High Quality Deinterlacing Using Inpainting and Shutter-Model Directed Temporal Interpolation

by

David Tschumperlé & Bernard Besserer

Laboratoire Informatique, Image, Interaction (L3i)

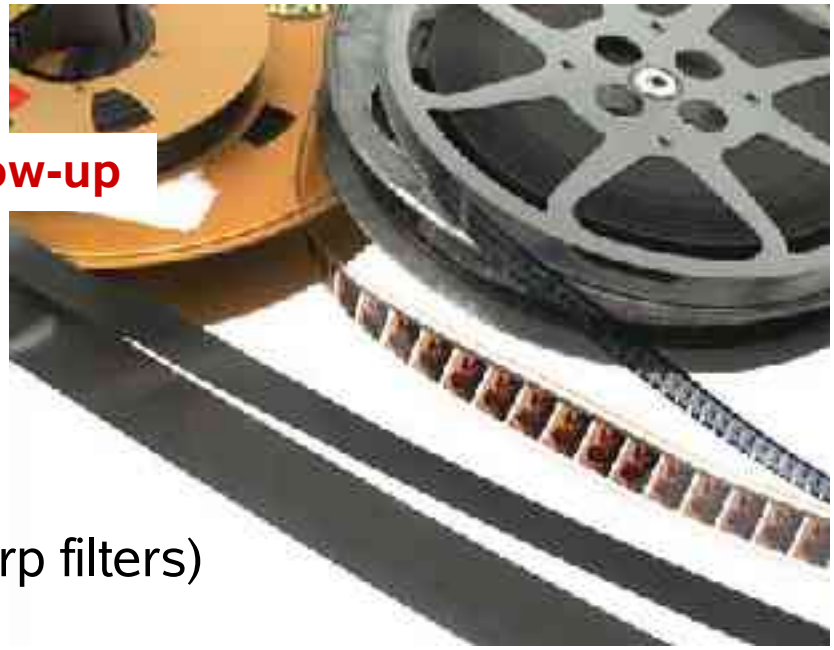
Université La Rochelle

FRANCE

Overview

- **Description of a High Quality (HQ) de-interlacing process.**

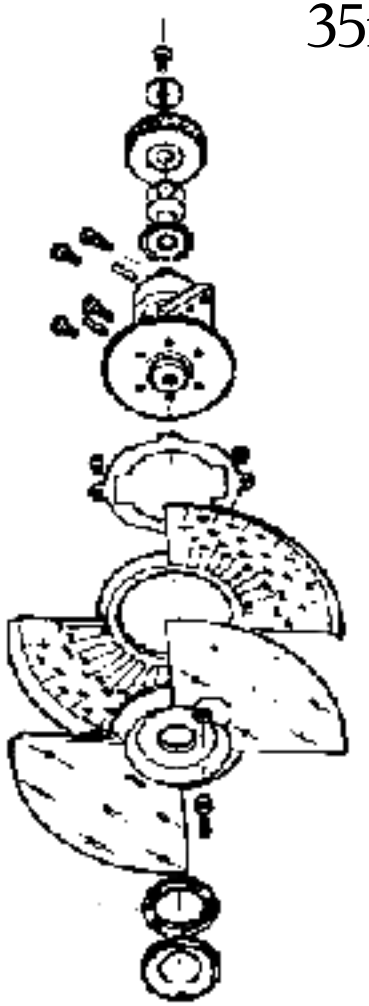
Main application : Tape to film blow-up



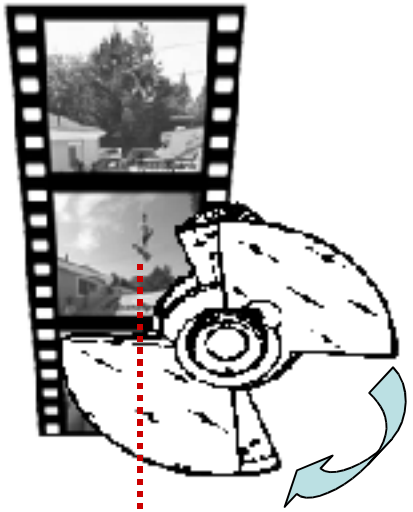
- **Applied research :**
  - Chaining and Adaptation of well known methods (inpainting, motion estimation, warp filters)
- **Contents of the talk :**
  - *Film and video image capture, an overview*
  - *What is de-interlacing*
  - *Process description*
  - *Results, Conclusion, Future Works*

Overview : film camera exposition

- **Image capture is progressive for film cameras**
  - Exposition is full frame
  - A rotating shutter covers the film during transport and uncover the film during exposure time
  - Variable exposure = variable angle for the open sector
  - if motion ➔ motion blur (integration over time)



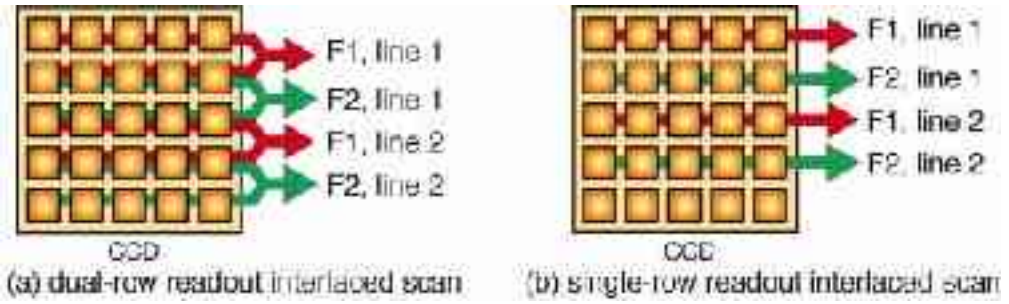
ARRI
35mm

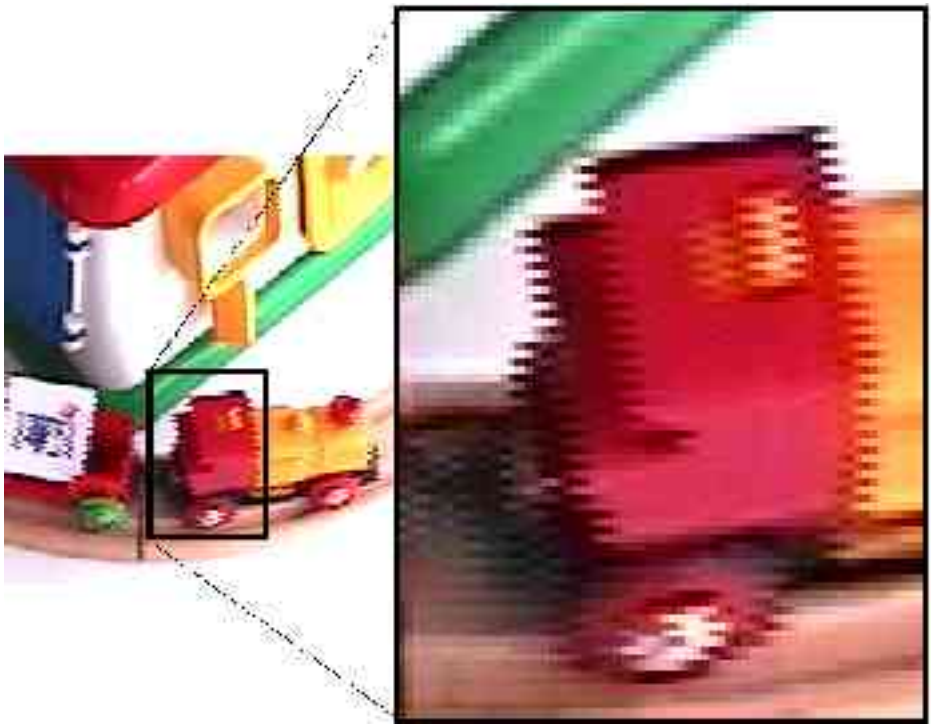


Optical axis

Overview : video camera integration

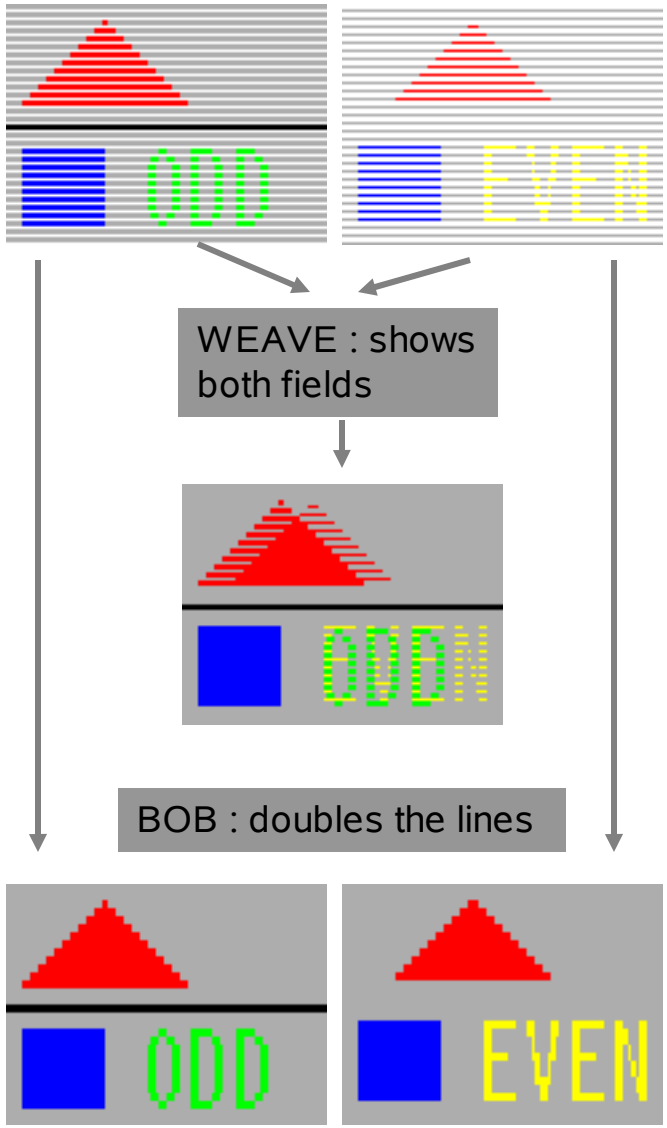
- **Video (PAL/SECAM, NTSC) is interlaced**
- **For most of the CCD arrays used, image integration is interlaced**
- **Integration time is short**
- **If motion :**
  - the playback is smooth, because rendering device (TV set) is also interlaced
  - But if looking at a still image, the "comb" effect become visible





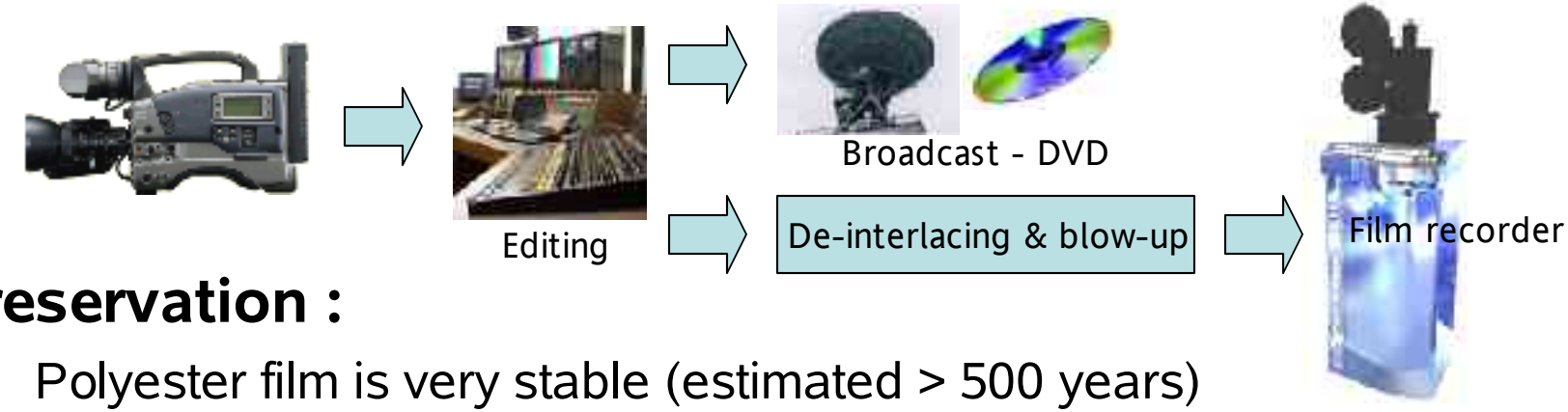
De-interlacing

- **Real time deinterlacing (DVD player if paused)**
  - BOB / WEAVE
- **Motion adaptive de-interlacing : switch between BOB and Weave according to motion**
- **Other approaches use :**
  - Fourier analysis
  - T-shaped spatio-temporal filters
  - …



HQ de-interlacing : Why ?

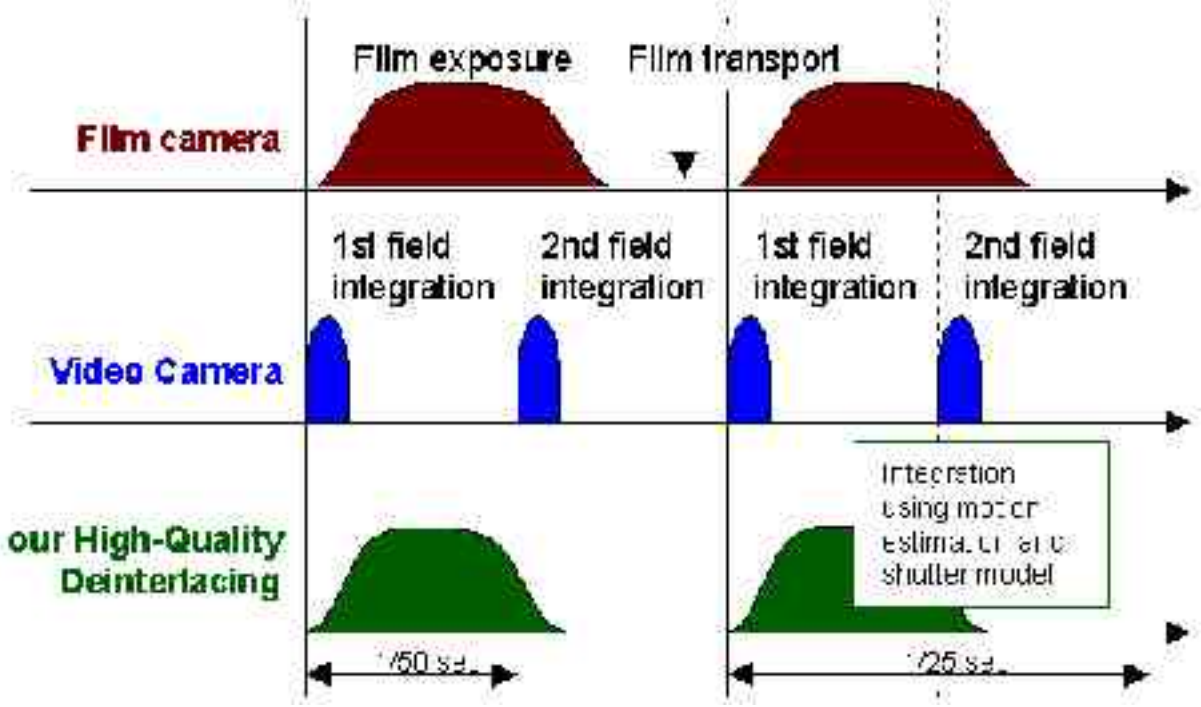
- **D-cinema rush (digital from camera to projection) :**
  - few theatres are equipped - in which countries ?. What is the standard ? (16mm and 35mm reels are standard worldwide)
- **Producing on video is inexpensive :**
  - for low budget feature films, documentaries, commercials,…
  - but film distribution goes trough the (35mm equipped) film theatres



- **Preservation :**
  - Polyester film is very stable (estimated > 500 years)
  - while digital media is evanescent (remember, the 5¼ floppies, used only a decade ago, with 720 Ko data on it)

Our challenge

- **Achieve high quality de-interlacing for both moving and steady shots**
  - Simulate the progressive integration ➔ create motion blur
  - Maintain image quality even if resized to higher resolution
- **We have to estimate the motion between fields**



HQ de-interlacing : 1st step

- **Create an accurate "full frame" from a single field**
  - It's a spatial interpolation, but :
    These frames will be used for motion estimation (H&S method), so the edges should be well recovered
- **Inpainting : PDE regularization of tensor images**
  - Each point of the image is an smoothed structure tensor : holds information about the local image structure (isophote direction)

$$G_\sigma = G * \mathrm{Gauss}(\sigma) \quad \text{where} \quad \forall x, y \in [w, h], \quad G(x, y) = \sum_{i}^{3} \nabla U_i \, \nabla U_i^T$$

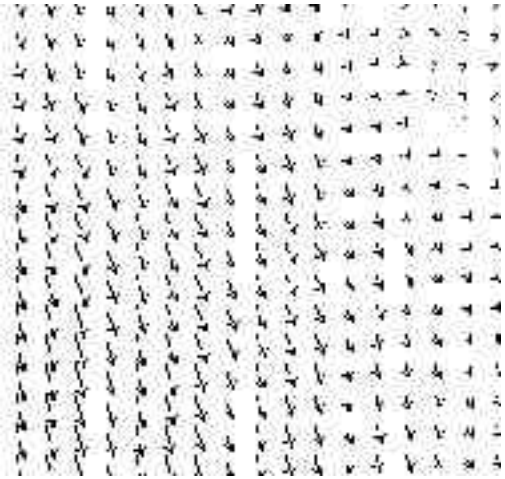
U : [w, h] → [0, 255]^3 (color image)

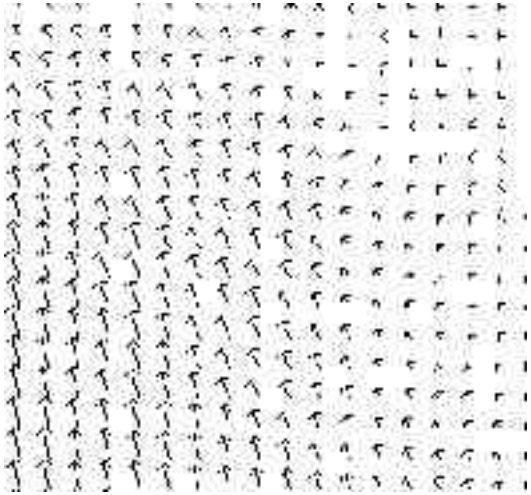
  - Filling the blank lines : average each set of two lines in the direction of the estimated color isophotes

Check previous work of David Tschumperlé for more information

HQ de-interlacing : 2nd step

- **A motion estimation is needed :**
  - for temporal decimation
    from 50 interpolated frames/sec to 25 frames/sec
  - and for a temporal integration scheme
- **Well-known Horn & Schunck method**
- **Forward and backward motion fields are computed**
  - forward motion (odd to even), backward motion (even to odd)
  - not exactly opposed vector fields : occlusions, noise.





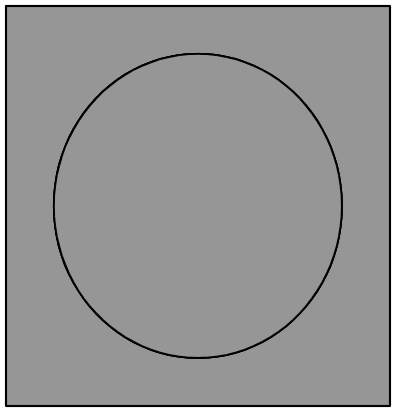
HQ de-interlacing : 3rd step

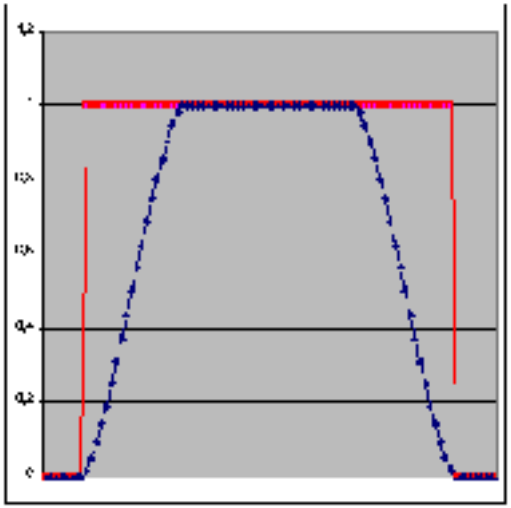
Integration to produce the output images

$$I_{desinterlaced}(x,y) = \int_{t\ 0}^{\frac{1}{2}} S(t)\ I'_{odd}(x - tm_f(x,y)_x, y - tm_f(x,y)_y)\ dt$$

$$+ \int_{t=\frac{1}{2}}^{1} S(1-t)\ I'_{even}(x - tm_b(x,y)_x, y - tm_b(x,y)_y)\ dt$$

- S(t) represents what we call the *shutter characteristic function* : **surface** uncovered and covered by the rotating shutter.





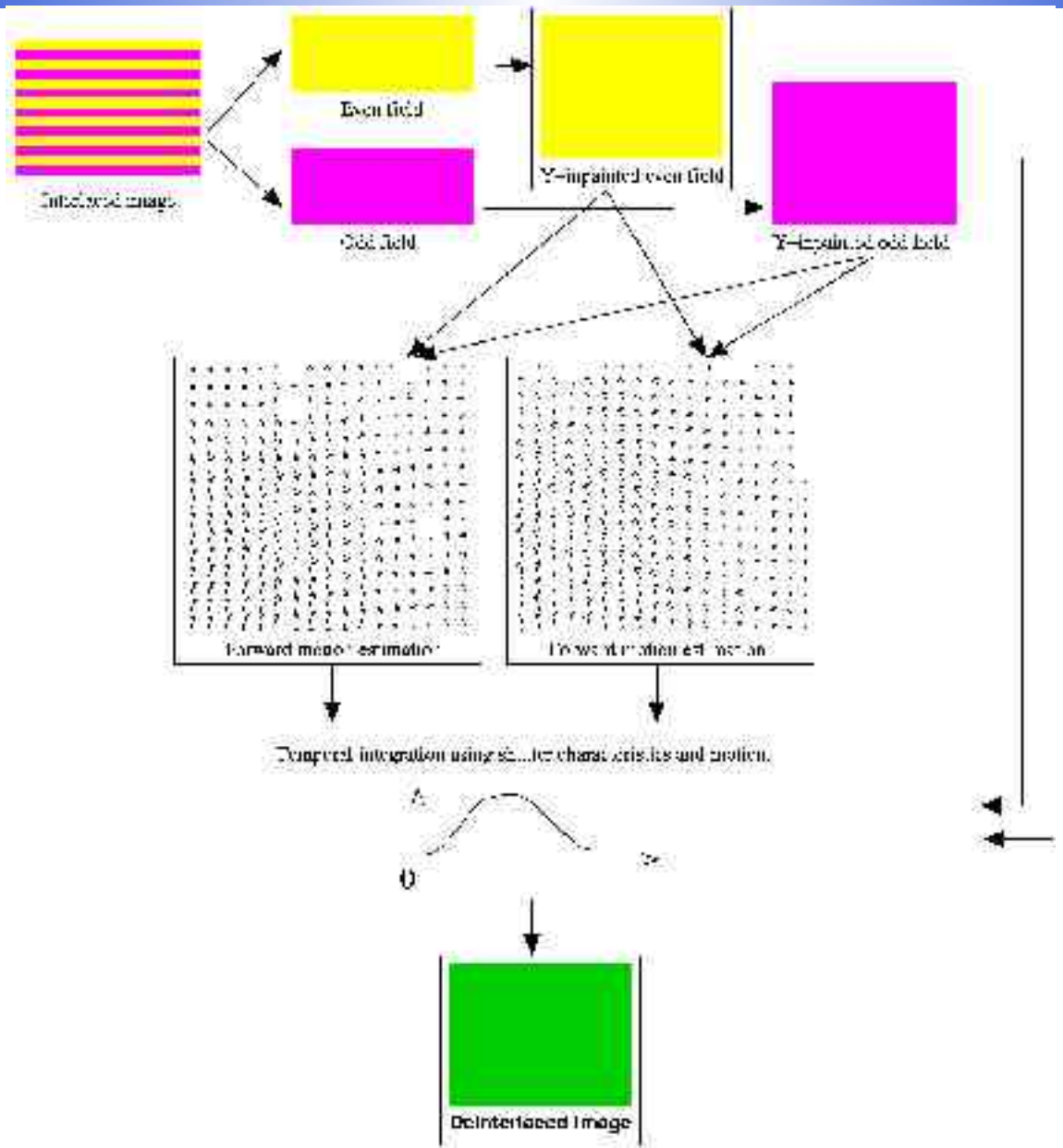
HQ de-interlacing : last step

- **Resizing**
  - Video resolution : 720 X 576
  - Image recorder : 2K (2048 X 1536) or 4K (4096 X 3072)
  - HDTV (1920 X 1080)
- **Edge enhancement : traditional high-pass methods raise noise…**
  - Warp filter : moving information according to image gradient.
  - Related to tensor images and regularisation

From video to 2K : bilinear interpolation

From video to 2K : our de-interlacing scheme + warp filter

Overall workflow



Results

The torch juggler...

Interlaced original image

Results

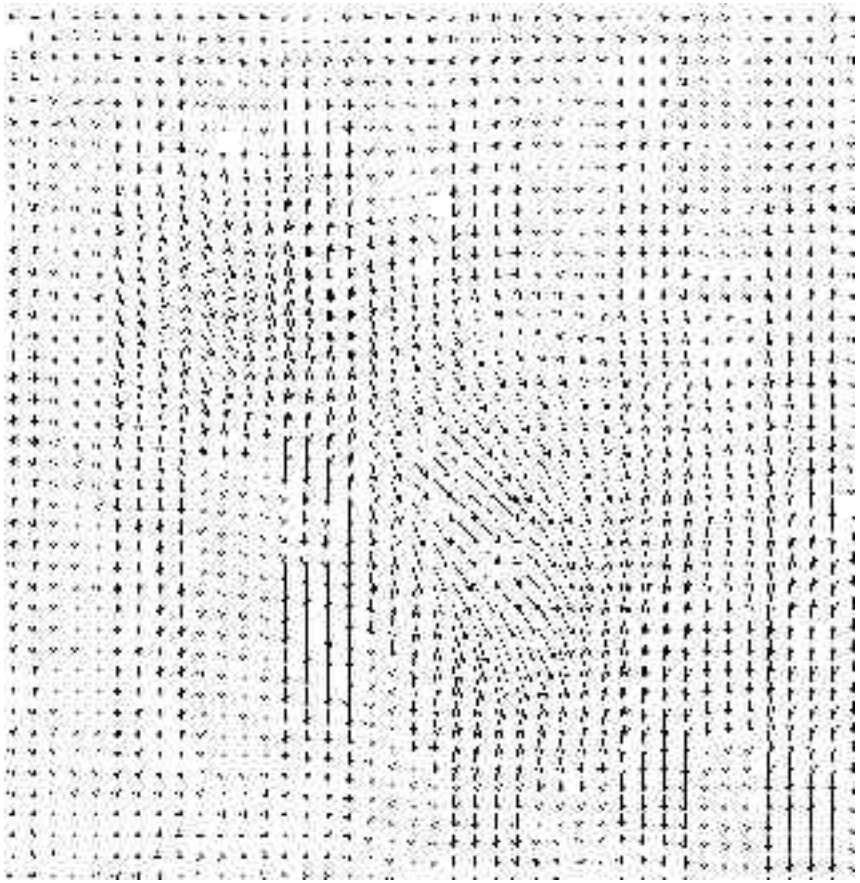
Odd field

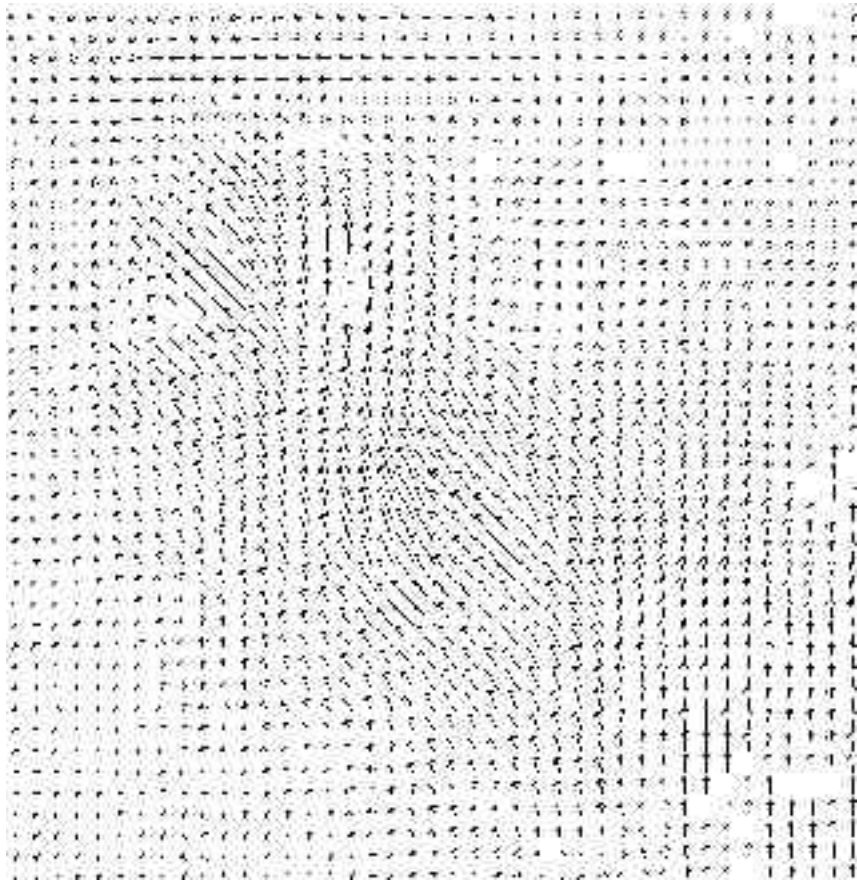
Even field

Results

Forward motion vectors

Backward motion vectors





Results

Deinterlaced image

De-interlaced image after warp filter (no resizing)

Conclusion / Future works

- **Very good results**
- **Slow, requires a lot of computational power**
  - Fortunately, image recorder are also slow (several seconds / image)
  - Improvement in speed and user feedback while adjusting parameters
- **Future works**
  - Complete retiming (from 25 to 24 frames/sec)

Thank you for your attention