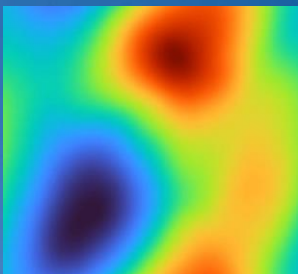




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What? Why? How? Deblurring Images



Viktor Palm



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Vijayakumar Anand

CIPHR Group

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5th November 2022



OUTLINE

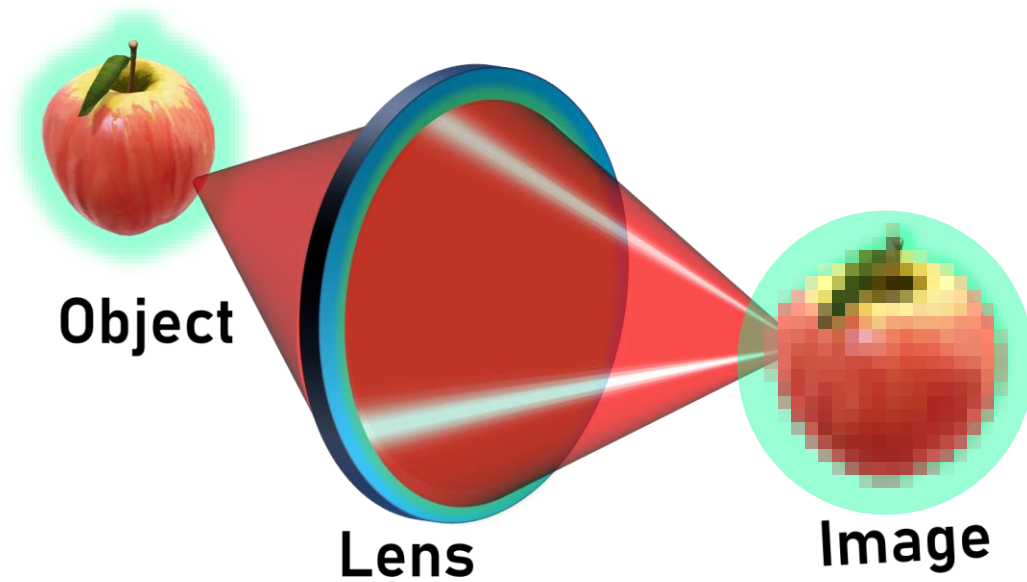
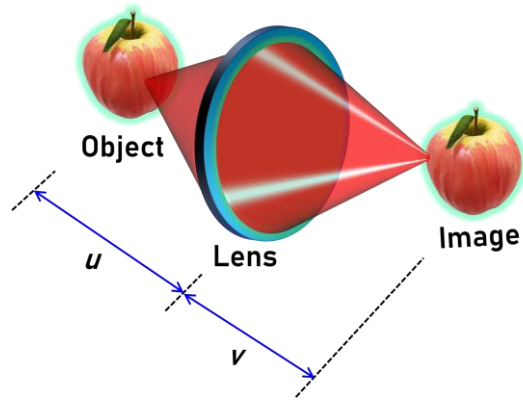
- **What and Why Deblurring**
- Concepts of linear imaging systems
- Forms of correlation - MATLAB
- Lucy-Richardson algorithm
- Summary



What and Why Deblurring

Blurring occurs due to a variety of reasons

- 1. Out of focus
- 2. Motion



What and Why Deblurring

Blurring occurs due to a variety of reasons

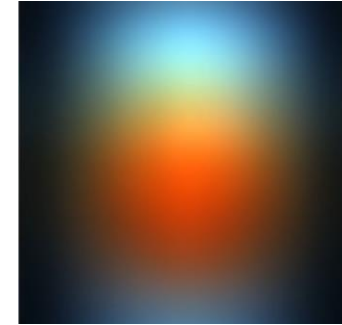
- 1. Out of focus
- 2. Motion



Object



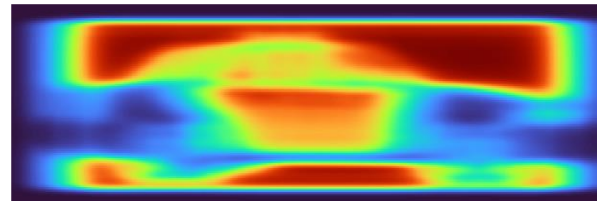
Camera image



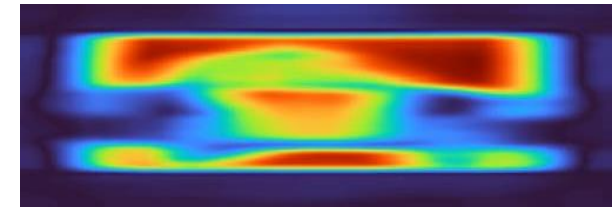
Computational reconstruction



Object in motion



Camera image



Computational reconstruction

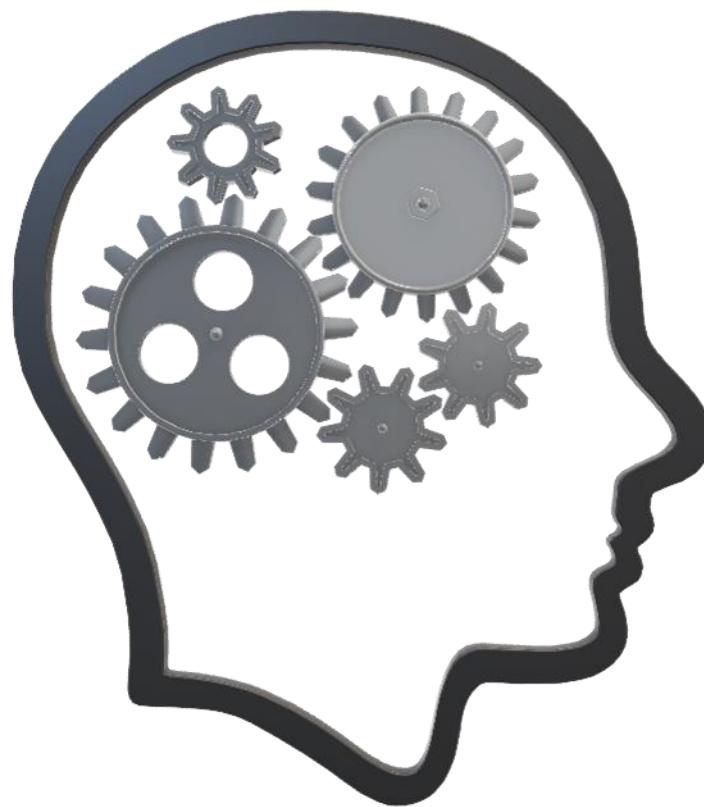


OUTLINE

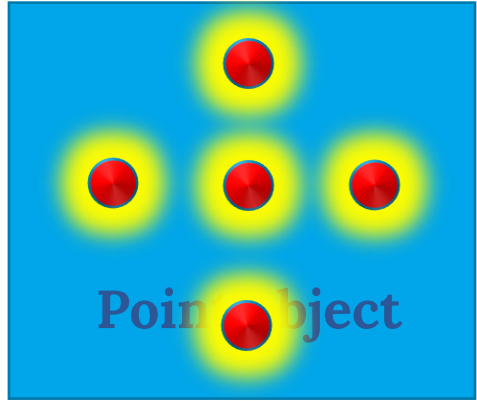
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Linear imaging systems – Vending machine concept

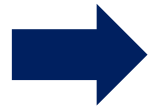


Linear imaging systems – Vending machine concept



Point object

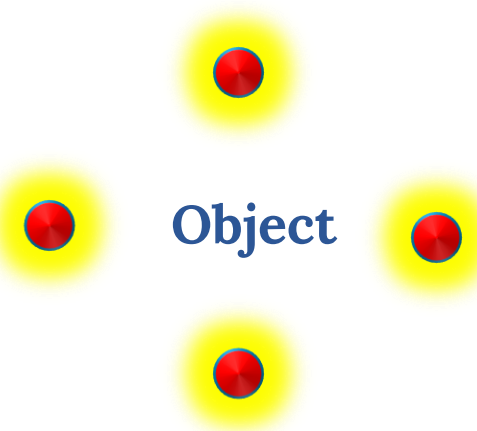
Monitor



Optical system



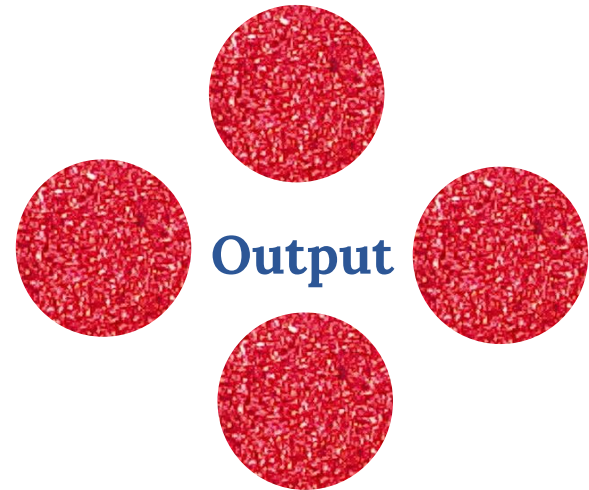
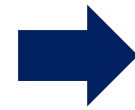
PSF



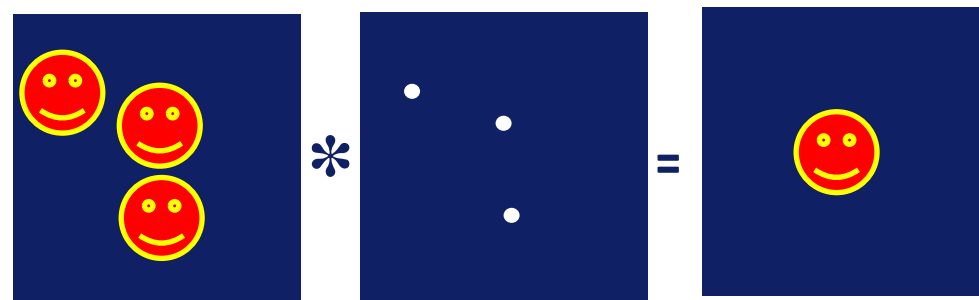
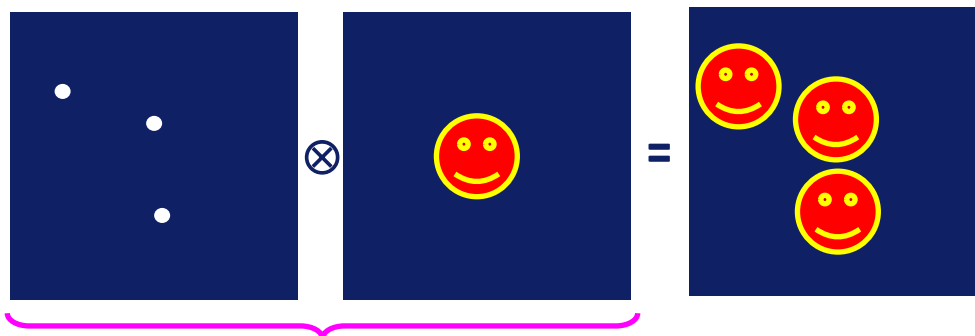
Object



Optical system



Output



↓

$$F^{-1} \left(F \left\{ \begin{array}{c} \cdot \\ \cdot \\ \cdot \end{array} \right\} \times F \left\{ \begin{array}{c} \text{smiley} \end{array} \right\} \right)$$

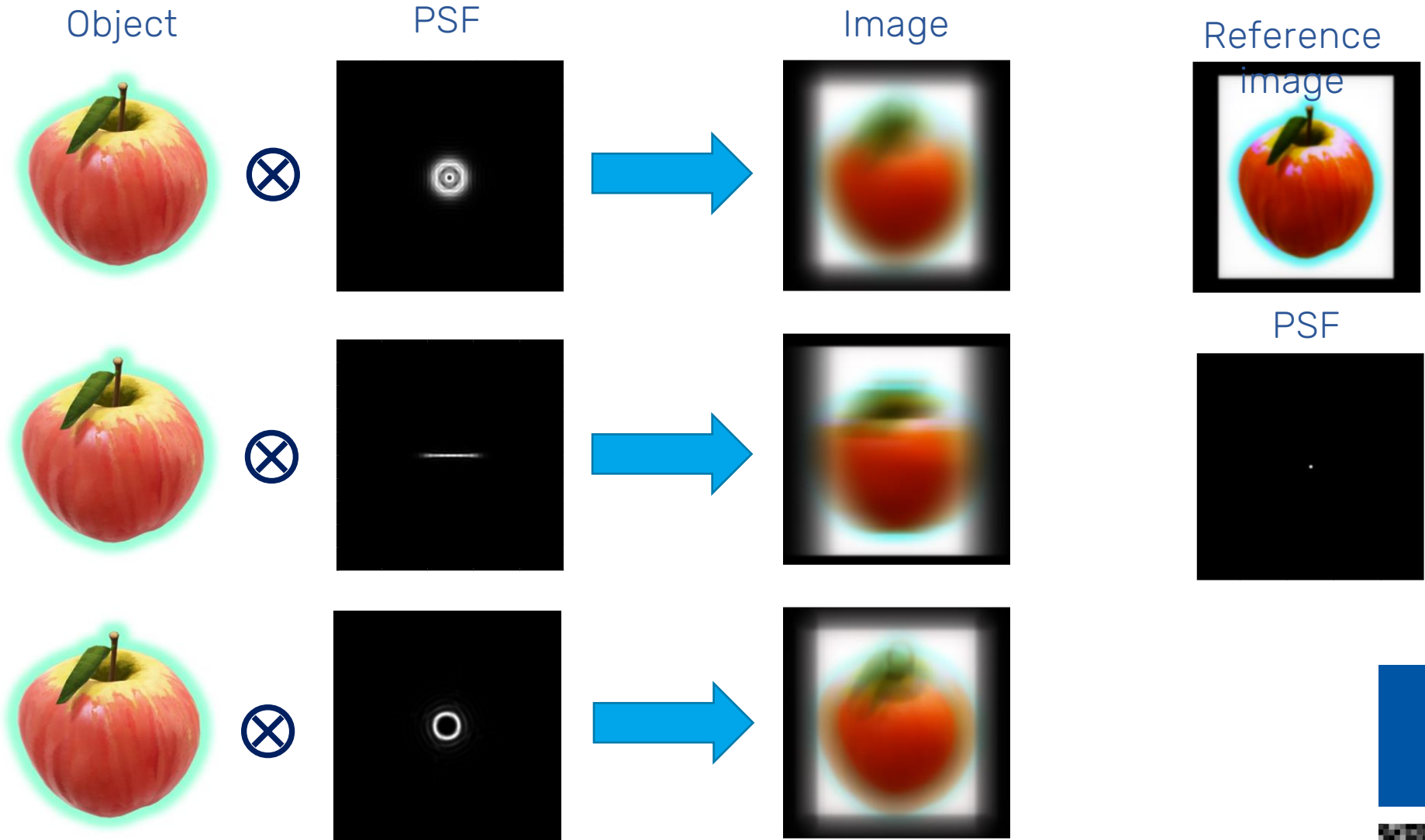
Convolution

$$F^{-1} \left(F \left\{ \begin{array}{c} \text{smiley} \\ \text{smiley} \\ \text{smiley} \end{array} \right\} \times F \left\{ \begin{array}{c} \cdot \\ \cdot \\ \cdot \end{array} \right\} \right)$$

Correlation

— Complex conjugate

Examples of convolution with PSFs



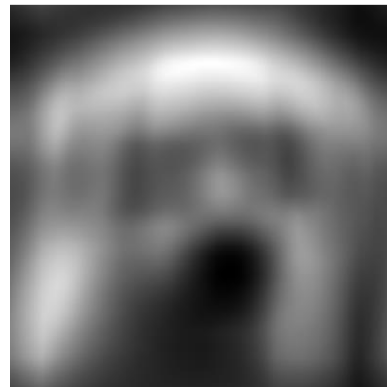
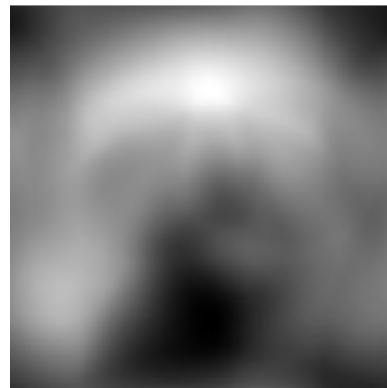


OUTLINE

- Direct and Indirect imaging concepts
- Infrared microspectroscopy
- **Forms of correlation - MATLAB**
- Lucy-Richardson Rosen algorithm
- Summary



1. Matched Filter ($\alpha=1, \beta=1$)
2. Phase-only filter ($\alpha=0, \beta=1$)
3. Weiner Filter or Inverse filter ($\alpha=-1, \beta=1$)
4. Non-linear filter (α, β)
5. Regularized filter (PSF with noise)

**Ground truth****Blurred****Deblurred**

MATLAB code – Participants 1.m

<https://bit.ly/ciphr-ws211>



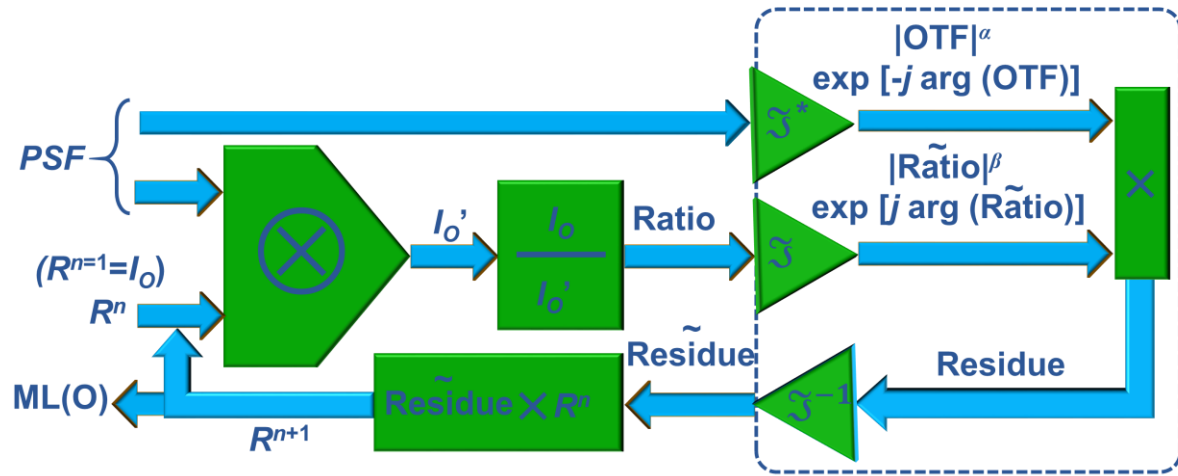
OUTLINE

- What and Why Deblurring
- Concepts of linear imaging systems
- Forms of correlation - MATLAB
- **Lucy-Richardson algorithm**
- Summary

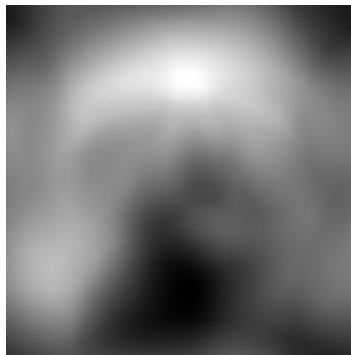


Lucy-Richardson-Rosen algorithm

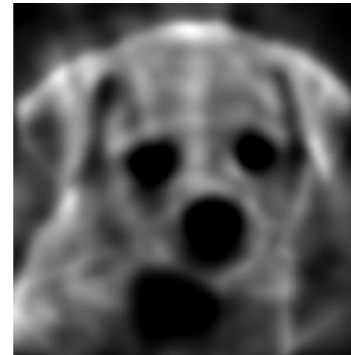
Lucy-Richardson Algorithm: The LRA approach is iterative where the $(n+1)^{th}$ reconstructed image is given as $I_R^{n+1} = I_R^n \left\{ \frac{I_p}{I_R^n \otimes I_{PSF}} \otimes I_{PSF}' \right\}$, where I_{PSF}' refers to the complex conjugate of I_{PSF} and the loop is iterated until an optimal reconstruction is obtained.



Ground truth



Blurred



Deblurred





OUTLINE

- What and Why Deblurring
- Concepts of linear imaging systems
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- **Summary**



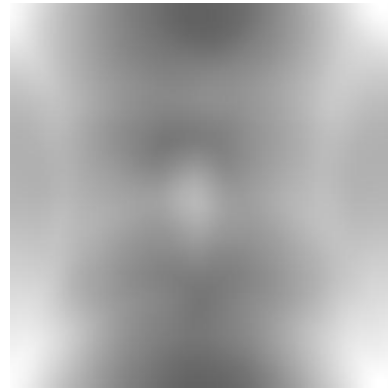
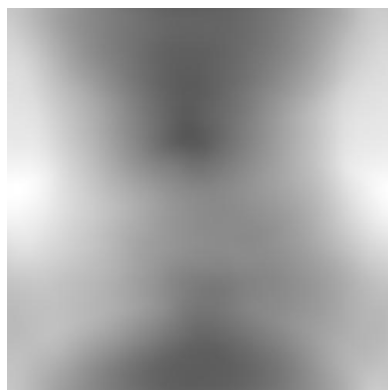
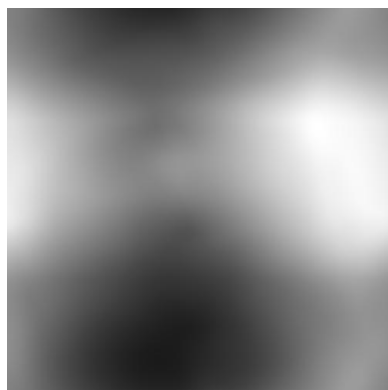
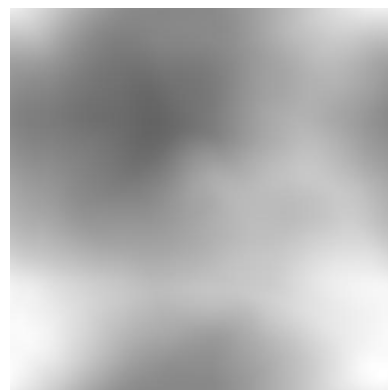
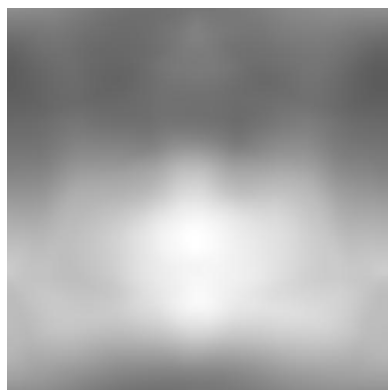
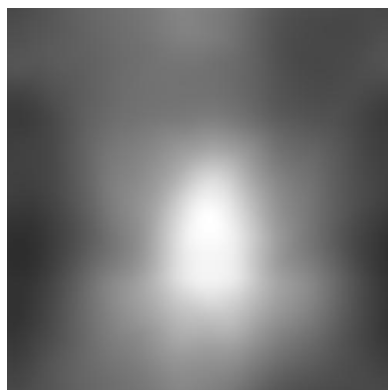
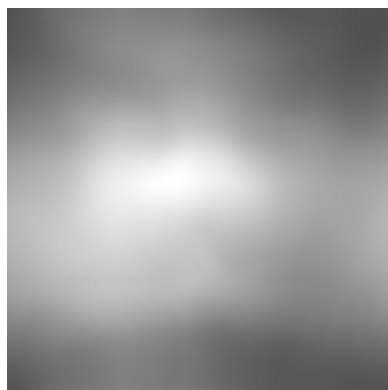


- The fundamentals of blurring and deblurring have been discussed.
- Convolution and correlation concepts have been presented.
- Different types of deblurring methods discussed and demonstrated.





Who is who?



Clue (PSF) - I am a uniform disc. My radius (in pixels) is the sum of 8 consecutive prime numbers after the number 5.



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Questions ???



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