

# Image Enhancement

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# Gliederung

- ✦ Übersicht und Motivation
- ✦ Textvorstellung
- ✦ Zusammenfassung
- ✦ Referenzen



# Übersicht und Motivation

- ✧ Image Enhancement?
  - ✧ Bilder „verbessern“
  - ✧ bessere Erkennbarkeit
  - ✧ besserer „Input“



# Übersicht und Motivation

- ✧ Zwei grundsätzliche Methoden:
  - ✧ Bildbereich (Pixel)
  - ✧ Frequenzbereich
- ✧ Hier: Beispiele aus beiden



# Textvorstellung

## ✧ „A Modified Edge Directed Interpolation For Images“

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## A MODIFIED EDGE DIRECTIONAL INTERPOLATION

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### ABSTRACT

A modification of the new edge-directional interpolation method is presented. The modification eliminates the interpolation error accumulation problem with the original method, and further improves the training window structure, and further improves the covariance matching into multiple directions to solve the covariance mis-match problem. Simulation results show that the proposed method achieves remarkable performance in preserving the edge smoothness compared with other methods in literature. It also achieves consistent objective performance among a variety of methods.

### 1. INTRODUCTION

Image interpolation is a process that estimates the unknown pixels from a set of known pixels. High quality interpolated images are obtained when the unknown pixels are interpolated according to the edge information of the original images. A number of edge-directed interpolation methods that make use of the local statistical properties to interpolate the unknown pixels have been proposed to be able to obtain high visual quality without the use of edge map [1–6]. The *Nearest Edge Directed Interpolation* (NEDI) method in [1] models the image as a second-order locally stationary process and estimates the unknown pixels using the maximum likelihood prediction. A covariance of the image pixels within a training window is required for the computation of the prediction coefficients. Compared to the conventional methods, e.g. the bilinear method or the bicubic method, the NEDI method preserves the sharpness and continuity of the interpolated edges. However, this method computes the prediction coefficients for the nearest neighboring pixels along the edge direction, which degrades the quality of interpolation. In this paper, the NEDI method has difficulty in text images because of the large kernel size, which results in a lower peak signal-to-noise ratio (PSNR) level. Markov random field (MRF) based method [2] models the image as a Markov random field and extends the edge estimation in other pixels by increasing the number of neighboring pixels. The MRF model-based method is able to preserve the continuity of the interpolated edges and also maintains the sharpness of the interpolated image, thus enhances the visual quality. In this paper, a more accurate MRF model is proposed to improve the interpolation quality.



# A Modified Edge Directed Interpolation For Images

- ✧ Interpolation von Bildern
  - ✧ Von niedriger in hohe Auflösung!
  - ✧ Unbekannte Pixel durch Analyse bekannter Pixel schätzen



# A Modified Edge Directed Interpolation For Images

- ✦ Interpolation über Kantenerkennung:
  - ✦ Gängige Methode
  - ✦ Autoren schlagen Verbesserung vor



# A Modified Edge Directed Interpolation For Images

- ✦ Beispiel: New Edge-Directed Interpolation (NEDI)
  - ✦ Lineare Vorhersage, ein „Training Window“
    - ✦ Ergebnis:
      - ✦ Scharfe, durchgängige Kanten
      - ✦ Diagonalen: Nur 4 benachbarte Pixel
        - ✦ senkt Qualität



# A Modified Edge Directed Interpolation For Images

- ✦ Beispiel: Improved New Edge-Directed Interpolation (iNEDI)
  - ✦ Modifikation NEDI
  - ✦ Lernfenstergröße entspr. Kantengröße variiert
    - ✦ Bessere Qualität!



# A Modified Edge Directed Interpolation For Images

- ✧ NEDI und iNEDI
  - ✧ Ein Lernfenster
  - ✧ Gewichtung durch Kovarianz
    - ✧ Häufig fehlerhaft, weil eingeschränkt!



# A Modified Edge Directed Interpolation For Images

- ✧ Modified Edge-directed Interpolation (MEDI)
- ✧ MEDI: Vier Lernfenster
  - ✧ Gesuchter Pixel jeweils im Zentrum
  - ✧ Vier Gewichtungen - Vergleich
  - ✧ Je höher Energie des Lernfensters, desto wahrscheinlicher existiert eine Kante
  - ✧ Lernfenster mit höchster Energie: Lineare Vorhersage



# A Modified

✧ Modified B

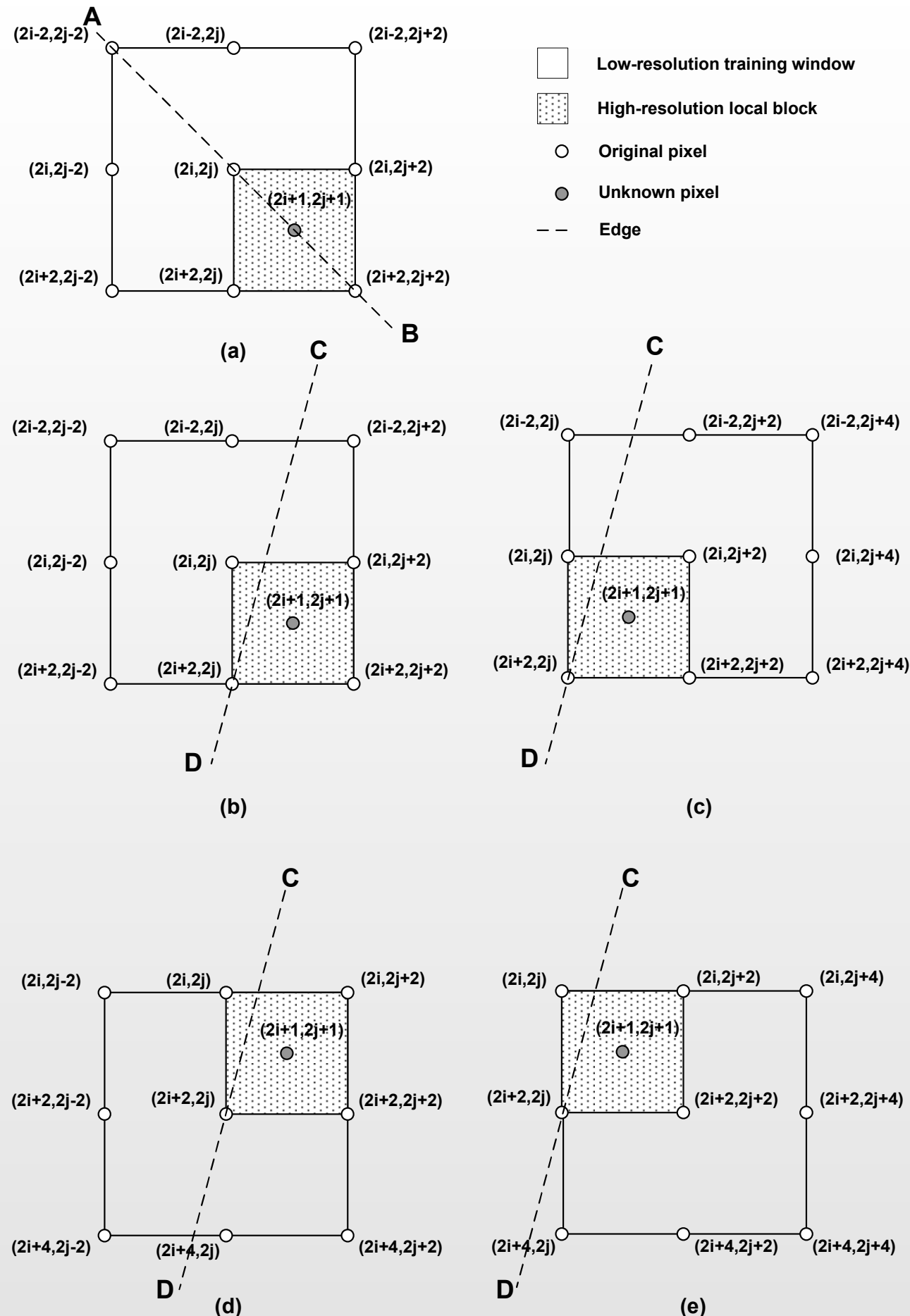
✧ MEDI: Vier

✧ Gesuch

✧ Vier Gew

✧ Je höher  
wahrsch

✧ Lernfens



or Images

Vorhersage



# A Modified Edge Directed Interpolation For Images

- ✧ Versuche
  - ✧ Bild auf 50% verkleinert
  - ✧ Dann Skalierung auf Originalgröße



# A Modified Edge Directed Interpolation For Images

- ✦ Ergebnisse
  - ✦ PSNR-Wert (peak signal to noise - Verhältnis maximale Signalstärke zu Störsignal)
  - ✦ SSIM-Wert (structural similarity index - Ähnlichkeit zweier Bilder)



# A Modified Edge Directed Interpolation For Images

- ✧ Synthetische Bilder
  - ✧ MEDI mit höchsten PSNR- und SSIM-Werten
- ✧ Natürliche Bilder
  - ✧ Ergebnisse bildabhängig
  - ✧ Kein klarer Sieger zwischen vorn liegenden (NEDI, MEDI)



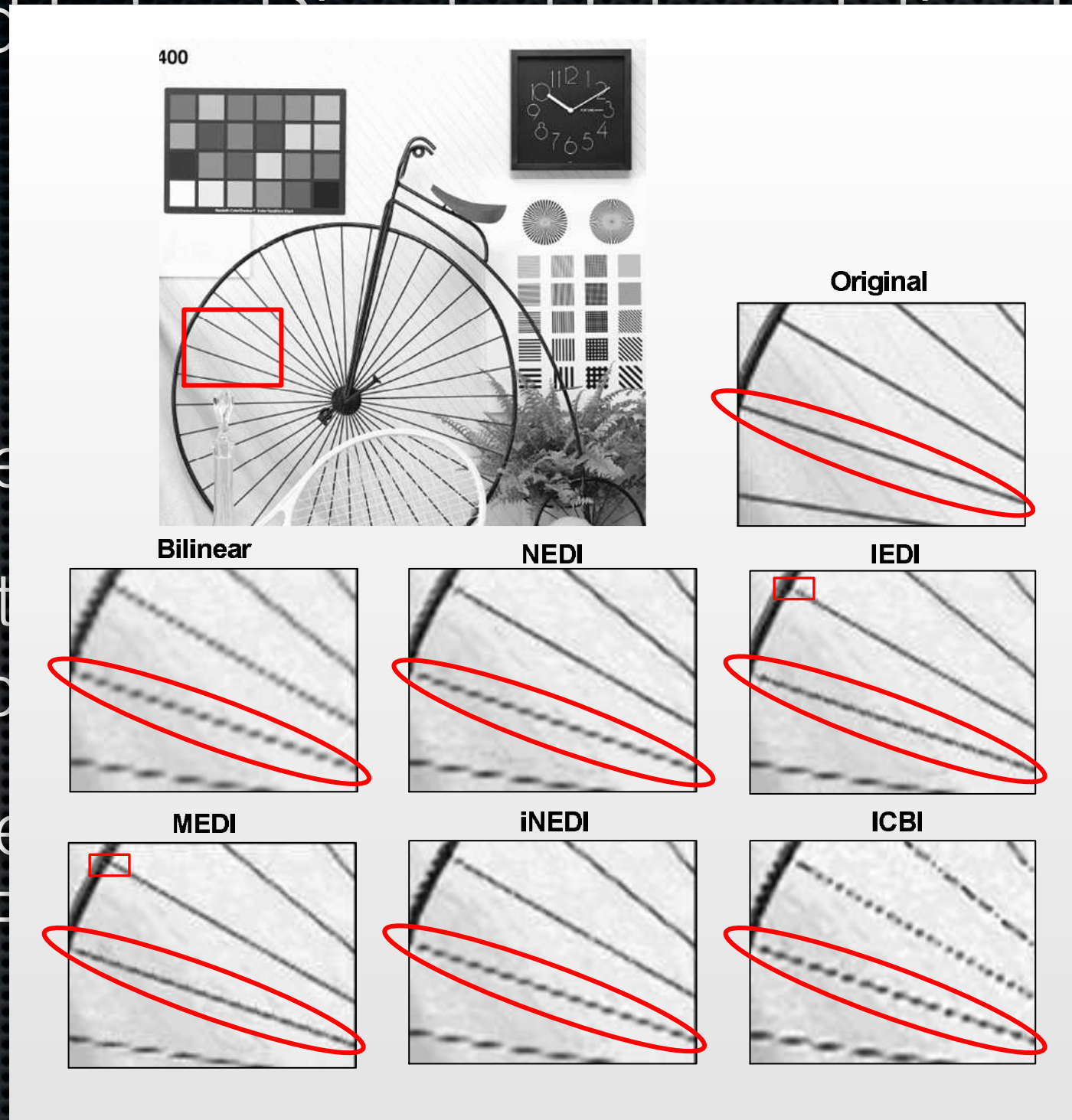
# A Modified Edge Directed Interpolation For Images

- ✦ Subjektive Betrachtung
  - ✦ Synthetische Bilder mit klaren Kanten: Nahezu identisch mit Originalen
  - ✦ MEDI liefert teilweise hervorragende Ergebnisse, löst einige Probleme anderer EDI-Verfahren



# A Modified Feature Displacement Metric For Images

- ✧ Subjektive
- ✧ Synthetisch  
identisch
- ✧ MEDI lie  
einige F



hezu

onisse, löst



# Textvorstellung

- ✦ „Image Denoising Using Over-complete Wavelet Representations“
  - ✦ Slaven Marusic, Guang Deng, David B. H. Tay
  - ✦ School of Electrical Engineering and Telecommunications, The University of New South Wales Sydney
  - ✦ Department of Electronic Engineering, La Trobe University Victoria

## IMAGE DENOISING USING OVER-COMPLETE WAVELET REPRESENTATIONS

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### ABSTRACT

Wavelet transforms have been utilised effectively for image denoising, providing a means to exploit the redundancy between coefficients at multiple scales. In this paper, a modified structure is presented that enables the utilisation of an unlimited number of wavelet filters. An alternative denoising technique is thus proposed with a simple mechanism for the utilisation of multiple wavelet filters. According to the probability distribution function associated with each subband of the transformed data (modelled by a Gaussian distribution), different denoising methods are adaptively applied. The proposed expansion is based on the use of either a Walsh-Hadamard Transform (WHT) or Independent component analysis (ICA) to remove dependencies between the data streams associated with each wavelet composition. The application of a number of different wavelet combinations along the rows and columns of the image are also explored.

### 1. INTRODUCTION

The wavelet transform has been widely shown to be a useful aid in the removal of Gaussian noise from images. Based on the concept of wavelet based image denoising by soft thresholding of wavelet coefficients [1], a number of techniques have been developed to further exploit the dependencies between wavelet coefficients across multiple scales. Among these, the utilization of undecimated wavelet transforms have demonstrated performance improvements in denoising applications while offering useful properties such as shift-invariance. More recently, the development of complex wavelet transforms has demonstrated near state-of-the-art performance while reducing the associated computational complexity. Producing an overcomplete wavelet representation using a dual-tree complex wavelet transform, through careful design also produces more directionally selective filters than conventional separable wavelet filters applied in two dimensions. The observed signal (or image) can be modelled as

$$\mathbf{x} = \mathbf{s} + \mathbf{r}$$

where  $\mathbf{s}$  is the signal and  $\mathbf{r}$  is the noise. This is represented as



# Image Denoising Using Over-complete Wavelet Representations

- ✦ Entrauschen von Bildern
  - ✦ Bildsignal und Rauschsignal trennen!
- ✦ Gängig: Nutzung von „Wavelet-Transformationen“
  - ✦ unwichtige, irrelevante Bilddetails aus Bilddaten entfernen



# Image Denoising Using Over-complete Wavelet Representations

- ✧ Bisher:
  - ✧ Ein Wavelet auf beide Dimensionen
  - ✧ Zwei Filterpaare



# Image Denoising Using Over-complete Wavelet Representations

- ✧ Bisher:

- ✧ Ein Wavelet auf beide Dimensionen
- ✧ Zwei Filterpaare

- ✧ Autoren:

- ✧ Unterschiedliche Wavelets auf Zeilen und Spalten
- ✧ Beliebige viele Filterpaare und Einzelfilter



# Image Denoising Using Over-complete Wavelet Representations

- ✦ Multiple Wavelet Denoising (MWD)
  - ✦ Beliebige Anzahl von Filtern → Mehr Charakteristika und unerwünschtes Rauschen
  - ✦ Voneinander trennbare Filter → gleichzeitig alle Kombinationen eines Filterpaares auf Dimensionen anwendbar



# Image Denoising Using Over-complete Wavelet Representations

- ✦ Neues Verfahren führte im Test zu ähnlichen Ergebnissen wie bisherige
- ✦ ist aber wesentlich flexibler!



# Textvorstellung

## ✧ „Edge-Preserving Wavelet-Based Multisensor Image Fusion Approach“

✧ Lahouari Ghouti, Ahmed Bouridane and Mohammad K. Ibrahim

## Edge-Preserving Wavelet-Based Multisensor Image Fusion

Lahouari Ghouti

**Abstract**—Images emanating from multiple sensors are successfully exploited to reduce human and machine errors in practical vision systems. Multiresolution-based fusion schemes have shown interesting potential in the fusion of images from possibly different types of sensors that need to be processed. However, most of the proposed schemes treat all details equally regardless of their local importance. On the other hand, the human visual system is more sensitive to edge details. We propose an image fusion scheme where edge details, characterized by wavelet maxima, are considered more important than plain and low activity image regions. The proposed fusion offers a trade-off between feature-based and pixel-based fusion schemes. Images are combined in the wavelet domain using a multiresolution representation that is sensitive to image edges. A comparison of the proposed method with current multiresolution-based fusion schemes shows that the proposed method can achieve better performance in terms of preserving important details in the combined image.

### I. INTRODUCTION

In recent years, there has been a growing interest in image fusion of images obtained using multiple sensors in academic, industrial, and military due to the important role it plays in various applications related to these fields. Image fusion, or multisensor image fusion, aims at combining two or more source images of the same scene into an image that retains the most important or salient features present in all the source images. This is achieved by a specific fusion scheme. The composition of multiple images provide increased interpretation capabilities and reduce both human and machine errors in detection and recognition. Moreover, image fusion can be performed at different processing levels according to the type of fusion that takes place: pixel [1], feature [1] and cognitive [2]. In this paper, we are interested in developing a fusion scheme that combines aspects of pixel-level and feature-based approaches.

In pixel-level approach, all or a set of pixels from the source images are combined to compute the value of a pixel in the fused image. Simple arithmetic operations or sophisticated combination schemes can be applied for this purpose. It is worth noting that the adopted method should, in essence, contribute to a considerable improvement for all posterior processing tasks such as object detection and human/machine vision.



# Textvorstellung

## ✧ „Improved Image Fusion Using Balanced Multiwavelets“

✧ Lahouari Ghouti, Ahmed Bouridane and Mohammad K. Ibrahim

## Improved Im

Lahouari Ghouti

**Abstract**—This paper presents the use of wavelets for image fusion. The proposed image fusion technique incorporates the use of balanced multiwavelets. This technique uses multiple wavelet and scaling functions for image fusion. Wavelet-based fusion techniques have been successful in combining perceptually important image features. The human visual system (HVS) sensitivities are incorporated in the design of wavelets. Balanced multiwavelets have attracted attention for their desirable properties. They can simultaneously achieve symmetry, orthogonality, compact support and approximation order higher than scalar wavelets. Filters with shorter length are used yielding lower complexity than scalar wavelet.

### I. INTRODUCTION

With the availability of multi-sensor data in various fields such as remote sensing, machine vision, medical imaging, and military application, effective image fusion has received much attention in the literature. In sensor image, each of the input images contains information that cannot be discarded.

Image fusion can take place at the signal, feature, transform, and symbol level. Fusion techniques range from the simplest method of pixel averaging to more sophisticated state-of-the-art methods such as multiresolution analysis, networks-based fusion. Initially, multi-sensor image fusion was correctly aligned on a pixel-by-pixel basis [1], and successful fusion.

Usually, more generic requirements are imposed on the fusion outcome such that: All relevant information from the input images must be preserved in the resulting image. This is the "information-preserving" rule [2]. Any irrelevant information as noise should be discarded from the result. The human visual system (HVS) is primarily sensitive to motion. Any artifacts or inconsistency that would distract the observer should be also suppressed. The fusion technique employed, should not introduce such artefacts.

In this paper, the fusion based on balanced multiwavelets is introduced for the first time. The results clearly demonstrate the advantages of this approach. The paper is organized as follows: In section 2, we briefly review a general image fusion scheme and then we will introduce the use of balanced multiwavelets in image fusion.



# Edge-Preserving Wavelet-based Multisensor Image Fusion Approach / Improved Image Fusion Using Multiwavelets

- ✦ Multisensor-Bilder
  - ✦ Aus mehreren Einzelbildern zusammengesetzt
  - ✦ unterschiedliche visuelle Sensoren, selbes Motiv
- ✦ Paper: Verschiedene Ansätze zur Generierung und Qualitätsverbesserung



# Edge-Preserving Wavelet-based Multisensor Image Fusion Approach

- ✧ Paper 1:
  - ✧ Verwendung symmetrischer MultiWavelets zur Erzeugung von Multisensor-Bildern
  - ✧ Wichtige Bestandteile sollen erhalten bleiben, Besonderheiten verstärkt werden



# Improved Image Fusion Using Multiwavelets

- ✧ Paper 2:
  - ✧ Fusion zweier Multisensor-Bilder
  - ✧ Wichtigste Bildinformationen werden in einem fusionierten Bild zusammengefasst



# Textvorstellung

## ✦ „Super Resolution Image By Edge-Constrained Curve Fitting In The Threshold Decomposition Domain“

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### SUPER RESOLUTION IMAGE THRESHOLD DECOMPOSITION

Department of Electronic and Computer Engineering,  
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Clearwater Bay

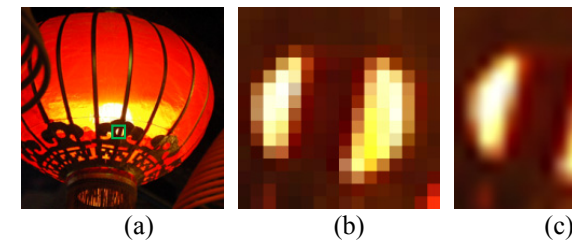


Figure 1: (a) Original image of 256 by 256 pixels; (b) bi-cubic, and our proposed algorithm); (e)-(f) (duplicate).

#### ABSTRACT

An edge-constrained curve-fitting method is proposed to produce super-resolution (SR) images from a low-resolution source image. The novelty of this method lies that a threshold decomposition is applied on the source image to obtain binary images, and then an edge-constrained curve-fitting method is applied on the resulting set of binary images. This method focuses on tiny objects and thin structures so as to achieve better visual results even when a large zoom-in factor is used. The results are compared with those achieved by using bi-cubic interpolation, showing the ability of our algorithm to produce better visual quality in smooth areas as well as for sharp small objects.

#### 1. INTRODUCTION

Generating a super-resolution (SR) image from a low-resolution (LR) source image is a long-studied problem. Several methods have been achieved in recent years in this area via various approaches, such as the example-based method [1], the sparse-based method [2], and hyper-resolution [3]. A drawback of these methods is that they heavily rely on some model or a large database. As a result, the robustness over various kinds of images remains as a problem. Another limitation of these techniques is that most of them can only enlarge a source image 2 to 8 times in both dimensions, whereas problems arise when a bigger zoom-in factor is required. This is not ideal because enlarging a source image by a big factor is usually achieved by several iterations – each round of running the (same) method will generate artifacts and these artifacts will propagate to the next rounds. Motivated by these existing works mentioned above, we will develop a novel technique in this paper.



# Textvorstellung

## ✦ „Wavelet Domain Image Resolution Enhancement Using Cycle Spinning And Edge Modelling“

- ✦ Alptekin Temizel, Theo Vlachos
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- ✦ Centre for Vision, Speech, and Signal Processing (CVSSP), University of Surrey, Guildford (UK)

## WAVELET DOMAIN IMAGE RESOLUTION ENHANCEMENT USING CYCLE SPINNING AND EDGE MODELLING

Alptekin Temizel

<sup>1</sup>Honeywell Video Systems-Visioprime, 3

<sup>2</sup>Centre for Vision, Speech, and Signal Processing

### ABSTRACT

In this paper we present a wavelet domain image resolution enhancement algorithm. An initial high-resolution approximation of the original image is obtained by means of zero-order interpolation in the wavelet domain. This is further processed using the proposed methodology which reduces ringing. A critical element of the algorithm is the adoption of a simplified edge profile model. A description of edge degradations such as blurring and aliasing is used to model the resolution loss. Linear regression using a minimal training set of low-resolution originals, is finally employed to rectify the degraded edges. Our results show that the proposed method outperforms conventional image interpolation approaches, both in objective and subjective terms, while it also compares favourably with the state-of-the-art methods operating in the wavelet domain.

### 1. INTRODUCTION

Resolution enhancement of pictorial data is desirable in many applications such as monitoring, surveillance, medical imaging, and remote sensing. It is a classic signal interpolation problem. Conventional approaches such as zero-order interpolation (nearest neighbour) cause severe pixelation impairments while bilinear interpolation invariably result in undesirable levels of blurring across salient edges. Recently several efforts in the literature have used wavelet-domain methodologies with the intention of addressing some of the problems associated with conventional interpolation. A common feature of these algorithms is the assumption that the low-resolution (LR) image to be enhanced is the low-pass subband of a high-resolution (HR) image which has been decomposed using a decimated wavelet transform. A trivial approach would be to construct an approximation to the HR image by filling the high-frequency subbands (normally containing high-frequency information) with zeros followed by the application of the inverse wavelet transform (IWT). It is interesting to note that this approach is capable of outperforming bilinear interpolation in many cases, has never appeared in the literature probably due to its simplicity. More sophisticated methods have attempted to estimate the missing high-frequency detail wavelet coefficients in an effort to improve the quality of the reconstructed images.

In [1] and [2] estimation was carried out by examining the evolution of wavelet transform extrema from finer to coarser scales. Edges identified by an edge detection algorithm in lower-frequency subbands were used to formulate a template for estimating the missing high-frequency subbands. Only coefficients with significant magnitudes were estimated as the evolution of the wavelet transform among the scales was found to be difficult to model using a single set of coefficients. Significant magnitude coefficients correspond to image discontinuities and consequently only the portions of the image containing



# Super Resolution Image By Edge-Constrained Curve Fitting In The Threshold Decomposition Domain / Wavelet Domain Image Resolution Enhancement Using Cycle Spinning And Edge Modelling

- ✧ In beiden Papern:
  - ✧ Generierung eines hoch aufgelösten Bildes
  - ✧ aus einem niedrig aufgelösten



# Super Resolution Image By Edge-Constrained Curve Fitting In The Threshold Decomposition Domain

- ✧ Paper 1:
  - ✧ analytische Herangehensweise
  - ✧ Kanten im niedrig aufgelösten Bild
  - ✧ übertragen in hochauflösendes
  - ✧ Füllung mit weiterem Algorithmus (im Paper nicht näher erläutert)
  - ✧ *Scharfe Kanten, aber unnatürlich wirkendes Bild*



# Super Resolution Image By Edge-Constrained Curve Fitting In The Threshold Decomposition Domain

- ✧ Paper 2:
  - ✧ mathematische Herangehensweise
  - ✧ komplettes Bild wird vergrößert
  - ✧ Im Anschluss: Bereinigung des Bildes
  - ✧ *Kanten weniger scharf, Bild wirkt aber natürlich*



# Zusammenfassung

- ✦ Unterschiedliche Methoden zur Bildverbesserung
- ✦ Aber alle im 2D-Raum
- ✦ Anwendung im 3D-Raum?
  - ✦ Durchaus vorstellbar
  - ✦ Unterschiedlich stark anzuwenden
  - ✦ Änderungen an den Algorithmen notwendig



# Referenzen

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