IDENTIFYING TOP/BOTTOM FIELD IN INTERLACED VIDEO

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ABSTRACT

This paper elaborates an approach that can be adopted to determine top/bottom fields in an interlaced video. Knowing the top and bottom field is important if the video is de-interlaced using Field Combination, Weaving + Bob, Discard and other algorithms based on motion detection. Determining the field information helps to re-construct the frame with lesser artifacts. This approach can be used if the top/bottom field information is not provided by video decoder chip.

INTRODUCTION

Interlaced video has been in use for more than 50 years. When dealing with interlaced video, de-interlacing algorithms are essential to remove any interlacing artifacts. There are many de-interlacing algorithms available for NTSC/PAL interlaced video. For low-end systems (system with less processing capability), following approaches can be considered:-

Algorithm	**Description**	**Quality**	
		Stationary	**Moving**
Weaving / Field Combine	Combine the top and bottom field to form a single frame	Same as the source	Artifacts due to time delay between top and bottom field
Discard	Discard the top or bottom field, resize (double the height) other field to construct a frame	Stair case artifacts due to resize/line copy. Image quality degrades.	Stair case artifacts due to resize/line copy. Image quality degrades.
BOB	Interpolate the top and bottom field (resize) and construct the frame at doubled FPS	Image quality is same or better than the discard algorithm. Edges of the objects in the video frame may be incorrect in size and colour. Flickers if the display refresh rate is incorrect or variable.	Image quality is same or better than the discard algorithm. Edges of the objects in the video frame may be incorrect in size and colour. Flickers if the display refresh rate is incorrect or variable.
BOB + Weaving	Use the previous top or bottom field data to construct the frame at doubled FPS	Same as the source	Close to the source. Lesser artifacts than all the above

The captured frame shown below depicts the stair-case artifacts of discard algorithm.

Figure 1: Discard

If the field order is unknown (or not provided by the video decoder chip) then Discard or Bob algorithm is the efficient method to de-interlace.

Figure 2: Bob + Weaving

In most cases, frames re-constructed by Field Combination or BOB + Weaving quality will be close to the original input frame.

Most of the NTSC/PAL video decoder provides the field order information. However, in some systems, it may not be possible to get field order due to some operations like serial/parallel conversion. Also the video can be of various resolutions and type (NTSC, PAL, etc.). Therefore, the algorithm needs to use a common mechanism to determine the field order.

Field Dominance Algorithm

Each digitized input video frame contains two parts which is received as a top and bottom field with respect to time order.

$$\underbrace{Frame1(top), Frame1(bottom)}_{frame\ 1}, \underbrace{Frame2(top), Frame2(bottom)}_{frame\ 2}, \ldots$$

If the field order information from video decoder chip is not available and the de-interlacing algorithm receives an top field first, then re-construction of the frame is illustrated below.

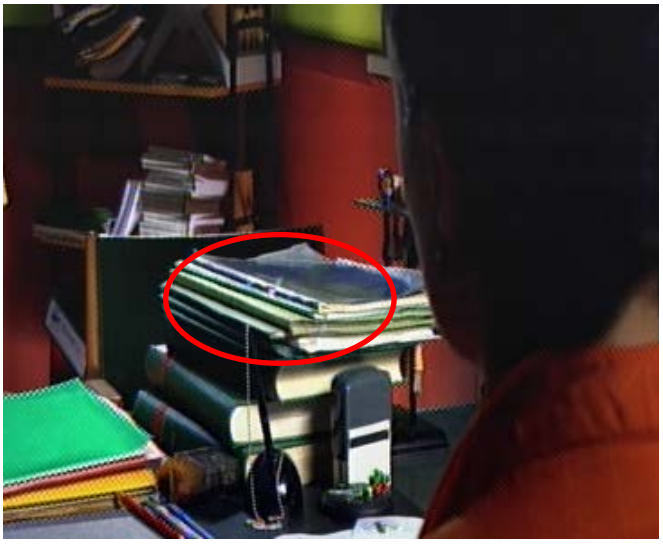

Figure 3: Proper Field Ordering

$$\underbrace{frame\ n(top), frame\ n(bottom)}_{frame\ n}, \underbrace{frame\ n+1(top), frame\ n+1(bottom)}_{frame\ n+1}, \ldots$$

In this case the video frames are re-constructed correctly.

If the algorithm receives the bottom field as a first field then the field order is reversed. Re-construction of the video frames in such a case is illustrated as below:

$$\underbrace{frame\ n(bottom), frame\ n+1(top)}_{frame\ n}, \underbrace{frame\ n+1(bottom), frame\ n+2(top)}_{frame\ n+1}, \ldots$$

For Example, YUV 4:2:2 little-endian data with top field dominance will be stored as shown

Line 1(top1) → **U0 Y0 V0 Y1 U2 Y2 V2 Y3...**
Line 2(bottom1) → **U0 Y0 V0 Y1 U2 Y2 V2 Y3...**
Line 3(top2) → **U0 Y0 V0 Y1 U2 Y2 V2 Y3...**
Line 4(bottom2) → **U0 Y0 V0 Y1 U2 Y2 V2 Y3...**
.
.
.
Line n → **U0 Y0 V0 Y1 U2 Y2 V2 Y3..**

In this case the quality of the re-constructed frame is same as the input source.

If field order is reversed, then progressively weaved data may look as follows

Line 1(bottom1) → **U0 Y0 V0 Y1 U2 Y2 V2 Y3...**
Line 2(top2) → **U0 Y0 V0 Y1 U2 Y2 V2 Y3...**
Line 3(bottom2) → **U0 Y0 V0 Y1 U2 Y2 V2 Y3...**
Line 4(top3) → **U0 Y0 V0 Y1 U2 Y2 V2 Y3...**
.
.
.
Line n → **U0 Y0 V0 Y1 U2 Y2 V2 Y3..**

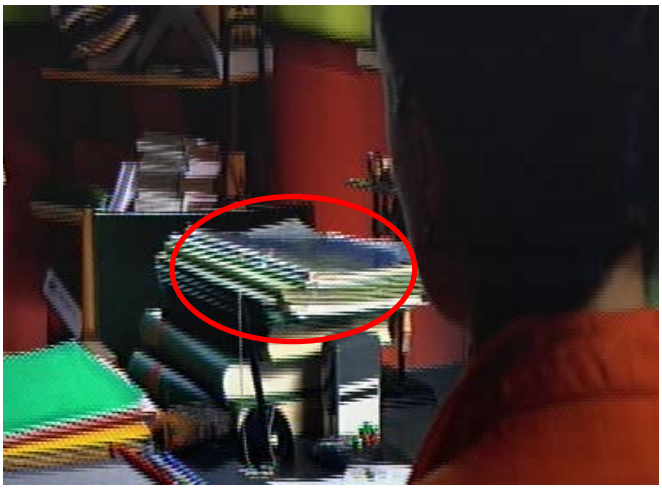

Figure 4: Field-swap artifacts

The re-constructed frame quality is not good due to the swapped lines.

To determine the field order, the algorithm must assume the field order is correct and then interpolate the two consecutive lines of the top fields using the 2-points or 6-points median algorithm and compare each pixel's luminance against the bottom line's pixels. This procedure can be repeated again assuming the field is reversed. Comparing these two helps in identifying the field order.

Assuming the luminance values of the frame are arranged in the following order

Line 1, y(1) → x1,x2,x3...
Line 2, y(2) → x1,x2,x3...
Line 3, y(3) → x1,x2,x3...
Line 4, y(4) → x1,x2,x3...
.
Line n-1, y(n-1) → x1,x2,x3...**x(m-1),x(m),x(m+1),**...
Line n, y(n) → x1,x2,x3...x(m-1),**x(m)**,x(m+1),...
Line n+1, y(n+1) → x1,x2,x3...**x(m-1),x(m),x(m+1),**...

the top field confidence for any point fi(x(m), y(n)) point can be calculated by,

$$fo1(x(m),y(n))=\begin{cases}1 & median\begin{pmatrix} fi(x(\text{m-1}),y(\text{n}-1)) \\ fi(x(m),y(\text{n}-1)) \\ fi(x(\text{m+1}),y(\text{n}-1)) \\ fi(x(\text{m}-1),y(\text{n+1})) \\ fi(x(m),y(\text{n+1})) \\ fi(x(\text{m+1}),y(\text{n+1}) \end{pmatrix} \approx fi(x(m),y(n)) \\ 0 & else \end{cases}$$

In the above formula, luminance value of column x(m) and row y(n) can compared with the calculated median value(interpolated).

We can also calculate the bottom Field confidence by,

$$fo2(x(m),y(n))=\begin{cases}1 & median\begin{pmatrix} fi(x(\text{m}-1),y(\text{n+1})) \\ fi(x(m),y(\text{n+1})) \\ fi(x(\text{m+1}),y(\text{n+1})) \\ fi(x(\text{m}-1),y(\text{n+3})) \\ fi(x(m),y(\text{n+3})) \\ fi(x(\text{m+1}),y(\text{n+3})) \end{pmatrix} \approx fi(x(m),y(n)) \\ 0 & else \end{cases}$$

Sum of all top field confidence gives the total top confidence value $\sum fo1(x(m),y(n))$ for the frame. Similarly the total bottom field dominance values can be calculated by adding all the bottom confidence values $\sum fo2(x(m),y(n))$.
Following formula helps to determine if the field is swapped or not.

$$swap=\begin{cases}0 & \sum fo1(x(m),y(n)) > \sum fo2(x(m),y(n)) \\ 1 & else \end{cases}$$

Once the field information is detected, it is necessary to run this algorithm at regular interval to reaffirm the file order.

Accuracy

Input Video Data	**Accuracy (in %)**
Moving Picture	99 – 100
Still picture (paused video or picture)	95 – 100
Still picture (paused video or frame with same color)	>75

Performance

Event	**Timings (in millisecond)**
Time to determine field order (2 - point mean algorithm running on 400mhz ARM Cortex-*M3*)	33 - 99
Time to detect re-plug and correct the Field order (Algorithm runs every 1000 ms)	1000-3000

CONCLUSION

The interpolated video data will approximately be equal to the original data. This method is more reliable to identify the field dominance for most video data and hence improves the picture quality dramatically.

2-point median algorithm can be substituted to reduce the CPU load further.
Further, this algorithm is influenced by input video data and the field order may change as a result of the video input cable being removed/re-plugged. So, it's necessary to run this algorithm at periodic interval to correct the field dominance accordingly.

About Authors

Raja Subramanian is a member of the engineering team at Mistral Solutions Pvt Ltd. He has completed Masters in Computer Science from Bharathidasan University and has 14 years of experience in designing technical solutions in the area of audio, video, storage and user interface for consumer electronic products. His expertise is in the field of autonomous navigation, video surveillance and data security.

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