Radiance 4.2 Changes for 2014

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Highlights

• Official 4.2 release (finally!)
• Improved Perlin noise function
• Improved sampling appearance in rpict
• New “origin” command in rvu
• Hessian-based error control for irradiance caching
• New getinfo -c option
• rcollate and rmtxop utilities manipulate matrices
• rfluxmtx program to simplify rcontrib operation
Radiance 4.2 Release

• Last official release (4.1) was November 2011
• Most people continue to use the CVS HEAD, which is also compiled and available from NREL
• Even so, it’s good to make it official when a stable point is reached
• It seemed like it was time
Improved Perlin Noise Function

• Original implementation did not follow Perlin’s version very closely
  – not as band limited as it should be
  – had issues with over-range values

• New implementation based on Perlin’s improved version from 2002 SIGGRAPH
  – translation from java by Rahul Narain
  – much nicer output
Improved Perlin Noise Function

Original implementation

New & improved version

Blue regions are outside (-1,1) range
Improved Perlin Noise Function

Marble using original noise

Marble using improved noise
Improved RPICT Sampling

• With `-u0` (default) option, `rpict` uses anti-correlated sampling
• Original implementation gave pixels a “brushed” appearance
• New implementation uses a 2-D Hilbert space-filling curve to improve appearance
Improved RPICT Sampling

Old “brushed” look

New “screen door” look
Improved RPICT Sampling

Old “brushed” look

New “screen door” look

Easier to see section from windscreen
New RVU “origin” Command

• Suggested by John Mardaljevic
• Provides a convenient means to get “fly on the wall” view
• Helpful for debugging light leaks, etc.
• Usage:
  
  origin [xo yo zo [ xd yd zd ] ]
  
  Without arguments, use cursor to choose surface to look away from...
RVIEW “origin” Command

Follow “origin” command by selecting the surface position where you want your new view point to be placed, looking in the direction of the surface normal.

The “up” vector will be changed automatically if the normal vector coincides with the current one, unlike other view commands.
RVIEW “origin” Command

The new view will have the same type and size as the previous one, to be consistent with other rvu commands. This can be changed with a subsequent “view” command.
RVIEW “origin” Command

Oftentimes, the user will want to change the view to a hemispherical fisheye or similar to study the light arriving at the surface point.

view -vth -vh 180 -vv 180
Hessian-based Error Control in Irradiance Cache

• The Hessian matrix holds 2\textsuperscript{nd} order derivatives or “curl” of a multi-dimensional scalar function

• In *Radiance*, we can use it to bound errors in the indirect lighting calculation

• The Hessian tells us what errors to expect as we extrapolate a cached irradiance value

• This in turn tells us how closely to space our calculations to maximize efficiency
Practical Hessian-Based Error Control for Irradiance Caching

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Figure 1: Our new Occlusion Hessian significantly outperforms both the Pure and the Bounded Split-Sphere (clamped to the gradient and 150px max spacing) for irradiance caching. It also performs significantly better than the recently published occlusion-unaware Hessian error metrics by Jarosz et al. [2012].
This paper introduces a new error metric for irradiance caching that significantly outperforms both the Pure and the Bounded Split-Sphere heuristics. Our new Occlusion Hessian significantly outperforms both the Pure and the Bounded Split-Sphere heuristics, by enforcing the triangle inequality between cache records, and maximum radii constraining the radius based on the gradient and bounding the allowed error. Unlike the Split-Sphere heuristic, it is not necessary to arbitrarily clamp the comarbitrary hemispherical sample distributions and it supports elliptical error bounds.

The decision of whether to interpolate or not is central to the quality and efficiency of the algorithm. Ward et al. proposed to determine maximum radii to approximate an upper bound on the rate of change of irradiance at the cache point. This basic approach produces unacceptable results in many more cache points. Unfortunately there are many common failure cases where this basic approach produces unacceptable results. This has led to several modifications and additions to the original metric to more robustly deal with such failure cases, by ex-G clampimg to minimum and maximum values whenever possible.

The table below summarizes how the new error metric builds on recent work using second order gradients and improves the accuracy of the Hessian in complex scenes, and this makes it possible for the first time to use a radiometric error metric. It also performs significantly better than the recently published occlusion-unaware Hessian error metric. It also augments a suboptimal heuristic and, in the process, introducing many more parameters, which makes it more difficult to control the many more corrections, though they demonstrated that this idea shows promise their preliminary investigation fell short of a full practical implementation. Instead of modifying the original heuristic, Jarosz et al. analyzed global illumination, instead of modifying the original heuristic, and proposed an alternative. While analyzing global illumination, they showed that the cache point radii could be derived from an irradiance Hessian instead of the Gradient, and showed how this could potentially be applied to obtain an improved error metric for irradiance caching. The core idea was to use a second-order Taylor expansion as a principled approach to improving the accuracy of the algorithm. Ward et al. proposed to determine maximum radii to approximate an upper bound on the rate of change of irradiance at the cache point. This basic approach produces unacceptable results in many more cache points. Unfortunately there are many common failure cases where this basic approach produces unacceptable results. This has led to several modifications and additions to the original metric to more robustly deal with such failure cases, by enforcing the triangle inequality between cache records, and maximum radii constraining the radius based on the gradient and bounding the allowed error. Unlike the Split-Sphere heuristic, it is not necessary to arbitrarily clamp the arbitrary hemispherical sample distributions and it supports elliptical error bounds.

The table below summarizes how the new error metric builds on recent work using second order gradients and improves the accuracy of the Hessian in complex scenes, and this makes it possible for the first time to use a radiometric error metric. It also performs significantly better than the recently published occlusion-unaware Hessian error metric.
Improved Sampling of Hemisphere

Theta/Phi Sampling Pattern

Shirley-Chiu Sampling
Example Scene

NRC cubicle office with 3M daylight redirecting film
Irradiance Cache Comparison

Old cache value placement  New cache value placement

Approx. 1/3 as many values for similar accuracy
Cruiser Model (1)
Cruiser Model (2)
Cruiser Model (3)
Cruiser Model (4)
Issue with T-junctions

Old value placement  Evaluation point safe from other side
Issue with T-junctions

New value placement
Evaluation point sees other side

Result: indirect illumination where there should be none
Issue with T-junctions

• Nearly fatal flaw, unnoticed by authors
  – spoke with Wojciech & Henrik; they said it did not show up in any of their test scenes (no T-junctions)
  – most fixes reintroduce issue with packed corners

• After 3 or 4 failed attempts, I found a fix
  – add visibility check on certain cache values
  – store “corral” flags identifying possible occluders
  – solves issue without crowding values in corners
Issue with T-junctions

New value placement  Short ray test finds obstruction

Only test when corral says there’s a hazard
Assigning Corral Flags

Set of 32 corral flags indicate potential occluders

These directions will be checked with short rays before extrapolation
Results Comparison

Schwarzhaupt et al.  

With corral check
Changes from User Perspective

• Old ambient files will not be recognized
  – new structure adds elliptical radii & corral flag
  – more compact representation

• Adjusted -aa to match old behavior, rather than target actual accuracy
  – too sensitive and difficult to control otherwise

• Other options are essentially the same

• Compile with -DOLDAMB to get old behavior
New `getinfo -c` Option

• Hacker’s option to manipulate data segment
• Runs the given command after header, as if:
  
  `( getinfo < file ; \ 
    echo $command ; \ 
    getinfo - < file | $command )`

• Example:
  
  `getinfo -c rcalc -if -of -e ‘$1=10*$1’ < input.mtx > output.mtx`
New \texttt{rcollate} and \texttt{rmtxop} Comands

- General multi-component matrix operations
- \texttt{rcollate} “reshapes” matrix data, changing $N_1 \times M_1$ matrix into $N_2 \times M_2$ matrix (same number of elements)
  - can “transposes” matrix elements $N \times M \Rightarrow M \times N$
  - adds/removes/manipulates header
- \texttt{rmtxop} loads matrixes into double arrays, concatenates, scales, sums, transforms
Matrix File Format

```plaintext
#?RADIANCE
gendaymtx -of nyc01.sp1.wea
LATLONG= 42.75000000 -73.80000000
NROWS=146
NCOLS=8760
NCOMP=3
FORMAT=float

followed by binary float data,
row is outer sort, then columns, then components
...

The file above is 146*8760*3*4 bytes = 14.6 Mbytes
```
rcollate Details

• Never interprets data elements
  – fast: ASCII components are copied as text blocks
  – can transpose very large matrix by mapping file
  – useful for feeding rcalc & converting its output
  – however: cannot convert data between formats

• Flexible regarding information header
  – can work without header (-h)
  – can add missing header (-hi)
  – can remove unwanted header (-ho)
rcollate Examples

Feed rcalc one RGB record at a time & remove header:
rcollate -oc 1 -oh input.mtx | rcalc -e ‘$1=$1+$2+$3’

Transpose a 100×25 2-comp. float matrix w/o headers:
rcollate -h -ir 100 -ic 25 -ff2 -t input.mtx > output.mtx

Add a header to binary data as required by rmtxop:
rcollate -ih -ir 30 -ic 19 -fd3 input.mtx | rmtxop ...
rmtxop Details

• Reads matrix data, operates in memory
  – minimal header information needed:
    • NCOMP, NROWS, NCOLS, format
  – also accepts Radiance pictures and BSDF (XML) files
  – writes ASCII, float, double, and RGBE formats
  – has as many as 3 matrices in RAM at a time
    • uses double type (8-bytes/component) for all input

• More flexible than dctimestep
  – but somewhat less memory- & time-efficient
    • dctimestep uses float data, optimizes matrix multiplication
**rmtxop Examples**

Convert matrix BSDF to picture:
```
rmtxop -fc bsdf.xml > bsdf.hdr
```

Concatenate matrix from *stdin* and write as ASCII:
```
... | rmtxop -fa left.mtx  > output.mtx
```

Convert RGB matrix to grayscale and add another:
```
rmtxop -c .3 .6 .1 rgb1.mtx + gry2.mtx > gryout.mtx
```

Concatenate three matrices, transposing second:
```
rmtxop inp1.mtx -t inp2.mtx inp3.mtx > out.mtx
```
New rfluxmtx Program

• Long-promised front-end to rcontrib
• Simplifies common operations
  – generates hemispherical surface samples
  – sets rcontrib bin variables and *.cal files
• Generalizes sampling for light pipes, etc.
• Replacement for genklemsamp
  – will also simplify genBSDF implementation
Basic `rfluxmtx` Operation

`rfluxmtx [-v][rcontrib options] sender.rad receiver.rad [-i system.oct][system.rad ..]`

- Most options are simply passed to `rcontrib`
  - the `-v` option reports on execution
- Sender file contains single sender object
  - special comments identify sampling basis
- Receiver file contains one or more objects
  - similar comments indicate sampling bins
- System files given to `oconv` before `receiver.rad`
Comparison to genklemsamp

```bash
ovconv -w -f material_detailed.rad simple.rad \
  dummysky.rad > dumbsky.oct

genklemsamp -vd -0.415671599 0.909514773 0 -c 20000 \
  material.rad bg4wind.rad \
  | rcontrib -n 2 -c 20000 -faf -e MF:4 -f reinhart.cal \
    -b rbin -bn Nrbins -m skyglow \
    @rtc_dmx.opt dumbsky.oct \n  > bg4.dmx
rm dumbsky.oct

rfluxmtx -v -n 2 -c 20000 -ff @rtc_dmx.opt bg4wind.rad \
  dummysky.rad -w material.rad simple.rad \n  > bg4.dmx

rfluxmtx: opening pipe to: rcontrib -fo+ -n 2 -w -ab 2 -ad 300 -fdf -c 20000 \n   -f reinhartb.cal -p MF=4,rNx=0,rNy=0,rNz=-1,Ux=0,Uy=1,Uz=0 \n   -bn Nrbins -b rbin -m skyglow -b 0 -m groundglow -y 145 \n  'oconv -f -w material.rad simple.rad dumbmysky.rad'

rfluxmtx: sampling 145 directions
```
Sender File

rfluxmtx -v -n 2 -c 20000 -ff @rtc_dmx.opt bg4wind.rad \
dummysky.rad -w material_detailed.rad simple.rad \
> bg4.dmx

#@rfluxmtx h=kf u=+Z

Translucent_20 polygon zone02.rad00014b
0
0
12
-0.733460650921  11.5416867963  0.762
-0.733460650921  11.5416867963  2.7178
0.652638345832  12.1751696194  2.7178
0.652638345832  12.1751696194  0.762

No need to define material “Translucent_20”
Receiver File

rfluxmtx -v -n 2 -c 20000 -ff @rtc_dmx.opt bg4wind.rad \
  dummysky.rad -w material_detailed.rad simple.rad \
  > bg4.dmx

void glow skyglow
  0
  0
  4 1 1 1 0

skyglow source sky
  0
  0
  4 0 0 1 360

void glow groundglow
  0
  0
  4 1 1 1 0

groundglow source ground
  0
  0
  4 0 0 -1 180

Separate (uniform) ground source
Advantages of rfluxmtx

• Simpler operation
  – manages rcontrib parameters/order
  – generates source sample rays
• Handles non-planar sources & receivers
• Unifies hemispherical sampling methods
  – consistent application of Tregenza & Reinhart sky, Klems hemispherical bases, Shirley-Chiu disk
• Sender & receiver need not be parallel
• Receiver may be reused as subsequent sender
Pass-through Mode

• Specify ‘-’ in place of sender file, e.g.:
  
  sample_generator | rfluxmtx [options] - receiver.rad

• *rfluxmtx* executes *rcontrib*, but does not generate sample rays
  
  – standard input is sent to *rcontrib* directly

• Same behavior as executing command reported by *-v* option
  
  – provided primarily as a convenience
Example Pass-through Mode

vwrays -ff -vf back.vf -x 600 -y 600 \ 
  | refluxmtx -v `vwrays -vf back.vf -x 600 -y 600 -d` -n 4 \ 
  -ffc -ab 12 -ad 50000 -lw 2e-5 - window.rad testroom.mat testroom.rad

refluxmtx: running: rcontrib -fo+ -n 4 -ab 12 -ad 50000 -lw 2e-5 -x 600 -y 430 \ 
  -ld- -ffc -c 1 -o vmx/window_%03d.hdr -f klems_full.cal \ 
  -bn Nkbins -b 'kbin(0,1,0,0,0,1)' -m windowglow \ 
  '!oconv -f testroom.mat testroom.rad window.rad’

#@refluxmtx h=kf u=Z o=vmx/window_%03d.hdr

void glow windowglow
  0
  0
  4 1 1 1 0

windowglow polygon window
  0
  0
  ...

...
Conclusions

• Radiance 4.2 release is official
• Includes new Hessian-based “ambient” calc
• Many(!) other improvements since 4.1
• New rfluxmtx program present, but still undergoing bug fixing & improvements
  – Keep up-to-date with CVS HEAD if interested
• Photon-mapping integration building on 4.2