



A 1.3 megapixel FPGA-based smart camera for High Dynamic Range real-time video

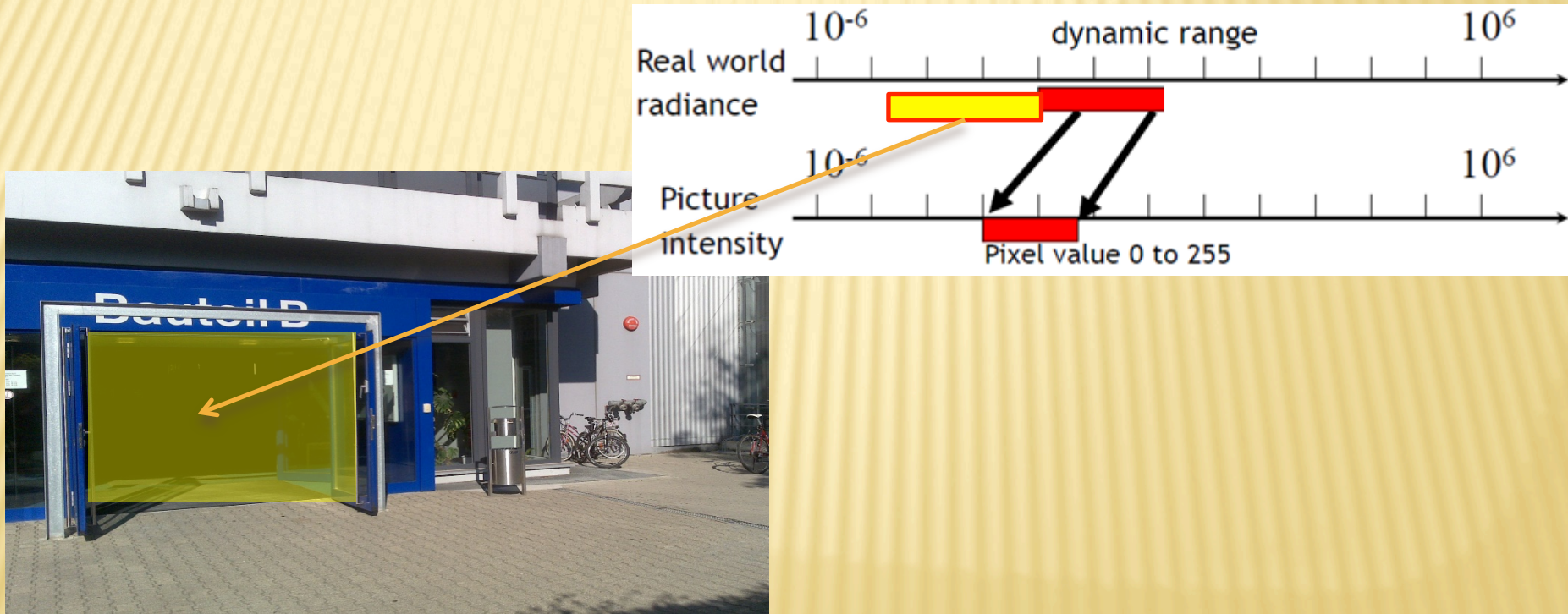
Pierre-Jean Lapray, Barthélémy Heyrman
and Dominique Ginjac
LE2I, University of Burgundy, DIJON

ICDSC'13
NOVEMBER 2013, PALM SPRINGS, USA

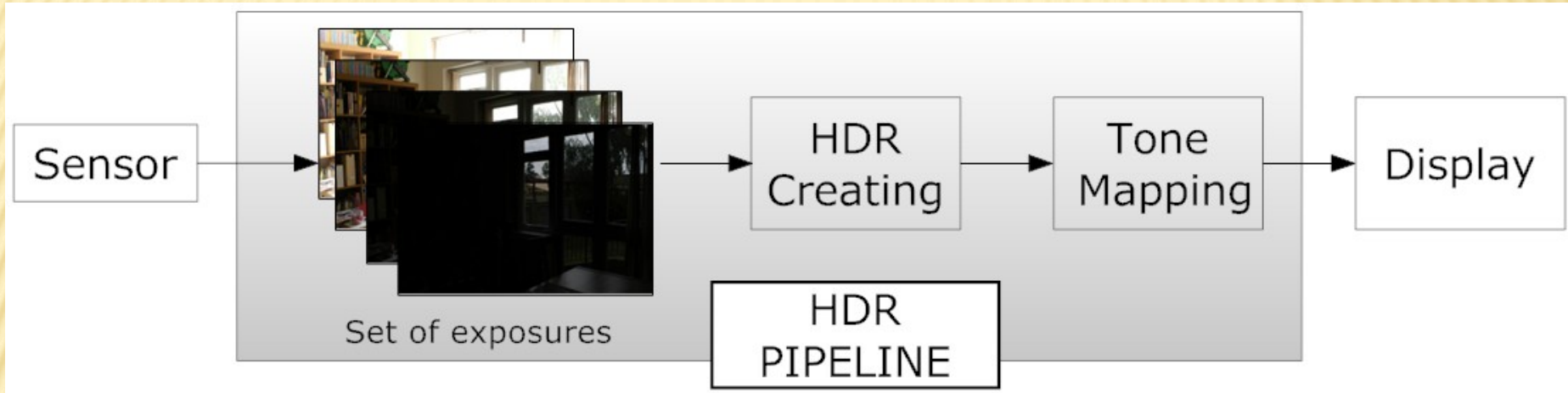


HIGH DYNAMIC RANGE IMAGING (HDR)

- ✗ Dynamic range is the ratio between the maximum (white) and the minimum (black) measurable light intensities.



HIGH DYNAMIC RANGE IMAGING (HDR)



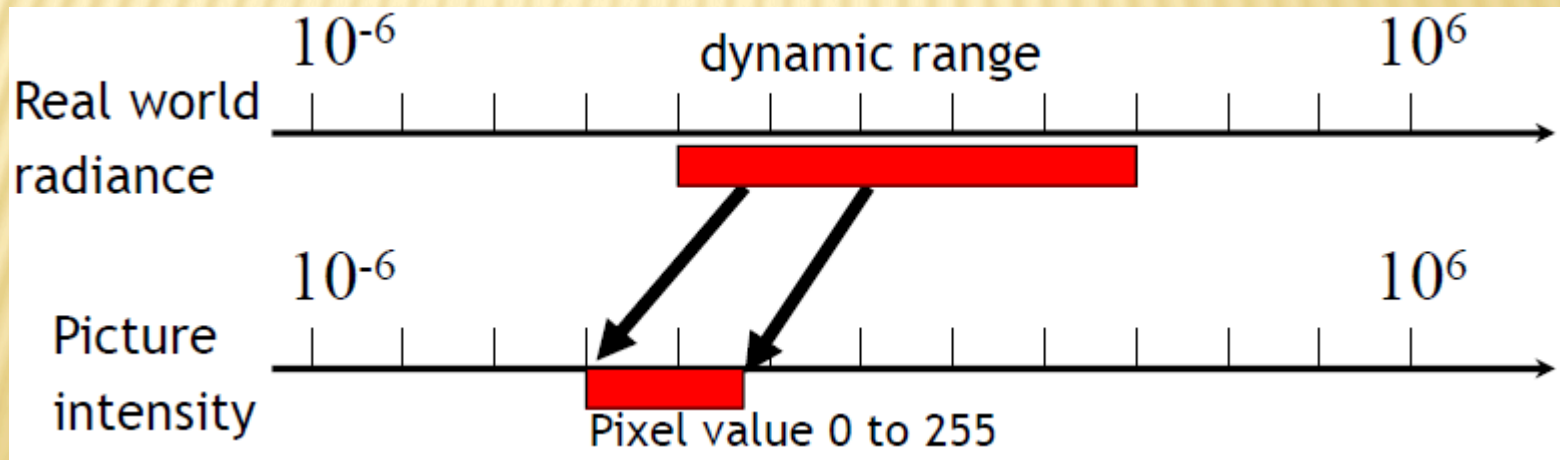
EXAMPLE of
DISPLAYED
RESULT

SET OF EXPOSURES

EXP=1/125s



EXP=1/2s

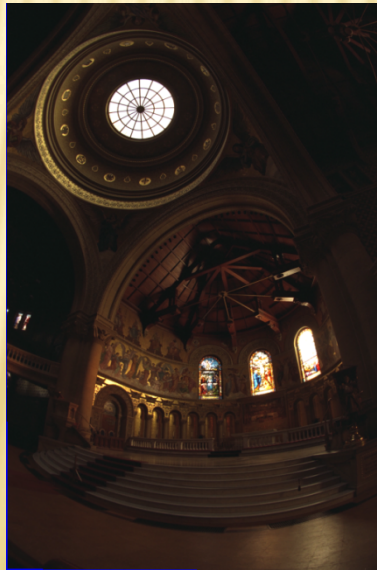


HIGH DYNAMIC RANGE IMAGING (HDR)

Example:

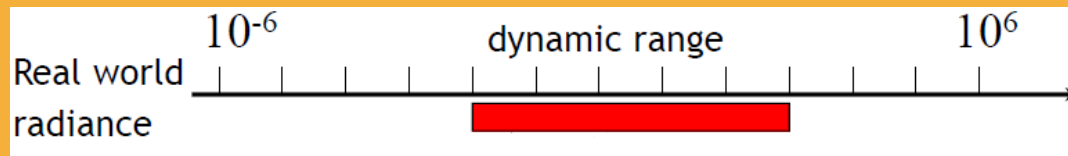
At left, an HDR image consisting of details in dark and illuminated areas

Below, the acquisitions made by a camera.



HDR CREATING

- ▶ Paper by Debevec et. al.
- ▶ To recover dynamic range (radiance, E_i) of the scene
 - ▶ To recover the response function of the imaging process



Digitization
to obtain Z_{ij}

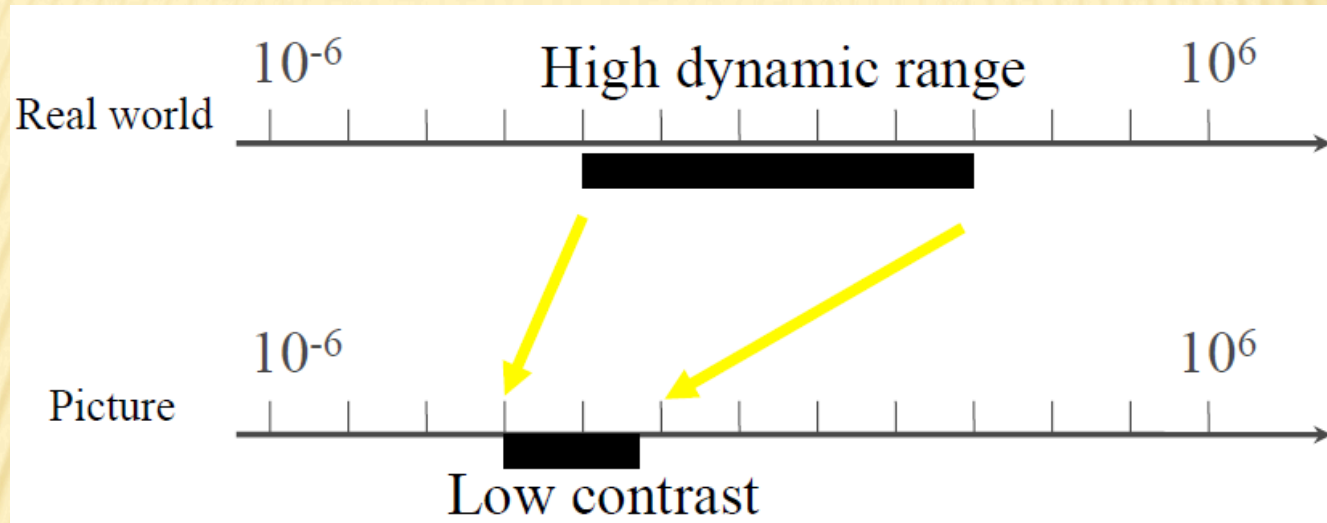
$$Z_{ij} = f(E_i \Delta t_j)$$

$$\ln f^{-1}(Z_{ij}) = g(Z_{ij}) = \ln E_i + \ln \Delta t_j$$

$$\ln E_i = g(Z_{ij}) - \ln \Delta t_j$$

$$\ln E_i = \frac{\sum_{j=1}^P w(Z_{ij})(g(Z_{ij}) - \ln \Delta t_j)}{\sum_{j=1}^P w(Z_{ij})}$$

tone mapping operator (TMO)



- ✗ To render the HDR data to match the dynamic of conventional hardware display
- ✗ Two types : Global and Local TMOs
- ✗ We choose a global TMO by Duan et al. to be implemented:

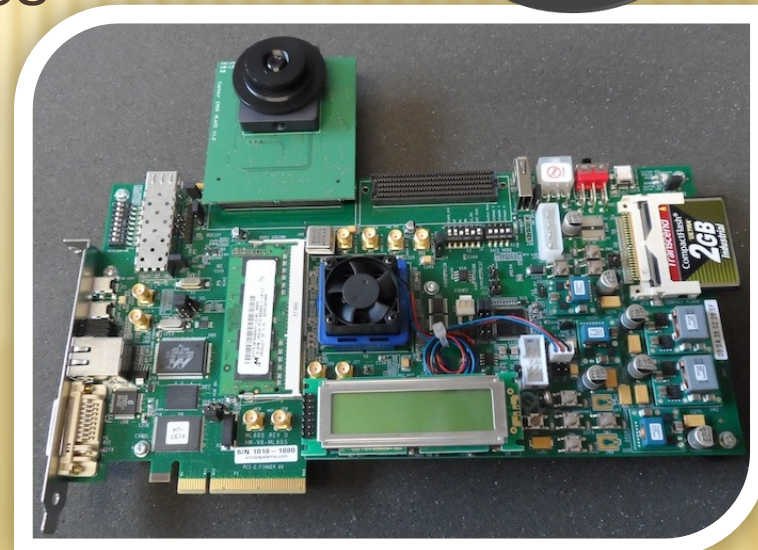
Displayable
value

$$D_{ij} = C * (D_{max} - D_{min}) + D_{min}$$

$$\text{with } C = \frac{\log(E_{ij} + \tau) - \log(E_{ij(min)} + \tau)}{\log(E_{ij(max)} + \tau) - \log(E_{ij(min)} + \tau)}$$

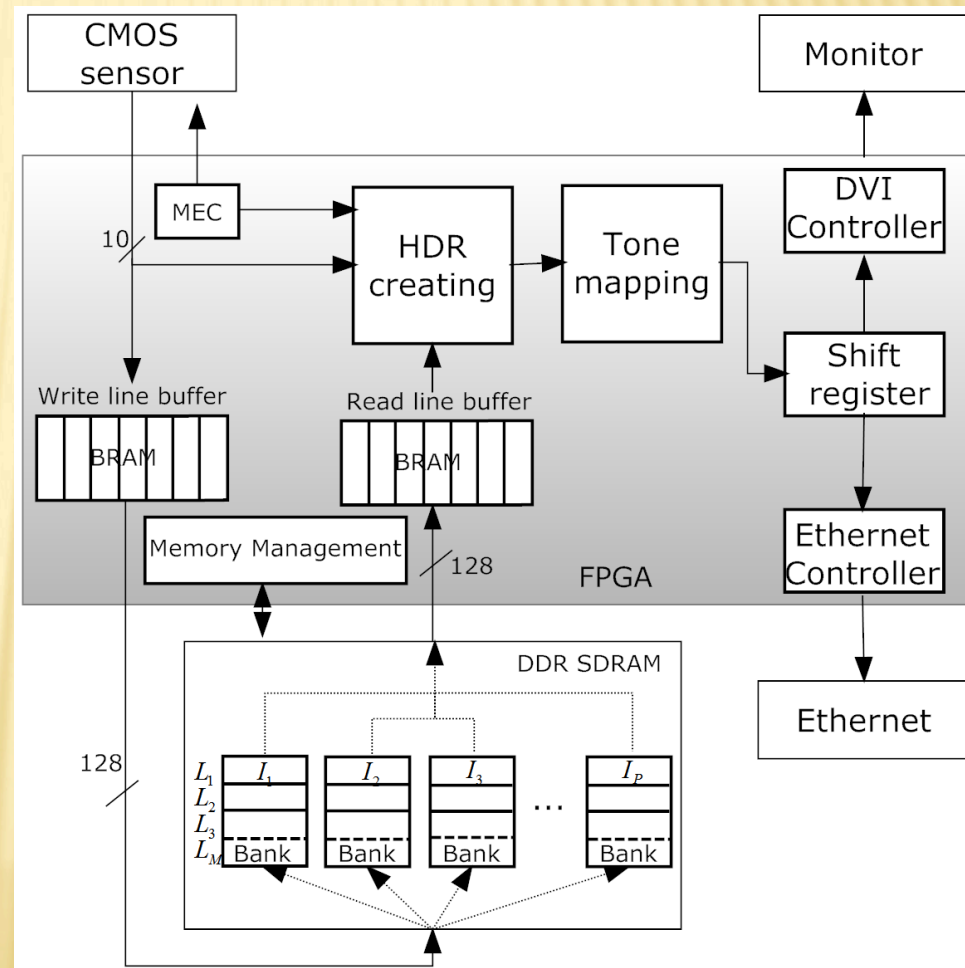
HARDWARE

- ✗ The prototyping platform : HDR video
- ✗ Virtex 6 FPGA development board (ml605)
- ✗ e2V LDR sensor
 - + 1.3 Megapixel at 60 fps
 - + high sensitivity, low power
 - + global shutter mode
- ✗ Several communication interfaces
 - + Ethernet
 - + DDR3 SDRAM
 - + serial interface
 - + DVI
- ✗ Design without processor



DESIGN

- ✖ VHDL & VERILOG definition
- ✖ 3 images (low, middle and high exposures)
- ✖ Hardware modules
 - + Auto exposition control
 - + Memory management
 - + HDR+Tone mapping



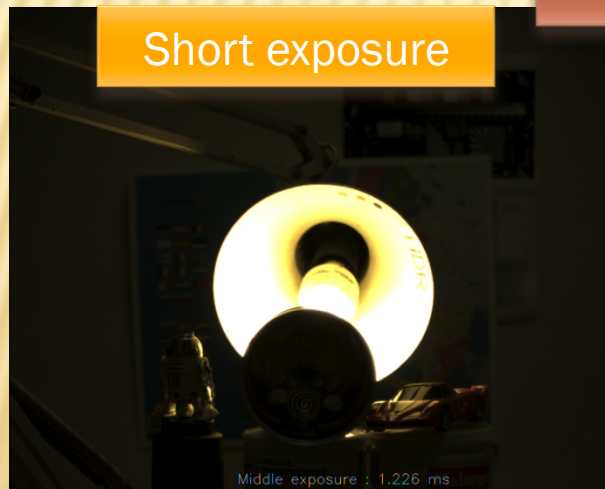
MULTIPLE AUTO EXPOSURE CONTROL

- ✗ Adapted algorithm from Gelfand et al.
- ✗ Based on histogram calculations
 - + each of the three exposures are updated each time an image is captured by the sensor
- ✗ Exposure times choosen:
 - + For High exposure: Δt_H
 - ✗ <10% of pixels are saturated in black
 - + For Low exposure Δt_L
 - ✗ <10% of pixels are saturated in white
 - + For Middle exposure
 - ✗ :
$$\Delta t_M = \sqrt{\Delta t_L \times \Delta t_H}$$

MULTIPLE AUTO EXPOSURE CONTROL



IN REAL-TIME



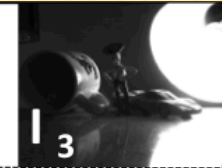
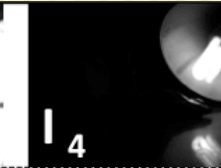


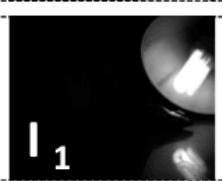
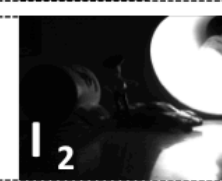
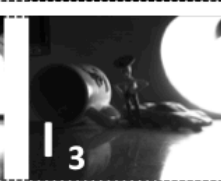
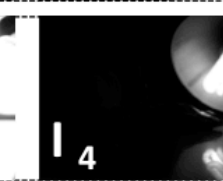

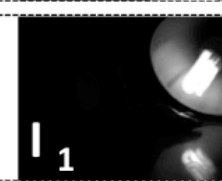
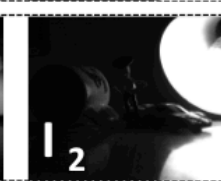
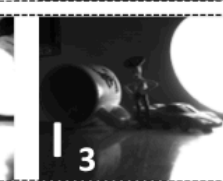
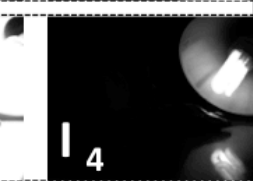
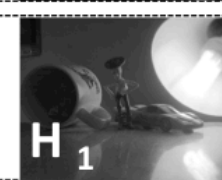
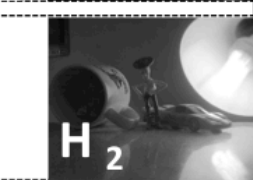


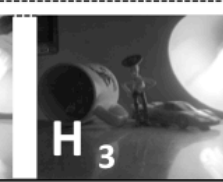



BEFORE auto exposure

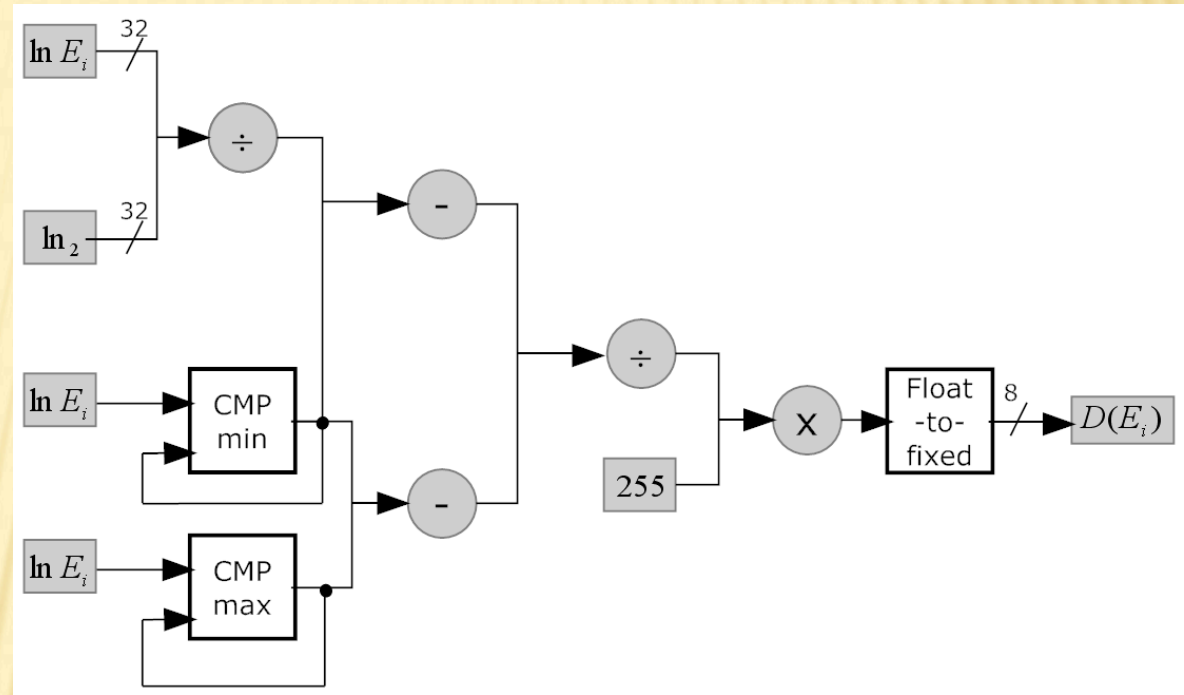
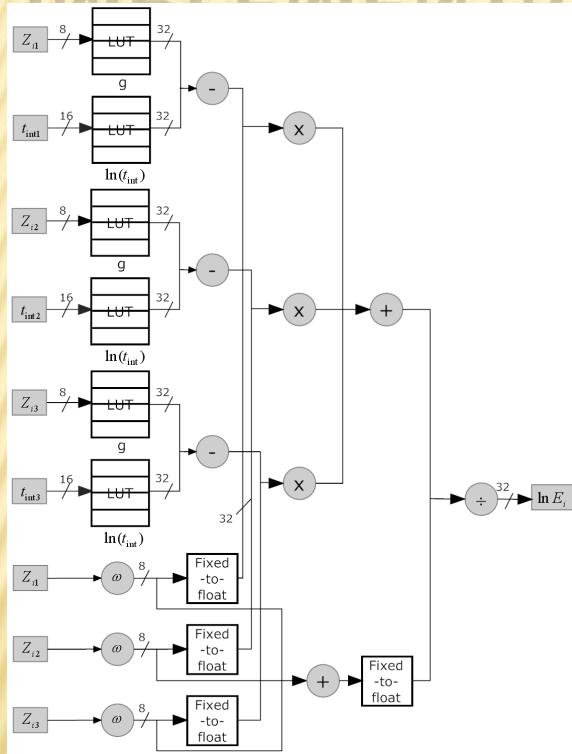
AFTER auto exposure

THE SENSOR + MEMORY MANAGEMENT

- ✖ Sends sequentially 3 exposure times (low, middle and high exposures)
- ✖ 3 video streams performed in parallel

Sensor Output						
Memory						
Memory						
Standard technique						
Our technique						

IMPLEMENTATION



- ✖ Floating point IEEE754 implementation in VHDL
- ✖ 3 images in input

HARDWARE SYNTHESIS AND IMPLEMENTATION

Project Summary x Device x

Project Settings

Project name: project_1

Product family: Virtex-6

Project part: [Virtex-6 ML605 Evaluation Platform \(xc6vlx240tff1156-1\)](#)

Top module name: [top_test_e2v](#)

Device

Synthesis (Complete)

Part: xc6vlx240tff1156-1

Strategy: [TimingWithoutIOBpacking](#)

Flow: [XST](#)

Util: 14.0 %

FMax: 167.322 MHz

Messages

Summary: 0 errors
0 critical warnings
4202 warnings

Go To: [Messages](#)
[Log](#)
[Reports](#)

Implementation (Complete)

Part: xc6vlx240tff1156-1

Strategy: [MapTimingIgnoreKeepHierarchy](#)

Flow: [ISE](#)

Util: 12.0 %

FMax: 122.504 MHz

Timing Score: 0

Unrouted: 0

Resources

RTL Estimation | Synthesis Estimation | Netlist Estimation | **Implemented Utilization**

Part: xc6vlx240tff1156-1

Register	7%
LUT	12%
Slice	21%
IO	34%
Bonded IPAD	6%
Bonded OPAD	5%
RAMB36E1	2%

Global utilization & FMax

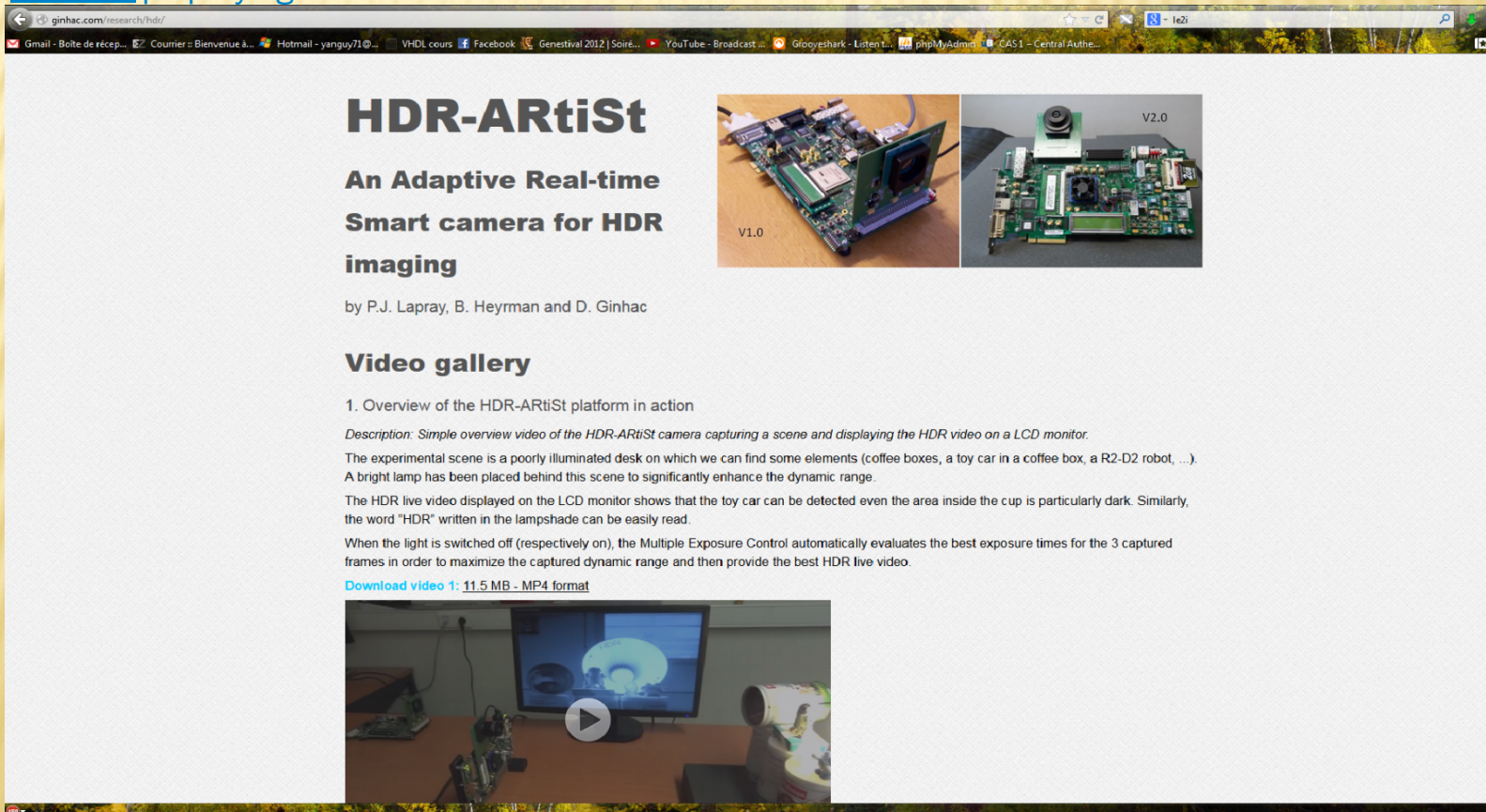
Implemented Utilization

DEMONSTRATION

✕ Website: video demonstration

+ At <http://ginhac.com/research/hdr/>

Contact: plapray@gmail.com



HDR-ARTiSt

An Adaptive Real-time Smart camera for HDR imaging

by P.J. Lapray, B. Heyrman and D. Ginhac

Video gallery

1. Overview of the HDR-ARTiSt platform in action


Description: Simple overview video of the HDR-ARTiSt camera capturing a scene and displaying the HDR video on a LCD monitor.

The experimental scene is a poorly illuminated desk on which we can find some elements (coffee boxes, a toy car in a coffee box, a R2-D2 robot, ...). A bright lamp has been placed behind this scene to significantly enhance the dynamic range.

The HDR live video displayed on the LCD monitor shows that the toy car can be detected even the area inside the cup is particularly dark. Similarly, the word "HDR" written in the lampshade can be easily read.

When the light is switched off (respectively on), the Multiple Exposure Control automatically evaluates the best exposure times for the 3 captured frames in order to maximize the captured dynamic range and then provide the best HDR live video.

[Download video 1: 11.5 MB - MP4 format](#)



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THE END

Gracias
MERCI
ARIGATO
thank you