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TECHNICAL APPLICATION OF DENOISING KALMAN FILTER FOR ARTIFACT REDUCTION IN MRI ANATOMIC IMAGE INFORMATION

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ABSTRACT

Fatsups and BLADE sequences are used to reduce artifacts and clarify anatomical images. Based on theoretical studies, the STIR, BLADE sequences, the addition or subtraction of parameters, and the addition of artificial intelligence used still have a weakness, namely increasing the scanning time to be longer. Another technique that can be used and sequences and parameters on MRI is the denoising Kalman filter technique in the Matlab (Matrix Laboratory) program. The denoising technique is applied after the scanning process. Denoising will not increase the MRI scanning time. This systematic review aims to know the technical application of denoising Kalman filter for reduction artifacts on MRI examination. The search was done using google scholar, WILEY, IEE Explore, SPRINGER, PERPUSNAS, and Scopus in English with 2004-2020 articles period. The keywords are MRI artifact, reducing artifacts, and the Kalman filter algorithm. A review of 4 articles of filter Kalman intervention on MRI Brain, MRI Abdomen, and MR Cardiac shows that the Kalman filter is good enough to reduce artifacts and improve anatomical information. The Kallman filter could reduce flow artifacts, improve image quality and clarify anatomical images on MRI.

Keyword: artifacts MRI, *reducing artifacts*, algorithm Kalman filter

Introduction

Artifacts have the potential to degrade image quality and can lead to an inaccurate diagnosis[1]. Artifacts on MRI are classified as problems with incorrect geometry, physiological phenomena of the body, or physical limitations[2]. Artifacts such as blood flow can provide useful image contrast but can reduce the diagnostic quality of the flow arteries' physiological movements (flow artifacts) [3,4]. Flow artifacts and physiological movements from the patient can appear and interfere with areas of possible abnormality and obstruct anatomy[4]. The MRI examination artifacts can be overcome by setting parameters such as reducing Time Echo, reducing FOV (Field of View), increasing bandwidth, adding T2 sequences fat-saturation (fat-sat), or even adding artificial intelligent [5]. Using fatsup, The addition of MRI parameters or artificial intelligence to the MRI examination can be used to reduce flow artifacts and artifacts due to movement in patients. The addition of other sequences such as the BLADE sequence can also reduce blood flow movement and enhance anatomical imagery [6]. But even though it can reduce artifacts, the STIR and BLADE sequences used still have a drawback, namely the longer the scanning time will take [7]. Use of other techniques In addition to sequences and parameters on MRI, the filter Kalman denoising technique

is used in the Matlab (Matrix Laboratory) program. One of the denoising techniques used to overcome this problem is the use of filter Kalman. Kalman filter is one of the algorithms in the Matlab program that can smooth image [9].

Kalman filter is part of the denoising technique. Kalman filter can be used to overcome noise or artifacts without removing other important information [8]. Denoising technique is needed for medical image processing [9]. The denoising technique is applied after the scanning process. Denoising will not increase MRI scanning time because the post-image acquisition is an effective and inexpensive alternative [10]. This method is effective for preserving image features and enhancing image quality [11]. Image denoising has an important role in MRI image processing before a radiologist analyzes the image. The denoising process aims to obtain more detailed MRI images and remove noise or artifacts in MRI images while maintaining important information [12].

Methods

The method used is a systematic literature review. Systematic Literature Review is a systematic, clear, comprehensive literature study that identifies, analyzes, evaluates, and interprets all research findings on a research topic to answer relevant research questions.

Result

Arrange Research Questions

P (Population) is an MRI image artifact.
I (Intervention) is a Kalman filter denoising technique.
C (Comparison) is the MRI control group (non filtering / Non-Kalman filter).
O (Outcome) results from an image using the denoising Kalman filter technique on MRI flow artifacts.
C (Context) is an MRI (flow artifact image MRI) examination.

Search Strategy Literature

The research journals method uses Google Scholar, Springer, Wiley, IEEE Xplore, and Elsevier. The research articles obtained are scientific articles that have been published. The search for scientific articles was carried out using the keywords MRI artifacts, reducing artifacts, and the Kalman filter algorithm. Also, article searches use keywords with Boolea

operator logic. Such as artifacts AND MATLAB, reducing OR improve image quality in MRI, Kalman filter, AND MRI. These keywords can expand or narrow the search results. All literature obtained is literature in English. The next step is to screen articles based on the years 2004-2020. After screening, articles were found that matched the researchers' criteria. Article titles that are deemed by the research objectives are then put together and screened based on titles, abstracts, and keywords. Furthermore, screening was carried out based on the abstract and full text of the article. The following is a flow chart of the literature search in this systematic review.

Inclusion And Exclusion Criteria

The inclusion criteria included all literature published in English, articles published between 2010-2020, original research articles or journal reviews, available full text, articles on MRI artifact reduction, and MRI artifacts with the Kalman Filter. Exclusion criteria included all literature published not in English, articles published in years outside the inclusion criteria scope, not full-text journals, articles outside the theme of MRI, artifact reduction, and Kalman filters.

Critical Appraisal Methods

Critical analysis of articles used the Critical Appraisal Skills Program (CASP) tools.

Data analysis

Data analysis was carried out by combining all data that met the inclusion criteria, analyzing the article's contents, then coding the articles to be reviewed. After that, the data that has been collected will be

searched for similarities and differences, then discuss to conclude.

Processing Data

Research data processing was carried out using a synthesis review. Synthesis review systematically synthesizes existing research evidence in search of research articles, critical appraisal, and synthesis of research results to answer a question.

Data Extraction

Data extraction was done manually using summary tables. The table is summarized based on the first author's name, year of publication, country of study, population, sample, intervention, comparison, and study results.

Data Synthesis

The data is presented narrative. Data presentation includes the article's characteristics, Kalman filter for MRI, and MRI image results after MRI application.

Discussion

Article searches were carried out through Elsevier (SCOPUS), IEEE Xplore, WILEY, SPRINGER, PERPUSNAS, and Google Scholar. Articles are collected based on title, abstract, and keywords. Then get articles that match the theme. The articles are then compiled based on full text. Based on the full text of the article, it is found that the article is suitable for review. The total number of journal articles obtained is 258 based on keywords that have been planned, namely MRI artifacts, reducing artifacts, and the Kalman Filter algorithm. After that found 40 articles based on eligibility. From the articles screened based on the inclusion criteria, 4 articles were found. Then the 4 articles were reviewed. The denoising Kalman filter technique intervention results were performed on MRI Brain to reduce artifacts due to CSF movement and blood flow. The artifact is reduced then an assessment of image quality is carried out by assessing the PSNR and MSE. The PSNR result is 34,211; for MSE the value is 7.90 E 05. A well-visualized anatomical image includes a liver image. The review results in the next article are the application of the Kalman filter to the DWI MRI Brain sequence.

After the intervention, an assessment of image quality was carried out by measuring the SNR value. Also, the anatomical images of the DWI sequence of Gray Matter and White Matter anatomy are evaluated well. The statistical test on applying the Kalman filter obtained significant results, namely ($P < 0.0001$). The denoising Kalman filter technique in other article searches was carried out on the T1 Weighted MRI Brain sequence and flip angle variations. After the intervention, image quality was assessed by calculating the SNR in the lateral geniculate nucleus (LGN), white matter, gray matter, and visual cortex. Furthermore, statistical tests were carried out to obtain the results of ($P < 0.002$). Anatomical images appear to be well visualized, namely white matter, gray matter, and LGN. The results of the research on Cardiac MRI artifacts show that Kalman filter intervention can improve image quality. The value on the RMSE measurement is 0.0010. Anatomical images that can be evaluated include the left ventricle and myocardium. Blood flow, Cerebro Spinal Fluid (CSF) can cause artifacts on the T1 Weighted sequence MRI Brain. Cardiac MRI has interfering artifacts, one of which is the heart's movement, according to the results of the article.

The research article results on the DWI MRI Brain sequence contained artifacts and noise originating from CSF flow (cerebrospinal fluid), blood flow, and patient movements outside the examination. This can be reduced by using Kalman filtering. Kalman filter can smooth out images that contain noise and artifacts. The dynamic movement of the heart on cardiac MRI can cause artifacts or noise. On MRI of the abdomen, the artifacts come from repetitive physiological movements of the body. The research results in the article indicate that the denoising Kalman filter technique can reduce

artifacts caused by repetitive movements to improve image quality and anatomical image information.

Research by Shin (2013) was conducted on the MRI Brain examination after T1 Weighted. In this sequence, a Kalman filter was applied to reduce artifacts arising from blood flow and CSF. In Shin's (2013) research, artifact reduction begins with a linear process and then continues with the input and output processes. This process is also known as the prediction and correction process, according to Mohinder (2001). Shin (2013) researched the initial process with a random system in fields where artifacts were present.

Sam's research (2018) reduces the DWI sequence (Diffusion-Weighted Image) MRI Brain examination. In this research, the Kalman filter discusses the general problem of estimating the discrete controlled time process, which is regulated by stochastic linear equations in a random system. Baron (2013) conducted a study to reduce artifacts on MRI of the abdomen caused by breathing movements. Artifacts are in the Gradient Echo sequence. An image that contains artifacts is applied to the Kalman filter contained in MATLAB.

In a study conducted by Xue (2012), a Kalman filter was applied to reduce artifacts due to heart motion on Cardiac MRI. The Kalman filter is applied to the GRAPPA sequence inputted in MATLAB. Kalman filter was applied in Shin's (2013) study to reduce artifacts from blood flow and CSF. These artifacts can cause noise in the T1 Weighted sequence. One of the advantages of the Kalman filter is an effective estimator in estimating system dynamics involving white noise.

Sam's research (2013) states that artifacts occur in the DWI (Diffusion-Weighted Image) MRI Brain sequence. Kalman filters are applied to remove noise and artifacts from a signal without reducing other important information. So that anatomical image information such as white matter and gray matter can be evaluated properly.

Artifacts on MRI such as in cardiac examinations, such as in Xue's study (2012) or abdominal examination, such as in Baron's (2013) study, often encountered repetitive movements. Such as blood flow, CSF flow, patient movements, or physiological movements outside the examination. Kalman filter is useful for controlling a process that occurs repeatedly.

In Sam's research (2018), Kalman filters can also refine images as one of the MATLAB filters. Kalman filter has the ability to predict and perform correlation analysis between various kinds of data. In Sam's research (2018), Kalman filters are not stable for numerical filtering or large computational times.

After the Kalman filter intervention reduces the image containing artifacts, the image quality on the MRI can be assessed by measuring the SNR. SNR is performed by performing ROI on anatomies that are obstructed by artifacts. Like Shin's (2013) research, doing ROI on white matter, MRI brain gray matter. Assessments are also carried out on anatomical images such as liver images in Sam's (2018) assessment, which is evaluated well after applying the Kalman filter.

All of these studies carry out the Kalman filter process after the inspection is complete to not add to the inspection time. Also, in this process, the Kalman filter can be carried out on a different computer to help radiology specialists access its image.

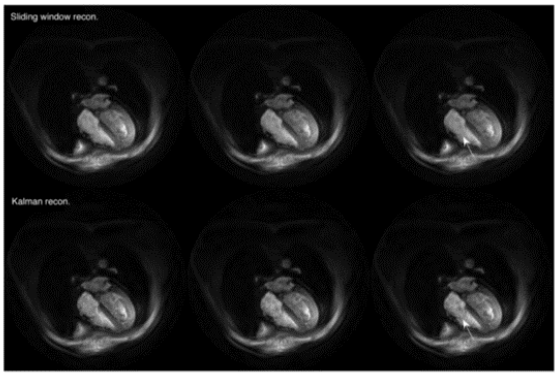

Figure 1 MRI cardiac image before and after intervention

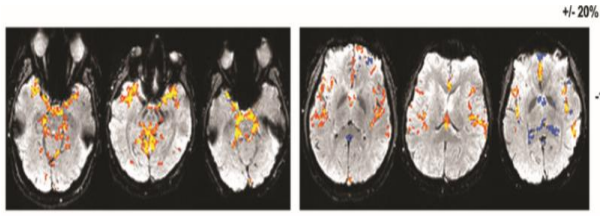

Figure 2 Brain MRI before intervention

Conclusion

The denoising Kalman filter technique is based on a linear system followed by a prediction and correction process. An image that contains artifacts can be denoised after inspection. Kalman filters have the potential to reduce artifacts that occur due to repetitive movements. Such flow artifacts on MRI Brain, MR Cardiac, and MR Abdomen images arise due to blood flow, CSF flow, patient movement, swallowing movements, or physiological movements in patients outside the examination. Kalman filter is useful for refining images, improving image quality and anatomical information on MRI images.

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