TACKLING OCCLUSION IN SCAN RATE CONVERSION SYSTEMS

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ABSTRACT
We present a motion compensated frame rate up-conversion algorithm, which aims at reducing the interpolation artefacts in occlusion areas. This algorithm uses motion vectors estimated between two successive frames, and uses the same 2 frames for the up-conversion.

1 INTRODUCTION
In modern high-end televisions for the consumer market, motion compensated frame rate conversion techniques are used to increase the perceived video quality. Increasing the frame rate from 30 Hz to 75 Hz or 100 Hz eliminates annoying flickering artefacts, and can also eliminate motion judder of film. The common approaches suffer from occlusion, i.e. they cause annoying artefacts known as halo [2] around foreground objects. In this paper, we present a novel up-conversion algorithm that reduces this artefact significantly. The algorithm uses motion vector fields estimated between two successive frames [1], and uses the same two frames in the up-conversion. Hence, it is more economical than methods which use 3 or 4 frames, e.g. [3].

2 OCCLUSION IN MOTION ESTIMATION AND UP-CONVERSION
In general, a motion estimator determines a motion vector (for a group of pixels) by selecting the best matching motion vector from a set of candidate vectors. The match criterion is usually a Sum of Absolute Differences (SAD) obtained by fetching pixels from frame \( n \) and comparing those with pixels fetched from frame \( n+1 \) shifted over the candidate motion vector \( \hat{C} \), i.e.:

\[
e(\hat{C}, \hat{x}, n) = \sum_{\hat{y} \in B(\hat{x})} |F(\hat{x} - \alpha \hat{C}, n) - F(\hat{x} + (1 - \alpha) \hat{C}, n + 1)|
\]  

(1)

Here \( B(\hat{x}) \) is the block located at block position \( \hat{x} \), \( \hat{x} \) is a pixel position, \( F(\hat{x}, n) \) is a luminance value, \( n \) is the image number and \( \alpha \) is a relative position. In occlusion areas no motion vector can result in a correct match, since the background is only present in one of the two frames. In case of uncovering, new information that is not present in frame \( n \) appears. In case of covering, information disappears and is not present in frame \( n+1 \). Consequently, the motion vector field is unreliable in occlusion areas.

![Figure 1](image)

Fig. 1. a) The motion vector field is shown as a transparent overlay. At the boundaries of the foreground object, the motion vector field is incorrect. b) As a result, the upconverted image shows a 'halo' around the foreground object.

Usually, information from both images is used in the temporal up-conversion. For example, motion compensated averaging (MCA) uses a motion compensated pixel from frame \( n \) and from frame \( n+1 \):

\[
F(\hat{x}, n + \alpha) = \frac{1}{2} F(\hat{x} - \alpha \hat{D}, n) + \frac{1}{2} F(\hat{x} + (1 - \alpha) \hat{D}, n + 1)
\]  

(2)

with \( \hat{D} \) being the displacement or motion vector. Even if the correct motion vector is used, the result in occlusion areas is wrong since either the pixel from frame \( n+1 \) or the one from frame \( n \) is wrong. In occlusion areas the foreground vector is usually estimated and applied for compensation which adds to the problem. The resulting halo effect is shown in Figure 1b.

3 UP-CONVERSION WITH REDUCED HALO
Our solution to the halo problem consists of a number of steps:
1. Find the occlusion area.
2. Determine the occlusion type.
3. Calculate the background motion vector.
4. Perform a robust up-conversion using the occlusion type and background motion vector.

The term robust in the last step is paramount. While halo is an annoying artefact in the background, artefacts in the foreground are completely unacceptable. Therefore, step 4 should be robust against errors that can be made in the first three steps.

It is assumed that the start of an occlusion area is a distinct discontinuity in the motion vector field. The actual width of the occlusion area depends on the occlusion type, the motion vectors on either side of the edge and on $\alpha$.

The motion vectors to the left and right of the discontinuity, $\vec{D}_{L}$ and $\vec{D}_{R}$, are used to determine the occlusion type:

$$\text{type} = \begin{cases} \text{uncovering} & \text{if } D_{L,x} < D_{R,x} \\ \text{covering} & \text{if } D_{L,x} > D_{R,x} \end{cases}$$

where $D_{L,x}$ is the horizontal component of the motion vector left of $D_{L,x}$.

The background motion vector is selected from the motion vectors in the neighbourhood of the current pixel by using a parametric model of the background motion. The model is determined in a similar manner as described in [1]. The motion vector with the smallest distance to this parametric model is assumed to be the background motion vector.

The actual up-conversion that we propose is a median of three luminance values:

$$F_\text{sa}(\hat{x}, n + \alpha) = \text{median}_c[F(\hat{x} - \alpha \vec{D}_{best}, n), F(\hat{x} + (1 - \alpha) \vec{D}_{best}, n + 1), F(\hat{x} + (\alpha - \alpha) \vec{D}_{best}, n + c)]$$

with $c = 0,1$ for covering and uncovering respectively. $\vec{D}_{best}$ is the background vector selected from the motion vectors in a neighbourhood surrounding $\hat{x}$. $\vec{D}_{best}$ is the best matching vector for pixel $F_\text{sa}(\hat{x}, n + \alpha)$ in that neighbourhood. This vector contributes to the robustness of the up-conversion. The combination of the pixel fetched with the background vector reduces the halo effect. In image regions without occlusion a simple MCA according to Eq. 2 is used.

4 EXPERIMENTS

A result of the proposed halo reduction scheme is given in Figure 2. A quantitative comparison is given in Table 1. This table shows the Mean Squared Error (MSE) between interpolated images from four sequences, see Figure 3, and their corresponding originals. The MSEs are averaged over more than 60 images. Table 1 gives the MSEs for the MCA and the halo reduction algorithms. Although the differences in MSE seem small, note that they represent large improvements in the occlusion areas.

![Fig.2 a) Halo caused by up-conversion with an MCA. b) Same image but now interpolated by using the new halo reduction scheme.](image)

![Fig.3 Sequences used in the experiments. From left to right: ryan, mummy, bond, woman.](image)

5 CONCLUSIONS

A new frame rate up-conversion algorithm reduces the artefacts in occlusion areas significantly, without introducing annoying errors in foreground objects. Subjective and objective results show the improvement of this algorithm over other up-conversion algorithms.

REFERENCES

