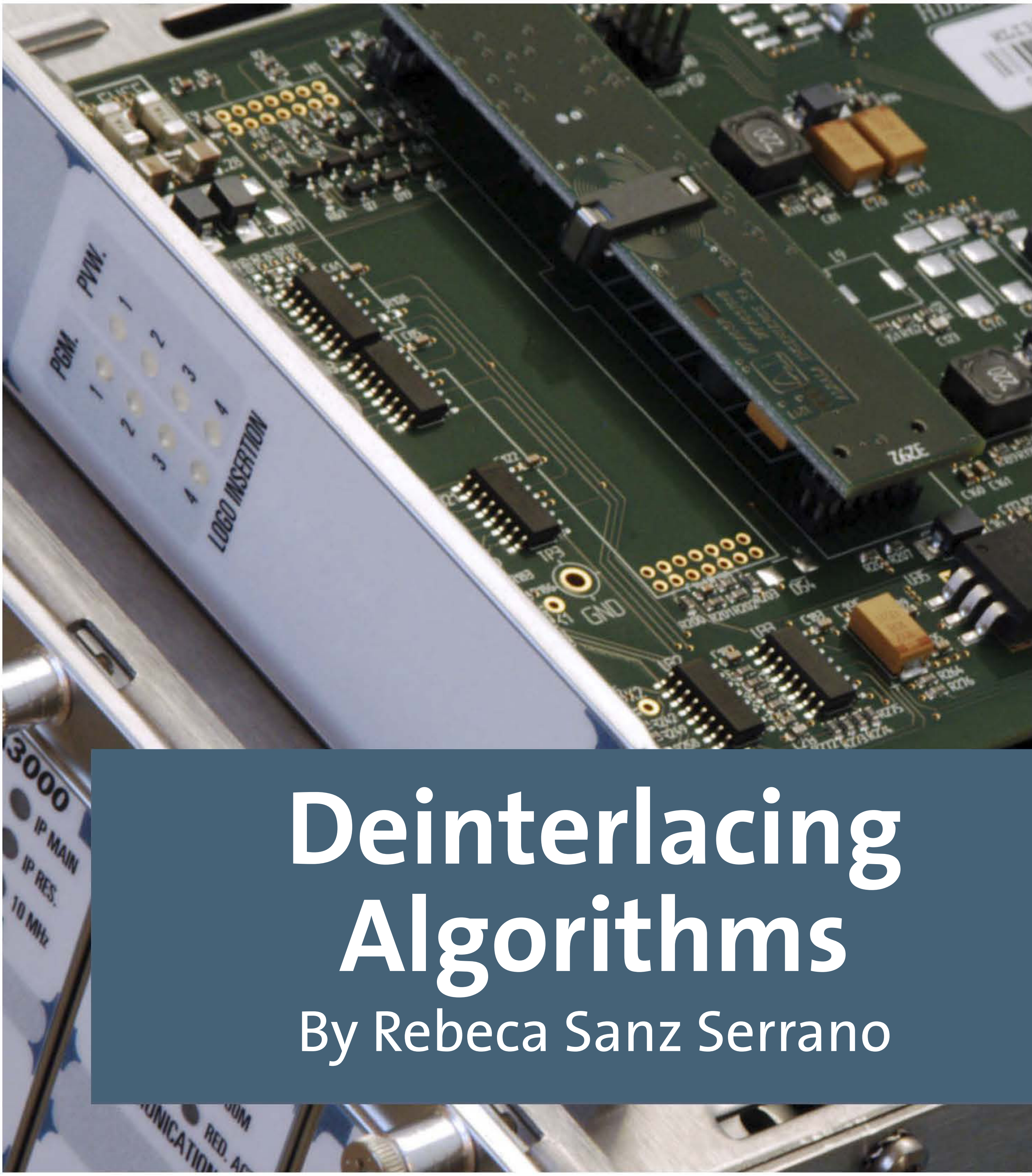

Deinterlacing Algorithms

By Rebeca Sanz Serrano

Albalá Ingenieros S.A.
Medea, 4 - 28037 Madrid - Spain

Deinterlacing Algorithms

By Rebeca Sanz Serrano

This article has been registered with the Registry of Intellectual Property of the Community of Madrid on February 9th 2016 with the number of registration entry 16/2016/1999.

Introduction

Interlacing is a video system dating from the 1940's when various television systems were defined, all of which were naturally analog. The camera sweeps the uneven numbered lines first, generating the first field and then sweeps the even numbered lines to generate the second field. As a consequence each image frame is built from two fields that do not occupy the same instant of time. Various artifacts can appear in the image due to the sampling structure of interlaced systems. For example, aliasing can occur in the presence of high vertical frequencies and a specific blinking known as flicker can appear in the image. Figure 1 shows a graphical representation of the sampling structure of an interlaced system.

The reason that such a system was established is because both cinema and television are based upon a series of frames containing static images projected at a frequency high enough to give the sensation of movement. The film industry worked with a frame rate of 18 to 24 frames per second, whereas for TV two frame rates were established: 25 fps in Europe and 30 fps in the Americas. These rates were considered high enough that the human brain would accept movements, even rapid ones as if they were continuous, meaning that no gaps or jerky motion would be noted. Nonetheless these frame rates turned out to be insufficient to eliminate flickering.

Doubling the frame rate would have been an enormous cost in film or, in the case of television this would have required doubling the bandwidth of the broadcasting channels. Even though a doubled frame rate would have eliminated the flicker it would not provide a notable improvement in the jerkiness of movements and therefore did not justify the added cost. The resolution at the time was sufficient without doubling the cost, taking into account that these are subjective considerations and are usually based on the average behavior of the human eye-brain combination.

The film industry chose a simple solution; projecting each frame twice and reducing the flicker without added cost. For television the interlaced system was invented, allowing the electron beam to scan the screen twice, once with each field, in order to display the complete frame. Each field is displaced vertically from the other by the distance of one line. The result is equivalent to the duplicated projection of a single frame in film.

Naturally, given the current state of technology in the video industry - providing high definition spatial resolution, progressive scan temporal resolution at 50 or 60 Hz and digital video recording the facts regarding interlacing seem laughable. Furthermore, the high bandwidth and immense memory capacity needed can both be reduced using a variety of mathematical compression algorithms.

Nonetheless there is still a huge amount of existing video footage recorded in interlaced formats. What's more, even today the interlaced system continues to be used even though modern cameras can record both frames in a progressive scan.

Interchanging programs recorded in various video formats requires deinterlacing any images that come from interlaced source material. Such images are first modified from analog to digital format with adjustment of the number of lines and frames both to switch from standard definition to high definition and vice-versa and to convert between the video systems of different countries.

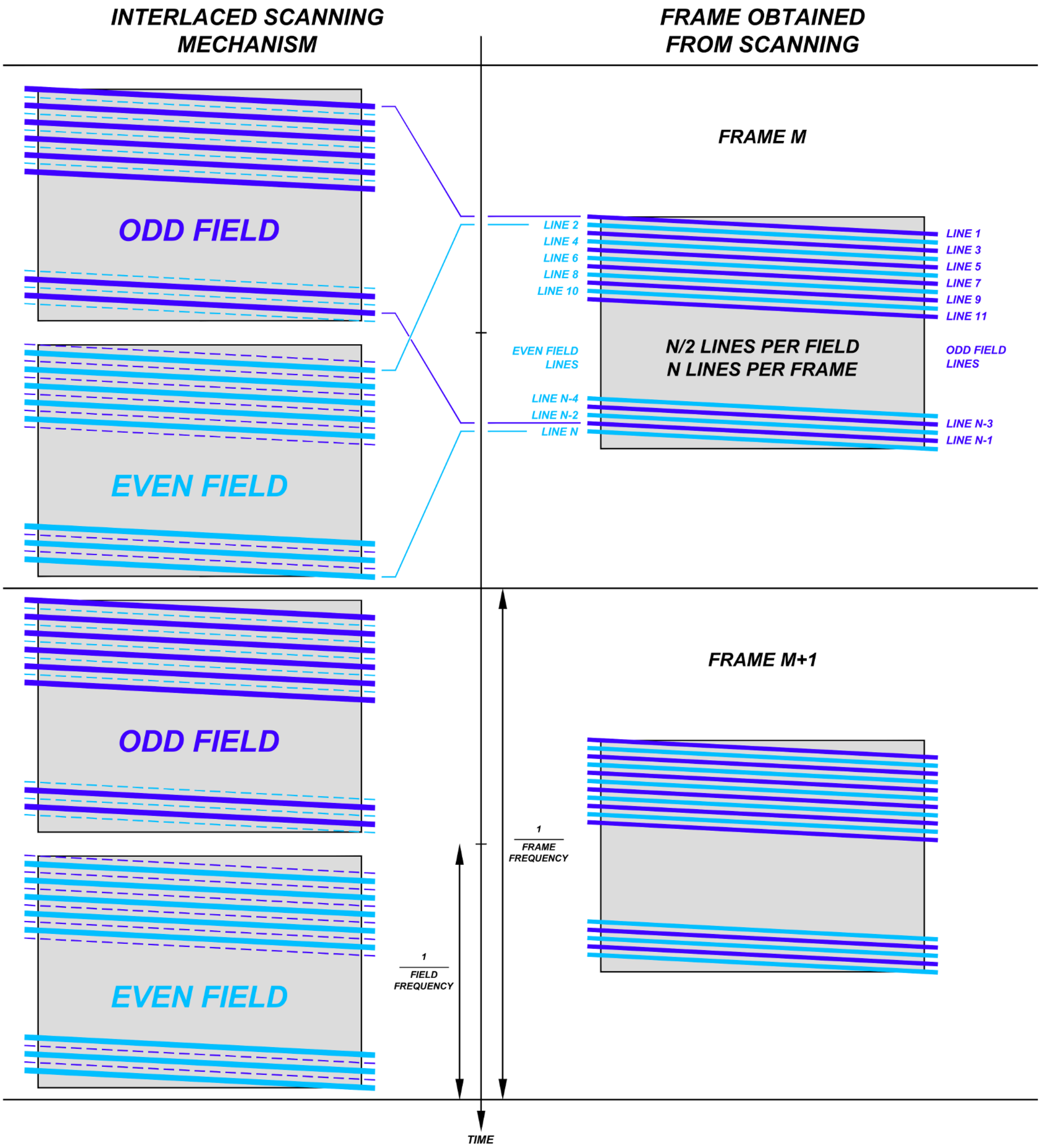

Figure 1: Sampling structure of interlaced video.

NTSC to PAL conversion is quite common, where adaptation from 30 to 25 frames in SD or 60 to 50 frames in HD is performed, respectively. These changes all require deinterlacing to create progressive scan frames for editing and sequence processing of the video.

Deinterlacing consists of estimating the number of missing lines in each field of an interlaced video signal in order to produce a progressive scan signal. A great variety of algorithms exist to perform this process with varying levels of complexity. This document will explore and compare deinterlacing algorithms based on temporal interpolation, spatial interpolation, Motion Adaptive and Motion Compensation techniques.

Temporal Interpolation Deinterlacing

One of the simplest families of deinterlacing algorithms is that of temporal interpolation, based upon the information from adjacent frames to estimate the missing lines. The simplest of these methods is replication of the previous field. The advantage of this algorithm is that it achieves the highest resolution when there is little movement in the video. However when there are large movements the field replication method can generate artifacts that are highly visible.

Figure 2 shows an example of deinterlacing using the field replication method where the deinterlaced video is a blue rectangle passing in front of the static image of a face on a diagonal path. The resolution of the image of the face is very good, but the edges of the blue rectangular demonstrate the notorious visible artifacts due to the poor response of this algorithm to moving objects.

Figure 2: Deinterlacing using field replication

Spatial Interpolation Deinterlacing

Another basic member of the deinterlacing algorithm family is spatial interpolation, which consists of using the lines present in the field currently being displayed to estimate the missing lines. The simplest of these algorithms is known as Line Average (LA). One descendant of Line Average that merits attention is an algorithm that performs a search for the borders of the image to perform spatial interpolation, Edge Line Average or ELA. These algorithms reduce the stepped effect at the borders of the image and offer the best results for the spatial algorithms family. The greatest advantage of spatial algorithms is the lack of visible artifacts during movement in the video, however their principal disadvantage is that because they only use information from the field currently being displayed they reduce the vertical resolution.

Figure 3 shows the same video sequence as before but using spatial interpolation deinterlacing with an ELA algorithm. As before, the image of the face is static while a blue rectangular moves across it on a diagonal path. None of the visible artifacts are present on the edges of the blue rectangle, but the resolution of the static image is noticeably reduced.

Figure 3: Spatial deinterlacing using Edge Line Average (ELA)

Comparison of Spatial and Temporal Deinterlacing

Figure 4 shows the results of temporal deinterlacing via replication of the previous field and using Edge Line Average spatial deinterlacing side-by-side.

As mentioned previously the main problem with the previous field replication algorithm is the appearance of visible artifacts on moving objects, as seen in the blue rectangle. On the other hand, when using spatial interpolation deinterlacing a loss in vertical resolutions results; this effect is especially noticeable in the eye, the eyebrow and the definition of the hair.

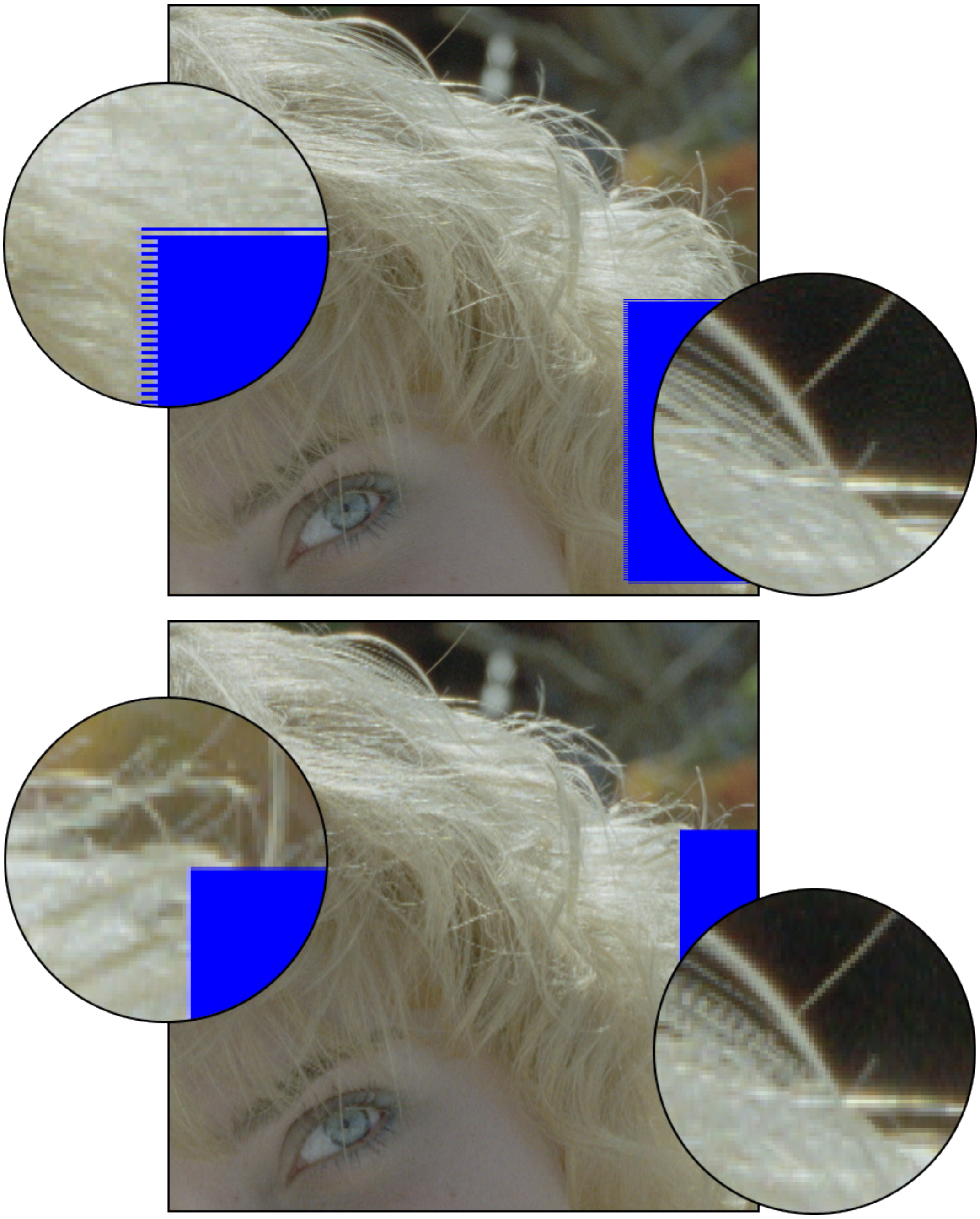

Figure 4: Comparison of temporal deinterlacing (top) and spatial deinterlacing (bottom)

Deinterlacing with Motion Adaptive Algorithms

Since spatial algorithms are better for images with movement and temporal algorithms are better for static images, deinterlacing methods have evolved to combine the best of both types, giving rise to so-called Motion Adaptive algorithms. Motion Adaptive deinterlacing detects the level of variation between the pixels of consecutive fields and performs a combination of spatial interpolation and temporal interpolation based upon the amount of pixel variation observed. This family of algorithms are currently the most wide-spread.

Figure 5 shows the results of deinterlacing the same video sequence with the static face and the blue rectangular moving across it in a diagonal pattern using a Motion Adaptive algorithm. No artefacts are visible on the borders of the blue rectangle, and yet the resolution of the static face image is similar to that of the field replication temporal interpolation algorithm.

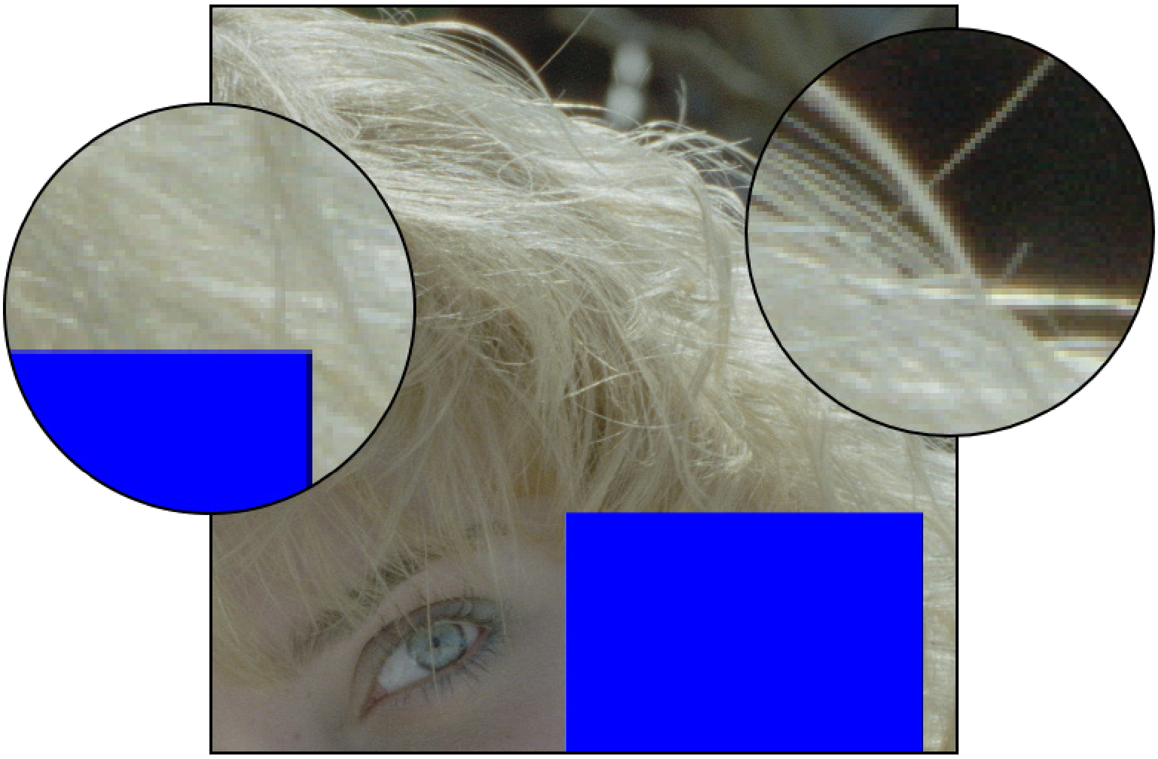

Figure 5: Deinterlacing using a Motion Adaptive algorithm

The main problem with this algorithm is the loss of vertical resolution of any moving objects in the video, however this loss is lower than it would be with pure spatial interpolation because the loss only occurs in areas with movement. The result is a barely perceptible reduction in resolution for the human eye during rapid movement, although with relatively slow movements this loss is more noticeable. Such slow movements can be produced when an object passes in front of a still background or during camera movements such as pan and zoom, etc.

Figure 6 shows the results of deinterlacing with an Adaptive Motion algorithm on a video sequence where the camera is moving forward such that the entire frame is moving.

Figure 6: Deinterlacing with an Adaptive Motion algorithm of a video sequence containing camera movement

Deinterlacing with Motion Compensation Algorithms

Another family of algorithms that also merit attention are the Motion Compensation group. These algorithms attempt to estimate the movement between two consecutive fields by calculating motion vectors. This is done by performing temporal interpolation on the regions of two consecutive fields that are mostly alike. Searching for the regions with minimal change between consecutive fields requires significant computing power.

This family of algorithms function exceptionally well when movement in the image is by only a few pixels and the movement vectors are well estimated, especially for textured images with high vertical resolutions. However visible artifacts can appear if the movement vector calculations contain errors and the movement in the image is by a large number of pixels. For this reason the use of Motion Compensation algorithms needs to be combined with other deinterlacing methods so that erroneous calculation of movement vectors can be detected and combined with other more precise estimation methods to avoid visible artifacts.

Figure 7 shows the results of deinterlacing a video sequence in which the camera moves forward, putting the entire frame in motion. For this example a combination of Motion Adaptive and Motion Compensation algorithms were used. The result is an image in which high vertical resolution is maintained without visible artifacts.

Figure 7: Deinterlacing using a Motion Compensation algorithm

Comparison between Motion Adaptive and Motion Compensation Algorithms

Figures 8 and 9 show the differences between deinterlacing with a Motion Adaptive algorithm and deinterlacing with a robust method combining Motion Compensation with an adaptive algorithm. In both cases the video sequences were recorded with the camera in motion.

Each of the two comparisons demonstrate that the Motion Compensation algorithm achieves greater resolution in the deinterlaced frame.

The river-and-house sequence displays higher resolution, especially in the windows of the home, the leaves of the tree on the left and the oblique lines on the roof, where reduced aliasing is also observed.

For the aerial view of Stockholm improvements can be seen mainly in the windows of the buildings, the details at street-level such as in the streetlights, the cars and the trees as well as the artifacts that appear in the roofs.

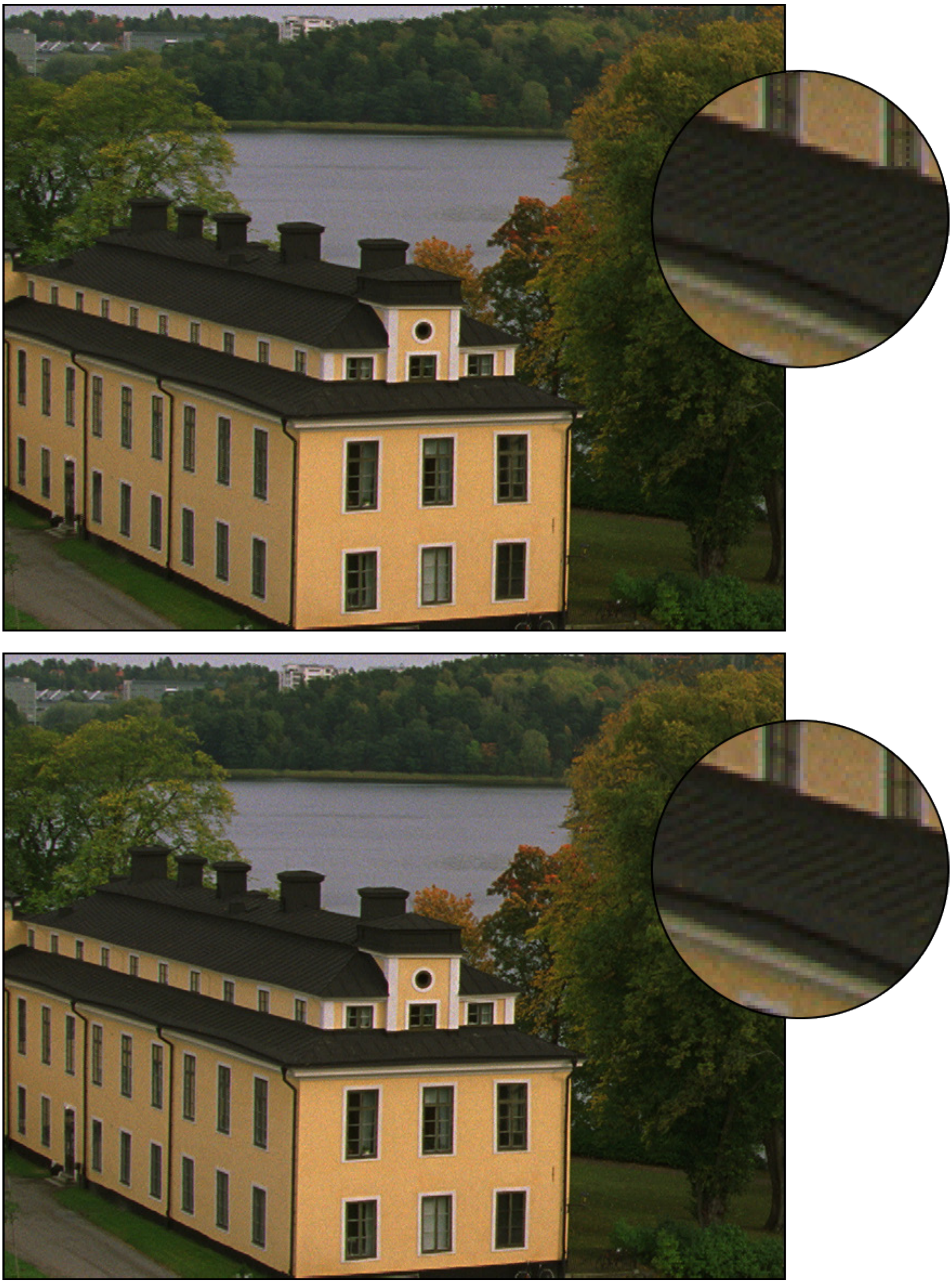

Figure 8: Comparison of Motion Adaptive deinterlacing (above) and Motion Compensation deinterlacing (below)

Figure 9: Comparison of Motion Adaptive deinterlacing (above) and Motion Compensation deinterlacing (below)

Conclusion

Deinterlacing algorithms based on treatment of the entire frame in the same manner regardless of the motion present in the video such as spatial interpolation and temporal interpolation are relatively simple, but the results are lacking when compared to methods that consider motion in the image to apply corrections.

Algorithms that analyze motion, whether partial or occupying the entire image are more efficient even though they require more mathematical computation and require faster and more powerful processors. Within this family of algorithms one group consists of the Motion Adaptive type, which applies either spatial or temporal interpolation to those areas of the video image that require one or the other, thereby adapting to any motion present in a given video sequence. The other group of algorithms is the more advanced Motion Compensation type, which requires higher computational power to achieve higher resolution in the final results.

The HXC3000C01 from Albalá Ingenieros uses an algorithm developed in-house based upon Motion Compensation with extraordinary results. Thanks to this algorithm the HXC3000C01 provides high quality deinterlacing that is especially evident in video that contains textures and slow movement.

Albalá Ingenieros, S.A.
Medea, 4 - 28037 Madrid
Spain
+34 913274453
www.albalaing.com