# PROTOTYPE OF HIGH DYNAMIC RANGE CAMERA

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Real-time HDR (High dynamic range) cameras are useful in numerous special tasks, e.g. in electrical and pulse TIG (Tungsten Inert Gas) welding, in improving human vision in extreme or too light situations, laser applications, in increasing driving safety under adverse conditions etc.

The final form of the intended device maybe a special wearable helmet, HMD head mounted display) or other specialized device. An adequate platform for generating driving signals, calculations and processing is either an FPGA (Field Programmable Gate Array) or a sufficiently fast microcontroller. FPGA can provide fast processing of incoming data and fast accomplishment algorithms of video processing with low power consumption on a hardware level compared to a microcontroller implementation.

Typical cameras have only limited dynamic range, which cannot cover all scenarios. In cameras, the dynamic range is the ratio between the largest and the smallest light illumination, for which a small incremental difference in the illumination is still discernible [1]. In a typical non-HDR camera, many details will get lost due to very bright or very dark regions in the image area. Using a HDRC (High dynamic range camera) the underexposition or overexposition is largely avoided.

One of the methods how to artificially increase the dynamic range of a non-HDRC is combining two or more differently exposed frames, see fig. 1.

Figure1. Photos with different exposure

In order to understand the principles of taking HDR images, there needs to understand differently exposed pictures [1]. Let us assume a sequence of frames

$$f_i \in \{f_1, f_2, f_3 \ldots\} \quad (1)$$

obtained by various expositions. Each frame has its specific exposure level $k_i$ which can be controlled, i.e. the sequence of frames depends on the levels of exposure and photoquantity and can be described as follows

$$f_i = f\left(k_i q\left(x, y\right)\right) \quad (2)$$

where $k_i$ is a level of exposition, $q$ is a photoquantityand $x$ a nd $y$ are spatial coordinates. This series of frames is necessary to consider true photoquantity.

The method of forming HDR image using normal camera is minutely described in [1]. Let $f$ be a function which represents camera response function

(CRF), whereas $f$ is a tonal value in scalar point, and a tonal image in a matrix one (e.g. a picture from a camera) [1]. Considering that the tonal value $f$ is linearly changed with the value of pixel but only in a unit space, so with $n$-bit pixel value $v$ which get back from a camera, $f_i$ is

$$f_i = (\nu + 0{,}5)/2^n \qquad (3)$$

where we have $N$ images with different exposures $k_i$. The subscript be tokens that it is $i$-th in a Wyckof set [2]. It means that the image set distinguishes only in an exposure. By definition $k_i < k_{i+1}\ \forall\ i < N$. Using $f^{-1}$ as the mathematical inverse of $f$ if it has only one argument, and otherwise as a joint estimator of photoquantity $\hat{q}$.

To composite 2 images, the LUT (lookup table) should be obtained for a camera. LUT is a composition of a set of operations for creating HDR images from an alternating exposure set [1]. To build LUT firstly it is necessary to work out the CRF using formula (3). An evaluation of the photoquantity $\hat{q}$ is calculated from pixel values $f_1$ and $f_2$. It can be realized by using weighted average with the certainty function $w$ and with the CRF $f$ [1]. To increase the speed of the process there may be included special conditions.

$$\hat{q} = f^{-1}_{\Delta EV}(f_1, f_2) = \begin{cases} q_{\max} & \text{if } f_1 > \beta \\ q_{\min} & \text{if } f_2 < \alpha \\ \dfrac{f^{-1}(f_1)\cdot w(f_1) + f^{-1}(f_2)\cdot w(f_1)/2^{\Delta EV}}{w(f_1)+w(f_2)} & \text{otherwise} \end{cases} \qquad (4)$$

where $\Delta EV$ is the exposure difference between $f_1$ and $f_2$; $\alpha, \beta$ are saturation parameters; $q_{\max}$, $q_{\min}$ are the estimated $\hat{q}$ values at the saturation points. After obtaining $\hat{q}$, dynamic range compression for LDR display is executed $(\hat{q})$. After new compressed $\hat{q}_c$ is found it is possible to use CRF to the $\hat{q}$ [1]. To tune contrast level there can be used function $k$.

$$Q_f = k(Q) \qquad (5)$$

With the help of the combination of the above functions all possible values of $f_1$ and $f_2$ is obtained (fig. 2):

$$Q_f = k\left(f\left(c\left(f^{-1}_{\Delta EV}(f_1, f_2)\right)\right)\right) \qquad (6)$$

To avoid all complex processing actions the WDR CMOS sensor will be used. The NSC1005 is a Native WDR CMOS image sensor with an HD ready resolution of 1280 × 720 active pixels and ultra-low power consumption: less than 260 mW full frame. Thanks to the Native WDR technology, the NSC1005 sensor delivers a dynamic range of more than 140dB in a single shot, without compromising image quality rendering. Using this sensor will grant ultimate quality of image without any processing.

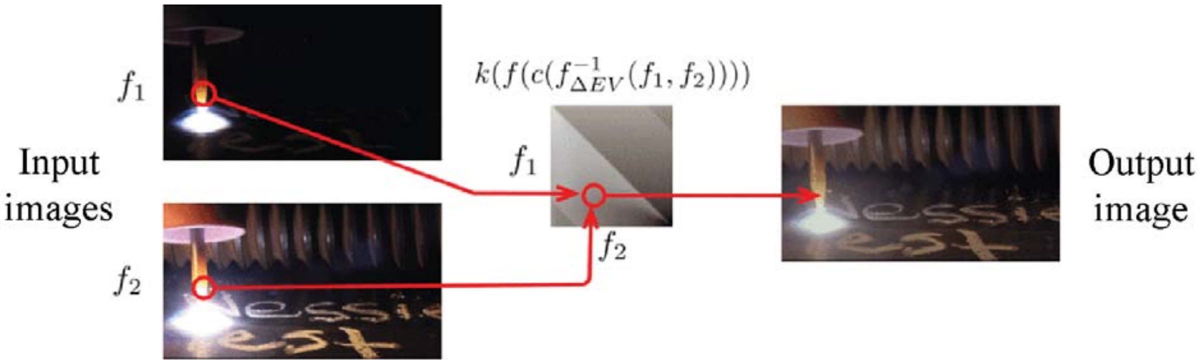


Figure 2. Composing two frames with different exposures

The initial prototype of the camera is expected to be built based on an FPGA with reduced power consumption Intel Cyclone 10 LP which is available on the Intel CYC 1000 board and NSC1005 sensor for the camera.

Application, fundamentals, mathematical description and two methods of formation of HDR image has been reviewed. The main aim is to make a prototype of HDR camera using low power consumption computation units such as Intel Cyclone 10 LP and highly sensitive sensor such as NSC 1005 to shoot HDR video in real-time.

**References**

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**Анотація**

Запророновано реалізацію камери з широким динамічним діапазоном на ПЛІС з використанням сенсору NSC1005 для спеціальних потреб. Представлені базові метамитичні співвідношення, які описують метод розширення динамічного діапазону камери.

Ключові слова: HDR, HDR камера, експозиція, ПЛІС, кадр, зображення.

**Аннотация**

Предложено реализацию камеры с широким динамическим диапазоном на ПЛИС с использованием сенсора NSC1005 для специальных нужд. Представлены базовые математические соотношения, описывающие метод расширения динамического диапазона камеры.

Ключевые слова: HDR, HDR камера, экспозиция, ПЛИС, кадр, изображение.

**Abstract**

The implementation of a camera with a high dynamic range on the FPGA using the NSC1005 sensor for special needs is proposed. Basic mathematical relationships are presented which describes a method for expanding the dynamic range of a camera.

Keywords: HDR camera, exposure, FPGA, frame, image.