insignificance. The initial LIS is modified by removing all elements that belong to a chain. Later on, the LIR gets broken down into RSS elements which are placed into the LIS and LIP elements as soon as they are found to be significant. Even though this does not contribute significantly to a drop in peak signal-to-noise ratio, this method redistributes the bits by a region discriminator technique using the WBC method which improves visual quality [5, 6].

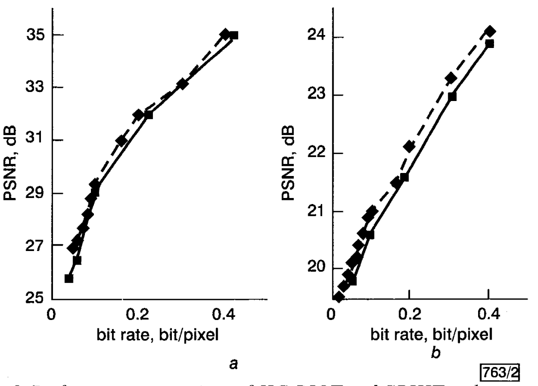

Fig. 2 *Performance comparison of HC-RIOT and SPIHT coders*

a Lena image
–◆– SPIHT-4
—■— Lena 0.04-11
b Mandrill image
–◆– SPIHT-4
—■— Man 0.04-11

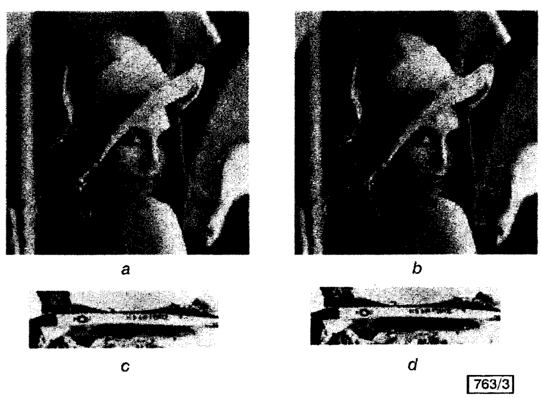

Fig. 3 *Region biased comparison results in base and enhancement layers*

a No perceptual filtering (base layer)
b Perceptual filtering (base layer)
c No perceptual weighting (enhancement layer)
d Perceptual weighting (enhancement layer)

Results: The performance of the HC-RIOT coder is comparable to a SPIHT coder at the same decomposition level (Fig. 2). The performance of the coder can be improved by optimising the LIR formation and search methods in the WBC option. However, the HC-RIOT coder provides some limited region classification and can manipulate smaller spatial regions than the SPIHT coder. This allows for the improvement of the perceptual quality by providing a means of discriminating between different types of regions. Fig. 3*a* and *b* indicate two images at the same low bit rate but perceptually filtered differently. In the first image, there was no discrimination between regions. In the second image, the weightings emphasised earlier transmission of the detail and edge features of the image in the bitstream. In the enhancement layers at higher bit rates, it seemed to improve text or similar high detailed features in images (Fig. 3*c* and *d*), though this was harder to determine.

Conclusions: The HC-RIOT is comparable to a state-of-the-art SPHIT coder at the same decomposition level. Through the WBC method, the codec gains an advantage by being able to classify wavelet blocks and group some of the blocks into larger regions. This can improve image quality in transmission by adding a perceptual weighting aspect. Furthermore, it can group similar contiguous regions together into larger regions that have common characteristics which is beneficial for object based strategies.

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Modelling deposition of surface texture

G. McGunnigle and M.J. Chantler

A class of surfaces formed by deposition are analysed and modelled. The surface derivative fields are estimated using photometric stereo and their spectra modelled. A published technique that uses the repeated addition of a primitive to simulate the surface is tested. The quality of the model is assessed by comparing simulated images with the originals. When used with photometric stereo and a surface spectrum model the technique is useful for modelling the appearance of the surface throughout the deposition process.

Introduction: Our work on applying texture analysis to rough surfaces relies on the use of surface models. The objective of this Letter is to model a class of surfaces formed by particle deposition. Several functional models of deposition have been advanced by physicists, see [1] for introduction. This Letter is empirical; we do not attempt to accurately model the underlying physical processes but only the resulting surfaces. The Letter combines three elements: a parametric model of the power spectral density of the surface height function [2]; a mechanism, due to van Wijk [3], that uses this model to simulate a series of surfaces; and photometric stereo [4] to estimate the surface data on which the simulations are modelled and assessed. When rendered the simulated surfaces resemble the original images. Van Wijk's method, together with an appropriate spectral model, is capable of simulating the appearance of this class of surface throughout the deposition process.

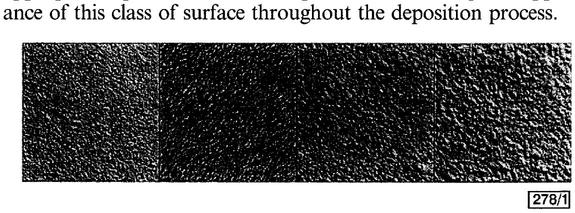

Fig. 1 *Mature surfaces*

The test surfaces are formed by depositing plaster powder onto a flat base. We analyse two image sets: the first set (Fig. 1) consists of four different surfaces that we describe as mature, i.e. surfaces where the deposition process is well advanced; the second set

(Fig. 2) consists of images of the same surface at different stages in the deposition process, we describe these as evolutive. Both the base and the powder reflect diffusely. The surface derivative fields are estimated using four light photometric stereo.

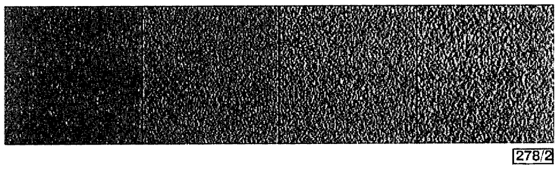

Fig. 2 *Evolution of test surface*

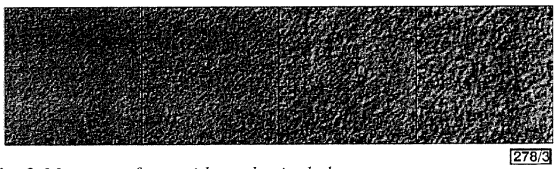

Fig. 3 *Mature surfaces with randomised phase spectra*

Mature surfaces: If a surface is Gaussian then it can be modelled using its power spectrum — altering the phase spectrum will give a different example of the same surface type. We test whether mature surfaces belong to this category by estimating the derivative fields and removing the phase information. The derivative fields are Fourier transformed, the phase spectra randomised and the transform inverted. The reconstituted fields were rendered and are shown in Fig. 3. The reconstituted surfaces have an appearance similar to the originals; the power spectrum is an adequate description for these surfaces.

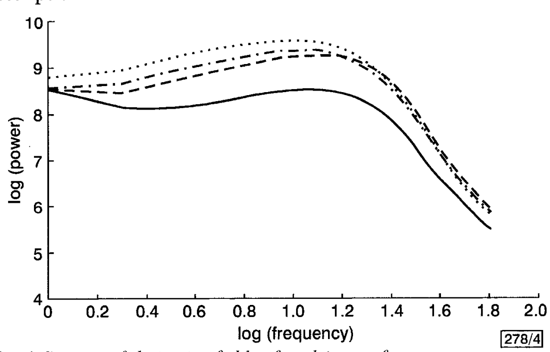

Fig. 4 *Spectra of derivative fields of evolving surface*

——— surface 1
– – – – surface 2
— · — surface 3
·········· surface 4

Evolutive surfaces: Phase is important for surfaces on which only a limited number of particles have accumulated and these cannot be properly modelled using only the power spectrum. Van Wijk presents a simple texture synthesis technique based on the addition of randomly placed primitives to the height function. Since this is a linear operation the spectrum of the surface is a scaled version of the primitive's spectrum. This is consistent with the measured spectra shown in Fig. 4; further deposits change the amplitude but not the shape of the spectrum. After many placements the surface converges to the mature, Gaussian surface type. However, the advantage of this technique is that, because it is an approximate analogue of the deposition process, it is capable of modelling surfaces where a limited number of particles have been deposited.

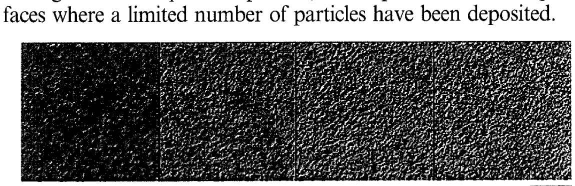

Fig. 5 *Simulation of surface evolution*

In practice, we simulate deposition by adding a series of impulse functions to the surface and then filtering in the frequency domain. The transfer function is equal to the (scaled) magnitude spectrum of the desired surface. In this work, we decided to use a parametric model of the power spectrum from the literature, the spectrum is clearly not fractal and we instead opted for the model proposed by Mulvanney *et al.* in [2]. The resulting surface evolution is shown in Fig. 5 and is similar to the measured images. The surface derivative spectra of the simulated surfaces were inferred from the rendered surfaces and are shown in Fig. 6. These resemble the measured spectra both in shape and in their evolution. The Mulvanney model is appropriate for this class of surfaces and Van Wijk's technique is an effective mechanism for modelling surface evolution.

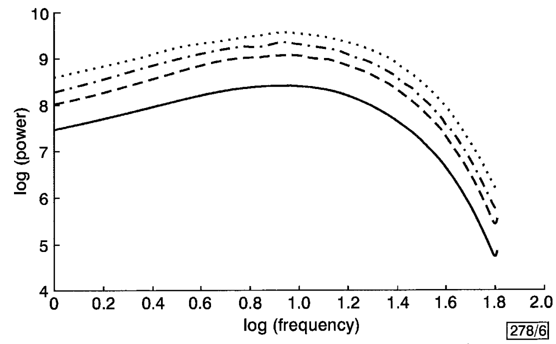

Fig. 6 *Spectra of derivative fields of simulated surface evolution*

——— surface 1
– – – – surface 2
— · — surface 3
·········· surface 4

Discussion: Surface formation by deposition is an illustration of the central limit theorem: as the number of random variables (i.e. increments due to particle impacts) increases, their sum, the height function, approaches a Gaussian distribution. A mature surface is therefore well described by the power spectrum alone. Earlier in the deposition process, the surface will be less Gaussian and phase information is important. Van Wijk's technique is a loose analogue of the physical process. It implicitly codes the phase information in a way that is physically meaningful, and since it uses the power spectrum it extends the use of spectral surface models to a class of non-Gaussian surfaces.

Conclusions: In this investigation, surfaces formed by particle deposition were analysed and modelled. The contribution of this Letter is to combine a model from tribology [2], a mechanism from computer graphics [3] and real data inferred using photometric stereo to simulate the appearance of this type of surface. Surfaces where the deposition process is advanced are modelled well by a description of the surface power spectrum. However, this is insufficient for surfaces on which fewer particles have been deposited. Van Wijk's technique, along with a parametric spectral model and surface characteristics inferred from photometric stereo, was found to be effective in modelling the surface from the initial deposits through to convergence to maturity.

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