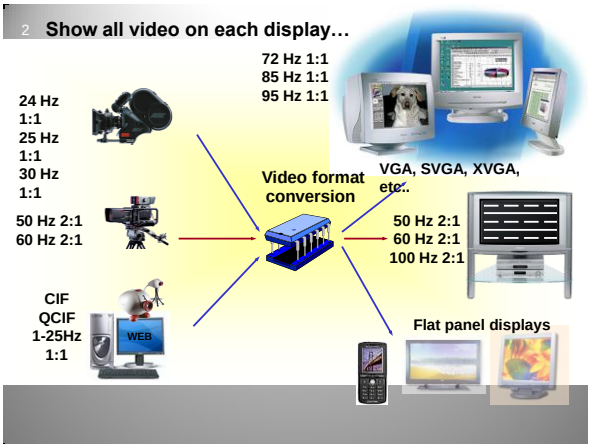
1

Picture-rate conversion

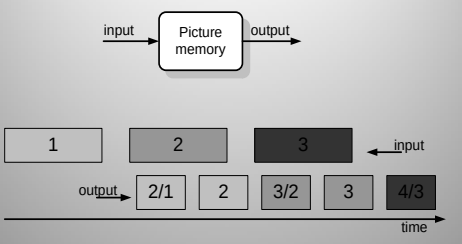
2 **Show all video on each display…**



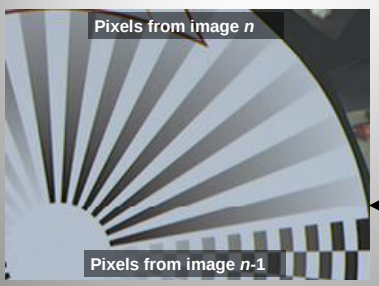
3

Simple methods

4 **Write a picture into memory and read out at different rate…**

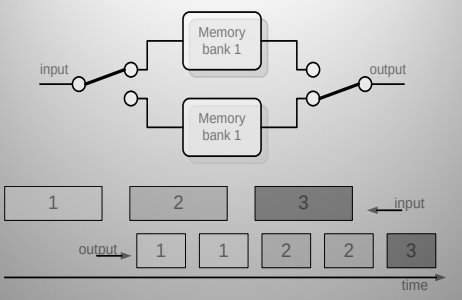


5 **Tearing: output image may be combination of 2 inputs…**



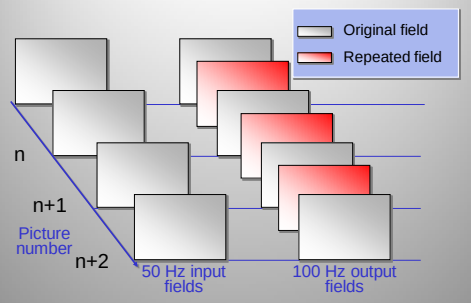
Position in image where read address and write address are the same

6 **Show an image until more recent image complete**

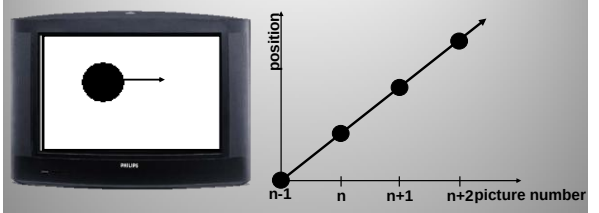


This solves the tearing, but what does it look like?

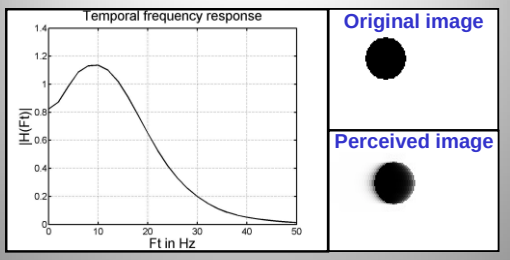
7 **Example – 50 to 100 Hz up-conversion**



8 **A moving ball on the screen**

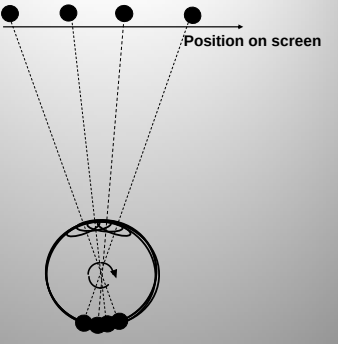


9 **Integration along temporal axis (fixed eyes)**

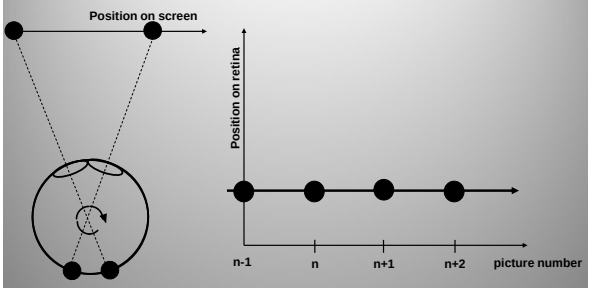


The human visual system integrates the light over a period of time, which translates into a temporal bandwidth limitation

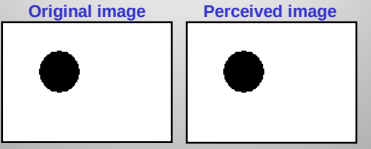
10 **Object tracking with the eye**



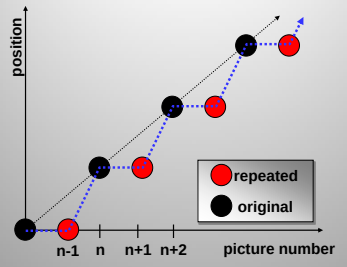
11 **A moving ball on the retina of the tracking eye**



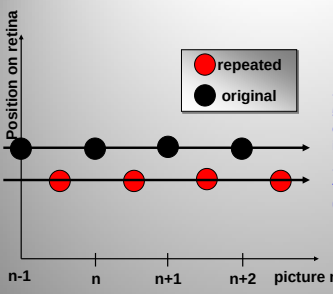
12 **Integration along motion trajectory (tracking eyes)**



13 **Picture rate conversion by repetition**



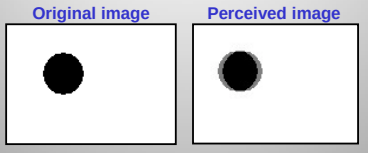
14 **Picture repetition on the retina of the eye**



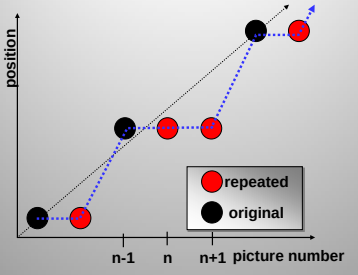
- If the input rate is higher than 50Hz both objects seem to be continuously available → double image
- If the input rate is much lower, the motion will appear jerky (judder)

demo

15 **Picture repetition, perceived result (input rate > 50Hz)**



16 **Picture rate conversion by repetition (24Hz film/60Hz TV)**



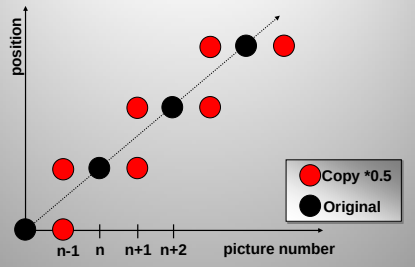
17 **Softening of motion judder**

- What film directors do:
  - Use shallow depth of focus (out-of-focus parts of image cause less high temporal frequencies)
  - Avoid rapid motion; slow zooms and pans, use tracking shots
  - Use large temporal aperture (insensitive film material) to defocus motion
- General consequence:
  - Blurring of non-stationary image parts
  - Loss of dynamic resolution

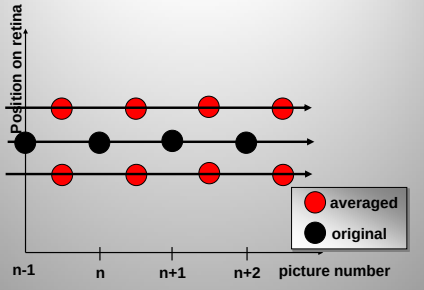
18

Higher order interpolation better?

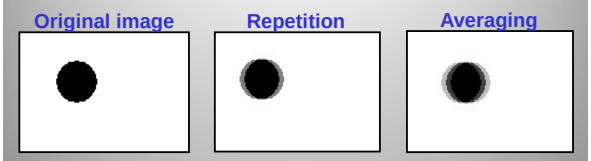
19 **Picture averaging (second order interpolation)**



20 **Picture averaging on the retina of the eye**



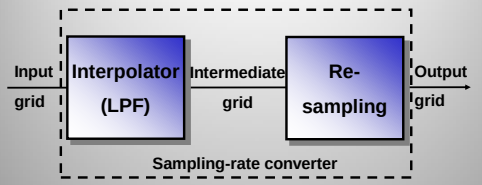
21 **Picture averaging, perceived result**



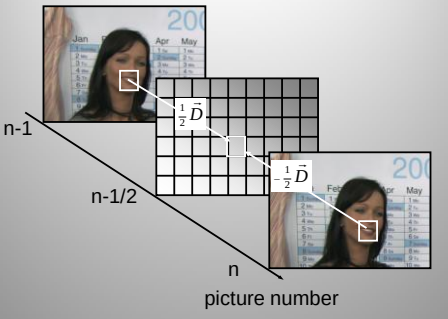
22

What is wrong with sampling-rate conversion?

23 **Sampling rate conversion theory**



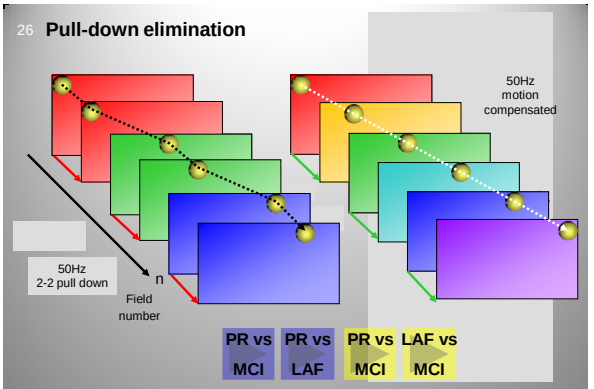
24 **Interpolate along motion trajectory…**



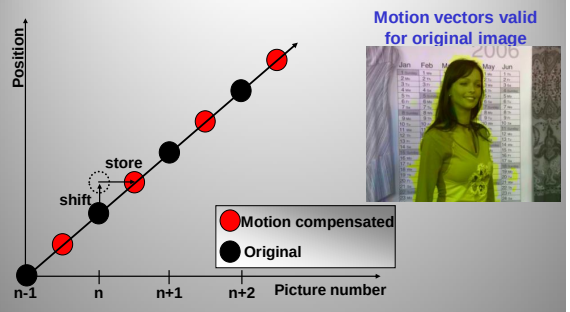
25

Motion compensated methods

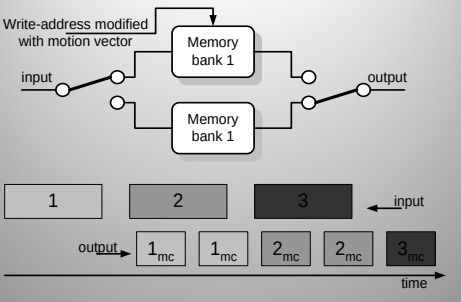
26 **Pull-down elimination**



27 **Picture-rate conversion using motion vectors**

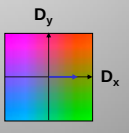


28 **This would be the implementation of the idea…**



29 **Motion estimation is what we need**

- Is there any motion?
- How fast?
- Into which direction?



ME

30 **True-motion vectors make the difference!**

FSB motion vectors

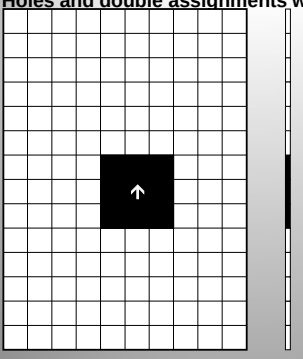
3D-RS motion vectors

31 **What's the ideal effect on the screen?**

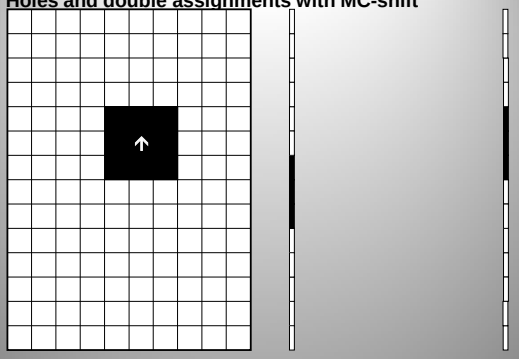
Non - Motion Compensated

Motion Compensated

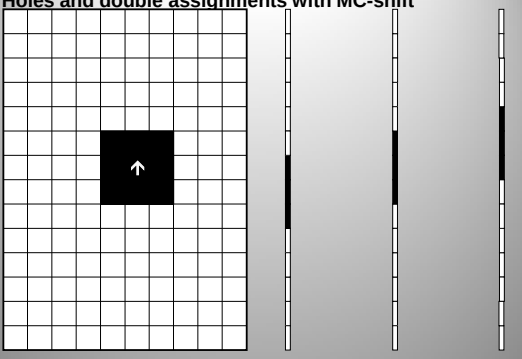
32 **Holes and double assignments with MC-shift**



33 **Holes and double assignments with MC-shift**

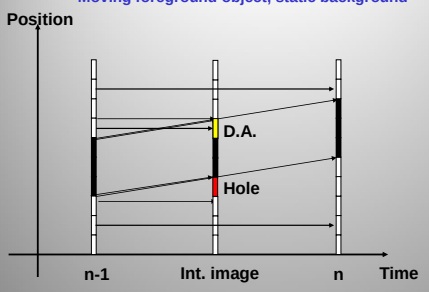


34 **Holes and double assignments with MC-shift**



35 **Holes and double assignments with MC-shift**

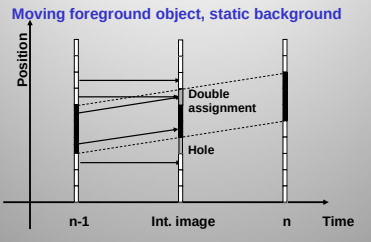
Moving foreground object, static background



shift

36 **Holes and double assignments with MC-shift**

Moving foreground object, static background

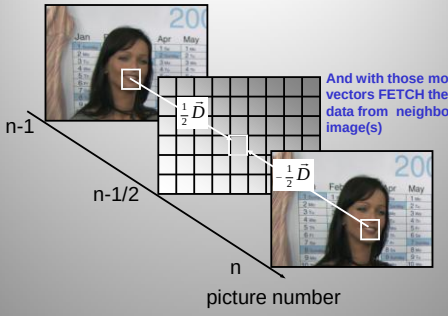


37 **This is how it looks on a natural image**

Previous original image

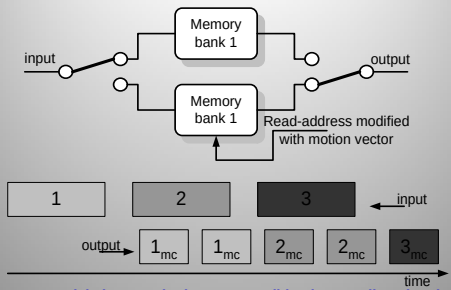
MC (shifted image)

38 **Estimate vectors that are valid in interpolated image**



And with those motion vectors FETCH the required data from neighbouring image(s)

39 **This would be the implementation of the idea…**



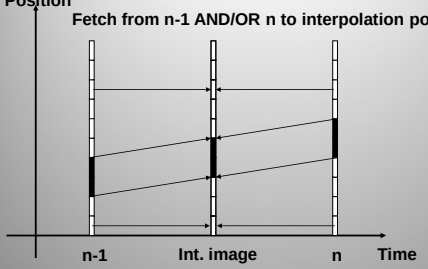
But it does not explain how to obtain vectors valid at intermediate time-instance…

40 **Solution for holes and double assignments**

Calculate vector field which is valid in image to be interpolated

Position

Fetch from n-1 AND/OR n to interpolation position

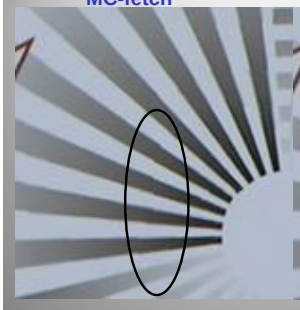


fetch

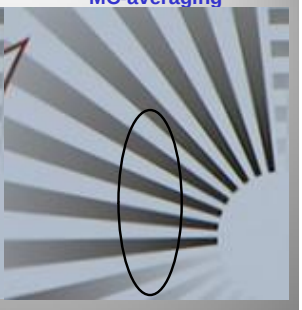
average

41 **Motion compensated picture averaging advantage**

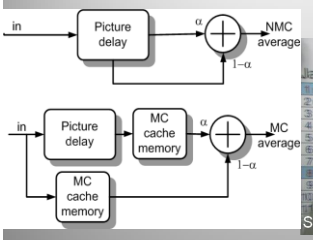
MC-fetch



MC-averaging



42 **MC picture averaging – Robustness problem**



NMC picture averaging

MC picture averaging

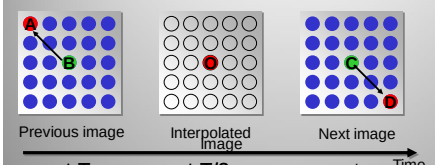
43

Robust interpolation

44 **Improved MC up-conversion**

- Status:
  - Specialized ME algorithms available for MC-picture rate conversion
- Problem:
  - Even specialized ME fails sometimes…
- Options:
  1. Protect stationary image parts
  2. Make MC-interpolation more robust
  3. Global fall-back processing for complex image sequences

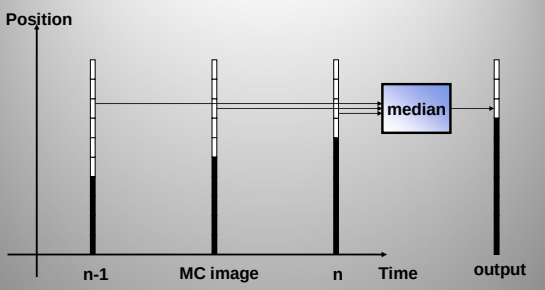
45 **Protect stationary parts using a 'static median' filter**



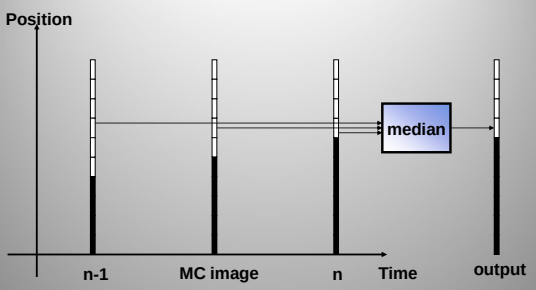
Output: O = median{ B, (A+D)\2 , C }

Smed

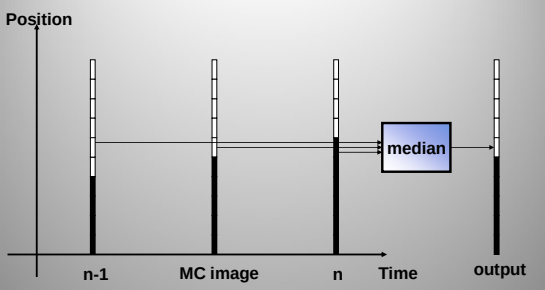
46 **Effect of static median on correctly MC-image**



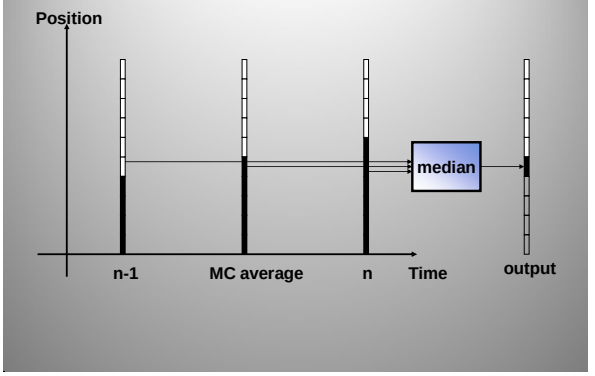
47 **Effect of static median on correctly MC-image**



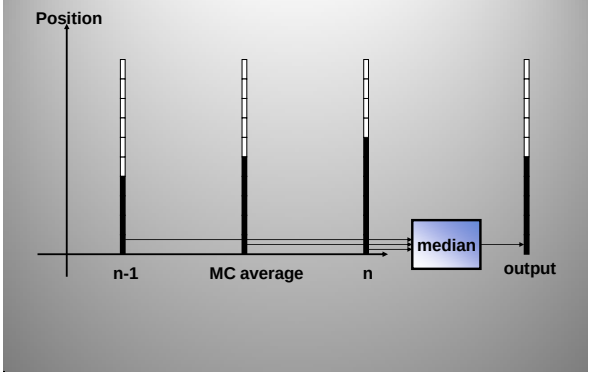
48 **Effect of static median on correctly MC-image**



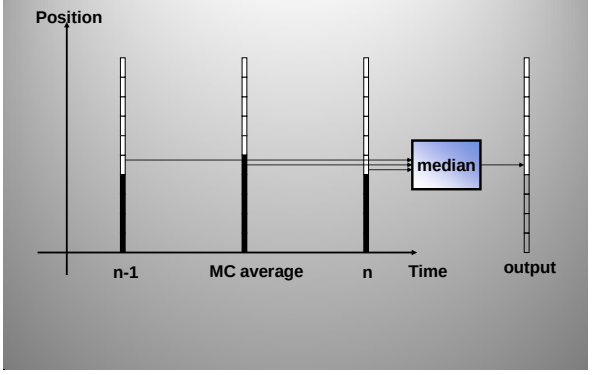
49 **Effect of static median on correctly MC-image**



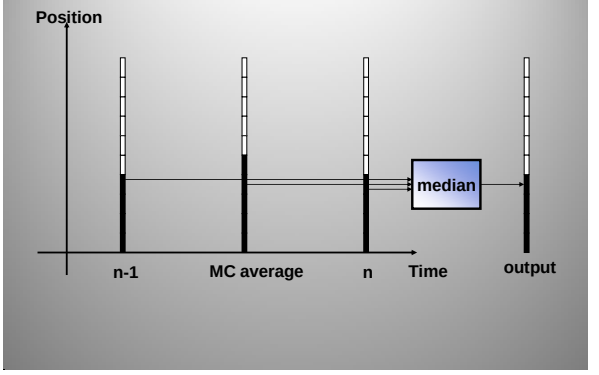
50 **Effect of static median on correctly MC-image**



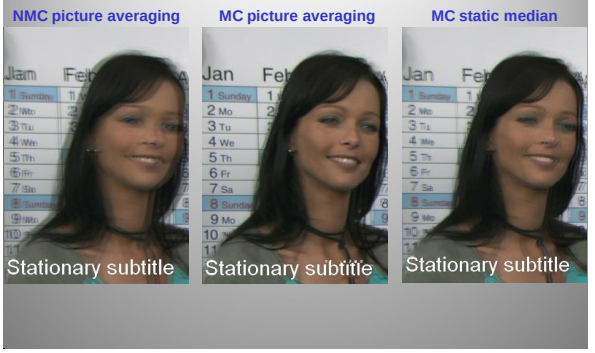
51 **Effect of static median on static image (wrong vectors)**



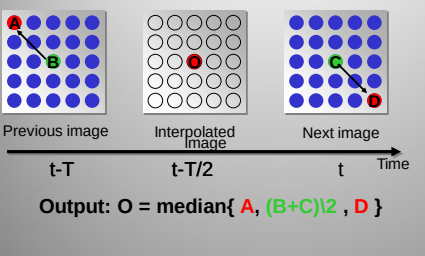
52 **Effect of static median on static image (wrong vectors)**



53 **Effect of static median on natural image**



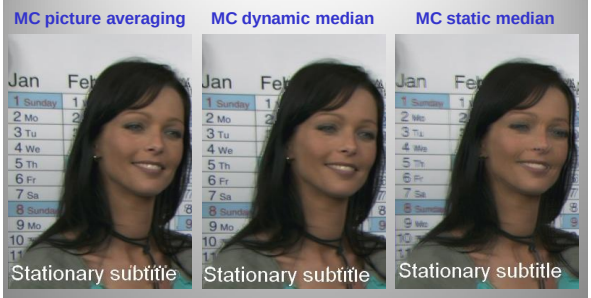
54 **Robust up-conversion using a 'dynamic median' filter**



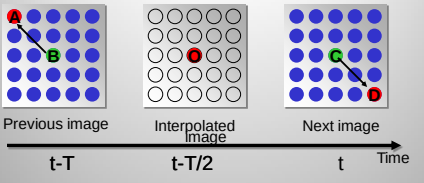
Dmed

Dmed Vs Av

55 **Effect of dynamic median on interpolated image**



56 **Reciprocal mixing (MICRONAS)**

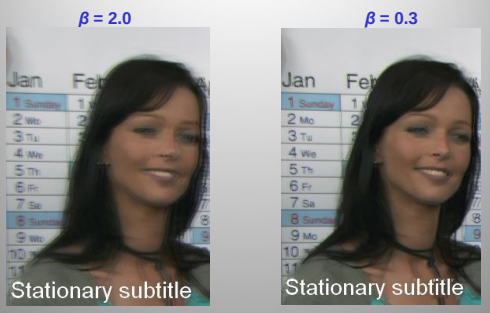


Output: O = k.(A+D)/2 + (1-k).(B+C)/2

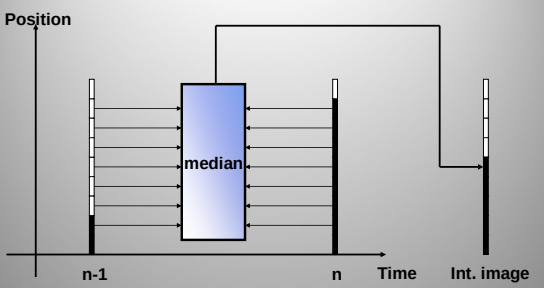
$$k = \frac{|B-C|}{\beta|B+C-A-D|+\delta}$$

k is clipped between 0 and 1, while: 0.1 < β < 2

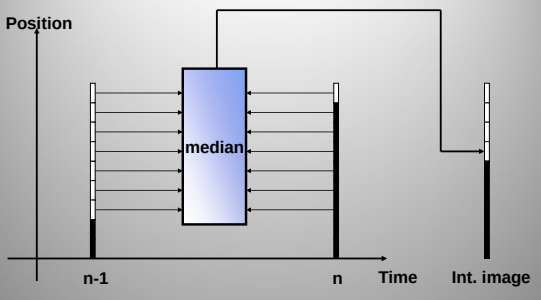
57 **Effect of reciprocal mix on interpolated image**



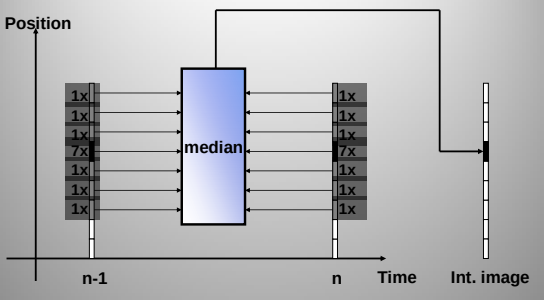
58 **Robust interpolation with CW-medians (UNIDO)**



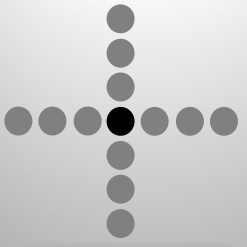
59 **Robust interpolation with CW-medians (UNIDO)**



60 **Median: problem with fine details → weighted median**



61 **Extension to two dimensional aperture**



Weighted 13 times

Weighted 1 time

62 **Can even be used without motion vectors…**

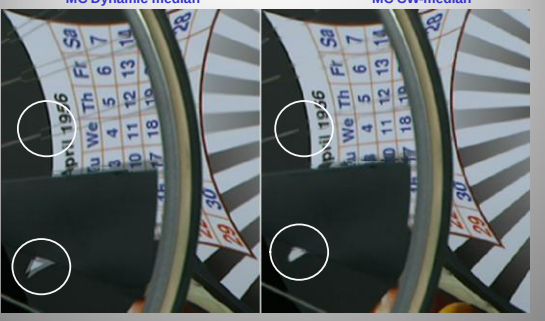
n-1 Int. image n Time

63 **Effect of CW-median on interpolated image with MVs**

MC picture averaging | MC dynamic median | CW median

64 **Correction of edges – elimination of thin objects**

MC Dynamic median | MC CW-median



65

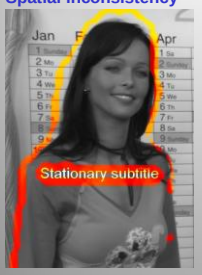
Simple occlusion adapted interpolation

66 **Simple refinement of the robust up-converter**

- Robust strategy (e.g. dynamic median filter)
  - In occlusion areas only (potentially unreliable vectors)
    - Occlusion occurs near transients in the vector field
- High quality (fragile) strategy (e.g. MC average)
  - In other areas (likely reliable vectors)

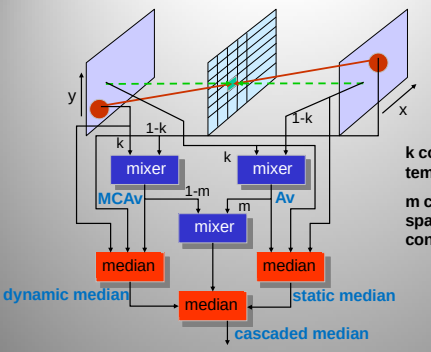
67 **Local smoothness to detect vector reliability**

Spatial inconsistency



Temporal inconsistency

68 **Cascaded median**

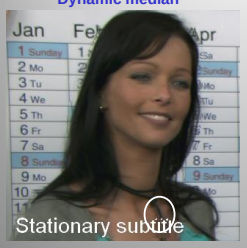


k controlled by temporal position

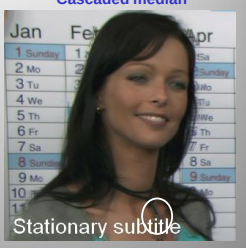
m controlled by spatial vector consistency

69 **Result of cascaded median on interpolated image**

Dynamic median



Cascaded median

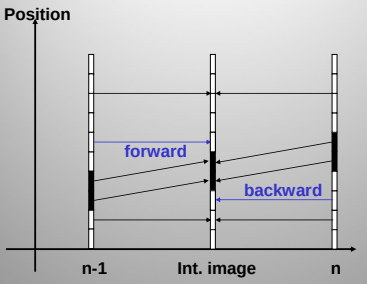


70

Advanced occlusion adapted interpolation

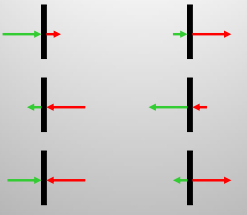
71 **Advanced occlusion adapted MC interpolation**

Switch between forward/backward prediction for (un-)covering



72 **Covering and uncovering detection**

The difference between the vectors near an edge in the motion vector field contains the clue to discriminate



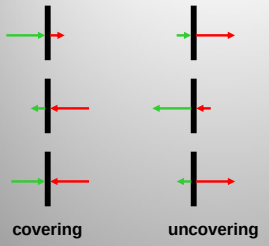
covering $D_{xr} - D_{xl} \geq 0$

uncovering $D_{xr} - D_{xl} \leq 0$

For vertical edges the same rules can be used for the vector y-component

73 This is what the covering/uncovering detection does…

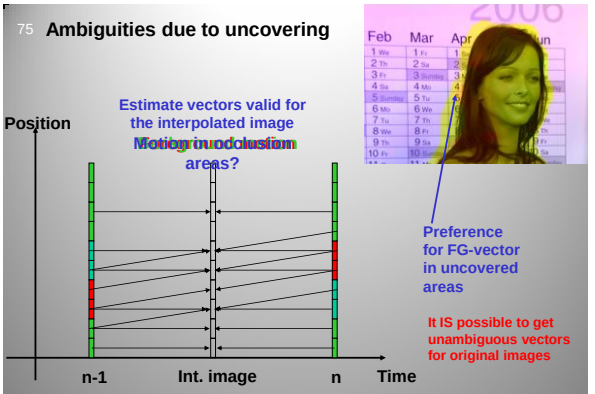
74 Covering and uncovering detection



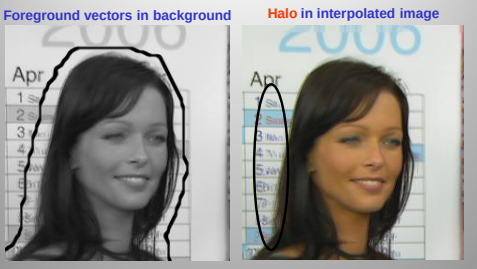
Complications:

- The direction of the motion vector need not be orthogonal to the edge
- The edge direction varies
- Can the vector field be accurate enough?

75 Ambiguities due to uncovering

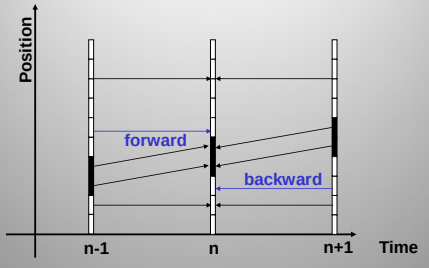


76 Consequences for interpolated image

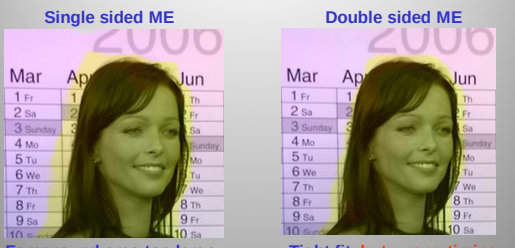


77 Unambiguous motion vectors for original images

Look for correspondences in BOTH neighbouring images, select prediction with the highest correlation



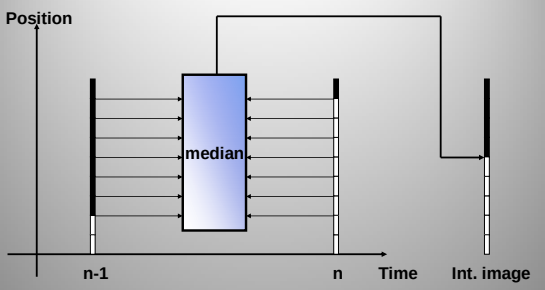
78 Comparison single and double sided prediction



79

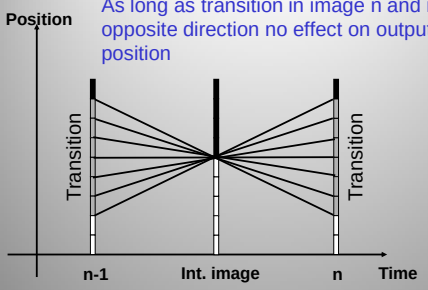
Vector field re-timing

80 **Vector field re-timing with median filters**



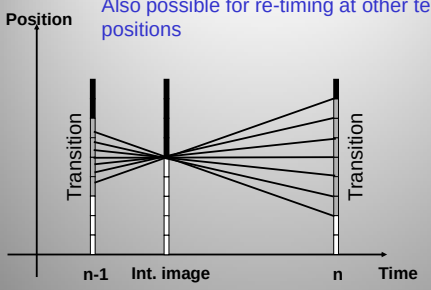
81 **Vector field re-timing with median filters**

As long as transition in image n and n+1 shift in opposite direction no effect on output edge position



82 **Vector field re-timing with median filters**

Also possible for re-timing at other temporal positions



83 **Re-timed vector field for interpolated image**

Vectors valid for previous image **Vectors after re-timing**