Laboratoire
Électronique
Informatique
et Image

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

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

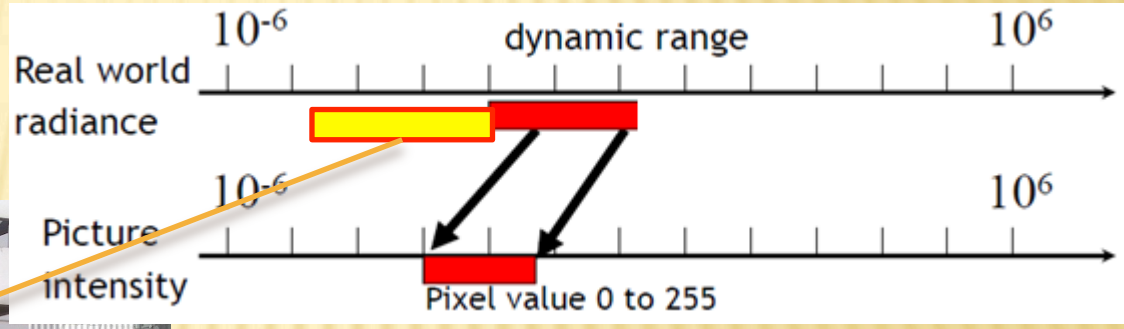
ICDSC'13

NOVEMBER 2013, PALM SPRINGS, USA

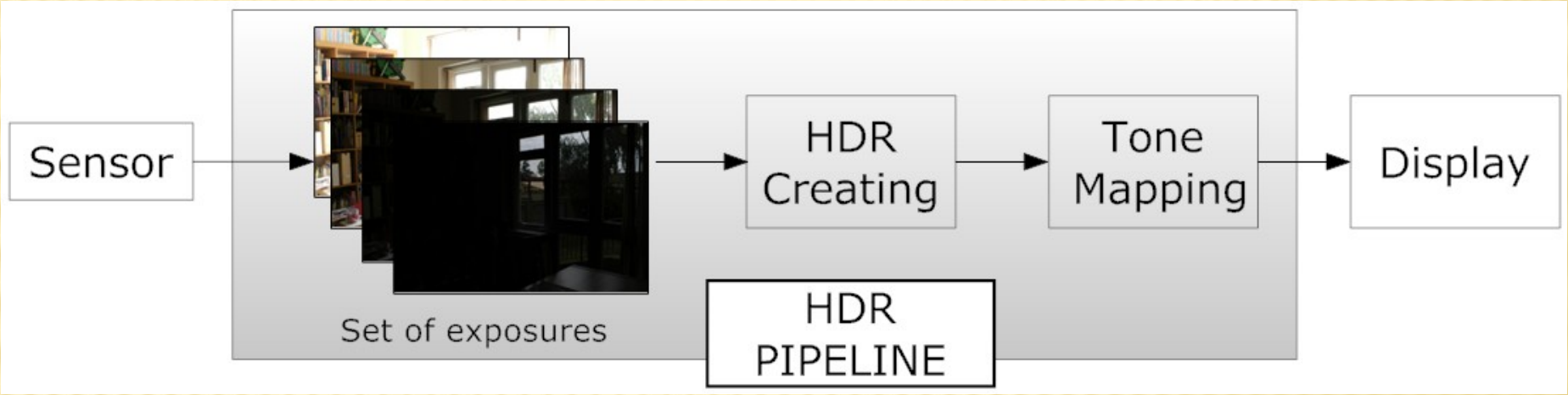

BauteilB

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)

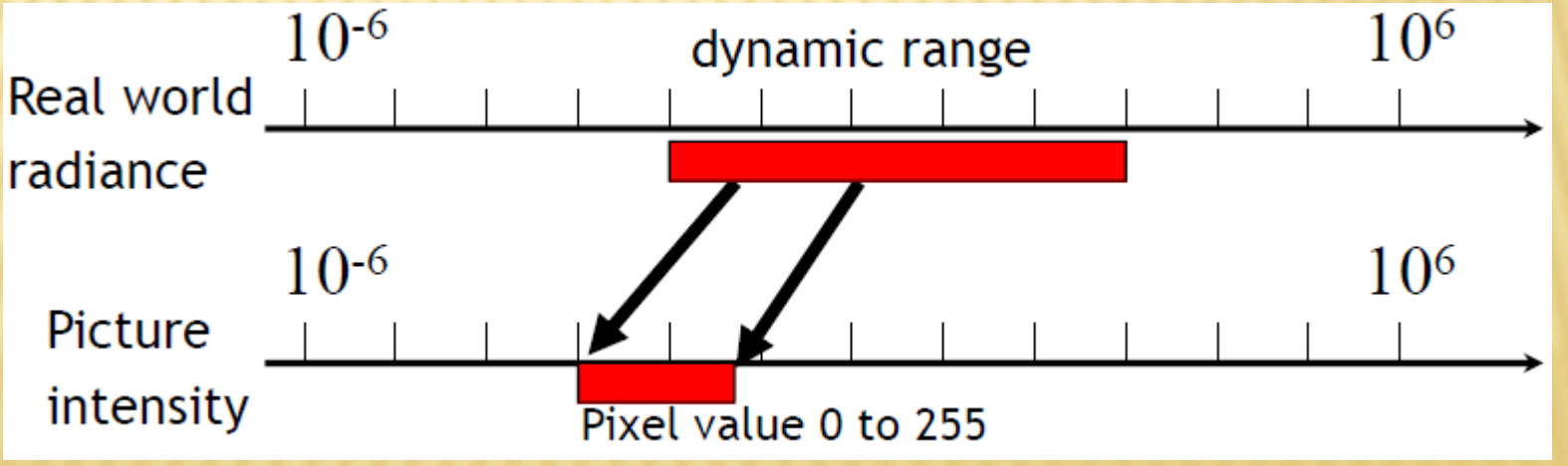


EXAMPLE of DISPLAYED RESULT

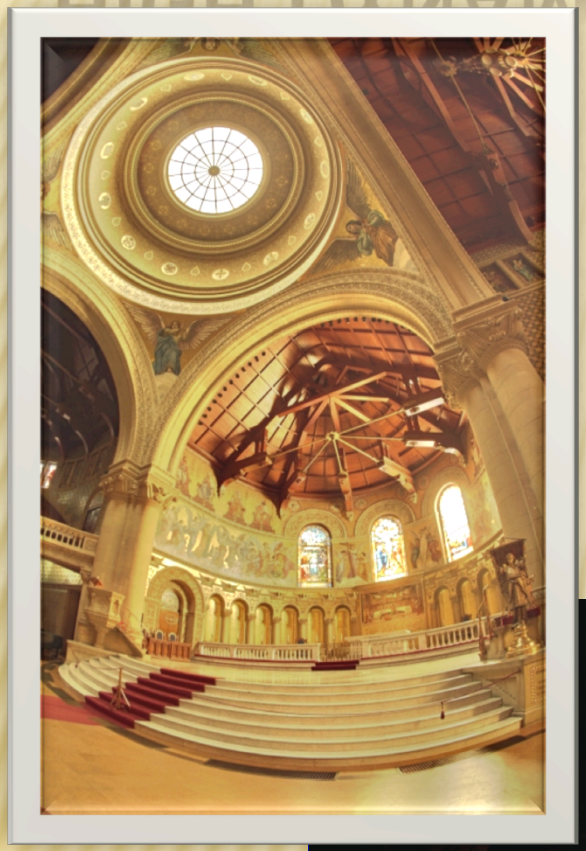
SET OF EXPOSURES

EXP=1/125s

EXP=1/2s



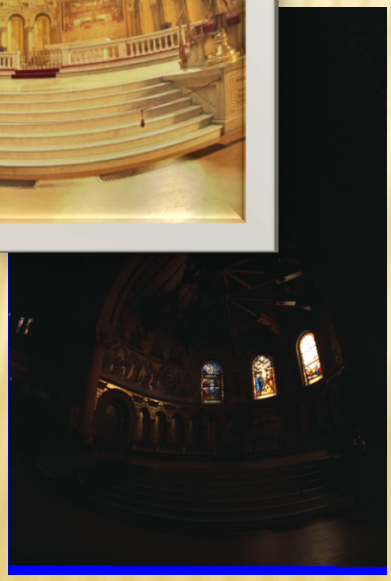
HIGH DYNAMIC RANGE IMAGING (HDR)

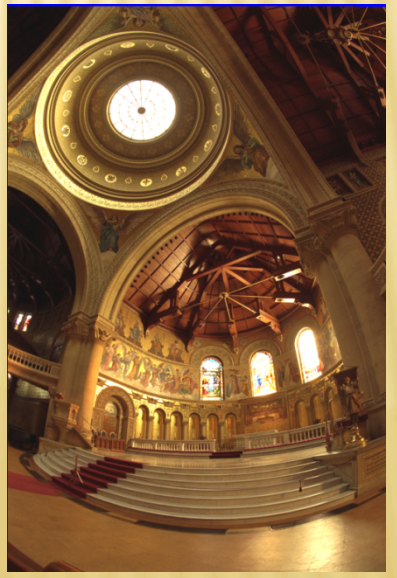


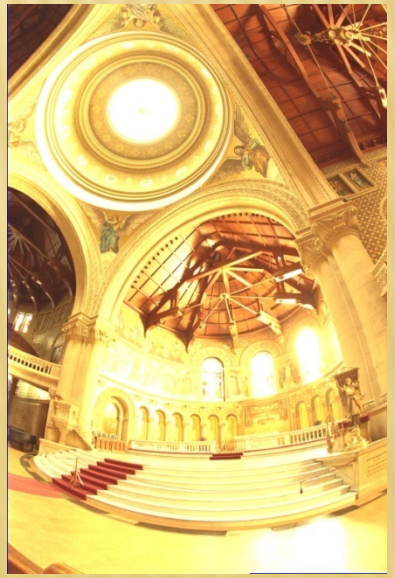
Example:

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

Below, the acquisitions made by a camera.





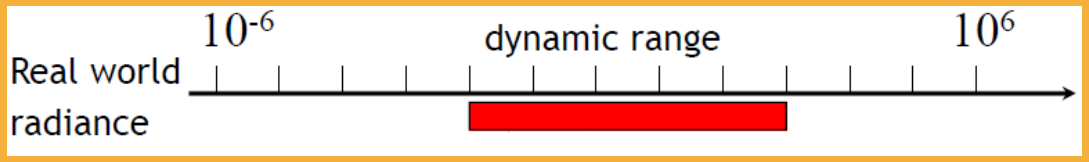


HDR CREATING

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

Pixel value

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



Digitization to obtain Z_{ij}

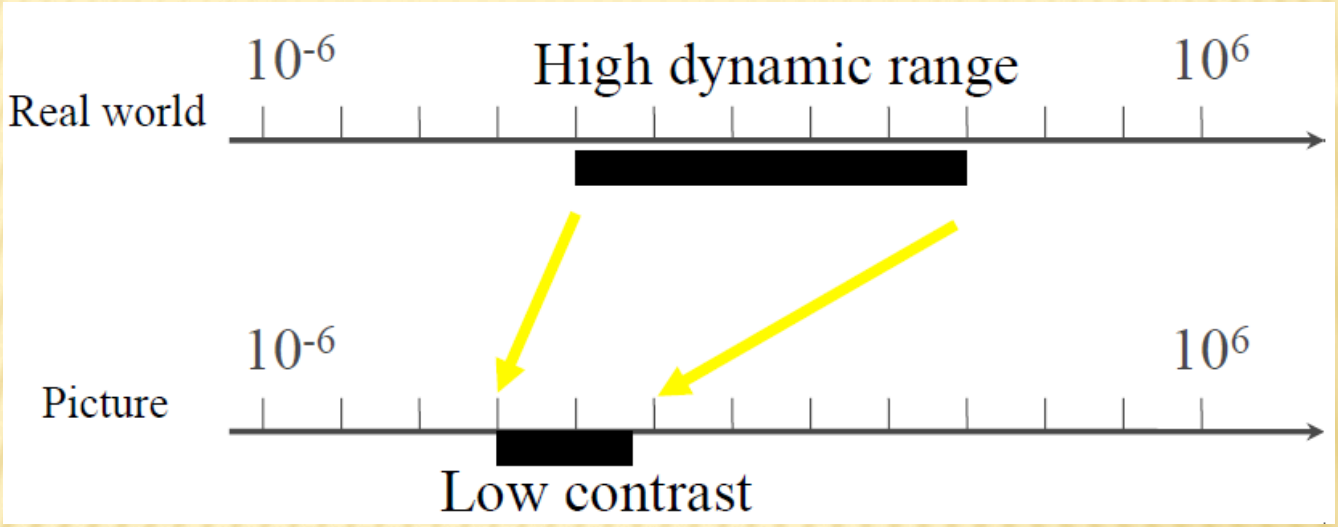
$$Z_{ij} = f(E_i \Delta t_j)$$

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

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

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

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:

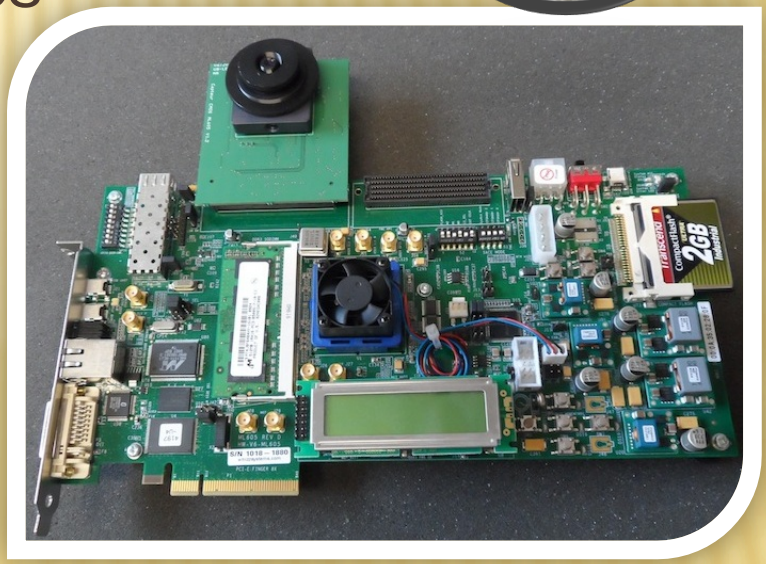
Displayable value

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

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

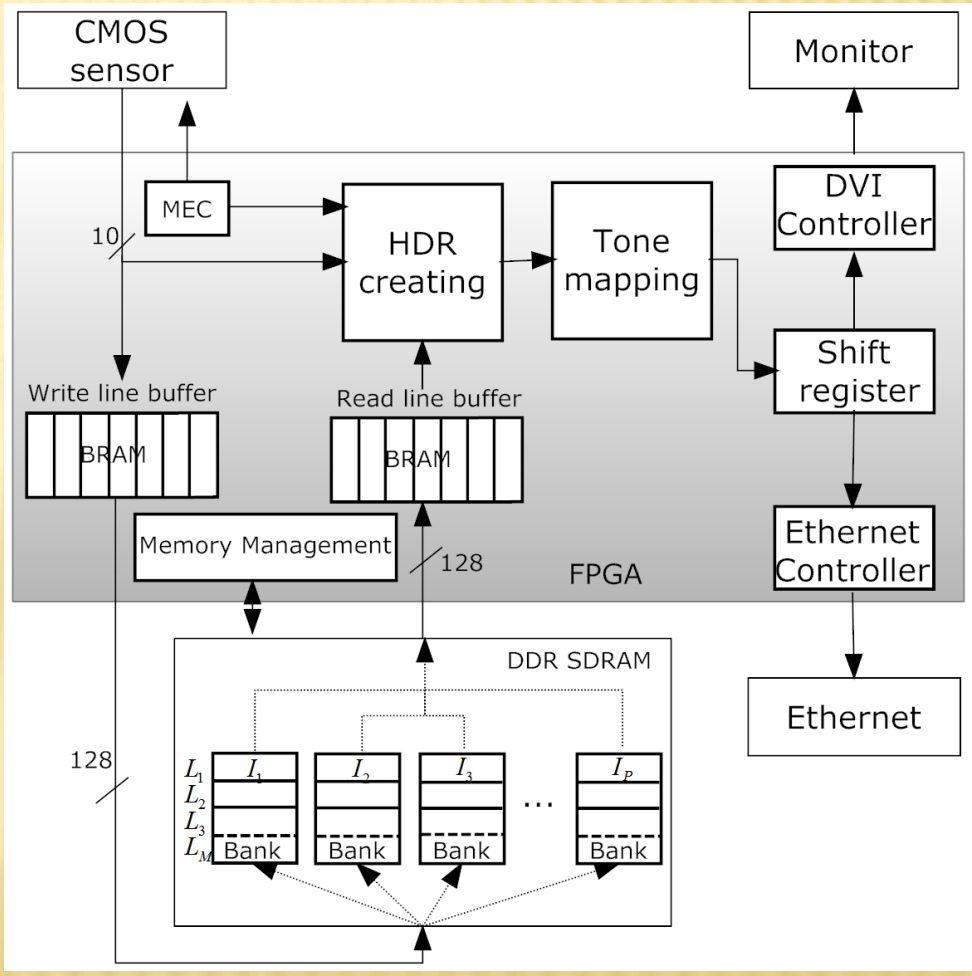
HARDWARE

- 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

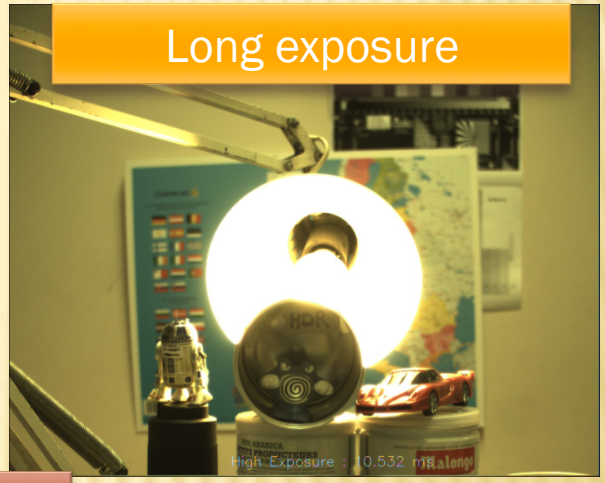
- VHDL & VERILOG definition
- 3 images (low, middle and high exposures)
- Hardware modules
  - Auto exposition control
  - Memory management
  - HDR+Tone mapping



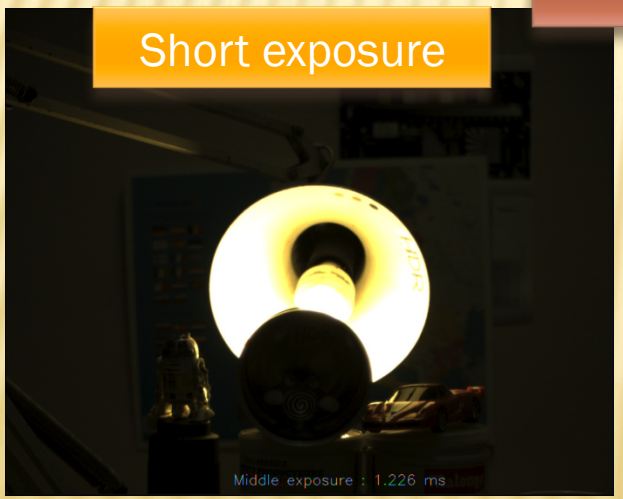
MULTIPLE AUTO EXPOSURE CONTROL

- 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
    - : $$\Delta t_M = \sqrt{\Delta t_L \times \Delta t_H}$$

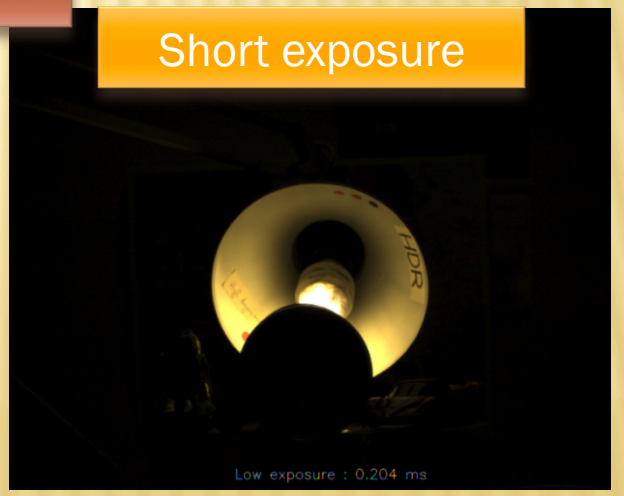
MULTIPLE AUTO EXPOSURE CONTROL



IN REAL-TIME



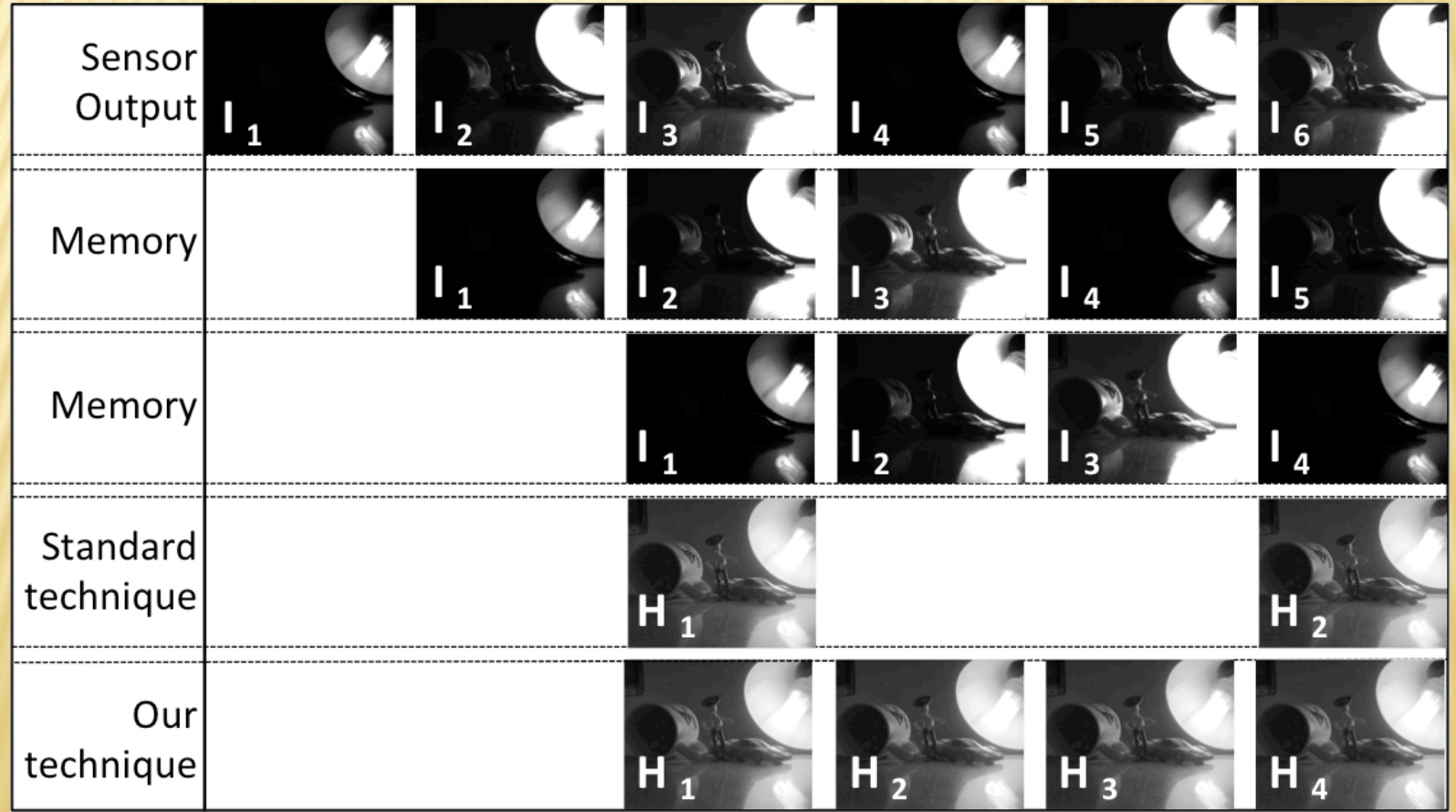
BEFORE auto exposure



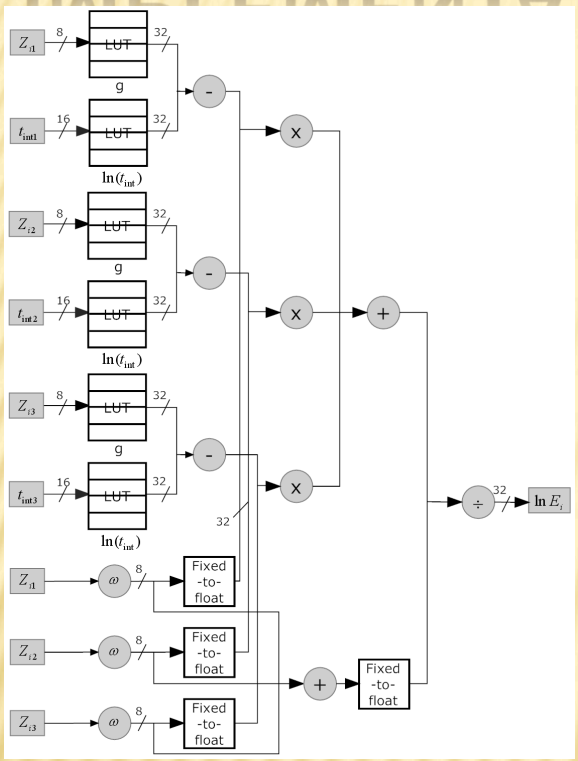
AFTER auto exposure

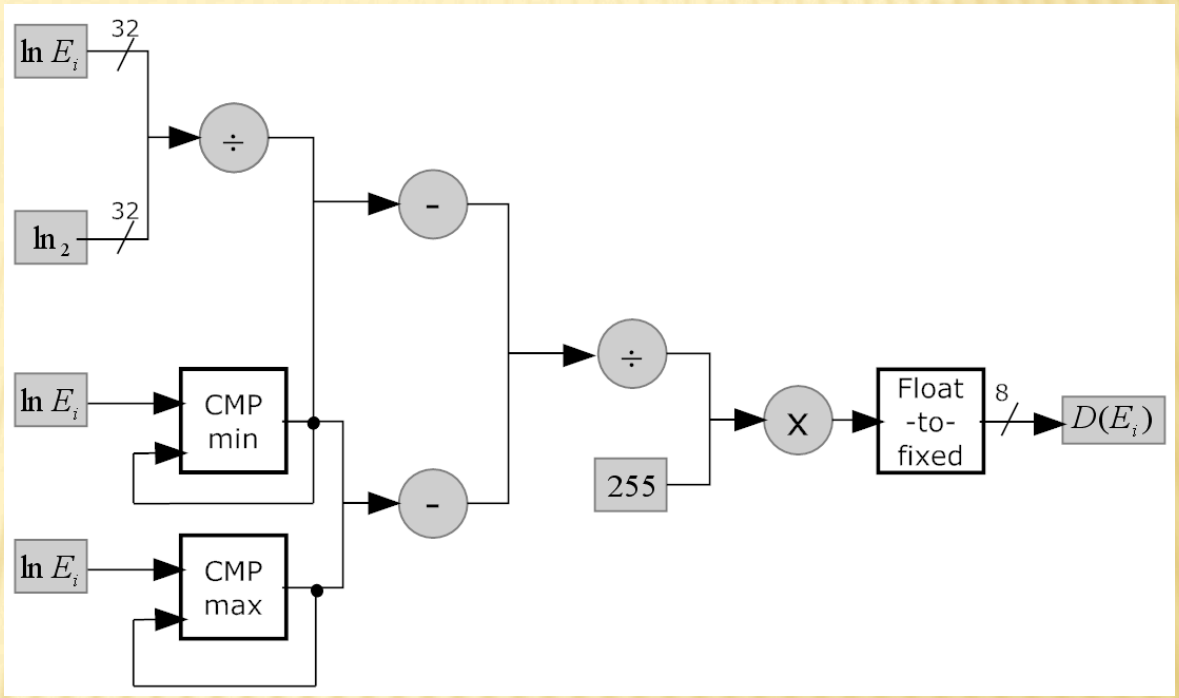
THE SENSOR + MEMORY MANAGEMENT

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



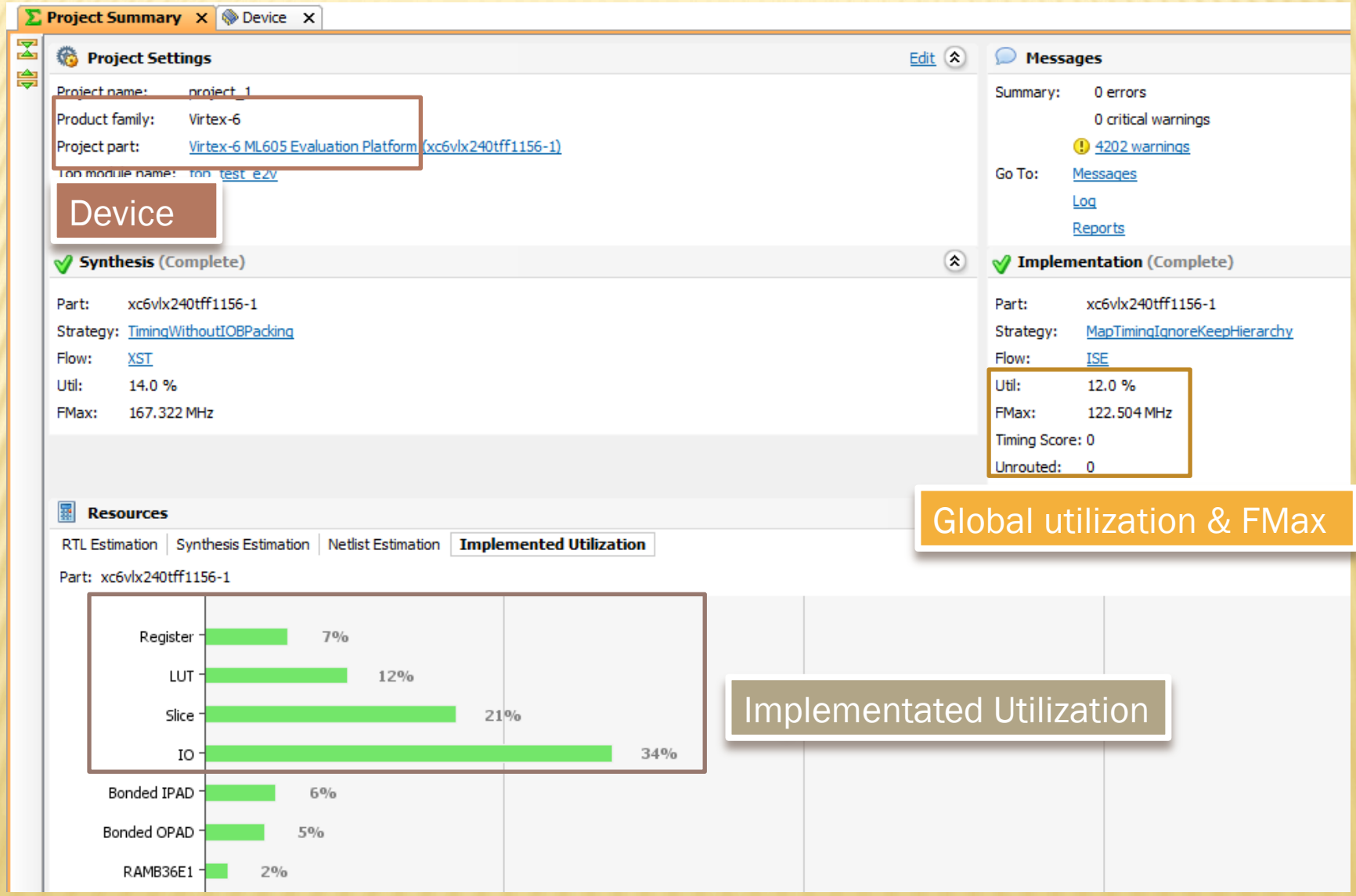
IMPLEMENTATION





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

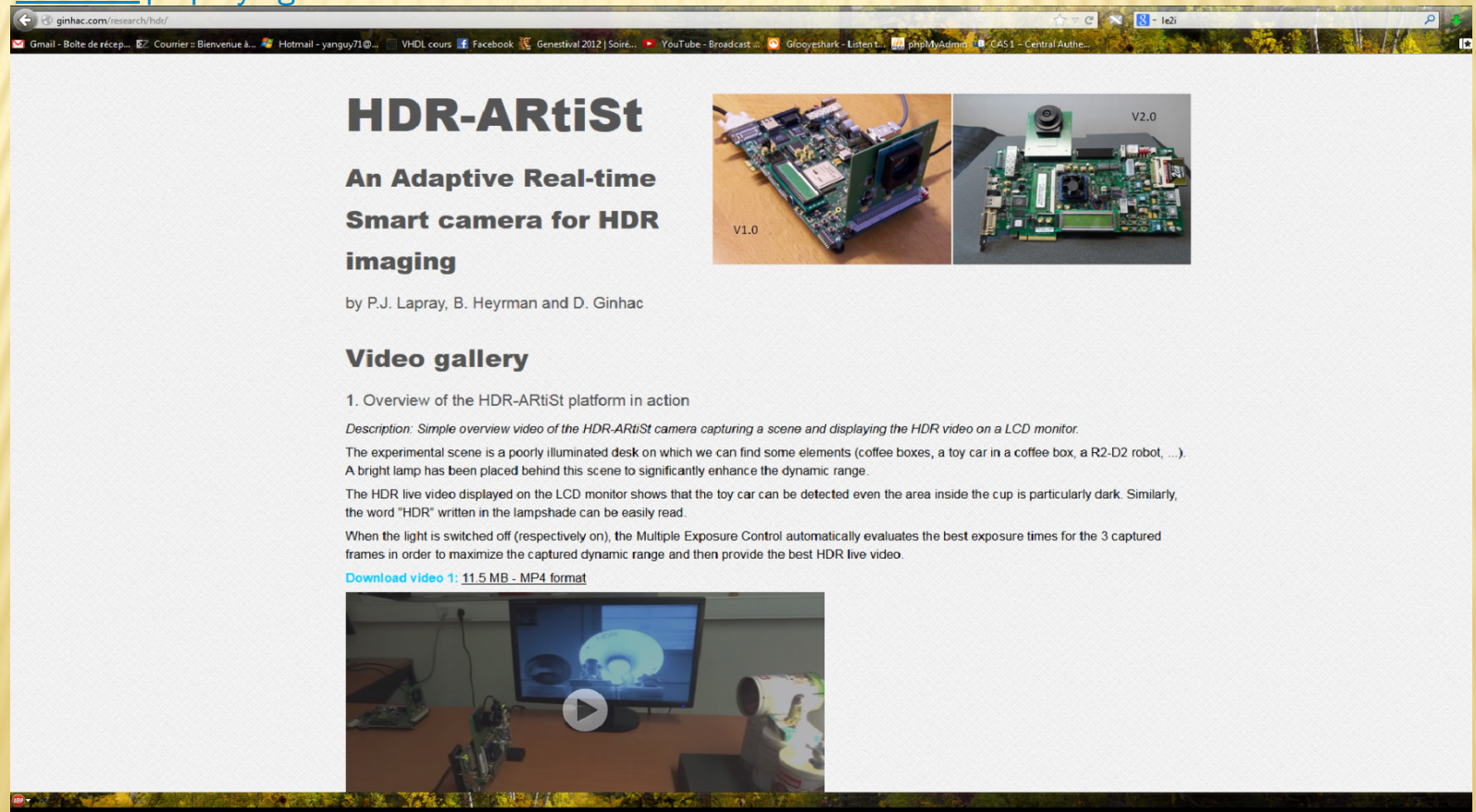
HARDWARE SYNTHESIS AND IMPLEMENTATION



DEMONSTRATION

- Website: video demonstration
  - At http://ginhac.com/research/hdr/

Contact: plapray@gmail.com



REFERENCES

- Paul E. Debevec and Jitendra Malik, “Recovering high dynamic range radiance maps from photographs,” in Proc. of the 24th Annual Conference on Computer Graphics and Interactive Techniques, 1997.
- Reinhard, E., Stark, M., Shirley, P., Ferwerda, J.: Photographic tone reproduction for digital images. In: Proceedings of the 29th Annual Conference on Computer Graphics and Interactive Techniques, pp. 267–276 (2002)
- Drago, F., Myszkowski, K., Annen, T., Chiba, N.: Adaptivelogarithmic mapping for displaying high contrast scenes. Computer Graphics Forum, In: 24th Annual Conference of the Eurographics Association, pp. 419–426 (2003)
- Jiang Duan, Marco Bressan, Christopher R. Dance, Guoping Qiu: Tone-mapping high dynamic range images by novel histogram adjustment. Pattern Recognition 43(5): 1847-1862 (2010)
- Z. Wang and A.C. Bovik. A universal image quality index. IEEE Signal processing Letters, vol. 9, no. 3:81-84, Mar. 2002
- Zhou Wang and Alan C. Bovik. Mean squared error: Love it or leave it? IEEE Signal Processing Magazine, 98-98-117, January 2009.
- Ureña, R., Gómez-López, J. M., Morillas, C., & Pelayo, F. (2012). Real-time tone mapping on GPU and FPGA. *EURASIP Journal on Image and Video Processing*, *2012*(1), 1.
- Guthier, B., Kopf, S., & Effelsberg, W. (2012, July). Optimal shutter speed sequences for real-time HDR video. In *Imaging Systems and Techniques (IST), 2012 IEEE International Conference on* (pp. 303-308). IEEE.

THE END

Gracias
MERCI
ARIGATO
thank you