Utilizing Motion Sensor Data for Some Image Processing Applications

Saragadam R V Vishwanath (EE10B035)
Under the guidance of Prof. A. N. Rajagopalan

Department of Electrical Engineering
IIT Madras

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Motivation

- Hand held devices get shaken when held loosely. Image degradation by motion blur. Can be used for various purposes.
- Computational photography now moving to ubiquitous mobiles
- Increased computational power. Hence, increased avenues.
- Additional data in the form of motion sensors. Increased scope of research.
- Flexible programming on the mobile camera. Ability to implement algorithms on the fly instead of offline computing.
- Not much work done in this area.

What do we have in hand

- A mobile that is easy to program.
  - Access to three-axis accelerometer.
  - Access to 5 mp camera with variable focus, exposure time and resolution.
  - Access to TCP communication for sending data to computer.
- A desktop computer that is very fast.
  - Python for writing all the applications.
  - WiFi dongle to receive data wireless.

Work Done

- Developing an application on mobile to send motion sensors data and images over TCP.
- Constructing a kernel with motion sensors data.
  - Synchronizing the accelerometer with exposure time.
  - Separating gravity and acceleration due to external force using low pass filtering.
- Image deblurring using semi-blind methods.
- Estimating depth using motion blur and shape from focus.
- Image registration for pure translation and pure rotation cases.

Image Deblurring

Primer

- Blur induced due to shake of the hand held camera.
- Ill-posed if no more information is available.
- Idea is to get either the PSF directly or get a good initial estimate.
- Trajectory can be estimated using data from accelerometer.
  - No scene depth information. Hence we iterate through a possible set of depths.
  - Drift due to erroneous gravity estimation. Hence we compensate by iterating through a set of possible drifts.

Image Deblurring

Results

Results of non-blind deconvolution using wiener deconvolution

Results of semi-blind deconvolution using Punnappurath et al's code.

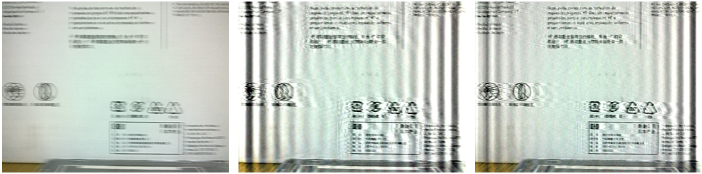

Image Deblurring

Inference

Pros

- Simple computation as we have enough data.
- Semi-blind performs same for high textured images. Converges quickly. Performs well for low textured images.

Cons

- If only accelerometer data is available, PSF can go completely wrong.
- No information from the image used.

Improvements

- Estimate a blind PSF and fuse it with calculated trajectory.
- Better estimation of kernel using other motion sensors data.

Depth Estimation

Primer

- Depth estimation using motion blur
  - Each pixel gets blurred by a different scale of the blur kernel, assuming no parallax
  - We have a sharp image, blurred image and the PSF estimate. Need to estimate scale at each point.
- Depth estimation using shape from focus
  - Farther the point from focus, more blurred the object becomes.
  - Need a *focus measure* which would peak when a region is completely focused. We use Sum Modified Laplacian.

Depth Estimation

Results – Motion blur

Depth from motion blur – Good case

Figure: Sharp image, blurred image and estimated depth. Brighter parts are closer to the camera.

Depth from motion blur – Bad case

Depth Estimation

Results – Shape from focus

Depth using shape from focus

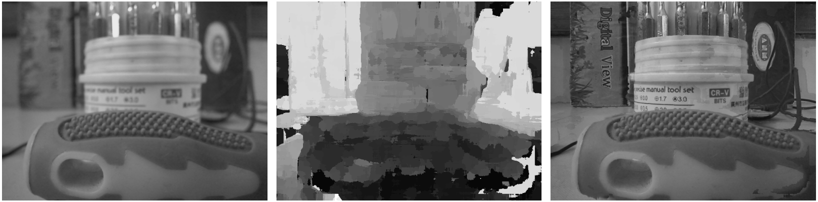

Figure: First image in the set. Estimated depth map and fully focused image. Darker regions are closer to the camera.

Depth Estimation

Inference

Depth from motion blur

- Pros
  - Low computational complexity.
  - Not much data needed. Only two images and motion sensor data. Easily available on the mobile platform.
  - Depth map is reliable with good kernel estimate.
- Cons
  - Shift in image pair or wrong kernel estimate gives a very bad depth map.
- Improvements
  - Segmenting image for more reliability.
  - A better metric than L_2 norm for comparing blurred and the reblurred image.

Depth using shape from focus

- Need better focus operator for low frequency areas.

Image Registration

Primer

- When capturing two images, we need the trajectory between the two positions.
- Simple registration may not work when one of the images is blurred.
- Motion sensors give the exact trajectory and can be used for registration.
- Even thoug hwe know the displacement in mm, we don't know in pixels, hence we iterate through a certain depths.
- With only accelerometer, we can either know the translation or rotation. Hence we see both the cases separately.

Image Registration

Results

Translation case

Rotation case

Image Registration

Inference

Translation

- Pros
  - Low computational complexity.
  - Search space drastically reduced to a small sector
- Cons
  - Bad calculated trajectory still a problem.

Rotation

- Pros
  - Low computational complexity.
  - Very robust for blurred images also
- Cons
  - Need to search for multiple positions in the exposure time, as the exposure time and accelerometer data are not synchronized.
  - Does not compensate for translation.
- Improvements
  - Adding gyroscope can aid in translational registration also.

Future Developments

- Mobile application is very versatile. Can be used for developing computational photography algorithms like video stabilization and super resolution
- All the algorithms we implemented are computationally cheap. Can be ported to the mobile platform with ease.
- Lot more can be done in deblurring by developing semi-blind algorithms or multi-channel algorithms.

Conclusion

- Mobile is a very versatile platform.
- Motion sensors very useful for various image processing applications. More accuracy and lesser computational load.
- Project has a lot of future scope for development.