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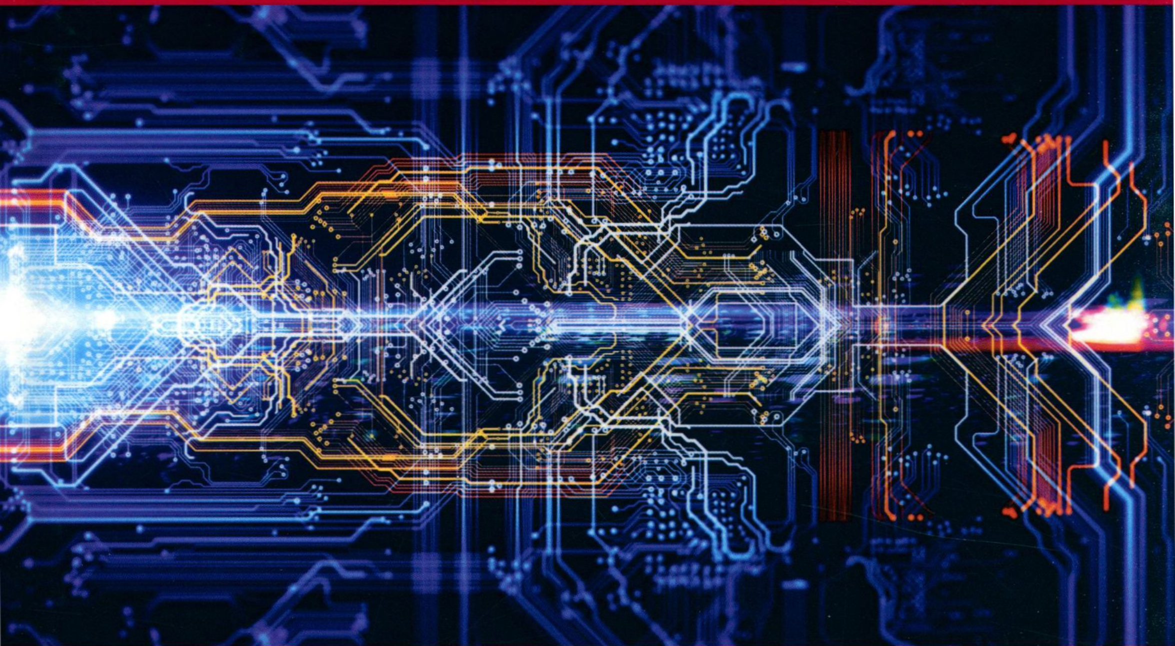

Architecture-Aware Optimization Strategies in Real-time Image Processing

Chao Li
Souleymane Balla-Arabe
Fan Yang

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In the field of image processing, many applications require real-time execution, particularly those in the domains of medicine, robotics and transmission, to name but a few.

Recent technological developments have allowed for the integration of more complex algorithms with large data volume into embedded systems, in turn producing a series of new sophisticated electronic architectures at affordable prices.

This book performs an in-depth survey on this topic. It is primarily written for those who are familiar with the basics of image processing and want to implement the target processing design using different electronic platforms for computing acceleration.

The authors present techniques and approaches, step by step, through illustrative examples. This book is also suitable for electronics/embedded systems engineers who want to consider image processing applications as sufficient imaging algorithm details are given to facilitate their understanding.

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Preface

In the image processing field, a lot of applications require real-time execution in the domains of medical technology, robotics and transmission, etc. Recently, real-time image processing fields have made a lot of progress. Technological developments allow engineers to integrate more complex algorithms with large data volumes onto embedded systems, and produce series of new sophisticated electronic architectures at an affordable price. At the same time, industrial and academic researchers have proposed new methods and provided new tools in order to facilitate real-time image processing realization at different levels. It is necessary to perform a deepened educational and synthetic survey on this topic. We will present electronic platforms, methods, and strategies to reach this objective.

This book consists of seven chapters ranging from the fundamental conceptual introduction of real-time image processing to future perspectives in this area. We describe hardware architectures and different optimization strategies for real-time purposes. The latter consists of a survey of software and hardware co-design tools at different levels. Two real-time applications will be presented in detail in order to illustrate the proposed approaches.

The major originalities of this book include (1) algorithm architecture mapping: we select methods and tools that treat simultaneously the application and its electronic platform in order to perform fast and optimal design space exploration (DSE), (2) each approach will be illustrated by concrete examples and (3) two of the chosen algorithms have been only recently advanced in their domain.

This book is written primarily for those who are familiar with the basics of image processing and want to implement the target image processing design using different electronic platforms for computing acceleration. It accomplishes this by presenting the techniques and approaches step by step, the algorithm and architecture conjointly, and by notions of description and example illustration. This concerns both the software engineer and the hardware engineer.

This book will also be adequate for those who are familiar with programming and applying embedded systems to other problems and are considering image processing applications. Much of the focus and many of the examples are taken from image processing applications. Sufficient detail is given to make algorithms and their implementation clear.

Chao LI
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Introduction of Real-time Image Processing

1.1. General image processing presentation

The traditional view of an image derives heavily from experience in photography, television and the like. This means that an image is a two-dimensional (2D) structure, a representation and also a structure with meaning to a visual response system. This view of an image only accepts spatial variation (a static image). In parallel, a dynamic image has spatial and temporal variation. In most contexts, this is usually referred to as video. This more complex structure needs to be viewed as a sequence of images each representing a particular instance in time. On the other hand, an image can be formed by taking a sampling plane through that volume and so the variation in three dimensions is observed. This may be referred to as a volume image. An image linked to a volume that changes with time is a further possibility. This has particular significance in medical imaging applications [MYE 09].

Image processing is a method to convert an image into digital form and perform some operations on it in order to get an improved image or to extract some useful information from it. A digital image described in a 2D space is usually considered as 2D signals while applying already set signal methods to it. Image processing forms a core research area within engineering and computer science too.

Image processing is an enabling technology for a wide range of applications including remote sensing, security, image data sets, digital television, robotics and medical imaging, etc. The goal of this technology can be divided into three levels: low, medium and high. Low-level image processing techniques are mathematical or logical operators that perform simple processing tasks. This "processing" level possesses both *image_in* and *image_out*. Medium-level image processing combines the simple low-level operators to perform feature extraction and pattern recognition functions. Using an *image_in*, this "analysis" level produces *measurements_out* (parameters). High-level image processing uses combinations of medium-level functions to perform interpretation. This "understanding" level treats *measurements_in* for high-level *description_out*. Usually, apart from these three levels, it is also necessary to apply preprocessing techniques that are designed to remove distortions introduced by sensors.

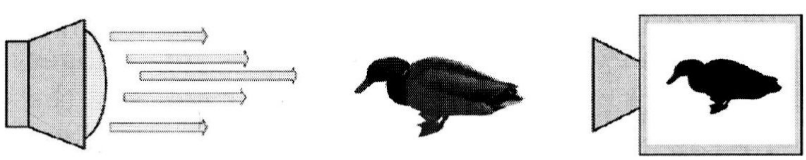

Figure 1.1. *Overview of the typical image acquisition process (see [MOE 12])*

Before any image processing can commence, an image must be captured by a camera and converted into a manageable entity. This is the image acquisition process (see Figure 1.1), which consists of three steps; energy reflected from the object of interest, an optical system that focuses on the energy and finally a sensor that measures the amount of energy. In order to capture an image, a camera requires some sort of measurable energy. The energy of interest in this context is light or electromagnetic waves. Each wave can have different wavelengths (or different energy levels or different frequencies). The human visual spectrum is in the range of approximately 400–700 nm.

After having illuminated the object of interest, the light reflected from the object now has to be captured by the camera composed of an optical system and an image sensor. The role of the first is to focus the light reflected from the object onto the second (a material sensitive to the reflected light). An image sensor consists of a 2D array of cells. Each of these cells is denoted a pixel and is capable of measuring the amount of incident light and convert that into a voltage, which in turn is converted into a digital number. The more incident light, the higher the voltage and the higher the digital number.

In order to transform the information from the sensor into an image, each cell content is now converted into a pixel value in the range: (0, 255). Such a value is interpreted as the amount of light hitting a cell. This is denoted the intensity of a pixel. It is visualized as a shade of gray denoted gray-level value ranging from black (0) to white (255). Standardly, a monochromatic, static image corresponds to a matrix of m rows and n columns. Therefore, the camera records $m \times n$ pixels of 8 bit values.

In order to capture a color image, the color camera must record three matrices of three primary colors red, green and blue. Recently, a lot of applications are realized using multispectral image processing, since the multispectral cameras are more available with reasonable prices. According to application needs, multispectral images are captured using different wavelengths (bands). They can be considered as a cube formed by 2D gray-level images. Figure 1.2 displays two typical test images in the area of image processing research. Figure 1.3 gives two multispectral cube examples; the right image is captured for a skin lesion assessment application.

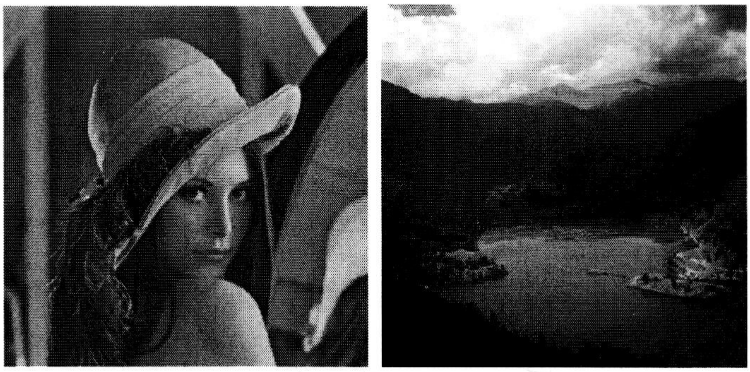

Figure 1.2. *Lena (gray-level image) and landscape (color image). For a color version of the figure, see www.iste.co.uk/li/image.zip*

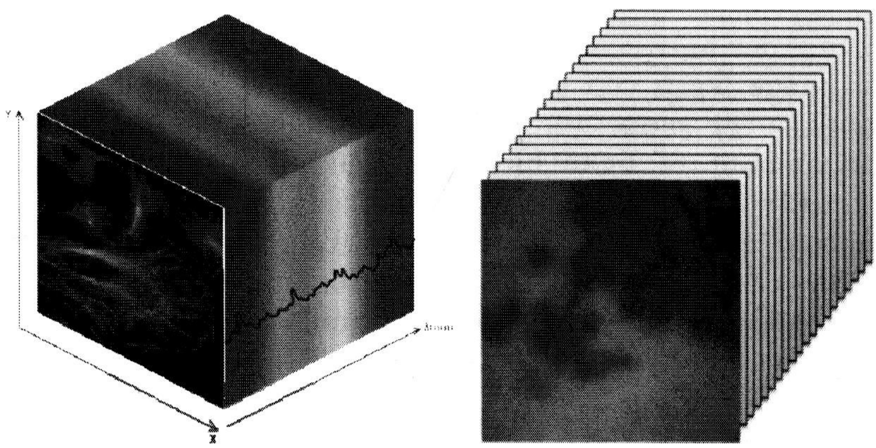

Figure 1.3. *Two multispectral image cubes. For a color version of the figure, see www.iste.co.uk/li/image.zip*

Certain tools are central to the processing of digital images. These include mathematical tools, statistical descriptions and manipulative tools. We can cite some more used such as *convolution*, *filtering in spatial and frequency domains*, *morphological operations* and *image transforms*,