REAL-TIME 2–3 PULL-DOWN ELIMINATION APPLYING MOTION ESTIMATION/COMPENSATION IN A PROGRAMMABLE DEVICE

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ABSTRACT

This paper presents a software package that performs real-time picture processing on a commercially available programmable device[1]. The package applies motion estimation and compensation techniques for judder-free display of movie material broadcast in 2–3 pull-down mode.

INTRODUCTION

Picture sequences come in various picture rates, from 24, 25 and 30 Hz for movie material to 50 and 60 Hz for video. Simple picture rate converters repeat the pictures until the next arrives, which results in blur and/or judder when motion occurs. These effects can be eliminated if the motion is known, but Motion Estimation (ME) has only recently reached a quality and price level that makes it suitable for consumer equipment [2]. This paper describes recent progress in ME and MC (Motion Compensation) for judder elimination from 60 Hz TV movies, using a software package that runs in real time on a programmable device [1]. De-interlacing and movie detection on this CPU has been reported previously [4], and the new concept is an extension of that work to high-end TVs and broadcast PCs.

THE ALGORITHMS

The package implements an MC algorithm [6] with order statistical filtering to guarantee robustness in the event of vector errors. This concept has already proven useful [2], but the ME part of the design is completely different. Rather than estimating vectors for *blocks*, we have applied a newly designed *object-based* ME method. Up to three different objects can be distinguished in the image, which in practice has proven to be adequate for most scenes. A parametric motion model is calculated for each of the objects, and the parameters (along with the object segmentation map) are used in the MC-upconverter. Here, "objects" mean image section(s) that can be described using the same motion model, and do not necessarily correspond to a single physical object in the scene. Figure 1 illustrates the image segmentation resulting from the proposed processing. Figure 2 shows that a movie detector is included. Similar to the movie detector described in an earlier paper [5], this recognizes movie and video formats using motion vectors integrated over a field period of the video signal. The detector recognizes both 2–3 and 2–2 pull-down. The latter was described [5] previously. The software supports conversion to progressive and interlaced TV formats as well as to VGA for PCs. De-interlacing is therefore required. This has been accomplished by applying field merging for movie material, and by using a vertical-temporal median filter [3] for video camera signals. Table 1 shows all options of the software converter.

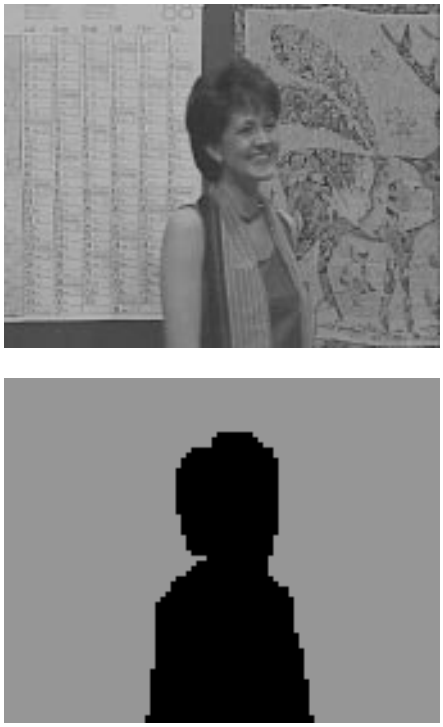

Fig.1 Picture and resulting segmentation.

1. The Philips TriMedia processor IC is commercially available as the TM1000.

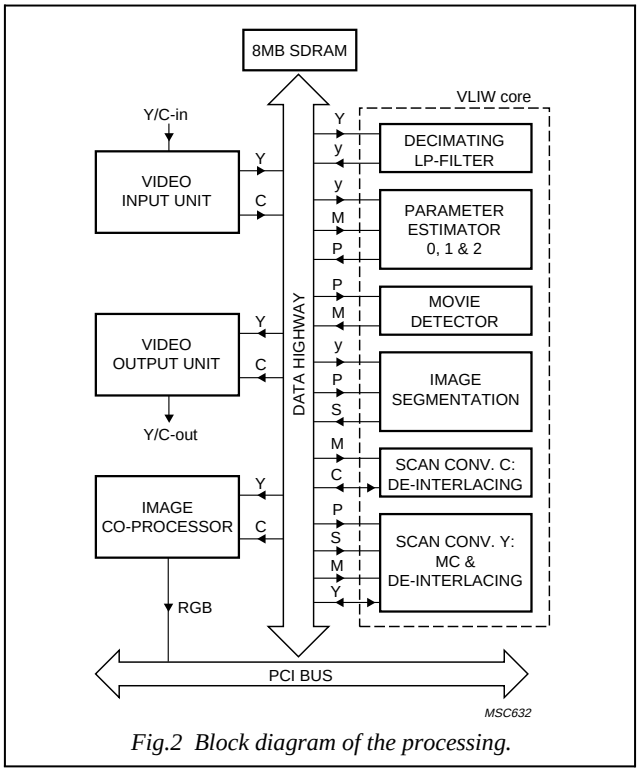

Fig.2 Block diagram of the processing.

Table 1 Conversion characteristics of the software.

Picture formats:			
Input	**Picture rate (pic./sec)**	**Output**	
525 lines/2:1	24, 30 (movie); 60 (video)	60 Hz (direct)	720×480/2:1 (CCIR601)
			720×480/1:1
		60 Hz (PCI)	640×480/1:1 (VGA)
625 lines/2:1	25 (movie); 50 (video)	50 Hz (direct)	720×576/2:1 (CCIR601)
			720×576/1:1
Velocity range (pixels/picture-period):			
Horizontal:		+/– 32	
Vertical:		+/– 16	
De-interlacing algorithm:			
Movie:		Field-merging	
Video:		VT-median filtering	
Motion compensation algorithm:			
Movie:		Order statistical filtering	
Video:		None (not required)	

CPU RESOURCE USAGE

Table 2 shows the CPU load for the various software modules and the total usage for the various formats. Evidently, formats that require more temporal interpolation require more processing power (2–3 vs. 2–2 pull-down movie). As can be seen, the load for parameter estimation and segmentation is not high compared to that of the scan conversion modules. This is partly achieved by operating the estimator and segmentation modules on downscaled images (see Fig.2). This "decimation" saves a factor of 8 (4 horizontal and 2 vertical) on image size for parameter estimation and segmentation, although even without this down-scaling, the new object-based ME can be regarded as highly efficient.

CONCLUSION

Recent progress in ME-, MC- and CPU-architectures has allowed a software package to run in real time on a commercially available processor, reproducing judder-free motion for movie material on TV and PC displays. The natural motion portrayal is better than any other available for the 60 Hz TV and PC market. The software automatically adapts the processing to movie and video, and supports many input and output scanning formats.

Table 2 Resources claimed by the software.

CPU USAGE (REAL-TIME OPERATION)[1]			
Mode	**Video (%)**	**2–3 movie (%)**	**2–2 movie (%)**
Decimation	5	5	5
Parameter estimation	6	5	4
Movie detection	0	0	0
Segmentation	28	11	14
Scan conversion Y	36	40	31
Scan conversion C	9	0	0
Total	84	61	54

1. Image size: CCIR601, processor: TM1000 @ 132 MHz.

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