Deblurring X-ray Transmission Images Using Convolutional Neural Networks to Achieve Fast CT Scanning

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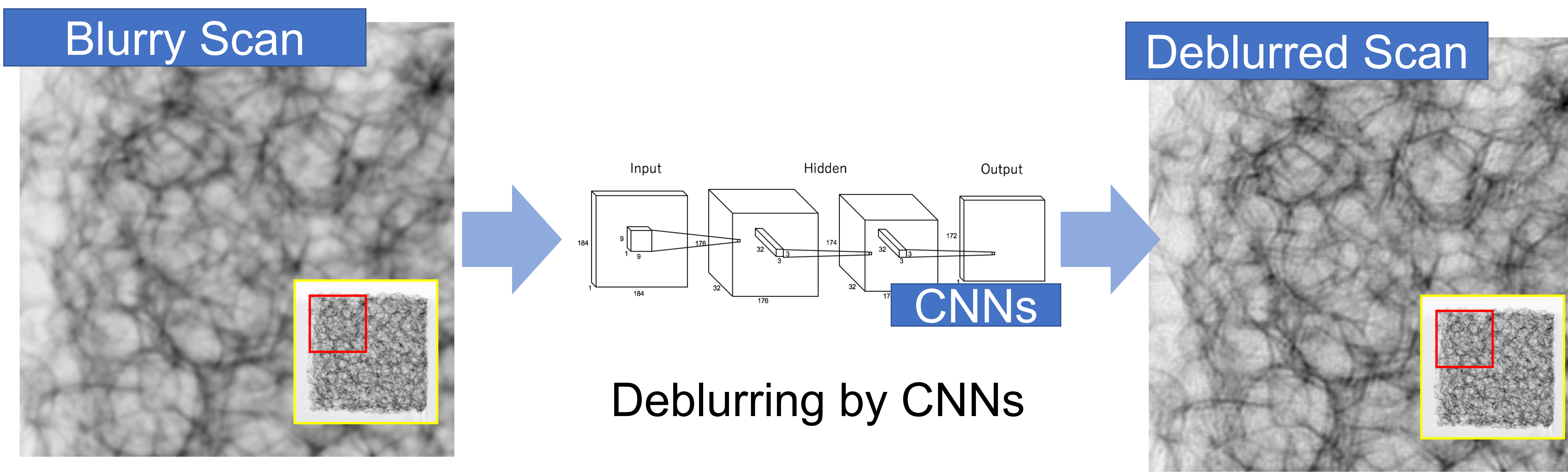

Agenda

1. Introduction
   A) Research Issue
   B) Key ideas of the proposed method
2. Method
   A) How to avoid the problem of the kernels’ difference
3. Experimental Results
   A) Deblurring results of E-cigarette
   B) Deblurring results of a stepped cylinder
4. Conclusion & Future Work

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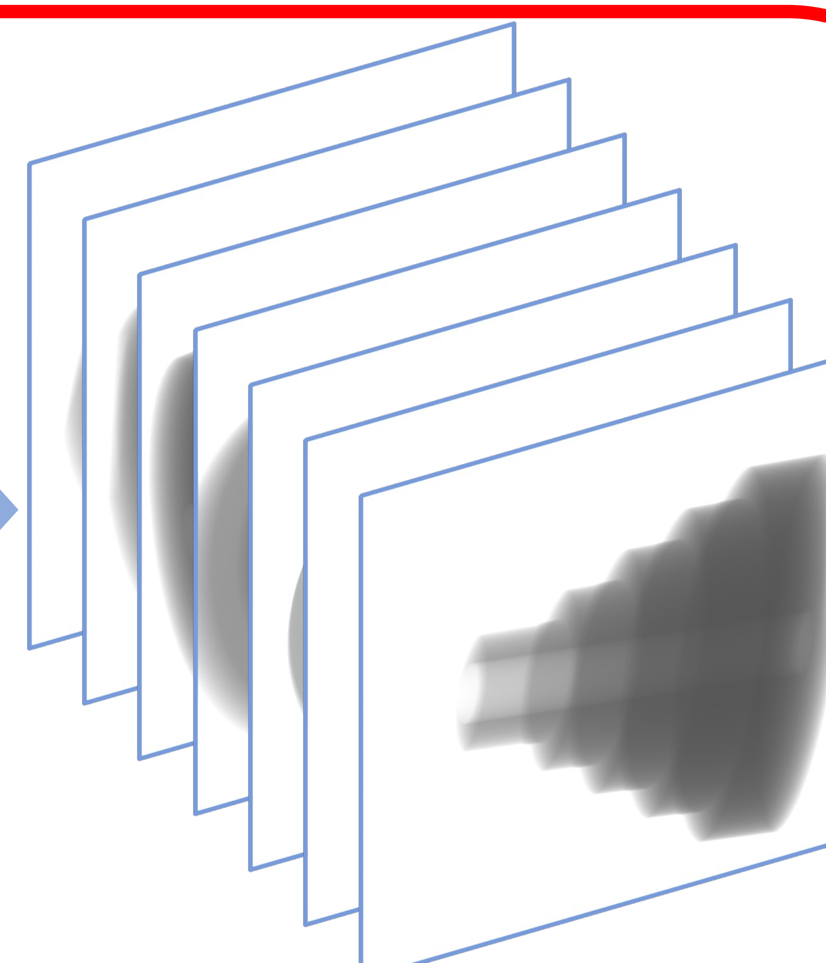
Issue

Research Issue

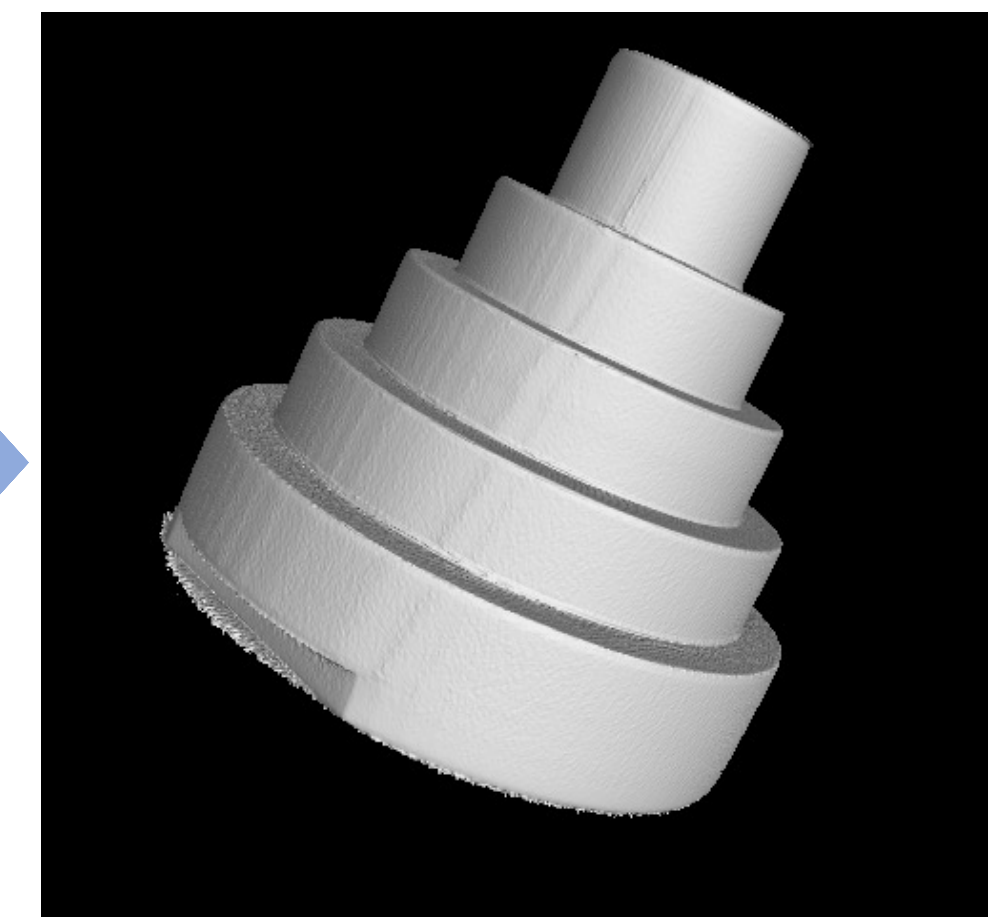
- Producing high-precision measurements takes a long time.
  - Thousands of sharp transmission images are required.

X-ray CT scanner

METROTOM1500 (from Carl ZEISS)



Thousands of Transmission Images



Reconstructed 3D Model

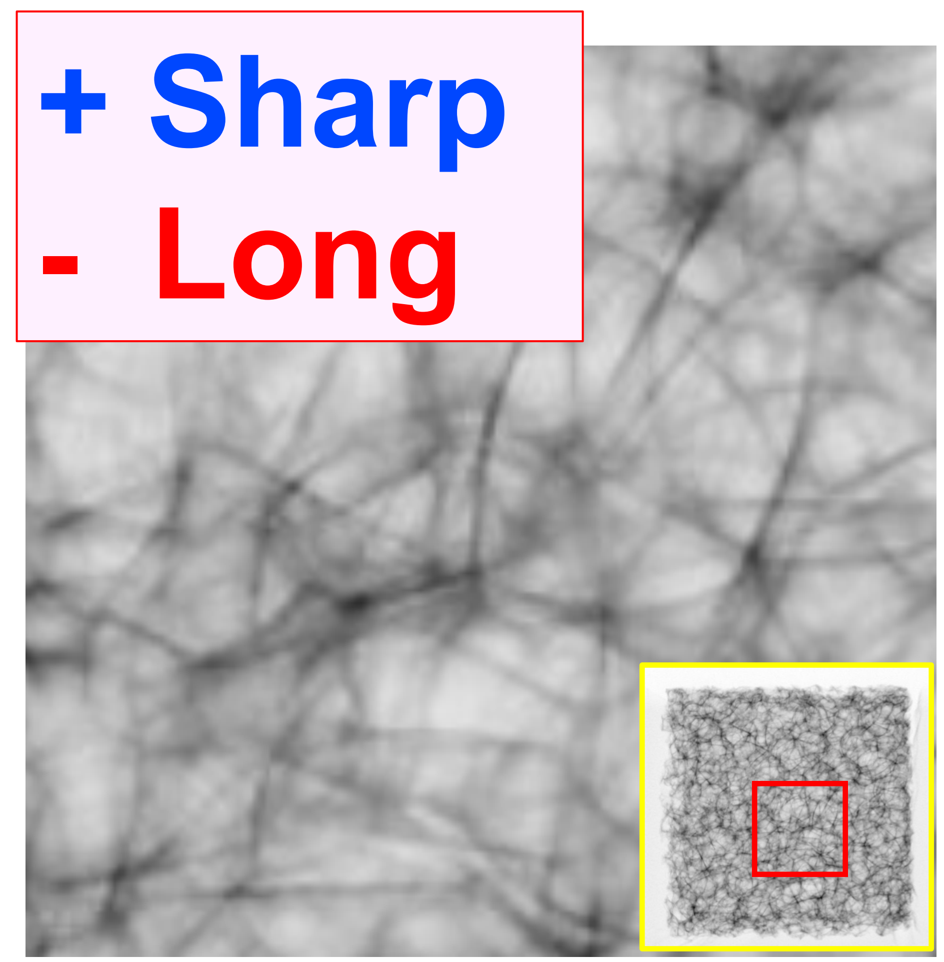
High-precision measurement needs several hours.

Property of X-ray Imaging

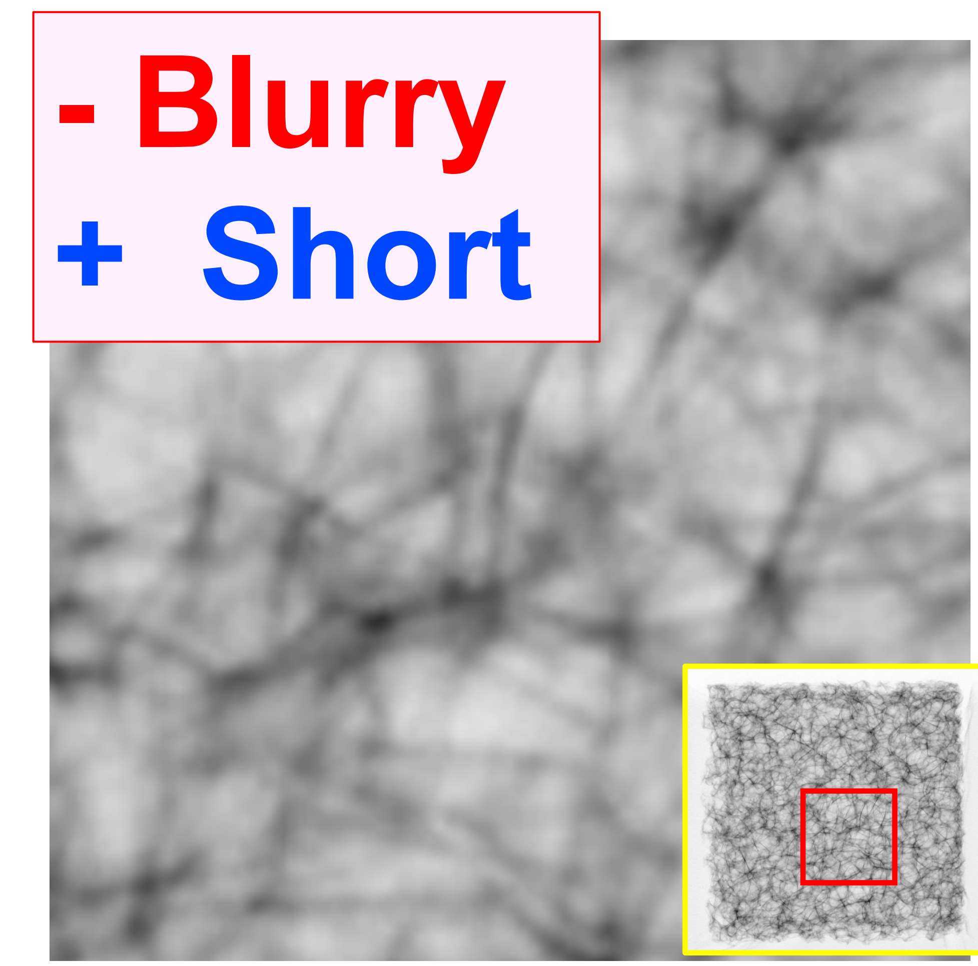
Property

- Use intensive X-rays and shorten the exposure time.
- However, the precision of measured objects is degraded because transmission images become blurry.

Porous Aluminum B



Sharp Transmission Image
Exposure Time: 4.000 (sec)
Voltage: 180kV
Current: 150μA

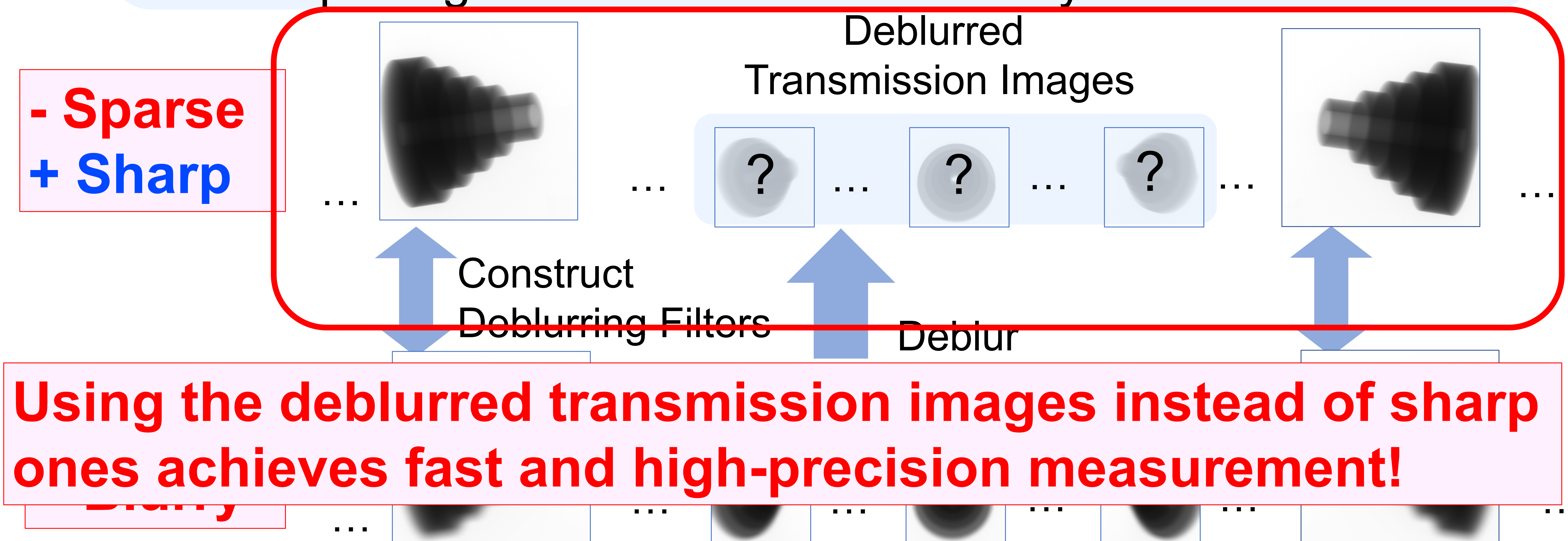


Blurry Transmission Image
Exposure Time: 1.000 (sec)
Voltage: 180kV
Current: 600μA

Key Ideas of the Proposed Method

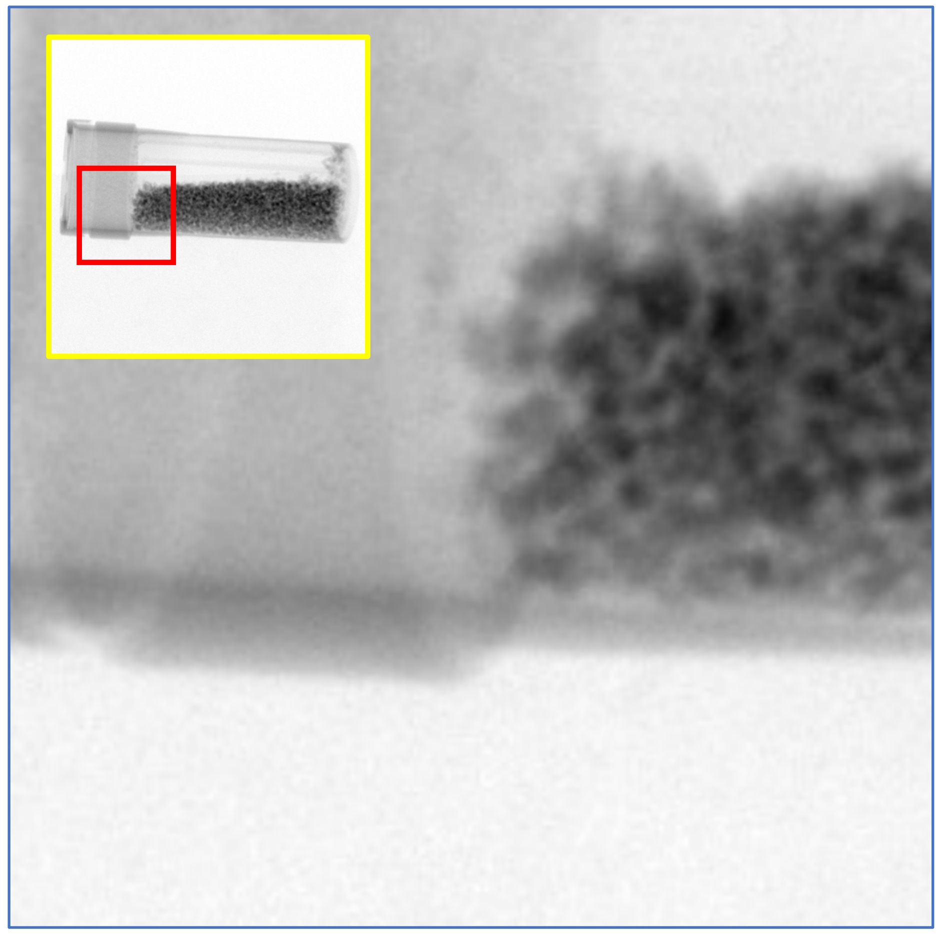
Key Ideas

1. Two image sequences are obtained.
   - Sharp images from sparse views.
   - Blurry images from dense views.
2. Construct deblurring filters.
3. Sharp images from dense views are synthesized.



Using the deblurred transmission images instead of sharp ones achieves fast and high-precision measurement!

Materials and Projection Angles



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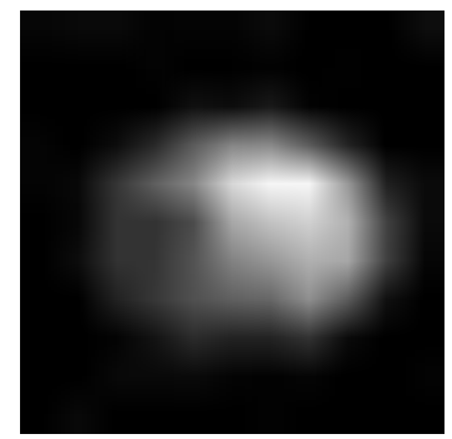
Blurring kernel
estimated by
least square method



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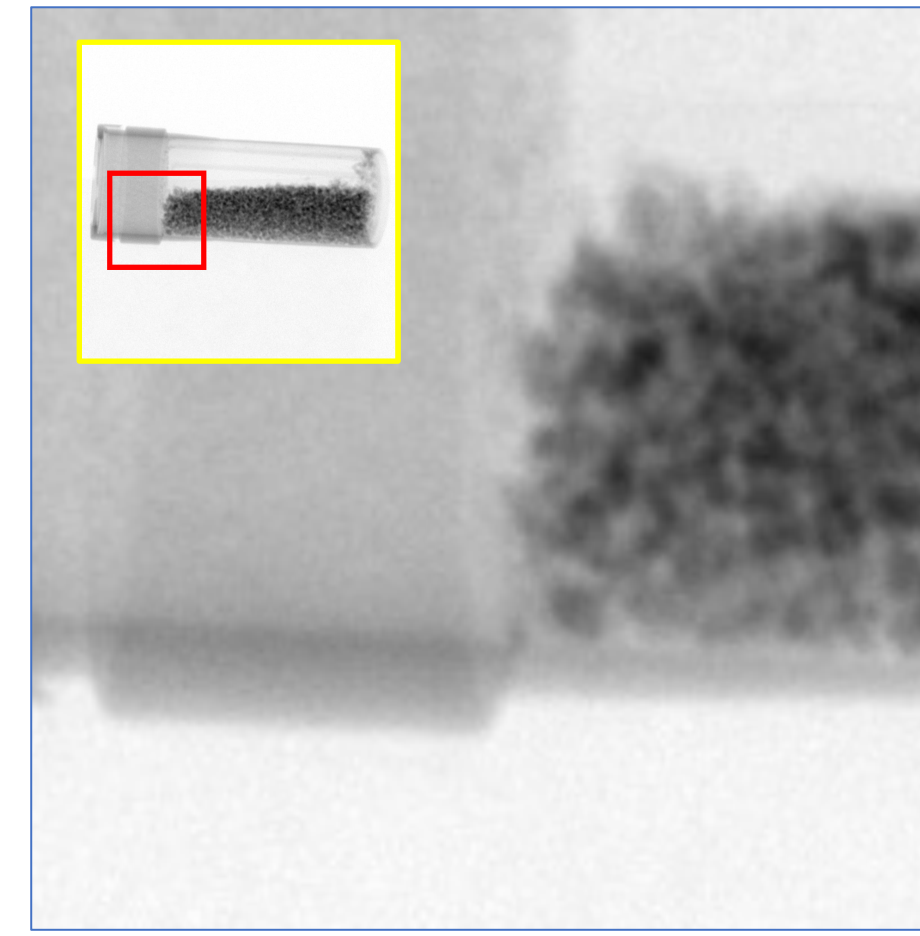
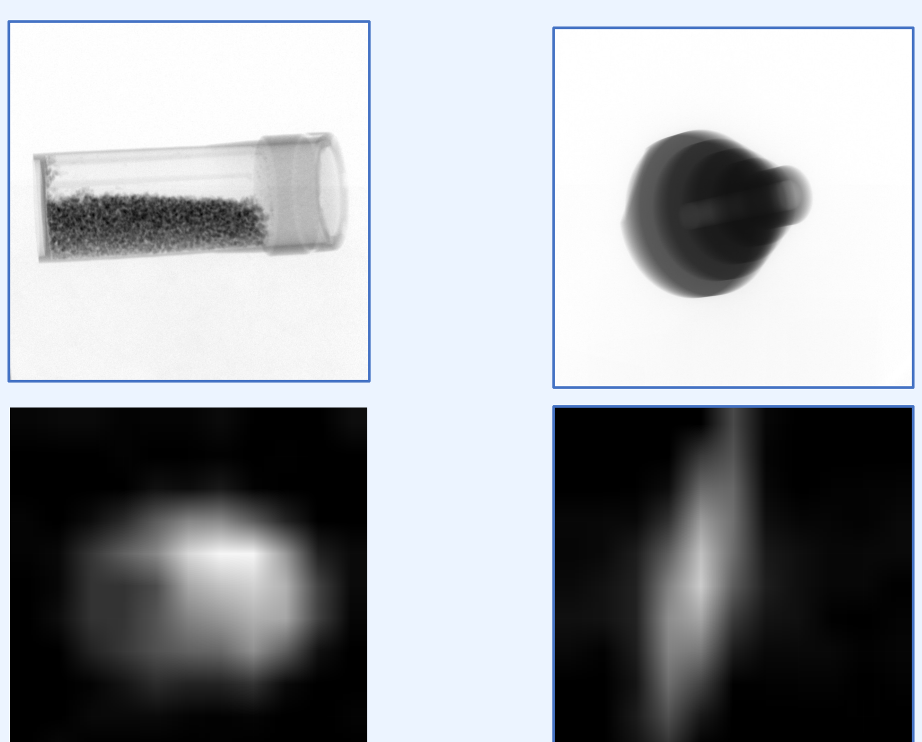
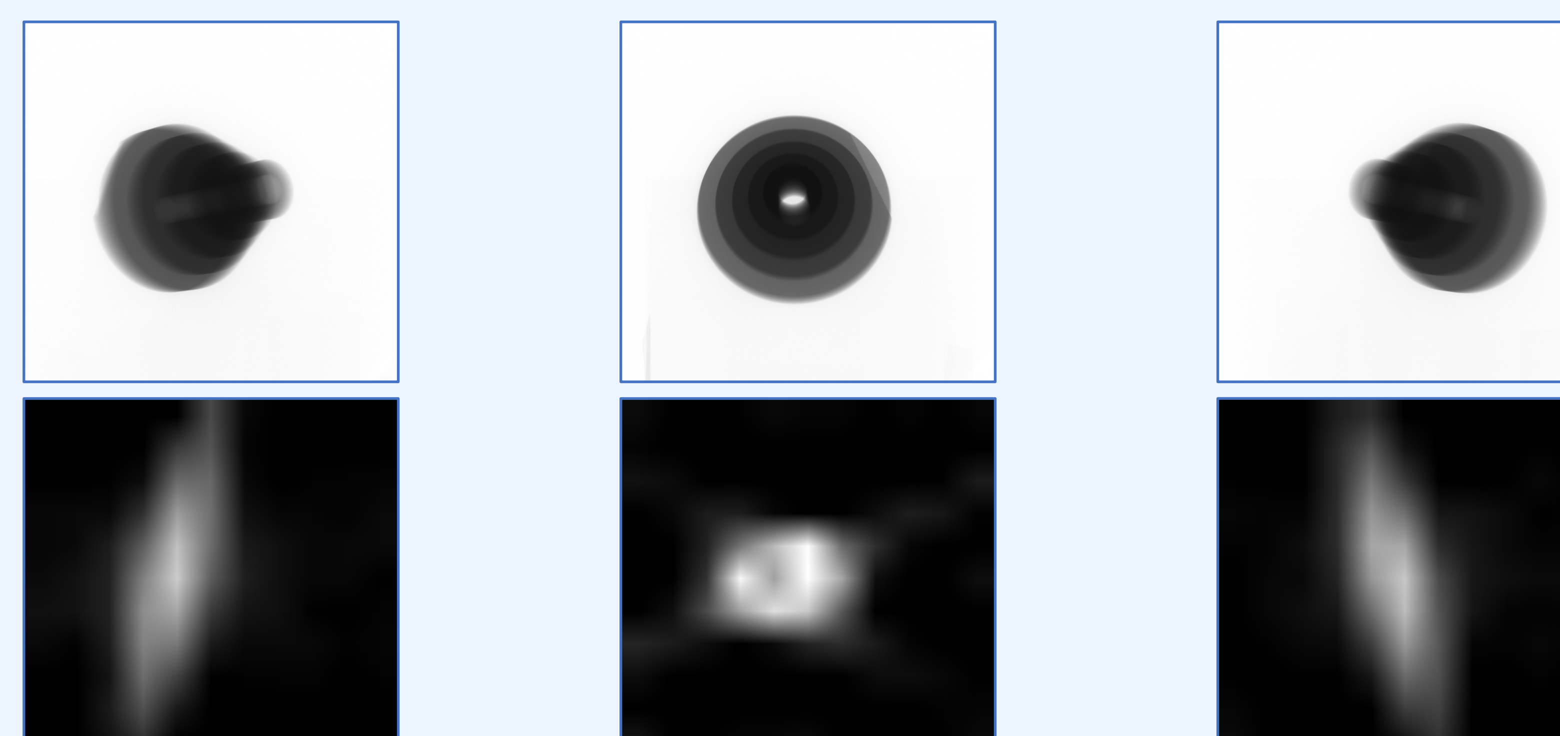


Different Materials



Different Projection Angles



Materials and Projection Angles

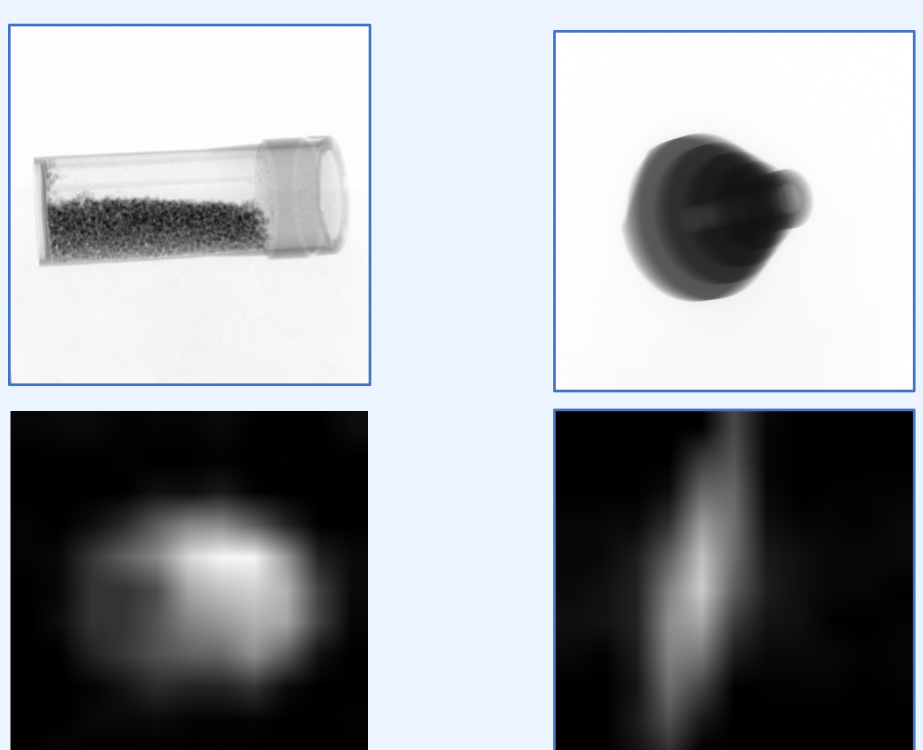
Problem

- The kernels depend on the object's
1. material
2. and their projection angles.

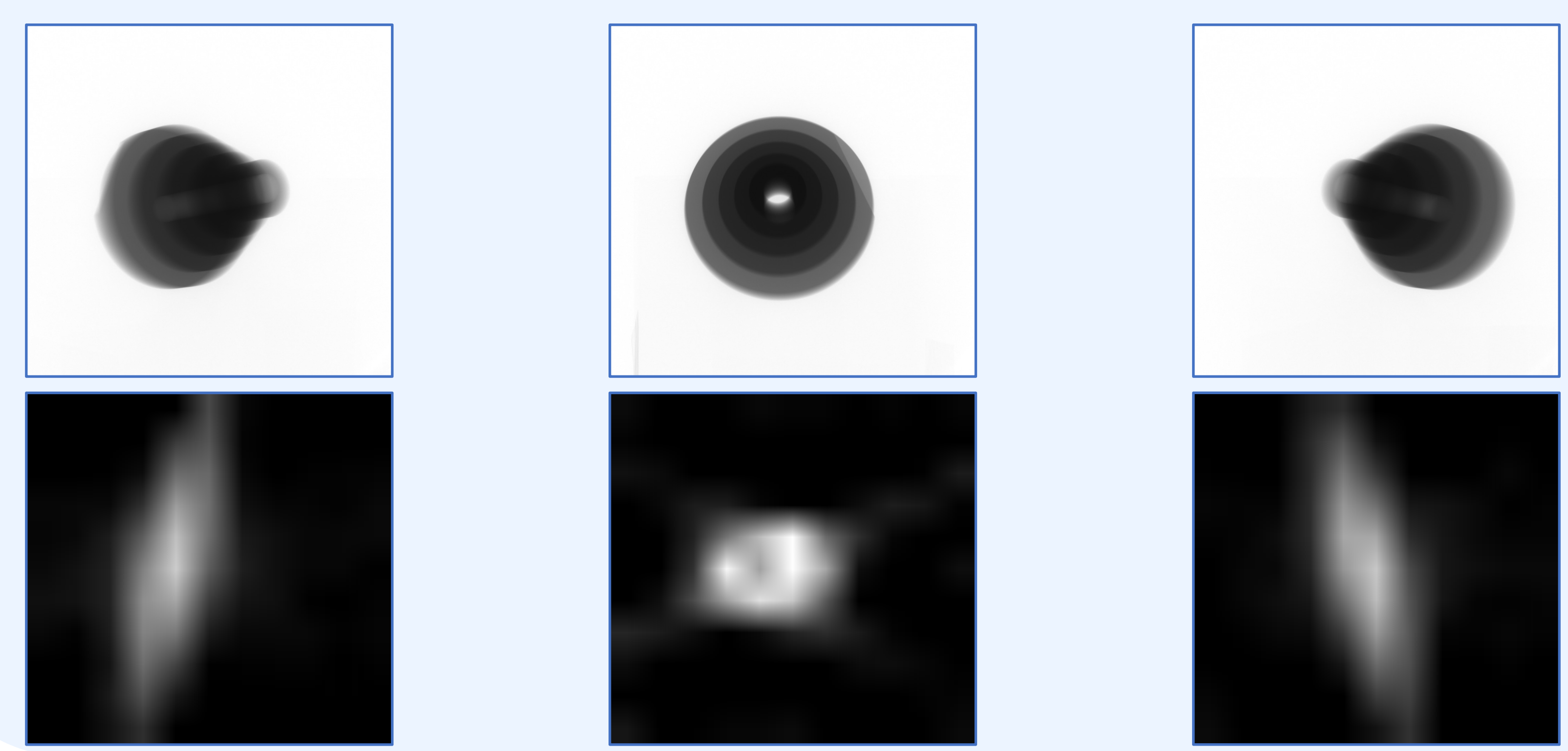
Solution

- Use Convolutional Neural Networks (CNNs) with fine-tuning and linear interpolation.

Different Materials



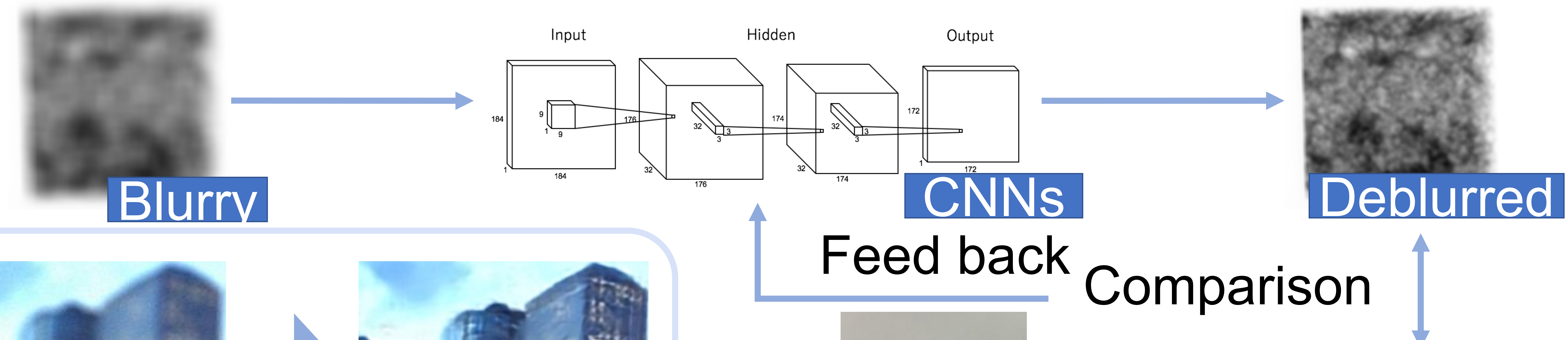
Different Projection Angles

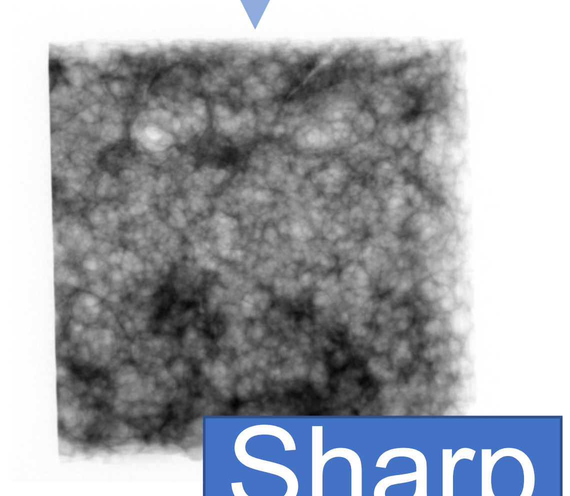


Convolutional Neural Networks (CNNs)

What are CNNs?

- Machine learning methods, whose main application is image processing (Alex et al, 2012).
- There are some studies for image deblurring (Schuler et al, 2013), (Xu et al, 2014).





Deblur by CNNs [3]

Porous Aluminum A

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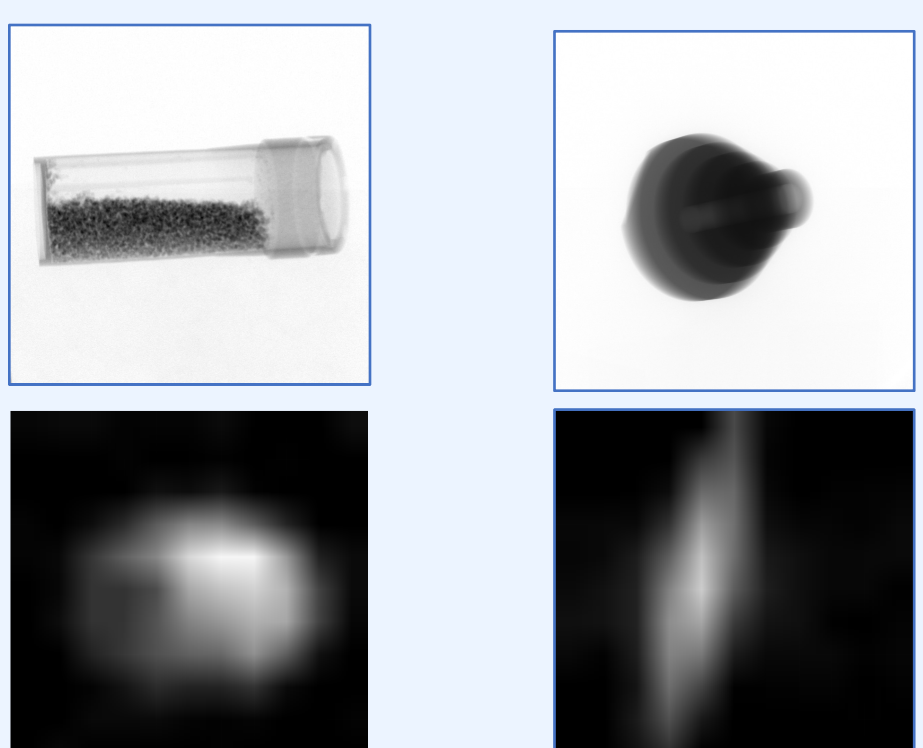
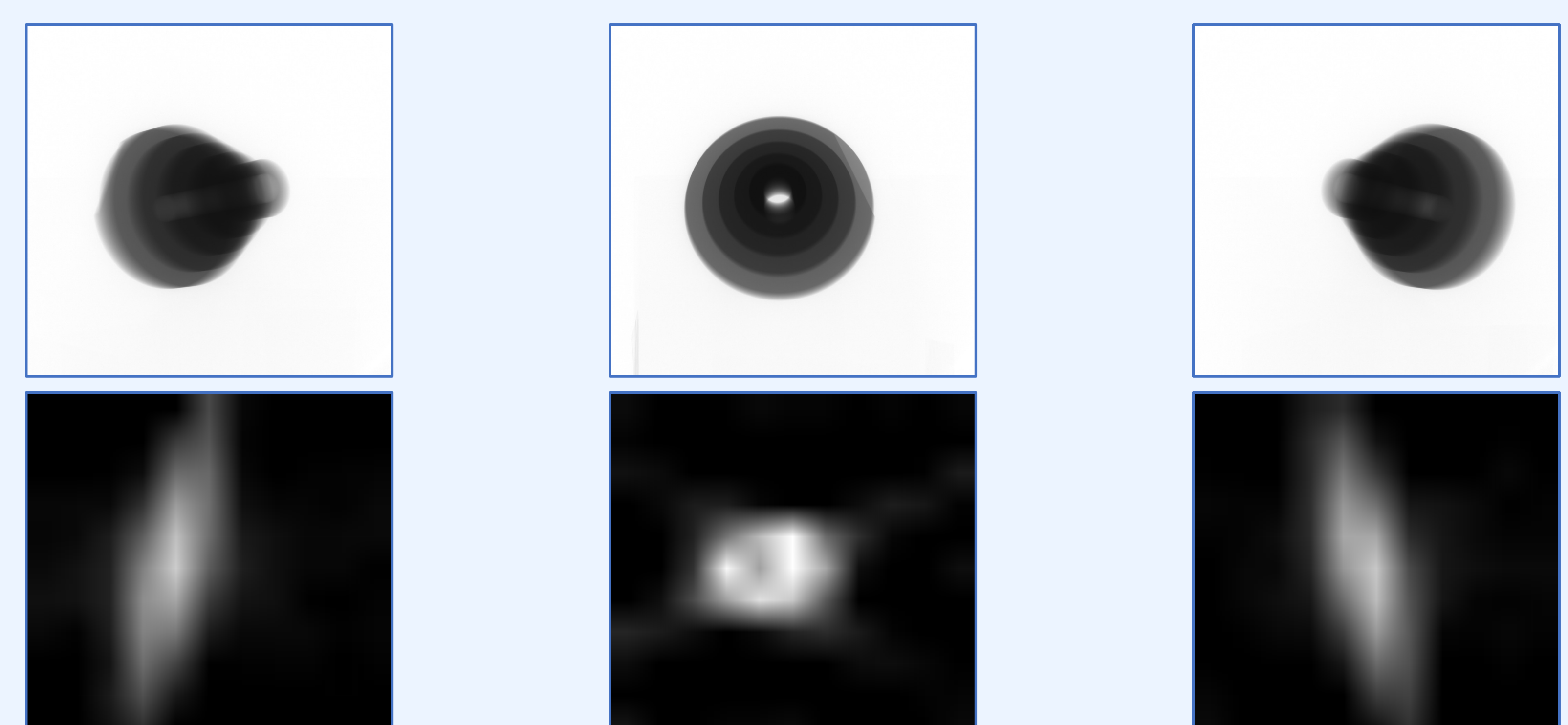
Solution

- Use Convolutional Neural Networks (CNNs) with fine-tuning and linear interpolation.

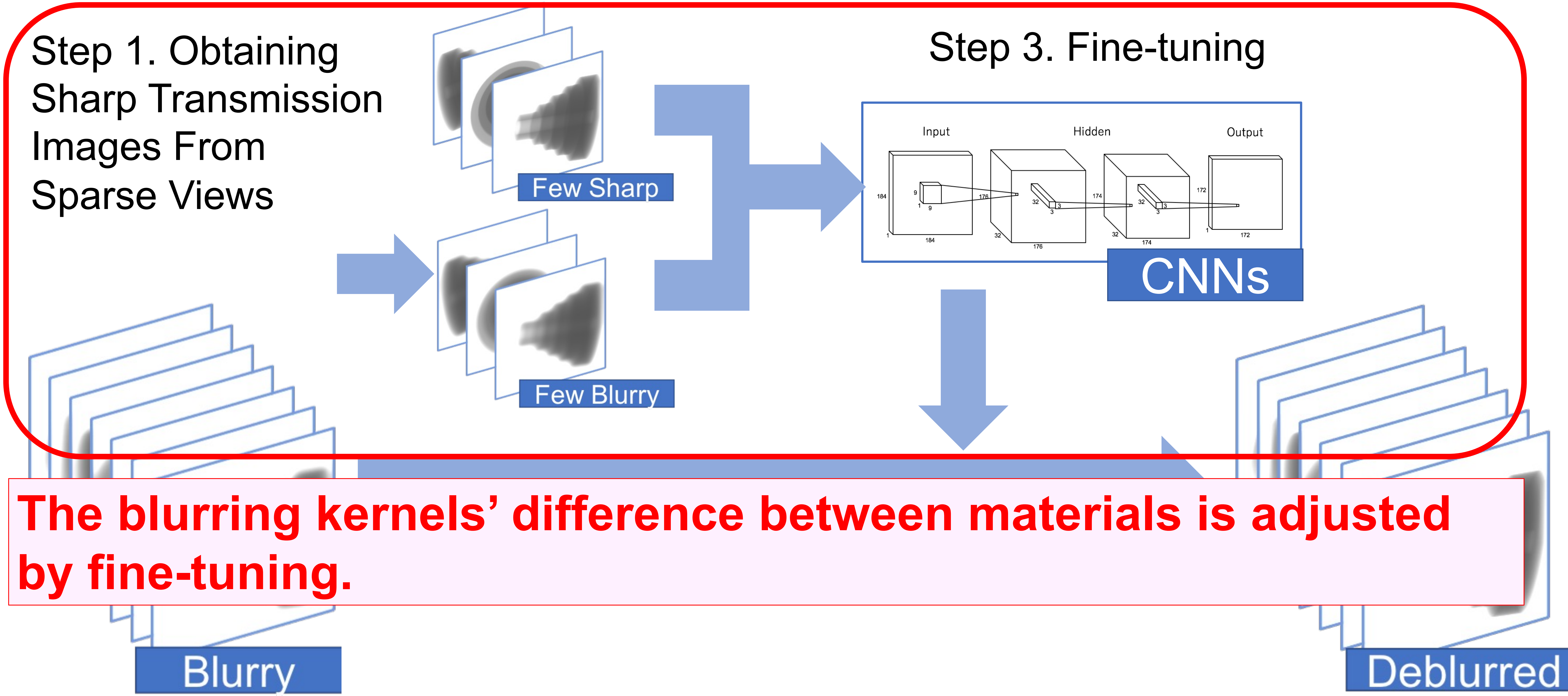
Different Materials



Different Projection Angles



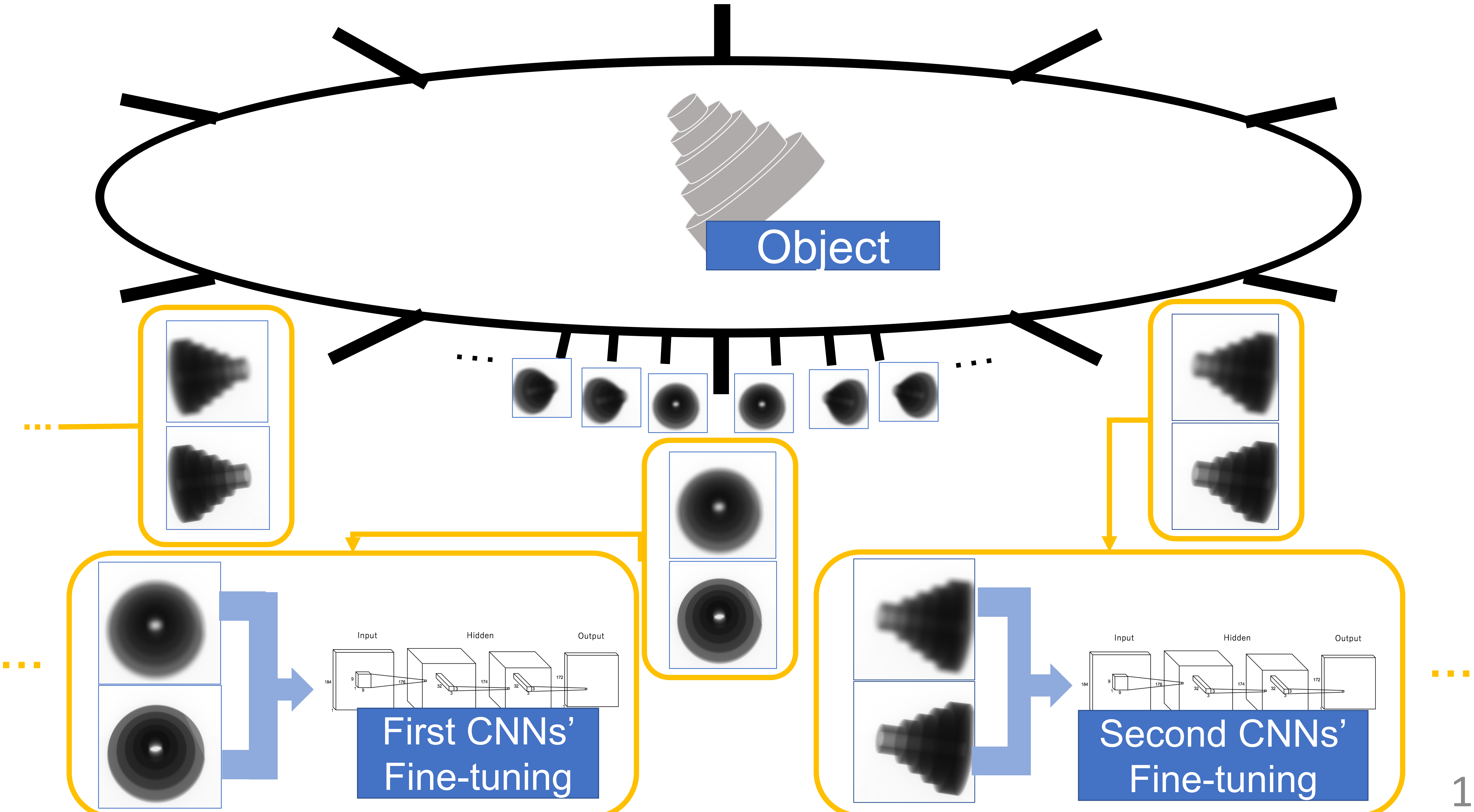
Deblurring with Fine-tuned CNNs



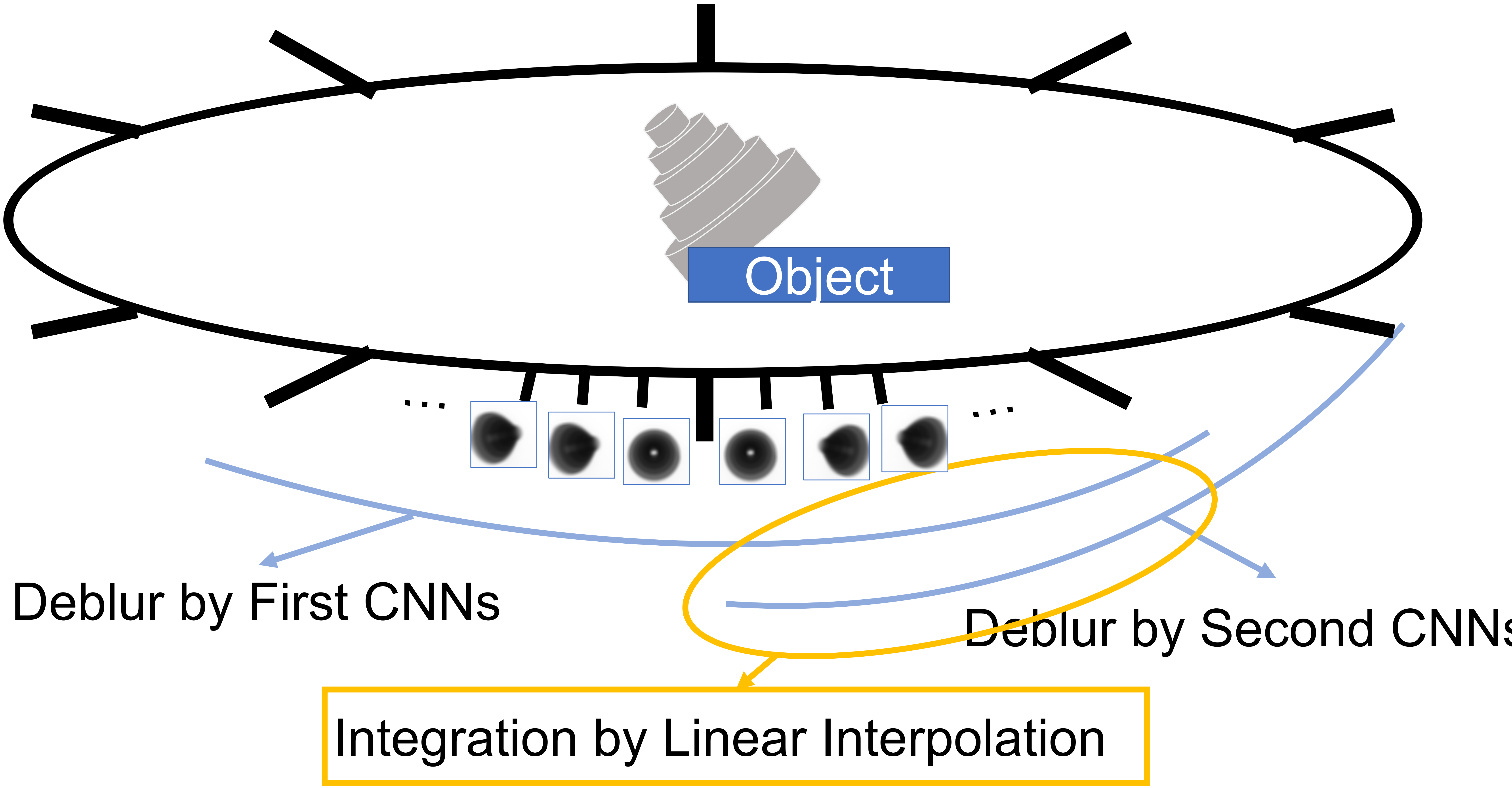
Step 2. Obtaining Blurry Transmission Images From Dense Views

Flowchart of the Proposed Rotational Fine-Tuning (RFT) Method

Rotational Fine-Tuning (RFT)



How to Integrate Outputs



The blurring kernels' difference between projection angles is adjusted by linear interpolation.

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Experiment

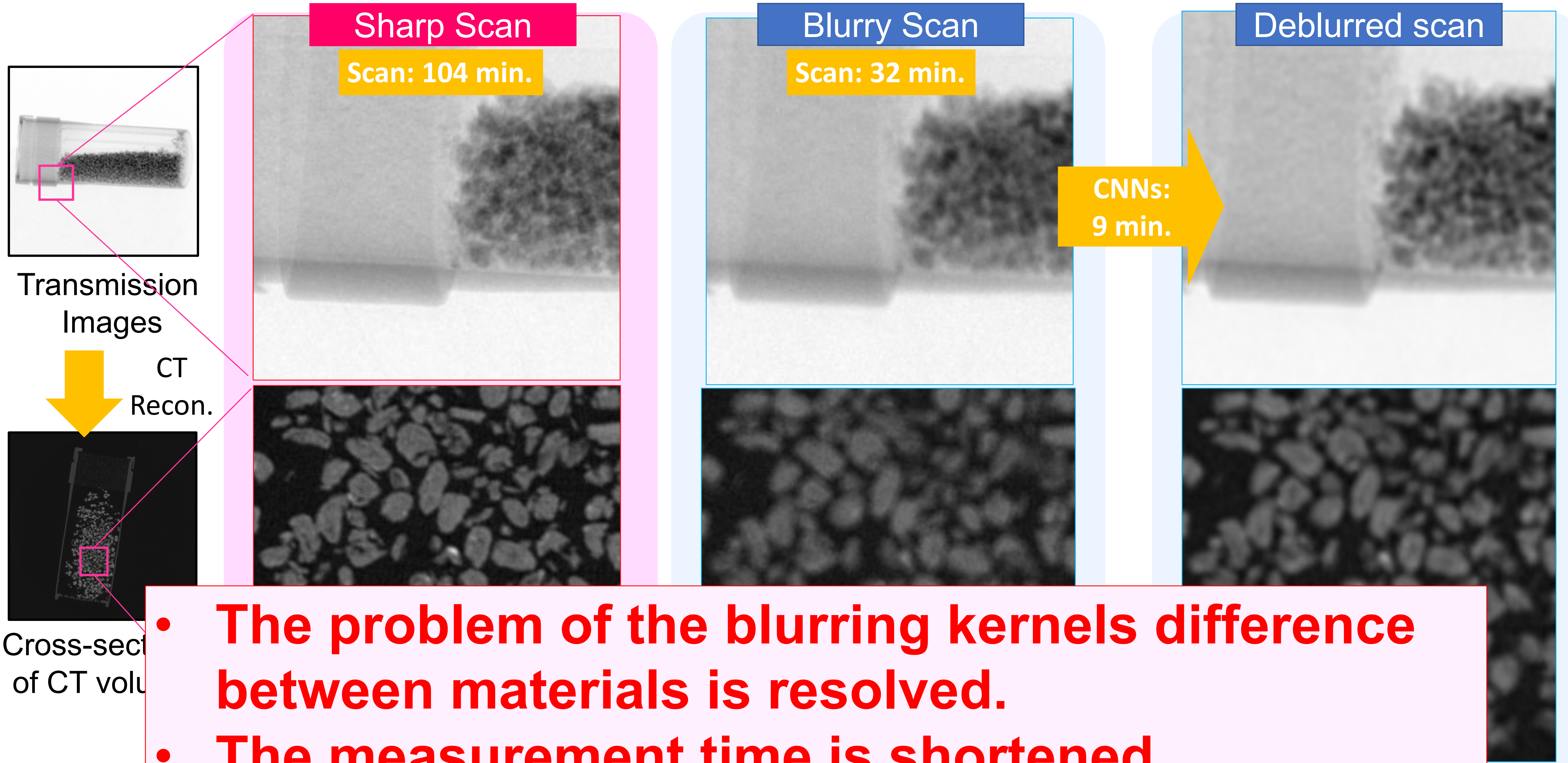
1. Precision

- The problem of the blurring kernels difference between materials is resolved?
- The problem of the blurring kernels difference between projection angles is resolved?

2. Total Measurement Time

- The total measurement time is shortened by proposed method?

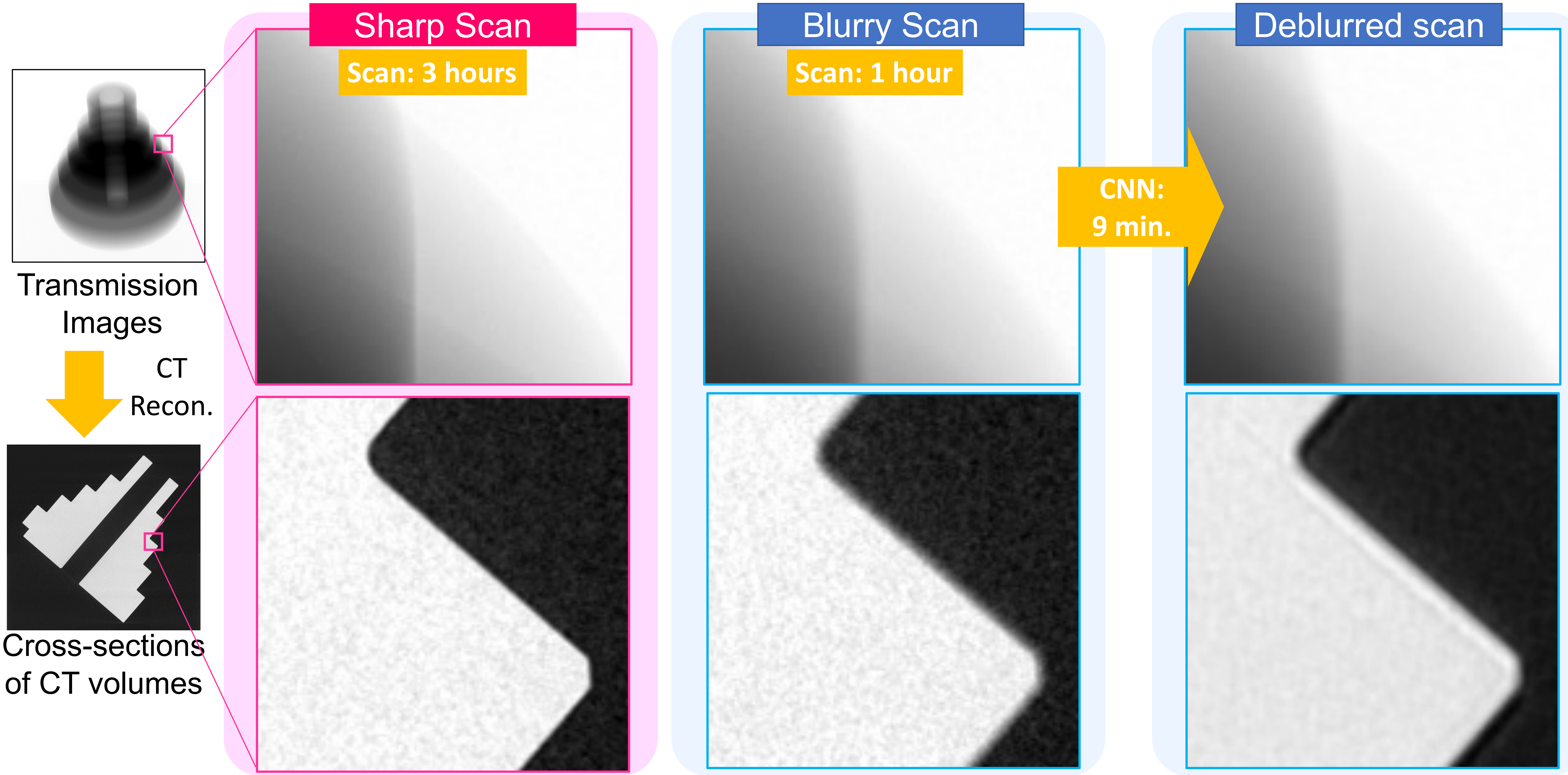
Result of Deblurring (E-cigarette)



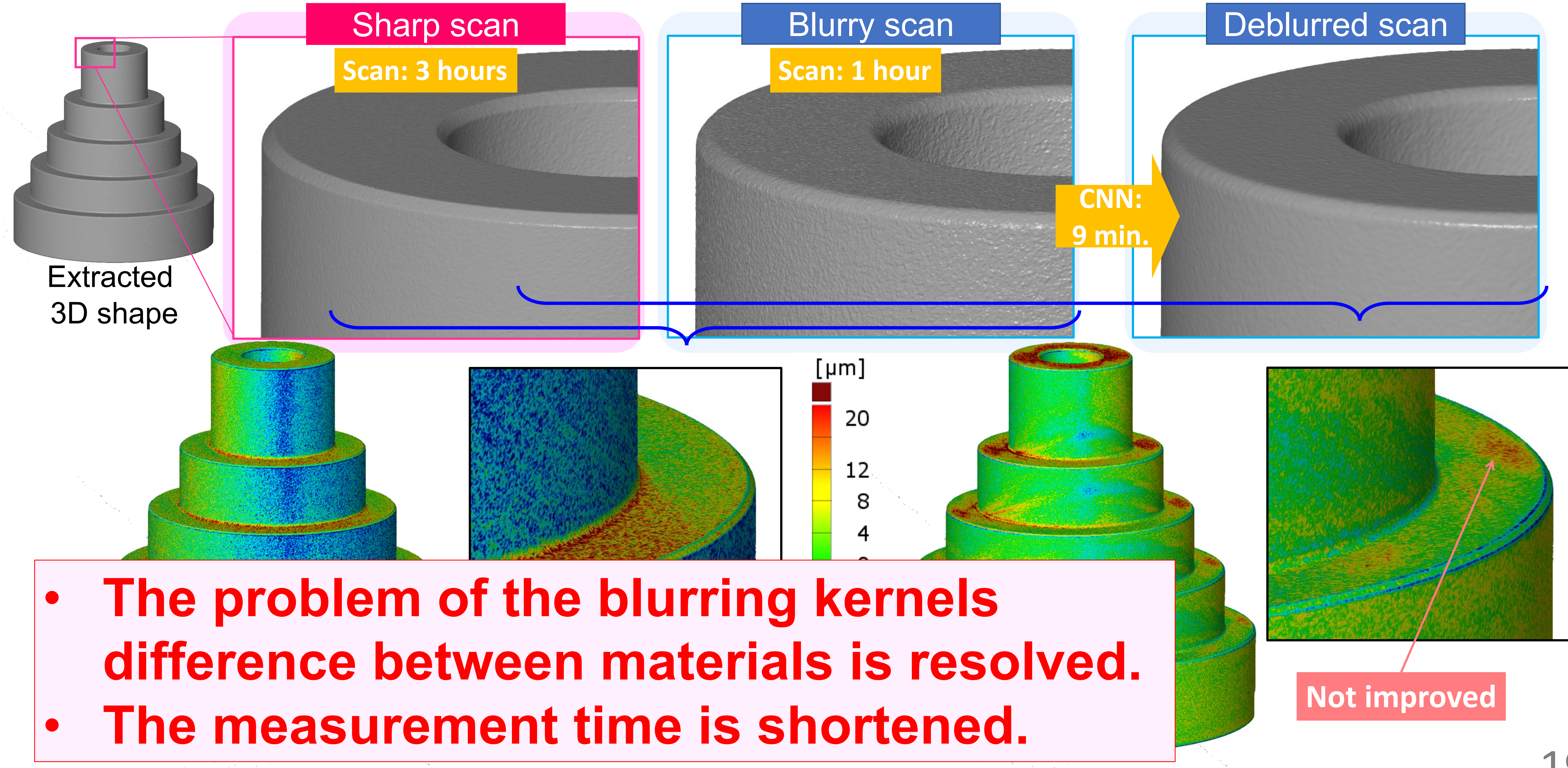
- **The problem of the blurring kernels difference between materials is resolved.**
- **The measurement time is shortened.**

*Reconstruction by Feldkamp (1984)

Result of Deblurring (Stepped Cylinder)



Result of Extracted Shapes (Stepped Cylinder)



- **The problem of the blurring kernels difference between materials is resolved.**
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Conclusion & Future Work

Conclusion

- Proposed RFT, a high-precision and short measurement method.
  - Blurry images are obtained in a short time, then they are deblurred by CNNs with fine-tuning and all outputs are integrated by linear interpolation.
- The problem of the blurring kernels difference caused by materials and projection angles is resolved.

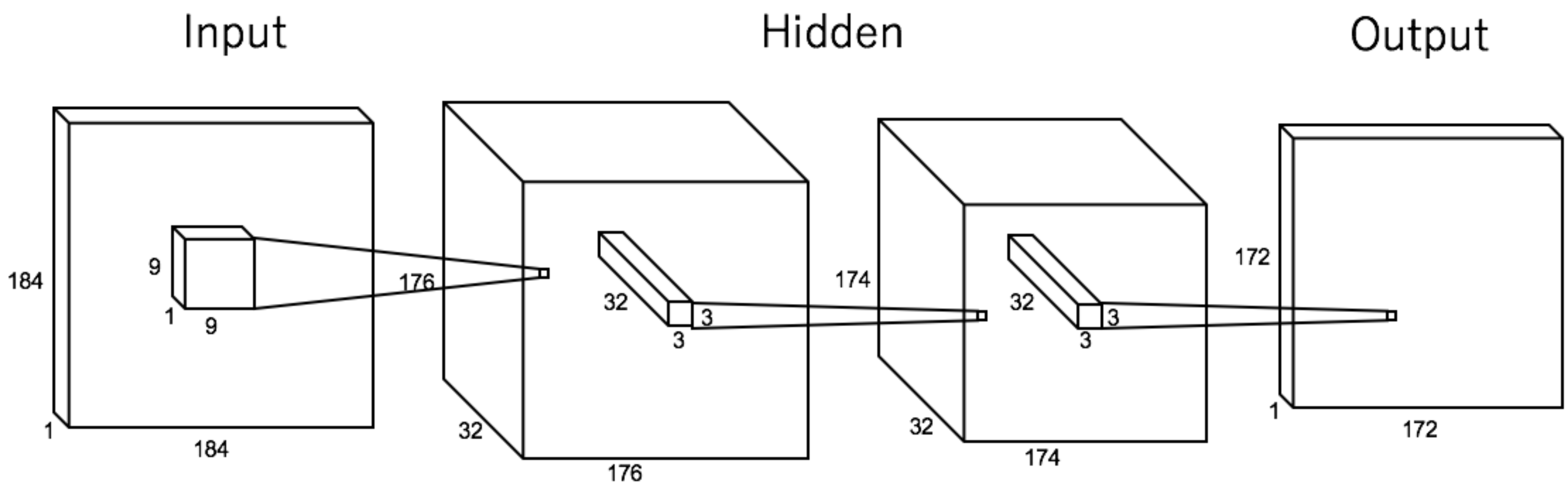
Future Work

- Combine our method and other problems with CT measurement.
  - Such as segmentation.
- Improvement of the performance of deblurring by employing other deblurring methods.

Reference

- [1] K. Alex, I. Sutskever, G. E. Hinton, Imagenet Classification With Deep Convolutional Neural Networks. Advances in neural information processing systems. (2012)
- [2] Schuler, C. J., Christopher Burger, H., Harmeling, S., & Scholkopf, B. (2013). A machine learning approach for non-blind image deconvolution. In *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition* (pp. 1067-1074).
- [3] L. Xu, J. SJ. Ren, C. Liu, J. Jia, Deep Convolutional Neural Network for Image Deconvolution, Advances in Neural Information Processing Systems, Vol.1 (2014), 1790-1798.
- [4] L.A. Feldkamp, L. Davis, J. W. Kress, Practical Cone-beam Algorithm, Josa a, Vol.1 (1984), 612-619.
- [5] D.Krishnan, R.Fergus, Fast Image Deconvolution Using Hyper-Laplacian Priors, Advances in neural information processing systems, Vol.1 (2009), 1033-1041

Architecture



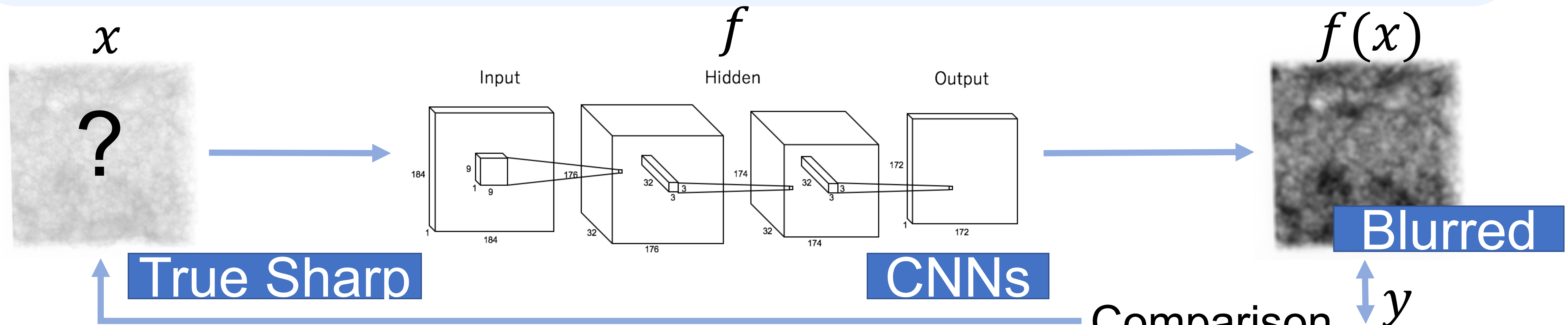
Abstract of structure

- All layers are convolutional layers.
- All activation functions are Rectified Liner Unit (ReLU).
- The network architecture was empirically determined.

RFT with Optimization-based Method

Optimization-based Method

- CNNs are pre-trained and learn how to “blur” sharp images.
- Sharp images are estimated by the gradient descent method.
- All conditions except for deblurring are the same as the direct deblurring method.



Estimation by the Gradient Descent Method

$$\hat{x} = argmin_x ||f(x) - y||^2$$

$$x_{t+1} = x_t - \frac{\partial}{\partial x} ||f(x) - y||^2 \Big|_{x=x_t}$$

Result of Deblurring (Stepped Cylinder)