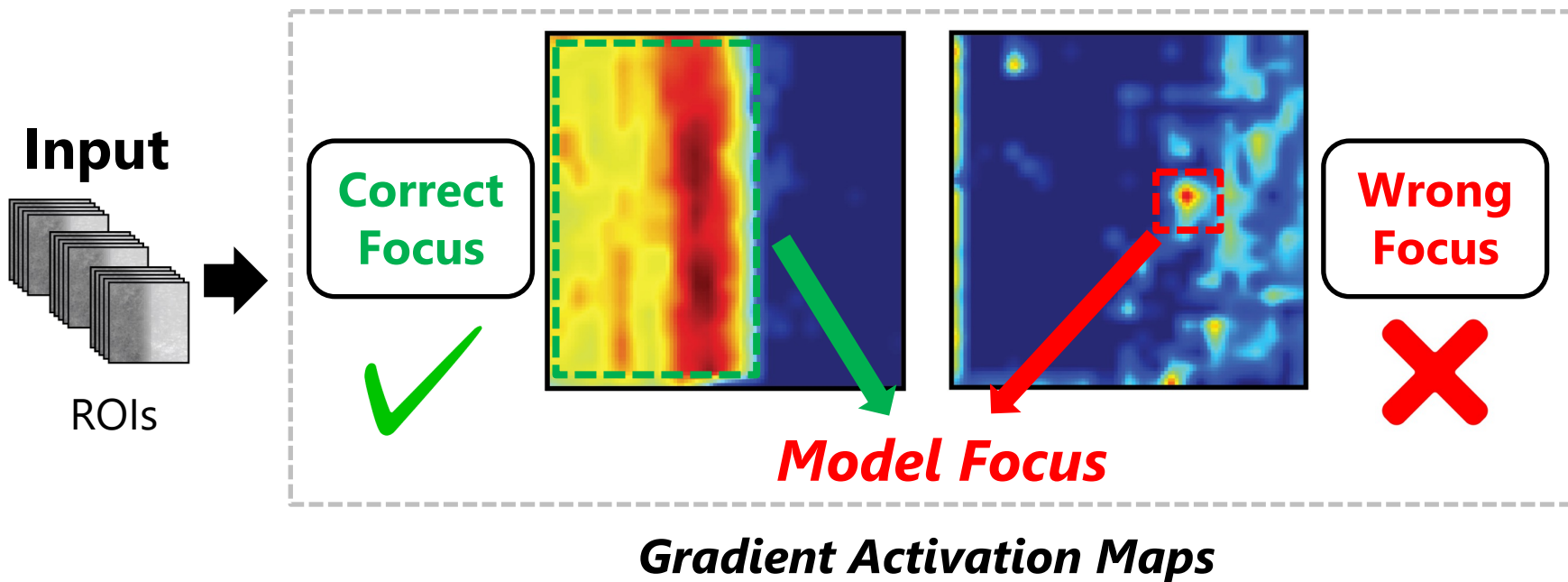
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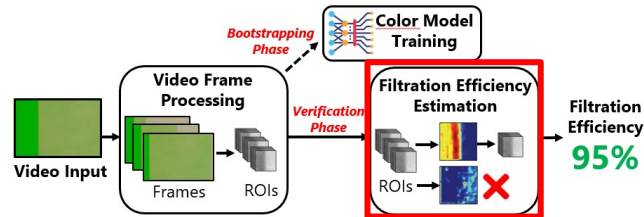
Filtration Efficiency Estimation



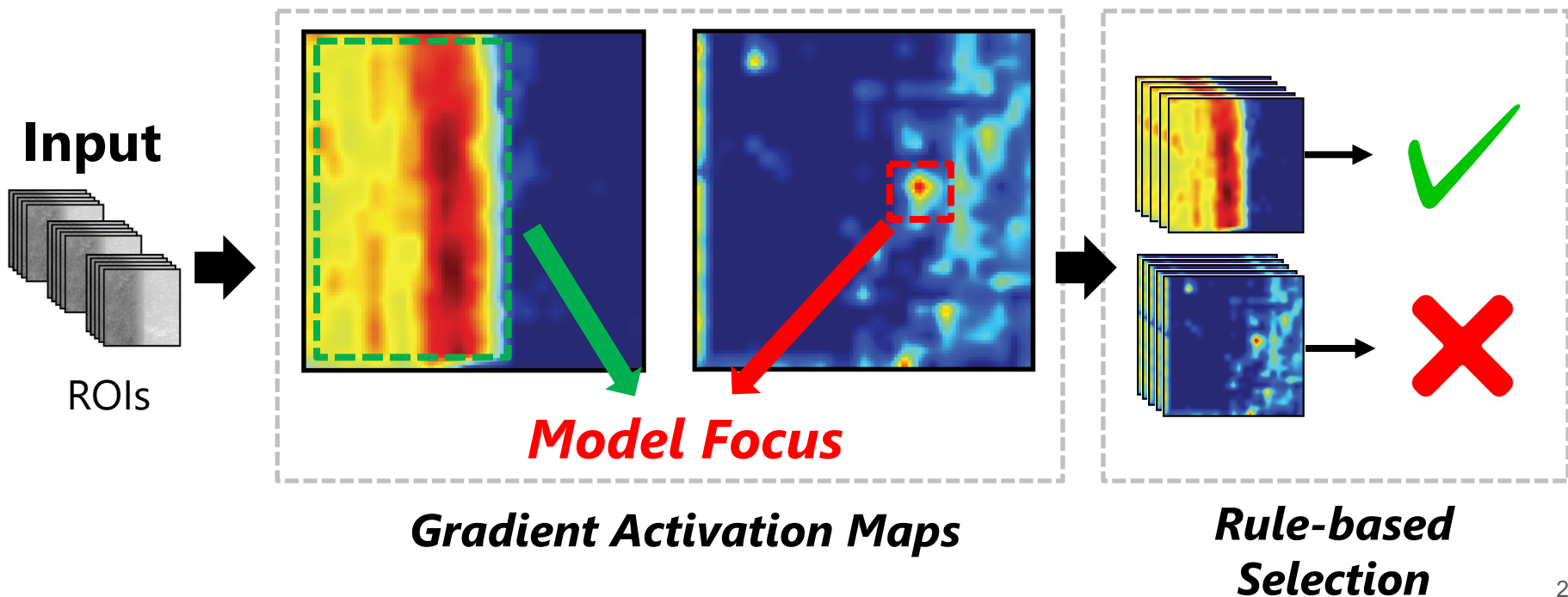
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Filtration Efficiency Estimation



Goal: To predict filtration efficiency **accurately and reliably** from ROIs



Evaluation Setup

- We test *FilterOp* with **27 different brands** of masks and filters



ToyoSafety
(P95)

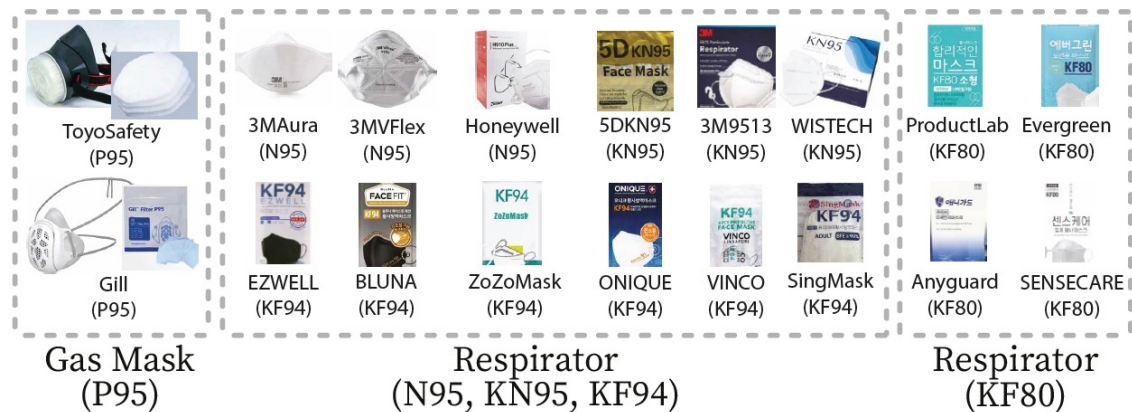


Gill
(P95)

Gas Mask
(P95)

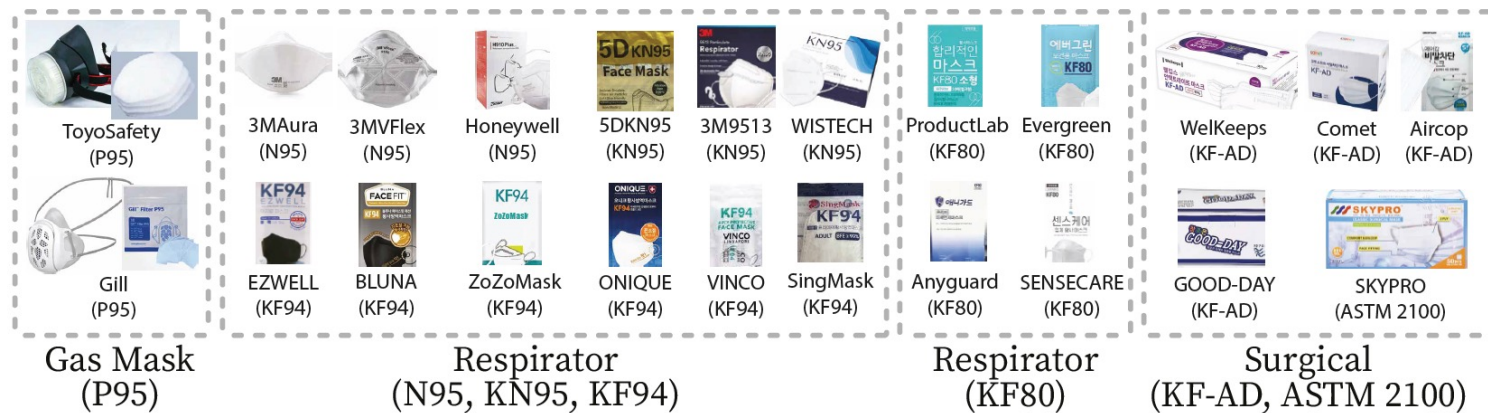
Evaluation Setup

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Evaluation Setup

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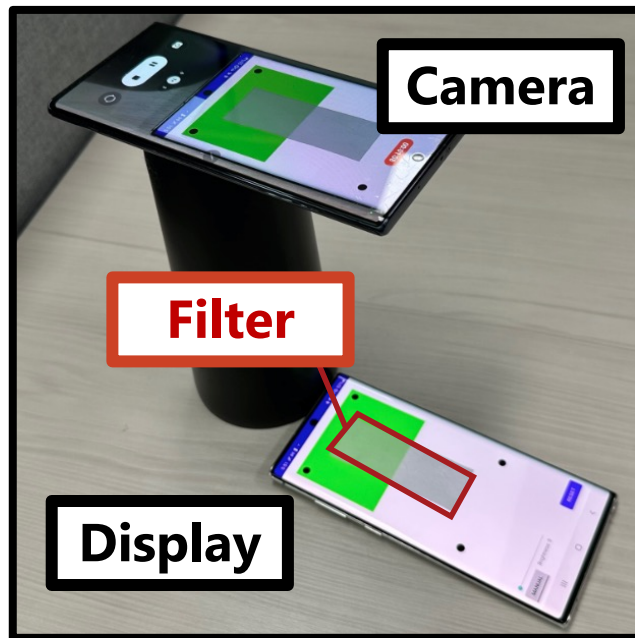
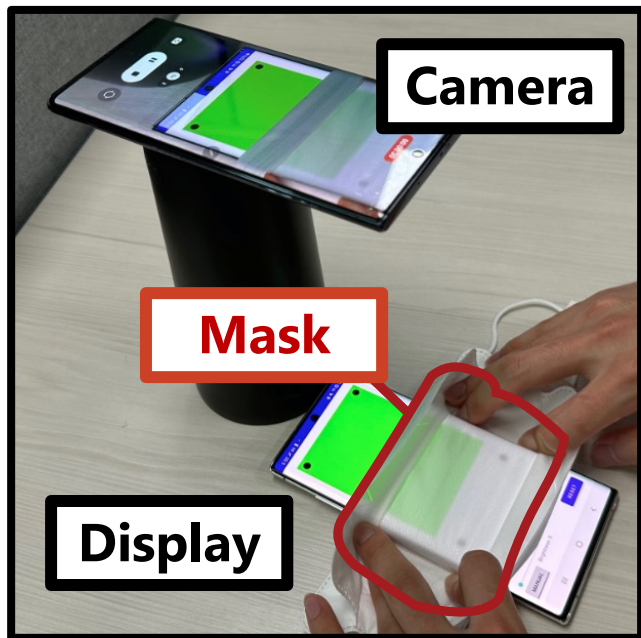
Evaluation Setup

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Evaluation Setup

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 - 148 instances for *FilterOp* testing



Evaluation Setup

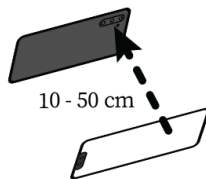
- We test *FilterOp* with **27 different brands** of masks and filters
 - 148 instances for *FilterOp* testing
 - **Ground truth** testing by a **certified organization**
 - All tests follow KF94 standard



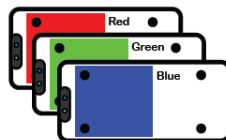
Summary of Evaluation Results

- Demonstrates **overall Mean Average Error of 2.7%** and **detection accuracy of 96.7%**

- Robust against **camera-to-display distances**

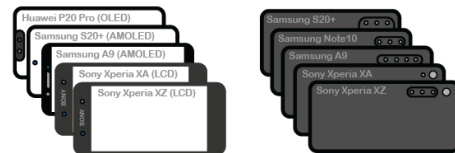


- Robust against **displayed colors**

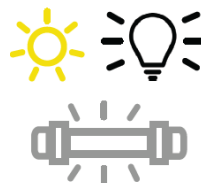


+ combinations

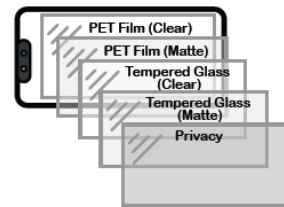
- Generalizes across **camera and display devices**



- Generalizes across **lighting conditions**

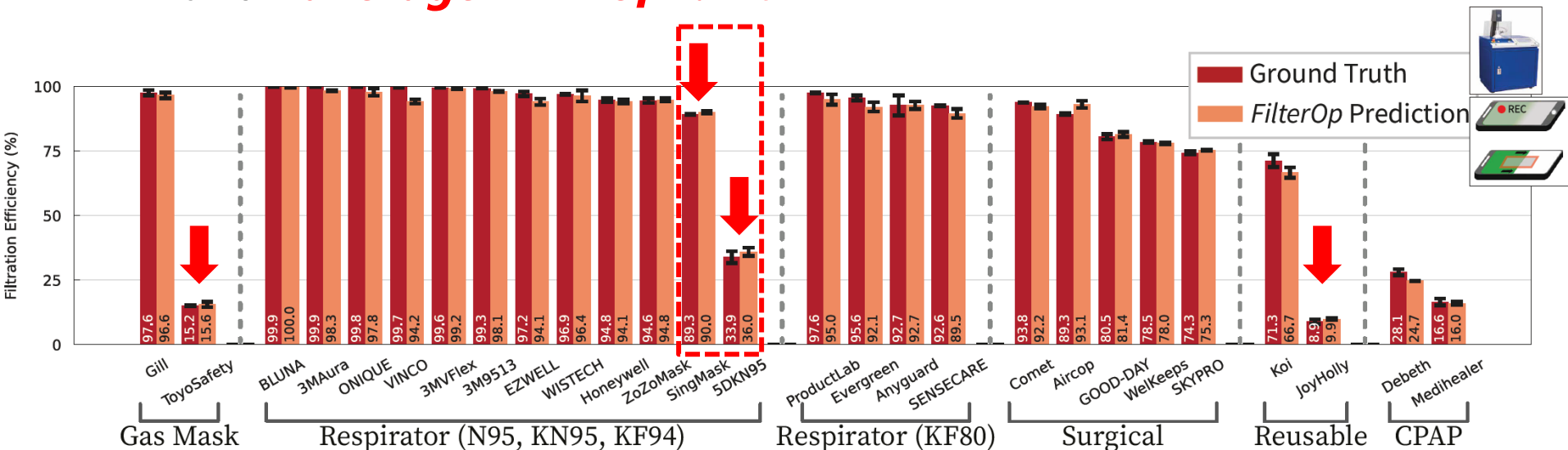


- Generalizes across **screen protectors**



Main Result

- FilterOp** achieves **comparable** filtration efficiency prediction with an **average MAE of 2.7%**



Discussion

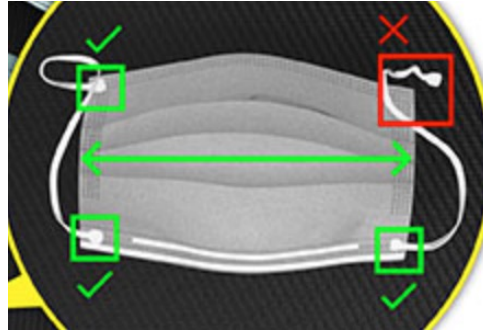
Authorities could train *FilterOp* with data collected in the certification process



Deployment

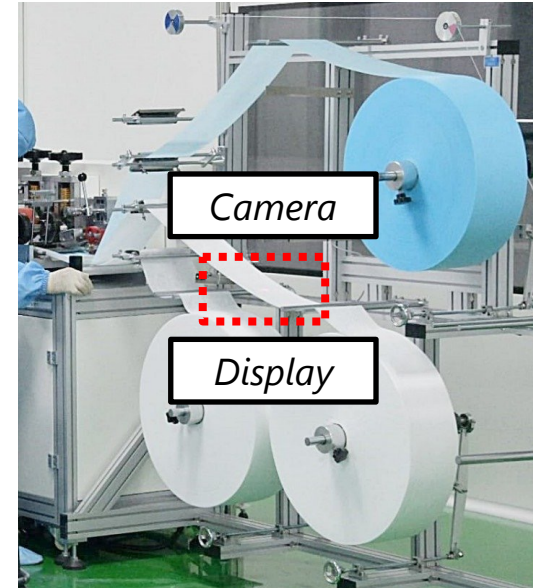
Not designed to detect **manufacturing defects**

In complement to existing **fit testing** and **defect detection**



Limitations

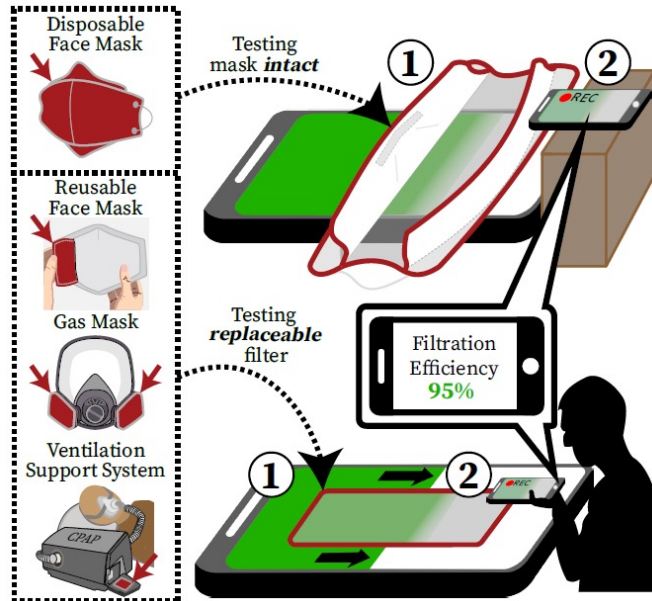
Quality inspection in mask and filter manufacturing



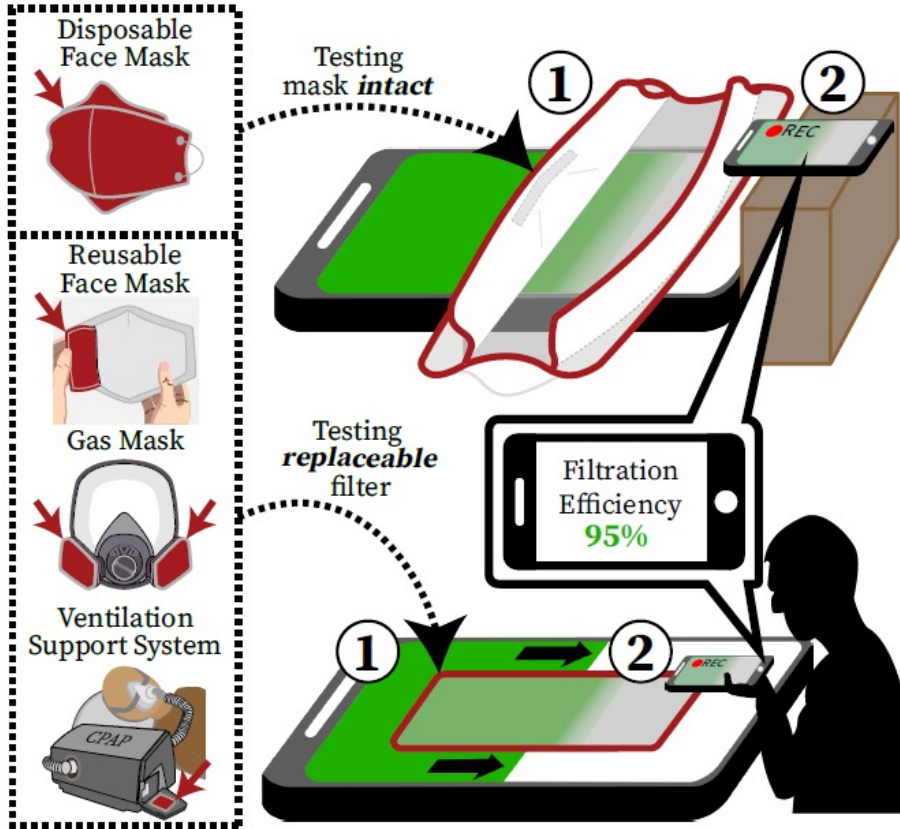
Extensions

Conclusion

- **FilterOp** uses smartphone **cameras** to test filtration efficiency
- Spur **novel ways** to **augment** computer vision on mobile platforms



Thank you!



Bangjie Sun

Graduate Tutor and PhD candidate at the National University of Singapore

I am a passionate researcher in **computer vision**, and **sensing**. I am currently pursuing my Ph.D. in National University of Singapore (NUS). My supervisors are [Prof. Jun Han](#) in Yonsei University and [Prof. Chan Mun Choon](#) in National University of Singapore. My research interests are in the intersection of computer vision and sensing systems.

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