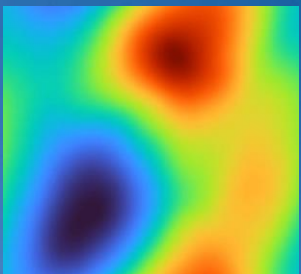




UNIVERSITY OF TARTU



What? Why? How? Deblurring Images



Viktor Palm



Amudhavel Jayavel



Praveen PA



Andrei Bleahu



Shiva Gopinath



Aravind Simon



Tiia Lillemaa



Vijayakumar Anand

CIPHR Group

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 857627 (CIPHR)



UNIVERSITY OF TARTU

5th November 2022



OUTLINE

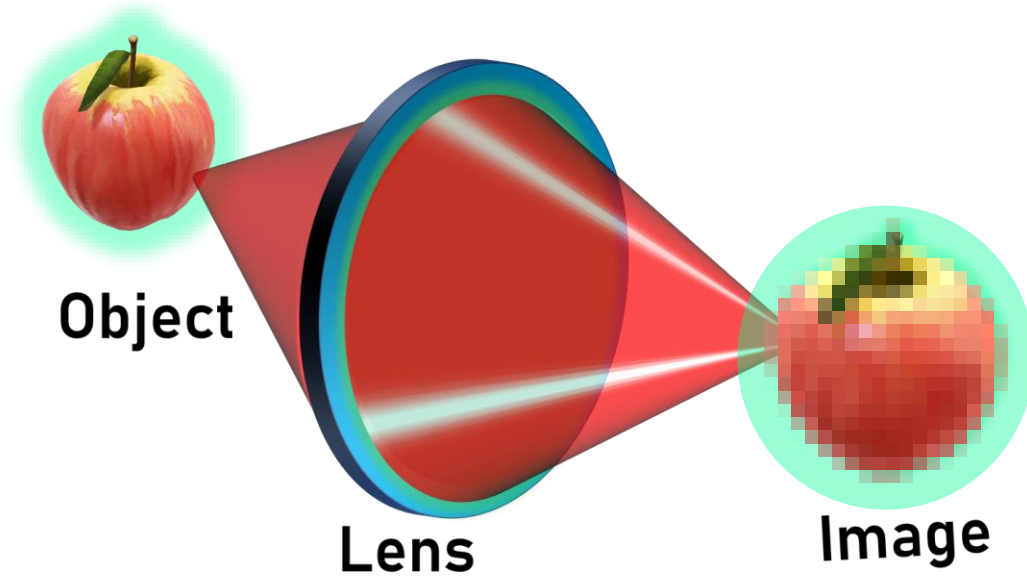
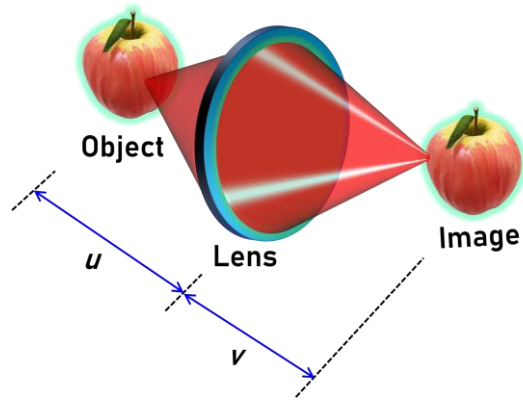
- **What and Why Deblurring**
- Concepts of linear imaging systems
- Forms of correlation - MATLAB
- Lucy-Richardson algorithm
- Summary



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

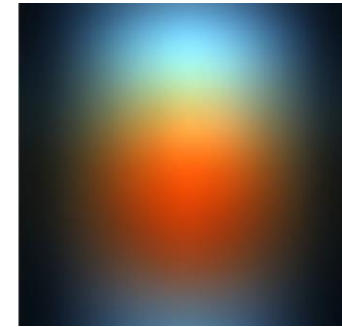
- 1. Out of focus
- 2. Motion



Object



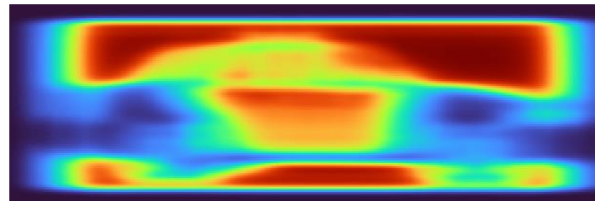
Camera image



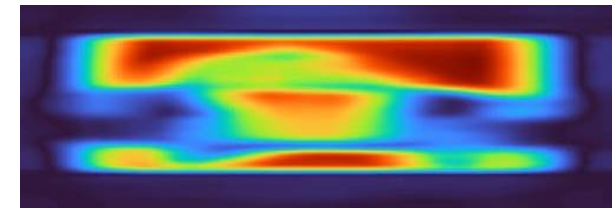
Computational reconstruction



Object in motion



Camera image



Computational reconstruction



OUTLINE

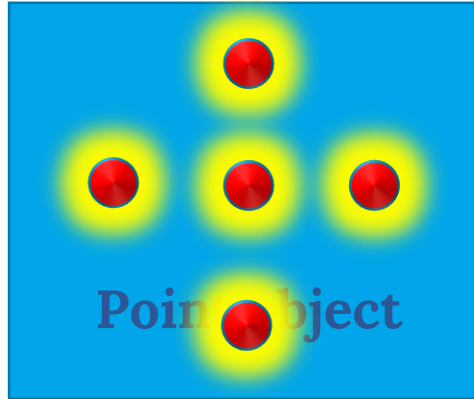
- What and Why Deblurring
- Concepts of linear imaging systems
- Forms of correlation - MATLAB
- Lucy-Richardson algorithm
- Summary



Linear imaging systems – Vending machine concept



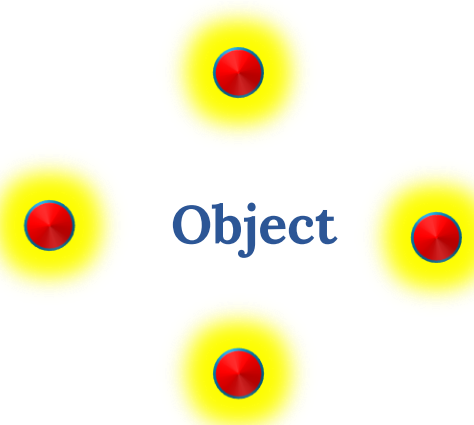
Linear imaging systems – Vending machine concept



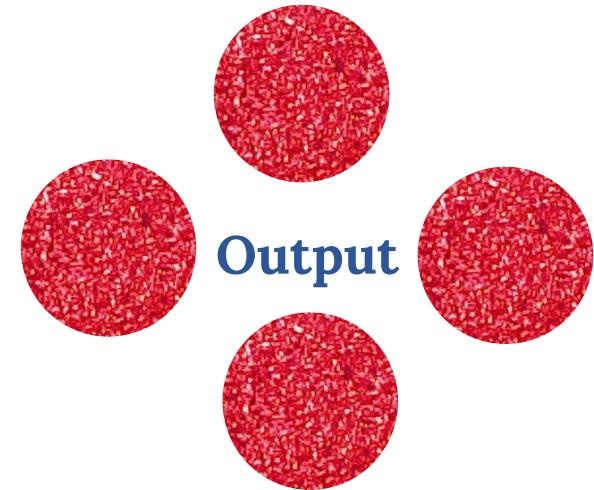
Optical system



PSF



Optical system





↓

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

Convolution

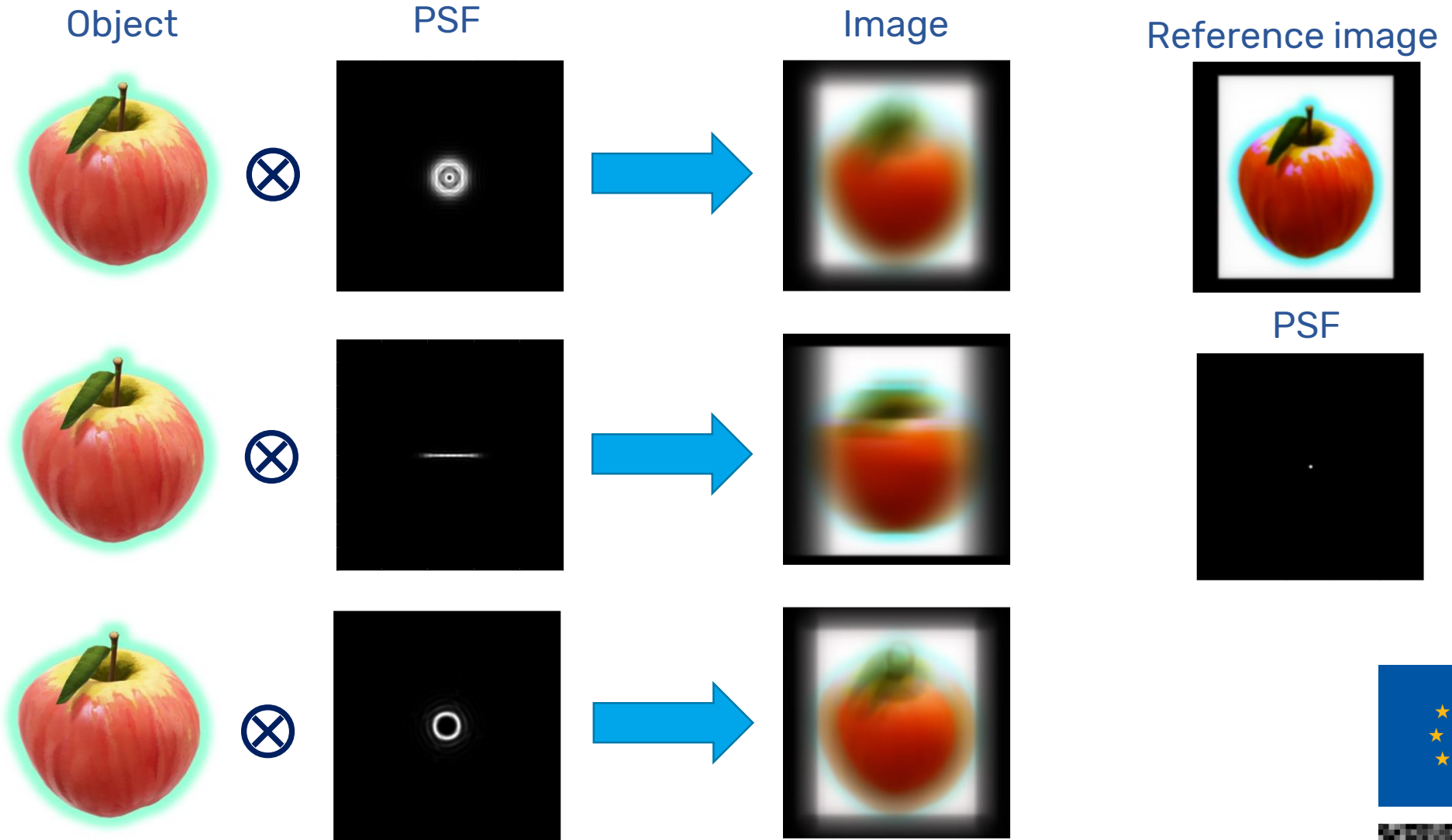
$$F^{-1} \left(F \left\{ \begin{array}{c} \text{smiley} \\ \text{smiley} \\ \text{smiley} \end{array} \right\} \times F \left\{ \begin{array}{c} \bullet \\ \bullet \\ \bullet \end{array} \right\} \right)$$

Correlation

— Complex conjugate



Examples of convolution with PSFs



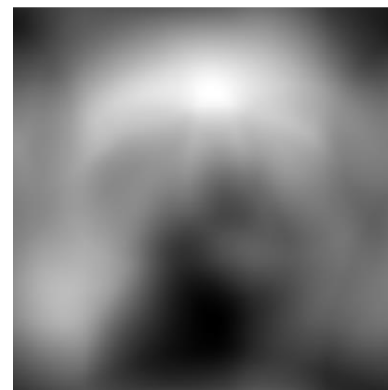


OUTLINE

- 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>



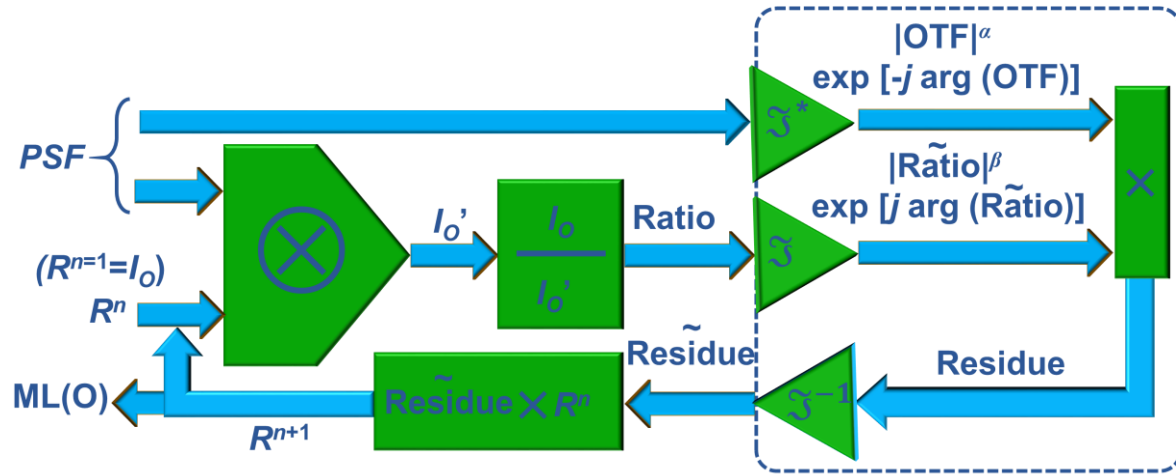
OUTLINE

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

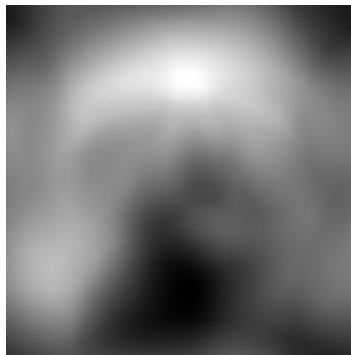


Lucy-Richardson-Rosen algorithm

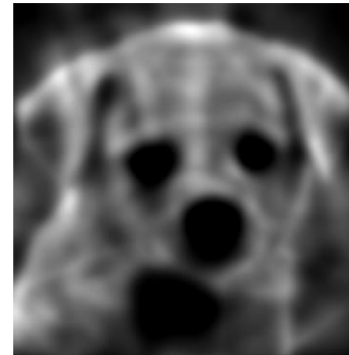
Lucy-Richardson Algorithm: The LRA approach is iterative where the $(n+1)^{th}$ reconstructed image is given as $I_R^{n+1} = I_R^n \left\{ \frac{I_p}{I_R^n \otimes I_{PSF}} \otimes I_{PSF}' \right\}$, where I_{PSF}' refers to the complex conjugate of I_{PSF} and the loop is iterated until an optimal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



Ground truth



Blurred



Deblurred





OUTLINE

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



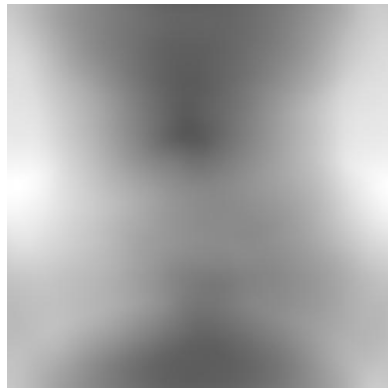
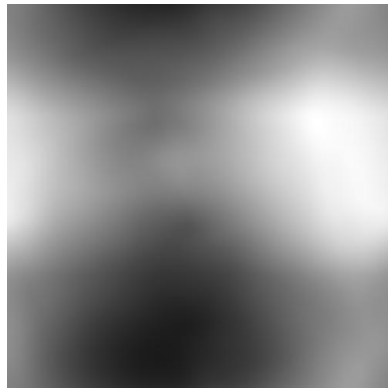
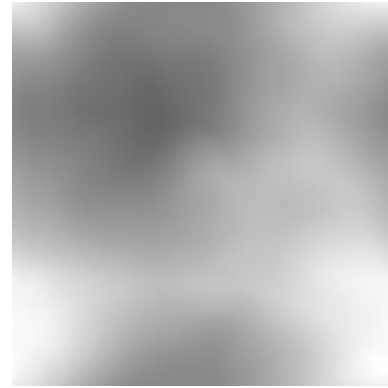
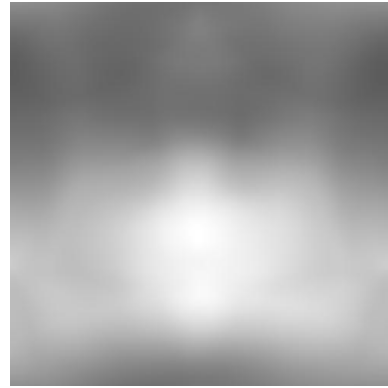
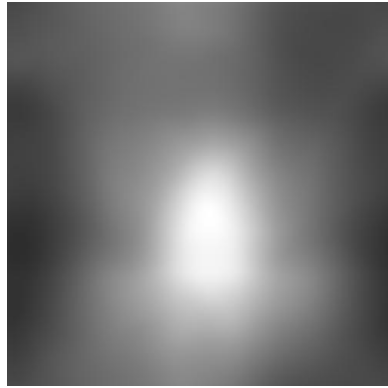
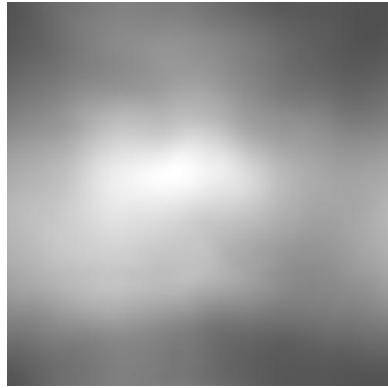


- The fundamentals of blurring and deblurring have been discussed.
- Convolution and correlation concepts have been presented.
- Different types of deblurring methods discussed and demonstrated.





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.



UNIVERSITY OF TARTU

Questions ???



unitartu



tartuuniversity

