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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) coef-
ficients, such as symmetry properties, into the
identification procedure. The resulting nonlinear
minimization problem is solved iteratively, yiel-
ding a very general identification algorithm. An
example of blur identification on synthetic data
is given.

I. INTRODUCTION

The first step towards the restoration of degra-
ded images is the identification of the kind of de-
gradation the image has suffered. Modeling a blur-
red 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 ima-
ge itself.

The earliest work on blur identification concen-
trated on identifying PSFs that have zeros only
on the unit bi-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 coeffi-
cients are related only to the image model, and
the MA coefficients only to the blur model (PSF).

Tekalp et al. [2] derived maximum likelihood
estimates for these ARMA parameters, and computed
them by first decomposing the PSF into four (cau-
sal) 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. Biemond 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 identifica-
tion problem as a constrained maximum likelihood
(ML) problem. The linear constraints incorporated
in the formulation represent a priori known rela-
tions between the blur (or image model) coeffi-
cients. The resulting nonlinear minimization pro-
blem 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 (pro-
babilistic) models for the image and degradation.
Next, in Section III, we formulate the identifica-
tion problem as a ML problem. In this section we
also describe the iterative algorithm for minimi-
zing the resulting ML index. Some preliminary ex-
perimental 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 $N \times N$ pixels) can be represented by the out-
put of a 2-D AR system

$$f(i,j) = \sum_{k,\ell \in W_A} a(k,\ell)f(i-k,j-\ell) + v(i,j), \quad (1)$$

where $a(k,\ell)$ are the image model coefficients, and
W_A the support of the image model, which is not
necessarily causal.
By lexicographically ordering of the image data
[1] we can use the more compact matrix-vector nota-
tion

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

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