number of poles and zeros is known and that a linear-phase component z^{-r} has been removed. Then, following Kopec [4], we can estimate the poles of $h[n]$ by using the covariance method of linear prediction (Chapter 5) with a prediction-error interval that is free of zeros. The Shanks, or other methods described in Chapter 5, can then be applied to estimate the zeros. The following example illustrates the approach on a real speech segment:

EXAMPLE 6.15 In this example, a rational z-transform consisting of 10 poles and 6 zeros is used to model a segment of the nasalized vowel /u/ in the word "moon" [4]. Homomorphic prediction was performed by first applying homomorphic filtering on the complex cepstrum to obtain an impulse response estimate. The log-magnitude spectrum of this estimate is shown in Figure 6.21b. The covariance method of linear prediction analysis was then invoked to estimate the poles, and the Shanks method was used to estimate the zeros. The method estimated a zero near 2700 Hz, which is typical for this class of nasalized vowels (Figure 6.21c). ▲

Other zero estimation methods can also be combined with homomorphic filtering, such as the Steiglitz method (Exercise 5.6). In addition, forms of homomorphic prediction can be applied to deconvolve the vocal tract glottal source from the vocal tract transfer function. Moreover, this synergism of homomorphic filtering and linear prediction analysis allows, under certain conditions, this source/system separation when both zeros and poles are present in the vocal tract system function (Exercise 6.22).

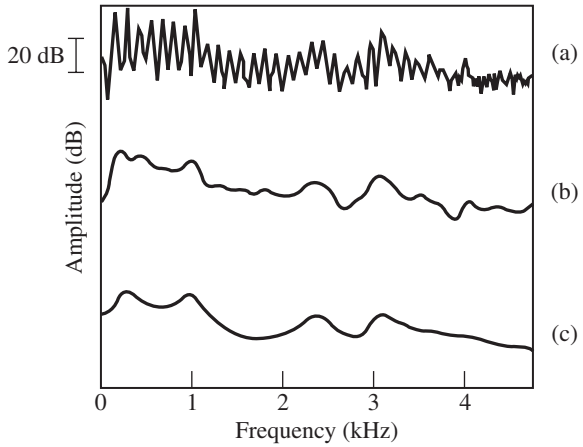

Figure 6.21 Homomorphic prediction applied to a nasalized vowel from /u/ in "moon": (a) log-magnitude spectrum of speech signal; (b) log-magnitude spectrum obtained by homomorphic filtering (low-time filtering the real cepstrum); (c) log-magnitude spectrum of 10-pole/6-zero model with zeros from Shanks method.

SOURCE: G.E. Kopec, A.V. Oppenheim, and J.M. Tribolet, "Speech Analysis by Homomorphic Prediction" [4]. ©1977, IEEE. Used by permission.