DETECTION OF FAULTS PRESENTED ON OLD OPTICAL SOUND TRACKS USING MATLAB

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Abstract

This paper deals with the Matlab application used for the detection of the most common faults present on scanned copies of old optical sound tracks, using benefits of image processing toolbox. Algorithms developed for transversal scratches, longitudinal scratches and dirt blotches detection are descibed. The application allows user to load scanned optical sound track, review it using various analysis tools and perform detection of selected fault type, review each detection step results and, where possible, change detection parameters to achieve the best possible result. Binary masks according to detected faults serve as an output. Additional functions of track analysis are for example the zoom function, evaluation of gray levels across and along the track, evaluation of histogram and simulation of selected fault impact with help of 3D spectrograms. Detection results using described algorithms implemented in previously mentioned application are presented and discussed.

1 Introduction

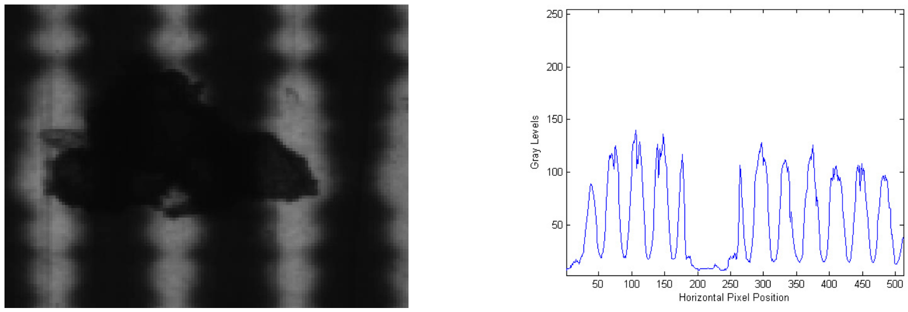
Motion pictures are not only theatrical art but also a vivid record of past life. Unfortunately, films deteriorate and nitro based ones are additionally highly inflammable. Deterioration can only be slowed down by storing prints at very low temperatures, which is not possible in all cases because of the costs of such a procedure and the number of films. In the past, the only possible method of a heavily damaged film material restoration was "by hand". This could be only done by experienced professionals. Furthermore such kind of restoration takes a lot of time because every frame has to be processed manually. Fortunately, the development of powerful computer technologies allows us to preserve them by transferring (scanning) movies to new digital media. Proper restoration is needed before backup by several reasons. Restoration improves the subjective quality of the material, therefore it leads to increasing a commercial value. Digital restoration, if it is correctly programmed, is generally more precise than manual and could be automated.

2 Common Relevant Faults

Most relevant faults, considering frequency of their appearance and their audibility, were chosen [1]. In this section, representative samples will be shown.

Blotches can be regions of dirt or result of the loss of gelatin covering the film. We can find two different types - black (see Figure1) and white blotches. White blotches occur when there is some dirt on the film negative. They are not so common as black blotches, thus only black ones should be considered as relevant.

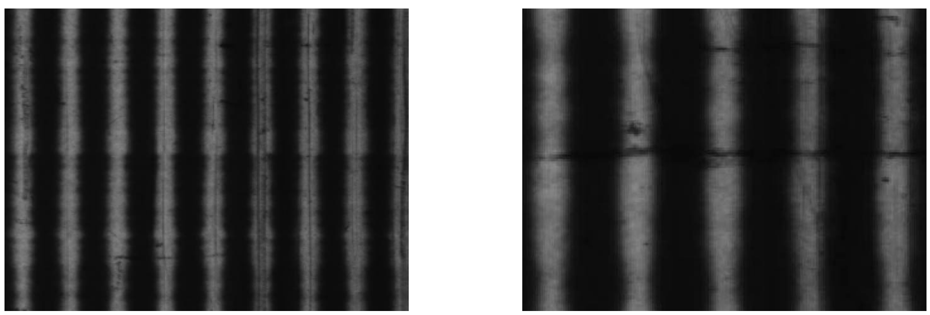
Longitudinal scratches are caused by playing the movie on badly maintained reproduction units or with abrasion with a piece of dirt during playing. They are very often appearing, as we can see in Figure2(a).



(a) (b)

Figure 1: (a) Dirt Blotch on a Film Positive (b) Corresponding Gray Levels Across the Track

Transversal scratches also appear quite often. This fault is caused by improper handling and storing of film material. Mostly common these were done when the film was wound onto the reel and surfaces rubbed against each other. They are usually not affecting whole width of sound track and are wider than logitudinal ones (see Figure 2(b)).



(a) (b)

Figure 2: (a) Longitudinal Scratches (b) Transversal Scratches

3 Detection of Selected Faults

3.1 Trace Interruptions

There are several different faults which can result into trace interruption, but we are interested only in black blotches and transversal scratches. Method of trace interruptions detection was outlined in [2]. This method was extended with automated trace centers detection. Detection can be divided into following steps:

1. Noise Filtering
2. Binarization
3. Detached Traces Localization
4. Labeling Connected Components
5. Localized Faults Categorizing

Proper noise filtering is essential preprocessing step. If noise reduction was not done, it could lead to disturbance of further processing algorithms followed by their malfunction. For this, median filter [3] is used. Filter dimensions were set to 1x8 pixels to preserve vertical details.

Next, image is binarized, simply by classifying all pixels with gray values above the threshold as 1, and all other pixels as 0.

Now we need to locate trace centers, which will be used as initial points of the detection. Traces in the first line of binarized track window are labeled [4]. If number of traces is lower or higher than expected, it means that there is at least one trace impaired by a fault and the next line is examined. If the number of detected traces is exactly the expected number, each trace width and a mean width is computed and they are compared. If the width of each trace is within allowed deviation, line is considered to be unimpaired by a fault and a center position of each trace is computed.

After the center of each trace is localized, detection of interruptions can be applied using previously mentioned algorithm proposed in [2]. Each pixel belonging to the center of each trace is examined. If the pixel is black, it means that trace is probably interrupted and pixel according to this position is marked in the binary mask representing found faults. After that, pixel to the left from center is examined. If it is also black, it is marked. This is done until white pixel or track boundary is reached. The same analysis of neighboring pixels is done to the right from the center. If both directions were examined, center pixel of the next trace is processed. If all traces in current line were processed, the next line is analyzed.

The next step after creating the binary mask corresponding to detected trace interruptions is to label connected pixels by unique labels. This will give us possibility to separate detected faults from each other and determine their positions and dimensions. Connected component, is usually defined as a set of connected, non zero pixels, where two pixels being connected means that it is possible to construct a path including only non zero pixels between them [4].

Once the interrupted traces were detected and each interruption was given its own label, sorting process can start. The purpose is to determine which fault caused the detected interruption. This is done by comparing the shape of each interruption with a different fault model. If the shape of interruption was detected properly, there is a high probability that corresponding fault will be chosen correctly.

3.2 Longitudinal Scratches

Method described in this section uses an analysis of a gray value line 1st derivation (gradient). We can divide the process of vertical scratches detection into following steps:

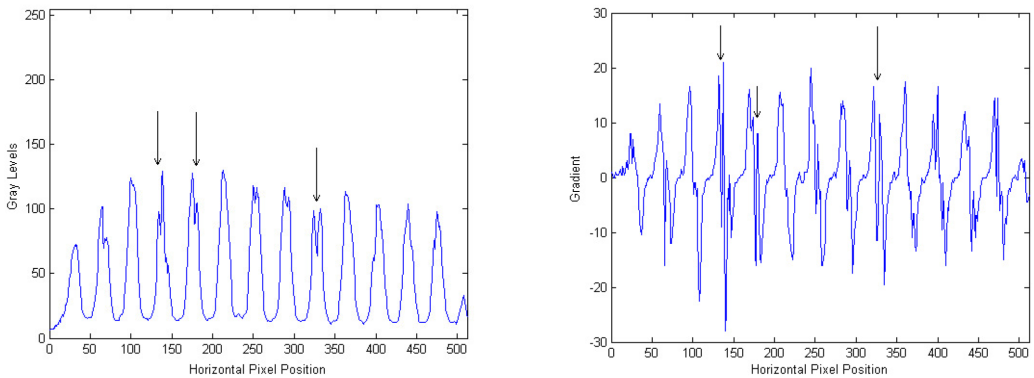
1. Computing the Gradient
2. Analysis of Gradient
3. Discarding Faulty Detections

The image is processed line by line. An example of processed line gray levels can be seen in Figure 3(a). We can notice here a rapid change of the gray level on spots with present scratches (marked with arrows). But this change is not so rapid to perform a scratch detection based only on a gray levels analysis. Hence the gray levels in each line are derived to obtain its gradient values. Partial derivation in a digitized image is approximated by the 1st difference in the x

and y direction [3]. We are interested only in vertical structures here, so only difference in the x direction will be used:

$$\Delta x f(i,j) = f(i,j) - f(i,j-1) \tag{1}$$

The graph of such gradient computed for line in Figure 3(a) can be seen in Figure 3(b). We can notice here more rapid changes between neighbouring gradient values on spots with present scratches than changes of gray levels. Next, thresholding is performed to mark the most significant changes of gradient. These spots are marked as scratches. It is obvious that this method produces some faulty detections, caused for example by dust particles present. Their filtering is based on a fact, that longitudinal scratches are long vertical structures, so too short structures can be discarded as faulty detected. Analysis of each detected pixel's neighborhood is performed. If the analyzed pixel is part of a structure shorter than three pixels, or even a standalone one, it is assumed to be faulty detected and therefore deleted from the binary mask. Value of 3 pixels was set according to minimal audible faut length [1].



(a) (b)

Figure 3: (a) Gray Levels Across the Track (b) Gradient Across the Track

3.3 Transversal Scratches

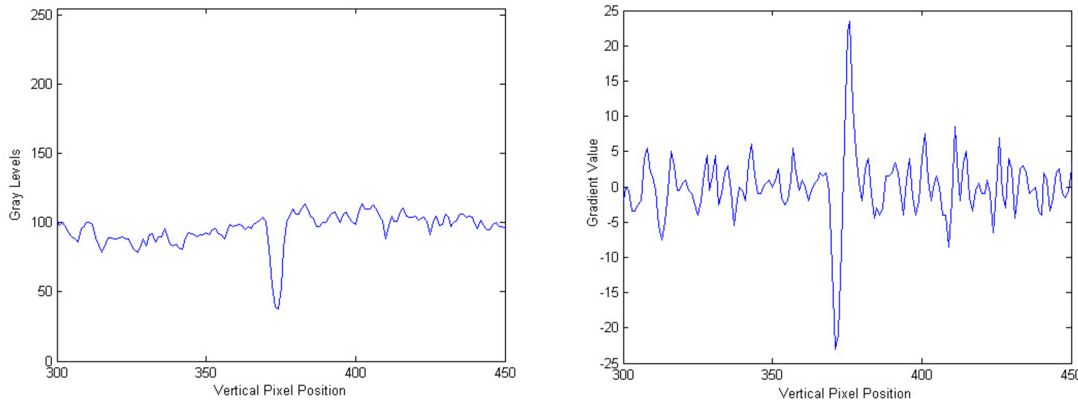
Transversal scratches detection is slightly different from longitudinal scratches detection. Transversal scratches are wider, so just detection of gradient extremes does not solve the problem. Following steps have to be done:

1. Computing Gradient
2. Analysis of Gradient
3. Discarding Faulty Detections

Transversal scratches are resulting in horizontal trace edges, so we will compute the gradient in vertical (y axis) direction:

$$\Delta y f(i,j) = f(i,j) - f(i-1,j) \tag{2}$$

Example of gray levels in column affected by a scratch and the gradient of the same spot can be seen in Figure 4. We can see that a scratch has sharp edges and is resulting in local gradient



(a) (b)

Figure 4: (a) Gray Levels in Column Affected by Transversal Scratch (b) Gradient of the Same Column

extremes. Next, noise filtering has to be applied to reduce extreme gradient values invoked by for example dust. Again, median filter with dimension of 8x1 pixels is used.

The gradient image is scanned column by column, line by line. If there is found gradient value lower than the first threshold, it indicates a start of the scratch. Current pixel position is marked as faulty to the binary mask and gradient value under the current one is evaluated. If it is lower than the second threshold, pixel is also marked as faulty. This continues until higher gradient value than the second threshold, which indicates end of the scratch, or the end of the track window is reached. However, detached traces due to low sensitivity of recording equipment or spots with high dynamic range of recorded sound can be also detected as start of the scratch as well as dirt blotches. Such faulty detections have to be removed.

To analyze detected fault size, we have to label connected components [4]. Once connected components, representing each detected fault, are labeled, their size can be evaluated. As we are interested only in transversal scratches, following conditions can be applied to consider detection to be a transversal scratch:

- horizontal size at least 5 pixels
- vertical size within the range <3;8> pixels
- horizontal/vertical size ratio at least 1,5

If labeled detection does not meet at least one of these conditions, it is removed from the binary mask. This will remove all detections caused by other faults.

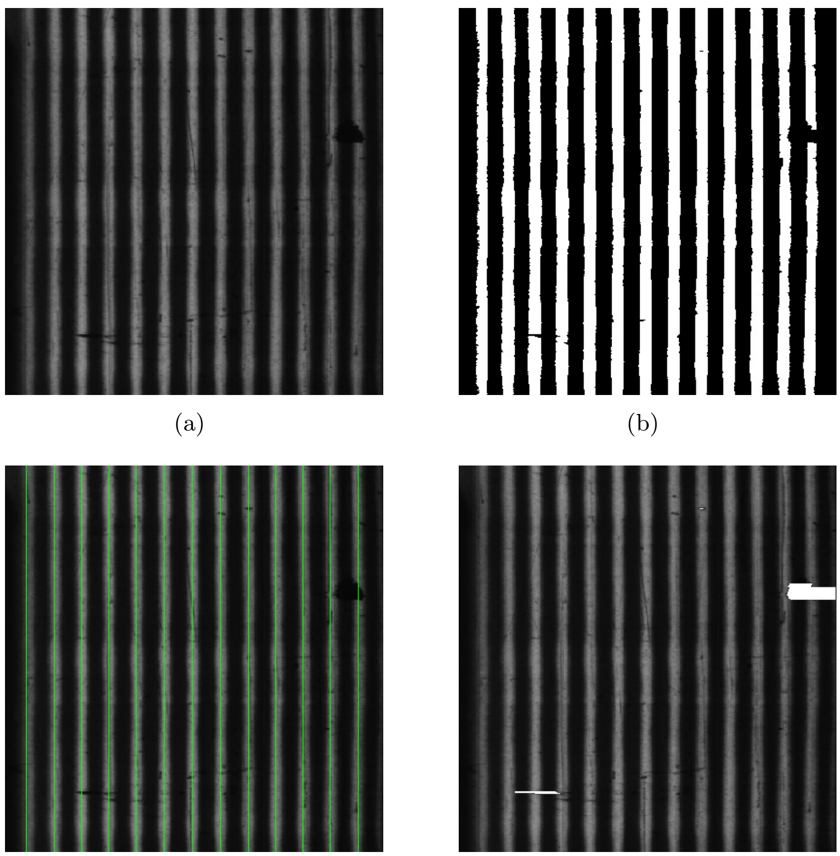
Next step to discard remaining faulty detections is to binarize the track and compare it with the binary mask. High binarization threshold has to be used in order to ensure that not even edges of scratches with slightly lower gray levels will be considered to be part of a trace. All binary mask pixels having value 1 on the same position where binarized track has also 1 (considered to be a part of the trace) are removed.

4 Results

The sound track used for the testing was from heavily corrupted German movie "Im Tal der Wiese", produced in 1942. Sound track contained in this movie was multiple double sided variable area code with 13 traces. It was scanned into *.raw format using these parameters:

- 512 pixels per line
- 2000 pixels per frame
- 256 gray levels

In Figure 5(a) we can see original track window impaired by a black blotch and a transversal scratch. Track is binarized (see Figure 5(b)) and traces centers are detected (see Figure 5(c)). On last figure (see Figure 5(d)) we can see original track window with marked faults. Both transversal scratch and black blotch were successfully detected.



(a) (b)

(c) (d)

Figure 5: (a) Original Track (b) Binarized Track (c) Detected Traces Centers (d) Track with all Faults Marked

In Figure 6(b) we can see binary mask according to detected longitudinal scratches presented on original track (see Figure 6(a)) before faulty detections filtering. Faulty detections are filtered (see Figure 6(c)) and detected scratches are marked in Figure 6(d). As we can see, heavy scratches were detected successfully. Just very slight scratches, which do not impaire sound quality were not detected.

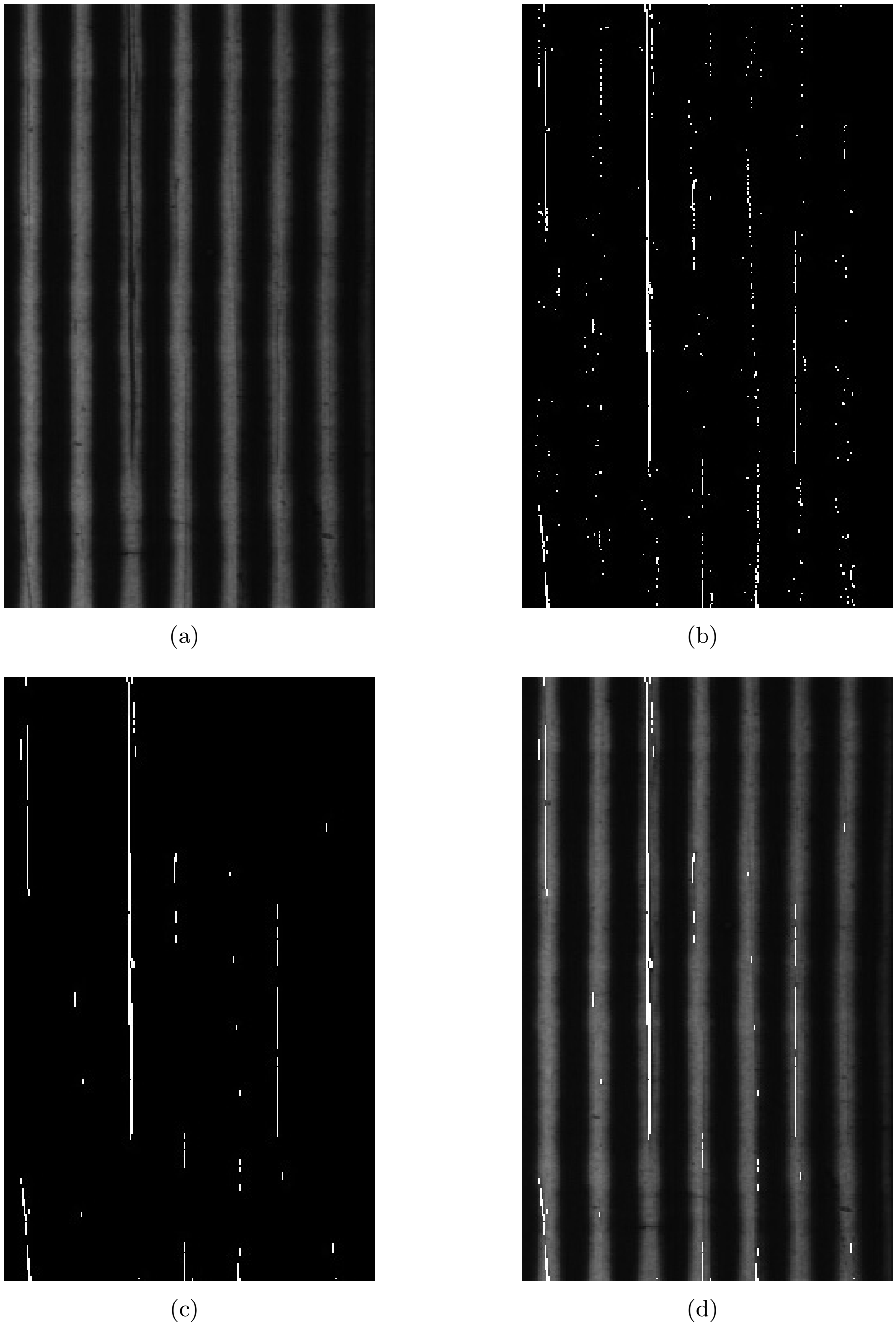


Figure 6: (a) Original Heavily Scratched Track (b) Binary Mask of Detected Scratches (c) Binary Mask without Faulty Detections (d) Original Track with Marked Scratches

Gradient image of original track window (see Figure 7(a)) can be seen in Figure 7(b). Scratches are detected (see Figure 6(c)) and filtered using binarized track (see Figure 7(d)). Finally we can see original track window with marked scratches in Figure 7(e).

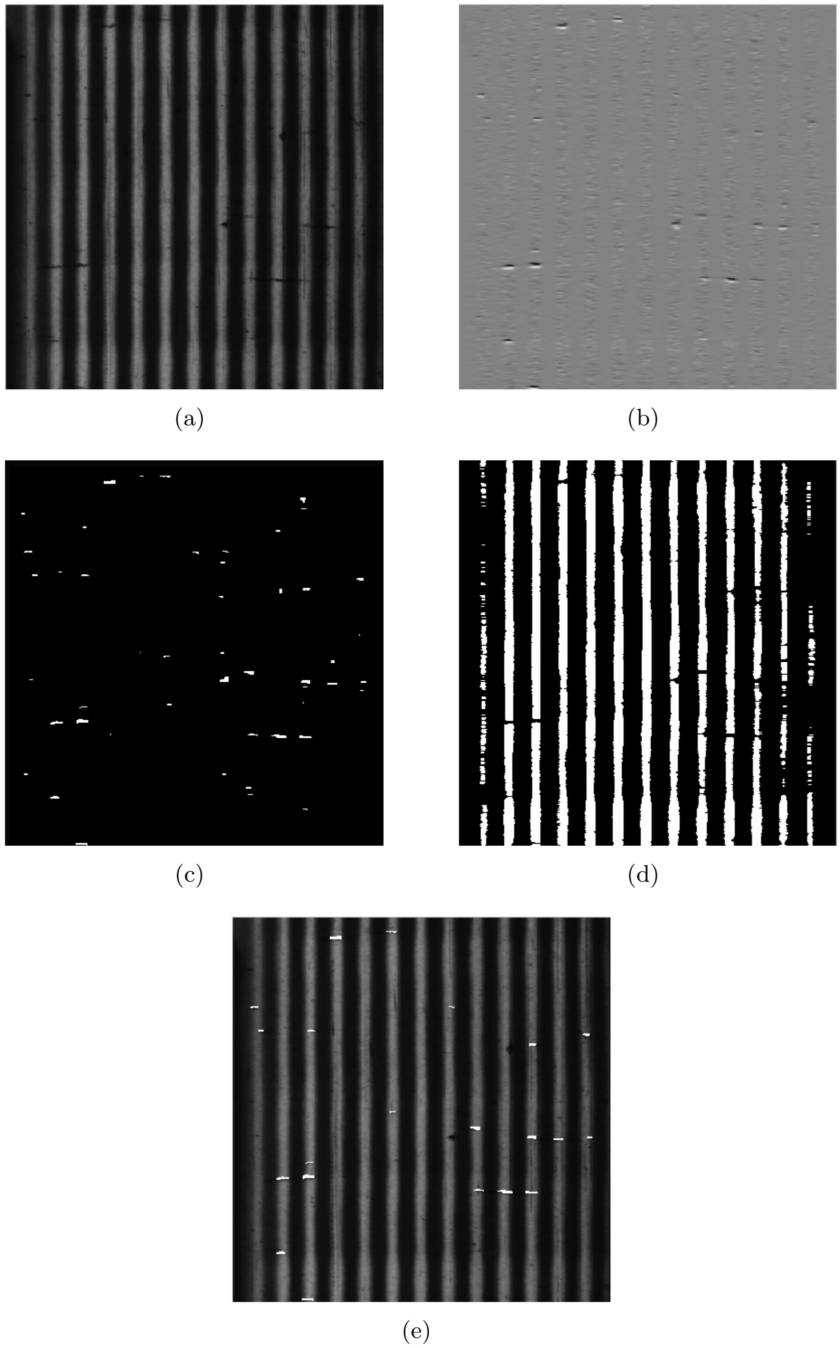


Figure 7: (a) Original Heavily Scratched Track (b) Gradient in Vertical Direction (c) Binary Mask before Filtering (d) Binarized Track (e) Track with Marked Scratches

5 Conclusion

All above mentioned detection algorithms were implemented in the Matlab application. Parameters of each detection step can be changed, if possible, to experiment with their settings in order to receive the best detection results. Binary masks representing detected faults serve as the output. This application could be later extended by faults removal algorithms to provide fully automated detection and removal. Algorithms work accurate enough to serve as initial point for such restoration.

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