## Coherent radiance capture of scenes under changing illumination conditions for relighting applications

Céline Loscos
CReSTIC-SIC
Université de Reims Champagne-Ardenne

## Motivation

- We can use reality as a basis and enhance it with virtual modifications
  - Object insertion/removal
  - Relighting
- Usually needs some knowledge about
  - Geometry
  - Illumination


## General Problems with Complex, Uncontrollable scenes

- Geometry
  - Some (outdoor) scenes contain **many details difficult to model**
    - buildings, trees, fauna, people, cars, …
  - Some (outdoor) scenes are **less easy to control**
    - people passing, cars driving, objects moving because of wind

## General Problems with Complex, Uncontrollable scenes

- Illumination
  - Complex illumination
    - direct: Sun
    - indirect: Sky & Objects
  - Difficult to control
    - sun intensity too high to capture with camera
    - clouds drifting in sky have significant effect on stability outdoor illumination

## Solutions

- Geometry
  - by using image processing techniques as shadow detection/object recognition, geometry loss can be compensated for
  - movements during HDRI capturing can be compensated

## Solutions

- Geometry
- Illumination
  - detect illumination changes and compensate
  - use homogenous filter to reduce sun intensity
  - capture light probe at different positions in the scene
  - …

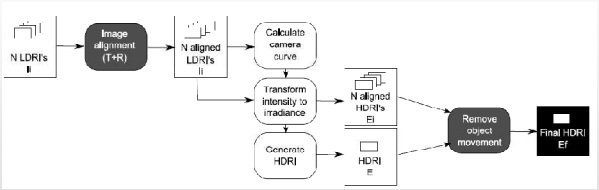
## Automatic generation of HDRIs for dynamic scenes

K. Jacobs, C. Loscos, G. Ward, IEEE Computer Graphics and Applications, 2008.

## Capturing radiance

- Take photographs
- Convert the colour value to radiance
- Use of HDR composition

## HDR traditional pipeline



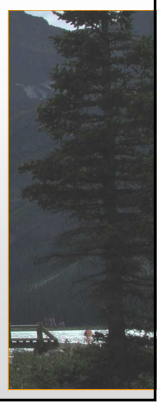

## Example 1

- LDR sequence (Low dynamic range)

- Problems and expected solution

## Example 2

- Ghosting



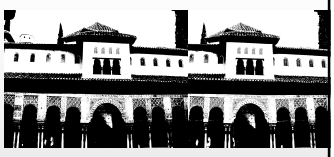
## Methodology

1. Alignment exposures using MBT prior to camera curve calibration
2. HDRI generation proceeds in the usual manner
3. Detect pixels in HDRI that correspond to motion region in the different exposures (HCM & LCM)
4. Substitute those pixels in the HDRI by the values from 1 exposure
5. Choose the exposure that shows the least saturation for this particular region

## Alignment

MBT: median bit transform

- Threshold each exposure with the median intensity value, for each exposure use a different threshold
- Calculate translational misalignment
- Calculate rotational misalignment
- Iterate between the two



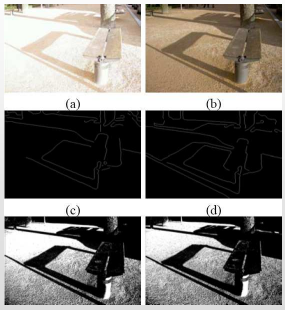
MTB

Canny edge detector

## Example 2

Canny edge detector

MTB




## Alignment sequences

Unaligned

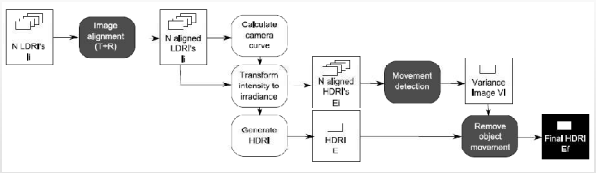
Aligned

## Detection of movement

HCM: high contrast movement

- Background and moving objects have high contrast
- Motion pixels show high variance between different exposures
- Calculate variance image and threshold, dilate and erode image to extract regions of pixels in motion area


## HDR Methodology with the movement detection




## Detection of movement

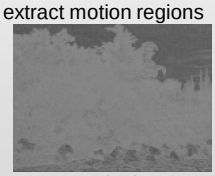
LCM: low contrast movement

- background and moving objects have low contrast
- Variance will be low in motion regions

## Detection of movement

LCM: low contrast movement

- Background and moving objects have low contrast
- Variance will be low in motion regions
- Different measure based on entropy
- Calculate uncertainty image and threshold, dilate and erode image to extract motion regions

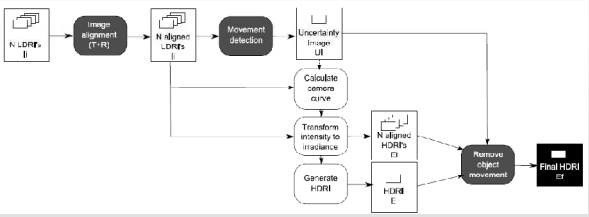


uncertainty image

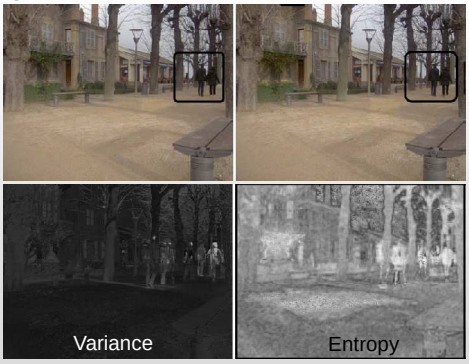
## Detection of movement

LCM: low contrast movement

## HDR methodology with LCM detector




## Comparison




## Conclusion

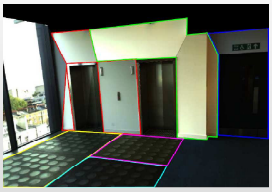
- It is possible to apply robust methods
  - To align a sequence of LDR images
  - To detect regions of movement in a sequence of LDR images
- Limitations
  - Regions of movements are LDR in the final HDR

## Coherent radiance capture of scenes under changing illumination conditions for relighting applications

K. Jacobs, A. Hjorth Nielsen, J. Vesterbaek, C. Loscos
Springer Visual Computer, 26(3), March 2010

## Introduction

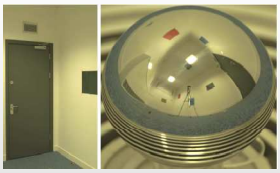
- Problem: illumination changes during the capture process



- Solution: capturing the illumination during the capture process

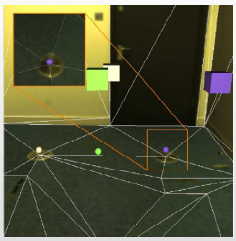
## Capturing the illumination with a reflective ball

- Take two pictures for each capture
  - Pic 1: The environment
  - Pic 2: A reflective ball close to the environment
- Pic 1 is used for geometry reconstruction and radiance representation
- Pic 2 represents the overall illumination at the time when Pic 1 was taken
- Idea: no recording on where the ball is



## Registering the illumination with the model

- Use of a semi-automatic method to register the position of the ball in the scene
  - Use of the reconstructed model
  - Point matching between the scene points in the environment and the ball



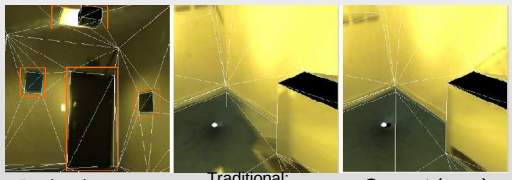
## Measured errors

| | | M (cm) | E (6) | E (>6) | D (6) | D (>6) |
|---|---|---|---|---|---|---|
| LP1 | x | 70.73 | 74.69 | 72.60 | 5.57 | 2.52 |
| | y | -2.02 | 1.70 | -0.36 | | |
| | z | 189.88 | 188.67 | 189.61 | | |
| LP2 | x | 80.16 | 83.77 | 81.08 | 4.95 | 2.95 |
| | y | -1.14 | 2.08 | 1.53 | | |
| | z | 63.91 | 64.94 | 64.77 | | |
| LP3 | x | 248.31 | 246.99 | 248.38 | 3.31 | 1.04 |
| | y | -13.03 | -10.32 | -12.10 | | |
| | z | 133.58 | 132.22 | 134.04 | | |

**Table 1** Modelled (M) and Estimated(E) positions of the light probes shown with exactly 6 points of input and between 15 to 20 points, and the difference (D) in centimeters of three light probes LP1, LP2, and LP3.

## Projecting the radiance to the local scene

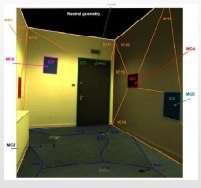
- In order to calculate reflectance properties or illumination, needs of knowing surface radiance
- Projection of the radiance captured on the mirror ball onto the reconstructed objects
- No assumption that objects are far



Projection | Traditional: incorrect | Correct (ours)

## Coherent BRDF estimate

- For each surface, estimate its BRDF (diffuse)



Model description

Diffuse reflectance 1 pass

Diffuse reflectance Coherence

## Results

- Simulation of the original scene

Simulated Original Difference

## Results

- Relighting and object insertion

Original Simulated Virtual object insertion

## Video

## Conclusion

- Uncontrollable environments are reality
  - Necessity of methods
    - To capture them
    - To work with them
- It is possible to capture radiance
  - Of a scene with moving objects
  - Of a scene with changing illumination

## Possible improvements

- Less user intervention
- Work with video stream
- HDR radiance values in areas of movements
- Physically accurate estimation and relighting

## Thank you