# A Multi-objective Memetic Algorithm for Intelligent Feature Extraction

Paulo V.W. Radtke[1,2,⋆], Tony Wong[1], and Robert Sabourin[1,2]

[1] École de Technologie Supérieure,
Laboratoire d'Imagerie, de Vision et d'Intelligence Artificielle,
Department de Génie de la Production Automatisé,
1100, rue Notre Dame Ouest, Montréal, QC, Canada H3C 1K3
[2] Pontifícia Universidade Católica do Paraná,
Rua Imaculada Conceição 1155, Curitiba, PR, Brazil 80215-901
radtke@livia.etsmtl.ca

**Abstract.** This paper presents a methodology to generate representations for isolated handwritten symbols, modeled as a multi-objective optimization problem. We detail the methodology, coding domain knowledge into a genetic based representation. With the help of a model on the domain of handwritten digits, we verify the problematic issues and propose a hybrid optimization algorithm, adapted to needs of this problem. A set of tests validates the optimization algorithm and parameter settings in the model's context. The results are encouraging, as the optimized solutions outperform the human expert approach on a known problem.

## 1 Introduction

Image-based pattern recognition (PR) systems require that pixel information be first transformed into an abstract representation suitable for recognition, a process called feature extraction [1]. A methodology that extracts features for PR must select the most appropriate transformations and determine the spatial location of their application on the image. Related to the feature extraction process is the feature subset selection (FSS) operation [2]. FSS further refines the extraction process by selecting the most relevant features, within the extracted feature set, in order to reduce classifier's computation effort in the classification stage and improve recognition rate. A comparison of FSS methods in [3] indicates that genetic algorithm (GA) based approach performs better than traditional methods when the problem size is large (more than 50 features). In the context of isolated handwritten digits, Oliveira et al. applied a GA based FSS [4] to optimize classifier accuracy and feature set cardinality using a weighted vector. They postulated that a multi-objective genetic algorithm (MOGA) could further enhance the obtained results. Their postulate was later confirmed in

⋆ Author for correspondence.

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[5], where MOGA outperformed GA on the same problem. The superiority of MOGA in FSS is also confirmed by Emmanouilidis et al. using sonar and ionosphere data [6].

It is now understood that the advantage of MOGA lies in the inherent diversity of the optimized solution set, avoiding the population convergence to a single local optimum. However, the application of MOGA in FSS also faces a number of difficulties. In essence, classifier training is based on a finite set of labeled observations – the training set. The classifier may perform differently when presented to unknown observations, i.e., data not in the training set. This behavior is verified in [5] where the feature set optimized by a MOGA produces a recognition rate that is different for the optimization set compared to a set of unknown observations. This behavior can be explained by the fact that the input domain used in the MOGA optimization process does not match the one used in the classification stage of the recognition process. Thus, the corresponding objective spaces are also non matching because the same classifier is used in the optimization and the classification stages. Another difficulty arises when two or more feature sets sharing similar elements exist in the MOGA population. In the context of FSS, similar feature sets should yield comparable performances for a given classifier. If these feature sets also possess the same cardinality then the genetic selection operator is likely to emphasize the one with the highest recognition rate. Since the FSS problem has non matching objective spaces, the selected feature set may not perform adequately in the classification of unknown observations. Furthermore, the genetic selection operation is complicated by the dominance principle used in most Pareto-based MOGAs. The primary aim of the FSS operation is to reduce feature set cardinality while maintaining the highest possible recognition rate. This implies a mixed-integer objective space and standard dominance relationship can not be implemented directly. Due to the existence of the $L_1$ norm, special steps must be taken in order to ensure diversity on the Pareto-front. Finally, due to the non matching input domains and objective spaces, a non dominated feature set in the optimization stage is not necessarily non dominated in the classification stage.

Considering these aspects, we propose in Sect. 2 a methodology for feature extraction of isolated handwritten symbols formulated as an evolutionary multi-objective optimization problem (MOOP), supported by earlier experiments in [7]. Section 3 analyze the MOOP and verify the issues discussed in the context of isolated handwritten digits. Sections 4 to 6 describe an optimization algorithm adapted to the FSS problem and present a series of tests to verify its efficiency. Section 7 presents the conclusions.

## 2 The Intelligent Feature Extractor Methodology

Traditionally, human experts are responsible for the choice of the feature set. It is most often determined by using domain knowledge on a trial and error basis. We propose to use the domain knowledge in a methodology formulated as an