**Image Analysis**

**Critical Analysis – Denoising of PET Images by Context Modelling Using Local Neighbourhood Correlation**

Submitted for the MSc in

Advanced Computer Science

April 18

By

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Word Count: 0

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[Figure 13: This image shows the seventh figure used in the paper Denoising of PET Images by Context Modelling Using Local Neighbourhood Correlation with the caption of “Example patient 3; head and neck segmentation (top). Example patient 4; liver segmentation. The images on the left were processed with a 3D extension, the ones on the right were processed without.” (Huerga, et al., 2017). 17](file:///C:\Temp\!!!Work!!!\Semester%202\Image-Analysis\Report\Critical%20Analysis%20–%20Denoising%20of%20PET%20Images%20by%20Context%20Modelling%20Using%20Local%20Neighbourhood%20Correlation.docx#_Toc512396326)

# Critical Analysis

This paper is written regarding the development of a new noise reduction algorithm for PET image data. As is stated in the paper, there is already a vast body of research into this field, however new methods are always required as technology is always improving.

This paper is quite recent and was published in a high profile journal.

## Title

The main strength of the title is, that it is short and to the point, this means that anyone browsing through a list of papers may choose to read this paper, in particular, because its title is easy to parse and inoffensive.

However, a major weakness of the title is, the fact that it doesn’t adequate describe the content of the paper. The vast majority of the paper references wavelet decomposition and this is not mentioned in the title at all, whereas the phrase “neighbourhood correlation” from the title is not repeated once in the body of the paper.

## Authors

A main strength of the authors of this paper is, that between them they have written numerous papers in the past, some authors having written more than others and some having written none, however as a collective they are quite well experienced. In addition, the authors are from a good spread of institutions and roughly equally represent both genders.

However, the main weakness of the authors is, that they are not geographically diverse, all of the institutions that are represented among the authors are situated within a few miles of each other in Madrid, Spain.

## Acknowledgements

The main strength of the acknowledgements/funding section of this paper is, that because the research was not funded by an external body it can be assumed that there may be less bias in the research and thus, by stating that the research was not funded, anyone reading the paper can come to the same conclusion, this conclusion may make people more willing to read the rest of the paper.

However, the main weakness of the acknowledgements/funding section is, that it is located at the end of the paper, in order for the strength above to be applicable this section has to be read before the rest of the paper.

## Abstract

The main strength of the abstract is, that it makes a good case as to why this research is worthwhile conducting. It states that in PET imaging there is a low signal-to-noise ratio (SNR) and to get the best images out of this device the SNR needs to be reduced, this is exactly what the rest of the paper then goes on to detail.

However, a weakness of the abstract is, that it doesn’t discuss the rationale behind why the method, explored in the rest of the paper, is different or better from the methods already used for this function. An additional weakness of this section is, that it fails to lay out a concrete hypothesis which the paper as a whole addresses.

## Introduction

The main strength of the introduction is, that a large amount of background research into other solutions and references to other solutions have been included, this can be seen from the line starting “There are different approaches for removing noise in PET images”. Another strength would be, that the case as for why this research is relevant has been expanded upon from the abstract.

Some of the weaknesses of the introduction include, the fact that wavelet decomposition is discussed at length throughout the entire introduction but no effort is made to explain what wavelet decomposition is or how it functions. In addition, the authors go on to use first person language towards the end of the introduction in the sentence “Our method is proposed”. In a similar place the authors also make a forgone conclusion as to the effectiveness of the proposed solution in the sentence “The proposed noise-reduction technique is able to maintain uptake values”.

## Materials and Methods

The main strength of the materials and methods is, the fact that this section contains enough information to recreate the study itself, this section is very information dense giving details on the exact procedures used at every instance. In addition, the research has been performed on a large sample of regions of interest (ROIs) (1800), however this information is not revealed until later in the discussion section.

Also, the preliminary research is performed on readily available phantoms which can be acquired easily, the fact that these phantoms are quite old (2001) is both a strength and a weakness. Because they are so old there should be a large body of research performed with the phantoms, legitimising this research further. However, because the phantoms are old they may be outdated and better options may now be available.

The main weakness of the materials and methods is, that although this section provides enough information to reproduce the actual study itself it does not give any detail on the incidental tests that were performed during the main study, this is demonstrated in the following sentence “The photometric error has been checked (after the whole filtering process) and found to be within the limits of diagnostic utility.”, there is no information on how to test this photometric error nor what would be within the limits of diagnostic utility. In addition, there is no information on how participants were selected for the study. Finally, certain images were acquired using only one bed position while others were acquired using multiple bed positions, there is no justification for this.

## Table 1

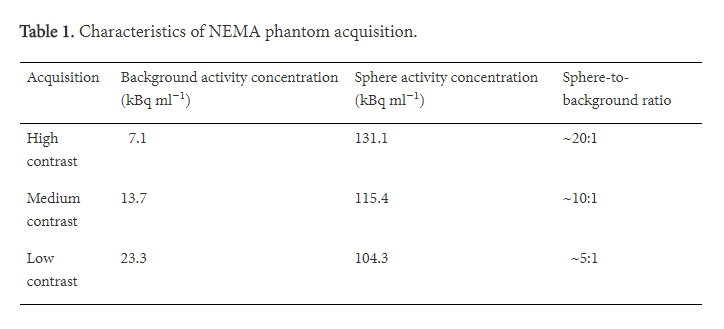


Figure 1: This image shows the first table used in the paper Denoising of PET Images by Context Modelling Using Local Neighbourhood Correlation (Huerga, et al., 2017).

As can be seen from Figure 1 the main strength of table 1 is, that the acquisition labels are quite detailed, meaning that the rest of the data in the table is more relevant with context.

However, the main weakness of table 1 is, that the ratio of the spheres size to background size is an approximation, by obscuring the actual ratio the data in the rest of the table becomes less relevant.

## Results

A main weakness of the results section is, that again parts of this section have been written in the first person. Additionally it has been determined that a 5x5 window is the best size to be used to perform the experiment, it is not discussed if other window sizes have been tested it is just stated that this has been chosen for code simplicity.

Finally, parts of the section execution time appear to be more relevant to the materials section of the paper than the results section, for example the sections regarding the computer used to run the algorithm. Parts of this execution time section also appear to be flawed, for instance, it is claimed that the CPU used was clocked at 2.93 MHz, this is impossible as no Intel i3 processors have even been clocked this low (Intel, n.d.). In general the hardware and software used to run this application are subpar, a computer intended for serious academic work should be running the most up to date 64 bit operating systems which from the specifications given does not seem to be true.

## Figure 1

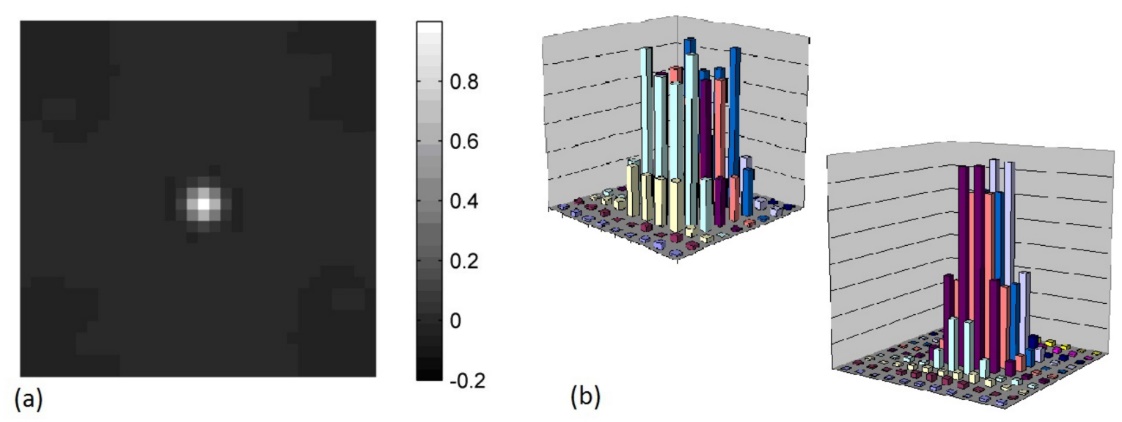


Figure 2: This image shows the first figure used in the paper Denoising of PET Images by Context Modelling Using Local Neighbourhood Correlation with the caption of “The autocorrelation function normalised to the maximum pixel value: (a) 2D image, (b) display of matrices of weight for the first level. Diagonal orientation (top) and horizontal (bottom).” (Huerga, et al., 2017).

As can be seen from Figure 2 the main strength of figure 2 is, that the data being represented has been normalised, this means that the relative difference between each part of the figure is easier to determine without having to worry about scale, however when data is normalised it is converted to be of size 1, which is true of the above diagrams, what is also true of data which has been normalised is that its magnitude is usually represented as being between 0 and 1, which in this case is not true as can be seen in the diagram on the left. The scale of the diagram on the left starts at -0.2.

A weakness of figure 2 is, that the diagrams on the right do not have a scale and as such do not really represent anything, additionally, even if they were to have a scale, because of their projection it would be virtually impossible to read an individual bar against this scale. Also, it is not possible to compare the two diagrams against each other because both diagrams have different rotations.

There is a better way to visualise this data than the method which has been chosen.

## Table 2

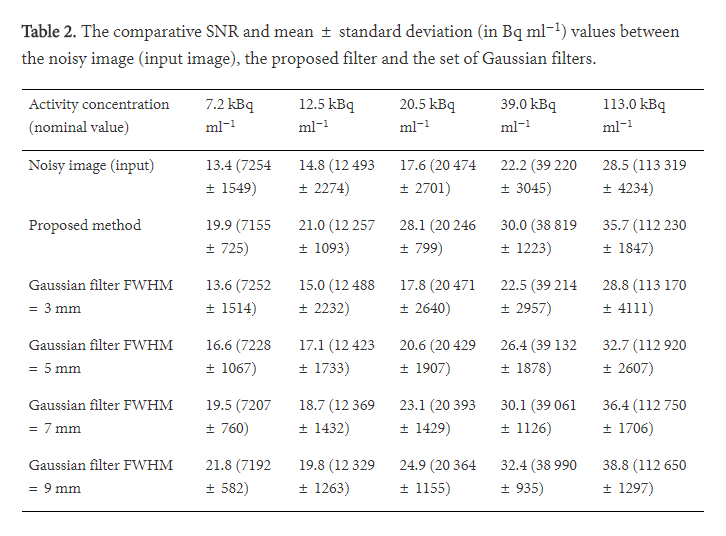


Figure 3: This image shows the second table used in the paper Denoising of PET Images by Context Modelling Using Local Neighbourhood Correlation (Huerga, et al., 2017).

As can be seen above from Figure 3 the main strengths of table 2 is, that it contains a lot of information in a very concise format and that it also shows both results and deviations for numerous different concentrations.

## Figure 2

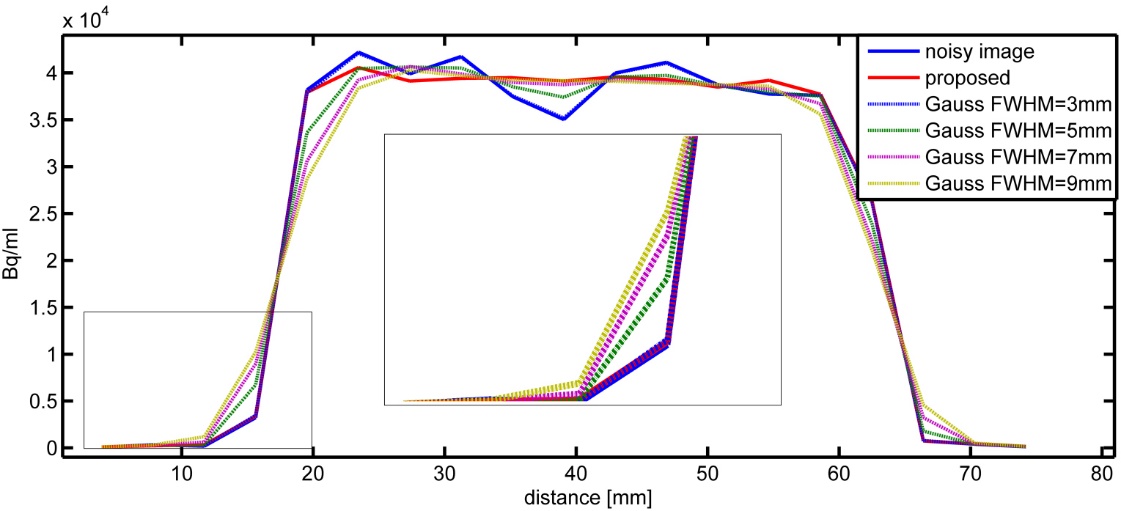


Figure 4: This image shows the second figure used in the paper Denoising of PET Images by Context Modelling Using Local Neighbourhood Correlation with the caption of “A profile plot for the cylindrical phantom with nominal (injected) activity of 39.0 kBq ml−1. The profile was taken horizontally, from the middle of the phantom.” (Huerga, et al., 2017).

As can be seen from Figure 4 the main strength of figure 2 is, that it contains a lot of information in a small format.

However, the main weakness of figure 2 is that albeit that this graph may contain a lot of data it is almost impossible to differentiate any of it because a lot of the data is so close together, the authors have tried to negate this by providing a scaled up view of one part of the graph but when it is scaled up the data loses all meaning because it can no longer be related to the y axis. Additionally, this graph only represents the data from the 39.0 kBq ml−1 concentration, there is no justification as to why only this concentration has been chosen.

## Table 3

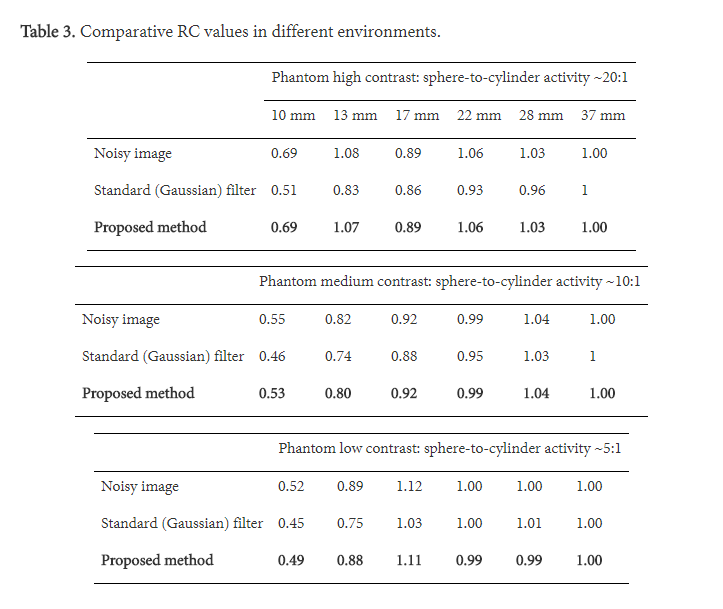


Figure 5: This image shows the third table used in the paper Denoising of PET Images by Context Modelling Using Local Neighbourhood Correlation (Huerga, et al., 2017).

As can be seen from Figure 5 the main weakness of table 3 is, that it refers to a standard Gaussian filter but nowhere in the text nor in the table does it describe what this filter is. Additionally, two of the points in the table are not to 3 significant figures while every other point is. Finally, the proposed method row is emboldened while no other row is, this could be taken to be manipulation of the person reading the report as putting figures in bold may make them appear to be greater and as such make that specific item appear superior.

## Table 4

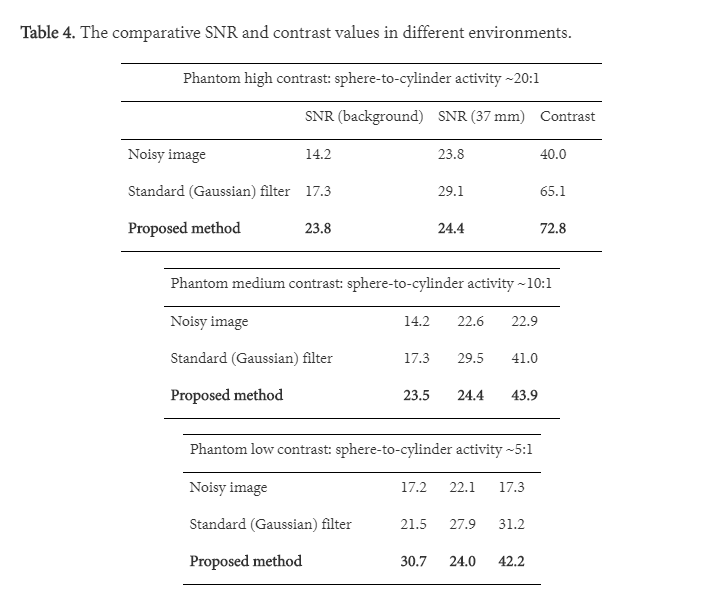


Figure 6: This image shows the fourth table used in the paper Denoising of PET Images by Context Modelling Using Local Neighbourhood Correlation (Huerga, et al., 2017).

As can be seen from Figure 6 the main weakness of table 4 is, that it only takes into account the SNR of a 37mm instance, there is no reference to this choice in the text or in the table.

## Figure 3

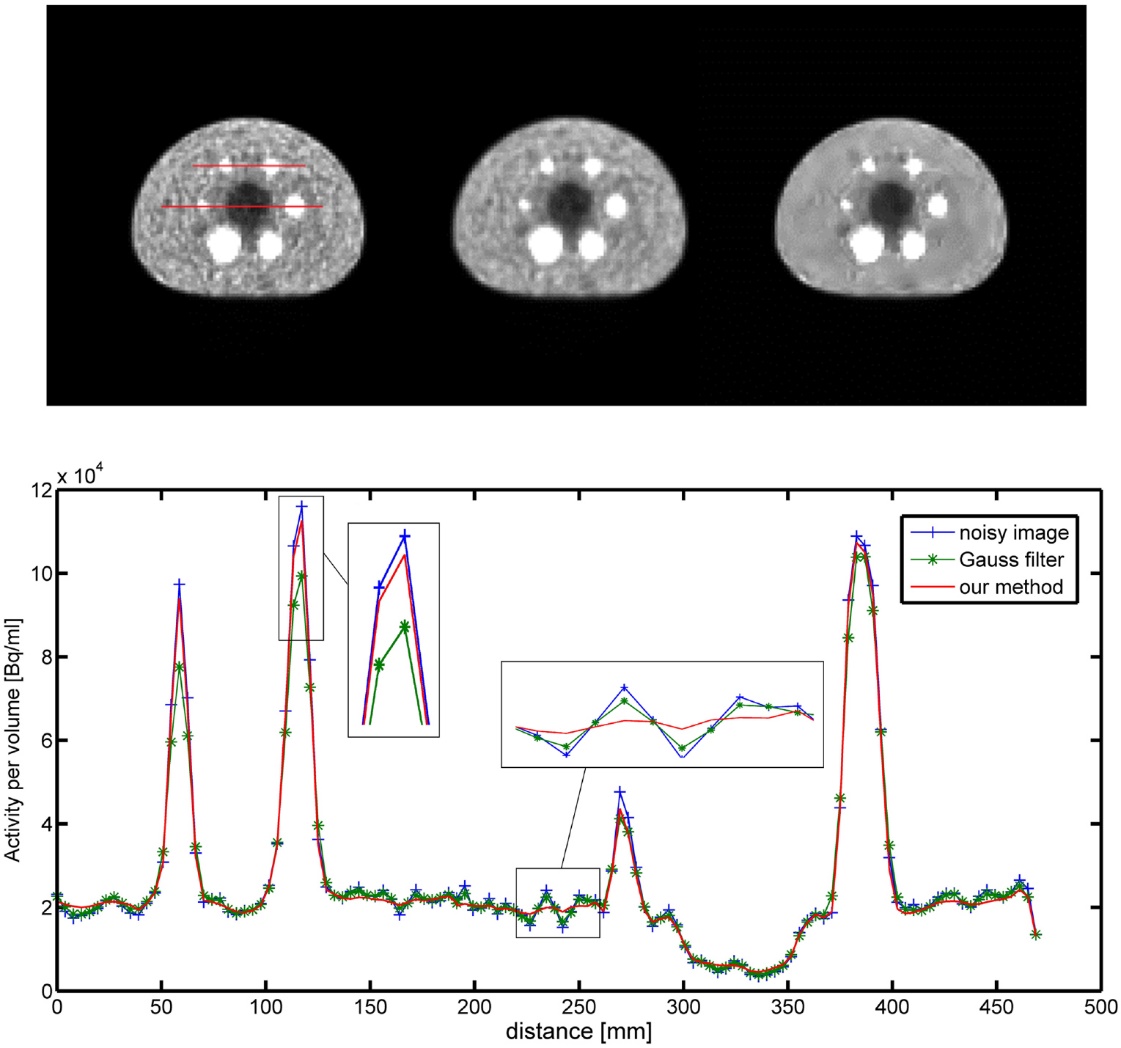


Figure 7: This image shows the third figure used in the paper Denoising of PET Images by Context Modelling Using Local Neighbourhood Correlation with the caption of “A visual evaluation in the LOW-CONTRAST case. Top: image without post reconstruction filter (left), standard Gaussian filter processing (middle), wavelet filter processing described (right). Bottom: profiles through smaller spheres (peaks corresponding to the spheres of diameters 13 mm, 17 mm, 10 mm and 22 mm, left to right).” (Huerga, et al., 2017).

As can be seen from Figure 7 the main strength of figure 3 is, that the actual image above gives a real visualisation of the results of the proposed method this also allows for the visual comparison of the methods available.

However, the main weakness of figure 3 is, that there is a large red box on the left most image, this box is never explained and otherwise is a detriment to the overall figure as it covers part of it. Additionally, the style of graph used, which has already been discussed above, could be replaced by a more tangible image which represents the difference between the unfiltered and filtered images by subtracting one from the other, this would give a visual representation of the noise being removed. Finally, the first person is used again in the “our method” label.

## Table 5

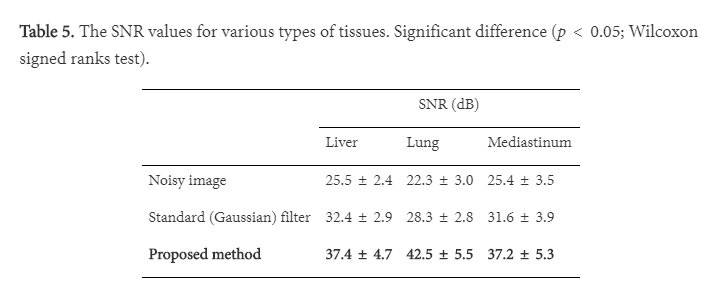


Figure 8: This image shows the fifth table used in the paper Denoising of PET Images by Context Modelling Using Local Neighbourhood Correlation (Huerga, et al., 2017).

The strengths and weaknesses of table 5 which can be seen in Figure 8 can be seen above.

## Table 6

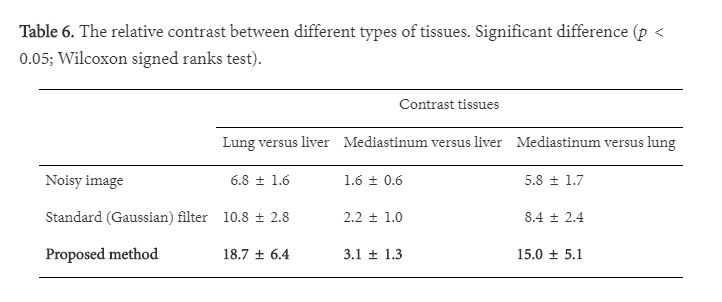


Figure 9: This image shows the sixth table used in the paper Denoising of PET Images by Context Modelling Using Local Neighbourhood Correlation (Huerga, et al., 2017).

The strengths and weaknesses of table 6 which can be seen in Figure 9 can be seen above.

## Figure 4

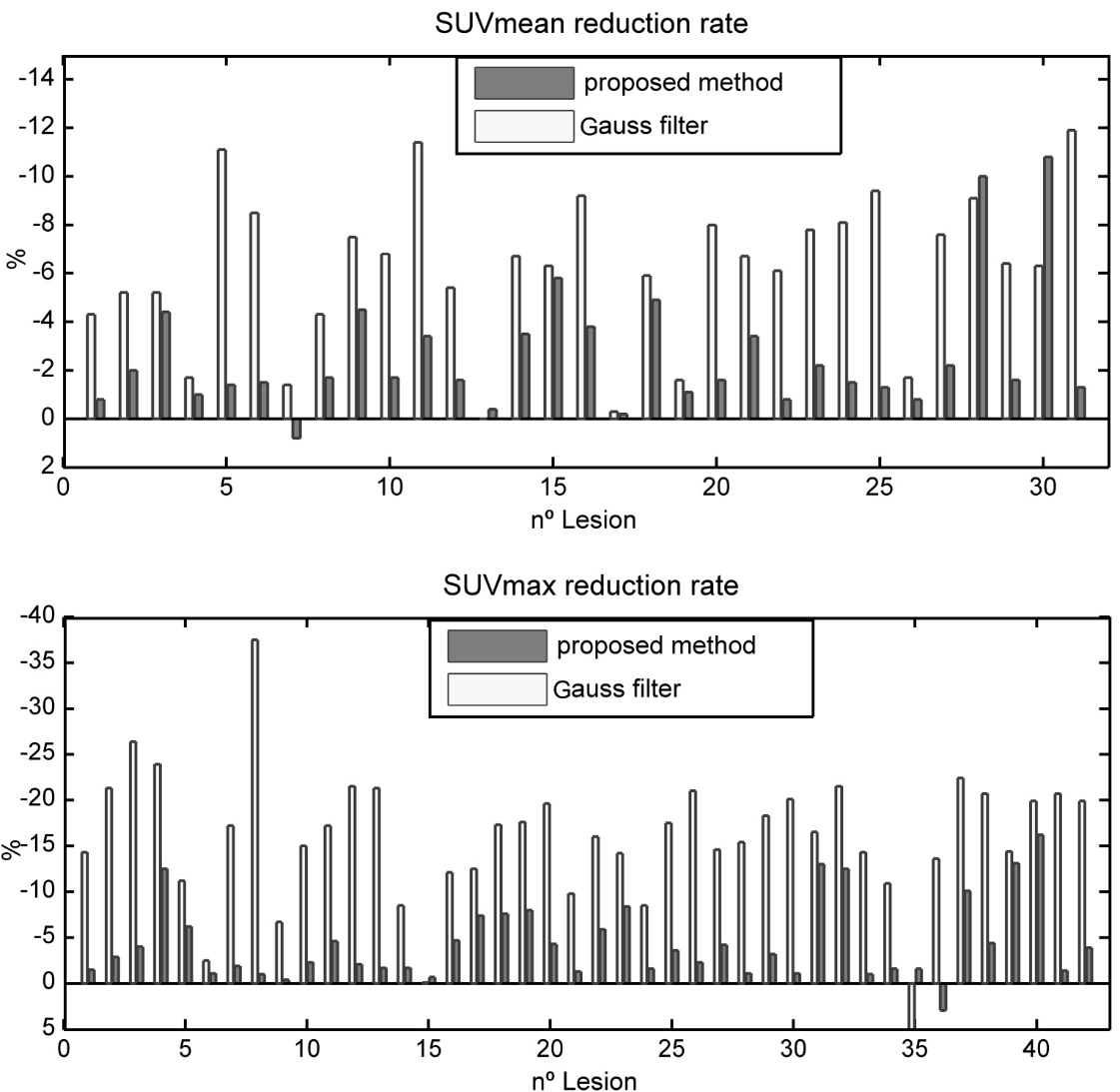


Figure 10: This image shows the fourth figure used in the paper Denoising of PET Images by Context Modelling Using Local Neighbourhood Correlation with the caption of “A comparison of the SUVmean (top) and SUVmax (bottom) reduction rates (%) in more than 40 lesions from different patients.” (Huerga, et al., 2017).

As can be seen from Figure 10 the main strength of figure 4 is, that the difference between the proposed method and Gaussian filter is very easy to distinguish from the graph, the other graphs above should have been visualised in this manner.

The main weakness of figure 4 is, that the number of lesions changes for no reason between the two graphs.

## Figure 5

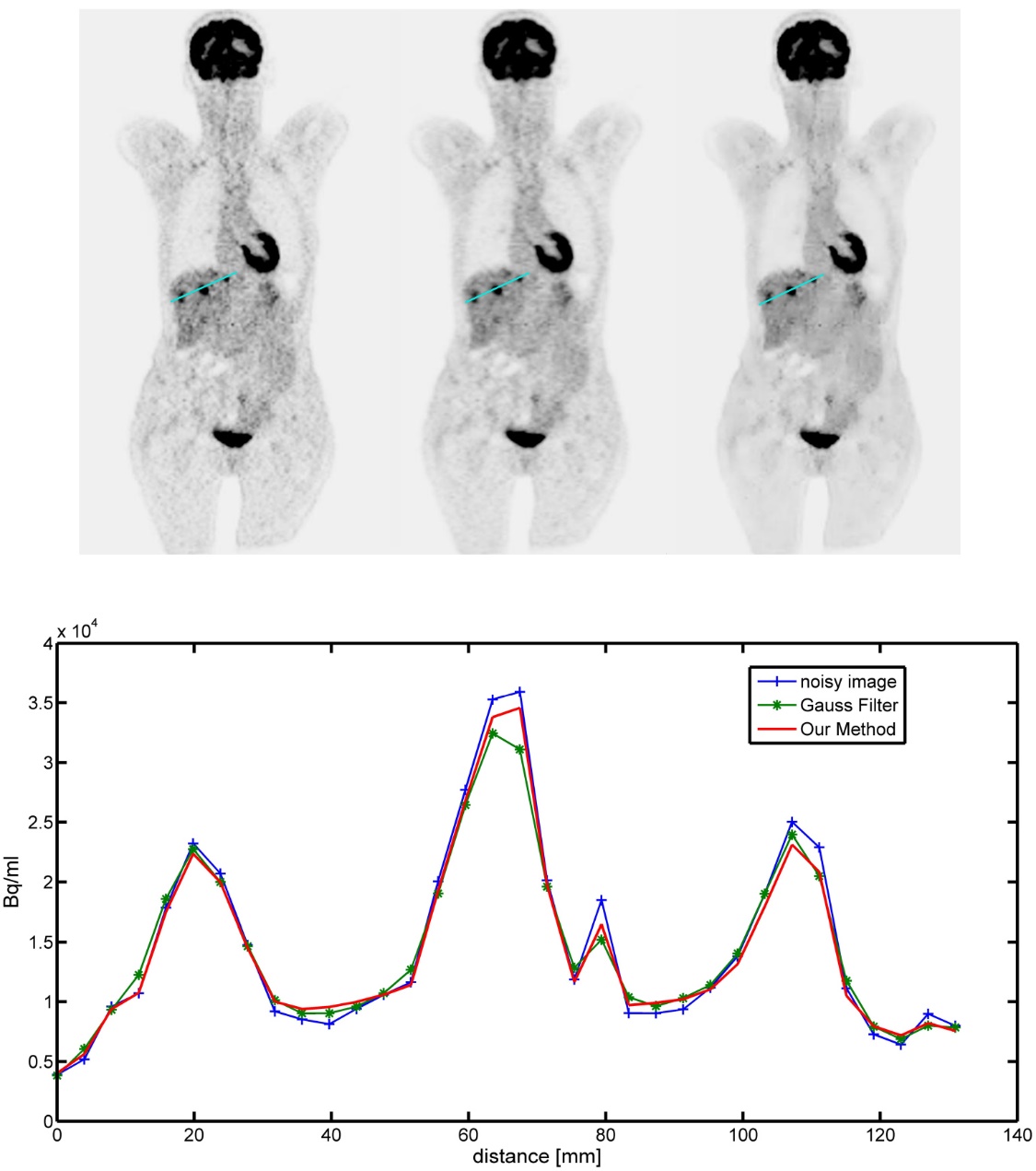


Figure 11: This image shows the fifth figure used in the paper Denoising of PET Images by Context Modelling Using Local Neighbourhood Correlation with the caption of “Example patient 1; coronal slice with liver lesions. Top: image without post- reconstruction filter (left), standard Gaussian filter processing (middle), wavelet filter processing described (right). Bottom: the profiles for each image through the lesion are shown.” (Huerga, et al., 2017).

As can be seen from Figure 11 the main strength of figure 5 is, that this is a representation of the real world application of the proposed method.

The main weakness of figure 5 is, that there is an unexplained cyan line in the centre of the image which blocks the view of the lesion in the image. All of the weaknesses which applied to figure 3 also apply to this figure.

## Figure 6

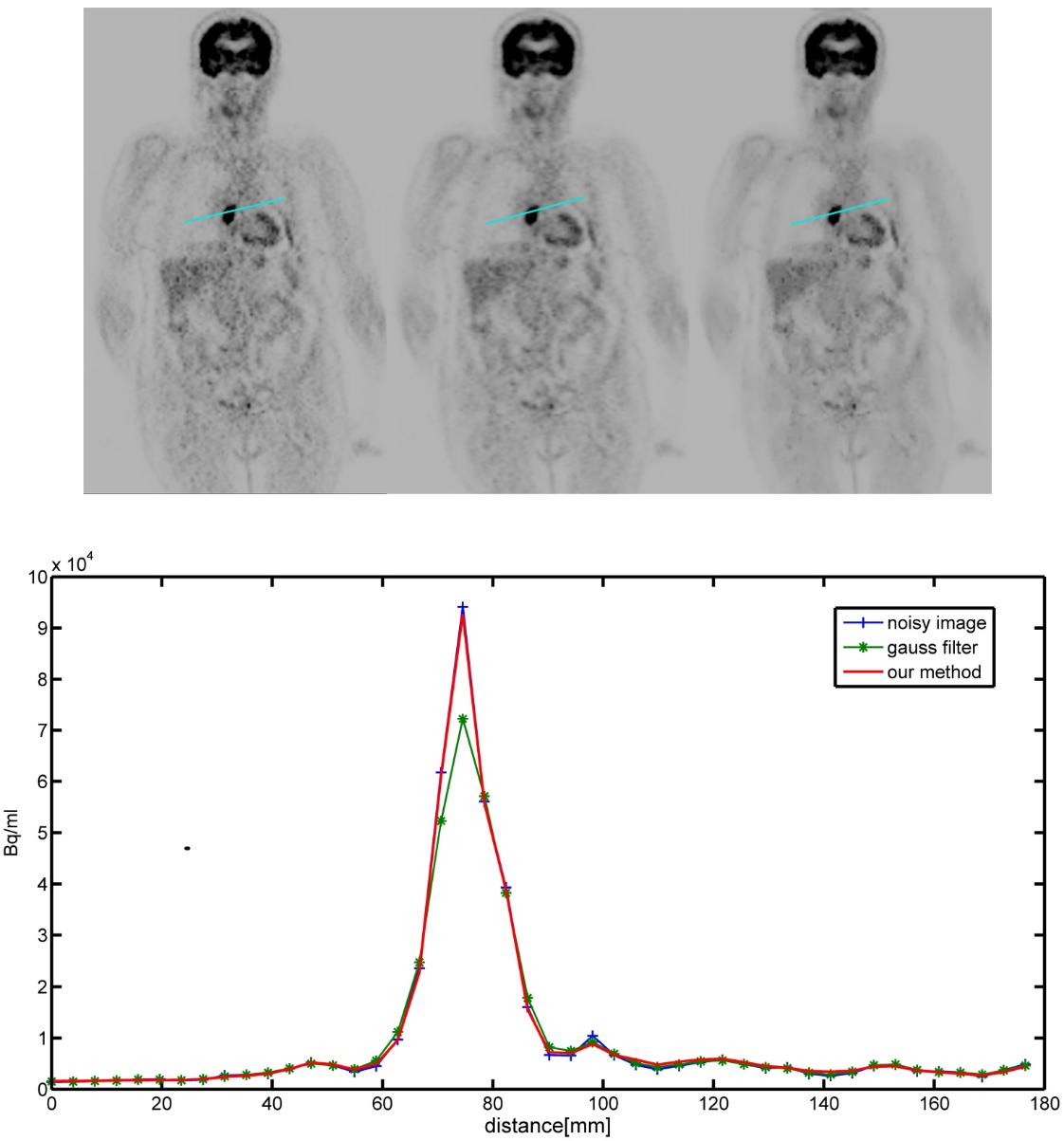


Figure 12: This image shows the sixth figure used in the paper Denoising of PET Images by Context Modelling Using Local Neighbourhood Correlation with the caption of “Example patient 2; coronal slice with mediastinum lesion. Top: image without post-reconstruction filter (left), standard Gaussian filter processing (middle), wavelet filter processing described (right). Bottom: profiles are shown for each image throughout the lesion.” (Huerga, et al., 2017).

Any strengths and weaknesses which applied to figure 5 which can be seen above in Figure 11 also applies to figure 6 which can be seen above in Figure 12.

## Figure 7

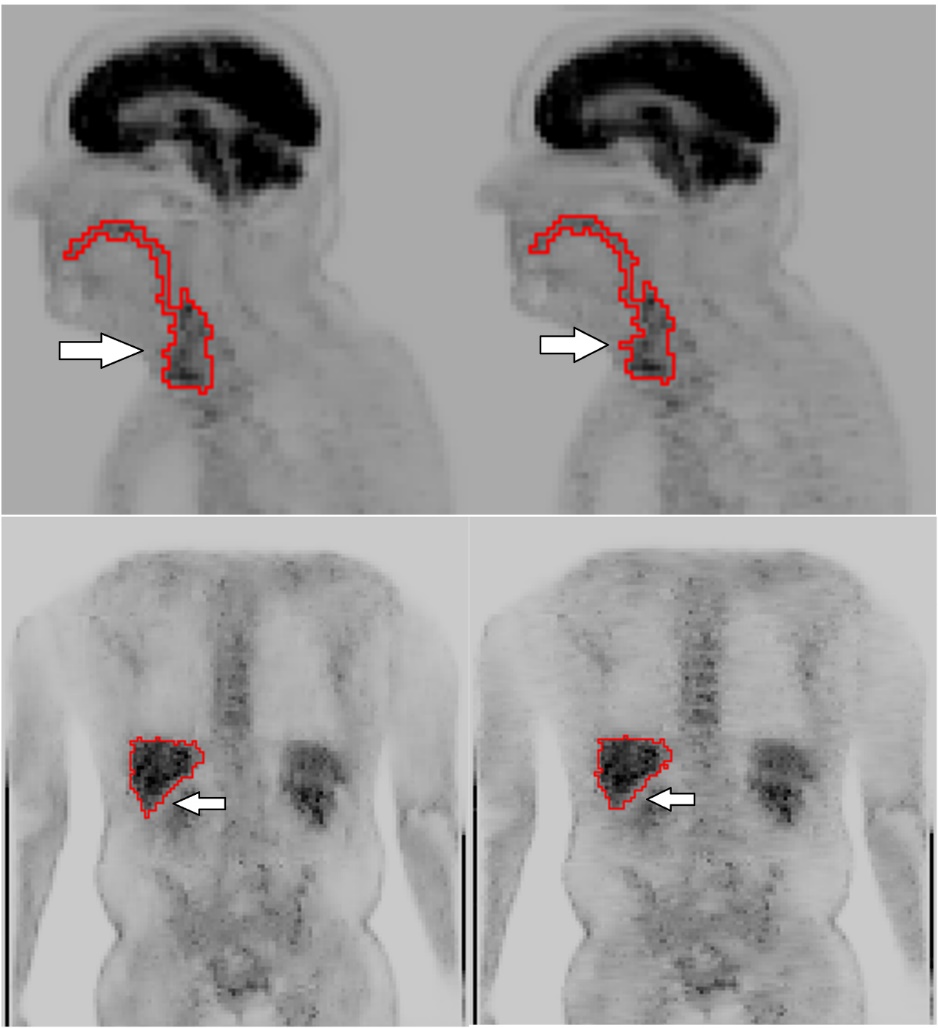


Figure 13: This image shows the seventh figure used in the paper Denoising of PET Images by Context Modelling Using Local Neighbourhood Correlation with the caption of “Example patient 3; head and neck segmentation (top). Example patient 4; liver segmentation. The images on the left were processed with a 3D extension, the ones on the right were processed without.” (Huerga, et al., 2017).

As can be seen from Figure 13 the main strength of figure 7 is, that it is a very clear example of a segmentation the red outline stands out from the image.

The main weakness of figure 7 is, that there is a large unnecessary unprofessional arrow added to the image, the segmentation is already obvious. Additionally, there is a lot of redundant image around the ROI, this could have been cropped out to make the ROI larger. Finally, again an image showing the difference between the two segmentations would have demonstrated the noise being removed, this is lacking.

## Discussion

The main strengths of the discussion/conclusion is, that it performs quite an in depth recap on what has already been read, before moving onto concluding the results of the paper. Also, towards the bottom of the discussion it is mentioned that this research is compliant with additional research conducted by the European Association of Nuclear Medicine. Having research which falls in line with something performed by such a large official body provides legitimacy to this research.

However, one weakness with this section is, the fact that as with other sections in this paper first person language is used throughout the discussion section. Additionally, it is mentioned in this section that 20% of computation time spent performing the algorithm is used solely on the new addition which has been proposed, it is never mentioned how this figure is calculated.

Also, in the conclusion section it is determined that this solution is “good” but never describes what is meant by this term or really how this conclusion has been reached, this could be solved by tying this conclusion back into what was written in the discussion section. Finally, as mentioned in the abstract, there is no hypothesis to be confirmed or rejected.

## References

The main strength of the references is, that there are quite a lot of references which have been used thoroughly throughout the paper.

The main weakness is, that a lot of the references are quite old, at one point the paper references that a piece of research is “state of the art” and then backs this up with a reference from 1999 which at this point is nearly 20 years ago. Another weakness is that a lot of the references are from the same people, for instance S.G. Chang, D.L. Donoho, S.G Mallat and F.E Turkheimer all appear twice.

# Conclusion

In conclusion, this paper strives to prove that the proposed method of noise reduction for PET image data is superior to established methods and while evidence has been found to support this, a lot of the evidence has been represented incorrectly or unusually in this paper.

If the paper were revised to provide better data visualisation and correct for other spelling and grammar mistakes the actual content of the paper seems relatively sound and the noise reduction technique discussed could have application in image analysis.

References

Huerga, C. y otros, 2017. Denoising of PET images by context modelling using local neighbourhood correlation. *Physics in Medicine & Biology,* 62(2), pp. 633-651.

Intel, s.f. *4th Generation Intel® Core™ i3 Processors.* [En línea]   
Available at: https://ark.intel.com/products/series/75025/4th-Generation-Intel-Core-i3-Processors  
[Último acceso: 25 April 2018].