Analysis of the variability in digitised images compared to the distortion introduced by compression

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The ear and the eye …

- The ear can easily recognise that noise is present

- The eye does not see any noise in the image, and so we think it is perfect, but it does contain noise …

Introduction

- Its “assumed” that a production camera is of sufficient quality … for retention without loss
- But there has been little objective assessment of the quality or consistency of images produced in digitisation studios
- That is the topic addressed in this paper

Let's look at some images …..
First demo ….

- (demo comprising two sets of images
  - One set has noticeable differences
  - The other does not have noticeable differences
  - One set comprises lossless images and the other lossy images
  - Which is which?
- The set without noticeable differences comprises lossy images
- The set with noticeable differences comprises lossless images
- These differences originate in the imaging process)

Second demo ….

(demo comprises a digital thermometer

- Two different concepts
  - The physical property being measured
  - A measurement comprising the “signal” and the error, including noise, introduced in the measurement process
- The temperature reading shows noticeable variations
- Samples have a spread of values – any reading is as valid as any other
- An approximation of the measurement:
  - is typically very close to the measured value
  - Any difference is insignificant compared with the variations in the measurements
  - The approximation is as valid or plausible as the original reading)

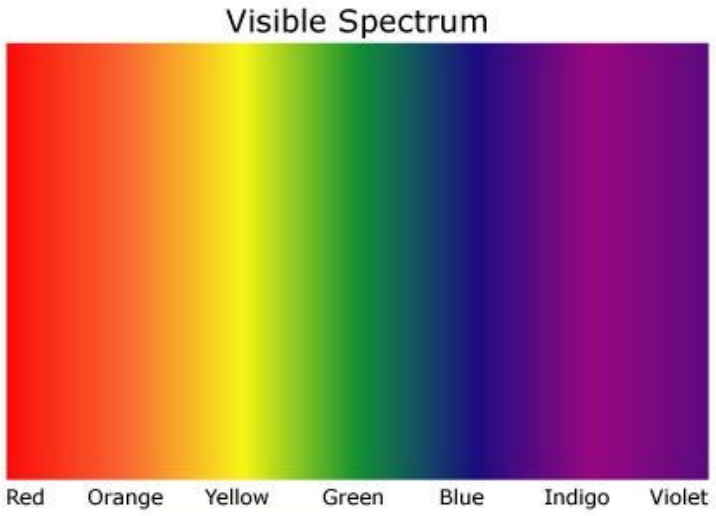
Some comments & responses or questions and answers

- Q: We should preserve the original as it's the best we have
- A: Once we know noise is present then we know there are many "best" possibilities – no one is better than another

- Q: We should preserve the original since in the future there will be better ways to process or enhance images
- A: We would need multiple images of the "same" item, but we routinely only create one image of an item

More ….

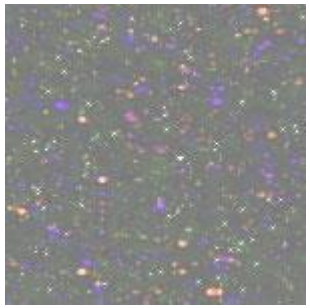
- Q: We should not be reliant on “visually lossless”
- What colour is in the rectangle?
- It is not yellow – it is a mix of red and green seen as yellow
- Visible light is not simply a mix of red, green & blue
- A: If you use a standard camera and computer software then you have implicitly decided that visually lossless is OK



Types of noise in the imaging process

- Random noise
- Fixed pattern noise
- Banding noise
- Dark current noise
- Shot noise
- Amplifier noise
- Quantisation noise
- Colour noise
- Readout noise
- Photon noise

random noise



fixed pattern noise

banding noise

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Digitised: quantitative assessment – 1

- We used three physical samples (A,B and C)
- Each sample was imaged swiftly five times in an identical manner - total of 15 images for each camera/scanner.
- Repeated with ten cameras and scanners
- Seven of which produced images of sufficient quality for detailed automated quantitative assessment
- Resulted in 21 sets of five images
- Each set of five images produces 10 pairwise comparisons
- Total of 210 pairwise comparisons with 7 cameras/scanners

Digitised: quantitative assessment – 2
Summary of comparisons PSNR (dB)

Sample	A	A	B	B	C	C
	Av	Max	Av	Max	Av	Max
Device						
N01	30.790	36.742	31.400	37.024	36.742	36.942
N02	32.712	36.431	36.874	36.925	36.390	36.656
N03	30.083	37.042	32.009	38.277	32.048	37.916
N04	30.095	37.373	30.391	37.823	36.123	37.348
N05	41.449	42.128	42.317	43.000	42.197	42.508
N06	29.851	31.286	28.011	31.335	29.669	30.961
B07	19.479	33.842	22.878	38.862	16.687	36.347

Digitised: quantitative assessment – 3
Summary of average and maximum values

Device	Average of Averages	Average Maximum	Maximum of Maxima	Device Type
N01	32.984	36.903	37.024	Phase 1
N02	35.325	36.671	36.925	Phase 1
N03	32.732	37.745	38.277	Phase 1
N04	33.014	37.515	37.823	Phase 1
N05	41.988	42.545	43.000	Hasselblad
N06	29.728	31.194	31.335	Scanner
B07	26.360	36.350	38.862	Phase 1

Phase 1
37 – 39 dB

Hasselblad 43 dB

Scanner 31 dB

Two best match pairs were selected for further analysis:
PSNR 43.000 dB N05 Hassleblad N05B4 & N05B5
PSNR 38.862 dB B07 Phase 1 B07B3 & B07B5

Compressed: quantitative assessment - 1

	Image Set N05B	
Compression designation	Compres-sion ratio*	PSNR dB
lossless	1.00	Infinity
minloss	1.70	50.477
G2	1.68	50.255
G3	2.24	46.224
G4	2.64	44.476
G5	3.20	42.836
G6	4.26	41.341
G7	5.59	39.576
G8	7.46	37.231
G9	9.94	35.135
G10	14.90	32.412
G11	19.83	31.566
G12	29.73	29.798

Best match image pair 43.000 dB →

* compared with lossless JPEG2000

Compressed: quantitative assessment - 2

	Image Set N05B		Image Set B07B	
Compression designation	Compres-sion ratio*	PSNR dB	Compres-sion ratio*	PSNR dB
lossless	1.00	Infinity	1.00	Infinity
minloss	1.70	50.477	1.59	49.906
G2	1.68	50.255	1.57	49.709
G3	2.24	46.224	2.60	43.745
G4	2.64	44.476	3.06	42.153
G5	3.20	42.836	3.71	40.044
G6	4.26	41.341	4.94	37.685
G7	5.59	39.576	6.48	36.220
G8	7.46	37.231	8.64	34.299
G9	9.94	35.135	11.51	31.952
G10	14.90	32.412	17.26	29.417
G11	19.83	31.566	22.97	28.535
G12	29.73	29.798	34.44	26.738

Best match image pairs
43.000 dB →
38.862 dB →

* compared with lossless JPEG2000

Qualitative assessment - 1

- 1st group:
  - Compared each best match pair with compressed versions of one of the pairs
  - Asked for least difference and most difference between three alternative images
- 2nd group: assessed compressed images with original at X1 and X20 magnification
- 3rd group: assessed minimally lossless images with alternative lossless images X20 and X60

Qualitative assessment - 2

- 1st group:
  - Compared each best match pair with compressed versions of one of the pairs
  - Asked for least difference and most difference between three alternative images

Consistent with quantitative assessment

- 2nd group: assessed compressed images with original at X1 and X20 magnification
- 3rd group: assessed minimally lossless images with alternative lossless images X20 and X60

Qualitative assessment - 3

- 1st group:
  - Compared each best match pair with compressed versions of one of the pairs
  - Asked for least difference and most difference between three alternative images
- 2nd group: assessed compressed images with original at X1 and X20 magnification
- 3rd group: assessed minimally lossless images with alternative lossless images X20 and X60

Consistent with quantitative assessment

At X1 compression by 6 is “perfect”

At X20 compression by 1.8 is “perfect”

Qualitative assessment - 4

- 1st group:
  - Compared each best match pair with compressed versions of one of the pairs
  - Asked for least difference and most difference between three alternative images
- 2nd group: assessed compressed images with original at X1 and X20 magnification
- 3rd group: assessed minimally lossless images with alternative lossless images X20 and X60

Consistent with quantitative assessment

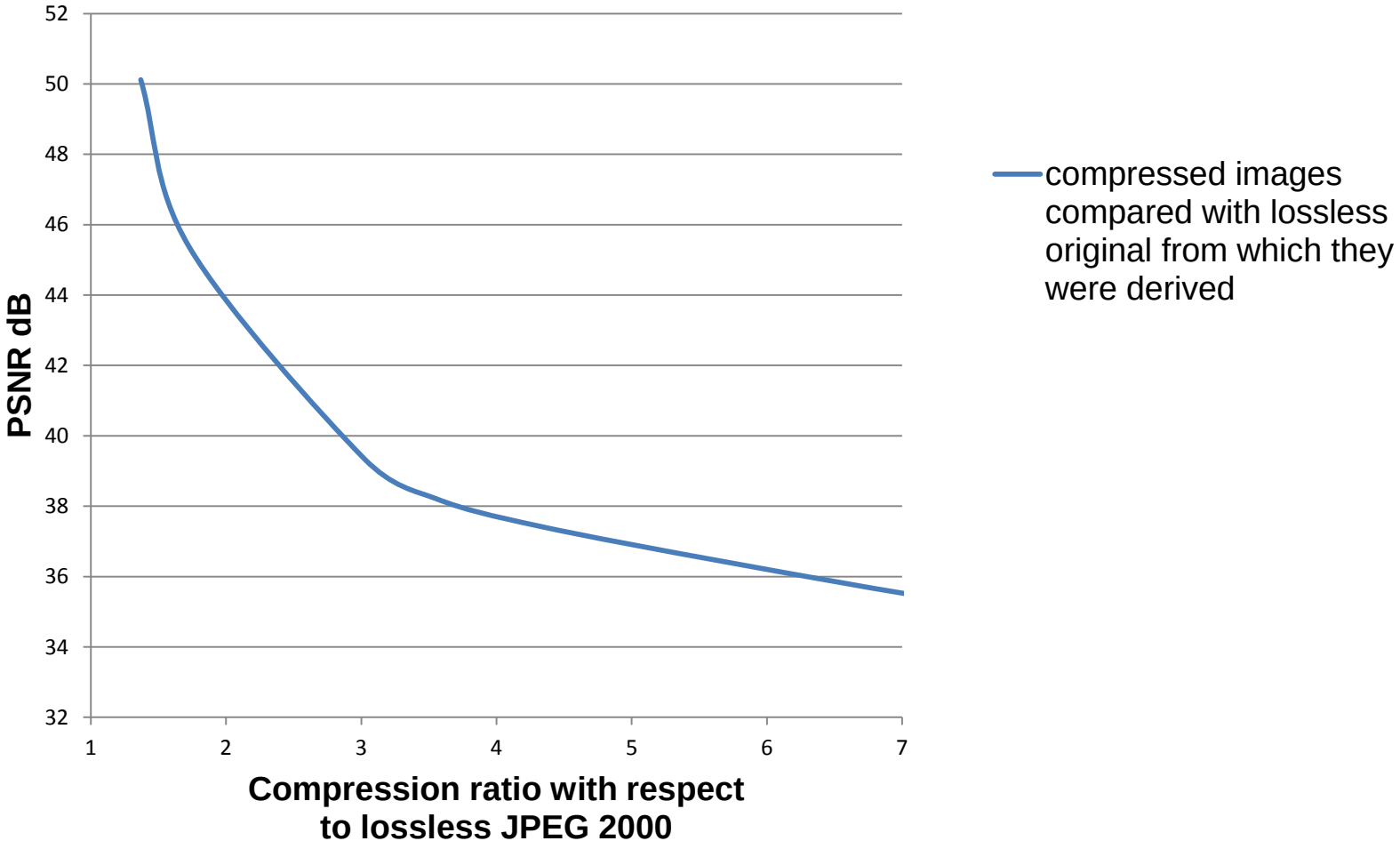
At X1 compression by 6 is “perfect”

16% could see phantom differences

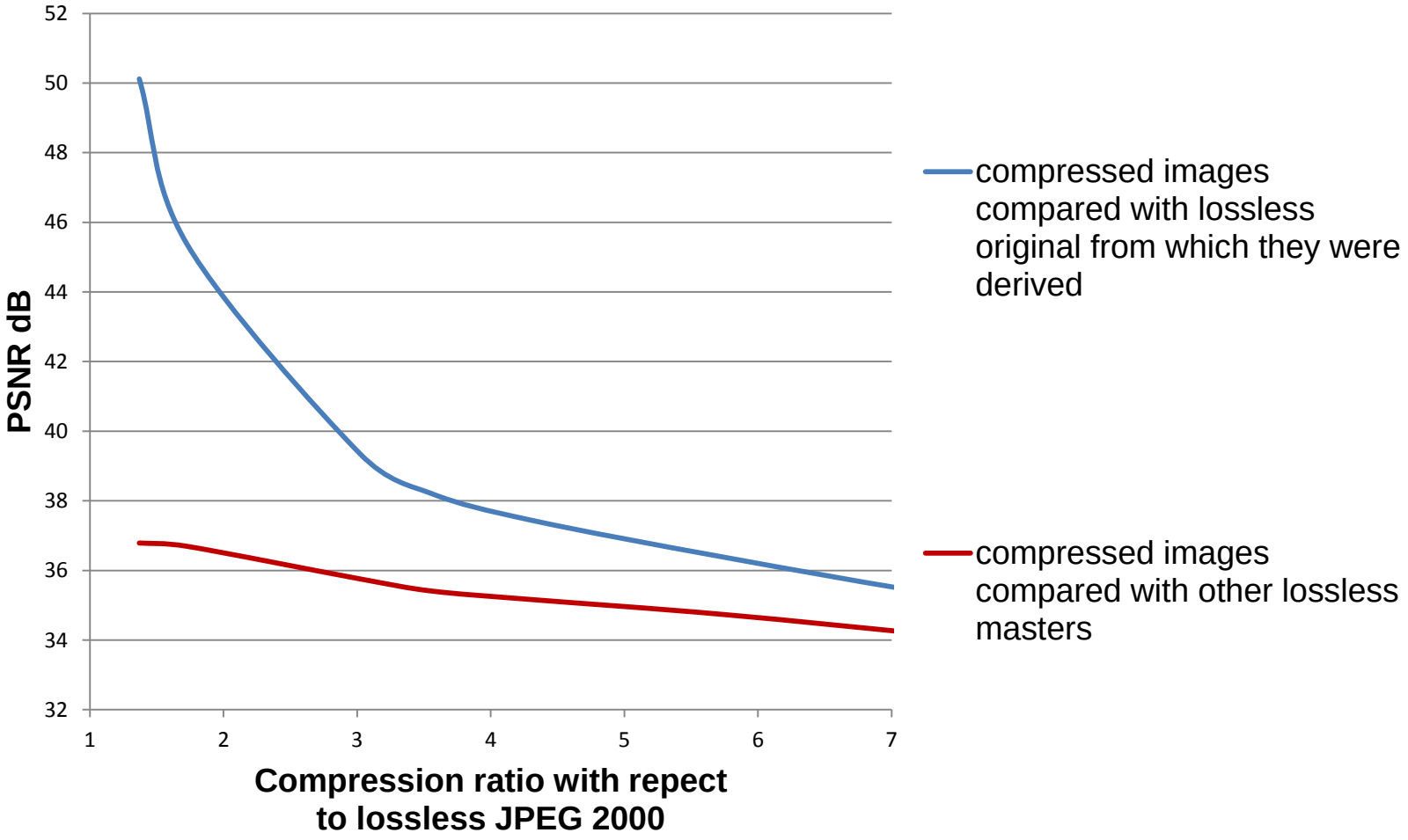
At X20 compression by 1.8 is “perfect”

~50% rejected other master files

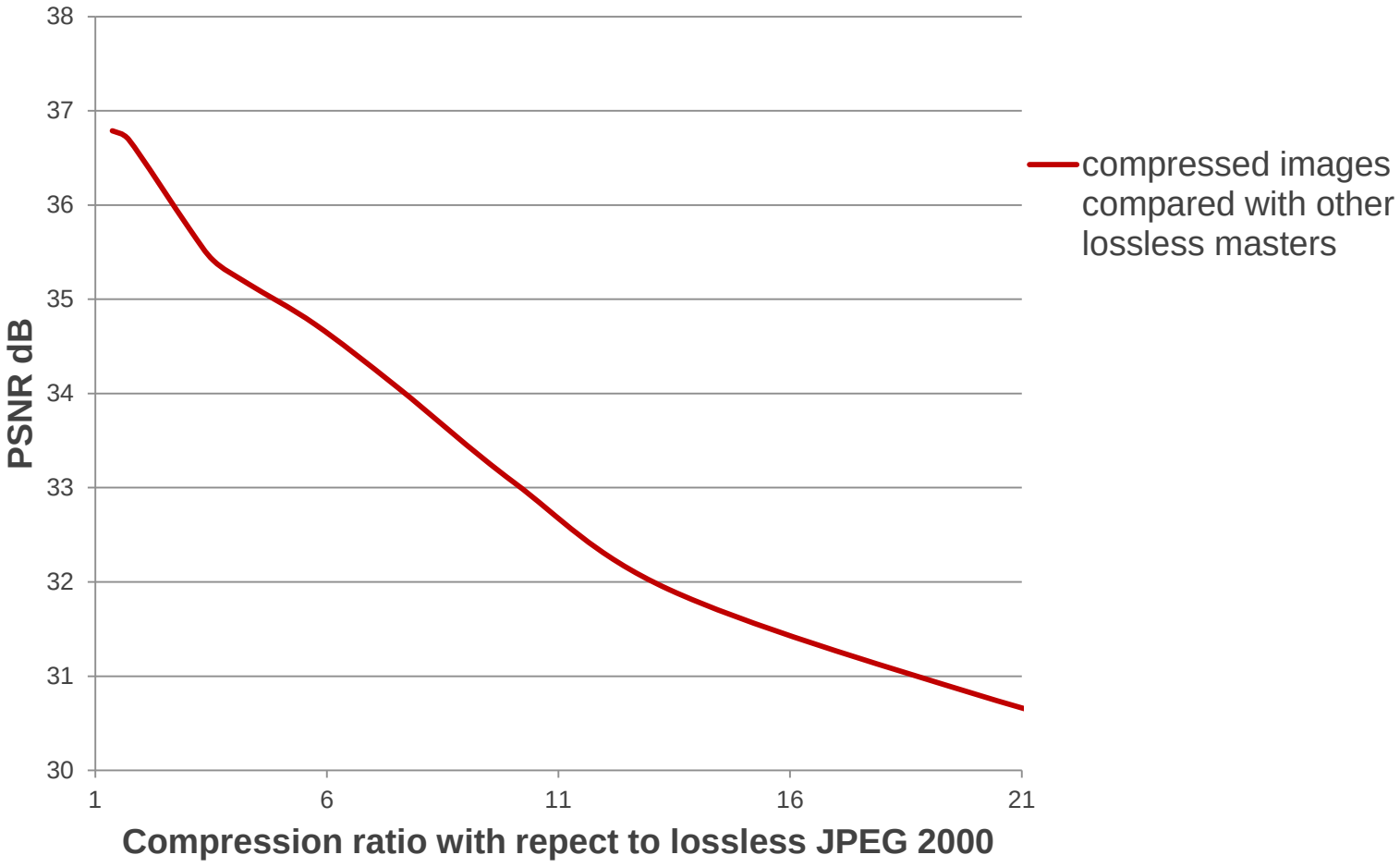
Quantitative digitised & compressed – 1 Compressed with lossless original(s)



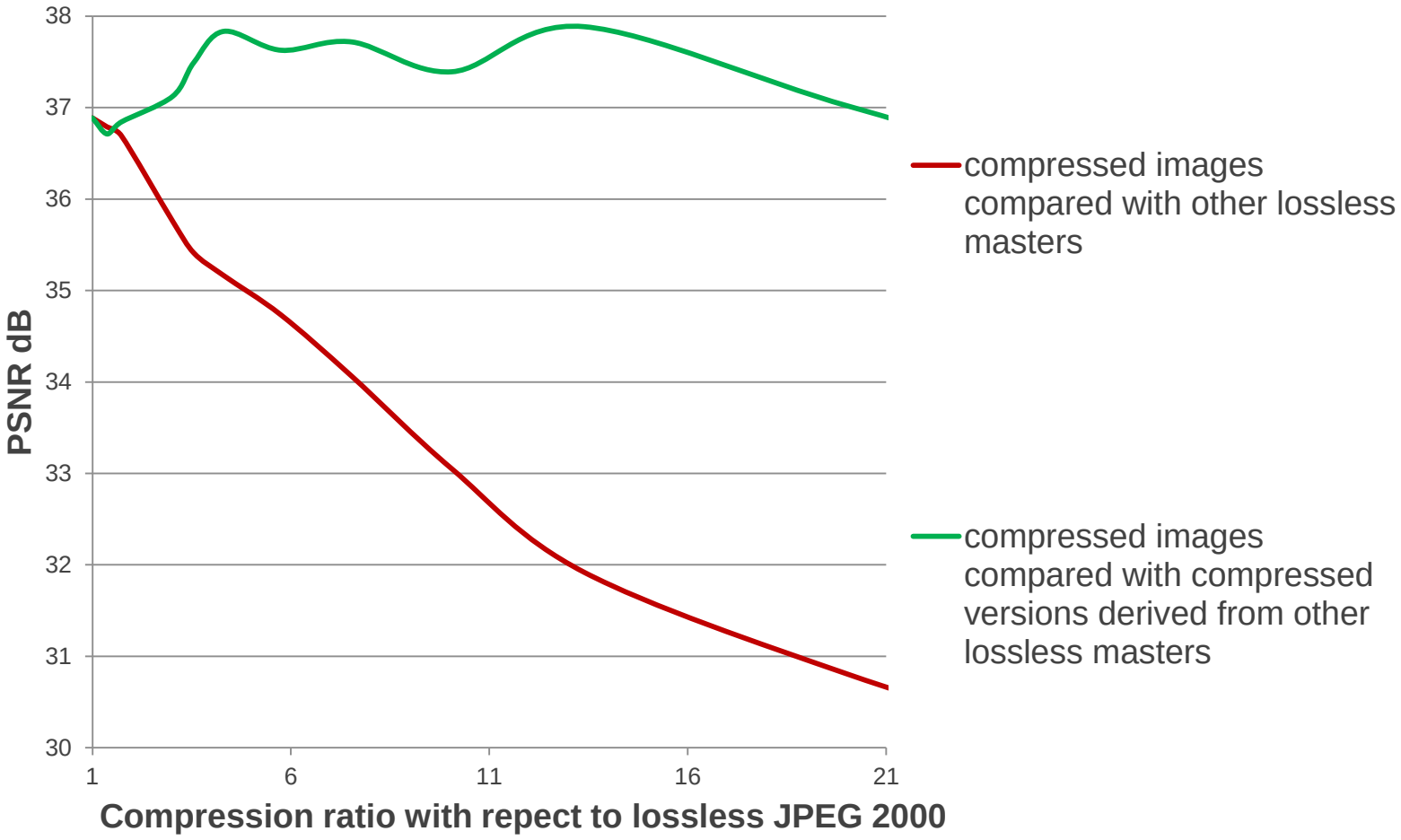
Quantitative digitised & compressed – 2 Compressed with lossless original(s)



Quantitative digitised & compressed – 3
Compressed with lossless original - rescale



Quantitative digitised & compressed – 4 Compressed with compressed original(s)



Concluding remarks - 1

- The literature describes noise in the imaging process
- We have characterised it for digitised images
- The variation from a modest level of compression can be much less than that with the inherent noise
- A significant proportion of the cost is to store this noise
- Indicative cost savings are 30-70% of lossless JPEG 2000

“as a conservative guide 2/3 of the cost is simply storing noise”

Concluding remarks - 2

- There is increasing pressure on cost – are we spending it in the best way?
- If you are minded to continue to store lossless originals then consider
  - the value for future users in seeing the noise with today's cameras
  - go home and invest in the "best" cameras that reduce the noise
- Consider saving compressed images and using the money on digitising and making more content available
- Will future users value the noise we have stored, or value content that otherwise would not have been digitised?

Thank you

Link to the full technical paper at iPres 2013

Acknowledgements

Kjetil Iversen and his staff at the National Library of Norway
Andrew Austin and his staff at the British Library
Ken Tsang - software

Examples from 25 comments

- I found this very difficult! Like going to the optician who says 'is this better or worse' and all I can answer is 'it's different.
- Interesting but my eyes hurt now!
- Doing this survey made my eyes go funny!
- I was quite impressed to spot no differences in the larger images - perceivable to me at the time anyway.
- The questions about whether things were acceptable for preservation and presentation were really two different questions: images that are good enough for presentation are rarely good enough for preservation, which is a very different animal, so this should really have been addressed separately: all of them were fine for presentation, but I would have said that none were suitable for preservation, because each showed some change or loss of fine detail."

Qualitative assessment - 2
Questionnaire responses - 1st group

Quantitative
Best matches

Qualitative
Assessment:

Image Set N05B						
Compress designation	Compres-sion ratio	PSNR dB	**Least** change **all**	**Most** change **all**	*Least change pair*	*Most change pair*
G3	2.24	46.224	**90%**			
G4	2.64	44.476	**4%**		*72%*	*21%*
43.0 → G5	3.20	42.836		**48%**		
Master				**52%**	*21%*	*74%*

Image Set B07B						
Compress designation	Compres-sion ratio	PSNR dB	**Least** change **all**	**Most** change **all**	*Least change pair*	*Most change pair*
G4	3.06	42.153	**96%**			
G5	3.71	40.044		**14%**	*71%*	*33%*
38.9 → G6	4.94	37.685		**82%**		
Master					*26%*	*64%*

Assessment based on 146-175 responses

Qualitative assessment - 3
Questionnaire responses – 2nd group

- Comparison responses sought as: perfect, acceptable, marginal or unacceptable
- At X1 magnification:
  - G8 or lower is “perfect” with ~6 x compression ratio
  - G10 is “acceptable” with ~13 x compression ratio
- At X20 magnification:
  - G2 is “perfect” with 1.8 x compression ratio
  - G3 is “acceptable” with 2.3 x compression ratio

Qualitative assessment - 4
Questionnaire responses – 3rd group

X1 magnification	Original	Minimally lossless	Alternative masters
Perfect	84%	90%	4-5%
Acceptable			53-66%
Marginal or Unacceptable			28-42%

X60 magnification	Original	Minimally lossless	Alternative masters
Perfect	93%	73%	1-3%
Acceptable			32-56%
Marginal or Unacceptable			41-66%