

Embedded Image Processing on the TMS320C6000 DSP: Examples in Code Composer Studio and MATLAB by Shehrzad Qureshi, Springer, 2005, ISBN: 0-387-25280-0. Reviewed by Konstantinos Konstantinides, Hewlett-Packard, k.konstantinides@ieee.org.

There is certainly no shortage of books on image processing. A quick search for books on the topic using Amazon.com yields more than 15,000 results. Refining the search to focus on books that use MATLAB narrows the list to about 75—certainly a much smaller pool of books to choose from, but still not a short list. So why should one consider purchasing Shehrzad Qureshi's new book, *Embedded Image Processing on the TMS320C6000 DSP: Examples in Code Composer Studio and MATLAB*? The answer is simple. While most image processing books on the market address either fundamental theory or applications, this book focuses on *embedded* image processing and, more specifically, on the efficient implementation of image processing algorithms on the TMS320C6000 family of digital signal processors (DSPs) from Texas Instruments (TI).

A few of the challenges in implementing algorithms in an embedded system include dealing with fixed-point arithmetic processors, arranging memory management, and using real-time operating systems. For example, implementations for desktop systems typically use floating-point arithmetic; therefore, data precision issues are rarely a concern. On the other hand, many of the most cost-efficient and fast DSPs use only fixed-point arithmetic, which means that the position of the decimal point, data scaling, quantization effects, and other data

precision issues must be carefully managed by the programmer. Similarly, while implementations for desktop systems seldom require programmers to worry about memory management and how data are transferred in and out of the desktop, efficient implementations on embedded systems require proper memory management and data transfers. Last but not least, each embedded system comes with its own unique real-time operating system and set of utilities that need to be mastered before one even writes the first line of code. These and other similar issues are effectively addressed by this book.

The text is divided into six chapters: "Introduction," "Tools," "Spatial Processing Techniques," "Image Filtering," "Edge Detection and Segmentation," and "Wavelets." Additionally, the text is supported by two appendices. Each chapter is accompanied by a list of references, and the author also provides many useful Internet resources for image processing tools. As indicated by the chapter titles, the text includes several image processing programming examples, ranging from simple spatial filters to more advanced nonlinear filters and wavelet-based processing. Each example is introduced in multiple steps. First, the author provides a short introduction of the algorithm fundamentals. The reader should not expect to learn image processing from this book, but there is sufficient material to understand the basic principles behind the algorithms and to implement them in either MATLAB or C. The author then provides a high-level reference implementation either in MATLAB or in C/C++ using Microsoft's Visual Studio .NET 2003. A high-level reference implementation is a very common (and highly recommended) practice in embed-

ded programming since it provides invaluable aid in both high-level algorithm optimization and debugging. For its MATLAB implementations, the book provides additional references and describes useful techniques for using MATLAB's Graphical User Interface (GUI) Builder, the Image Processing Toolbox, the Wavelet Toolbox, and the Link for Code Composer Studio. For Visual Studio projects, the author shows how to use simple image processing user interfaces and how to take advantage of existing image processing libraries, such as Intel's Integrated Performance Primitives (Intel IPP). Finally, the algorithm is implemented on either the floating-point C6701 DSP or the fixed-point C6416 DSP using TI's Code Composer Studio (CCStudio). The book provides numerous useful pointers on how to best setup and use CCStudio and related software toolkits including TI's real-time operating system (DSP/BIOS) as well as DSPLIB and IMGLIB, TI's highly optimized libraries of frequently used signal and image processing algorithms.

There is a common misconception that efficient DSP programming requires using assembly code. This might have been the case in the early days of DSP processors. However, there have been significant advances in DSP compilers in recent years, which free users from the burden of programming in assembly language. As the author points out, there are many high-level optimization techniques that programmers can use before they resort to assembly-level programming. The book provides some very simple and efficient techniques for optimizing execution speed, including using loop optimizations, intrinsic functions (highly optimized

function calls), and direct memory access (DMA). While the emphasis is on programming, the book includes multiple figures, images, and screen shots of the programming environments. These facilitate a better understanding of the coding examples and also help illustrate how to use the programming tools described in the book.

The book is intended for signal and image processing practitioners or software developers that plan to use a TI DSP. However, most of the programming techniques demonstrated here can easily be applied to other embedded platforms. According to the author, all examples have been tested and debugged on either the TI C6701 Evaluation Module or the C6416 DSP Starter Kit. There are plenty of source code listings in the book, but

all source code and project files are also included in the accompanying CD-ROM. The CD-ROM includes many test images and one test video clip. The reader should be fluent in programming in C, and some exposure to MATLAB, C++, Visual Studio, and the TI development tools could help. The book may also be useful to DSP students who would like to use the TI development boards for DSP-related projects.

Qureshi's focus on embedded image processing and, in particular, on the efficient implementation of image processing algorithms on the TI TMS320C6000 family of DSPs makes this book stand out. Other books focus on either embedded image processing—and, in particular, on architectures [such as *Architectural Enhancements*

for Color Image and Video Processing on Embedded Systems by Jongmyon Kim (ProQuest, 2006)]—or on MATLAB implementations of existing image processing algorithms. Therefore, we believe this text has no direct competition at the time of publication.

Overall, the book is well written and succeeds in filling a big void in image processing literature, tackling how to efficiently implement signal and image processing algorithms using embedded processors. There is no better way to learn than by example, and the book offers plenty of them. The book and the accompanying source code in the CD-ROM should be valuable resources to all signal processing practitioners who want to embark on embedded DSP programming. **SP**

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