Modern High Dynamic Range Imaging at the Time of Deep Learning

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Abstract

In this tutorial, we introduce how the High Dynamic Range (HDR) imaging field has evolved in this new era where machine learning approaches have become dominant. The main reason for this success is that the use of machine learning and deep learning has automatized many tedious tasks achieving high-quality results overperforming classic methods. After an introduction to classic HDR imaging and its open problem, we will summarize the main approaches for merging of multiple exposures, single image reconstructions or inverse tone mapping, tone mapping, and display visualization.

CCS Concepts

• ***Computing methodologies*** → ***Computational photography; Image processing;***

1. Presenters Information

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2. Keywords

- High Dynamic Range (HDR) imaging
- Standard Dynamic Range (SDR) imaging
- Convolutional Neural Networks (CNNs)
- Machine Learning (ML)
- Deep Learning (DL)

3. Tutorial Length

We propose a half-day tutorial; 2x90 minutes.

4. Outline of the Tutorial

In our tutorial, we will first introduce the HDR imaging pipeline in its different stages: capturing (multiple/single exposures), storing, and visualization (tone mapping and native visualization). Then, we will show how deep learning has been used recently to improve quality in the different stages of the pipeline. Our approach is, to sum up different methods and show the key ideas (network, training, dataset, and loss functions) that make these approaches important and interesting.

- Introduction to HDR Imaging (25 min):
  - Capturing;
  - Inverse Tone Mapping;
  - Tone Mapping;
  - HDR Displays;
  - HDR Metrics.
- Introduction to Main Deep Learning Architectures (15 min):
  - Convolutional neural networks (CNNs);
  - Fully Convolutional networks (FCNs)
  - The U-Net model;
  - Generative adversarial networks (GANs).
- Multiple-exposure Reconstruction (40 min.):
  - Alignment of images captured at different exposure times [KR17, YZL*20, WRK21, NWL*21, LEPM22, PGAM20, PCLT21, PCS*22, LWW*22];
  - Alignment of videos frames with varying exposures [KR19, CCG*21, PCS*22];
  - Reconstruction of images/videos with spatially varying exposure/single shot [MIPW20, XLW*22, ÇBM*22].
- **COFFEE BREAK**
- Single-exposure Reconstruction (40 min.)
  - Inverse Tone Mapping for SDR content [EKM17, EKD*17, MBHD18, LAK18, SRK20, LLC*20, PCLT21, WZW19, EMU19, XSXZ19, ZA21];

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  - Joint-Problems [KOK20, KOK19].
  - Quality Assessment [EHH*21, HME*22].
- Visualization (30 min.)
  - Tone mapping for HDR content [PKO*21, VHF21, ZZWW22, RSV*20, ZLD*22, WCS*22, SRK20, OMH21];
  - Deep Learning for HDR displays [DDLC20, DMC*22].
- Deep HDR Metrics for Images (30 min.):
  - Reference-based Deep Learning HDR metrics [WGY*18, ABCM20];
  - No-reference Deep Learning HDR metrics for images [KVDC18, BAMC20, BAM*23].

5. Tutorial Requirements

To fully follow this tutorial, the audience needs to know:

- Classic image processing;
- Basic machine/deep learning concepts;

6. Presenters Resume

6.1. Francesco Banterle

Francesco Banterle is a Researcher at the Visual Computing Laboratory at ISTI-CNR, Italy[†]. He received a Ph.D. in Engineering from Warwick University in 2009. During his Ph.D. he developed Inverse Tone Mapping that bridges the gap between Low Dynamic Range Imaging and High Dynamic Range (HDR) Imaging. He holds two patents, one sold to Dolby, and the other one of these was transferred to goHDR and then sold. His main research fields are high dynamic range (HDR) imaging (acquisition, tone mapping, HDR video compression, and HDR monitors), augmented reality on mobile, and image-based lighting. Recently, he has been working on applying Deep Learning to imaging and HDR imaging proposing the first Deep-Learning based metrics with and without reference. He is co-author of two books on imaging. The first one is "Advanced High Dynamic Range Imaging" [BADC17] (first edition 2011, second edition 2017), which is extensively used as a reference book in the field together with its MATLAB toolbox called the HDR Toolbox[‡]. he second book "Image Content Retargeting" [ABA*16], which shows how to re-target content to different displays in terms of colors, dynamic range, and spatial resolution.

6.2. Alessandro Artusi

Alessandro Artusi received a Ph.D. in Computer Science from the Vienna University of Technology in 2004. He is currently the Managing Director of the DeepCamera Lab at CYENS (Cyprus)[§] who recently has joined, as a funding member, the Moving Picture, Audio and Data Coding by Artificial Intelligence (MPAI), a not-for-profit standards organization established in Geneva. He is currently the Cyprus representative in the ISO/IEC/SC 29 imaging/Video compression standardization committee, as well as representing Cyprus in two main working groups WGs 4 and 5. Prior to the above, he has been committee member of the IST37 of the British Standard Institute (BSI) and representing the UK in the JPEG and MPEG committee's. He is the recipient, for his work on the JPEG-XT standard, an image compression system for HDR content, of the prestigious BSI Award. His research interests include visual perception, image/video processing, HDR technology, objective/subjective imaging/video evaluation, deep-learning, computer vision and color science, with a particular focus to deploy the next generation of imaging/video pipeline. He is also the co-author of the "Advanced High Dynamic Range Imaging" book [BADC17] (first edition 2011, second edition 2017), which is a reference book in the HDR field, and author of the "Image Content Retargeting" [ABA*16] book, which shows how to re-target content to different displays in terms of colors, dynamic range, and spatial resolution.

† http://vcg.isti.cnr.it

‡ https://github.com/banterle/HDR_Toolbox

§ https://www.cyens.org.cy/en-gb/research/pillars-groups/visual-sciences/deep-camera/

7. Similar Previous Courses/Tutorials

7.1. SIGGRAPH ASIA 2011: Multidimensional Image Retargeting

This course was held in Hong Kong [BAA*11], and it covered how to adapt content (images and videos) for different target displays in terms of dynamic range, color gamut, aspect ratio, spatial resolution, temporal resolution, etc. This course covered classic inverse tone mapping and tone mapping, and no deep-learning techniques were covered.

7.2. EUROGRAPHICS 2012: Mapping Images to Target Devices

This course was held in Cagliari (Italy) [BAA*12], and it covered how to adapt content (images and videos) for different target displays in terms of dynamic range, color gamut, aspect ratio, spatial resolution, temporal resolution, etc. This course covered classic inverse tone mapping and tone mapping, and no deep learning techniques were covered.

7.3. EUROGRAPHICS 2016: The HDR-video Pipeline

This course was held in Lisbon (Portugal) [UBEM16], and it covered the full HDR-video pipeline. Perhaps this is the closest course to the one we propose in terms of covered topics such as capturing, tone mapping, inverse tone mapping, and displays. However, our course has an emphasis on modern HDR imaging using machine learning and deep learning. Moreover, the previous course was focused only on HDR imaging using classic algorithms without learning. In our, tutorial, we want to highlight the advantages of Deep Learning and its challenges.

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