

# M6.4

## ITERATIVE IDENTIFICATION AND RESTORATION OF IMAGES

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### ABSTRACT

In order to restore distorted images, the unknown blurs have to be identified from the blurred images themselves. We formulate the blur identification problem as a constrained maximum likelihood problem. The constraints directly incorporate a priori known relations between the blur (and image model) coefficients, such as symmetry properties, into the identification procedure. The resulting nonlinear minimization problem is solved iteratively, yielding a very general identification algorithm. An example of blur identification on synthetic data is given.

### I. INTRODUCTION

The first step towards the restoration of degraded images is the identification of the kind of degradation the image has suffered. Modeling a blurred image as the output of a 2-dimensional linear system, the identification problem is the problem of estimating the unknown characterizing point-spread function (PSF) of this system. One approach to blur identification is to obtain a model of the blurring system from the physical nature of the problem. Unfortunately, one has hardly ever enough a priori knowledge to determine the PSF in this way. Therefore, the information about the blurring process has to be determined from the blurred image itself.

The earliest work on blur identification concentrated on identifying PSFs that have zeros only on the unit  $\mathbb{R}^2$ -circle [1]. One of the shortcomings of this method is that PSFs which do not satisfy this requirement, such as a properly truncated Gaussian PSF, cannot be identified. In more recent work [2,3] the original image is first modeled as a 2-D autoregressive (AR) process. Then, if the observed blurred image is assumed noiseless, the image and blur model identification problem is specified as a 2-D autoregressive moving-average (ARMA) identification problem, where the AR coefficients are related only to the image model, and the MA coefficients only to the blur model (PSF).

Tetaly et al. [2] derived maximum likelihood estimates for these ARMA parameters, and computed them by first decomposing the PSF into four (real) quarterplane convolutional factors, each of

which is stable in its direction of recursion, and next identifying each of these factors recursively. This approach assumes that the unknown PSF is real, symmetric (i.e. zero phase) and has a positive Fourier transform. Sissord et al. [3] showed that the 2-D ARMA identification can be done in parallel, where each of the parallel channels requires the identification of a 1-D complex ARMA process. An intermediate high-order AR approximation step is used to compute these ARMA coefficients.

In this paper we formulate the blur identification problem as a constrained maximum likelihood (ML) problem. The linear constraints incorporated in the formulation represent a priori known relations between the blur (or image model) coefficients. The resulting nonlinear minimization problem is solved by employing an iterative gradient based minimization procedure. It is conceptually advantageous to use iterative methods, since they offer the possibility of incorporating a priori knowledge about the original blur and image model into the identification procedure. Furthermore, since they act upon one complete image they are free from the causality restrictions imposed by recursive techniques.

In Section II we describe the mathematical (probabilistic) models for the image and degradation. Next, in Section III, we formulate the identification problem as a ML problem. In this section we also describe the iterative algorithm for minimizing the resulting ML index. Some preliminary experimental results are presented in Section IV. Finally, Section V summarizes relevant conclusions and discusses areas of further research.

### II. IMAGE AND DEGRADATION MODELS

#### Basic Model Development

It is assumed that the original image  $f(i,j)$  (of the size  $M \times N$  pixels) can be represented by the output of a 2-D AR system

$$f(i,j) = \sum_{k,l \in \mathbb{Z}^2} a(k,l) f(i-k, j-l) + v(i,j), \quad (1)$$

where  $a(k,l)$  are the image model coefficients, and  $v_k$  the support of the image model, which is not necessarily causal.

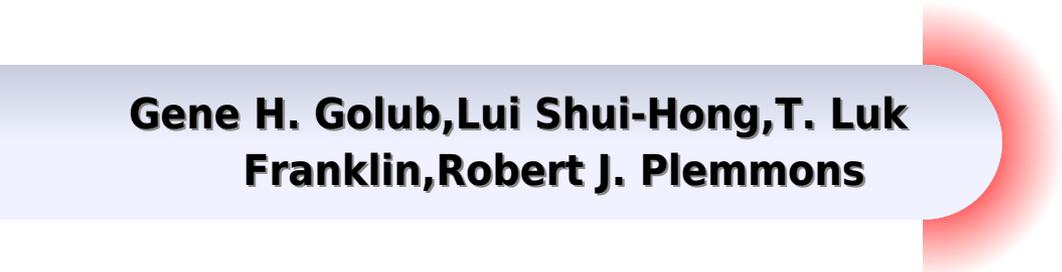
By lexicographically ordering of the image data [4] we can use the more compact matrix-vector notation

$$f = Af + v, \quad (2)$$

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### **Table of Contents Iterative Identification And Restoration Of Images**

1. Understanding the eBook Iterative Identification And Restoration Of Images
  - The Rise of Digital Reading Iterative Identification And Restoration Of Images
  - Advantages of eBooks Over Traditional Books
2. Identifying Iterative Identification And Restoration Of Images
  - Exploring Different Genres
  - Considering Fiction vs. Non-Fiction
  - Determining Your Reading Goals
3. Choosing the Right eBook Platform
  - Popular eBook Platforms
  - Features to Look for in an Iterative Identification And Restoration Of Images
  - User-Friendly Interface
4. Exploring eBook Recommendations from Iterative Identification And Restoration Of Images
  - Personalized Recommendations
  - Iterative Identification And Restoration Of Images User Reviews and Ratings
  - Iterative Identification And Restoration Of Images and Bestseller Lists

5. Accessing Iterative Identification And Restoration Of Images Free and Paid eBooks
  - Iterative Identification And Restoration Of Images Public Domain eBooks
  - Iterative Identification And Restoration Of Images eBook Subscription Services
  - Iterative Identification And Restoration Of Images Budget-Friendly Options
6. Navigating Iterative Identification And Restoration Of Images eBook Formats
  - ePub, PDF, MOBI, and More
  - Iterative Identification And Restoration Of Images Compatibility with Devices
  - Iterative Identification And Restoration Of Images Enhanced eBook Features
7. Enhancing Your Reading Experience
  - Adjustable Fonts and Text Sizes of Iterative Identification And Restoration Of Images
  - Highlighting and Note-Taking Iterative Identification And Restoration Of Images
  - Interactive Elements Iterative Identification And Restoration Of Images
8. Staying Engaged with Iterative Identification And Restoration Of Images
  - Joining Online Reading Communities
  - Participating in Virtual Book Clubs
  - Following Authors and Publishers Iterative Identification And Restoration Of Images
9. Balancing eBooks and Physical Books Iterative Identification And Restoration Of Images
  - Benefits of a Digital Library
  - Creating a Diverse Reading Collection Iterative Identification And Restoration Of Images
10. Overcoming Reading Challenges
  - Dealing with Digital Eye Strain
  - Minimizing Distractions
  - Managing Screen Time
11. Cultivating a Reading Routine Iterative Identification And Restoration Of Images
  - Setting Reading Goals Iterative Identification And Restoration Of Images
  - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Iterative Identification And Restoration Of Images
  - Fact-Checking eBook Content of Iterative Identification And Restoration Of Images
  - Distinguishing Credible Sources
13. Promoting Lifelong Learning

- Utilizing eBooks for Skill Development
  - Exploring Educational eBooks
14. Embracing eBook Trends
- Integration of Multimedia Elements
  - Interactive and Gamified eBooks

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