SUBJECTIVE VS OBJECTIVE IMAGE QUALITY

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ABSTRACT

Image quality demands have been investigated for different applications of stereoscopic evaluation. For that purpose, the quality of image pairs was judged by experienced stereo operators in subjective scales for contrast, sharpness, granularity, interpretability and overall quality. The judgment was made in real working situations with the images oriented in stereo instruments. The result showed different demands for different applications. It is being used for deriving frequency weight functions for integration of modulation transfer functions into image quality marks. The frequency weight functions will be a useful basis for further investigations into the dependence of subjective quality upon the frequency content of images.

KEY WORDS: Image Quality, Modulation Transfer Functions, Microdensitometry, Questionnaire

1. INTRODUCTION

Aerial image quality is discussed extensively in photogrammetric as well as in photographic literature. Most often, the scope is to predict the potential capability of an optical/photographic system to resolve fine details. It is important however, not only to predict the quality potential of an aerial imaging system and to produce aerial photographs of the highest possible quality, but also to be able to assess the quality of images at hand. Quality assessment of images produced may be of great importance in predicting the quality of the final image evaluation result (cf. Trinder 1986) as well as the time needed for the work and the amount of complementary geodetic measurements needed.

There are two principally different ways of assessing image quality, featuring a subjective and an objective approach, respectively. Both methods have their pros and cons, as have been discussed e.g. by Boberg (1973 and 1988). Moreover, images are evaluated for different applications and in different types of instruments. This implies that for an image or an image pair, image quality demands may differ. For example, stereo-plotting or block triangulation in an analytical or an analog instrument, photo interpretation, orthophoto production and image digitizing may raise different demands on the quality of the images used. An investigation into the nature of these different demands is necessary as a basis for the evaluation of image quality assessment criteria.

The main project "Assessment of aerial image quality", out of which this report shows a part, deals with the problem of finding objective measuring methods for assessing aerial image quality, methods that are relevant with respect to subjectively experienced image quality in the stereo instrument.

In this report, a subjective and an objective approach to the problem are reported of. Subjective image quality is investigated with the help of a questionnaire to stereo operators. Determination of objective image quality parameters in the form of system MTF via edge gradient analysis is discussed. The project is limited to large-format (23x23 cm) aerial photographs from mapping cameras of wide or super wide angle type.

2. METHODS

2.1 Questionnaire for subjective quality

Image quality demands have been investigated for different purposes of stereoscopic evaluation, viz. block triangulation, large and small scale topographic map compilation, profiling and DEM measurement, orthophoto generation and image interpretation. The investigation was made in the form of a questionnaire, directed to Swedish stereo operators. They were asked to judge images oriented in their instruments, i.e. in real working situations. Image quality was assessed in subjective scales from 0 to 10 for four quality parameters and for overall quality:

- -Overall density D
  - 0 = too dark
  - 5 = fair
  - 10 = too light
- -Contrast C
  - 0 = too soft
  - 5 = fair
  - 10 = too hard
- -Sharpness S
  - 0 = strongly unsharp
  - 5 = acceptable
  - 10 = very sharp

-Granularity G
0 = very large grain
5 = normal
10 = very fine grain
-Overall quality Q
0 = useless
5 = acceptable
10 = unsurpassed

The image identification number was asked for in order to make it possible to measure objective image quality parameters in the images assessed, and to compare the result with the subjective overall quality mark given each strip by the National Land Survey (see Boberg 1986 and 1988). Also descriptive parameters like photo agency, film type, stereo instrument type and optical magnification used was asked for. Finally, personal comments were requested.

Out of around 150 distributed questionnaires, 76 were answered. The answers came from stereo operators employed by governmental agencies (the National Land Survey, the National Road Administration, the Geological Survey and others) and from private mapping firms. The following image evaluation purposes were represented:

-Block triangulation
5 answers (7%)
-Large scale (1:400 – 1:4 000) topographic or cadastral map compilation
33 answers (43%)
-Small scale (1:5 000 – 1:50 000) topographic map compilation
18 answers (24%)
-Profiling and DEM measurement
7 answers (9%)
-Orthophoto generation
0 answers
-Image interpretation
13 answers (17%)
-Total
76 answers

2.2 Evaluation of the questionnaire

In order to determine which image quality factor had the greatest influence upon the overall quality mark, regression analysis was applied to the answers. For each answer pair (Q_{Pn} ; Q_O), where Q_{Pn} represents the partial quality factor n and Q_O is the overall quality mark, a two-dimensional graph was plotted with the help of a statistical program. In the cases where the correlation coefficient exceeded 0.6, also a regression function was calculated. The same calculations were performed on answers stratified according to the image evaluation purposes.

In the same way, the overall quality mark of the questionnaire was compared with the subjective overall quality mark given by the National Land Survey, also on stratified answers.

2.3 MTF as objective quality parameter

As a result of previous discussions on different objective image quality criteria (see Boberg 1973 and 1988), the modulation transfer function (MTF) is chosen as the most promising parameter to be compared with subjective assessments. In order to be able to determine MTF of images at hand, the edge gradient analysis (EGA) method (see e.g. Scott et al 1963, Welch 1971, Gerencser 1976, Gliatti 1976) using micrometer traces across natural density steps is used.

For microdensitometry a Joyce-Loebl Mk III CS microdensitometer was equipped with digital encoders and connected to a PC. The Joyce-Loebl is a two-beam microdensitometer with the specimen in one beam and an adjustable grey wedge in the other (Figure 1). Balancing the two beams gives the density value. Welch (1971) as well as Gliatti (1976) recommend an effective slit of 1-5 x 80-200 µm. Under these circumstances, the microdensitometer can be regarded as free from partial coherence or excessive noise, according to Welch (1971). The grey wedge density range was ΔD = 1.64 density units, covering normally developed diapositives. According to National Land Survey standards, D = 0.3-1.2, giving ΔD = 0.9 density units. The linear scanning scale was calibrated using a glass scale with 0.1 mm divisions.

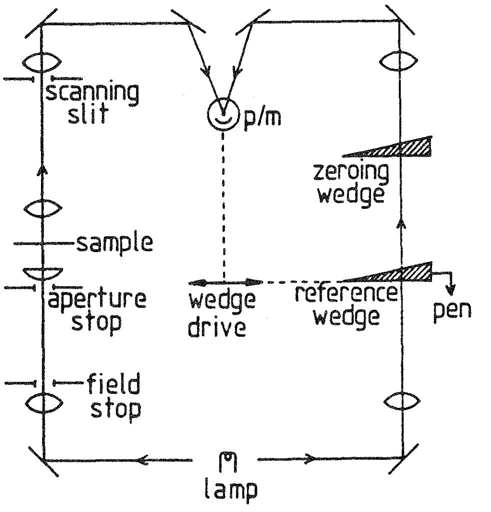

Figure 1. The measuring principle of the Joyce-Loebl Mk III CS microdensitometer

In order to include the whole imaging process into the MTF, no reduction of density values into exposure values via the DlogH curve was made. This presupposes that the photographic process is linear. Earlier investigations into this (Boberg 1988) showed that this assumption normally is realistic, provided that the copies are sufficiently exposed. The process thus preserves the photographic contrast enhancement as well as edge enhancements by development effects (the Eberhard effect), which are of importance for image interpretability and therefore should influence the quality parameter.

A PC software package was developed for this project, featuring interactive control of the measuring and calculating process. The microdensitometer trace is digitized with desired frequency and graphically presented. The trace is truncated according to choice and if desired smoothed by an adjustable low-pass Butterworth filter. The density step is derivated into a line spread function, from which (after possible further smoothing) the MTF is calculated by a fast fourier transform (FFT), which is normalized. The area below the MTF curve may be integrated into a numerical value.

The microdensitometer was tested on a number of traces on images earlier quality judged by stereo operators. Only a few images have been measured yet, however. Therefore, no results of the comparison between subjective and objective methods can be presented, but some experiences concerning practical measurement problems and the need for further development of the software could be drawn.

3. RESULTS

3.1 The questionnaire

79 percent of the images judged were black and white diapositives, 16 percent were color or color infrared diapositives. 59 percent of the instruments used were analytical plotters, 28 percent were analog plotters, 13 percent were interpretation instruments. On the average, an optical magnification M_0 = 9.1x was used, with a standard deviation s_M = 3.3x.

The mean values D_0 etc and standard deviations s_D etc of the different subjective quality parameters and of the overall quality (see part 2.1) were found to be as follows:

-Overall density D	$D_0 = 4.9$	$s_D = 1.1$
-Contrast C	$C_0 = 4.5$	$s_C = 1.5$
-Sharpness S	$S_0 = 5.0$	$s_S = 2.2$
-Granularity G	$G_0 = 4.7$	$s_G = 1.6$
-Overall quality Q	$Q_0 = 5.2$	$s_Q = 2.0$

Correlations between these parameters were investigated. The descriptive parameters flying height and instrument magnification showed no correlation to overall quality. Correlation of the different quality parameters to overall quality gave the following result (figure 2 a-d):

-Density D:	Second order regression, $R_{QD} = 0.41$
-Contrast C:	Linear regression, $R_{QC} = 0.63$
-Sharpness S:	Linear regression, $R_{QS} = 0.82$
-Granularity G:	Linear regression, $R_{QG} = 0.65$

Brock (1970, p 87) emphasizes that subjective sharpness is dependent on the contrast of the edge. To check if this was verified in this investigation, judged sharpness was correlated to judged image contrast (figure 3). A linear regression gives R = 0.62.

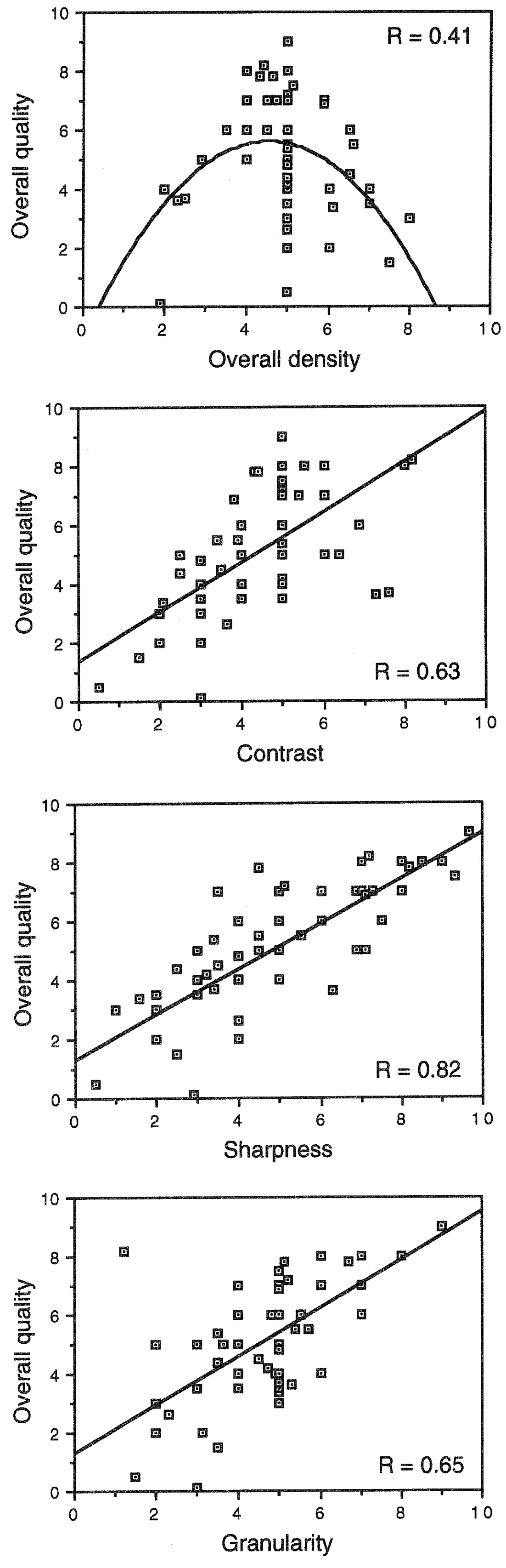

Figure 2. Correlation of four subjectively assessed quality parameters to assessed overall quality

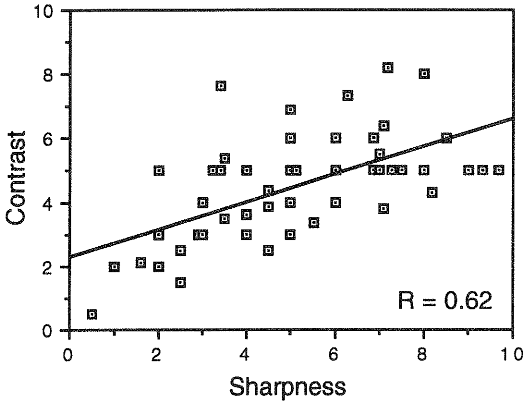

Figure 3. Correlation of judged sharpness to judged image contrast

Granularity should be more evident under high optical magnification. To check this, the two parameters were plotted against each other. No correlation was found, however.

Influence of film type is for the moment difficult to establish with statistical significance, but the tendency is that color film gives higher quality marks than B/W or CIR film. The same is valid for instrument type. Analytical instruments give slightly higher quality marks than analog or image interpretation instruments.

The subjective overall quality mark of the questionnaire showed no significant correlation to the National Land Survey (NLS) subjective quality assessment (figure 4, R = 0,28). Neither did any of the different subjective quality parameters of the questionnaire show any correlation to the NLS quality mark.

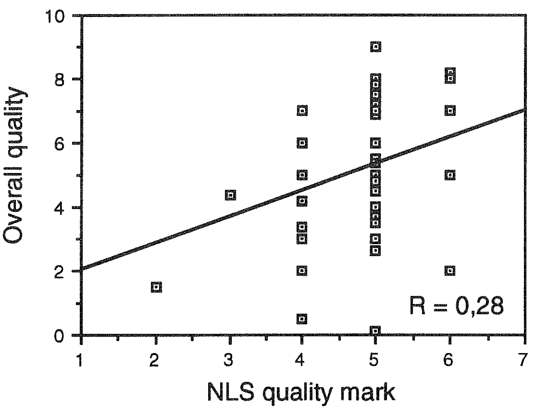

Figure 4. Correlation of image quality assessed by the National Land Survey to overall image quality assessed by stereo operators

3.2 Microdensitometry and MTF determination

As a main objective of the project is to establish a bridge between subjective and objective image quality criteria, MTF determination of a major part of all image pairs judged in the questionnaire is planned to be performed, and the result for each image pair will be compared with the result of the questionnaire.

As mentioned above, because of problems with the PC connection to the microdensitometer, time has not allowed enough traces to be measured for valid conclusions to be drawn. Instead, work has been concentrated upon optimizing the measurement system.

4. DISCUSSION

4.1 Influential factors on subjective quality

All quality parameters have mean values slightly below 5, i.e. close to fair, acceptable or normal values. The standard deviations are moderate, except for sharpness. Images in general are thus regarded as having fair density, being slightly too soft, having an acceptable sharpness and being slightly too grainy.

The overall quality is judged acceptable, but with large variation.

The fact that flying height was not correlated to the assessed overall quality showes that the latter was judged independently of flying height, only with respect to experienced normal or at the best obtainable quality. This strengthens the relevance of the other results of the questionnaire.

As might be expected, image sharpness had the strongest influence on subjectively experienced image quality. In fact, sharpness is the only quality parameter that shows a clear correlation to overall quality. For contrast and granularity weak but evident correlations to overall quality were found. The conclusion of this evidence is, that objective quality parameters primarily should reflect image sharpness, secondly granularity and contrast.

For the subjectively assessed quality parameter overall density, the best correlation function to overall quality is of second order (figure 2a). This means, that an adequate overall density corresponds to the highest quality marks. This is in accordance with the experience (see e.g. Brock 1970 p 152) that the resolution capability of an emulsion is greatest in a medium background density range (figure 5).

Concerning the influence of edge contrast on subjective sharpness, according to Brock (1970), it must be concluded that it is small in this material.

It is surprising (cf. e.g. Trinder 1986) to find no correlation between granularity and optical magnification. The explanation might be, that optical magnification has too small variation in this material.

The tendency that color film gives higher quality marks than B/W film is in accordance with the experience by Trinder (1986) that photogrammetric measuring precision is around 20% higher on color photography.

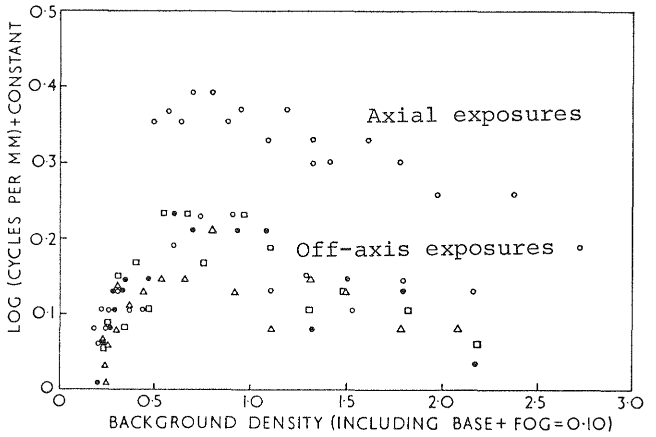

Figure 5. Variation of resolving power with density for an aerial film (Brock 1970, p 152)

It is of great interest and importance to find no significant correlation between the subjective overall quality mark or the different subjective quality parameters of the questionnaire and the NLS subjective overall quality mark. Truly the assessment situations are not identical, and the NLS mark concerns a whole photo strip (Boberg 1986), but this is not a sufficient explanation. Either the qualities of the diapositive and of the negative are totally uncorrelated, or the assessment situations, monocularily by office personnel, in a stereo instrument by stereo operators, are too different. This should be further investigated.

4.2 Experiences of microdensitometry and EGA

Like experienced by other authors (Gerencser 1976, Gliatti 1976), smoothing of the microdensitometer trace and cutting off the trace edges are highly subjective moments, which strongly may influence the final result. These moments should if possible be avoided. It is highly desirable to find a more objective way of reducing the influence of granularity as well as the instrumental noise.

On the other hand, as the objective is to measure an overall image quality parameter, the photographic adjacency (Eberhard) effect, which definitely may increase interpretability, should be preserved.

An objective noise reduction method that preserves the adjacency effect might be accomplished by adapting to the measured edge trace a theoretically derived model for a noise-free edge response curve with adjustable steepness. The theoretical edge curve could be derived from a diffraction-limited edge image superimposed upon the Eberhard-effect curve of the actual photographic material and developer, of variable strength depending upon edge contrast. This process might be carried out either in the spatial or in the frequency domain.

The influence of granularity on image quality and interpretability should be paid regard to separately.

Further development of the microdensitometer software is also needed concerning the integration of the MTF curve into a quality parameter. The integration should include frequency weight of the MTF curve, the weighting function being chosen with the objective to yield an integration result of relevance for subjectively assessed quality in a certain application.

A similar approach is the use of a contrast sensitivity (CS) curve of the eye as lower integration limit (cf. Trinder 1986). A threshold modulation (TM) curve of the photographic material, as recommended by Trinder, could not be used as lower integration limit here, as the properties of the photographic material is already included in the MTF.

5. CONCLUSIONS

Determination of the quality of aerial photographs at hand should be based upon objective measurements of quality parameters. The choice of these parameters, as well as the method of calculation, must take into account subjectively experienced image quality. In this report different parameters that influence subjectively experienced image quality have been studied.

Subjective quality assessment monocularily in negatives and stereoscopically in diapositives, respectively, showed no significant correlation. This has to be investigated more in detail, but indicates that the observation situation may influence the result.

It is shown, that among judged parameters, image sharpness has the largest influence upon overall quality assessment, while mean density, contrast and granularity influence in a more limited sense. This strengthens the hypothesis that frequency weighted modulation transfer functions is the most promising approach to the problem of deriving objectively determined quality marks of subjective relevance. More attention has to be paid to the process of deriving such image quality marks.

6. ACKNOWLEDGEMENTS

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