High Dynamic Range Imaging

Sensors and Architectures

SECOND EDITION

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Arnaud Darmont

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Arnaud Darmont

Arnaud Darmont (1979–2018) was the founder and CEO of Aphesa, a company that provided image-sensor consultations. He served as an SPIE course instructor and session chair for IS&T/SPIE Electronic Imaging. In December 2017, he joined the European Machine Vision Association as a Standards Manager and introduced two new standards in less than a year. He completed work on this edition before his passing. His enthusiasm and drive as a member of SPIE and the machine-vision community lights the way for others to follow.

Preface

HDR photograph made of exposure bracketing with three shots and post-processed in Photomatrix Pro and Lightroom (courtesy Christian Michaux).

This book collects the knowledge about image sensors, dynamic range, high dynamic range (HDR) image sensors, and HDR applications gained from over 16 years in the image sensor and imaging business as an engineer, project manager, researcher, instructor, business development manager, and consultant.

With my first employer, Melexis, I worked on one of the first HDR global shutter CMOS image sensors and its related reliability and production testing. At that time, very few publications were available on in-pixel HDR imaging and its issues and difficulties, even though several companies (such as FillFactory, IMEC, PhotonFocus, Awaiba, Melexis, and Micron) already had device prototypes and were building the knowledge internally. No company had experience with the full production testing of such devices, and everything had to be made to meet automotive standards.

At Aphesa, several of our custom camera projects or consulting projects were related to or involved HDR. We had several pipe inspection projects, including oil and gas applications, or medical endoscopy applications in which lighting was very difficult to control and the irradiance of the scene was very uneven. The scenes also had some highly reflective parts and lowly reflective parts simultaneously. HDR techniques were implemented in the sensor, in the

camera, or in the host software. Later, we saw more multispectral or hyperspectral projects that had very large differences in the signal levels between bands, causing imaging difficulties similar to what we had encountered in HDR, and therefore techniques derived from HDR were used.

When the first edition of this book was published in October 2012, it was the first comprehensive text about HDR techniques used in pixels and in cameras or software with an engineering level of technical details. Since then, HDR photography has become more popular.

In 2015, I started teaching image sensors and imaging more widely than the SPIE HDR course that inspired this book, and a lot of questions were raised by attendees. It became necessary to update the book with the answers to some of these questions.

In 2017, I joined the European Machine Vision Association as part-time manager of standards, and one of the first actions taken was to extend the EMVA1288 standard to be compatible with HDR image sensors and cameras. There is also an initiative to extend the Gen<i>cam standard to offer HDR pixel formats and compatible data containers and controls.

Since the first edition, things have evolved quickly in the field of HDR because of the use of HDR in consumer markets such as DSLR and mobile, and also because of the development of autonomous vehicles, drones, and the latest generation of camera-based driver-assistance systems.

Therefore, the philosophy of the book has evolved. The explosion of HDR applications has led to a significant increase in the number of algorithms and publications on the topic, so this volume serves as a starting point for exploring HDR imaging by introducing the core concepts with schematics and equations and going deep into the general principles.

This book provides readers with an intermediate-to-advanced knowledge of HDR image sensors and techniques for industrial and non-industrial applications. HDR is increasingly being used in automotive on-board systems, autonomous vehicles, road traffic monitoring, and in industrial, security, medical, and military applications, as well as in photography. It offers advantages such as greater robustness against direct sunlight or reflection of strong lights on metals, and better detection of objects located in shadows. The book is not about the artistic side of HDR images, although some aspects of HDR photography are mentioned, and several photographs are included for illustration. Some aspects of system testing are also introduced. Instead, it describes various sensor and pixel architectures to achieve HDR imaging, as well as software approaches to create HDR images out of lower dynamic range sensors or image sets. Some methods for automatic control of exposure and dynamic range of image sensors are introduced. The most important optical effects are also considered.

Arnaud Darmont
September 2018