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Evaluation of different distortion correction methods and interpolation techniques for an automated classification of celiac disease☆

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ABSTRACT

Due to the optics used in endoscopes, a typical degradation observed in endoscopic images are barrel-type distortions. In this work we investigate the impact of methods used to correct such distortions in images on the classification accuracy in the context of automated celiac disease classification.

For this purpose we compare various different distortion correction methods and apply them to endoscopic images, which are subsequently classified. Since the interpolation used in such methods is also assumed to have an influence on the resulting classification accuracies, we also investigate different interpolation methods and their impact on the classification performance. In order to be able to make solid statements about the benefit of distortion correction we use various different feature extraction methods used to obtain features for the classification.

Our experiments show that it is not possible to make a clear statement about the usefulness of distortion correction methods in the context of an automated diagnosis of celiac disease. This is mainly due to the fact that an eventual benefit of distortion correction highly depends on the feature extraction method used for the classification.

1. Introduction

Today, medical endoscopy is a widely used procedure to inspect the inner cavities of the human body. As a consequence different medical fields exist for which automated decision-support systems based on endoscopic images have been developed [1]. But since images taken with endoscopes often suffer from various kinds of degradations, a pre-processing of the images is often necessary in order to make them useful for an automated analysis [2] (to cope with e.g. sensor noise, focus and motion blur, and specular reflections [1]).

A different type of degradation, present in all endoscopic images, is a barrel-type distortion. This type of degradation is caused by the wide-angle (fish eye) nature of the optics used in endoscopes (although the strength of the distortion varies depending on the endoscope used). Such a distortion

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is also claimed to affect diagnosis since it introduces non-linear changes in the image, due to which the outer areas of the image appear significantly smaller than they actually are [3]. As a consequence the estimation of area or perimeter of observed lesions can be significantly incorrect depending on the position in the image [4,5]. With respect to an automated classification such distortions are also suspected to lead to corrupted features due to an inhomogeneous magnification [6]. It has also been mentioned in literature that barrel-type distortions might lead to "complications using token matching techniques for pattern recognition" [4]. Since the seminal work on distortion correction (DC) for endoscopic images [6] several distortion correction procedures have been developed to overcome the problems caused by such distortions [4,5,7,8].

To the best of our knowledge up to now there are only a few studies available, which investigate the impact of barrel-type distortions and distortion correction on the accuracy of automated classification systems for endoscopic images [9–12].

In [9] the impact of distortion correction on the classification accuracy regarding celiac disease images has been investigated. Gschwandtner et al. showed that most feature extraction methods evaluated failed to take advantage of applying distortion correction as a pre-processing step to the endoscopic images, resulting in a decreased classification accuracy. In the follow-up work in [11] the authors evaluated another distortion correction method with a similar outcome. In [12] the authors evaluated the distortion correction methods from [9,11] with additional feature extraction methods. In this work the authors showed that only a few feature extraction methods are able to take a slight advantage of distortion correction (with respect to the overall classification rates). The work presented in [10] investigated the impact of distortions and interpolation artifacts caused by distortion correction methods on the accuracy of a classification of celiac disease images. The clear outcome was that there is indeed a negative impact of barrel-type distortions on the classification accuracy. Moreover, this negative effect gets more apparent the farther away from the center of distortion (CoD) features are extracted. But it has also been shown that this also accounts to distortion corrected images due to interpolation artifacts. The bottom-line result of all four studies was that the interpolation artifacts caused by the distortion correction are very likely one reason why the classification results have not been improved.

To facilitate a more thorough investigation of the effect of distortion correction on the accuracy of an automated diagnosis of celiac disease, the present work compares four different distortion correction methods (instead of two methods at most, like in earlier studies). In addition, this work is the first study which also compares various different interpolation methods used for distortion correction (previous studies were based on bilinear interpolation only). To be able to make solid statements about the usability of the different distortion correction methods in the context of endoscopic image classification, we use various different feature extraction methods, which are evaluated on distortion corrected images.

The remaining part of this work is organized as follows: in Section 2 we briefly describe the medical background of celiac disease, the staging system commonly used to diagnose this disorder, and the motivation behind automated classification systems targeted at this disorder. After a discussion of barrel-type distortions and the problems inherent to this type of degradations in Section 3, we describe the methods for distortion correction evaluated in this work in Section 4. In Section 5 we then briefly summarize the feature extraction methods used throughout our experiments. Experimental results and configuration details for our experiments are presented in Section 6, followed by a discussion in Section 7 and concluding remarks in Section 8.

2. Automated classification for celiac disease diagnosis

Celiac disease, commonly known as gluten intolerance, is a complex autoimmune disorder that affects the small bowel in genetically predisposed individuals of all age groups after introduction of food containing gluten. Characteristic for the disease is an inflammatory reaction in the mucosa of the small intestine. During the course of the disease the mucosa looses its absorptive villi and hyperplasia of the enteric crypts occurs, leading to a diminished ability to absorb nutrients.

Endoscopy with biopsy is currently considered the gold standard for the diagnosis of celiac disease. During standard upper endoscopy at least four duodenal biopsies are taken. Microscopic changes within these specimen are then classified in a histological analysis according to the Marsh classification proposed in 1992 [13]. Subsequently, Oberhuber et al. proposed the modified Marsh classification [14] which distinguishes between classes Marsh-0 to Marsh-3, with subclasses Marsh-3a, Marsh-3b, and Marsh-3c, resulting in a total number of six classes. According to the modified Marsh classification Marsh-0 denotes a healthy mucosa (without visible changes of the villous structure) and Marsh-3c designates a complete absence of villi (villous atrophy).

In accordance to the work in [9,11,10], we consider the four classes Marsh-0 and Marsh-3a to Marsh-3c only throughout this work, since visible changes in the villi structure can be observed only for classes Marsh-3a to Marsh-3c (in case of the classes Marsh-1 the number of intra-epithelial lymphocytes is increased and in case of Marsh-2 the crypts of Lieberkuhn are proliferated). In addition, in this work we focus on the 2-classes case only (i.e. Marsh-0 and Marsh-3) since in this case the image database available is fairly well balanced with respect to the images in each class. In the remaining part of this work we denote these classes by "no-celiac" and "celiac".

Throughout the past decades automated classification systems got an emerging field of research for endoscopic diagnosis and treatments [15]. An automated system identifying areas affected by celiac disease in the duodenum would offer the following benefits (among other):

- Methods helping to locate specific areas for biopsies might improve the reliability of celiac disease diagnosis. Especially when considering that biopsies are invasive and thus the number of biopsies taken should kept small, assisted biopsy site targeting is desirable. Such a targeting can be supported by an automated system for the detection of areas affected by celiac disease.