Published in OPTIMAX 2017 : Radiation dose, image quality optimisation, the use of new technology in medical imaging, Oslo, pp. 21-25, ISBN 978-1-912337-09-05 which should be cited to refer to this work

A philosophical proposition: 'is there such a thing as an objective measure of medical image quality?'

P Hogg[1], I.H.R. Hauge[2], J Jorge[3]

[1] University of Salford, UK

[2] Oslo and Akershus University College of Applied Sciences, Oslo, Norway;

[3] Haute École de Santé Vaud, University of Applied Sciences and Arts, Western Switzerland, Lausanne, CH

It requires very strong minds to resist the temptation of superficial explanations: *Albert Einstein*

Until relatively recently research in the medical imaging field has tended to be positivist in nature, drawing on traditional research designs from the fundamental sciences, such as physics and engineering, and also human studies in medicine. The general intention is to exert control over the research process in order to minimise error to discover new knowledge thereby identifying truth. Fundamental to this approach is the need to be objective throughout the whole research process. These underlying philosophical research principles apply to the assessment of image quality in medical imaging and with this in mind we shall explore the notion of subjective and objective measures of image quality.

Medical image quality can be assessed in two different ways. The first method involves the use of a visual approach, in which human observers assess images for quality, by assessing a range features and characteristics within the image. In clinical practice this is normally done with a suggested medical condition in mind. This visual approach is often described as subjective in the literature, perhaps due to the possible variations of opinion that exist between different observers and also within the same observer at different points in time. Using this approach a numeric value might be assigned to the quality of an image quality, alternatively a qualitative description of its quality might be provided. The second method involves physics-based approaches

which provide numeric measurements of image quality; examples include Signal to Noise Ratio (SNR) and Contrast to Noise Ratio (CNR). The physics-based approaches are usually described as objective measures of image quality, probably due to the fact that if the analysis is performed in the same way on successive occasions, then the result is expected to be the same. Consequently much store is placed on the physics-based approaches because at first sight they are said to offer better reproducibility which is perhaps due to their [perceived] higher objectivity.

In this chapter we shall explore the notion of *subjective* and *objective* approaches to the assessment of image quality and we will propose that visual and physics-based methods are both subjective but if done adequately they will both offer valuable and perspectives on medical image quality that would be complementary in nature.

First let us consider definitions of *subjective* and *objective*. A subjective view is said to be influenced by or based on personal beliefs, feelings and prior knowledge and experience. It therefore stands to reason that a subjective view could vary between people and also within the same person as time progresses. By contrast, an objective view is not influenced by personal beliefs, feelings and prior knowledge and experience; it is said to be impartial or natural. The terms subjective and objective are used in medical imaging literature to reflect these definitions and with these definitions in mind, at a superficial level, it follows that visual measures of medical image quality would appear to be subjective and that physics-based measures would appear to be objective.

It is intuitive that visual appreciation of medical image quality must be affected by beliefs, feelings, prior knowledge and experience. As experience and knowledge increase then the ability to make a better informed judgement about medical image quality would also increase: a student radiographer (novice) would probably reach a less informed and different conclusion to that of a consultant radiologist (expert). Beliefs play a part in decision making too, for instance some people might prefer one particular texture within an image whilst others prefer something else. Feelings play a role too and this can be highly complex. Assessing a medical image for its quality when the observer is ‘tired’ versus ‘not tired’ could impact the result; also being ‘stressed’ versus ‘not being stressed’ could have an impact on the outcome too. Not surprisingly, appreciation of images using visual means can be highly subjective and this is not disputed; however it does represent how images are appraised routinely in the clinical setting. Similarly, it is intuitive that physics-based measures of a medical image quality must be objective, as they present numeric values that can be analysed using

mathematical formulae to give highly specific and often singular answers about the quality of an image.

However, is the differentiation between visual/subjective and physics-based/objective really that simple? Are the physics-based approaches totally objective in nature or might it be that high levels of subjectivity are inherent and unavoidable within them? Let us consider the process of making physics-based measures of image quality, using SNR as a catalyst to facilitate a discussion into whether physics-based measures are truly objective in nature. SNR involves placing regions of interest (ROIs) onto images, then extracting data from the ROIs and then analysing the data with equations to reach a conclusion about a specific aspect of quality inherent to an image. First we should acknowledge that at various junctures throughout the process of calculating SNR important decisions need to be made which can affect the results and therefore the conclusions. With this in mind let us explore the notion of subjectivity within physical-based measures of image quality.

The first decision surrounds the actual use of SNR as a measure, as alternatives to SNR exist for assessing medical image quality. By definition SNR only assesses noise in an image and it does not take into account other important image attributes, such as *other* physical measures or indeed whether the image is of adequate quality in order to establish a diagnosis. The decision making process when selecting SNR as an indicator of quality would certainly take into account the research question, however it would be influenced by individual researcher preferences as well as their prior knowledge and experience. Consequently, there is a level of subjectivity inherent in the decision making process when selecting SNR as an indicator of image quality.

When placing an ROI certain decisions need to be made. These include 1. the size of the ROI and 2. the exact location in which it would be placed and 3. the number of ROIs used. Various arguments can be made about ROI size, these might be practical (e.g. the image might be small, so the ROI would also have to be small) and theoretical (e.g. a larger ROI is better than a smaller ROI in order to minimise random variation between pixels). To improve objectivity in decision making the researcher can draw on various theories to minimise, but not eliminate, researcher subjectivity in an attempt to improve objectivity, reliability and validity. The ROI must then be positioned somewhere in the image. If the image is completely uniform then the decision making process would be fairly straight forward, albeit edge effects might need some consideration. However, the scenario of a uniform medical image rarely exists as nearly all medical images, human- or phantom-based, contain a range of structures of differing sizes,

textures and densities/intensities. The placement of the ROI is therefore a complex process, which is informed by the research question, theory and researchers' prior experience in order to minimise, but not eliminate, subjectivity. In some cases computer programmes have been written to automatically position ROIs to help improve ROI positioning; however such software will have been written by human programmers who are equally laden with their own preferences, prior experiences and inherent knowledge. Whilst automated approaches minimise variations in where ROIs could be placed between and within researchers who place them, the computer programmes still impose a subjective bias which has been forced on them by the programmer. Also, several computer programmes might exist to achieve automatic ROI placement and each could position ROIs differently; these differences would again be influenced by the biases and assumptions imposed by the programmer. Also the actual selection of a specific automatic computer-based approach for ROI placement introduces another level of subjectivity, which again could be based upon personal beliefs, feelings and prior knowledge and experience. The final step is the mathematical treatment of the ROI data. For SNR to be calculated at least two methods exist and they produce similar but not the same result. Again the researcher makes a decision on which mathematical method to use and once more the decision making process can be influenced by personal beliefs, feelings and prior knowledge and experience.

It becomes clear that the process of making physics-based measures of image quality is laden with many decision points that can be heavily influenced by personal beliefs, feelings and prior knowledge and experience. Consequently, it can be argued that physics-based measures of image quality cannot be considered to be truly objective as there are many points within the process that allow for human intervention and subjectivity. With this notion in mind we propose that physics measures (e.g. SNR) of medical image quality should be named *physical measures of image quality* rather than objective measures of image quality. On the same basis *visual measures of image quality* should be named as such, rather than simply calling them subjective measures of image quality.

Points of reflection: It is possible that any measure of image quality, whether physical or visual, has the potential for subjectivity and therefore bias. Rather than considering measurement objectivity, perhaps researchers should have in mind the will and the duty of objectification when producing new knowledge to demonstrate how the experimental measurements are performed to be accurate, precise, valid and reliable. Maybe we would take the view that objectivity is only a shared subjectivity among the scientific community?

References

1. *http://dictionary.cambridge.org/dictionary/english/subjective*
2. *http://dictionary.cambridge.org/dictionary/english/objective*