Flutter Shutter Video Camera for Compressive Sensing

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Image formation model





Low-speed images work for static scenes

Video capture of high-speed scenes



open

shut



Video capture of high-speed scenes



Rich video on a voxel budget





1 Megapixel x 30 fps 175 x 175 x 1000 fps

30 million voxel budget

Increasing fps decreases light throughput

Video formation model



Optical coding approaches

Spatial-muliplexing

Single Pixel Camera [Wakin et al. 2006]

-Complex hardware -Full control of A

Per pixel sensor control

Flexible Voxels Gupta et al. 2011] CPEV [Hitomi et al. 2010,

-Implement on CMOS -Single bump per pixel per frame

Per pixel shutter control

P2C2 [Reddy et al. 2011]

-LCOS -Per pixel coded exposure



Exposure

Global shutter control

FSVC – Global shutter control

Recovering x

= Ax



• Goal is to find $\hat{x} \approx x$

Use scene assumptions to guide reconstruction

Scene assumptions

Periodicity

Coded Strobing [Veeraraghavan et al. 2011]



80x

Linear with known velocity

Flutter Shutter [Raskar et al. 2006]





Linear dynamical systems

CD-LDS [Sankaranarayanan et al. 2010]



20x-50x

General motion

Flexible Voxels [Gupta et al. 2010] P2C2 [Reddy et al. 2011] CPEV [Hitomi et al. 2011] FSVC

6x-16x

Recovering high-speed video

Locally linear motion model
Union of subspaces (UoS)

General motionTV minimization

Union of subspaces (UoS)



dimensional subspace

High-speed PCA subspace approx.

Union of subspaces (UoS)



Patch based reconstruction

Patch recovery with UoS prior

Speed = 1.38 pixels/high-speed frame Direction = 61° 0.15 $\|y - \hat{y}\|$ 0.1 $\|y\|$ 0.05 $\frac{0}{2}$ 1.5 100 150 200 250 300 350 Speed 0.5 50 0 0 (pixels/frame) θ v^* : speed = 1.35, θ = 63°

Recovery with UoS prior





 ${\mathcal X}$

TV minimization recovery

Videos have sparse gradients

$$\hat{x} = \underset{x}{\operatorname{argmin}} \|y - Ax\| + \lambda \|\nabla x\|_{1}$$

 Use TVal3 to perform fast reconstruction on XT slices

Union of subspaces recovery (6x)

Hairnets advertisement placard moving right



TV minimization recovery (6x)

Dancer clapping causes a chalk cloud to form



Experimental setup

PointGrey Machine Vision cameras were used to simulate FSVC

Flea3 grayscale camera operating at 8 fps



Real data results 6x (UoS)

Observed frames



Recovered video (6x)



Conclusions



Hardware complexity



Questions?