Detecting Stripe Artefacts in Ultrasound Parametric Images

Antje Vollrath[1], Christian Kier[1], Karsten Meyer-Wiethe[2], Günter Seidel[2], Til Aach[1†]
[1]Institute for Signal Processing, University of Lübeck, D-23538 Lübeck, Germany
[2]Department of Neurology, University Hospital Schleswig-Holstein, D-23538 Lübeck, Germany

Abstract

Parametric ultrasound images visualising a patient's brain perfusion often suffer from stripe artefacts – a darker, radially oriented image region originating from inhomogeneities in the cranial bone or the dura mater. We present an algorithm for detecting these artifacts with regard to automatic evaluation of parametric images. The algorithm exploits that stripe artefacts by virtue of their origin are always parallel to the ultrasound beam. After image preprocessing the algorithm amplifies vertical structures with a suitable filter kernel. It then continues to work on single possible stripe artefacts which are marked as such based on their average grey values in different subparts. Our results show that the algorithm recognizes stripe artefacts with an error rate of 0-7% in different images with artificial and real artefacts. Thus, it provides an important step towards automatic image evaluation since stripe artefacts are very close in their local appearance to pathological areas.

1 Introduction

Ultrasound (US) harmonic imaging of the human brain promises to become a fast, inexpensive and well-tolerated bedside method in diagnosing acute ischemic stroke [1]. Ultrasound contrast agent (UCA) is injected into the patient's blood circuit and transcranial ultrasound is used to track its temporal distribution in an image sequence [2]. Current image analysis methods developed at our group provide the physician with parameters related to the patient's brain perfusion [3]. With the bolus harmonic imaging (BHI) method – a UCA bolus is tracked within the human cerebral microcirculation – four parameters (local peak intensity, area under curve, average slope, and time to peak) are provided as colour-coded images to allow the physician to quickly grasp the patient's condition.

Due to the calculation procedure [4] the images often suffer from so called stripe artefacts – darker image regions parallel to the US beam. They originate from local imhomogeneities in the cranial bone or the dura mater leading to additional absoption of the US pulse energy. While these artefacts are already visible in the original ultrasound image sequence they appear intensified in the resulting parametric image – especially in the local peak intensity image, because the corresponding image region does not fit the underlying model for calculating the parameters. Since pathological tissue also corresponds to low parameter values and thus to locally dark image areas, the automatic prior identification of these stripe artefacts is essential.

2 Detection of stripe artefacts

The proposed algorithm for artefact detection exploits the nature of these artefacts. Due to the US pulse absorption they appear always darker than the surrounding image area and are ray-like as the ultrasound beam. If the US image is regarded as a circle segment the artefacts are parallel to the circle radii and form a segment of the circle as well.

The general approach is to preprocess the image to intensify vertical structures. Then single circle sections are masked and examined for whether they contain a stripe artefact depending on their average grey value in all subsections of the stripe.

2.1 Preprocessing

To enhance stripe artefacts we convolve the image with a 5x5 horizontal derivative kernel. This filter amplifies structures having a vertical orientation component, and thus also the radially orientated stripes. Deviations between a stripe artefact and vertical components of up to 45° may occur, since the US fan covers an angle of 90° wide. This mismatch could be avoided by a prior transformation of the US image from Cartesian to polar coordinates. The downside of this is that the stripes become very wide in the upper border area of the US fan, thus requiring computationally expensive large-area analysis. Practice shows that this transform, though theoretically justified, can be skipped. The resulting image is thresholded to obtain a binary image.

[†]T. Aach is now with Institute of Image Processing and Computer Vision, RWTH Aachen, D-52056 Aachen, Germany

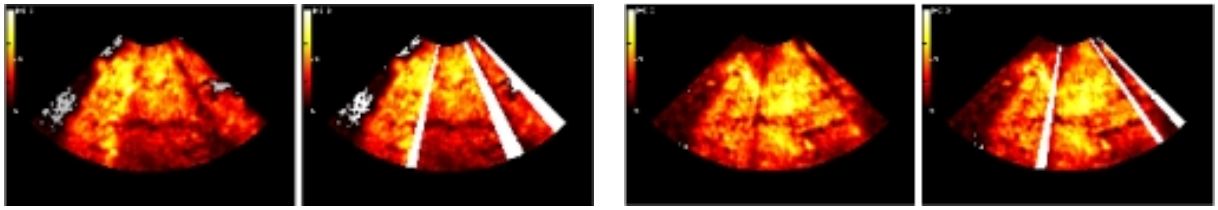

Figure 1: Parametric images with their corresponding results of stripe detection.

2.2 Detection of single artefacts

The algorithm divides the US fan area in separate circle segments to process each one individually. The specific form and position of the artefacts is taken into account by masking circle segments. Mask generation is a compromise between accuracy and speed because the smaller a circle segment becomes the more segments are needed to cover the image area and the longer the computation takes.

Convolving the image with a derivative kernel keeps the dark stripe artefacts dark while intensifying other image areas. Thus, the decision whether or not a circle segment is an artefact is based on its average grey value which has to be below a certain threshold. However, by averaging a complete segment false positives occur when the lower part is dark and the upper part not bright enough to compensate. This situation is quite common since the lower part of the image represents already the opposite brain hemisphere, which lies relatively far from the US probe and thus has a lower backscatter signal amplitude. To avoid these misjudgements, the segment is divided in five parts with equidistant borders which are averaged separately. Only when all five average intensity values are below the threshold, the segment is marked as a stripe artefact. **Figure 1** shows two parametric images (LPI) and the detected artefacts as superimposed white stripes.

3 Results and conclusions

To assess the performance of the algorithm it was tested on three classes of parametric US images: without artefacts, with normal artefacts and with artificial artefacts. The artificial artefacts were not circle segments but larger black areas not necessarily parallel to the US beam to test the robustness of the algorithm. The results given as percentage of wrongly marked pixels with respect to the image are 0-3%, 5-7%, and 0-1% respectively.

The proposed detection algorithm is an important step towards the goal to obtain the same information about poorly perfused brain areas from ultrasound bolus harmonic imaging as it is possible with more costly methods like CT or MRI. It marks areas originating from bone or tissue irregularities forming unrecoverable artefacts. Since the artefact areas contain unusable or false information, they have to be excluded from further analysis. The results show the robustness of the algorithm with respect to artefacts with deviations from our straight forward model of a stripe artefact. In its main discipline – normal stripe artefacts – the worst case is a false positive rate of 7%.

By detecting stripe artefacts, the algorithm overcomes the inherent shortcomings of the bolus harmonic imaging method and improves the presentation of the resulting parametric images. Moreover, it is a step necessary for automatic assessment of ultrasound parametric images to aid inexperienced physicians with their diagnosis. BHI in conjunction with this stripe artefact detection algorithm is in clinical evaluation in our group. It will be integrated into our UCA parametric imaging methods to form an expert application and promises to be an inexpensive and fast help in diagnosing acute stroke at the patient's bedside.

References

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