Segmentation of Image Areas Changed due to Object Motion Considering Shadows

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- Introduction
- Change Detection
  - Difference Criterion (DC)
  - Edge Criterion (EC)
  - Reflection Criterion (RC)
  - Evaluation
- Experimental Results
- Conclusions

Research was mainly performed at the Institut für Theoretische Nachrichtentechnik und Informationsverarbeitung, Universität Hannover

Introduction

Segmentation of moving objects

- image analysis:
  - object recognition
  - multimedia databases
- image coding:
  - intelligent spatial allocation of bits
  - segmentation–based coding (OBASC/2nd generation)
  - object scalability

Introduction

Scene classes

- static camera
  - temporal change detection
- camera motion, zoom, pan
  - segmentation of motion
  - global motion compensation, temporal change detection

Introduction: Segmentation Methods

Segmentation of motion

- accurate motion model
- segmentation of estimated parameters
- expensive to implement
- overlapping moving objects

Temporal change detection

- no motion model
- segmentation of parameters directly derived from the image sequence
- easy to implement
- static/changed

Introduction: Change Detection for Moving Objects

Thoma/Bierling 89

- difference image
- morphological filter

Aach, Kaup, Mester 93

- difference image
- markov random field
- smoothness constraint

Problem: object boundary, moving shadows

Introduction

Ostermann 90

- difference image
- edge image
- morphological filter

Problem: shadows

Skifstad 89

- temporal contrast

Problem: spatial resolution, object boundary, object texture

Detection of Changed Image Areas

Goal: Segment objects moving in front of a static background

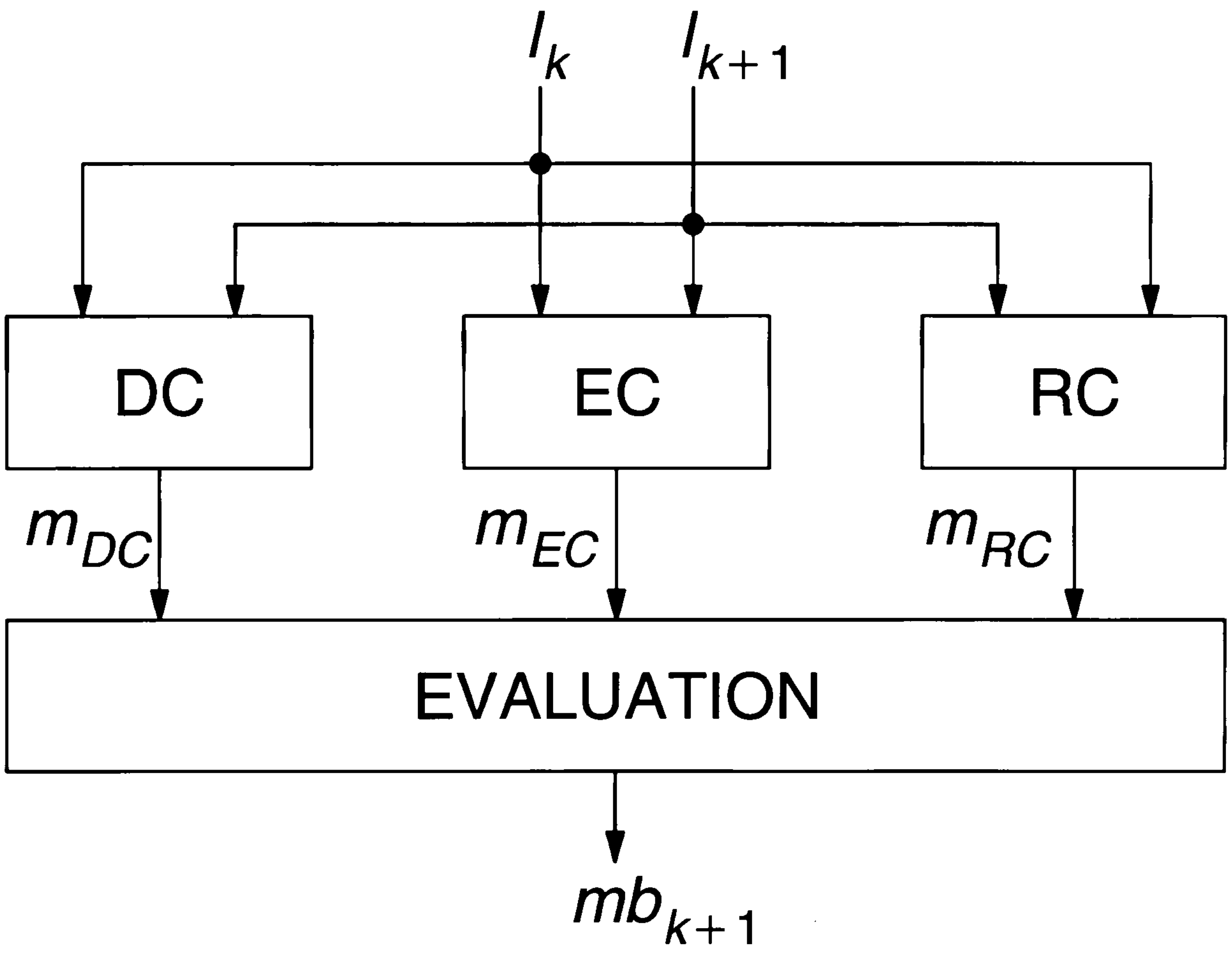
Disturbances:

- Camera noise
- Camera apertur
- Moving shadows

Assumptions:

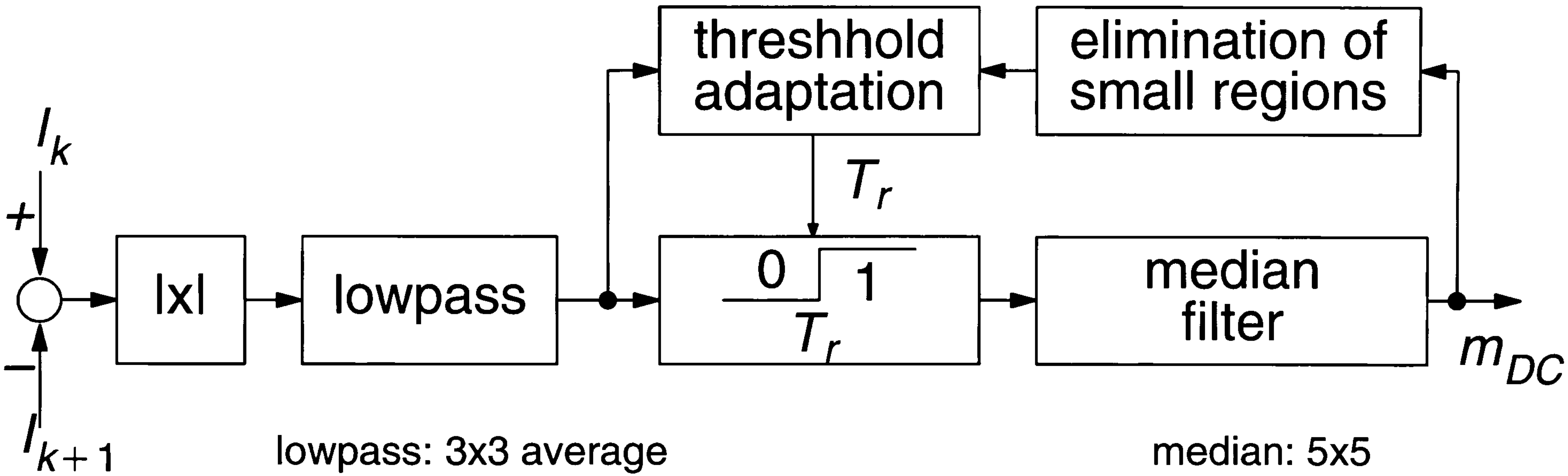
- Significant change of image signal (*D*ifference *C*riterium)
- Edge at boundary between object and background (*E*dge *C*riterium)
- Opaque object (*R*eflection *C*riteria)

Change Detection: Block Diagram



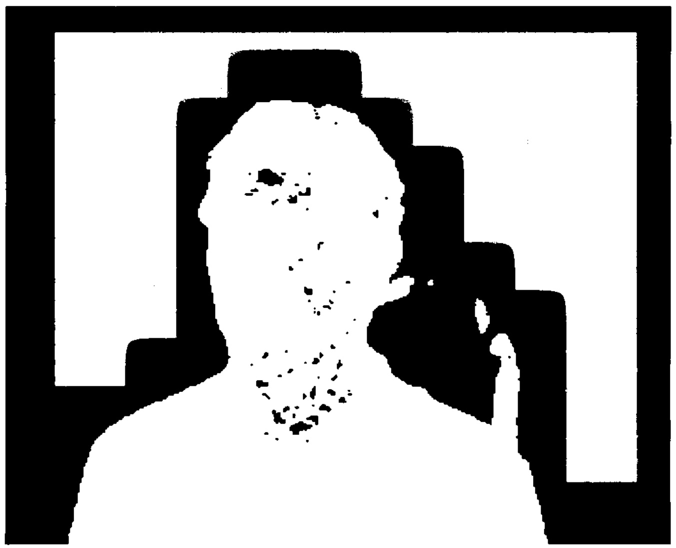
DC: difference criterion EC: edge criterion RC: reflection criterion

Change Detection: Difference Criterion



lowpass: 3x3 average

median: 5x5

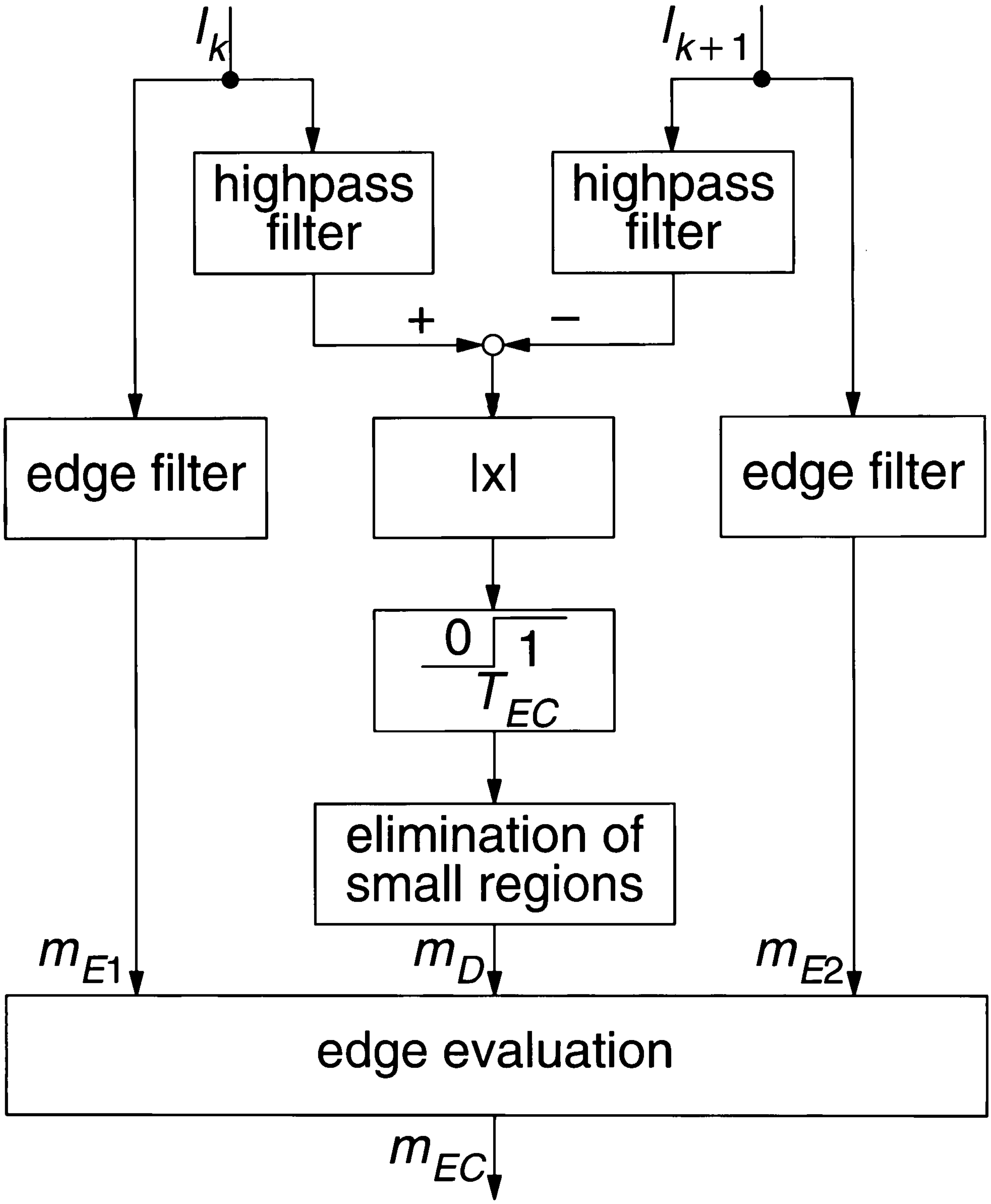


static

changed

Change Detection: Edge Criterion

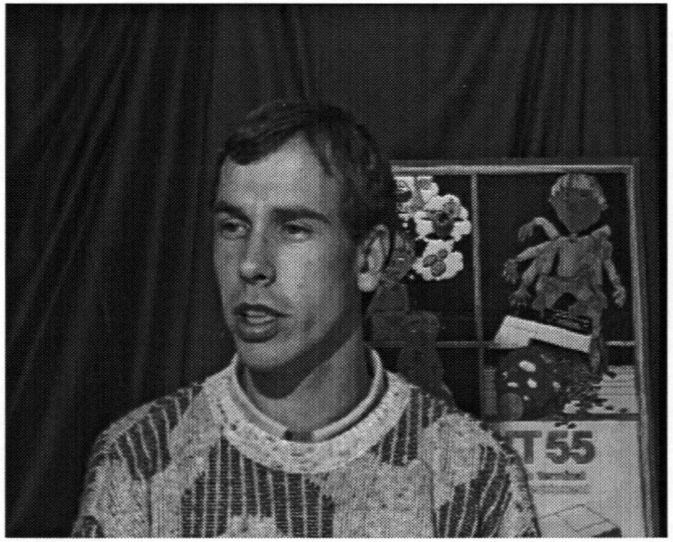
Detect moving edges

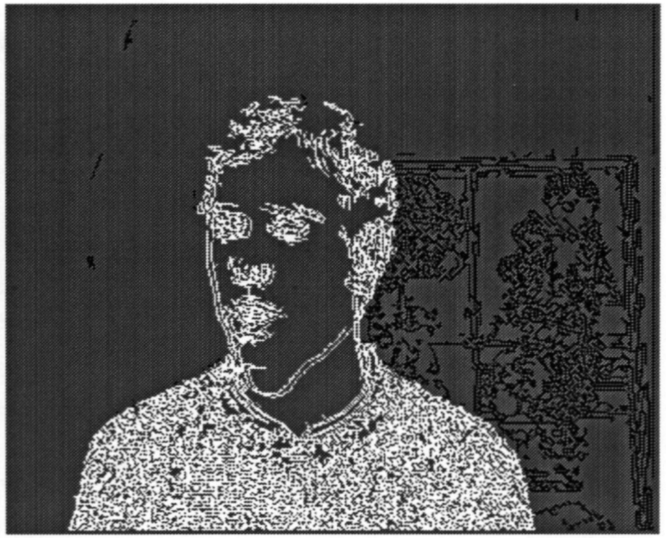


Change Detection: Edge Criterion

Distinguish moving edges from static edges

$m_{E1}(\mathbf{x}) \vee m_{E2}(\mathbf{x})$	$m_D(\mathbf{x})$	$m_{EC}(\mathbf{x})$
edge	changed	moving
edge	static	static
no edge	–	don't know





- static
- moving
- don't know

Change Detection: Reflection Criterion

Image signal assuming diffuse illumination:

$$I(\boldsymbol{x}) \approx E(\boldsymbol{x}) \cdot R(\boldsymbol{x})$$

$I(\boldsymbol{x})$ – image signal, $E(\boldsymbol{x})$ – illumination, What is that

$R(\boldsymbol{x})$ – bidirectional reflection function

Temporal contrast:

$$C(\boldsymbol{x}) = \frac{I_k(\boldsymbol{x})}{I_{k+1}(\boldsymbol{x})} = \frac{E_k(\boldsymbol{x})}{E_{k+1}(\boldsymbol{x})} \cdot \frac{R_k(\boldsymbol{x})}{R_{k+1}(\boldsymbol{x})}$$

Object motion:

$$C(\boldsymbol{x}) = \frac{E_k(\boldsymbol{x})}{E_{k+1}(\boldsymbol{x})} \cdot \frac{R_k(\boldsymbol{x})}{R_{k+1}(\boldsymbol{x})} \neq const \quad \forall \boldsymbol{x} \in \boldsymbol{O}$$

> locally varying contrast

Shadow:

$$C(\boldsymbol{x}) \approx \frac{E_k(\boldsymbol{x})}{E_{k+1}(\boldsymbol{x})} = const. \quad \forall\ x \in \boldsymbol{O}$$

> locally constant contrast

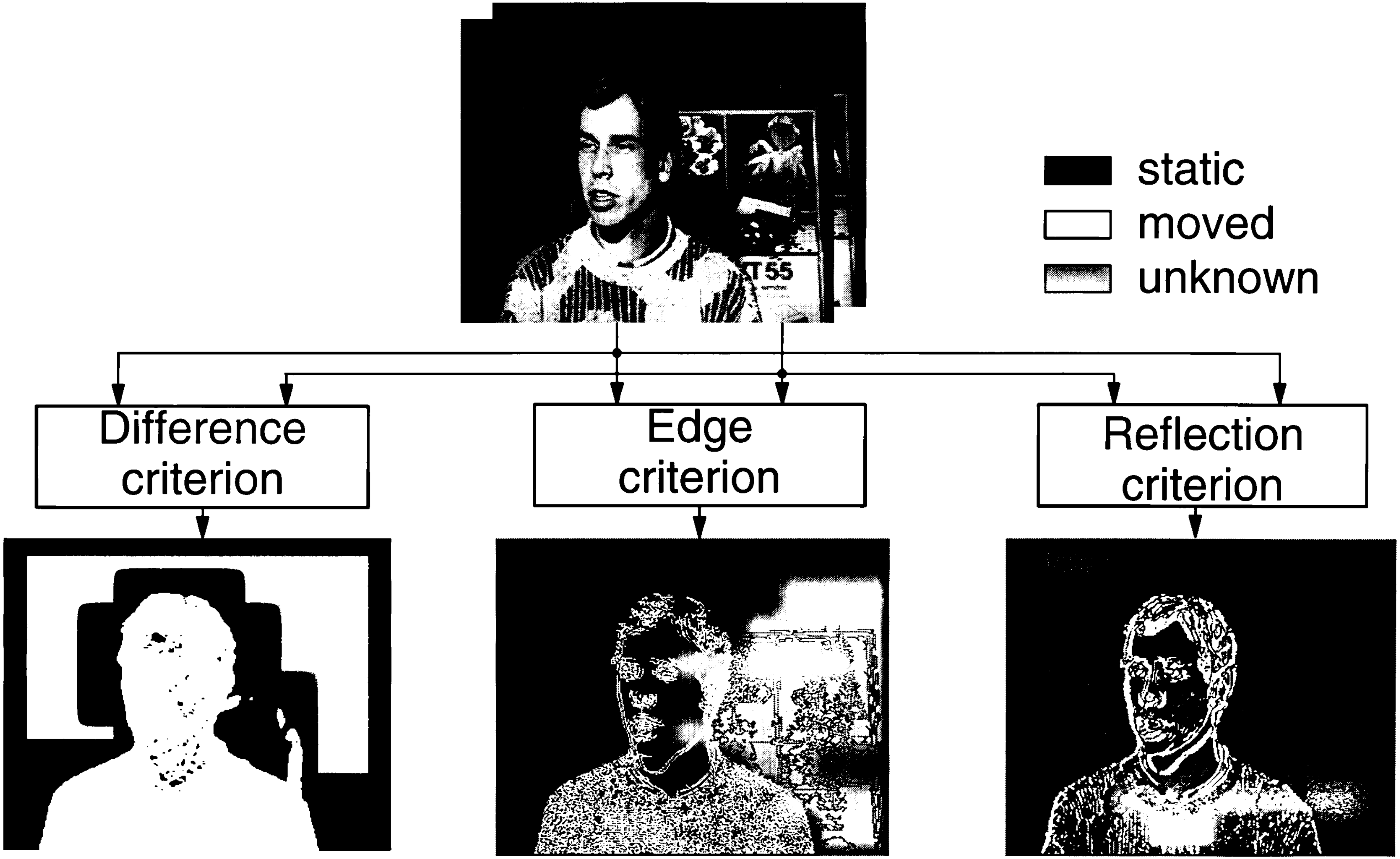
Change Detection: Reflection Criterion

$$C(\boldsymbol{x}) \approx \frac{E_k(\boldsymbol{x})}{E_{k+1}(\boldsymbol{x})} = const. \quad \forall\ x \in \boldsymbol{O}$$

> only if shadow or moving smooth surfaces

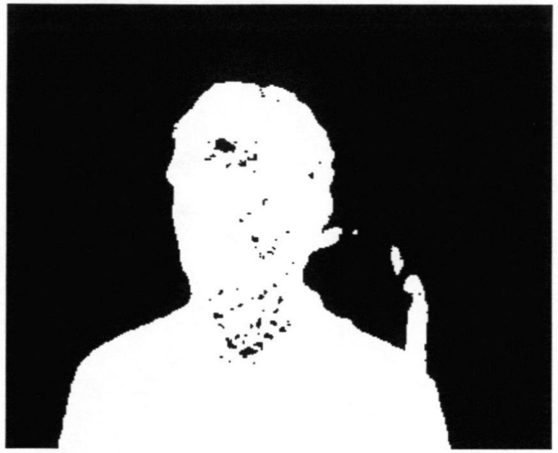
Distinguish constant contrast regions from varying contrast regions

Change Detection: Evaluation

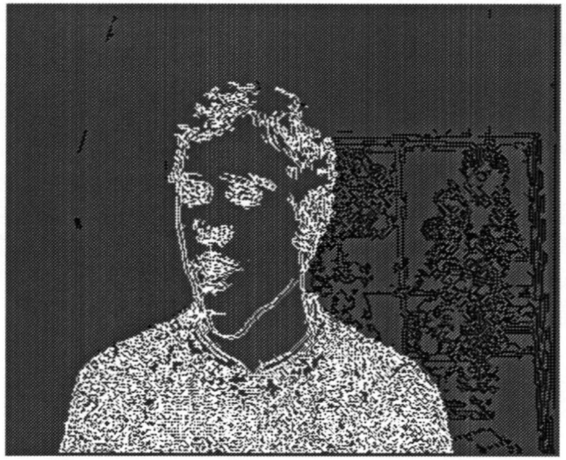


Evaluation

DC



EC



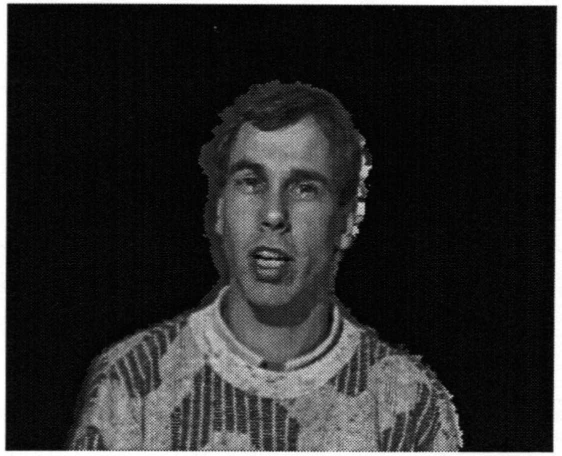
RC

static   moved   unknown

3 labels/pel

Assign moved/static to each region depending on

- label
- size
- neighbourhood



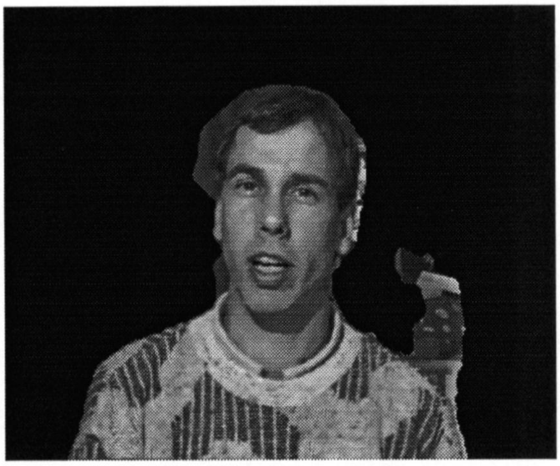
Result

Results: Real Image Sequences

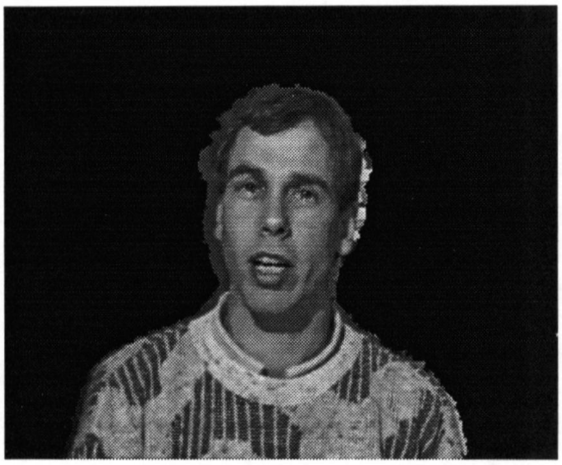
Application: Video coding

- Change detection between background memory and current image

DC only



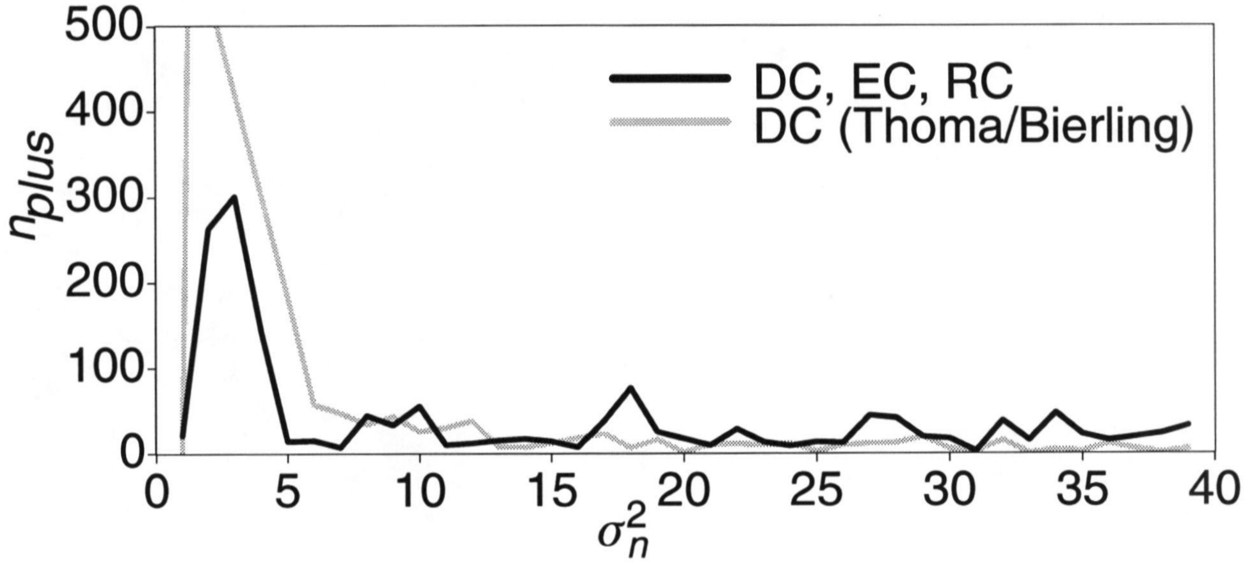
DC,EC,RC



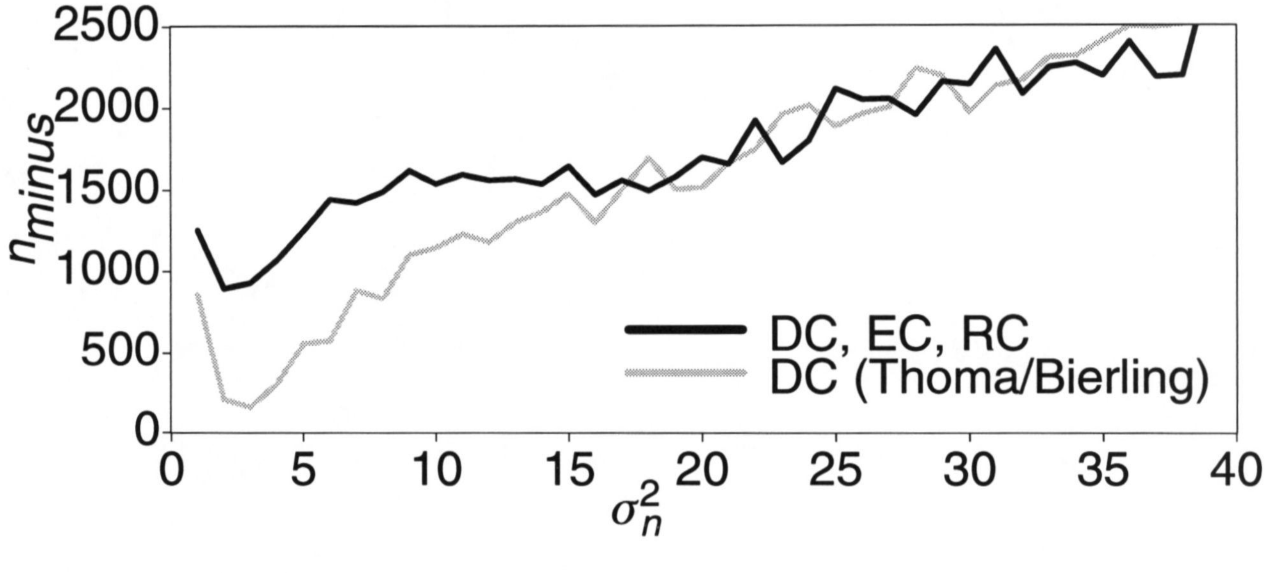
Results: Precision of Segmentation Mask

Noisy image pairs with known segmentation

n_{plus}: mask too large

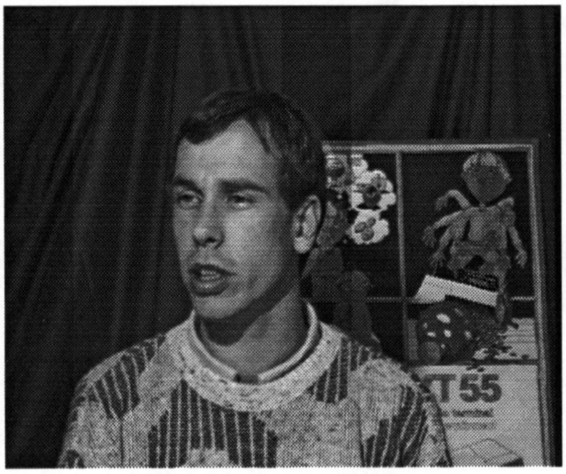


n_{minus}: mask too small



Results: Shadows

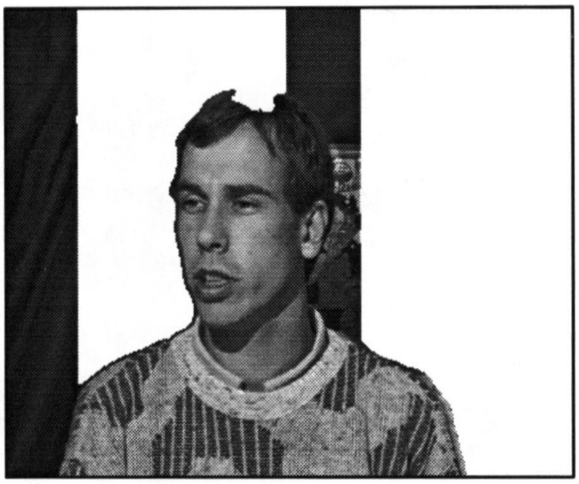
Test images with shadow

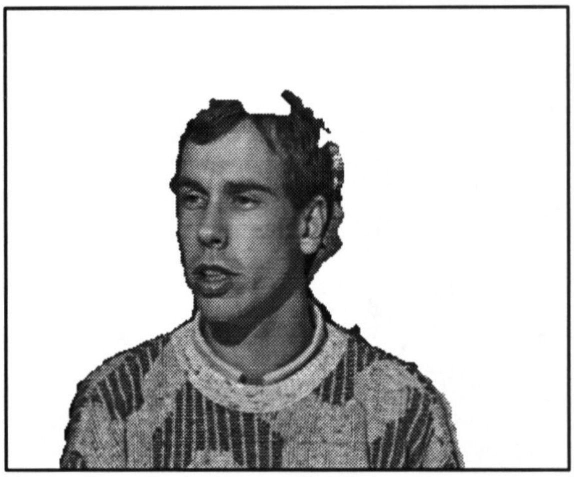


Segmentation

DC

DC,EC,RF





Correct segmentation for

$$0.8 \leq C(\boldsymbol{x}) \leq 1.25$$

Conclusions

Change detection algorithm for segmentation of moving objects

- difference criterion
- edge criterion
- reflection criterion
- joint evaluation

Disturbing influence of shadows removed

Improved precision of segmentation

Applications in image coding and image analysis

Segmentation of Image Areas Changed due to Object Motion Considering Shadows

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1: Introduction

For low bit–rate video coding, several segmentation–based coders have been proposed which describe a moving object by its shape, motion and its surface texture. Proposals based on region–based techniques define a region with homogenous texture in a still frame and track the motion of a region over time [5][9]. Regions with similar motion might be combined to objects. In object–based analysis–synthesis coding, an object is defined as having homogenous motion [7][3][11]. Each object is tracked over time. These two classes of segmentation–based coders apply motion–compensation in order to predict the current frame from the previous frames. The motion–compensation relies on the assumption that changes between consecutive frames are due to motion of opaque objects. As far as illumination is concerned, they assume constant local illumination and diffuse reflecting surfaces. Hence, an algorithm is required which estimates the image regions changed due to object motion. Moving shadows should not be identified as moving objects, since motion compensation does not work on shadows.

Assuming a stationary camera as in applications like desktop video–conferencing, this task is frequently tackled using a temporal change detector [2][6][4][1]. These algorithms cannot distinguish between changes due to moving objects or moving shadows. In [12], an algorithm using a shading model has been proposed to detect moving objects. However, the shading model only allowed an evaluation for blocks of size 5x5 pels and larger. It does not allow a precise estimation of object boundaries. Furthermore, this criterion is not able to detect moving objects with a smooth surface texture.

Here, an algorithm is proposed which evaluates the temporal changes between consecutive images using a temporal difference criterion (DC), a contour criterion (CC) [8][10] and a reflection criterion (RC) (Fig. 1.1). The output of the three criteria in combined such that the image areas changed due to object motion, i.e. the moving object and the area uncovered due to object motion, are estimated.

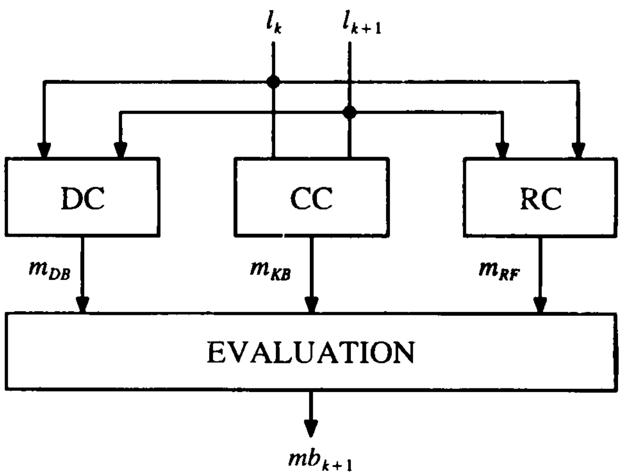

Fig. 1.1 Block diagram of the detector of the image regions changed due to object motion (luminance signal l_k, difference (DC), contour (CC) and reflection (RC) criterion).

*Research was partly carried out at the Institut für Theoretische Nachrichtentechnik and Informationsverarbeitung, Universität Hannover, Germany.

2: Detection of image areas changed by object motion

The DC binarizes the difference image between the luminance signals l_k and l_{k+1} using a noise adaptive threshold. Morphological operators are applied to the binary image, in order to smooth boundaries and eliminate small regions.

The CC computes for both images l_k and l_{k+1} a contour image. By comparing the contour images, moving and static contours are determined.

The RF assumes that the image signal $l(x)$ depends on the illumination $E(x)$ and the bidirectional reflection function $R(x)$. $R(x)$ accounts for the wavelength of the illumination, surface material and the geometrical arrangement of illumination, camera and surface. The illumination $E(x)$ depends on ambient and direct light. Assuming diffuse illumination and parallel projection and a constant k_b, the image signal is given by the reflection model

$$l(x) = k_B \cdot E(x) \cdot R(x). \tag{2.1}$$

Assuming this reflection model, a temporal contrast can be computed:

$$K(x) = \frac{l_k(x)}{l_{k+1}(x)} = \frac{E_k(x)}{E_{k+1}(x)} \cdot \frac{R_k(x)}{R_{k+1}(x)} . \tag{2.2}$$

If neighboring pels of an image do not change over time, $K(x)$ is 1 for these pels. If the illumination of these pels changes due to a moving shadow, $E(x)$ changes for the pels by the same amount but $R(x)$ stays constant. Hence, $K(x)$ is constant for neighboring pels. On the other hand, if an object moves, $E(x)$ stays constant but $R(x)$ changes arbitrarily for each pel depending on the surface texture. Hence, this reflection model allows to distinguish between temporal changes caused by object motion and moving shadows.

The output of the criteria DC, CC and RC are combined in order to generate the final pel–wise mask which marks the image areas changed due to object motion.

3: Experimental Results

Experiments have been carried out on several natural and artificial image sequences. In comparison to a change detector evaluating the difference signal only, it was found that the contour criterion allows for a more precise estimation of the object boundaries and that the reflection criteria is able to distinguish between moving objects and moving shadows as long as the shadow does not change the image intensities by more than 20%.

4: Literature

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