

Fast temporal reprojection without motion vectors

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motivation

a lot of coherence on the table, re-rendering similar things every few milliseconds!



image: Schied et al. *Gradient Estimation for Real-Time Adaptive Temporal Filtering* 2018

- many methods use motion vectors, for instance
 - temporal anti aliasing (TAA)
 - screen space adaptive importance sampling (ReSTIR)
 - input to (recurrent) neural networks

motion vectors

motion is incoherent, contradicting, and hard to track analytically!



"Seascape" by Alexander Alekseev aka TDM

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related work: path space

- possible to track every path space effect separately (do we want that? does it scale?):
- Zimmer et al. Path-space Motion Estimation and Decomposition for Robust Animation Filtering (EGSR 2015)
- Zeng et al.

Temporally Reliable Motion Vectors for Real-time Ray Tracing (CGF 2021)



related work: image space

Hasinoff et al.

Burst photography for high dynamic range and low-light imaging on mobile cameras (TOG 2016)

Darbon et al.

Fast nonlocal filtering applied to electron cryomicroscopy (Biomedical imaging 2008)

Burst photography for high dyna on mobile	amic range and low-light imaging e cameras	FAST NONLOCAL FILTERING APPLIE	D TO ELECTRON CRYOMICROSCOPY
Samuel W. Hasinoff Dillon Sharlet	Ryan Geiss Andrew Adams	Jérôme Darbon ¹ , Alexandre Cunha ² , Tony	F. Chan ¹ , Stanley Osher ¹ , Grant J. Jensen ³
Jonathan T. Barron Florian Kainz Google I	Jiawen Chen Marc Levoy Research	¹ Department of Mathematics, Un ² Center for Advanced Computing Rese ³ Division of Biology, Calife	iversity of California Los Angeles arch, California Institute of Technology ornia Institute of Technology
		{jerome, chan, sjo}=math.ucla.e	du, {cunha,jensen}≅caltech.edu
	al las	ABSTRACT	
		We present as officient algorithm for norhead amage filtering with a rewriting of the recently proposed mode almass filtering with the separable property of neglaborhood filtering to offer a fast parallel and vesturised implementations in contemporty whether and memory complexity of the registration of the separable property of fast that a straik, non-vesturical implementation and it sades linearly with image size. We demonstrate is officiency in data stars from <i>Canaba neur concernent transgrams</i> and a separation generating to the separability of the separation of the second strain from the second strain of the second strain strain second strain from the second strain second strain second strain second strain from the second strain second strain second strain second strain from <i>Canaba neuron</i> second strain second strain second strain from <i>Canaba neuron</i> second strain second strain second strain second strain second strain second strain second strain second strain second strain second strain second strain second strain from <i>Canaba neuron</i> second strain second strain second strains from <i>Canaba neuron</i> second strains second strains second strains from <i>Canaba neuron</i> second strains strains second strains second strains second strains strains second strains second strains strains second strains second strains second strains strains second strains second strains second strains second strains strains second strains second strains strains second st	$F_{E} \ 1. This composition shows a section of a typical low contractory of the proton of the typical process of the proton the level of the size nor applying our filter. $
Figure 1: A comparison of a conventional camera pipeline (left, mid	idle) and our burst photography pipeline (right) running on the same	of the nonlocal means scheme in the context of cryoimaging. With such development we provide biologists with an attractive filtering tool to facilitate their scientific discoveries.	 a challenging problem. First and foremost, the amount of noise i significantly high (see Fig. 1), far beyond what is commonly foun in regular photography and other microscopy technologies. A signa
Figure 1: A comparison of a convertional cancers pipeline (efg. mi chiphone cancers. In this low-light setting (about 0:2 last), the com (middle preveals hower spatial densiting, which result densiting converses the signal boosties with, which generated densiting artifact pres, so it can be deployed on a mobile cancer and acade as a caldulatity the figure has been made and preselve by high term the every calculativity of generates have made and preselve by high term the every	they and ear heart photography pipeline (right) ranning on the same entroid converse pipeline inderexpose (right). Brightming the image al and an implementary blockby appearance. Fusing a larrar of images are supervisored to the second second second second second and the second second second second second second second abstitute for the convertised pipeline in almost all circumstances. For al photographs.	of the nonlocal means scheme in the centre of cryoimaging. With such development we provide hologins with an attractive filtering root to facilitate three scientific discoveries. Inter Terrom – Norkola mean filtering, image devising, electron cryomicroscopy, image vectorization, SIMD, parallel image processing. 1. INTRODUCTION	a challenging problem. First and foremost, the answard of noise significantly high (see Fig. 1). In the word what is commonly four in regular photography and other microscopy technologies. A signation to noise ratio of 1 is down is not uncommon [1]. Second, large, high resolution images are the rule and the trend is to continue interesting the CCD resolution to chain images with the vesh inder levels of data that compares the rule of the rule high resolution in the CCD resolution of an isotration in the single can be even limited as the rule of the rule high resolution in the rule high resolution limited is a neutrino of interest is 10 the high rule and we work with limited in a neutrino of interest is 10 the high rule and we work with the rule of the rule (1) the rule of the rule (1)
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Figure 1: A component of a survey state of the state of t	Ethy and our hurst photographic phytoletter (19(k)) reasoning on the same ain an unperlocately blockly appearance. Fasting a barr of magin generectary. Be encourage the reader to soon in. Wile energy phytole- tation of the source of the source of the source of the source and honorogenetics. New works: computational photography, high dynamic trage Concepts: Comparing methodologies - Comparational pho-	of the nonlocal mones scheme in the control of cryomaging. With our development responsible loopings with an attractive fibration of the facilitate three scientific discoveries: the factor of the science of the science of the science processing. 1. INTRODUCTION Elseven cryomicsmoothy at markable technology enabling new discoveries at subcellular scale. Stadies at such scale and new discoveries at subcellular scale.	a challenging problem. First and foremost, the answare of robic significantly high (see Fig. 1), the freedom whit is sommored) from the term of the source of the source of the source of the source of the network of the source of the source of the source of the source of the source of the source of the source of the source of the source of source of the source of the source of the source of the source of the source of the source of the source of the source of the source of the source of the source of the first, strengther of the source (12), solida are a fore points with the source of the point of the source of the source of the source of the point of the source of the source of the source of the source likely solved and beneficient of the moment- son likely solved and beneficient of the source of the source of the source likely solved and beneficient on the source of the source likely solved and beneficient on the source of the source likely solved and the source of the source of the source likely solved and the source of the source of the source likely solved and the source of the source likely solved and the source of the source likely solved and the source likely so
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we'll combine ideas from these last two to arrive at a fast technique

shift images against each other and take difference [Darbon et al. 2008]



 \blacktriangleright shift images against each other and take difference s=(0,0)



black is better: zero shift looking pretty good for the static parts!

 \triangleright shift images against each other and take difference s=(0,250)





 \triangleright shift images against each other and take difference s=(250,250)



shift images against each other and take difference s=(250,0)



- this could be good for the moving circle
- input is noisy, pixel difference doesn't tell us much
- use patch-based difference, equivalent to blurring the difference images [Darbon et al. 2008]

 \triangleright shift images against each other and take difference s = (0,0)





 \triangleright shift images against each other and take difference s=(0,250)





 \triangleright shift images against each other and take difference s=(250,250)





 \triangleright shift images against each other and take difference s=(250,0)



which shift vector s has the smallest error for each pixel?

$$s = (0,0)$$
 $s = (0,250)$ $s = (250,0)$ $s = (250,0)$

. . .

(50, 250)

.

implementation



acceleration: hierarchical matching

 \triangleright enables smaller windows |S| (we use 5x5)



- enforces coherence/smoothness (a good thing?)
- offset vectors limited to one of the discrete shifts we tested!

smooth upsampling of offsets [Hasinoff et al. 2016]

- generate "landscape" of distance values in 5x5 grid (for each pixel)
- fit quadric, compute minimum
- subpixel offsets from low res matching buffers!

	$s_x = -2$	$s_x = -1$	$s_x=0$	$s_x = 1$	
$s_y = -2$	• • •	• • •	• • •	• • •	
$s_y = -1$	• • •	• • •	• • •	• • •	
$s_y=0$	• • •	• • •		• • •	
$s_y = 1$	• • •	• • •	• • •	• • •	
$s_y=2$	• • •	• • •		• • •	



blur

- fast blur on array of textures?
 - we use Kawase style blurs (on low res buffers)
 - requirement: need to preserve extrema of non-downsampled blur!
 - see our source code for current version (I'm sure this can be improved)

applications

- b this work is only dealing with offset/motion vector detection!
- no image merging/denoising/TAA!
- lots of applications in the paper





one more result (not in the paper)

- TAA for ray tracing with per-pixel filter importance sampling
- sample 3x3 Blackman/Harris

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vec2 res = vec2(cos(rand.y*M_PI*2.0), sin(rand.y*M_PI*2.0)); float r = 0.943404 * asin(0.636617 * asin(sqrt(rand.x))); // surprisingly good fit to inverse cdf return res * r;



let's look at some videos

- setting:
 - matching on AOV buffers
 - ⊳ 5x5 blur
 - 1920x1080
 - RTX 2080Ti
- will show two variants: full res and 4x4 subsampled input

offsets without subsampling: 5ms

the second and a second second second second second second second



offsets 4x4 subsampling: 0.5ms

Spectrum and a second a second as the



TAA without subsampling



TAA with 4x4 subsampling



accuracy vs. performance

the 4x4 has *better* edges because it doesn't undo the pixel filter importance sampling!





accuracy vs. performance

the 4x4 has *better* edges because it doesn't undo the pixel filter importance sampling!





conclusion

- **b** there may be inconsistent motion vectors even for one pixel
 - objects
 - shadows
 - reflections
 - procedural noise / water / clouds / fire ...
- coherence often works/helps to speed things up
 - work on downsampled buffer!
 - careful: don't enforce coherence where there is none

conclusion contd.

- presented a relatively fast technique for "motion vectors" in image space
 - 0.5ms / 1080p / 2080Ti (5x5 blur, 4x4 subsampling)
 - can still compute motion vectors in layers as [Zeng et al. 2021] at least don't have to manually run after each effect
- future work
 - how to optimally combine aligned frames for denoising? AMD FSR 2.0?
 - optimise more for speed!

thank you for listening!

code on github

https://github.com/hanatos/vkdt/tree/master/src/pipe/modules/align

updated occasionally

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hanatos align: fix merge trouble		503859b 6 minutes ago 🕥 History
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🗅 down2.comp	align: move from burst and fix feedback stuff in graph	
🗅 down4.comp		
🗅 flat.mk		
🗅 half.comp	align: enable 4x4 and fix some upsampling problems	
🗅 main.c		
🗅 mask.comp		
T merge.comp		
🗅 params		
🗅 readme.md		
🗅 var.comp	align: move from burst and fix feedback stuff in graph	
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image alignment		

this module is an implementation of Johannes Hanika, Lorenzo Tessari, and Carsten Dachsbacher, Fast temporal reprojection without motion vectors, Journal of Computer Graphics Techniques, 2021. it can be useful to align consecutive frames in real-time renders, as well as to stack hand-held short exposure photography for low-light or hdr.