High-Dynamic Range Imaging summary

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High-Dynamic Range Imaging

- **Introduction to HDR**
- HDRI Software Requirements
- HDRI Terminology
- Two Early HDR Implementations
- First Modern HDR Implementation
- HDR Methods
  - CRF based
  - SNR based
  - Variance based
  - NN based

Introduction to HDR

- There are many scenes with very high, or very low luminance points in the same frame.

- For example, a photo of the sunlit sky taken from within a dark room.

- Standard Low Dynamic Range (LDR) imaging techniques, can focus either on the dark, or the bright points of a scene.

Introduction to HDR

- This results to lost information, as only one luminance extreme can be handled at once.

- High Dynamic Range Imaging (HDRI) , manages to solve this problem by combining underexposed and overexposed shots of the same scene.

- The underexposed pixels bring out the details of the brightly lit areas, and vice versa.

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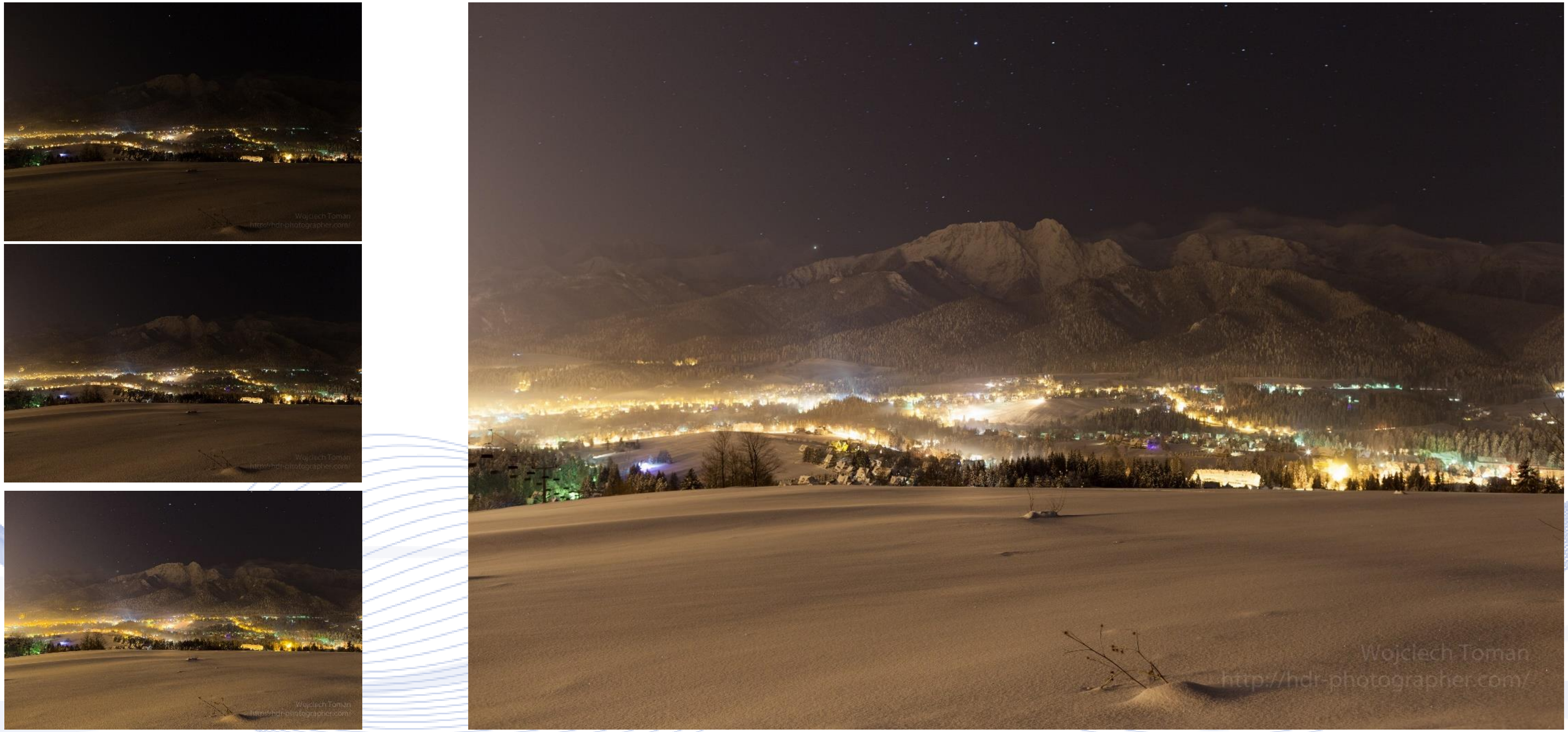
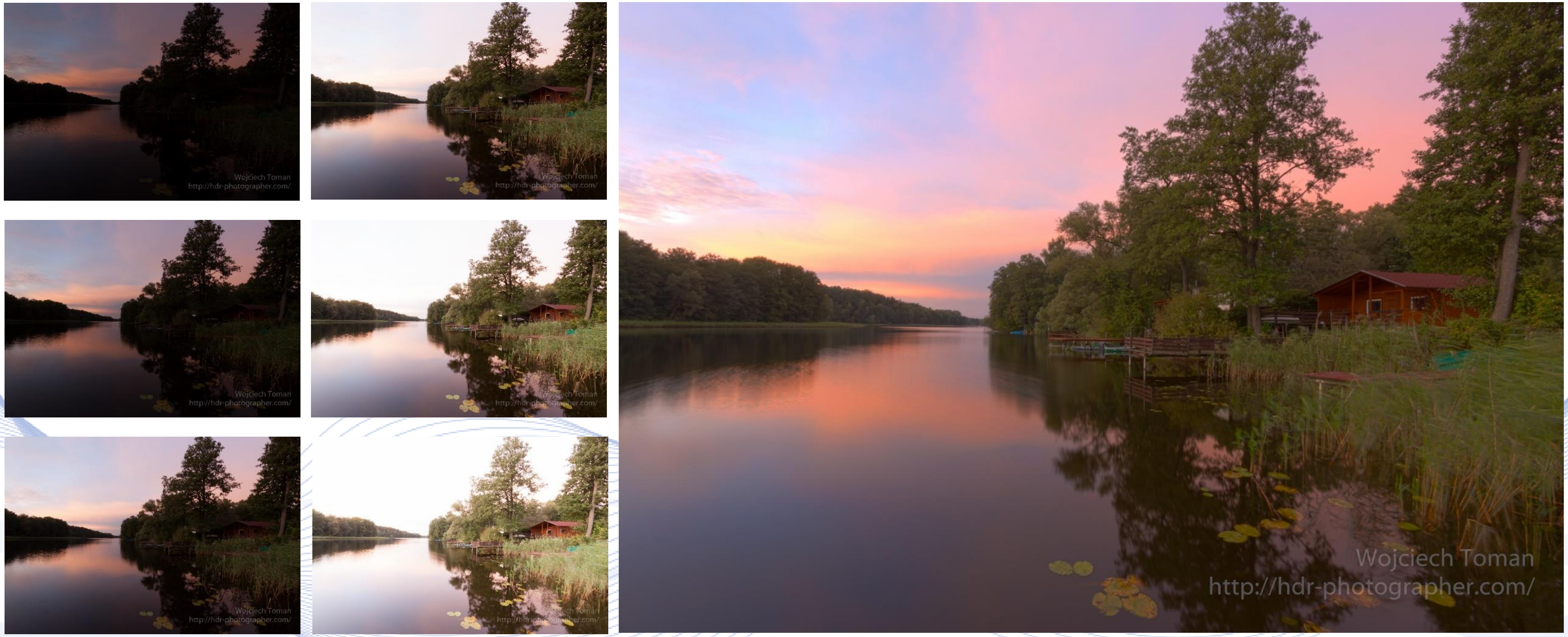
Introduction to HDR



LDR and HDR pictures of a nightscape at Giewont- [TOMAN-SAMPLE-HDR]

"Source images copyright by Wojciech Toman: http://hdr-photographer.com/"

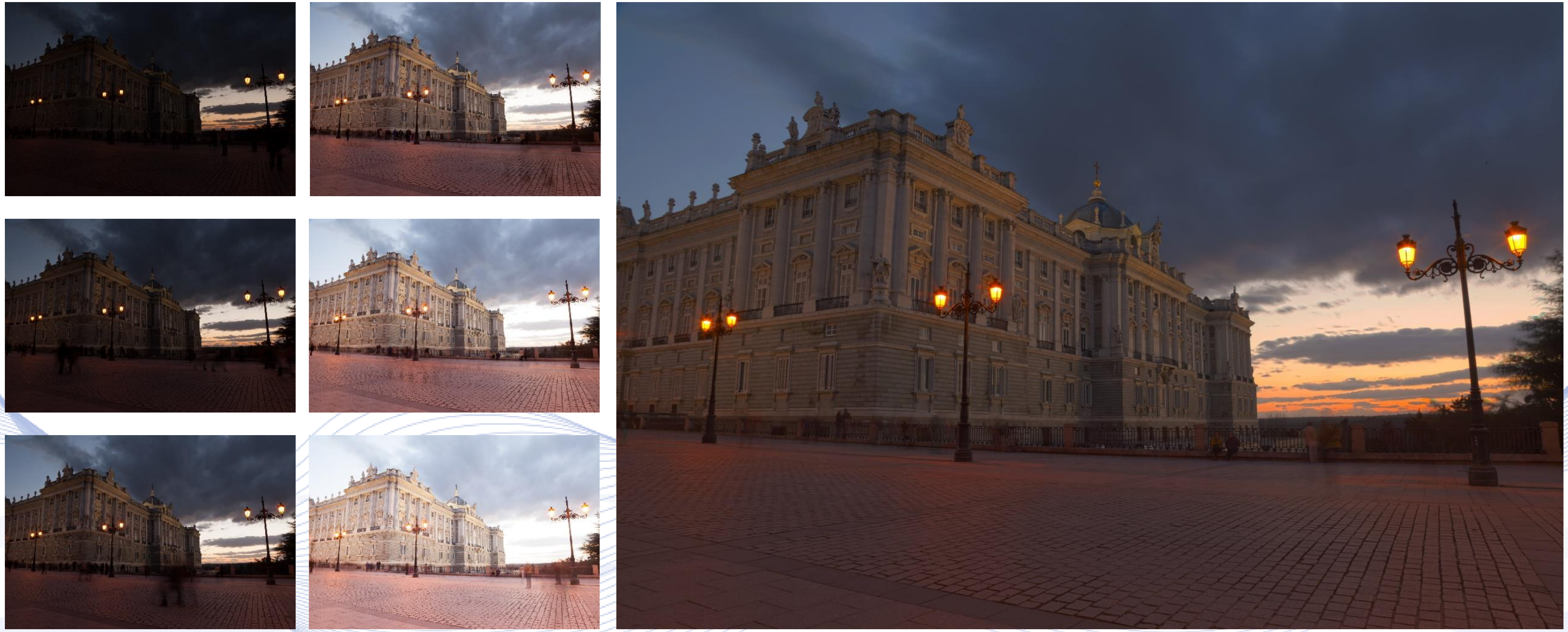
Introduction to HDR



LDR and HDR pictures of a colourful sunset - [TOMAN-SAMPLE-HDR]

“Source images copyright by Wojciech Toman: http://hdr-photographer.com/”

Introduction to HDR



LDR and HDR pictures of a palace in Madrid - [TOMAN-SAMPLE-HDR]

“Source images copyright by Wojciech Toman: http://hdr-photographer.com/”

HDR Imaging

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HDRI Requirements

- Conventional image formats have 8-bit colour, which translates to 8 bits for every colour channel (R-G-B).
- This means that there are $2^8 = 256$ colours for each channel, and $256^3 = 16.777.216$ colours in total, which is not enough.
- This indicates that new image formats are in order.
- Many ad-hoc attempts have been made, like Pixar’s 33-bit Log TIFF format, with 11 bits for each channel.

HDRI Requirements

- A simpler approach would be to address colours as floating point numbers to represent colours.
- A floating point system, would suggest 32-bit colour with 96 bits per pixel, which ensures quality but sacrifices storage.
- G. Ward proposed the more reasonable RGBA format, where 8 additional bits (for a total of 32) represent a common exponent.
- This results to better quality with more colours (~4 billion) without exceeding file sizes. This format is the most used.

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Terminology

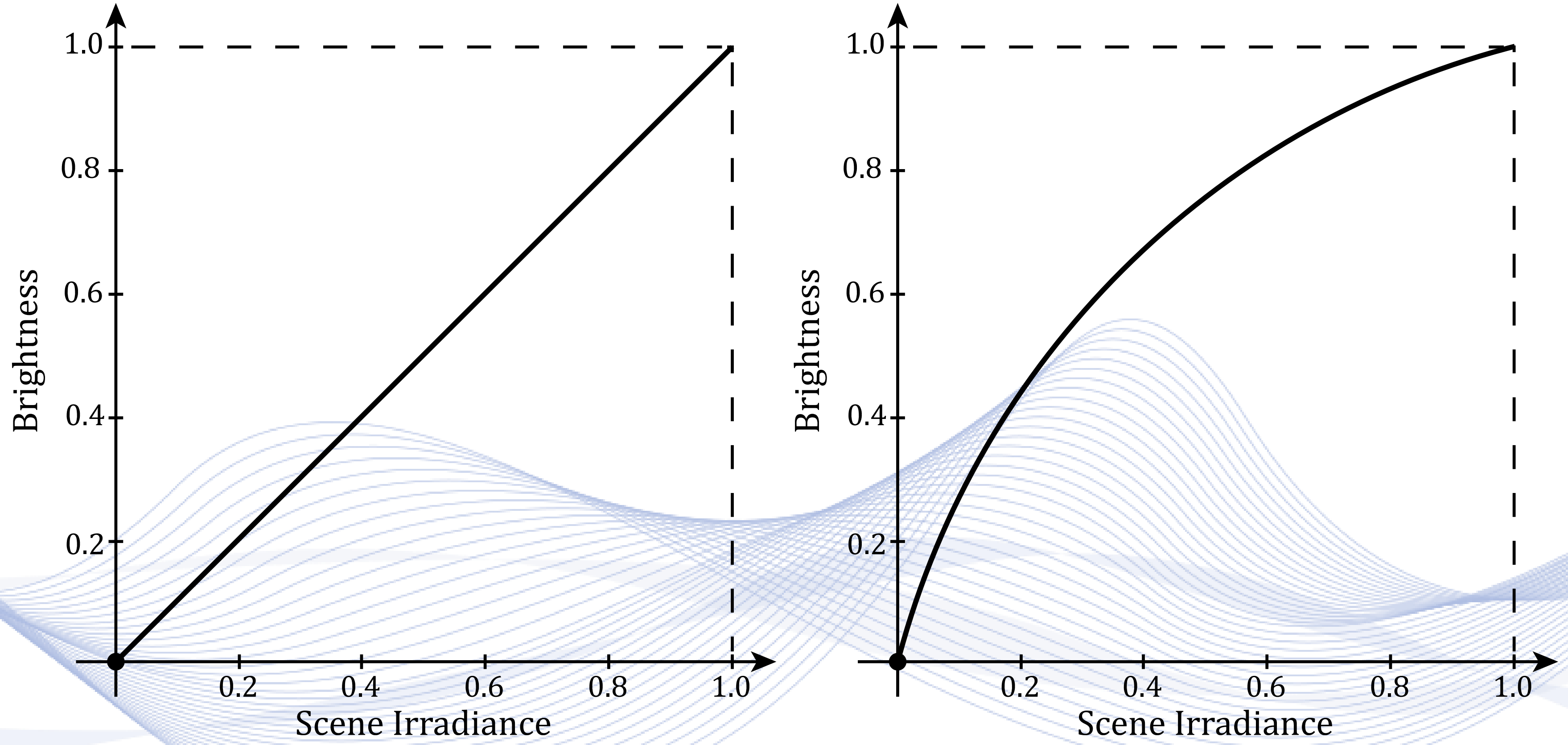
- **Exposure - E:** the amount of light that enters the camera. It can take different values depending on shutter speed, ISO, and aperture.
  - **Shutter Speed - Δt:** the speed at which the shutter of the camera closes and opens. The higher the shutter speed, the darker the final image.
  - **ISO:** the camera's sensitivity to incoming light. The higher the ISO the brighter the image, but it is susceptible to noise.
  - **Aperture - f:** the size of the lens opening from which light enters and hits the sensor. The smaller the aperture, the more light allowed on the sensor.

- **Dynamic Range:** The difference between the highest and the lowest brightness points in an image.

Terminology

- **Camera Response Function (CRF) –** *R*
- The CRF maps incoming scene irradiance to brightness values in the final image.
- This can achieve any desired colour profile and effects, such as more saturated colours.
- For this reason the CRF of a camera is considered a trade secret among manufacturers and is not publicly available.
- The ideal scenario would be a linear CRF which indicates absolute colour accuracy.

Terminology



Examples of linear (left) and non-linear (right) CRFs with normalized axis values.

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Terminology

- **Tone Mapping**
- The process of mapping the extended colours of an HDR image to conventional 8-bit colour ones.
- TM Operators are divided into Global and Local
  - **Global Operators:** the TM function is the same for all pixels of an image, thus providing more consistent results but risking inaccuracies in contrast.
  - **Local Operators:** the TM function gives different results from pixel to pixel; hence it is best suited for local features, but it may result in artifacts such as halo effects.

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Two Early HDRI Implementations

Seascape by Gustave le Gray – 1857 (source - [GETTY-GUSTAVE])

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First Modern HDR Implementation

- Both aforementioned methods refer to traditional photography with film.

- The first paper proposing an HDR method for digital cameras, was authored by S. Mann and R. W. Picard, in 1994.

- This technique is the one that paved most following algorithms for HDR photography.

HDR Imaging

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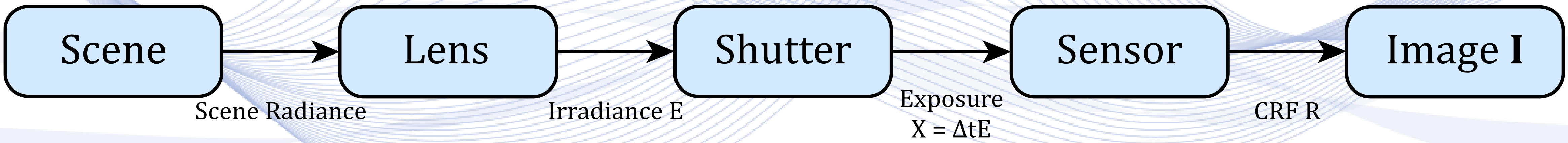
HDR Methods

- The pipeline for most HDR methods is very similar
- First, the CRF is be determined, a process called **self-calibration**.
- Then follows the final image composition method, also called **weighting**.



General image acquisition pipeline.

HDR Methods

- All following methods differ on the metric used to calculate the final image, which can be:
  - The CRF
  - The SNR (Signal-to-Noise Ratio)
  - The Variance

- Some methods using Neural Networks will also be presented.

HDR Methods

- **CRF based**
- SNR based
- Variance based
- NN based

CRF Based Methods

- **Mann & Picard Paper** (1994)
- This is the first ever modern HDR implementation.
- The first step is that of the *self-calibration algorithm*.

- Suppose:
  - A, B two differently exposed images of the same scene (the algorithm can be adjusted to more images).
  - $R(\cdot)$ an unknown CRF.
  - $\mathbf{E}$ an unknown incoming light irradiance vector.

HDR Methods

- CRF based
- **SNR based**
- Variance based
- Neural Network based

SNR Based Methods

- **Mitsunaga & Nayar paper** (1999).

- It is based on the Signal-to-Noise Ratio (SNR) of the image capturing process.
- Based on examination of various known CRFs, an unknown one can be modeled using a high-order polynomial for i being an image measurement before applying the CRF:

$$x = R(i) = \sum_{n=0}^{N} c_{\mathrm{n}} i^{n}$$

HDR Methods

- CRF based
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Variance Based Methods

- **Kirk & Andersen paper** (2006)

- This paper examines the weighting problem both from the linear and the logarithmic domain, while omitting self-calibration.

- Suppose M images with N pixels each, and $i \in [0, M]$ & $j \in [0, N] \subseteq \mathbb{Z}$, with $x(i, j)$ being the j^{th} pixel of the i^{th} image.

HDR Methods

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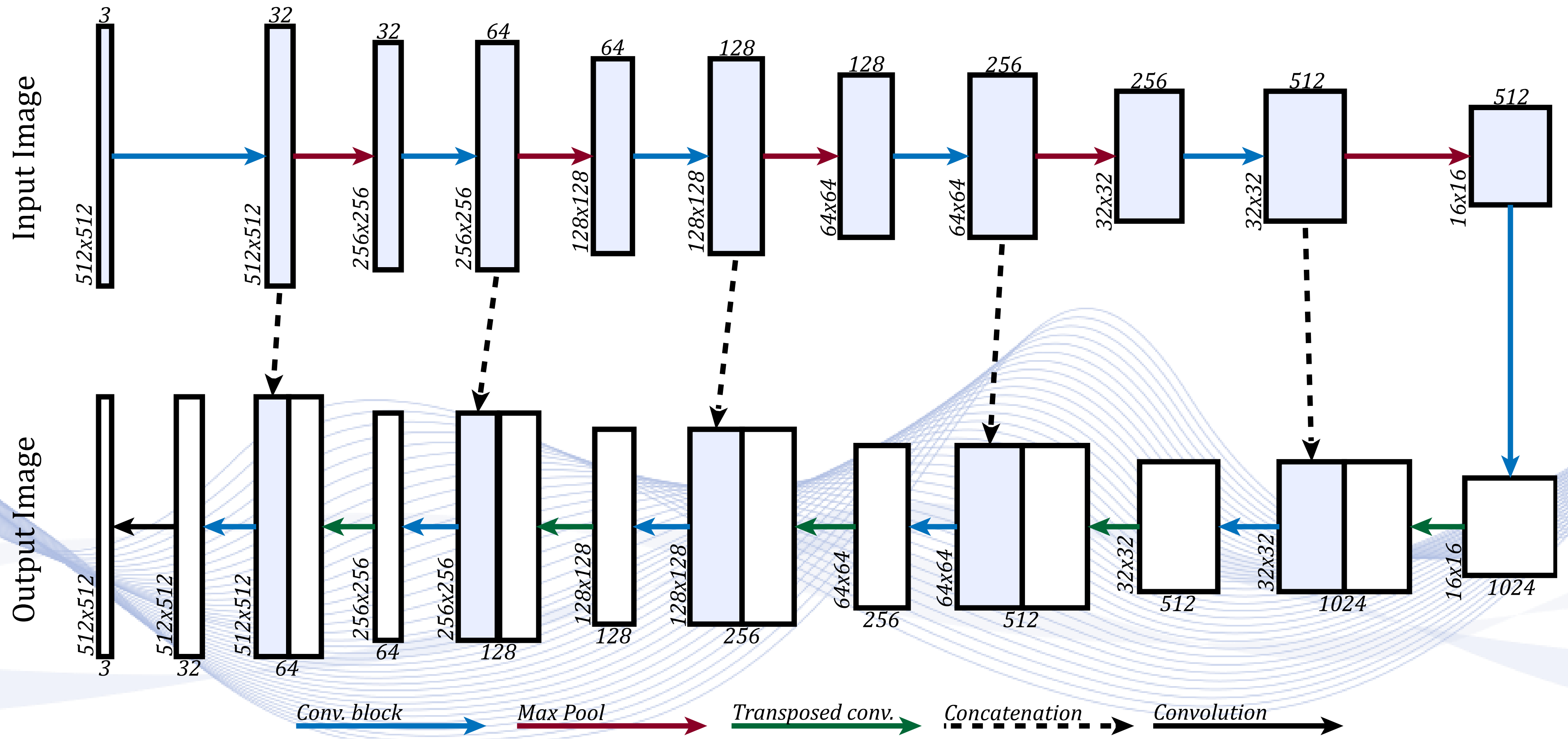
NN Based Methods

- **Kinoshita & Kiya paper** (2019)
- This paper uses Convolutional Neural Networks to achieve an HDR final image with no need for self-calibration.
- The main idea is to make use of an alteration of Reinhard’s global operator to help train a CNN which will generate HDR images from a single LDR picture.

NN Based Methods



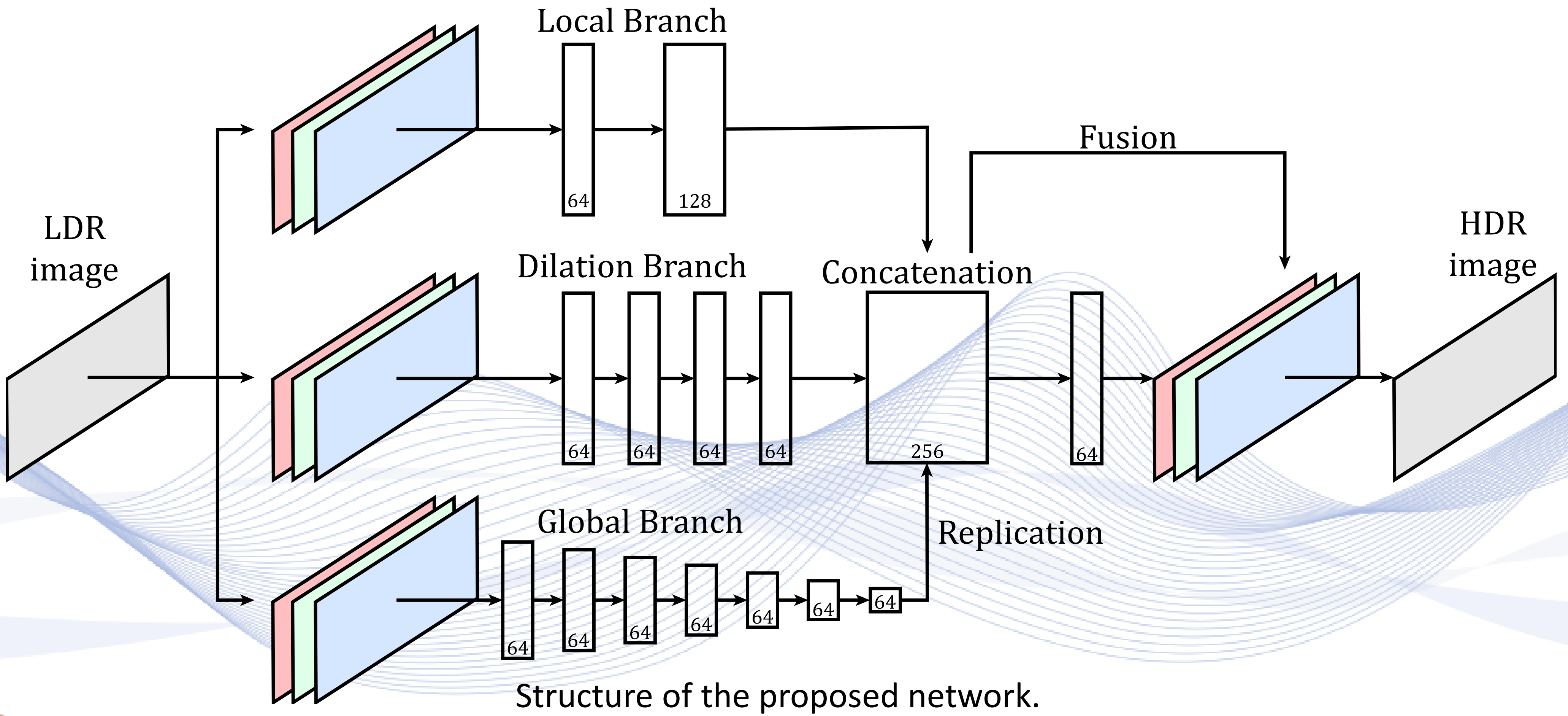
Structure of the proposed network.

NN Based Methods

- **Marnerides et al. paper** (2018)

- This paper introduces a CNN architecture for HDR expansion of LDR images, called ExpandNet.
- Again, no exposure bracketing is required, just a single LDR image.
- ExpandNet is comprised of three distinct branches, the Local, the Dilation, and the Global branch.

NN Based Methods



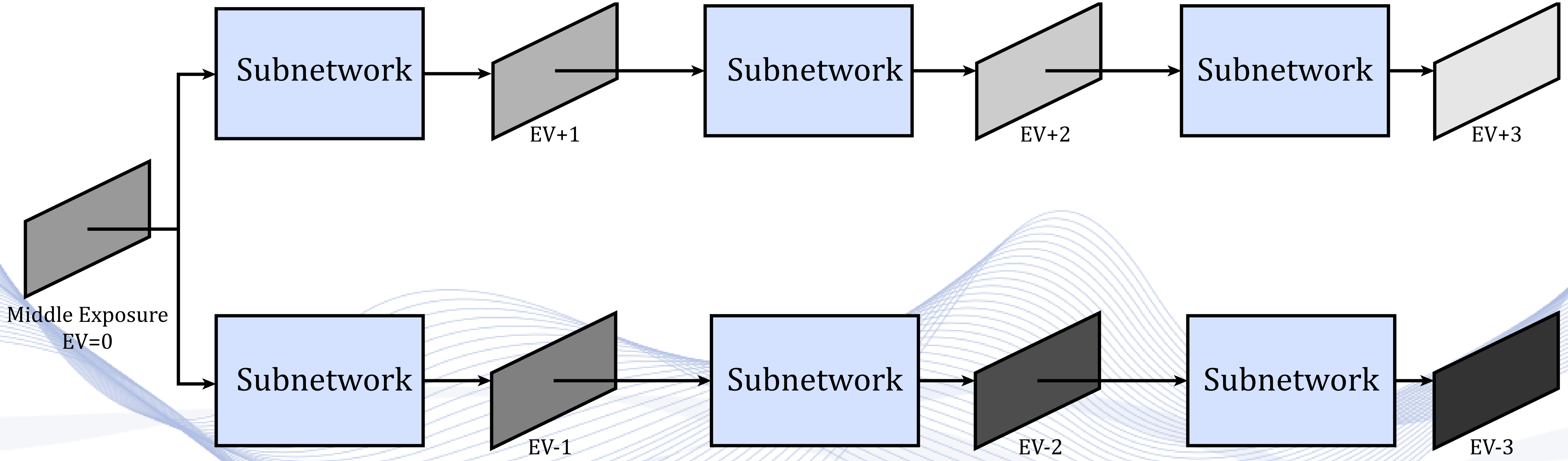
Structure of the proposed network.

NN Based Methods

- **Lee, An & Kang paper** (2018)

- This paper follows a different approach than the rest NN based ones.
- It suggests a way to generate differently exposed shots from the same single LDR image.
- This paves the road for other weighting methods reliant on exposure bracketing to construct the final HDR image.

NN Based Methods



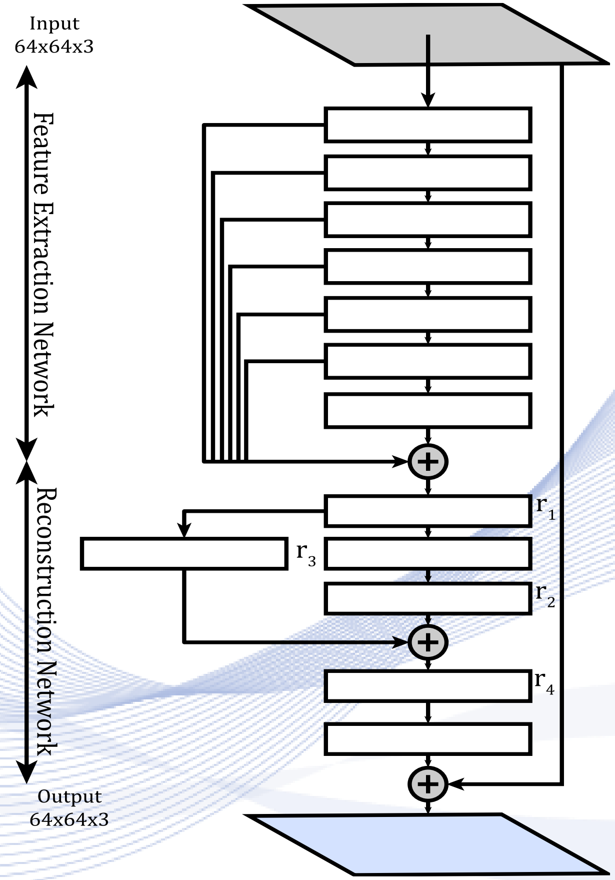
Structure of the proposed network.

NN Based Methods

- The goal is to get an image A with $EV_A = i$ and output an image B with $EV_B = j$.

- The subnetwork accepts and returns $64x64$ patches of A and B.

- There is a front and a rear part:
  - The front is comprised of 7 feature extraction blocks
  - The rear is comprised of 4 reconstruction blocks



Structure of subnetwork

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Q & A

Thank you very much for your attention!

More material in
http://icarus.csd.auth.gr/cvml-web-lecture-series/

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