# METHODS, APPARATUS AND PROGRAM STORAGE DEVICE FOR REMOVING SCRATCH OR WIRE NOISE, AND RECORDING MEDIA THEREFOR

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to methods and apparatus for removing noise from digital images, such as for example, digitized photographic images or computer generated images ("CGI") and more particularly to scratches in, or debris on, old motion picture and still photographic films, as well as special effects wires, or supports, used for special effects in motion picture scenes. The present invention further relates to noise induced into digital images due to transmission errors, or malfunctions of image recording or scanning equipment. The present invention also relates to program storage devices for the methods of the present invention, and to recording medium having recorded thereon digital data prepared using the methods of the present invention.

2. Description of the Related Art

With the growing proliferation of available channels for television broadcast and the increasing use of multimedia viewing platforms, many older motion picture and still frame films are likely to see increased use through transfers to video and digital formats. Unfortunately, many old motion and still photographic films have, over the years of use and viewing, become scratched or dirtied with dust or other debris. Since high definition and digital television formats, as well as other digital multimedia formats, will allow imperfections, such as scratches or debris on the film stock, to be quite noticeable to viewers, there is an increasing need for a method of removing scratches from digitized images without degrading or otherwise adversely affecting the perceived quality of the image.

In motion pictures, for example, certain special effects require actors, models or objects in a scene to be suspended or supported via a wire, cable, rod or the like or so as to create the effect of, for example the actor, model or object floating aloft. Typically, the appearance of these wires, cables, rods etc. is later removed from visibility in the scene during post production via optical processing or, more typically these days, via digital processing of the digitized film. Similarly in desktop publishing it is often desirable to remove unwanted portions of an image or erase scratches or blemishes from photographs. It should be noted that the usage of the term "scratch" or "scratch noise" as used herein, is intended to include all of the above noted types of noise which may occur in a digitized image.

A scratch in a digitized image presents itself as unwanted pixels in the digitized image. Scratch noise typically consists of a plurality of contiguous pixels rather than small isolated groups, or clusters, of pixels. In a digitized image, scratch noise may consist of an area of pixels of, for example, 10 pixels×100 pixels, and may fall in an area of the digitized image wherein details such as textures or edges are crossed by the scratch. In order to remove the scratch from the digitized image, the pixels which make up the scratch area must be replaced with pixel data which represents, or emulates the original data. In order to effectively repair scratched areas, this pixel data should allow the resulting image to be as sharp in the scratch area as in the surrounding area. Further, continuity of prominent edges should be maintained, and textures created to replace the wire or scratch pixels should match the surrounding texture.



The effectiveness of currently known techniques of digital processing varies according to the features of the image and their relative size within the image at issue and whether they are regularly or randomly occurring. Examples of regularly occurring features include a brick wall or fabric weave texture. Examples of randomly occurring features may include an asphalt roadway or concrete walk or sandy beach. The effectiveness of known techniques also depends upon the size and type of the scratch area. Scratches which show up as small, isolated clusters of noise pixels in smooth or blurred areas of an image are typically relatively easy to remove through known techniques such as filtering or simple cloning and painting techniques. However, existing noise removal techniques fall short where the scratch consists of a plurality of contiguous pixels or falls in a textured area of an image or in areas having prominent edges, or lines.

Currently known techniques of image noise removal can be generally categorized into two types: 1) intra-frame techniques and 2) inter-frame techniques. The difference between these two general types of techniques centers primarily on where data for replacement of noise pixels is obtained from. Inter-frame techniques typically copy pixel data needed to replace noise pixels from preceding or succeeding frames. Intra-frame techniques, on the other hand, typically utilize data within the image frame to be repaired for replacement of noise pixels.

Inter-frame methods typically fail to provide suitable results where the images/scenes at issue reflect an extreme level of camera movement or scene activity. These methods also tend to fall short where the scratch extends across several image frames, or where the damaged image frame is the only image frame available for providing data for repairing the image. Unfortunately, it is common for scratches to run across several image frames, because of the motion of typical motion picture films through a typical motion picture projector. In these situations, corresponding pixel data from a preceding/succeeding image frame is not readily available for replacement/copying to the scratched area.

Known techniques of scratch noise removal have addressed the problem of scratch noise removal in several ways, including: (a) low-pass and other linear filtering (b) median and other non-linear filtering, (c) statistical texture synthesis (d) cloning, i.e. copying another part of the image (e) painting manually (f) projection based methods and (g) methods based on solving simultaneous equations. However, these techniques have been less than successful in providing scratch removal so as to yield optimum results in a variety of scratch/image situations. Every image can be considered to be made up of many different undulating images, each having specific rate and amount by which they undulate. Such an analysis of an image into its component undulating images can be done by a method known as fast fourier transform ("FFT"). When the image is analyzed in this way and the information produced by FFT is manipulated, this is known as working in the frequency domain. When an operation is done to the image itself it is known as an operation in spatial domain.

The methods (a) to (e) suffer from the shortcoming that they work only in one such domain. Frequency domain algorithms can capture global structure of the image but lose local control (line continuity, sharpness). As a result, lines and other details become blurred. One problem shared by all spatial-only methods is that they have local control and information but do not have any information about the global structure of the image. The limitation to a local