Appendix A

Just Noticeable Difference Evaluations

'If I have seen farther than others,
it is because I was standing on the shoulders of giants.'

(Sir Isaac Newton)

This appendix presents the results from a series of psychophysical experiments which were performed to investigate the efficacy of the CIELUV colour difference equation (CIE, 1979). The experimental procedure is described by Pokorny *et al.* (1991) and proceeded as follows:

> A bipartite display was generated on a 20" Hitachi CM2198MSG computer monitor using an SGI RealityEngine^2 workstation. The two fields of the display occupied 2 degrees of the observer's visual field and were presented on a neutral-hued (mid-gray) background in order to fix the observer's state of adaption. The experiment was performed in an environment with high (photopic) light conditions and the observer was photopically adapted with corrected-to-normal vision.
>
> For each test, the subject was presented with an initial colour in both fields of the bipartite display. The subject was then free to increment the hue or saturation of the right-hand field until a perceivable difference was observed. At this point, the CIELUV colour difference (ΔE^*_{uv}) was noted for the two colours.

The experiment was repeated for a number of initial colours, and a number of increment hues and saturations, in order to evaluate the colour difference equation over a wide range of chromatic stimuli.

The following table presents a summary of the results obtained. The first two columns describe the initial colour of the bipartite fields and the increment colour which the observer was free to alter. The third columns presents the RGB specification of the initial colour; while the fourth column records the final RGB value of the right-hand field once the observer had located a noticeable difference. The last column presents the CIELUV colour difference value between the latter two RGB values.

Initial Colour	**Increment Hue**	**Initial RGB**	**Final RGB**	ΔE^*_{uv}
Red	Red	128,0,0	136,0,0	**3.93**
		128,0,0	120,0,0	**4.10**
		255,0,0	244,0,0	**3.54**
Green	Green	0,128,0	0,134,0	**2.33**
		0,128,0	0,121,0	**2.82**
		0,255,0	0,244,0	**2.79**
Blue	Blue	0,0,128	0,0,140	**4.85**
		0,0,128	0,0,117	**4.72**
		0,0,255	0,0,242	**3.48**
Cyan	Cyan	0,128,128	0,134,134	**1.67**
		0,128,128	0,123,123	**1.43**
		0,255,255	0,245,245	**1.81**
Magenta	Magenta	128,0,128	136,0,136	**3.10**
		128,0,128	120,0,120	**3.21**
		255,0,255	247,0,247	**2.00**
Yellow	Yellow	128,128,0	134,134,0	**2.10**
		128,128,0	122,122,0	**2.13**
		255,255,0	245,245,0	**2.23**
Black	Red	0,0,0	11,0,0	**29.02**
Black	Green	0,0,0	0,7,0	**28.20**
Black	Blue	0,0,0	0,0,15	**16.00**
Black	Cyan	0,0,0	0,8,8	**22.66**
Black	Magenta	0,0,0	11,0,11	**26.74**
Black	Yellow	0,0,0	7,7,0	**27.00**
Black	White	0,0,0	7,7,7	**19.00**

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Initial Colour	Increment Hue	Initial RGB	Final RGB	ΔE^*_{uv}
White	Red	255,255,255	235,255,255	**5.10**
White	Green	255,255,255	255,246,255	**3.43**
White	Blue	255,255,255	255,255,242	**4.46**
White	Cyan	255,255,255	255,247,247	**2.30**
White	Magenta	255,255,255	243,255,243	**4.42**
White	Yellow	255,255,255	247,247,255	**3.00**
Red	White	255,0,0	255,13,13	**28.82**
		128,0,0	134,6,6	**16.13**
Green	White	0,255,0	33,255,33	**25.00**
		0,128,0	5,133,5	**4.43**
Blue	White	0,0,255	15,15,255	**10.14**
		0,0,128	8,8,128	**11.54**
Cyan	White	0,255,255	41,255,255	**12.89**
		0,128,128	8,136,136	**3.18**
Magenta	White	255,0,255	255,20,255	**15.72**
		128,0,128	124,6,134	**5.19**
Yellow	White	255,255,0	255,255,45	**22.50**
		128,128,0	133,133,5	**2.84**
Red	Blue	255,0,0	255,0,24	**28.86**
		128,0,0	128,0,17	**28.73**
Red	Green	255,0,0	255,10,0	**17.38**
		128,0,0	128,7,0	**16.79**
Green	Blue	0,255,0	0,255,21	**13.04**
		0,128,0	0,128,17	**15.65**
Green	Yellow	0,255,0	25,255,0	**10.50**
		0,128,0	6,134,0	**3.36**
Blue	Yellow	0,0,255	15,15,255	**10.14**
		0,0,128	8,8,128	**9.37**
Blue	Magenta	0,0,255	16,0,255	**6.94**
		0,0,128	8,0,136	**7.50**

Table A.1: *CIELUV colour difference values for a range of chromatic stimuli.*

Appendix B

Example Spatial Frequency Segmentations

'If I have not seen as far as others,
it is because giants were standing on my shoulders.'

(Hal Abelson)

This appendix contains sample results produced by our image segmentation technique for extracting the perceived spatial frequencies within a digital image (see Section 3.1, page 67). This consists of a collection of images, each accompanied by an illustration showing the extent of all visual features found by the segmentation procedure. (Note that all computer-generated images were produced in full-colour, despite being rendered in greyscale for presentation in this thesis.)

We will begin by presenting the four levels of detail which were used for the user task performance study (see Section 5.2, page 147). For each of these we will illustrate the result of the feature extraction process and the subsequent spatial frequency calculation. Following from this, we will present a number of further example feature extractions, and also an example of the feature extraction process for an object which is rendered in flat-shaded, smooth-shaded, and texture mapped modes.

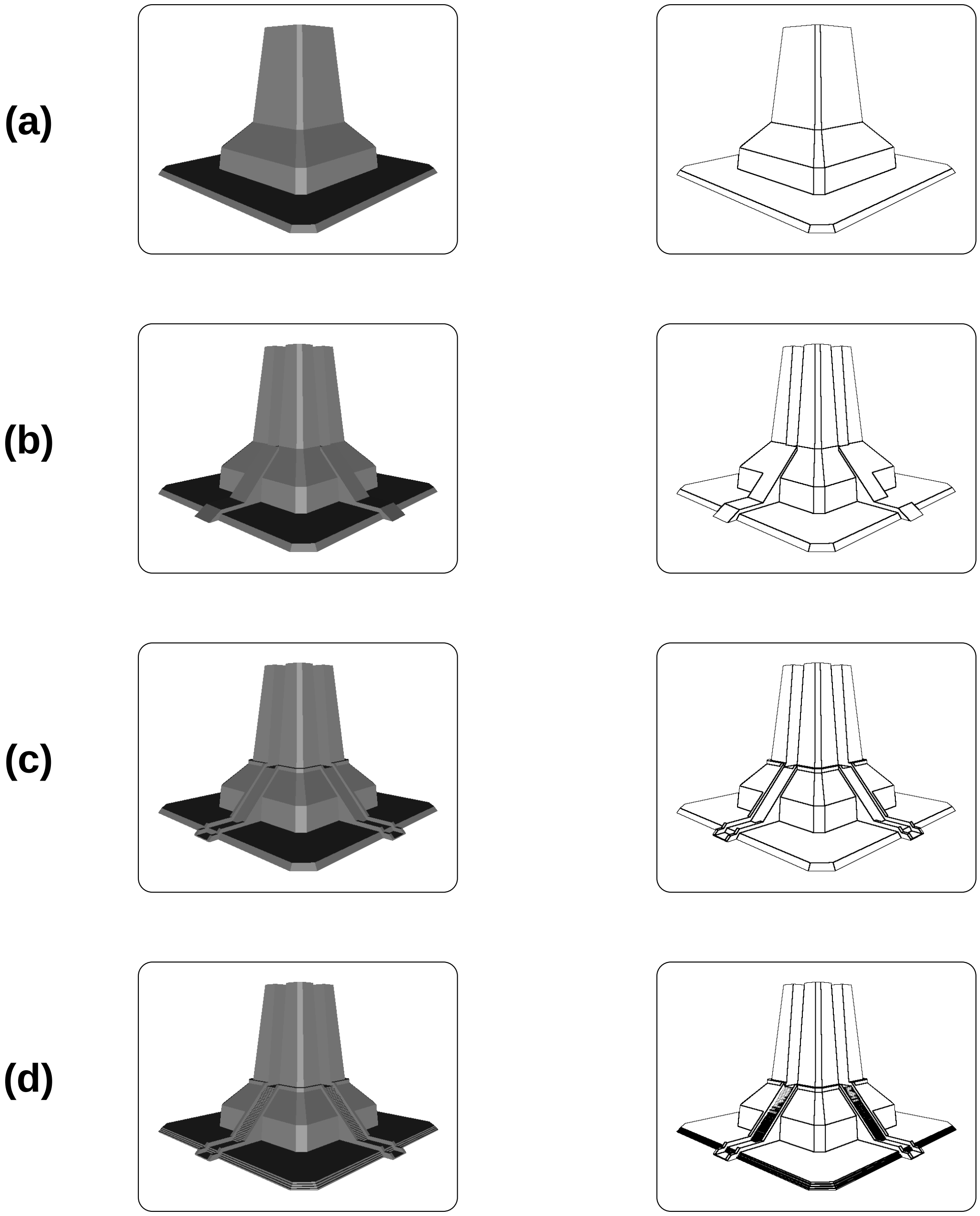

Figure B.1: *Feature segmentations for each of the 'temple' LODs which were used for the user task performance study. The figures on the left present the rendered image of each model, while the figures on the right illustrate the extent of all features which were located in the adjacent image.*

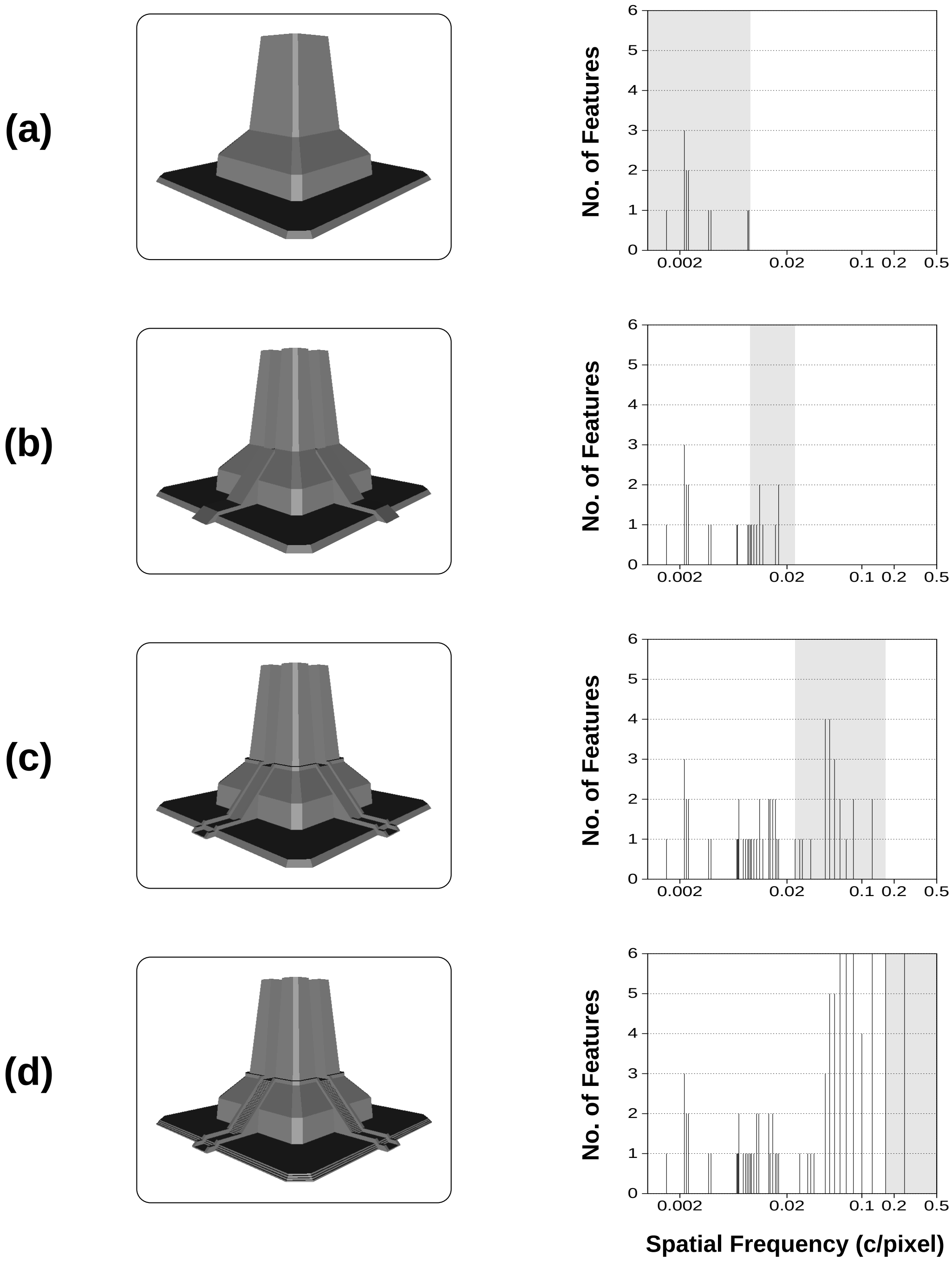

Figure B.2: *Relative spatial frequency (c/pixel) profiles for each of the 'temple' LODs. The shaded regions on each graph represent the frequencies over which that model can be used without defect (see Page 116). Note that in (d), the data have been thresholded to a maximum of 6 features in order to maintain readability and scale consistency between each graph.*

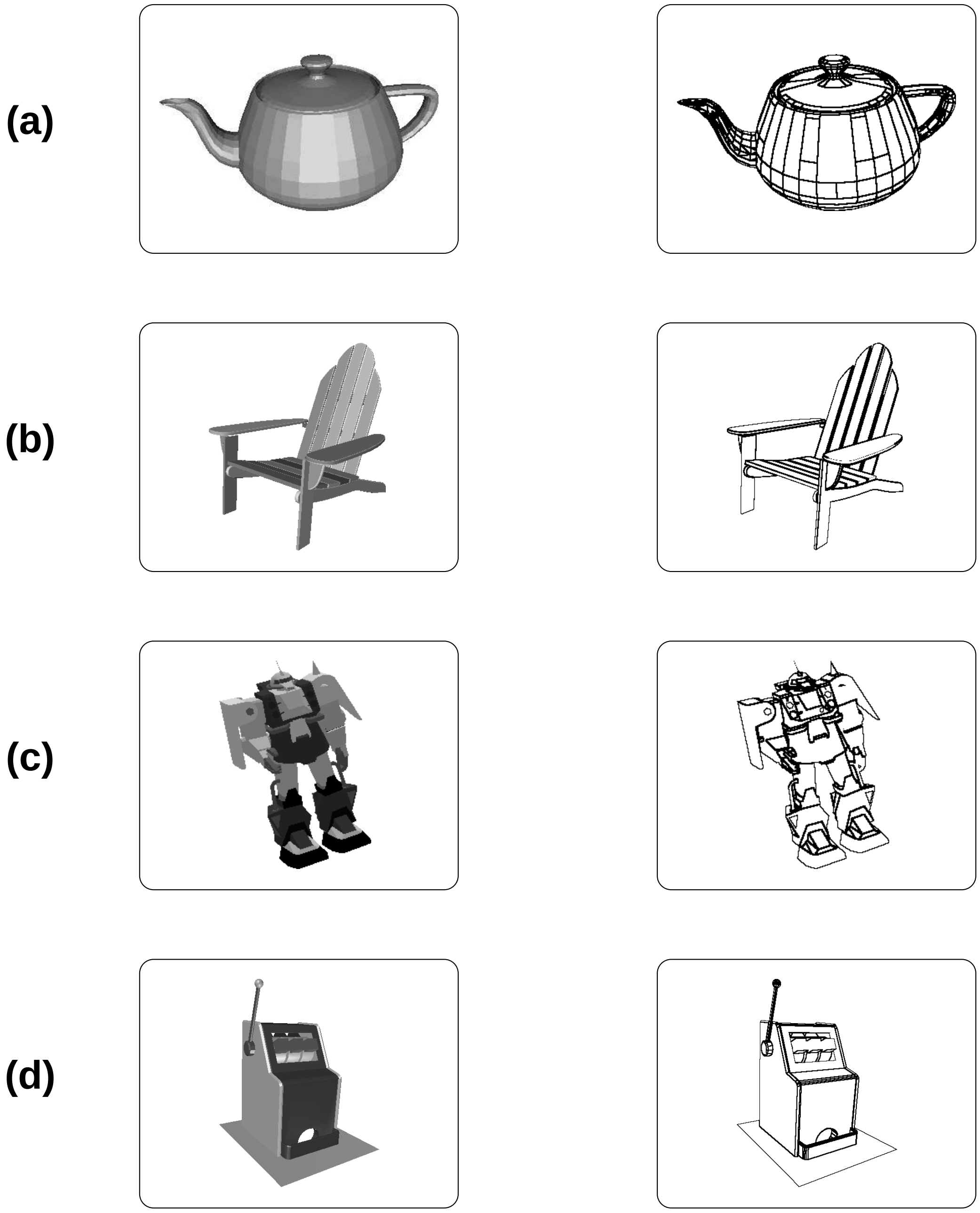

Figure B.3: *Feature segmentations for various objects: (a) the ubiquitous ‘teapot’, (b) ‘chair’, (c) ‘robot’, and (d) ‘slotMachine’. Models (a) and (c) were flat-shaded, while (b) and (d) were smooth-shaded.*

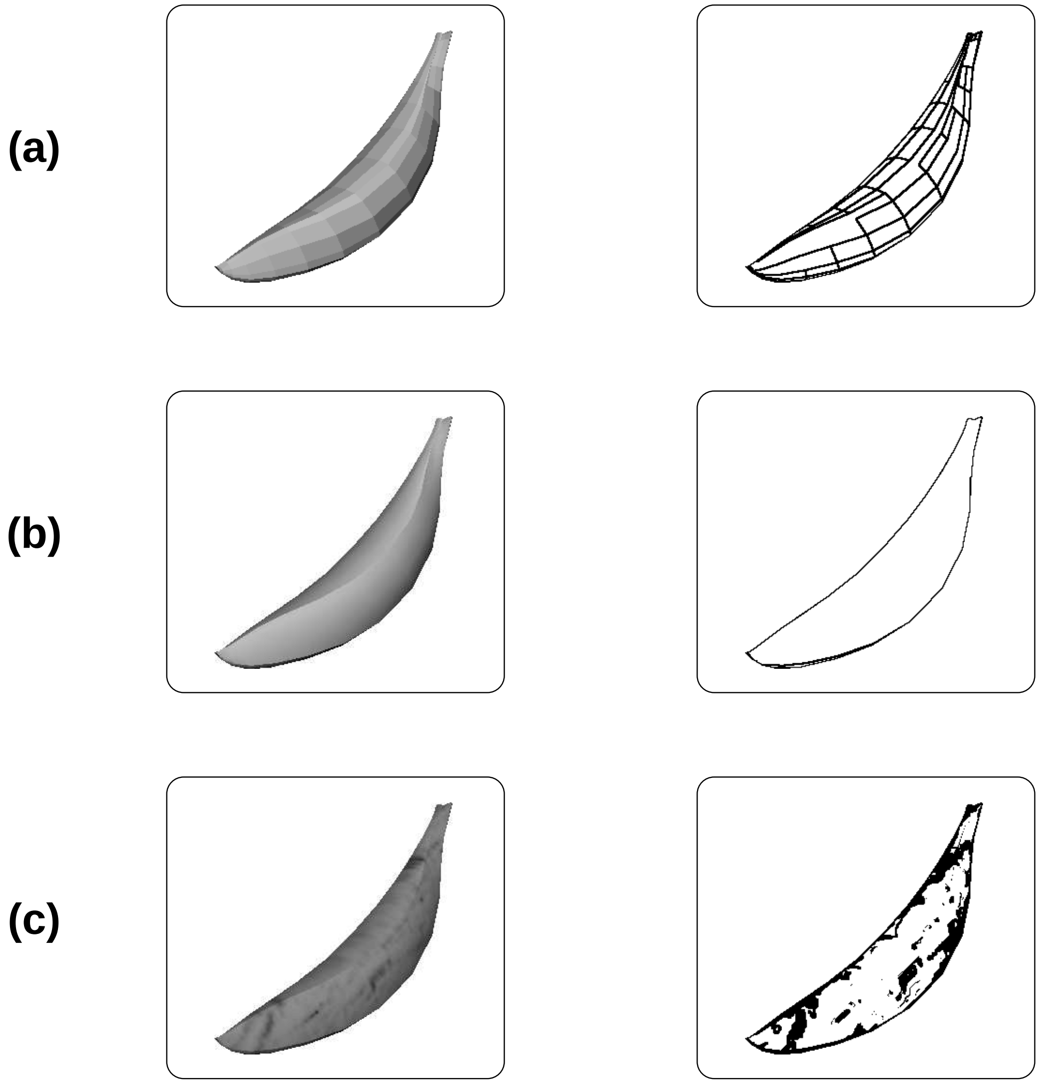

Figure B.4: *Feature segmentations for a single object under different rendering modes: (a) flat-shaded, (b) smooth-shaded, and (c) texture mapped. Note the dichotomy that the segmentation of (b) is far less complex than (a), but smooth-shading is generally more computationally expensive than flat-shading (see Section 6.2.1.2, page 170).*