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NXP's Motion Accurate Picture Processing (MAPP) gets the edge in fast-action HDTV

Author: Harm van der Heijden and Jacco van Gurp, NXP Semiconductors

Large-area high-definition LCD TV panels have transformed the shape of television, opening up new opportunities for set styling and a vastly improved viewing experience. They have also presented set-makers with significant challenges, not least of which is overcoming the fact that an LCD's sample-and-hold effect emphasizes motion judder. This motion artifact is particularly noticeable when displaying picture content derived from cine film, but the effect also causes significant motion blurring of 50-Hz or 60-Hz TV picture content.

"The basic problem is that high-definition TV pictures are so crisp, sharp and full of contrast that 20th century assumptions about suitable frame rates are no longer valid. We need to go for much higher frame rates than existing source material provides," says Harm van der Heijden, TV Picture Quality Architect at NXP Semiconductors. "For static pictures you can simply repeat frames in order to increase the frame rate, but for moving pictures you have to create entirely new intermediate frames that contain the correct spatial information for the time slot into which they will be dropped."

Motion estimation and compensation techniques to do just that have been around for some time and are now incorporated into many silicon vendors' TV chips. They nearly all rely on identifying matching pixel blocks in two consecutive frames, then calculating each block's motion vector and using it to shift the block into the correct position in the intermediate frame. However, the degree to which these techniques can keep track of picture motion and accurately interpolate intermediate frames varies.

"Many motion estimation-compensation techniques introduce image artifacts that are beginning to show up, especially with the move to high-definition TV," says Harm. "It's simply that as the overall picture quality improves, viewers are becoming much more critical of what they see."

Halo reduction

One artifact that commonly occurs is a so-called 'halo' around moving objects (see Figure 1). These halos occur because most motion estimation techniques only compare two consecutive cine frames in order to establish a motion vector for each pixel block. If the same pixel block can be identified in both frames, the motion vector is relatively easy to calculate. However, if a matching pixel block cannot be identified in both frames because something moving in the picture has caused it to be obscured or uncovered, a reliable motion vector cannot be established. All that motion compensation algorithms can then do is use a motion vector from surrounding pixel blocks in the hope that it is roughly correct. It is because this obscuring or uncovering of pixel blocks occurs at the edges of objects as they move relative to one another, leaving motion compensation algorithms no alternative but to use unreliable vectors, that halo artifacts appear in the TV picture. Many chip manufacturers try to mitigate the effect by simply blurring the picture in affected areas, but that in itself becomes noticeable to viewers.

NXP has now come up with a new motion estimation-compensation technique, which it debuted at this year's IFA Exhibition in Berlin, Germany, that drastically reduces halos. Instead of identifying matching pixels in two consecutive frames, it matches them across three consecutive frames, block matching between the current frame (*n*) and both the previous frame (*n-1*) and the next frame (*n+1*).

A pixel block that becomes obscured in frame *n+1* will still be identifiable in frames *n* and *n-1*, which means that its motion vector for frame *n* is determinable (see Figure 2a). Similarly, a pixel block that was obscured in frame *n-1* but becomes visible in frame *n* will be identifiable in frames *n* and *n+1*, once again allowing its motion vector to be determined (see Figure 2b). For frame *n*, it is therefore possible to establish a complete set of motion vectors for all pixel blocks (see Figure 2c). Applying the process to a 3-frame rolling window allows a complete set of motion vectors to be established for every cine frame.

"The performance of the motion compensation algorithms that create the intermediate frames relies heavily on the accuracy and completeness of the motion vectors," says NXP's LCDTV System Architect Jacco van Gurp. "However, you also need to know whether an individual vector was determined by forward or backward matching in order to apply it correctly, so the motion estimator and motion compensator need to be closely linked. You also have to interpolate the motion vectors themselves so that they temporally match the image data at the point in time where you are adding the intermediate frame."

Because the technique identifies pixels that are obscured or revealed in successive frames, the motion compensator also knows which pixels to use and which ones not to use in the interpolated frames. This adds significantly to picture detail and picture sharpness at the edges of moving objects.

HDTV

The current motion estimation/compensation challenge for HDTV is to push the frame rate up to 100 or 120 frames per second while also handling up to five times more pixels per frame than there are in a standard definition picture. For standard cine material captured at 24 frames per second, it means interpolating four intermediate frames between each cine frame. That in itself significantly increases the amount of computing power and memory needed. Block matching both forwards and backwards then adds further computing power and memory bandwidth requirement.

Motion estimation/compensation is not the only thing you need to do to get the most out of HDTV. Most TV formats don't utilize the full range of colors that appear in nature, so to produce truly lifelike pictures you need to intelligently map and process the colors of certain features through techniques such as blue sky enhancement, skin tone correction, blue stretch and green enhancement. Standard TV formats also fail to deliver the picture resolution and sharpness that HDTVs can display, so you need to scale up picture resolution and improve sharpness at the same time. You need to do it on every frame and you need to do it on resolutions up to 1080p@120Hz.

As part of its Motion Accurate Picture Processing (MAPP), NXP's new PNX5100 video post processor performs all of these motion estimation/compensation, picture improvement and picture scaling operations with 17-bit sub-pixel accuracy. To handle the required computing load, it features three on-chip media processors plus a dedicated video back-end that performs functions such as sharpness, contrast and color enhancement as well as graphics insertion. The MAPP combination of movie judder cancellation, motion sharpness and vivid color management successfully removes visible halo and blur to deliver an enhanced viewing experience – particularly when watching fast-moving sports and action movies. The chip's Automatic Picture Control (APC) feature dynamically adjusts the processing parameters used to obtain optimal improvement on every output frame.

The PNX5100 accepts 1920x1080p@60Hz LVDS input and produces a 1920x1080p@120Hz LVDS output. As a result, it fits seamlessly into an LCD TV's video pipe. To minimize total system cost, it uses industry-standard 300-MHz or 333-MHz DDR2 memory. Despite the chip's very high integration density in 90-nm CMOS, its power consumption is low enough to avoid the need for a cooling fan.

The PNX5100 comes with a reference design toolkit that helps TV manufacturers cut time-to-market and development risks. Moreover, it can be used as a stand-alone video-postprocessor or as a companion IC with a main TV processor, allowing motion accurate picture processing to be performed as a feature enhancement.

The PNX5100 is scheduled to go into full-scale production during the first quarter of 2008.