Project Completion Report

A. Project title: Real Time Implementation of H.264 Decoder for Heterogeneous Multicore Architectures

B. Project Summary

In today's world, digital video has a broad range of applications, such as, broadcast, DVD, video conferencing, video-on-demand, streaming and multimedia messaging. All these application use some sort of video compression techniques. Based on different applications of digital video, the motivation is to develop such video compression techniques that provide very high degree of compression without compromising the quality of the video. The latest video compression standard developed by JVT(ITU-T VCEG and ISO/IEC MPEG) is H.264 which achieves the best-ever compression efficiency and delivers excellent quality of video for a diverse set of applications like wireless, Internet, broadcast or satellite transmission and multimedia storage. H.264 delivers the same quality and provides 1.5 - 2 times better compression as compared to its predecessors including MPEG-4. This means that using H.264 provides better quality of video at much lower bit rates, saving bandwidth and storage costs as compared to previous generations of video codecs.

The compression provided by H.264 comes at the expense of high computational complexity and requires a lot of processing power. A highly optimized H.264 decoder consumes about 30-35% processing power of a desktop machine's processor running at 3 GHz. The mobile hand held devices and video playback devices cannot afford these general purpose CPUs because of higher power and cost requirements. For such devices dedicated multimedia processors are used, which, besides providing the required processing power, run at relatively low clock speed, consume lesser power and are more cost effective. To cater for the huge amount and type of processing involved in H.264 decoding, the latest trends are based on multicore media processor solutions. Multicore media processors are based on the idea of scalability of processing cores rather than the clock speed, thus providing high processing power by avoiding the limiting factor of power consumption at high clock speed.

The task being tackled here is the analysis, design and porting of the H.264 video decoder to run on heterogeneous multi-core systems. The focus will be to develop software architecture to address the issues of parallel processing, synchronization and interprocess communication to cater the needs of different heterogeneous multicore architectures. The proposed architecture will be ported to TI's DM 6467 heterogeneous multicore chip for real time H.264 decoding. This real time solution will provide 30 fps for baseline and main profile standards up to level 3.0, as specified by the ITU-T

With digital multimedia becoming a part of our daily lives, the proposed solution will be a step towards facilitating product development in this field and existing multimedia OEMs will greatly benefit from this development.

The scope of work included algorithm development, code optimization, hardware implementation, and finally DM6467 based real time H.264 decoder with display interface.

The project was divided into seven phases with one extension phase at the end.

Milestones and deliverables in each phase are defined as follows:

- Phase-1: Commissioning of equipment, hiring and training of engineers for H.264 standard and baseline C code

- Phase-2: Single processor optimized code for Main profile.
- Phase-3: Software Architectural analysis for multicore processors
- Phase-4: Software Architectural implementation for multicore processors and testing of multicore implementation
- Phase-5: Test plan development for final testing, DM 6467 architecture learning and architecture specific partitioning and porting.
- Phase-6: Assembly and DMA related optimization of baseline and main profile.
- Phase-7: Optimization of Decoder Application , Final integration and Testing

The first five phases were successfully completed within the prescribed time. However the sixth deliverable took extra time and the seventh phase started much later in the extension period of this project. The total budget of the project including extra period remained other the total approved budget.

The project was executed by a dedicated development team of experienced and young engineers & researchers either affiliated with Muhammad Ali Jinnah University and Altair Technologies (who was development partner) or hired specifically for the project. The initial development team was divided into two sub teams of Algorithm development & Hardware Implementation & Optimization. The development team for the project consisted of total 10 technical resources and 2 supporting staff. The 10 technical members included PD, JPD, 1 team lead, 5 developers and 2 research assistants. The supporting staff included an accountant and a coordinator. For extension period however, after the refusal of Altair Technologies to continue as development partner, the team was squeezed to a total of 7 technical members and one support staff.

C. Objectives and achievements

- **Original Project Objectives**

Research Objectives

To research the multicore programming and optimization techniques to port latest state of the art H.264 video decoder on a heterogeneous multicore processor chips. The idea is to achieve real time video decoder on a commercially available low clock speed multicore processors (TI's DaVinci). The primary focus will be on decoder's code partitioning techniques for multicore processor, scheduling and inter process communication. The approach will focus on heterogeneous multicore architectures in general and TI's Davinci platform in particular. Along with this, optimization techniques at algorithmic levels, C language and hand coded assembly will also be explored and implemented.

Academic Objectives

The academic objective of this project is to contribute to the publications in the area of video compression and multi-core processors and to train young engineers by making them a part of the development team. The project will also provide the PhD students with an opportunity to work on the latest and cutting edge technology. In this manner, the students will get expertise in the field of video compression and programming of multicore processors, during their stay in the academic institutions.

Industrial Objectives

There is a wide range of applications of real time video decoding. These include handheld mobile devices, video play back devices (DVD/HD players), video conferencing equipment and IPTV. The real time working solution of H.264 decoder on a commercially available multicore media processor will serve as a "buy of the shelf component" and the OEMs in the multimedia equipment manufacturing field can greatly benefit from it and can build their equipments based on the proposed solution.

Human Resource Development Objectives

The project covers the fields of Video Compression, Programming on Multicore processors and Code optimizations in C and Assembly languages. By inducting PhD students from the university and fresh graduates in the team, our objective is to train the manpower and develop expertise in the above mentioned fields. The project will provide a wonderful opportunity for industry-academia collaboration and will contribute in the development of a world class team in Pakistan, capable of working on the cutting edge technologies.

Other Objectives

To provide the young engineers with the opportunity to get the first hand knowledge and hands on experience of working in a professional setup of international standards.

- **Objectives Achieved**

Almost all the short term project objectives described above have been achieved up to a great extent. Among the research, industrial and organizational objectives the following benchmarks were achieved.

- An active research group of vision and pattern recognition systems (VisPRS) was established in Muhammad Ali Jinnah University, with primary research focus on biometrics and Video coding. Currently research group is working on Video coding and rate control. Work is also being done on Video Codec optimization and implementation of different embedded platforms . The research group currently has more than 15 active members including 1 group supervisor, 2 post PhD researchers, 10 PhD students, 2 Masters thesis students and a number of undergraduate students.

- An in depth research was carried out under this project on the current trends and latest algorithms in video coding, current video coding standards and high level and low level code optimization techniques for TI's Davinci platform.
- As algorithm development and optimization is a constant process of research, it has been done throughout the duration of the project.

- The research group has now active contribution in the field of video coding. Currently 1 PhD student is pursuing his PhD research in Video Encoding and bit-rate control. Two final year undergraduate projects have been completed using TI's DM6467 embedded platform. First was titled as, "Implementation of fast iris based identification system on Davinci DSP board" and the second project was, "Implementation of fingerprint verification system on DM6467 platform",

- Following research papers have been published/submitted as a result of research being pursued in this project. work done on the encoder optimization.

  - Muhammad Asif, Masood Farooq and Imtiaz A. Taj, "Optimized Implementation of Motion Compensation for H.264 Decoder", 5th International Conference on Computer Sciences and Convergence, Information Technology (ICCIT2010), pp. 216-221, Dec. 2010.
  - Muhammad Asif, Imtiaz A. Taj M. Atif, "Real time implementation of H.264 encoder on JZ4770 multicore processor", submitted to Electronics Letters (under review).
  - Muhammad Asif, Imtiaz A. Taj M. Tahir, "Hardware-software co-design of H.264 encoder ", to be submitted.
  - Muhammad Tahir, Imtiaz A. Taj, M. Asif, F. Mehmood, "A novel approach for load balancing of H.264 decoder on COTS heterogeneous multicore architectures", to be submitted.
  - Muhammad Asif, Imtiaz A. Taj, M. Atif, Rab Nawaz, , "A novel scheme for intra prediction mode selection of H.264 encoder ", to be submitted.

- As mentioned the development team consisted of 10 members including 6 young engineers who were trained in the field of video coding, code optimization and embedded systems and majority of them are now serving in different prestigious organizations.

- **Objectives not Achieved**

  As discussed above most of the objectives were met up to the completion of the project which was delayed due to lack of funds. In initial phase of the project target set for final implementation was 30 fps for baseline and main profile. After backing out of Altair Technologies as a development partner, a new team was assembled, as a result there were certain difficulties as the new team required training and familiarization of video coding and TI's Davinci platform. Therefore for the extension phase, the targets were reviewed and modified to 25 fps for baseline profile and 25 fps for main profile excluding CABAC. The revised targets have been achieved. However we dedicated a resource on CABAC implementation and were able to improve 'fp's figure for main profile with CABAC decoding.

D. Technology Transfer/Commercialization Approach

The technology developed during the project will be transferred to various stake holders in the following ways:

- The source code of H.264 decoder application has been submitted as the final deliverable thus enabling a large community to benefit from the outcomes of the project.
- Comprehensive documentation including user manual, installation guide, developer's kit, etc. has been submitted with the final release of the project to help developers and users of the application.
- Research Publications in reputed international conferences and journals are being published.
- The technical team trained during the project can be used as technology incubator in the

field of video coding and multimedia applications. A number of engineers have been trained in the project who will help to further propagate the skill in the industry in related fields.

- A number of seminars and workshops were arranged in the university to disseminate the finding/results of conducted research in video coding and optimization.

For commercialization of the product following steps are being taken:

- Contacts with different organizations who may be interested in developed video application as customer or as vendor have been established, including Altair Technologies , Streaming Networks.

One important point that has been noted during the interactions with different companies and potential customers is that of proof of reliability of the product.

E. Benefits of the Project

Software and Consumer Electronics Industries

- Companies all over the world working in the multimedia technologies and developing consumer products come under the category of direct customers / beneficiaries of the project. These multimedia products range from handheld multimedia devices, IPTV, playback devices etc. These solutions are based on different multimedia processors. The companies can either use the C implementation and port it to any processor or companies using TI's Davinci as the processor in their product can benefit from the outcome of the project and can buy off the shelf H.264 decoding solution and speed up their time to market. The cost effectiveness of the solution can be an important factor, especially when the products are developed in large numbers.
- Companies that are working on the multimedia solutions can use the outcome of the project to evaluate different heterogeneous multi-core processors as a candidate for their solution and H.264 as a targeted video decoder.
- Companies that are currently working on multi-core multimedia processor will be able to get helpful insight into the bottlenecks that arise with porting data and computational intensive video decoder to multiple cores and can counter these bottlenecks based on the outcomes of this project.
- First hand analysis of porting video decoders on multi-core system and the subsequent documentation will be helpful to OEM's to evaluate such systems for cost-effective implementation of their products.
- The techniques developed will be applicable to other decoders like MPEG-4, VC-1 and AVS and will allow the development teams all around the world to take advantage of it and use these techniques to expedite their real time implementations and hence cut the time to market their solutions.

Education Sector

- With the involvement of the academia during the project, the students got a chance to work on the latest cutting edge technology solutions and gave MAJU with an opportunity to start research in the fields of video compression, optimization techniques and software development for multicore processors.
- University is planning to introduce courses in the above mentioned fields, which in return

will result in the training of manpower for these fields.

- A number of seminars and a Workshop have been arranged by our research group on video coding and multimedia applications in MAJU.
- The project facilitated MAJU with the lab establishment containing latest state of the art, multi core processor based development boards along with complete software development environment, which is currently been used for future developments and research.

F. Assessment of Project Structure

- **Project Team**

  The composition of the development team was exactly as was defined in the project proposal. During the extension period, the size of the team was reduced to 9 as defined in change request for extension which was later approved.

  The team worked very efficiently in the first 5 phases of the project and the progress was exactly according to the initial plan. This was also highlighted in the progress reports of the corresponding quarters. The progress also slowed down and not only had some of the team members left the team. As a consequence the work on last two phases extended beyond the deadline.

- **Collaborations**

  The project was initially carried out by the project development team affiliated with MAJU in collaboration with Altair Technologies. No third party was involved in the development phase of the project. During the extension phase, new team was assembled and whole development was carried out by MAJU. However for commercialization of H.264 decoder solution, collaborations with Altair Technologies, Streaming Networks and other similar organizations are being pursued.

G. Research Approach

Different activities included in execution of the project were initial requirement specification and equipment procurement, algorithm development, algorithm optimization, application development for embedded platform, hardware implementation, system integration and finally performance evaluation and testing. During the project it was especially noted that the initially perceived research and development steps were accurate and the project went exactly according to the plan. Rigorous planning preceded every one of these tasks and it was made sure that the resources are properly and sufficiently assigned. All these tasks except the last two were completed and the phase wise deliverables were submitted in time.

Novelty of our research work was that we explored issues and bottlenecks in multicore application development in software for heterogeneous multicore platforms. Most of the previous research work either focuses on dedicated hardware solutions for H.264 decoding or use homogeneous multicore platforms.

H. Assessment of Project Schedule

As discussed earlier the first five phases were completed exactly according to the schedule. Sixth phase of the project got delayed. In the extension phase many difficulties were faced as the momentum of work broke and Altair Technologies refused to continue

development work.

I. Assessment of Project Costs

It is worth mentioning that the overall scope of the project was large and it took extra efforts from the development team to complete this project.

Moreover most of the development team disintegrated during a very critical phase of the project and an entirely new team was constituted in the extension period. Despite extended duration, the project has been completed keeping well within the total allocated budget.

J. Additional Project Funding obtained

No additional funding was obtained.