

Deinterlacing/interpolation of TV signals

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Outline

- A Review of some terminologies
 - Converting from NTSC to HDTV; What changes need to be considered?
 - Deinterlacing
 - Interframe and Intraframe Methods
 - Intraframe Methods
 - Comparison of intraframe methods
 - Interframe methods
 - Comparison of intraframe methods
 - Summary and future work
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Terminology: Frame vs Sequence

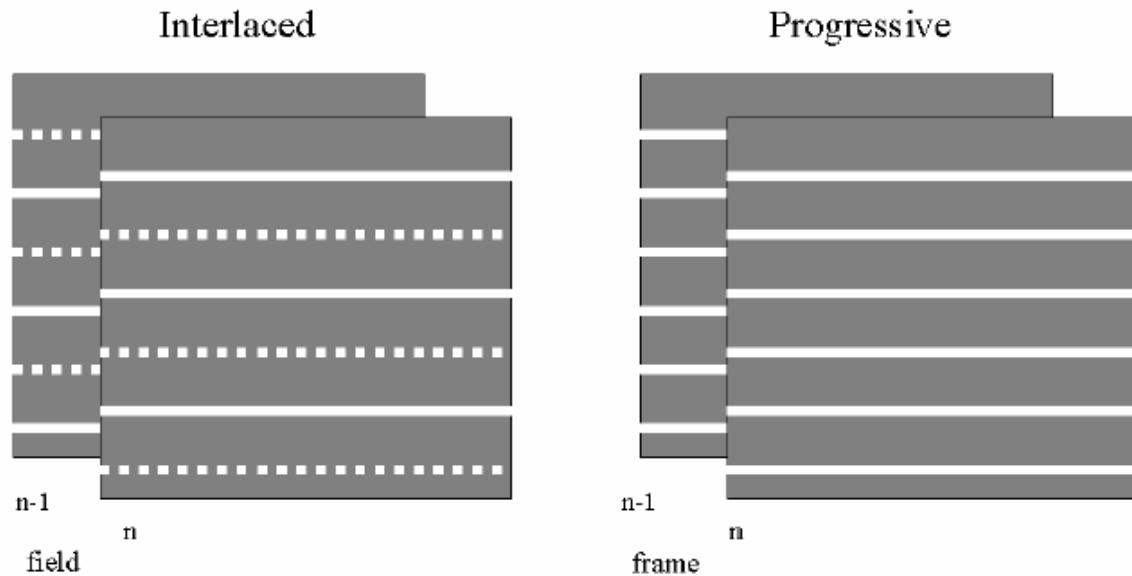
- A video *frame* is a picture made up of a 2D discrete grid of *pixels*.
 - A video *sequence* is a collection of frames, with equal dimensions, displayed at fixed time intervals.
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Terminology: Mathematical Definition of a sequence

- A video sequence is a three-dimensional array of data in the vertical, horizontal, and temporal dimensions. Let $F[x, y, z]$ denote the pixel in this three-dimensional sequence:
 - Then, for a progressive scan sequence $F[x, y, z]$ is defined for all integers x, y, z within the valid height, width, and time duration of the sequence.
 - If $F_i[x, y, z]$ is an interlaced source generated from the same progressive source:

$$F_i[x, y, z] = \begin{cases} F[x, y, z] & \text{mod}(y, 2) = \text{mod}(z, 2) \\ \phi & \text{otherwise} \end{cases}$$

Terminology; Scan Mode



- In interlaced fields either the even or the odd lines are scanned.
- In progressively scanned frames all lines are scanned in each frame.

Converting from NTSC to HDTV; What changes need to be considered?

vertical_size_value	horizontal_size_value	aspect_ratio_information	frame_rate_code	progressive_sequence
1080 ²	1920	1,3	1,2,4,5	1
			4,5	0
720	1280	1,3	1,2,4,5,7,8	1
480	704	2,3	1,2,4,5,7,8	1
			4,5	0
	640	1,2	1,2,4,5,7,8	1
			4,5	0

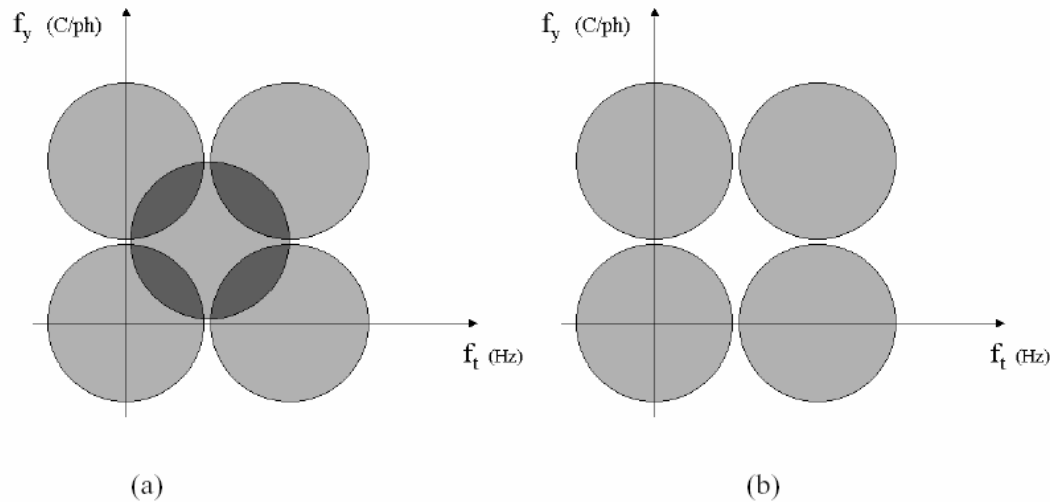
Legend for MPEG-2 coded values:
 aspect_ratio_information: 1 = square samples, 2 = 4:3 display aspect ratio, 3 = 16:9 display aspect ratio
 frame_rate_code: 1 = 23.976 Hz, 2 = 24 Hz, 4 = 29.97 Hz, 5 = 30 Hz, 7 = 59.94 Hz, 8 = 60 Hz
 progressive_sequence: 0 = interlaced scan, 1 = progressive scan

Deinterlacing

- Deinterlacing a video sequence involves converting the interlaced fields into progressively scanned frames.
- Ideal deinterlacing would double the vertical-temporal sampling rate and remove aliasing.
- For a given interlaced input , the output of deinterlacing, can then be defined as

$$F_o[x, y, n] = \begin{cases} F_i[x, y, n] & \text{mod}(y, 2) = \text{mod}(n, 2) \\ \hat{F}[x, y, n] & \textit{otherwise} \end{cases}$$

Vertical-temporal spectrum of interlaced scan video signal



- (a) Frequency spectrum of an interlaced signal along the vertical-temporal plane.
- (b) Ideal Output of deinterlacing algorithm
- The aliasing is due to the interlaced sampling.
 - The areas of overlap in (a) cannot be perfectly recovered by any deinterlacing algorithm, so the result in (b) is not possible in general.

Interframe and Intraframe Methods for deinterlacing/interpolation

● These reconstruction methods can be segmented into two categories:

- *intraframe*

Intraframe methods only use the current frame for reconstruction

- *interframe.*

Interframe methods make use of the previous and or subsequent frames as well.

Intra-frame Methods

- Intraframe methods are also called spatial methods.
- They do not require any additional frame storage.
- Their performance is independent of
 - the amount of motion present in the sequence.
 - the frame-recording rate.

So, Robustness to motion is one their characteristic.

- Considering only the information in the present field greatly limits their performance, due to the large temporal correlation that typically exists between successive frames.




Intra-frame Methods

- Well-known intraframe methods:
 - Line/pixel repetition
 - Linear interpolation
 - Parametric Image Modeling

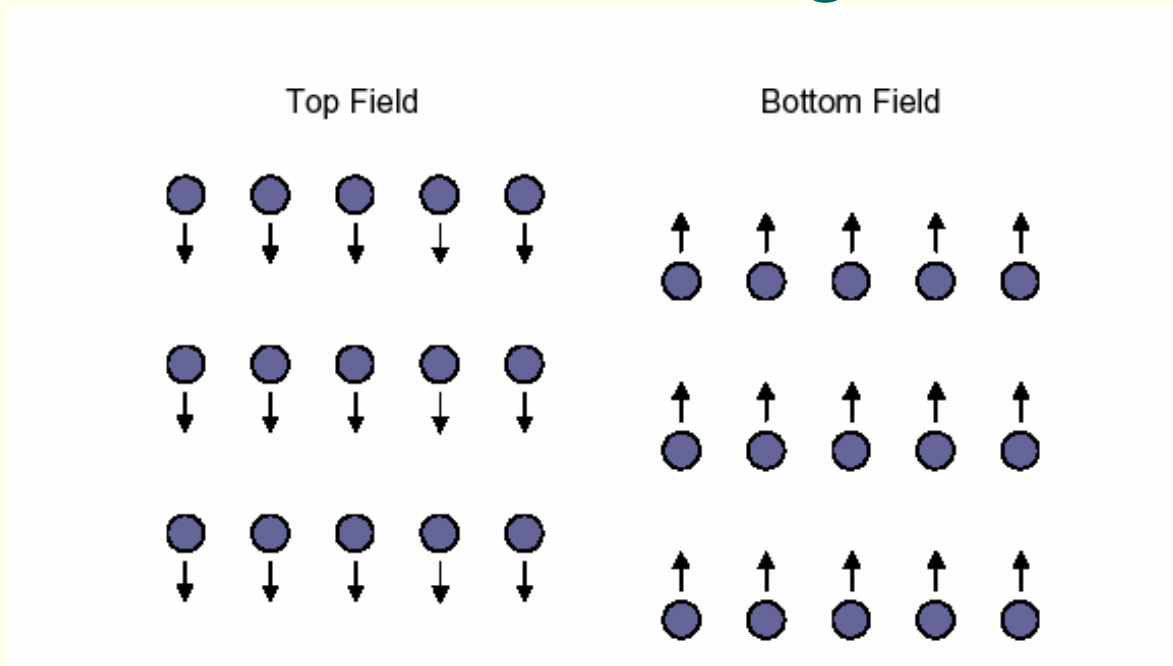




Intra-frame Methods: Line/Pixel Repetition

- This method is one of the simplest algorithms, and thus, of the first ones to be considered.
 - In this method, the missing lines/pixels are generated by repeating the nearest available line/pixel on their top/left neighborhood
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Intra-frame Methods: Line Repetition for Deinterlacing



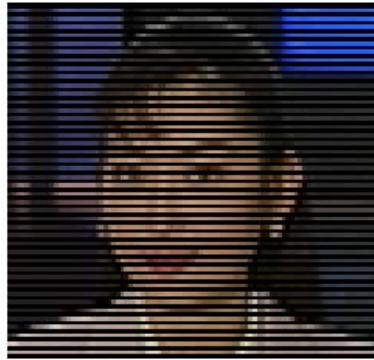
$$F_o[x, y, n] = \begin{cases} F_i[x, y, n] & y \text{ even} \\ F_i[x, y-1, n] & \text{otherwise} \end{cases}$$

$$F_o[x, y, n] = \begin{cases} F_i[x, y, n] & y \text{ odd} \\ F_i[x, y+1, n] & \text{otherwise} \end{cases}$$

Intra-frame Methods: Line Repetition for Deinterlacing



Original
(a)



Interlaced
(b)

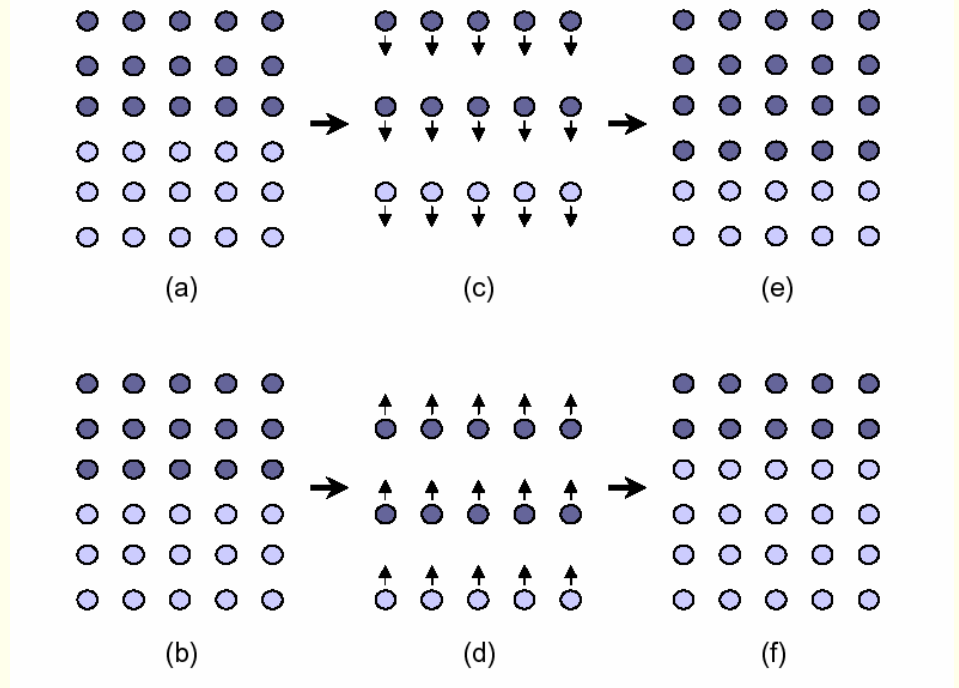


Line Repetition
(c)

- Output of line repetition shows a poor performance.
- It introduce severe jagged edge and jitter artifacts.

Line Repetition for Deinterlacing


- Comparing the deinterlaced frames, this method has incorrect reconstruction of the horizontal edges
- This will make the output sequence appear to shake.
- The rate of the resulted vibration corresponds directly to the frame rate of the video sequence.
 - At high frame rates, this shaking may become unnoticeable to the human eye.
 - At lower frame rates this effect becomes very noticeable and extremely annoying.



(a) (b) Consecutive progressive frames of a stationary image with a horizontal edge.
(c) (d) Corresponding interlaced fields.
(e) (f) Result of reconstruction.




Intra-frame Methods: Linear Interpolation

- Linear interpolation is slightly more advanced than line/pixel repetition.
 - In linear interpolation the missing line/pixels are reconstructed by averaging the line/pixels directly above and below.
 - It results in a slightly smoother picture than line/pixel repetition, but still has fairly poor performance.
 - It has the same problems as line/pixel repetition, such as aliasing and jitter.
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Intra-frame Methods: Parametric Image Modeling

- These are a more advanced form of spatial methods which utilizes image modeling.
 - They attempt to model a small region of an image through a set of parameters and basis equations.
 - Missing line/pixels are then reconstructed using linear interpolation.
 - They attempt to determine the contours of a shape in an image and interpolates along this direction to reduce interpolation errors.
 - They are some optimized suggested models, which can be used to spatially interpolate, interlaced video fields, for e.g.
 - Martinez suggests a Line Shift Model in which small segments of adjacent scan lines are assumed to be related to each other through a horizontal shift
 - Ayazifar similarly suggests a generalization of the Line Shift Model through a Concentric Circular Shift Model in which small segments of concentric arcs of an image are related to adjacent arcs by an angular shift.
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Intra-frame Methods: Parametric Image Modeling

- These methods tend to be less susceptible to noise.
 - They require more computations.
 - Depending on the order of model selected, the complexity of these algorithms can be greater than other methods.
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Comparison of intraframe methods

- (a) Line repetition.
- (b) Linear interpolation.
- (c) Martinez-Lim algorithm.



(a)



(b)



(c)

- The Martinez-Lim algorithm tends to generate the smoothest, most realistic images.
- It also suffers from some of the jitter effects although these effects are significantly reduced, compared to the other two methods.

Inter-frame Methods

- Inter-frame or temporal methods consider previous and/or subsequent frames to exploit temporal correlation.
- Well-known inter-frame methods include:
 - Field Repetition
 - Bilinear frame interpolation
 - Vertical-temporal median filtering
 - Motion compensated methods
 - Motion adaptive methods



Inter-frame Methods: Field Repetition

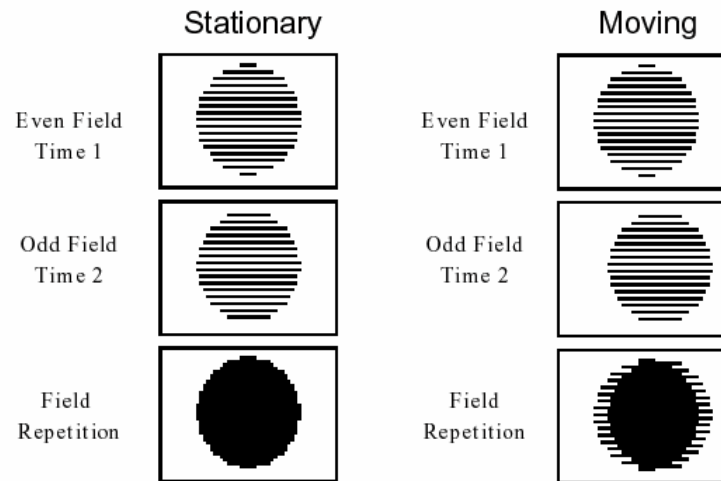
Field repetition refers to the generation of missing scan lines by copying lines from the previous frame at the same vertical position.

Field repetition is defined as:

$$F_o[x, y, n] = \begin{cases} F_i[x, y, n] & \text{mod}(y, 2) = \text{mod}(n, 2) \\ F_i[x, y, n - 1] & \textit{otherwise} \end{cases}$$

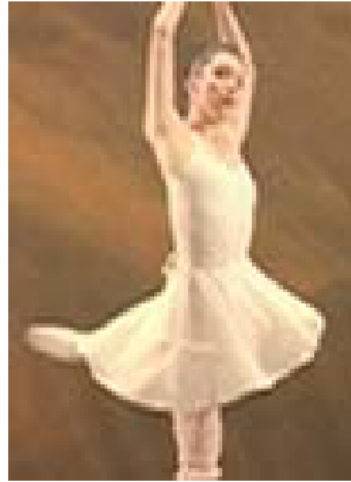


Inter-frame Methods: Field Repetition

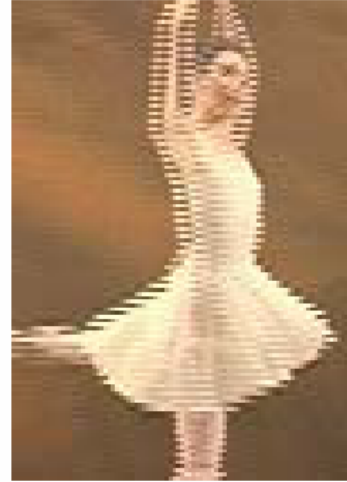


- The stationary circle is perfectly reconstructed by combining the even and odd fields.
- However, for the moving circle, the image is blurred since the even and odd fields are no longer properly aligned due to the motion of the circle between frames.

Inter-frame Methods: Blurred frame caused by field repetition



(a)



(b)

(a) Original progressive frame. (b) Frame produced using field repetition.

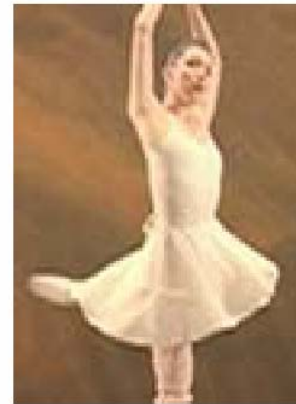
- Motion of the ballerina causes edges to be distorted resulting in a blurred image.

Bilinear Field Interpolation

- It uses the average of the previous and future frame lines for deinterlacing.
- The definition is
$$F_o[x, y, n] = \begin{cases} F_i[x, y, n] & \text{mod}(y, 2) = \text{mod}(n, 2) \\ (F_i[x, y, n+1] + F_i[x, y, n-1]) / 2 & \text{otherwise} \end{cases}$$
- It has essentially the same benefits and issues as field repetition.
 - Works very well in stationary regions,
 - Works poorly in moving regions.
- It introduces more blurring artifacts in the presence of motion since it blends three frames together rather than just two.

Inter-frame Methods: Bilinear Field Interpolation

- Three separate fields are visible in image (b).
- The result is a “ghostly” image with badly blurred edges.
- In this sense, when compared to field repetition, field interpolation is even more unacceptable.



(a)



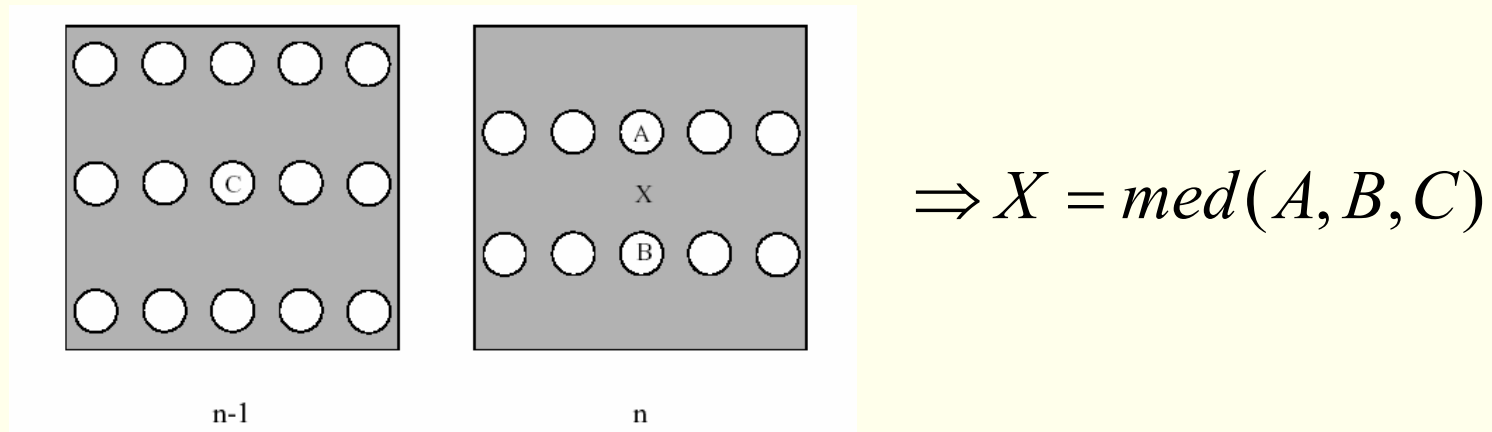
(b)

Inter-frame Methods: Vertical-Temporal Median Filtering

- Vertical-Temporal (VT) filters utilize neighboring pixels in the current and adjacent frames.
- In VT median filtering, a median operation is used rather than a linear combination of the surrounding pixels.
- VT median filtering is popular due to its performance and ease of implementation.
- Deinterlacing VT median filter for a 3-tap median filter is described as:

$$F_o[x, y, n] = \begin{cases} F_i[x, y, n] & \text{mod}(y, 2) = \text{mod}(n, 2) \\ \text{median}(F_i[x, y+1, n], F_i[x, y-1, n], F_i[x, y, n-1]) & \text{otherwise} \end{cases}$$

Inter-frame Methods: Vertical-Temporal Median Filtering




Median filtering adapts itself to moving and stationary regions on a pixel-by-pixel basis.

- So it will be robust to motion



Inter-frame Methods: Motion Compensated Methods

- The most advanced techniques for deinterlacing generally make use of motion estimation and compensation.
 - There are many motion estimation algorithms that can be used to estimate the motion of individual pixels between one field and then next.
 - If accurate motion vectors are determined, motion compensation (MC) can basically remove the motion from a video sequence.
 - If motion were perfectly removed, temporal interpolation could theoretically restore the original frames.
 - In general any non-MC algorithm can be converted to a MC algorithm.
 - However, only those techniques that perform better on stationary images will most likely be improved.
 - Some straightforward MC methods include field repetition, field interpolation, and VT median filtering.
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Inter-frame Methods: Motion Compensated Methods

- The most common method for determining motion vectors is through block matching algorithms.
- The “matching” criterion that is typically used is either mean square error or mean absolute error.
- A number of problems can arise when using block matching motion estimation scheme; for instance
 - when objects pass in front of one another, there are appearing and disappearing regions of the fields, which cannot be accounted for with motion vectors.
 - If an object moves beyond the motion vector search area, the motion vector will not be accurately determined.
 - The pixels may have sub-pixel motion. In this case, the motion vector actually should point between pixels or at missing lines in the previous field.



Inter-frame Methods: Motion Adaptive Methods

- Interlaced sequences can be perfectly reconstructed by:
 - interframe methods in the absence of motion
 - intraframe methods in the presence of motion
- Motion adaptive methods use a motion detector to take advantage of this fact by separating each field into moving and stationary regions.
- The algorithm then fades between a temporal method and a spatial method.
- The output of this type of motion adaptive algorithm can be represented as:


$$F_o[x, y, n] = \begin{cases} F_i[x, y, n] & \text{mod}(y, 2) = \text{mod}(n, 2) \\ \alpha \cdot F_{mot}[x, y, n] + (1 - \alpha) \cdot F_{stat}[x, y, n] & \textit{otherwise} \end{cases}$$

Comparison of inter-frame methods

- Motion adaptive methods had the most potential for using for deinterlacing/interpolation of video frames.
- Motion adaptive methods are designed to take advantage of the varying information that is present in different regions of a video sequence.
 - In stationary images, there exists significant correlation between the present field and the adjacent fields. Temporal methods such as field repetition are designed to benefit from this fact.
 - In moving regions, this temporal correlation does not exist, and more information can be found in adjacent pixels on the current field. Spatial methods take advantage of this fact.
- Motion adaptive methods attempts to combine the benefits of both temporal and spatial methods by segmenting each image into moving and stationary regions.
- In order to segment a video sequence into moving and stationary regions, motion adaptive methods must use some form of motion detection.



Summery and future work

- Considering the fact that, motion adaptive methods had the most potential for using for deinterlacing/interpolation of video frames; there should be some future work done on:
 - Finding an efficient motion detection method
 - Finding efficient temporal and spatial methods which could be used for combined deinterlacing-interpolation opration
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