From Image Capture and Display to Software Investigations

Sabine K McNeill

***Abstract*— This article describes a software-based approach to *A Virtual Image Chain for Perceived and Clinical Image Quality of Medical Display* published by the *Journal of Display Technology*.**

We describe a fundamentally different model based on new generic software methods. Their purpose is the innovative quantification and re-visualization of digital images. Our re-visualizations allow the expert to see more while the software quantifies more, e.g. the quantification allows for classifying and sorting images. Furthermore, our image data metrics allows for analysing image components and qualities inherent in images.

Based on these core methods, customised software systems can be developed that offer new procedures for testing and calibrating display quality with reference images while seeing and measuring more in individual and groups, if not masses of images.

***Index Terms*—digital image metrics, image classification, instrument calibration, software vision.**

Contents

Sabine K McNeill started her company *3D Metrics* in 2004 in London (phone +44 20 7328 3701); e-mail: sabine@3dmetrics.co.uk).

"Humboldt had a horror of the single fact, believing that in order to explore any one thing, one needs to approach it from all sides...
Every discovery opens up the imagination further, stimulating more discovery:
it enlarges the sphere of ideas,
excites a taste for investigation,
while the creation of new instruments of observation increases the intelligence."

Theodore Zeldin,
An Intimate History of Humanity, London 1994

Introduction

THIS document describes what a future software system could do not only for instrumentation companies and imaging engineers, but also everybody producing, interpreting or analysing digital images, especially in the medical field.

Since the author has developed her mathematical and metrological theories in private and independent research, they are not being described here. However, prototype software has been tried and tested extensively, and it is hoped that its screenshots invite the reader to imagine investigations and possible applications of his particular interest.

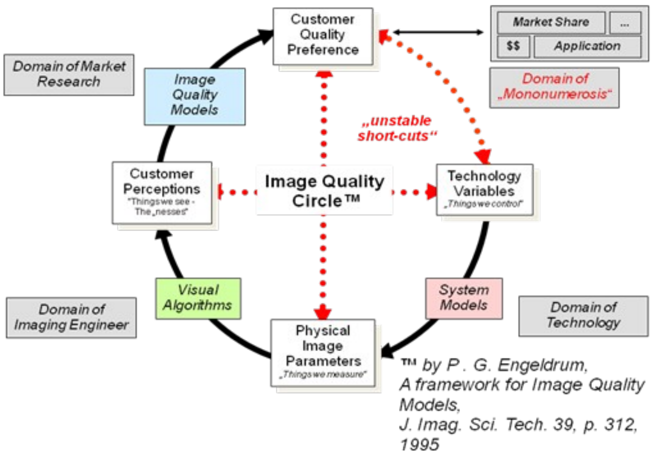
A general overview over possible software systems based on the experience of teaching programming and diagnosing programs at CERN[1] is given on our website[2] with reference to 3D Metrics @ CERN in 2006[3].

Two analogies from the previous article are being used:

1. The *Image Quality Circle* published in the above mentioned article covering
   a. "Mononumerosis"
   b. Technology
   c. Image Engineering
   d. Perceptions

2. The *Medical Virtual Image Chain* consisting of
   a. a virtual image
   b. a virtual medical display
   c. a virtual specialist.

The *Image Quality Circle* describes the full process from capturing to interpreting digital images.



From the Image Quality Circle to 3d Metric Investigation Cycles

Our parallels to the *Image Quality Circle* are as follows:

- "Mononumerosis", the desire for single numbers, is replaced by our *3d metric framework* for digital investigations
  - by offering quantifications on screen, *3D Metrics* provides *virtual measuring methods*
- The Technology domain is replaced by our *3dM software methods:*
  - user controls replace Technology Variables and allow for analyzing images individually as well as in small and large groups and collections
  - vocabularies replace System Models (pink box) and describe images as a whole, so that individual components and their distinctions, differences and similarities can be investigated
- The Image Engineering domain is matched by our *3dM* approach to Image Analysis:
  - Physical Image Parameters are replaced by our *image data metrics*
  - Visual Algorithms (green box) are replaced by our visualization techniques
- Customer Perceptions are matched by User Experiences and Interpretations:
  - Image quality models (blue box) are complemented by metric data bases with values ready for expert and general user investigation.

The hardware of image engineering using visual algorithms is thus replaced by image analysis software and visualization techniques.

The Technology Variables of "things we control" is translated into user controls of software systems.

The Physical Image Parameters of "things we measure" are embedded in vocabularies of descriptors, characteristics and qualities.

The Customer Perceptions of *the things we see – the "nesses"* – are the *qualities* that 3dM software quantifies. Input from experts ensures that the software gets trained to look for what the expert is familiar with before the general knowledge user explores its usefulness.

Image Quality Models (blue box) are thus replaced by levels of expertise and user preferences for adding 'virtual 3D' to the user experience which consists of:

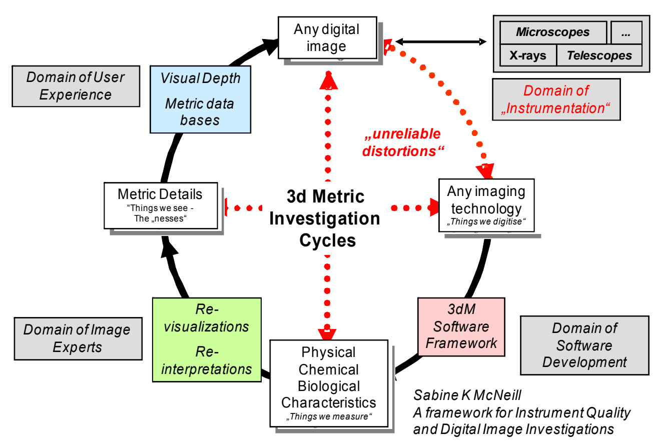
- Expert level controls that allow for populating vocabularies
- General knowledge level controls allow for zooming in and out of image areas not only in 2D but also in 'virtual 3D'
- 'Virtual 3D' adds visual depth and perspective for the human eye
- For the software developer, virtual 3D offers quantifications that can be compared in data bases.

This multi-dimensional approach to the complex challenge of improving image quality creates new Image Investigation Cycles:

A. From Test Images to Reference Images

The genericness of our methods allows for processing any digital image produced by any imaging technology. By including microscopes and telescopes, this means not only independence of application, but also of scale, beyond displays built for medical images.

Input from experts is therefore necessary to ensure that the physical parameters of the instrument are taken into account. The purpose is to gauge, calibrate and ensure that images are captured at optimum levels of operation.



B. From Reference Images to Engineering Parameters

Improving the quality of displays turns into cycles of investigation from grasping and interpreting visualizations to studying metric output. For the imaging engineer to optimise his design or calibrate instruments, parameters need to be defined with their limits and levels of tolerance.

C. From Image Re-Visualizations to Deeper Interpretations

For the medical specialists to interpret one image at a time, or the routine diagnostician who needs to scan thousands of images for reliable automation, different parameters need to be specified by medical experts.

The "things we control" thus become a panoply of menu options for different levels of expertise, for choices of virtual or actual instruments, for selections of scale, for picking from drop-down lists of vocabularies and for playing with controls to investigate the values associated with an image.

The 3d metric investigation of images results in quantifying "nesses" or qualities that, so far, have proven difficult to put numbers to.

For the Imaging Engineer, measuring such "nesses" means optimising the design and operation of instruments by:

- Deciding on reference images that produce reference or gauge values
- Determining acceptable levels of deviation
- Optimising, gauging and calibrating displays.

In a way, our software becomes the virtual medic, so that measuring medical "nesses" means:

- Deriving image data metrics as the basis for quantifying images as a whole and for forming part of image collections
- Proposing metric values derived from images for association and interpretation by actual experts
- Storing limit values and levels of tolerance proposed by actual experts
- The system and its users learning from expert and user input and feedback
- Managing the feedback between the computer's re-visualizations and visualizations on-screen, its store of values in data bases and people's perceptions and interpretations.

D. Re-Interpreting and Scanning Medical Images

For the actual medical specialist, measuring "nesses" means different things depending whether individual diagnosis or scanning for preventive purposes is the purpose. When building a system, expert input is required with an initial collection of images and associated parameters for:

- Populating vocabularies with terms that characterise what images represent
- Associating vocabulary terms with values based on experience
- Gaining new insights by *seeing more* in familiar images
- Learning more from the metric values proposed by the software
- Developing confidence when examining thresholds and standard values with associated images.

Medical experts learn from the experience of looking at lots of images over many years.

Our software may process the same amount of images in less than a minute. But the experience of the expert needs to be integrated into the system so that the automated processing of many images can be carried out in a meaningful way.

It is thus the interplay between expert input, software processing and the visual and metric output on screen that creates a new kind of expert system.

From the Virtual Image Chain to Digital Image Re-Interpretations

While the *Image Quality Circle* tries to find improvements for the technology of the display, 3d metric software offers processes for fine tuning the interplay between images and displays.

When paralleling the *Medical Virtual Image Chain* with 3d metric software, the feedback between hardware, software and human expertise results in 'virtual measuring'.

Virtual measurements are the metric results in data bases that become accessible for on-screen investigation.

Virtual 3D offers screenshots for grasping, comparing and interpreting which results in different kinds of insights.

We compare visually instantly and intuitively. To compare images quantitatively is the strength of our software methods. To interpret these quantifications is the task of the scientific expert, whether in the imaging or the medical domain.

The virtual image is thus replaced by real images that are differentiated into reference images for displays and reference images for diagnosis.

Display reference images are used for quantifying display parameters.

Replacing the virtual medical display, diagnostic reference images are used for establishing reference values from experience on one hand and from the proposals made by the software.

Medical virtual image chain

- Virtual image
- Virtual medical display
- Virtual specialist

3d metric Software

- Technology
  - Any image
  - Any instrument
- Expert Input
  - Reference values
- Digital Comparisons
  - Instrument calibration
  - Image qualities
- Visual Output
  - Screenshots
- Metric Output
  - Data bases

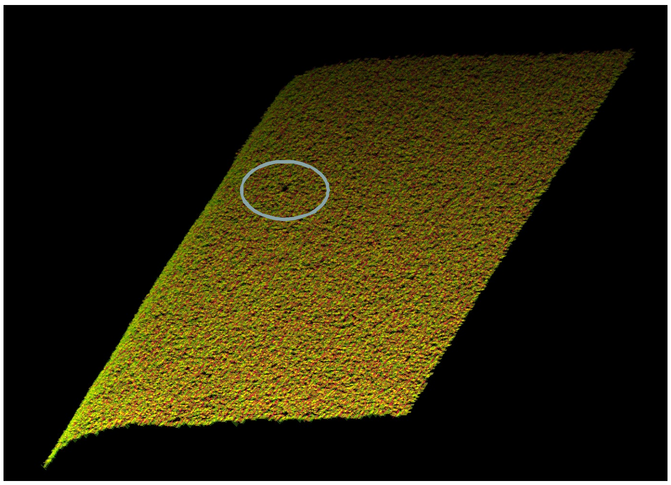
With our software methods in place, the virtual specialist becomes a group of experts and general knowledge users: the imaging engineer for the display, the medical expert for setting limits for mass scanning and the medical diagnostician for interpreting individual images.

Investigating Display Qualities

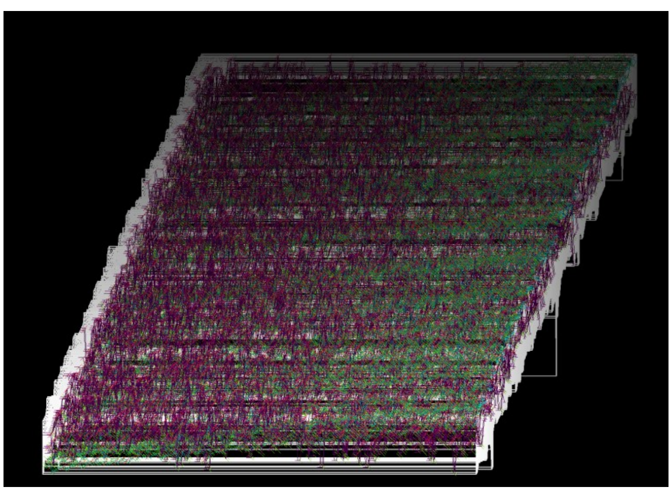
To investigate the quality of a display, its image is taken with a high speed camera and re-visualized with our software. For the purpose of creating ultimate reference images, our software should be used to compare images taken with different cameras.

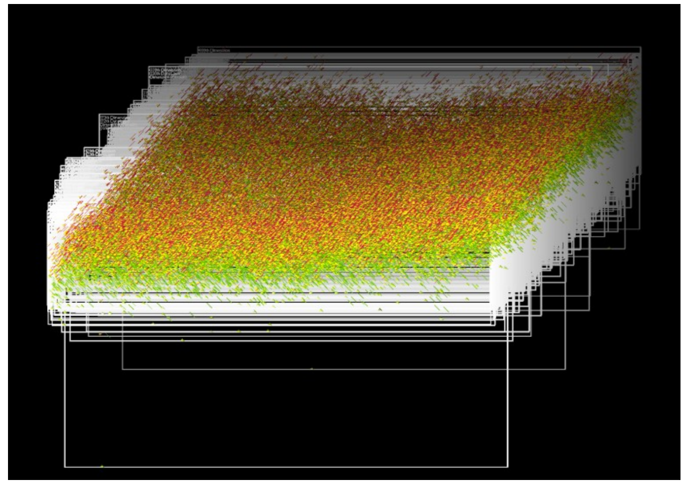
E. A Test Image as an Example for Reference Images

Our prototype software re-visualizes a part of this high speed camera image to reveal not only the display's curvature but also dead pixels. Systematic investigations will determine the best camera for optimising displays.



The investigation of the centre area of the display in the screenshot below allows us to detect patterns of a different kind that possibly serve the image engineer to make adjustments for improving display quality:





F. Views for the Interpretation of Imaging Engineers

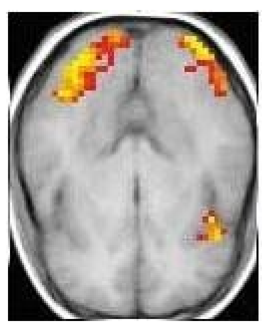
For our screenshots to be meaningful for imaging engineers, they have to feed the "nesses" or qualities that they are interested in with their particular experience and parameter values.

Our software supplies re-visualization and metrics, while the words for interpretation need to be customised into structured vocabularies and associations with data bases.

Investigating Single Images

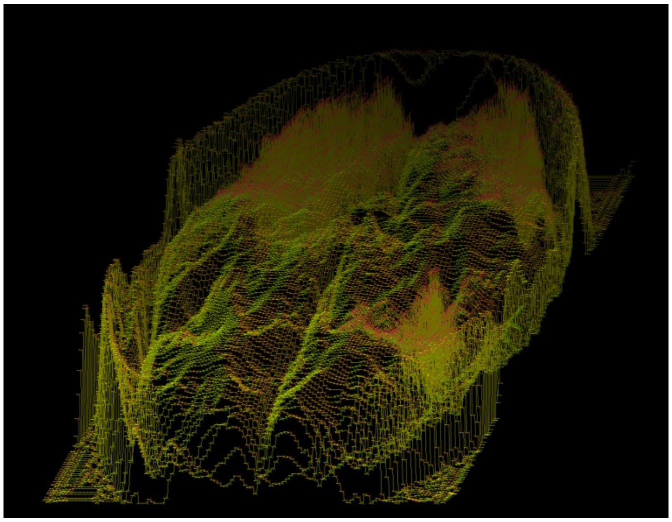
The human eye takes in one image at a time and can compare small quantities of images by their nature and by key characteristics, such as major patterns, key components, contrast and colours. Our software re-visualization offers not only extra depth and perspective as a first impression, it also offers user controls for investigating heights and angles at which to view the image contents.

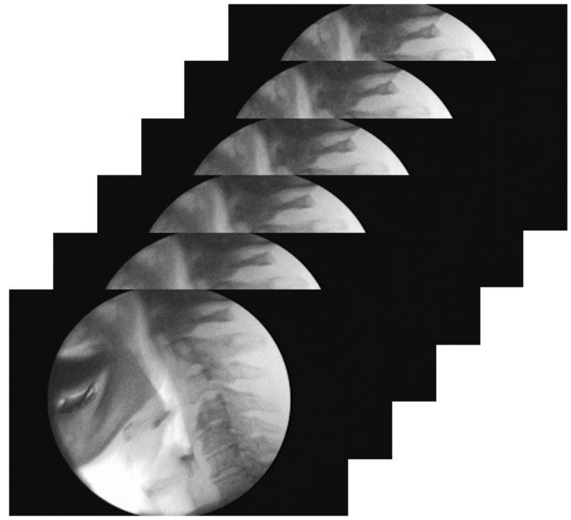
In the medical context, hundreds and thousands of images can be screened to examine which ones are outside threshold values and to let experts decide on standards and averages.

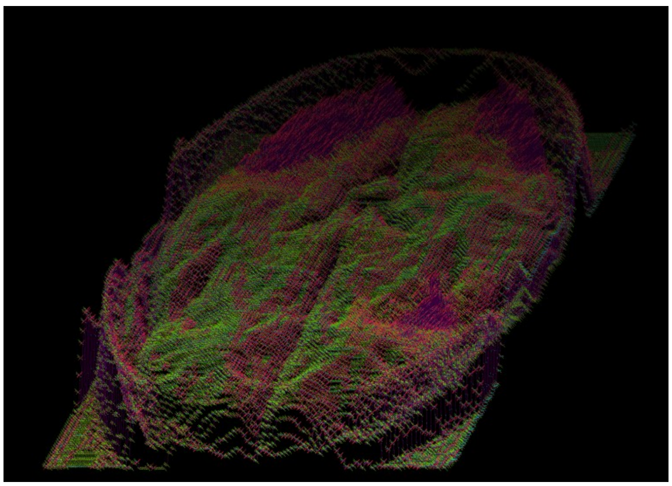


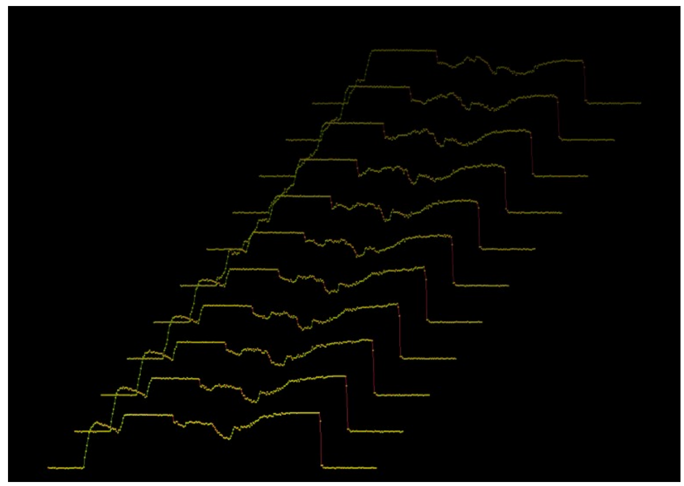
This functional MRI scan from the University Berkeley is re-visualized below with two different visualization options – just to illustrate the scope of possibilities for the eye to *see more* by detecting new patterns and distinctive factors.

Our software derives quantifications that experts need to describe and name.









Investigating Image Collections

The advantage of software over humans is the capacity of mass processing. Images, however, can only be processed when they can be quantified.

Our image data metrics allows for quantifications on different levels so that

1. Images can be given a proprietary classification index

2. Based on this index, images can be sorted.

3. Further metrics allow for the creation of "metric profiles" so that differences can be spotted by comparing profiles rather than full images.

4. Metric profiling leads to ranking according to parameters that are inherent in the image.

5. And finally, our image metrics allows for the analysis of the patterns, components and objects that characterise images.

To the eye, the above Fluor X-rays of a larynx seem identical. Our software, however, derives profiles that are visually discernable. Furthermore, the profiles can be stored in data bases for comparison with other collections.

Once again: experts need to tell us what they are looking for. But our quantifications and metrics can sort and rank, select above and below certain values, and the feedback between experts and software create a system of sophistication for reliable automation hitherto not available.

Conclusion

While the original article was aimed at improving the quality of perceiving images, this text explains the potential of our software methods for the purpose of testing the performance of displays and calibrating them with specially selected reference images.

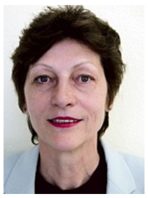
It also describes the added value and functionality for the analysis of digital images in general, individually and in collections.

In terms of domains, our software methods aid imaging engineers and different medical specialists. In terms of imaging technology, our software aids as a quality assurance tool.

In the context of image analysis, our software methods open the door to analysis combined with automation in unprecedented ways.

All in all, we hope to contribute a new instrument of digital investigation for advancing science and imaging technology.

References



Sabine K McNeill studied mathematics and computing at the then *Technische Hochschule* in Darmstadt, Germany before working as a software diagnostician at CERN. After a serious car accident on duty trip, she eventually left CERN and became an event organiser in London. Translating an article on prime numbers triggered her odyssey of 'software-aided thinking' which resulted in prototype software of three different kinds.

[1] http://public.web.cern.ch/public/

[2] http://www.3dmetrics.co.uk/

[3] http://www.3dmetrics.co.uk/index.php?page_id=10