A NOVEL APPROACH FOR MULTIMEDIA RENDERING PLATFORMS *

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ABSTRACT

We introduce a novel approach to implement multimedia rendering platforms, using reconfigurable-oriented hardware/software co-design. Disadvantages of current platforms include a very short obsolescence cycle, communication and computational performance limitations, large sizes of software components, and architectures not prepared to cope with future multimedia requirements. To overcome these, we propose a reconfigurable computing architecture to implement multimedia rendering platforms, flexible enough to support several new audio and video applications, such as decoding and mixing of multiple streams/objects, and spatial rendering. In this paper we present the Reconfigurable Digital Set-Top Box project, some original accomplishments in multimedia services design, partial results on the development of applications, and the implementation of a reconfigurable RISC microprocessor for future multimedia processing and rendering platforms. This approach permits to synthesize complete and integrated hardware/software systems on-the-fly/on-demand directly into the platform.

1. INTRODUCTION

Multimedia formats and coding standards have been experiencing a vast dissemination in the last years, and ported into many consumer electronics devices, such as audio/video appliances, digital set-top boxes, mobile technologies and digital assistants. Appliances more and more have to consider manipulating and processing the digital media in all stages, from generation through exhibition.

Current coding standards are far more complete and elaborate than were their predecessors. While MPEG-1 [1] and MPEG-2 [2] are oriented to coding elementary media components, MPEG-4 [3] and MPEG-7 are oriented to coding features and elements on a higher abstraction level. MPEG-1 and MPEG-2 audio parts essentially cover waveform coding, regardless of its source, and therefore could be applied to any audio type. On the other hand, MPEG-4 is object-oriented, and considers not only waveform coding but also different coding schemes for different audio sources, and multiple sources simultaneous processing.

Multimedia appliances are turning into personal systems in the near future. Mobile consumer electronics are increasingly gaining power processing and telecommunication capabilities, to enable multimedia access anywhere and anytime. Multimedia services tend to support personal profiles advanced browsing and filtering tasks. Indoor-equipment trends are to enlarge the multimedia experience, both in quality and interaction. Immersive virtual reality, telepresence and multiple user support are strong trends for the long term, making use of 3D audio and video.

All these features are hungry of processing power, and consume a considerable bandwidth. They require a fine tuning between transport systems (network access) and processing systems (decoders and displays) in order to permit satisfactory operation. Current systems' architectures are not fully oriented to concurrent multimedia streaming, processing, decoding and exhibition tasks. Modular sub-systems integration is still the paradigm in building multimedia electronics. This is mainly due to the need to assure compatibility among manufacturers on a fast growing multimedia market.

This fast pace, however, is the bottleneck in guaranteeing upgradability for all system modules in time, and at a reasonable cost. Future multimedia platforms are required to offer higher quality media display, and will need to manage bandwidth restrictions, interaction requirements and intellectual property rights while exhibiting an extended lifetime.

Based on our previous works in designing interactive multimedia services for digital networks [4], we have been developing a new concept for multimedia architectures, with focus on hardware and software co-design, counting on the paradigm of reconfigurable

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computing for all modular multimedia circuitry. Advantages are in exploring algorithm parallelism, building customized instruction sets for multimedia processing [5], and enabling upgradability [6], therefore improving lifetime for consumer terminals and reducing the time to market for new appliances.

We describe some successful prototypes of multimedia interactive service systems, and propose our novel architectural concept for reconfigurable multimedia platforms, flexible enough to host new rendering algorithms for audio and video streamed material. The long-term project considers the deployment of a series of multimedia devices based on a modular and incremental reconfigurable architecture.

The first platform will offer essential multimedia services, such as web browsing and e-mail facilities, prototyping an indoor device at a low cost available for the lower-income classes, especially in the developing countries.

Next prototypes should incorporate more complex multimedia functionalities, such as CATV tuning, MPEG audio/video decoding [7], networking and interactivity with service providers.

2. MULTIMEDIA DIGITAL SERVICES AND PLATFORMS

Communication platforms follow cultural and fashion trends. Mass consume of multimedia appliances and services are intimate to the entertainment and professional markets, which contribute to turn them obsolete very fast.

Analog platforms in the past could only receive programs, and had very limited return channel capabilities. Upgrade in this reign means disposal of old and purchase of new. Digital platforms, despite not suffering from analog technical limitations, can still be retired fast if they were not conceived to last through reprogramming their functionalities.

Several new interactive services are created every time for digital multimedia platforms. Multimedia on-demand streaming, for instance, is a very popular application. We present below two on-demand services designs. Their original conception addressed the use of open systems and resources to make them portable and synthesizable into reconfigurable systems.

2.1. On-demand and Interactive Multimedia

Multimedia services can be interactive or not. Multimedia experience is greatly improved through the use of interaction principles. Interaction models exist in several degrees, the most complex ones counts on real-time user's feedback processing, and are not based on local massive storage requirements. On-demand services lie into this category.

On-demand systems and services are based on full-duplex access networks. For multimedia ones, media storage and coding technologies are also required.

In the next two sections we present the design of two interactive on-demand multimedia services.

2.2 Musiface – Audio on-demand Network Player

Musiface is an Audio on Demand (AoD) application, which runs directly in a web browser, and is invoked as a usual web page (html archive). It was first conceived for providers of bi-directional CATV networks and Internet access pursuing a high quality audio-on-demand solution incorporated to a web browser [4].

Musiface is a first prototype of a series of possible applications that can be developed to allow CATV and ISP enterprises to offer a high degree of interaction in services. It was designed to operate over high-performance bi-directional networks (ATM or Fast Ethernet-based) and to operate in conjunction with a (proprietary) multimedia server system, which stores the audio media in RAIDs, manages access and billing tasks.

Developed in HTML and JavaScript™, the interactive interface permits the user to browse all available musical programs to play. Figure 1 (below) shows the Musiface graphical user interface (GUI).

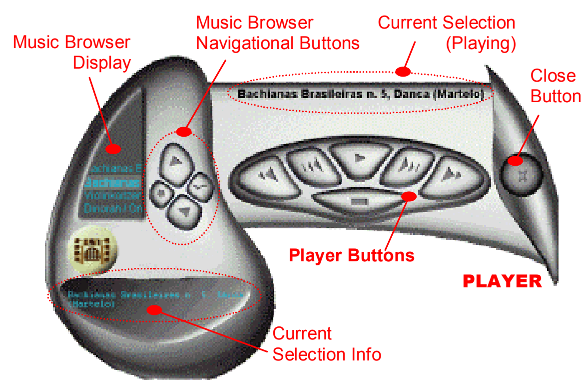

Figure 1 - Musiface AoD application (1st generation)

The application consists basically of three functional modules:

a) an <u>interactive music browser</u>, to search and retrieve musical programs (the user's graphical interface);
b) a <u>network interface</u>, capable of connecting to a remote SQL data base server, to a remote web server, and to a remote audio server (MPEG media server);
c) a <u>MPEG player</u>, capable of controlling the local MPEG decoder/player device.

These modules are shown interconnected in figure 2, and run on the same platform. To complete the service system architecture, there is a MPEG (audio) server, which stores the musical archives; a web server, to host the application source pages; and a data base server, which stores information about the musical collection.

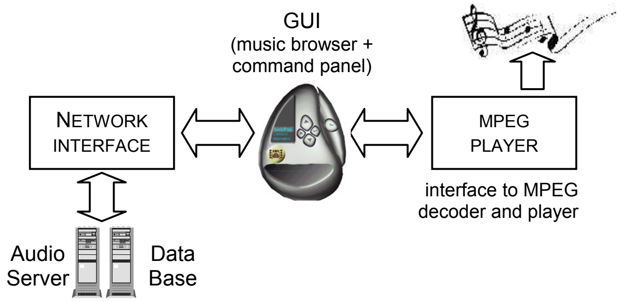

Figure 2 - Musiface functional modules

All servers and end-user platform communicate through an appropriate access network. Figure 3 illustrates the software protocol stack for the whole system.

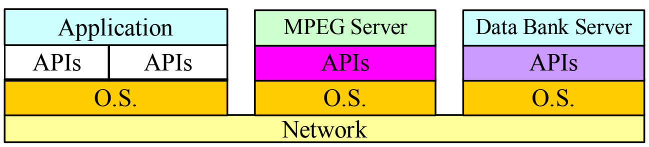

Figure 3 - System software organization

Musiface has three macro-states (illustrated in figure 4):

1. a <u>Boot phase</u>, where connection to servers and logging in are established;
2. a Stand-By or <u>Search mode</u>, where browsing occurs;
3. a <u>Playback mode</u>, where down streaming, decoding and playing are started.

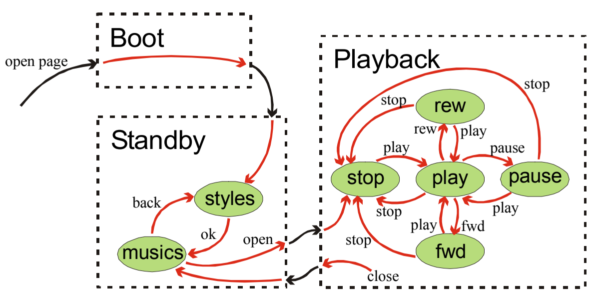

Figure 4 - Musiface operational macro-states

2.3 Polimidia – Video on-demand Interactive Browser

Polimidia is a Video on Demand (VoD) service originally conceived to make available a video collection in the digital format (MPEG-1), permitting an immediate access to the videos in any connected platform [8].

Similar to the Musiface machine in its media serving architecture, Polimidia goes beyond offering a more elaborate interactive interface through which users can browse and locate the content they are looking for, using several search schemes, including keywords search.

The figure 5 (ahead) illustrates a shot of the Polimidia interface in use.

Figure 5 - POLIMIDIA - VoD Interactive Browser

The GUI has an old-fashioned stylistic design. At the left side there is one field for keywords enter and search, one for subject search, and a larger area for returning found programs. A selected program is then retrieved from a MPEG video server, decoded and displayed in the upper right screen area. Additional information, if available, is displayed right beneath the video area.

3. RECONFIGURABLE SYSTEMS

There are several techniques to construct electronic circuitry, design boards and physically integrate components. More recently, beyond the scope of Application Specific Integrated Circuits (ASICs), the use of FPGAs (Field Programmable Gate Arrays) is gaining relevance to improve the processing power of dedicated systems, through the implementation of application specific circuits and critical algorithms. FPGAs provide a simplified project environment with a lesser cost than ASICs while providing high performance [9].

The most attractive feature in operating with FPGAs is its capability of re-synthesize an entire new digital system *on-the-fly* and *on-demand*. The reconfigurable computing/hardware approach can be thought as a method that mixes the programmability of micro processed systems with the reconfigurability of the hardware on the FPGA [10].

Our approach in conceiving multimedia rendering platforms is based on the extensive use of reconfigurable computing and FPGA resources. Rendering modules cover both audio and video decoding, processing and displaying. We present now our reconfigurable architecture, which can be scaled to create from simple platforms (with basic audio and networking features) to complex ones (with audio/video decoding, microprocessing power and networking).

3.1. Reconfigurable Multimedia Platforms

The main goal is to conceive and design multimedia platforms based on reconfigurable technology, both at low cost and capable of remote functional upgrades, without user intervention. We are developing a family of microprocessed multimedia terminals based on reconfigurable hardware, named “Reconfigurable Digital Set-Top Boxes” (RD-STB).

All devices in this proposed family derive from a general architecture with four relevant main components:

- application specific microprocessor(s)
- distributed memory
- a memory crossbar (interconnect bus)
- I/O interface modules

Figure 6 illustrates the proposed architecture, with four microprocessors, capable of dealing simultaneously with

- MPEG decoding
- Networking (transport of data through an access network)
- Video/Audio mixing/displaying
- Local Application Execution (JAVA)

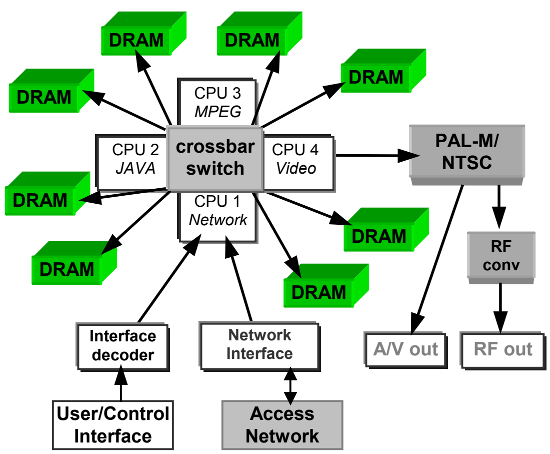

Figure 6 - General Architecture for the Multimedia Reconfigurable Platforms

The above architecture represents the “substratum” on which many multimedia platforms oriented to specific services can be designed. Multiple functional combinations can be designed out of this top-most architecture, just by selecting the desired set of multimedia rendering modules.

Platforms oriented to simpler services can base their design only using 1 or 2 processing units and less peripheral circuitry, enough to take care of the desired service. Future digital TV platforms are expected to make full use of this architecture.

Figure 7 shows the first RD-STB prototype board, used for synthesizing and testing different reconfigurable hardware modules of the platform family.

We are currently working on a simpler multimedia platform – the Web Box – which aims to offer basic web browsing and email capabilities to a home gateway, served, for example, by a dial-up connection (telephone).

This platform design is oriented to implement directly a mini-browser application, named FlyBrowser [11].

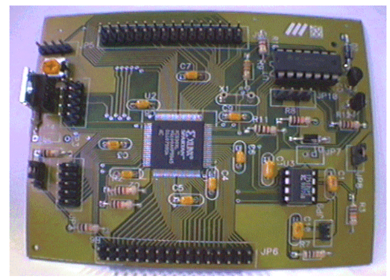

Figure 7 – First RD-STB prototype circuit board

The FlyBrowser is a reduced-core web browser application (less than 20KB) specifically developed to run under bandwidth restrictions and limited processing power, and customized/ported to this architecture.

It is oriented to a new system for mobile Internet browsing, with improved characteristics, providing very good graphical quality and the capacity of www navigation without necessity of content reformulation.

Figure 8 (below) examples two web pages rendered by the FlyBrowser application.

Figure 8 – FlyBrowser: two rendered web pages

The Web Box will incorporate a reconfigurable microprocessor, designed to implement the desired set of instructions and multimedia commands.

We have developed a 32-bit RISC core DLX-based to serve as main processor for the platform [12]. Design requirements included the right selection of the instruction set and internal organization, to promote performance and match applications needs. Figure 9 (next) shows the microprocessor general internal organization.

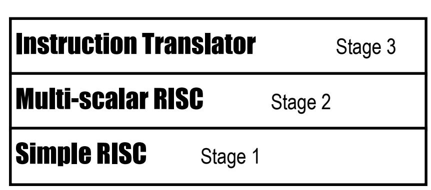

Figure 9 - Internal Organization for the 32-Bit RISC Microprocessor

In stage 1 a simple RISC core has been implemented based on a DLX compatible architecture [12]. A 4-stage pipeline scheme was developed, so that most of its 52 original instructions can be executed in a single clock cycle. Next stages (in design) are in charge of multi-scalar support, for instruction scheduling and hazard occurrence solving, and instruction translation [13] (stage 3), to permit Z80 instruction set to run on the DLX-based core. Z80 compatibility is desired once the FlyBrowser application and email routines were implemented originally using a Z80 compatible instruction set [14].

4. FUTURE WORKS

We are working on the next two members of the set-top boxes family, which will incorporate more complex functionalities such as MPEG-1,2,4 decoding, and multiple interfacing capabilities (analog video out, Digital TV decoding, LAN/modem access, multiple stream and surround audio).

Our main concern is to deploy in the mid term a programmable platform capable of dealing with transport and decoding of multiple streams. A third generation is on design phase, which will focus on newer multimedia codecs, newer services (semantic browsing), rendering and exhibiting processing (audio and video display).

The Reconfigurable Digital Set-Top Box (RD-STB) is a multimedia computer platform which is to support current set-top box functionalities, and host several services, such as web browsing, home network gate, teleconferencing, entertainment, security systems, etc.

Future units will even incorporate enhanced display systems, for an immersive 3D audio and video experience.

5. CONCLUSIONS

We are proposing the use of reconfigurable computing as substratum for the next generation architectures for multimedia platforms, counting on the advantage of building up a reprogrammable modular system capable of hardware and software upgradability on the fly and on demand, guaranteeing a longer life time for multimedia appliances.

The concept of reconfigurable multimedia platforms was introduced, and presented a long-term initiative for development of a series of increasing complexity devices. We presented the successful design of two multimedia on-demand interactive services, and introduced the Reconfigurable Digital Set-Top Box.

Also, it was introduced the development of a simpler web machine (the Web Box) based on our reconfigurable architecture. It is based on a reduced core web browser (less than 20KBytes of code) and an implementation of a 32-bit DLX microprocessor in FPGA, which will be the reference processor for the next developments of rendering multimedia boxes. The whole systems was described using less than 1 MB of data to represent both software and hardware components on a FPGA.

In the long term we expect that mass introduction of multimedia consumer electronics will make massive use of reconfigurable architectures oriented to multimedia rendering and easier upgradability features to cope with natural (and fast) human societies evolution.

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