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(54) Title: A SYSTEM AND METHOD FOR NOISE REDUCTION IN FLUOROSCOPY USING DWT

(57) Abstract: According to an embodiment, the disclosed system receives an image sequence in real time. An input image frame is selected from the received image sequence modified input image is generated by applying a weighted frame averaging on the input image and an image frame next to the/input image. A discrete wavelet transform (DWT) is applied to the input image to decompose into a first approximation band. The discrete wavelet transform (DWT) is further applied to decompose the modified input image into a modified approximation band, a vertical band, a horizontal band and a diagonal band. An inverse DWT is applied to the last obtained modified approximation band to result in a denoised output approximation band.

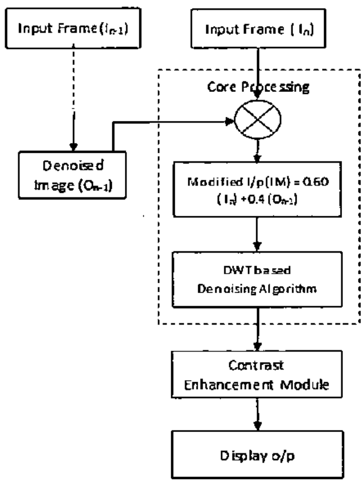

Figure 1

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ABSTRACT

A System and Method for Noise Reduction in fluoroscopy using DWT

According to an embodiment, the disclosed system receives an image sequence in real time. An input image frame is selected from the received image sequence. A modified input image is generated by applying a weighted frame averaging on the input image and an image frame next to the input image. A discrete wavelet transform (DWT) is applied to the input image to decompose into a first approximation band. The discrete wavelet transform (DWT) is further applied to decompose the modified input image into a modified approximation band, a vertical band, a horizontal band and a diagonal band. An inverse DWT is applied to the last obtained modified approximation band to result in a denoised output approximation band.

FIELD OF INVENTION

The invention generally relates to image processing and particularly to a system and method of noise reduction in fluoroscopy using a discrete wavelet transform (DWT).

BACKGROUND

Fluoroscopy is an imaging technique that uses X-rays to obtain real-time moving images of the interior of an object. Fluoroscopy provides continuous X-ray images of anatomies and is widely adopted as support in surgery procedures and diagnoses for real-time operations carried out on patient for a long period of time. Radiation-induced for long period may cause injuries to the skin and underlying tissues. To avoid the damage, very low X-Ray doses are used. As a result, fluoroscopic images are strongly corrupted by noise. These images exhibit severe signal-dependent quantum noise that is referred to as quantum mottle and generally modelled as Poisson-distribution.

Many denoising algorithms were designed specifically for both signal-dependent noise (AAS, BM3Dc, HHM, TLS) and signal-independent additive noise (AV, BM3D, K-SVD). However, the execution time for existing denoising algorithms is very high and it introduces blurring and therefore, can't be used in real time operations. Many of the existing systems uses FPGA/GPU implementations which are not cost-effective. Hence, there is a need to develop a computationally inexpensive solution.

In the existing system, consecutive 18 frames are averaged to get a noise free image. As 18 frame averaging is computationally heavy, the output images are displayed for every 18 frame and the resultant image suffers from trailing effect because of the motion in consecutive frames.

Hence, there is a need to devise a noise reduction algorithm for fluoroscopy images to address the above-mentioned challenges.

The present invention is directed to overcoming one or more of the problems as set forth above.

SUMMARY OF THE INVENTION

Exemplary embodiments of the invention disclose a system and method for performing real-time fluoroscopy image sequence processing. According to an embodiment, the disclosed system and method receives an image sequence in real time, the image sequence comprising a plurality of images. An input image frame is selected from the received image sequence. A modified input image is generated by applying a weighted frame averaging on the input image and an image frame next to the input image. A discrete wavelet transform (DWT) is applied to the input image to decompose into a first approximation band. The step of applying discrete wavelet transform (DWT) on the input image is repeated for a predefined number of times such that each decomposition uses previously obtained approximation band and generates a new approximation band. The discrete wavelet transform (DWT) is further applied to decompose the modified input image into a modified approximation band, a vertical band, a horizontal band and a diagonal band. An average modified approximation band is generated by computing average of the modified approximation band and the first approximation band. The discrete wavelet transform (DWT) is applied to decompose the average modified approximation band into a subsequent modified approximation band, vertical band, horizontal band and diagonal band. The step of generating the average modified approximation band is repeated followed by decomposition for a predefined number of times, such that each subsequent generation uses previously obtained modified approximation band and corresponding approximation band obtained by the repeating step of DWT on the input image. An inverse DWT is applied to the last obtained modified approximation band and last obtained thresholded vertical, horizontal and diagonal bands to result in a denoised output approximation band. The step of applying inverse DWT is repeated for a predefined number of times to obtain a final denoised output image, such that each time last obtained denoised output approximation band is used with the thresholded vertical, horizontal and diagonal bands obtained in a step previous to the corresponding denoised output approximation band.

BRIEF DESCRIPTION OF DRAWINGS

Other objects, features, and advantages of the invention will be apparent from the following description when read with reference to the accompanying drawings. In the drawings, wherein like reference numerals denote corresponding parts throughout the several views:

Figure 1 illustrates a high-level block diagram for noise reduction in fluoroscopy, according to an embodiment of the invention; and

Figure 2 illustrates a detailed block diagram of core processing for noise reduction in fluoroscopy, according to an embodiment of the invention.

DETAILED DESCRIPTION OF DRAWINGS

The following description with reference to the accompanying drawings is provided to assist in a comprehensive understanding of exemplary embodiments of the invention. It includes various specific details to assist in that understanding but these are to be regarded as merely exemplary. Accordingly, those of ordinary skill in the art will recognize that various changes and modifications of the embodiments described herein can be made without departing from the scope and spirit of the invention. In addition, descriptions of well-known functions and constructions are omitted for clarity and conciseness.

According to embodiments of the invention, a system and method for performing a real-time fluoroscopy image sequence processing is disclosed. Figure 1 illustrates a high-level block diagram for noise reduction in fluoroscopy, according to an embodiment of the invention. As illustrated, a modified input image may be generated from denoised image output O_{n-1} of an image frame I_{n-1}, and an image frame I_n that occurs next to the image frame I_{n-1}. According to an exemplary embodiment, the modified input image may be generated by performing weighted average of 60 percent of I_n and 40 percent of O_{n-1}. A Discrete Wavelet Transform (DWT) may be applied to the modified input image. According to an embodiment, the generation of the modified input image and DWT occur in a core processing module. According to another embodiment, the output from the core processing module may be fed to a post processing module. According to an embodiment, the post processing module may be a contrast enhancement module. According to an exemplary embodiment, the post processing may be performed using histogram equalization, adaptive histogram equalization or gamma correction.

Exemplary embodiments of the invention disclose a system and method for performing real-time fluoroscopy image sequence processing. According to an embodiment, the disclosed system and method receives an image sequence in real time, the image sequence comprising a plurality of images. An input image may be selected from the received image sequence. A modified input image is generated by applying a weighted frame averaging, on a denoised output of the input image and an image frame next to the input image. According to an exemplary embodiment, the modified input image may be generated by performing weighted average of 40 percent of denoised output of the input image and 60 percent of the image frame next to the input image. A discrete wavelet transform (DWT) is applied to the input image to decompose into a first approximation band. According to an embodiment, the DWT may be applied to the input image to decompose into multiple frequency bands including a first approximation band, a vertical band, a horizontal band and a diagonal band. The step of applying discrete wavelet transform (DWT) on the input image is repeated for a predefined number of times such that each decomposition uses previously obtained approximation band and generates a new approximation band. According to an exemplary embodiment, if predefined number of decompositions is defined as 2, then the DWT may be applied on the first approximation band to generate a second approximation band. According to another exemplary embodiment, if predefined number of decompositions is defined as 3, then the DWT may be further applied on the second approximation band to generate a third approximation band.

The discrete wavelet transform (DWT) may be further applied to the modified input image to decompose the modified input image into a modified approximation band, a vertical band, a horizontal band and a diagonal band. According to an exemplary embodiment, the decomposition of the modified input image may be performed using a Harr wavelet decomposition filter. An average modified approximation band is generated by computing average of the modified approximation band and the first approximation band. The discrete wavelet transform (DWT) is applied to decompose the average modified approximation band into a subsequent modified approximation band, vertical band, horizontal band and diagonal band. The step of generating the average modified approximation band may be repeated followed by decomposition for a predefined number of times, such that each subsequent generation uses previously obtained modified approximation band and corresponding approximation band obtained by the repeating step of DWT on the input image. According to an exemplary embodiment, a second average modified approximation band for the second generation may be computed by average of the corresponding modified approximation band and the second approximation band. Similarly, a third average modified approximation band for the third generation may be computed by average of the corresponding modified approximation band and the third approximation band.

An inverse DWT may be applied to the last obtained modified approximation band and last obtained thresholded vertical, horizontal and diagonal bands to result in a denoised output approximation band. According to an embodiment, the last obtained modified approximation band may refer to the modified approximation band corresponding to last level of decomposition of predefined levels of decomposition. According to another embodiment, the last obtained thresholded vertical, horizontal and diagonal bands may refer to the thresholded vertical, horizontal and diagonal bands corresponding to last level of decomposition. According to an embodiment, the thresholded vertical, horizontal and diagonal bands may be obtained by applying soft thresholding to the vertical, horizontal and diagonal bands. According to another embodiment, the soft thresholding may be applied to all vertical, horizontal and diagonal bands using Bayesian shrinkage estimate to suppress the noise present in the image. The step of applying inverse DWT is repeated for a predefined number of times to obtain a final denoised output image, such that each time last obtained denoised output approximation band is used with the thresholded vertical, horizontal and diagonal bands obtained in a step previous to the corresponding denoised output approximation band.

Figure 2 illustrates a detailed block diagram of core processing for noise reduction in fluoroscopy, according to an exemplary embodiment of the invention. A plurality of real time image frames of a fluoroscopy image sequence is received. According to an embodiment, the fluoroscopy image sequence may comprise a plurality of images. An input image frame I_n is selected from the image sequence and a modified input image (202) may be generated by applying a weighted frame averaging on the selected input image frame I_n and an image frame next to the input image frame I_{n+1}. According to an embodiment, a discrete wavelet transform (DWT) may be applied to the input image frame I_n to decompose into multiple frequency bands including a first approximation band $A_{(n-1)1}$(204). The DWT may be repeated on the input image for a predefined number of times. According to an exemplary embodiment, the DWT may be performed three times on the input image. The DWT may be applied on the first approximation band to generate a second approximation band (230). Similarly, the DWT may be applied on the second approximation band to generate a third approximation band (244).

The DWT (206) may be applied to the modified input image (202) to decompose the modified input image into a first modified approximation band A_{n1}(208), a first vertical band V_{n1}(210), a first horizontal band H_{n1}(212) and a first diagonal band D_{n1}(214). According to an exemplary embodiment, the decomposition of the modified input image may be performed using a Harr wavelet decomposition filter. An average of the first modified approximation band (208) and the first approximation band $A_{(n-1)1}$(204) may be computed to generate a first average modified approximation band MA_{n1}(216).

The DWT (218) may be applied to decompose the first average modified approximation band MA_{n1}(216) into a second modified approximation band A_{n2}(220), a second horizontal band

H_{n2}(222) and a second diagonal band D_{n2}(224) and a second vertical band V_{n2}(226). An average of the second modified approximation band A_{n2}(220) and the second approximation band $A_{(n-1)2}$(230) may be computed to generate a second average modified approximation band MA_{n2}(228).

The DWT (232) may be applied to decompose the second average modified approximation band MA_{n2}(228) into a third modified approximation band A_{n3}(234), a third vertical band V_{n3}(236), a third horizontal band H_{n3}(238) and a third diagonal band D_{n3}(240). An average of the third modified approximation band A_{n3}(234) and the third approximation band $A_{(n-1)3}$(244) may be computed to generate a third average modified approximation band MA_{n3}(242).

An inverse DWT (246) may be applied to the third average modified approximation band MA_{n3}(242) and thresholded third vertical band TV_{n3}(248), a third horizontal band TH_{n3}(250) and a third diagonal band TD_{n3}(252) to result in a first denoised output approximation band OA_{n2}(254).

The inverse DWT (256) may be applied to the first denoised output approximation band OA_{n2}(254) and thresholded second horizontal band TH_{n2}(258), second vertical band TV_{n2}(260) *and a second diagonal band* TD_{n3}*(262) to result in a second denoised output approximation* band OA_{n1}(264).

The inverse DWT (266) may be applied to the second denoised output approximation band OA_{n1}(264) and thresholded first vertical band TV_n(268), first horizontal band TH_n(270) and a first diagonal band TD_n(272) to result in a final denoised output image O_n(274).

Exemplary embodiments of the invention disclose a system for performing real-time fluoroscopy image sequence processing. The system for performing real-time fluoroscopy image sequence processing includes a pre-processing module, a core processing module and a post processing module. The pre-processing module may receive a fluoroscopy image sequence in real time. The image sequence may comprise a plurality of images. According to an embodiment, an input image may be selected from the received image sequence. The denoised output of the selected input image and an image frame next to the input image may be fed to a core processing module. The core processing module may generate the modified input image by applying a weighted frame averaging on the denoised output of the input image and the image frame next to the input image. Further, DWT based denoising algorithm may be applied to the modified input image for a predefined number of times. The final output of the core processing module may be a denoised output image. The output of the core processing module may be fed to a post processing module. According to an embodiment, the post processing module may enhance contrast of the denoised output image.

In the drawings and specification there has been set forth preferred embodiments of the invention, and although specific terms are employed, these are used in a generic and descriptive sense only and not for purposes of limitation. Changes in the form and the proportion of parts, as well as in the substitution of equivalents, are contemplated as circumstances may suggest or render expedient without departing from the spirit or scope of the invention.

Throughout the various contexts described in this disclosure, the embodiments of the invention further encompass computer apparatus, computing systems and machine-readable media configured to carry out the foregoing systems and methods. In addition to an embodiment consisting of specifically designed integrated circuits or other electronics, the present invention may be conveniently implemented using a conventional general purpose or a specialized digital computer or microprocessor programmed according to the teachings of the present disclosure, as will be apparent to those skilled in the computer art.

The embodiments of the present invention may be provided as a computer program product that may include a machine-readable medium, having stored thereon instructions which may be used to program a computer (or other electronic devices) to perform a process according to the present invention. The machine-readable medium may include, but is not limited to, floppy diskettes, optical disks, compact disc read-only memories (CD-ROMs), and magneto-optical disks, ROMs, random access memories (RAMs), erasable programmable read-only memories (EPROMs), electrically erasable programmable read-only memories (EEPROMs), magnetic or optical cards, flash memory, or other type of media/machine-readable medium suitable for storing electronic instructions. In addition to an embodiment consisting of specifically designed integrated circuits or other electronics, the present invention may be conveniently implemented using a conventional general purpose or a specialized digital computer or microprocessor programmed according to the teachings of the present disclosure, as will be apparent to those skilled in the computer art.

Appropriate software coding can readily be prepared by skilled programmers based on the teachings of the present disclosure, as will be apparent to those skilled in the software art. The invention may also be implemented by the preparation of application specific integrated circuits or by interconnecting an appropriate network of conventional component circuits, as will be readily apparent to those skilled in the art.

We Claim:

1. A method for performing real-time fluoroscopy image sequence processing, the method comprising:

selecting an input image frame from a received image sequence comprising a plurality of images;

generating a modified input image by applying a weighted frame averaging on the input image and an image frame next to the input image frame;

applying a discrete wavelet transform (DWT) to the input image to decompose into an approximation band;

repeating the step of discrete wavelet transform (DWT) on the input image for a predefined number of times such that each decomposition uses previously obtained approximation band and generating a new approximation band;

applying a discrete wavelet transform (DWT) to decompose the modified input image into a modified approximation band, a vertical band, a horizontal band and a diagonal band;

generating an average modified approximation band by computing average of the modified approximation band and a first approximation band and applying a discrete wavelet transform (DWT) to decompose the average modified approximation band into a subsequent modified approximation band, vertical band, horizontal band and diagonal band;

repeating the step of generating the average modified approximation band followed by decomposition for the predefined number of times, such that each subsequent generation uses previously obtained modified approximation band and corresponding approximation band obtained by the repeating step of DWT on the input image;

applying inverse DWT to the last obtained modified approximation band and last obtained thresholded vertical, horizontal and diagonal bands to result in a denoised output approximation band; and

repeating the step of applying inverse DWT the predefined number of times to obtain a final denoised output image, such that each time last obtained denoised output approximation band is used with the thresholded vertical, horizontal and diagonal bands obtained in a step previous to the corresponding denoised output approximation band.

2. The method as claimed in claim1, wherein the decomposition of the modified input image is performed using a Harr wavelet decomposition filter.

3. The method as claimed in claim1, further comprising post processing the reconstructed image for enhancing contrast of the image.

4. The method as claimed in claim 2, wherein post processing the reconstructed image is performed using histogram equalization, adaptive histogram equalization or gamma correction.

5. The method as claimed in claim 1, wherein the thresholding values are obtained using Bayes shrinkage estimation.

6. A method for performing real-time fluoroscopy image sequence processing, the method comprising:

receiving a plurality of real time image frames of a fluoroscopy image sequence comprising a plurality of images;

selecting an input image frame from the received image sequence;

generating a modified input image by applying a weighted frame averaging on the first image and an image frame next to the input image frame;

applying a discrete wavelet transform (DWT) to the input image frame to decompose into multiple frequency bands, the multiple frequency bands including a first approximation band;

applying the discrete wavelet transform (DWT) to the first approximation band to decompose into a second approximation band;

applying the discrete wavelet transform (DWT) to the second approximation band to decompose into a third approximation band;

applying the discrete wavelet transform (DWT) to decompose the modified input image into a first modified approximation band, vertical band, horizontal band and diagonal band;

generating a first average modified approximation band by computing average of the first modified approximation band and the first approximation band;

applying a discrete wavelet transform (DWT) to decompose the first average modified approximation band into a second modified approximation band, vertical band, horizontal band and diagonal band;

generating a second average modified approximation band by computing average of the second modified approximation band and the second approximation band;

applying a discrete wavelet transform (DWT) to decompose the second average modified approximation band into a third modified approximation band, vertical band, horizontal band and diagonal band;

generating a third average modified approximation band by computing average of the third modified approximation band and the third approximation band;

applying inverse DWT to the third average modified approximation band and thresholded third vertical, horizontal and diagonal bands to result in a first denoised output approximation band;

applying inverse DWT to the first denoised output approximation band and thresholded second vertical, horizontal and diagonal bands to result in a second denoised output approximation band; and

applying inverse DWT to the second denoised output approximation band and thresholded first vertical, horizontal and diagonal bands to result in a final denoised output image.

Dated this 29th day of March 2019

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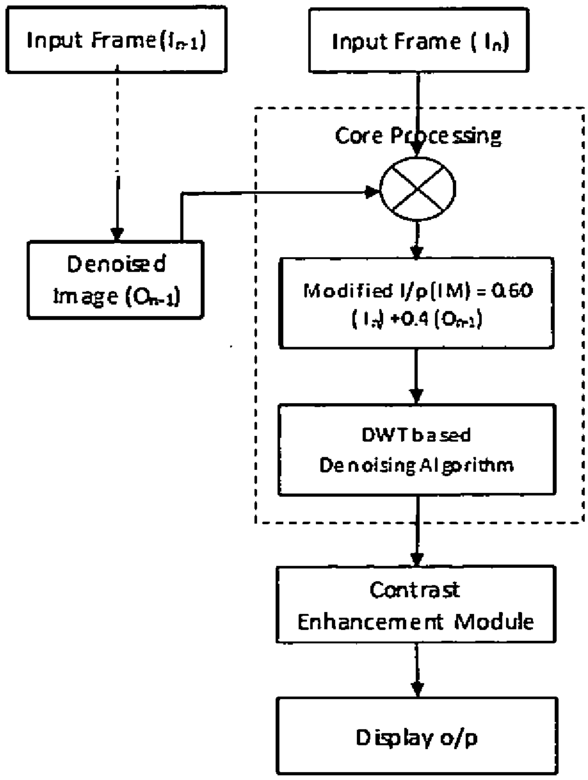

Figure 1

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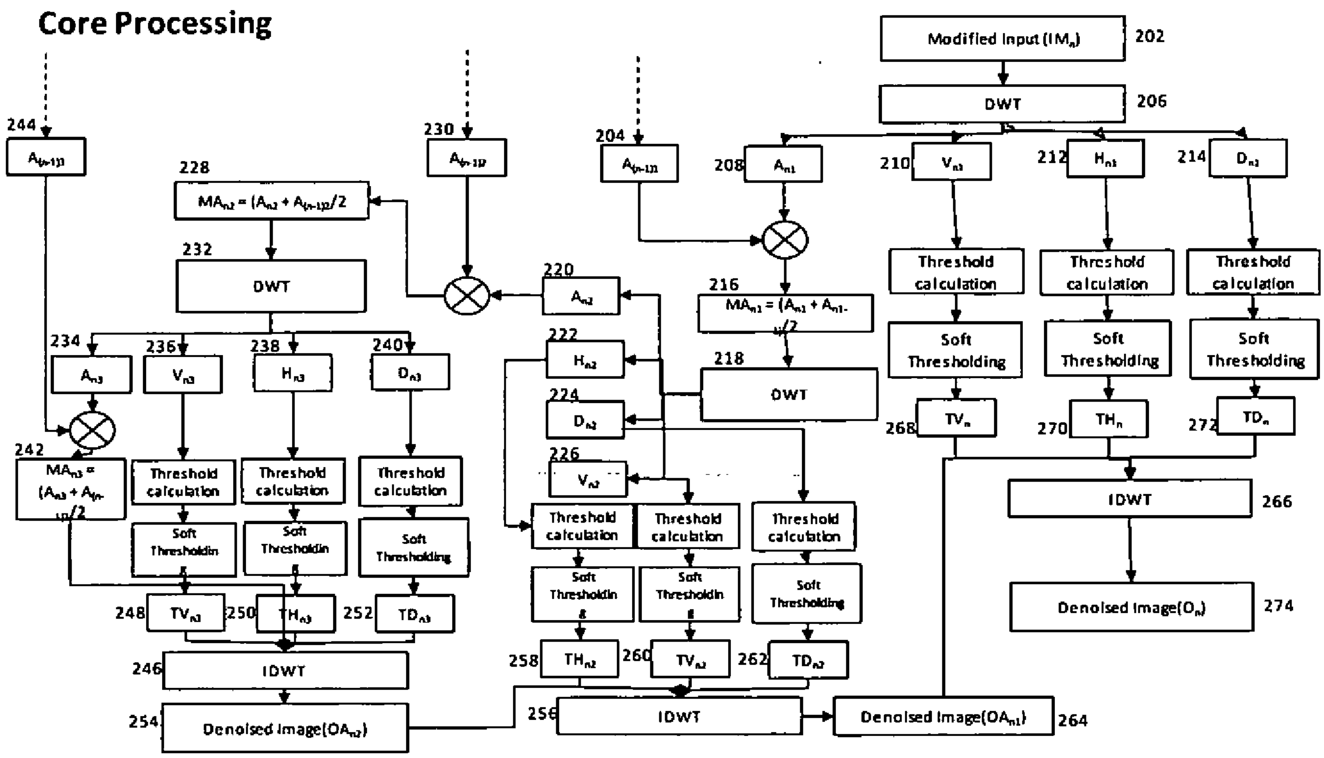

Figure 2

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