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The Reconfigurable Video Coding Standard

More than two decades of research in digital video technologies, together with the emergence of successful international standards for digital video compression, have led to a wide variety of digital video products using video compression for professional and consumer applications. Although many of these video compression standards share common and/or similar coding tools, there is currently no explicit way to exploit such commonalities at the level of the specifications nor at the level of implementations. Moreover, the possibility of taking advantage of the benefits of the continuous improvements of coding technology is only possible by replacing an old standard with a new one. This usually results in the replacement of the existing multimedia devices with new ones capable of handling the new deployed standards. Such necessity is not always well accepted by the public and professionals for obvious reasons.

The typical scenario exemplifying what happens to many users of multimedia devices is shown in Figure 1(a). After a period of usage, devices are not able to provide new features and services that are made possible through the evolution of new technology and new standard deployment. The only solution is to buy new equipment and keep (or get rid of) the old. Such a scenario was acceptable in the past when the rate of innovation was relatively slow and very few standards existed (in most cases just one), but not anymore with the rate of innovation that is taking place today. Moreover, the legacy of existing equipment constitutes a strong limit for the timely introduction of innovations and improvements that technology progresses could potentially provide.

The new Moving Picture Experts Group (MPEG) Reconfigurable Video Coding (RVC) standard intends to support the possibility of incremental deployment of new technologies, thus support scenarios in which equipment can be updated with new possible configurations of video compression technology. Such flexibility also becomes very attractive for developing new codec configurations presenting specific feature optimizations more appropriate for the different application domains.

The achievement of such objectives requires two essential components: 1) a new standardization framework with built-in evolutive features and 2) a higher level of flexibility and reconfiguration capabilities of video coding platforms. The MPEG RVC provides such new flexibility in standardization with

[MPEG RVC ENABLES, IN PRINCIPLE, THE SELECTION AND USAGE OF ANY ARBITRARY COMBINATIONS OF STANDARDIZED BASIC CODING ALGORITHMS.]

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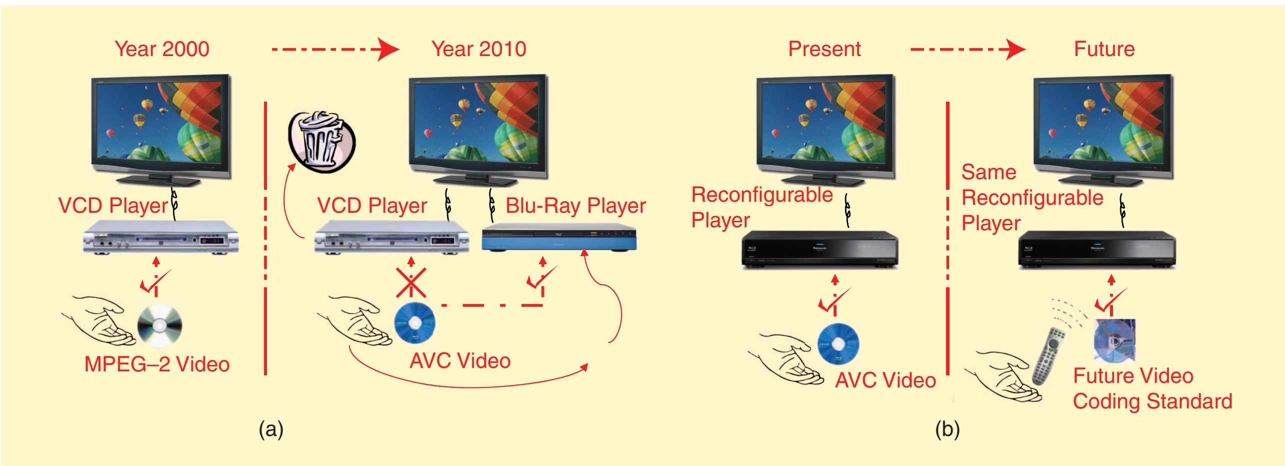


[FIG1] A simple example of the replacement scenario due to the emergence of a new technology is given in (a), where a new media player (current situation) must be purchased. In (b), the possibility to incrementally upgrade devices according to the evolution of technology (essential objective of the new emerging MPEG RVC standard) is shown.

the appropriate attention to the relevant, in this context, features of new emerging platforms characterized by higher processing power and flexibility provided by massive multicore and reconfigurable (co)processors.

BACKGROUND

MOTIVATION

The current scheme for the definition and standardization of new video coding technology results in a noticeably long time span between the validation of the new idea/concept and its implementation in consumer products as part of a worldwide standard. Each MPEG standard developed so far and issued by the International Organization for Standardization (ISO)/International Electrotechnical Commission (IEC) can be considered as a "frozen" version or a snapshot of state-of-the-art of video compression taken a few years before the standard was released in its final form to the public. Since some algorithms that are part of such standards are quite complex to be implemented on certain devices, or not necessary for all applications, they are included only into standardized "profiles," which simply constitute subsets of coding algorithms providing codecs implementations satisfying specific application constraints. Interoperability is thus guaranteed at the level of these standard profiles. However, it would be desirable for several application domains to be able to employ codecs made of other subsets of coding algorithms aiming at obtaining other tradeoffs or optimizing/maximizing other specific codec characteristics. The term "other" refers to all features other than coding efficiency that represent the usual main target of current compression standardization efforts. Although coding efficiency is fundamental, other tradeoffs, such as coding performance versus computational requirements or coding performance versus low latency, are not efficiently realizable within current standard profiles. However, it can be easily observed that the possibility of seeking new tradeoffs for codecs exists by considering the large number of coding algorithms already available in existing standard technology [MPEG-1, MPEG-2, MPEG-4 Part 2 and Part 10 with advanced video coding (AVC) and scalable video coding (SVC)] and all the possible meaningful combinations of them. Moreover, the increasing variety of application domains employing video compression, besides the traditional digital video broadcasting and storage, is looking for very specific optimizations that are different from the usual compression efficiency.

OBJECTIVES

For the reasons discussed so far, the emerging MPEG RVC standard presents an alternative paradigm for codec standardization and deployment aiming at providing a unified, dynamic, and incremental development, implementation, and adoption of standardized video coding solutions. MPEG RVC enables, in principle, the selection and usage of any arbitrary combinations of standardized basic coding algorithms, but obviously not all combinations are meaningful and interesting for a particular application. Such flexibility is achieved by adopting the concept of standardizing a unified library of video coding algorithms (at the moment taken from the existing standards, but incrementally upgraded with new successive algorithms) instead of adding more and more monolithic versions of new standard "profiles."

A new dataflow formalism and an Extensible Markup Language (XML) dialect are used for the description of new configurations of such algorithms that compose "new standard" codecs. The choice of the new specification formalism has been expressly done with the objective of supporting, by nonnormative implementation tools and methodologies, and the seamless (re)configuration of emerging massive parallel processing platforms. A conceptual view of the RVC standard and its expected impact on the reduction of the time for deployment of new video coding solutions is provided in Figure 2.

Another objective of the RVC standard is to enable software and hardware reuse across the various video coding standards that once used to be different and disjoint. As a result, designing new configurations and future multistandard video coding applications and devices becomes simpler. An additional challenge taken by the RVC framework is to provide a higher-level model specification for direct and efficient synthesis targeting a wide set of new generation of software and hardware platforms.

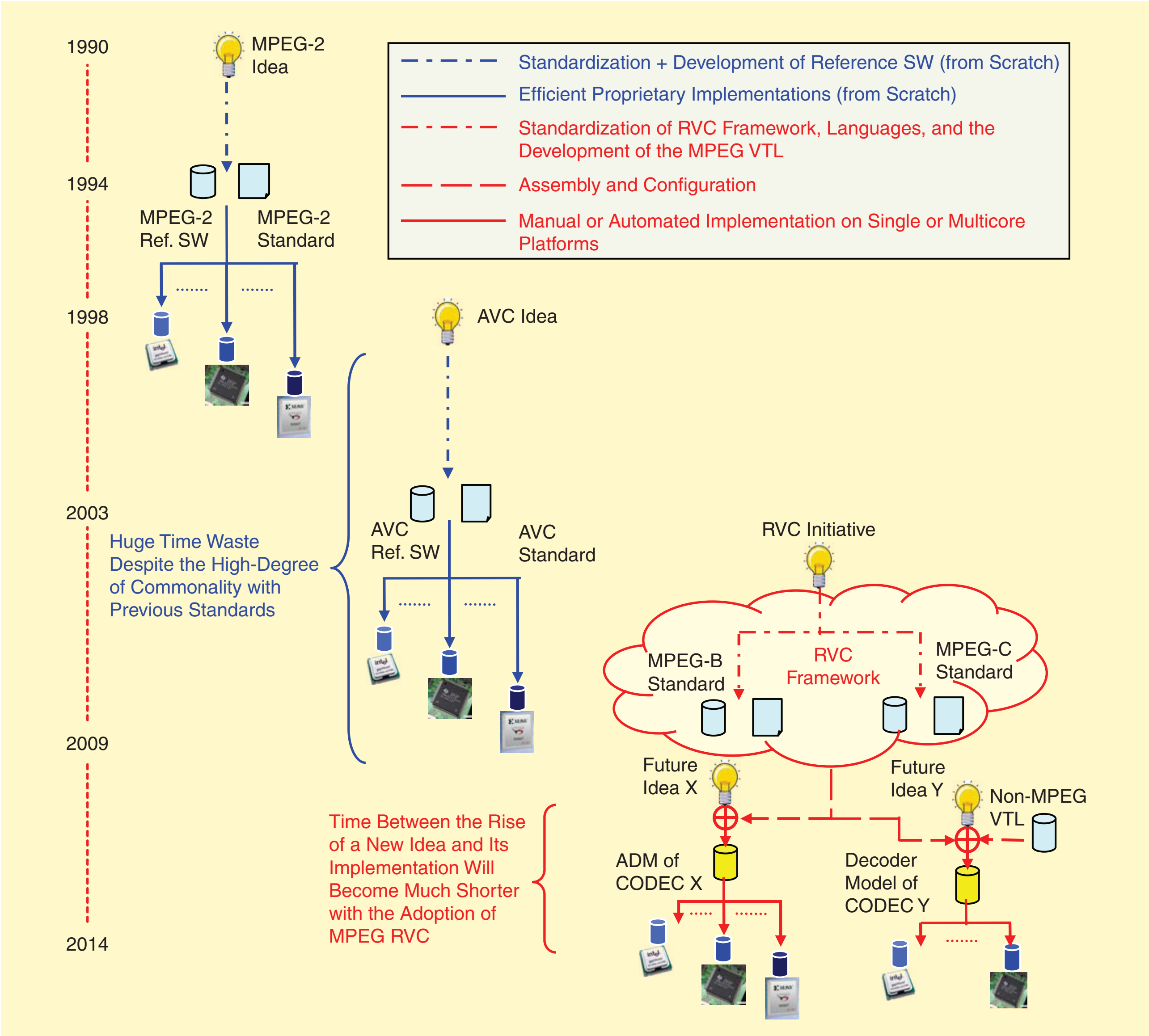
ISSUING BODY AND SCHEDULE

A first version of the RVC standard has been finalized by the ISO/ IEC, Subcommittee 29, Workgroup 11, better known as MPEG.

STRUCTURE OF THE STANDARD

Two standards are defined so far within the context of the MPEG RVC framework: ISO/IEC23001-4 (also called MPEG-B Part 4) and ISO/IEC23002-4 (MPEG-C Part 4).

- ISO/IEC23001-4 International Standard (IS) defines the overall framework as well as the standard languages that are used to specify a new codec configuration of an RVC decoder. The "Abstract Decoder Model" (ADM) is an executable description using modular dataflow formalism and constitutes the essential component of the specification of a new codec configuration. In more details the standard includes:
  - The specification of the Functional Unit Network Language (FNL), which is the language describing the video codec configurations. The FNL is an XML dialect that provides the instantiation of the functional units (FUs) composing the codec, their parameterization, as well as the specification of the connections.
  - The specification of the RVC-Bitstream Syntax Description Language (BSDL), which is a subset of the standard MPEG BSDL (ISO/IEC23001-4); a language syntactically describing the structure of the input encoded bit stream.
  - The specification of the RVC-CAL, the language that is used to express the behavior of each FU and consequently the behavior of any network of FUs described in FNL.



[FIG2] A conceptual view of the RVC standard illustrating the reduction of the time-to-deployment of video coding solutions.

RVC_CAL is used to specify all MPEG FUs that compose the "RVC MPEG Toolbox" available in ISO/IEC23002-4.

- ISO/IEC23002-4 IS specifies the unified library of video coding algorithms employed in the current MPEG standards. Up to now, the following two MPEG standards/profiles are fully covered:
  - MPEG-4 Part 2 Simple Profile.
  - MPEG-4 Part 10 (AVC) Constrained Baseline Profile.
- Amendment 1 of ISO/IEC23002-4 includes the conformance testing procedure as well as the reference software written in RVC-CAL of the RVC MPEG Toolbox. It is planned to be finally completed by the second quarter of 2010.
- Amendment 2 of ISO/IEC23002-4 that is currently under development will include MPEG-4 AVC High Profile (FREXT profile), MPEG-4 AVC Scalable Profile, MPEG-4 Part 2 Advanced Simple Profile and MPEG-2 Main Profile.

The mechanisms for the transport of RVC codec description and bit stream syntax descriptions are currently under core experiment stage. Various scenarios enabling downloads and dynamic update of codec configurations on processing platforms are analyzed so as to verify what (if any) amendment to MPEG-2 and MPEG-4 Systems standard are needed to support the widest class of deployment scenarios for RVC codecs.

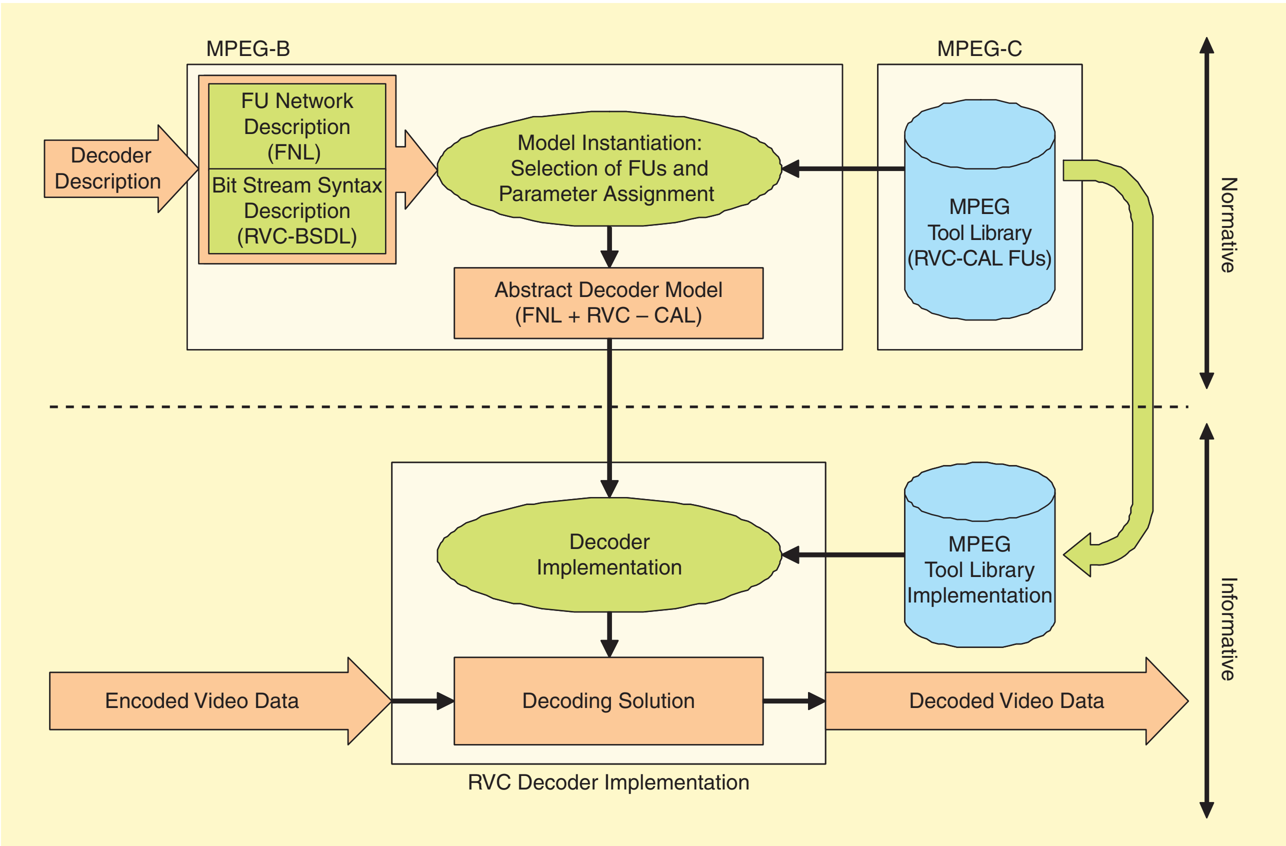
TECHNOLOGY

FUNCTIONALITIES

CAL is a dataflow language that was developed and initially specified as a subproject of the Ptolemy project at the University of California at Berkeley. With the objective of simplifying the development of implementation technologies and tools supporting both hardware and software synthesis, MPEG has standardized in ISO/IEC23001-4 a subset of the original CAL language, called RVC-CAL. The specification of all FUs included in the MPEG RVC library are normatively specified using RVC-CAL, which slightly restricts the data types, operators, and features that could be used in the original CAL language. To enable an effective possibility of codecs reconfigurations and an efficient reuse of components in codecs implementations, it is important to represent the components of the standard RVC library with an appropriate level of granularity. If the library is composed of too-coarse modules, they will be too large to allow their reuse in the wide spectrum of codec configurations; whereas, if the library component granularity level is too fine, the resulting number of modules in the library will be too large for an efficient and practical reconfiguration process at the codec implementation side. This may obscure the desired high-level description and modeling features of the RVC codec specifications.

THE CONCEPT OF THE RVC FRAMEWORK BASICALLY REVOLVES AROUND THE IDEA OF ASSOCIATING DECODER DESCRIPTION TO ENCODED VIDEO CONTENT.

The concept of the RVC framework basically revolves around the idea of associating decoder description to encoded video content. The decoder description includes two types of data: 1) the bit stream syntax description (BSD), which describes the structure of the bit stream. The BSD is written in RVC-BSDL; and 2) the FU network description (FND), which describes the connections between the coding tools (i.e., FUs). The FND is written in the so-called FNL. The decoder configuration process takes place by constructing the syntax parser based on the BSD, and the network of FUs based on the FND. The outcome of this configuration process is a normative behavioral CAL model of the decoder, namely the ADM, which may then serve as the implementation reference in terms of behavioral description. Any proprietary implementation of the standard library, specifically customized for a target platform, can be used for the implementation. To ensure a safe and secure reconfiguration process, the implementation process as defined in MPEG RVC provides open ways of reconfiguring a platform without the danger of downloading possibly malicious or dangerous code. In fact, only the codec configuration has to be taken from the outside world, whereas the "pieces of code" that are assembled to build an executable for the final implementation are either generated directly from the certified MPEG standard library or by the proprietary libraries that gain their reliability by being built either by the user him/herself or by a trusted source.



[FIG3] The normative and nonnormative components of the RVC framework. The normative components are the standard languages used to specify the ADM and the standard library of the FU. The informative parts are examples of tools that synthesize a decoder implementation possibly using proprietary implementations of the standard library.

ARCHITECTURE

Figure 3 illustrates both the normative and nonnormative components of the RVC framework. The figure shows how a decoding solution is built, not only from the standard RVC-CAL normative Video Tool Library (VTL) specification, which already provides an explicit, concurrent, and parallel model, but also from any nonnormative proprietary tool libraries, that if necessary, increases the level of explicit concurrency and parallelism for specific target platforms. Hence, the standard RVC specification that is already an explicit model for complex digital signal processing systems can be further improved or specialized by proprietary libraries that can be used in the instantiation phase of an RVC codec implementation. In other words, the MPEG RVC framework, by definition, fully integrates platform-specific optimization stages. In summary, the new MPEG RVC standard basically provides two levels of optimization that can be exploited for various implementations. The first is at the level of each component of the standard library, that are by definition independent dataflow components, while the second is the proprietary customization of each library module that maintains all its internal properties whatever configuration they are used in.

THE RVC FRAMEWORK IS INFORMATIVELY SUPPORTED BY SEVERAL TOOLS TO SECURE EFFICIENT DEVELOPMENT, RECONFIGURATION, AND IMPLEMENTATION PROCESSES.

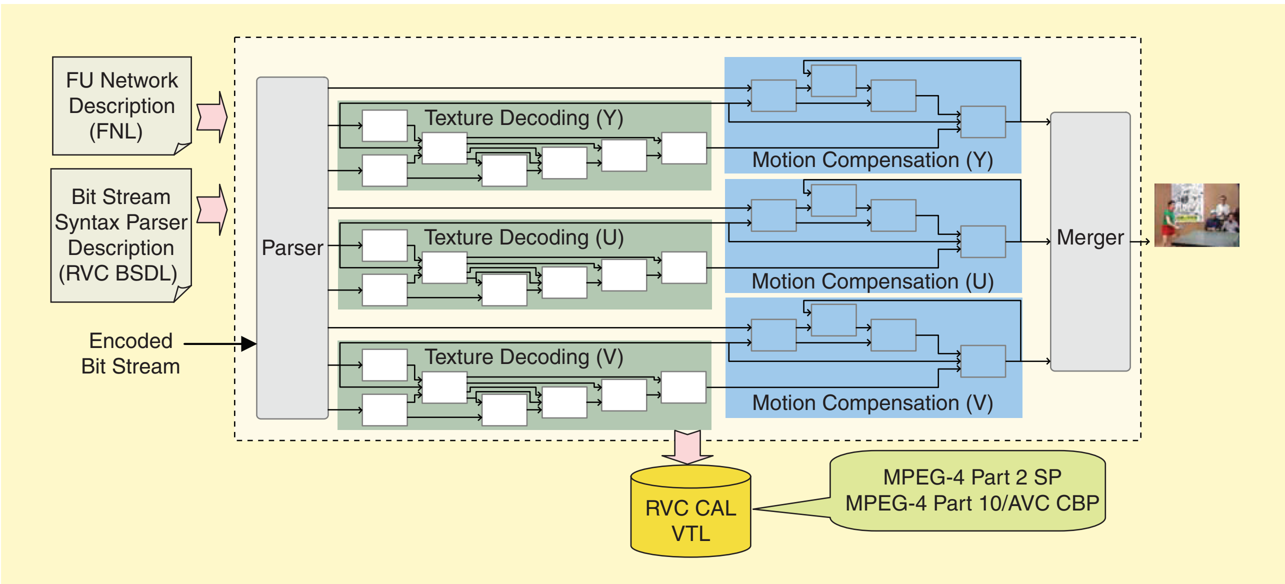
SUPPORTING TOOLS

The RVC framework is informatively supported by several tools to secure efficient development, reconfiguration, and implementation processes.

The more innovative and attractive tools are capable to directly synthesize the ADM into both Hardware Description Languages (HDL) and/or software (e.g., C, C++) implementations using the standard or the proprietary libraries of components. In fact, such properties of the RVC new specification formalism provide an appropriate starting point, which together with other advanced methodologies and tools, enable the implementation of RVC codecs on various target platforms. More information on supporting tools with their front ends and back ends directly generating implementations of RVC specifications, including compiled, run-time compiled, and heterogeneous forms is provided next.

COMPARISON WITH OTHER STANDARDS

Unlike current video coding standards that focus on defining one way of using specific coding algorithms, MPEG RVC conversely focuses on providing a framework that supports methodological approaches to let users specify their own codec configuration. Figure 4 represents an example of such a configuration where each box represents an instantiation of one component (FU) of the standard RVC library. The connections represent the dependencies between data tokens consumed at the input ports or generated at the output port of each library component. The topology of the network of components (FNL description) plus the BSD and the knowledge of the behavior of each FU (RVC VTL) provides a full behavioral specification of a RVC decoder configuration. Conventionally, decoders that are conformant to a specific standard and profile must support all the coding algorithms defined within that standard, regardless of the computational capabilities of the target decoding devices or the application requirements. Indeed, specifying such profiles in advance is inefficient as it is often not possible to identify all the application scenarios in which a codec will be used, at the time of its release. Nor is it feasible to provide a normative profile for each and



[FIG4] RVC description of an ADM.

every possible scenario. Such a drawback will no more exist with the deployment of the RVC approach, which provides the solution to such a problem by moving the conformance to the level of a normative library and by associating the description/specification of the decoder (i.e., the configuration of the standard library) to the encoded data. Thus several scenarios in which terminal devices with reconfiguration capabilities may acquire the description of a decoder structure can be envisaged. RVC provides the right formalism to support flexibility/reconfigurability within the implementation process, as well as the potential to define video coding standards targeting various types of applications and platforms.

[RVC PROVIDES THE RIGHT FORMALISM TO SUPPORT FLEXIBILITY/ RECONFIGURABILITY WITHIN THE IMPLEMENTATION PROCESS.]

PERFORMANCE

The results reported in many research works illustrate the advantages of using RVC-CAL as the specification language for the RVC standard. Being a dataflow language, RVC-CAL serves as an appropriate and unified starting point to specify applications targeting both software and hardware implementations. The availability of nonnormative tools assisting the transformation of an RVC specification into software and HDL reduces the difficulty that codec designers face when trying to manually import sequential (C and C++) codec specification targeting implementation on hardware or parallel platforms with multiple cores. The sequential approach provides very limited capability to expose parallelism. In a sequential program, many low-level implementation details and a specific sequence order of operations must be explicitly specified. However, such specific sequence of operations is just one among the possible and nothing

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RVC RESOURCES

The Reconfigurable Video Coding Standards

- ISO/IEC 23001-4:2009: Information technology: MPEG systems technologies—Part 4: Codec configuration representation [SC 29 N 10474] [Online]. Available: http://www.itscj.ipsj.or.jp/sc29/def/29view/29n10474c.htm
- ISO/IEC 23002-4:2009: Information technology: MPEG video technologies—Part 4: Video tool library [SC 29 N 104745] [Online]. Available: http://www.itscj.ipsj.or.jp/sc29/def/29view/29n10475c.htm

Technical Overviews

- E. S. Jang, J. Ohm, and M. Mattavelli, “Whitepaper on reconfigurable video coding (RVC),” in ISO/IEC JTC1/SC29/WG11 document N9586, Antalya, Turkey, 2008 [Online]. Available: http://www.chiariglione.org/mpeg/technologies/mpbrvc/index.htm
- S. S. Bhattacharyya, J. Eker, J. W. Janneck, C. Lucarz, M. Mattavelli, and M Raulet, “Overview of the MPEG Reconfigurable Video Coding Framework,” *J. Signal Process. Sys.*, 2009, Springer [Online]. Available: http://dx.doi.org/10.1007/s11265-009-0399-3
- I. Amer, C. Lucarz, G. Roquier, M. Mattavelli, M. Raulet, J.-F. Nezan, and O. Déforges, “Reconfigurable video coding on multicore: An overview of its main objectives,” *IEEE Signal Processing Mag.,* vol. 26, no. 6, pp. 113–123, Nov. 2009 [Online] Available: http://dx.doi.org/10.1109/MSP.2009.934107

Methodologies and Tools

- M. Wipliez, G. Roquier, and J.- F. Nezan, “Software code generation for the RVC-CAL language,” DOI—10.1007/s11265-009-0390-z [Online]. Available: http://www.springerlink.com/content/24247k7637224228
- J. W. Janneck, I. D. Miller, D. B. Parlour, G. Roquier, M. Wipliez, and M. Raulet, “Synthesizing hardware from dataflow programs,” DOI:10.1007/s11265-009-0397-5 [Online]. Available: http://www.springerlink.com/content/m0782rn651t00581
- C. Lucarz, J. Piat, and M. Mattavelli, “Automatic synthesis of parsers and validation of bitstreams within the MPEG reconfigurable video coding framework,” DOI: 10.1007/s11265-009-0395-7 [Online]. Available: http://www.springerlink.com/content/gg261p657x483m91
- S. S. Bhattacharyya, G. Brebner, J. W. Janneck, J. Eker, C. von Platen, M. Mattavelli, and M. Raulet, “OpenDF: A dataflow toolset for reconfigurable hardware and multicore systems,” *SIGARCH Comput. Archit. News* vol. 36, no. 5, June 2009, 29–35. DOI: http://doi.acm.org/10.1145/1556444.1556449
- G. Roquier, C. Lucarz, M. Mattavelli, M. Wipliez, M.Raulet, J. W. Janneck, I. D. Miller, and D. B. Parlour, “An integrated environment for HW/SW co-design based on a CAL specification and HW/SW code generators,” in *Proc. IEEE Int. Symp. Circuits and Systems*, May 2009, pp. 799–799.

Other Related Standards

- ISO/IEC 23001-5:2008—Technologies de l’information—Technologies des systèmes MPEG—Partie 5: Langage de description de la syntaxe bitstream (BSDL) [Online]. Available: http://www.iso.org/iso/fr/catalogue_detail?csnumber=50094
- ISO/IEC 14496-10:2005—Information technology—Coding of audio-visual objects—Part 10: Advanced Video Coding [Online]. Available: http://www.iso.org/iso/catalogue_detail.htm?csnumber=43058
- ISO/IEC 14496-2:1999—Information technology—Coding of audio-visual objects—Part 2: Visual [Online]. Available: http://www.iso.org/iso/iso_catalogue/catalogue_ics/catalogue_detail_ics.htm?csnumber=25034

meet the needs of these emerging radio astronomy tools.

For someone looking for an introduction to the field, there are not many other choices. B. Burke and F. Graham-Smith's *Introduction to Radio Astronomy* (second edition) covers much of the same ground but in less detail. It is suited for the technically knowledgeable reader who wants an overview of the field. *Radio Astronomy* (second edition) by J.D. Kraus is out of print, but it is worth a trip to library for its coverage of antennas and basic receiver theory. However, it predates current receiver technology and signal processing methods. Neither has the balance of engineering and astronomical depth that should keep *Tools of Radio Astronomy* the standard introduction. For the teacher, this book can serve as a text for a course on instrumentation and observational techniques in radio astronomy. Luckily, for the teacher (or self-taught student) there is a good selection of problems at the end of each chapter.

TOOLS OF RADIO ASTRONOMY IS QUITE TIMELY IN THAT IT WILL HELP SIGNAL PROCESSORS MEET THE NEEDS OF THESE EMERGING RADIO ASTRONOMY TOOLS.

The problems are at a consistent level and complement the discussion in the text. For the engineer with some background in electromagnetics, the first half of the book can be used as an introduction and reference for radio astronomical instrumentation.

The only significant shortcoming of this book is that the references devoted to instrumentation are not as well organized as those on astronomical sources. For some chapters, the references are divided into the categories "general," giving the basic references for the material covered in the text, and "specialized," which are pointers into the detailed literature. In other chapters, historically interesting papers and general references are mixed in with accounts of more recent work. Beginners in the field would have an easier time getting started with the literature if the scheme of the general and specialized categories were used consistently. This quibble aside, *Tools of Radio Astronomy* does a very good job of covering the basics of the field for the beginning user of the radio telescopes as well as for their builder. Furthermore, the production standard is high. The text is well laid out and equations are easy to read.

The fifth edition of *Tools of Radio Astronomy* is a conservative update of the basic material in the earlier editions, but it describes how the principles are being applied to the most recent telescopes. Although the book is aimed at astronomy students and professionals, it can also serve as an introduction for engineers working in millimeter wave remote sensing and terahertz imaging. And some may be inspired to take a hand in building the next generation of machines that take pictures of the radio universe.

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guarantees that it is appropriate for any specific platform. In fact, sequential descriptions hide the essential structure of the program among the code required to handle threads and platform specifics. Conversely, parallelism is implicit in the dataflow nature of RVC-CAL.

FURTHER TECHNICAL DEVELOPMENTS

Although encoders are typically not covered in MPEG video coding standards, it has been seen that the nature of the RVC framework actually embraces reconfigurable video encoders and even more complex multimedia computing systems. A core experiment that investigates the feasibility of having informative encoding tools within the RVC tool libraries is currently ongoing. Other interesting discussions are currently taking place in the RVC community, aiming at extending the approach and the specification languages of the RVC standard to cover other fields and applications that share common features with video coding or that could benefit of being included and embedded as part of the standard, such as computer graphics, cryptography, and video coding for wireless multimedia sensor networks.

RESOURCES

Several RVC Resources are listed in "RVC Resources."

AUTHORS

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