Digital Photographic Imaging Using MOEMS

Vasileios T. Nasis\textsuperscript{1}, R. Andrew Hicks\textsuperscript{II} and Timothy P. Kurzweg\textsuperscript{1}

\textsuperscript{1}Drexel University, Department of Electrical and Computer Engineering, Philadelphia USA
\textsuperscript{II}Drexel University, Department of Mathematics, Philadelphia USA

Presented

by

Vasileios T. Nasis
Presentation Outline

Problem Statement: Limitations of Current Digital Imaging Techniques

Proposed Method of Solution

Simulation Results

Proof of Concept Experimental Results

Future Work and Conclusions
Current Technique: Imaging Sensors

Digital Cameras use Solid State Devices called Image Sensors

Most Major Images Sensors are CCD and CMOS

Design Goal: Increase the Resolution of the captured image.

Drawbacks: Image Sensors can increase resolution by increasing the number of photo sensitive diodes (Photosites) on the chip:

More Photosites → Smaller Photosites → Less photos captured

Charged Coupled Device (CCD)
Current Technique: Image Mosaicing

Image Mosaicing is an image stitching technique.

**Design Goal:** High Resolution and Wide Field of View Imaging

**Drawbacks of Image Mosaicing:**

- Slow Acquisition Process
- Highly Dependant on Algorithm Used
Proposed Method of Solution

We Introduce into the Optics of the Image Sensor a Micro-Mirror Array.

MOEMs array Consists of Configuration of Micro-Mirrors Capable of Changing States Rapidly.

Incorporating MOEM Array into our Image Sensor, allow us to Capture Images at the Frame Rate of the Camera.

Advantages:

- Higher resolution images compared to the native camera used to capture images.
- Increase of FOV of the captured image, irrelevant to the lens.

System Model

MOEM array

Image Plane

Object Plane

Mirrors

System Model
The goal is to image a given surface and establish a correspondence between the object plane and the image plane.

Tilting a small flat mirror along a given ray, maps the ray from a point on the object plane to a corresponding one on the image plane.

A given correspondence between the pixels in an image plane and a collection of points on object plane can be achieved.

Correspondences can be created for every state of the mirror.
System Configuration
Simulation Setup

The Simulations were performed in POV-Ray (a graphical ray tracer) interfaced with MATLAB for pixel correspondance computation.

The Object Plane is composed of a checkerboard and three objects placed on top.

The mirror-array is placed at an angle 45 degrees with respect to a checkerboard.

The model of the mirror array was derived according to Lucent’ Wavestar Lambdarouter chip and therefore it has:

- 256 micro-mirrors
- Each circular mirror has 650μm
- Every mirror has 100 controllable states, in both φ and θ directions
Sampling Point Distribution

Positional Distribution Obtained from all the Mirrors and their Corresponding States.

The Distribution Depends on the Size, Pitch and Number of States of Each Mirror.
Simulation Results

From Each Frame the 256 Pixels get extracted-One from Each Mirror.
Using a 256 Pixels Image Sensor we generated and Image of 2.56Mpixels.
We can generate images of resolution much higher than the employed camera.
Object to Image Plane Point Correspondance

- Perspective Projection
- Pixel’s Mapping
Perspective Projection

Let $Ax + By + Cz + D = 0$ be the projection plane. If $(x_0, y_0, z_0)$ is the point to be projected and $(x_c, y_c, z_c)$ is the center of projections, then the parametric equations of the line are:

$$x = x_0 + (x_c - x_0)t$$
$$y = y_0 + (y_c - y_0)t$$
$$z = z_0 + (z_c - z_0)t$$

If $Z = 0$ and the Center of Projection is $(0, 0, d)$ then $t = \frac{-z_0}{d-z_0}$

$$X_p = x_0 + (0 - x_0)t = \frac{dx_0}{d-z_0}$$
$$Y_p = y_0 + (0 - y_0)t = \frac{dy_0}{d-z_0}$$
$$Z_p = z_0 + (d - z_0)t = 0$$
Pixel’s Mapping

\[
\begin{align*}
[x, y] & \rightarrow \left[ \frac{x-a}{b-a}, \frac{y-c}{d-c} \right] \\
x', y' & = \left( i \frac{x-a}{b-a}, j \frac{y-c}{d-c} \right)
\end{align*}
\]

**Note**: \(i \times j\) is the resolution of the image plane
Proof of Concept: Experimental Setup

- The camera used is Sony DFW-V300
- A 75-mm Double Gauss Macro Imaging Lens is attached on the camera
- The micro-mirror is a 2-D scanning circular Mirror Ø1mm from Fraunhofer IPMS

01/16/2006
Proof of Concept Results #1

The micro-mirror tilts only on one axis

Each snapshot has a resolution of 47x61

The resultant image has a resolution of 210x47 Pixels
Proof of Concept Results #2

- The mirror Tilts on Both Axis
- Each Snap shot has Resolution of 74x76
- The resultant image has a resolution of 101x102 Pixels
Future Work

We currently work on our second prototype using Lucent’ Wavestar Lambdarouter MOEM Chip.

This is a 16x16 micro-mirror array.

Each mirror has a diameter of 650μm and ±8 degrees of tilt on each axis.

Each mirror can be controlled individually and can be controlled easily within 50mdeg resolution.

The mirror can easily take over 100,000 states in the 2-D plane.
Challenges to Overcome

- The chip is packaged with an over glass to protect the mirrors from damage, corrosion and stray light reflection.

- The chip was designed for telecom applications and for operation in wavelengths 1300nm-1550nm.

- The particular antireflection coating on the over-glass creates high reflection on the visible range.

- This results in low light transmission to the mirrors which prohibit us to focus on the object plane through the mirrors.
Conclusion

- We have introduce a new approach to Digital Imaging based on MOEMS
- We have proven its validity through simulations and experimentally
- We are currently using Lucent’s Lambdarouter mirrors, and overcoming some of its inherent visible wavelength limitations
- We acknowledge the support from the National Science Foundation (ISS-0413021) and the LambdaRouter Wavestar chip and supporting drivers from Lucent Technologies.
Thank you!

www.ece.drexel.edu/moems

Vasileios T. Nasis, M.Sc
Ph.D Student
vasileios@ece.drexel.edu
+1 (215) 895 1378

R. Andrew Hicks, Ph.D
Associate Professor
hicks@math.drexel.edu
+1 (215) 895 2681

Timothy P. Kurzweg, Ph.D
Assistant Professor
kurzweg@ece.drexel.edu
+1 (215) 895 0549