Focus plane detection in Digital Holography

J. C. Filipinas\(^1\) and P. F. Almoro\(^2\), Ph. D.

\(^1\)Physics Department, Mindanao State University, Marawi City

\(^2\)National Institute of Physics, University of the Philippines, Diliman, Quezon City
Presentation Outline

1. Motivation of the Study
2. Digital Holography
3. Focus Quantifiers
4. Methodology
5. Results and Discussion
6. Summary and Conclusion
Motivation of the Study

Develop optical techniques for (with)

1. Nondestructive Testing

2. Fast Data Acquisition

3. Easy Access to Data
Digital Holography

Dennis Gabor – invented holography in 1948 as a method for recording and reconstructing the amplitude and phase of a wavefield.

Holography – Greek words ‘holos’ meaning ‘whole’ or ‘entire’ and ‘graphein’ meaning ‘to write’.

Images from
Digital Holography

Applications of Digital Holography

Focus plane detection problem

1. Focusing not intrinsic to reconstructions
2. Manual detection is skill dependent

Images from:
Focus Quantifiers

Focus quantifiers – statistical quantifiers that respond with the focusing of an image. Also referred to as focus measures and focus operators.


All focused composite image


Methodology

Phase – shifting digital holography

Legend:
PZT – piezoelectric transducer
BS – beam splitter
M – mirror
O – test object
CMOS – complementary metal oxide semi-conductor camera

Holograms

Reconstructions

Focusing
Methodology

Sample hologram

UK-Assignments.com

SAMPLE
Methodology

1. Four – bucket algorithm of the phase-shifting digital holography

\[ U_h(x, y, 0) = \frac{1}{4U_R^*} \{ I_1(x, y; 0) - I_3(x, y; \pi) + i[I_2(x, y; \pi/2) - I_4(x, y; 3\pi/2)] \} \]

2. Solve the Rayleigh – Sommerfeld diffraction formula

Using the convolution method yields the complex field

\[ U_0(x, y, z) = h(x, y, z) \otimes U_h(x, y, 0) \]

The impulse response function

\[ h(x, y, z) = \exp \left\{ \left( i\frac{2\pi}{\lambda} z \right) \left[ 1 + \left( \frac{x}{z} \right)^2 + \left( \frac{y}{z} \right)^2 \right]^{\frac{1}{2}} \right\} \frac{i\lambda z}{i\lambda z \left[ 1 + \left( \frac{x}{z} \right)^2 + \left( \frac{y}{z} \right)^2 \right]} \]

100 frames
100\lambda \text{ increment}

Methodology

3 Focus quantifiers used to evaluate focusing

Gray level variance (glva)

\[ \text{glva} = \frac{1}{M \times N} \sum_{x} \sum_{y} (g(x, y) - \mu)^2 \]

Energy of Laplacian (lape)

\[ \text{lape} = \sum_{x} \sum_{y} (g_{xx} + g_{yy})^2 \]

Tenengrad (teng)

\[ \text{teng} = \sum_{x=2}^{M-1} \sum_{y=2}^{N-1} (\nabla S(x, y))^2 \text{ for } \nabla S(x, y) > 1 \]

Methodology

3 Focus quantifiers used to evaluate focusing

Gray level variance (glva)

\[
\mu = \frac{1}{M \times N} \sum_{x} \sum_{y} g(x, y)
\]

Energy of Laplacian (lape)

\[
g_{xx} + g_{yy} = \begin{cases} 
-g(x - 1, y - 1) - 4g(x - 1, y) - g(x - 1, y + 1) \\
-4g(x, y - 1) + 20g(x, y) - 4g(x, y + 1) \\
-g(x + 1, y - 1) - 4g(x + 1, y) - g(x + 1, y + 1)
\end{cases}
\]

Tenengrad (teng)

\[
\nabla S(x, y) = \left[ (\nabla S_x(x, y))^2 + (\nabla S_y(x, y))^2 \right]^{1/2}
\]

\[
\nabla S_x(x, y) = \begin{cases} 
-\left[ g(x - 1, y - 1) + 2g(x - 1, y) + g(x - 1, y + 1) \right] \\
+\left[ g(x + 1, y - 1) + 2g(x + 1, y) + g(x + 1, y + 1) \right]
\end{cases}
\]

\[
\nabla S_y(x, y) = \begin{cases} 
+\left[ g(x - 1, y - 1) + 2g(x, y - 1) + g(x + 1, y - 1) \right] \\
+\left[ g(x - 1, y + 1) + 2g(x, y + 1) + g(x + 1, y + 1) \right]
\end{cases}
\]
Results and Discussion

Reconstructions of the phase and amplitude maps.
Results and Discussion

Focusing of the phase distribution.

Focusing of the amplitude distribution.

Focus plane at the 39th Frame corresponding to 27.4689 mm from the camera.
Summary and Conclusion

Summary

1. Phase – shifting digital holography was used to record the holograms of the USAF resolution target.

2. Three focus quantifiers were used to evaluate the image focus of the reconstructed phase and amplitude maps.

3. The calculated focus values of the frames were used to determine the focus plane of the maps.

Conclusion

1. Digital holography promotes fast and easy optical inspection.

2. Focus quantifiers facilitate the accurate detection of focus plane.
Acknowledgements

The authors are grateful for the support of the following institutions:

PCIEERD – DOST

MSU – Marawi City

CHED

OVCRD – UP Diliman
Thank You very much for listening!😊

UK-Assignments.com

SAMPLE Future Research

✓ Fringe projection profilometry
✓ Low cost digital holography
✓ Physics of autostereograms