US006256609B1

(12) **United States Patent**
Byrnes et al.

(10) **Patent No.: US 6,256,609 B1**
(45) **Date of Patent: *Jul. 3, 2001**

(54) **METHOD AND APPARATUS FOR SPEAKER RECOGNITION USING LATTICE-LADDER FILTERS**

(75) Inventors: **Christopher I. Byrnes**, Clayton, MO (US); **Anders Lindquist**, Täby (SE)

(73) Assignee: **Washington University**, St. Louis, MO (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **09/117,721**

(22) PCT Filed: **May 11, 1998**

(86) PCT No.: **PCT/US98/09576**

§ 371 Date: **Aug. 5, 1998**

§ 102(e) Date: **Aug. 5, 1998**

(87) PCT Pub. No.: **WO98/50908**

PCT Pub. Date: **Nov. 12, 1998**

Related U.S. Application Data

(63) Continuation-in-part of application No. 08/854,150, filed on May 9, 1997, now Pat. No. 5,490,791.

(51) **Int. Cl.**[7] **G10L 17/00**

(52) **U.S. Cl.** **704/246**; 704/219

(58) **Field of Search** 704/246, 247, 704/250, 219

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,151,091	3/1939	Dudley .	
2,243,526	5/1941	Dudley .	
4,209,836	6/1980	Wiggins, Jr. et al. .	
4,775,951	10/1988	Iwahashi et al. .	
5,048,088	9/1991	Taguchi .	
5,293,448	3/1994	Honda .	
5,940,791 *	8/1999	Byrnes et al.	704/219

OTHER PUBLICATIONS

K.J. Åström, *Introduction to stochastic realization theory*, Academic Press (1970).

K.J. Åström, Evaluation of quadratic loss functions for linear systems, in *Fundamentals of Discrete–time systems*: A tribute to Professor Eliahu I. Jury, M. Jamshidi, M. Mansour, and B.D.O. Anderson (editors), IITSI Press, Albuquerque, New Mexico (1993) pp. 45–56.

T.P. Barnwell III, K. Nayebi and C.H. Richardson, *Speech Coding: A computer Laboratory Textbook*, John Wiley & Sons, New York, (1996).

(List continued on next page.)

Primary Examiner—Richemond Dorvil
Assistant Examiner—Harold Zintel
(74) *Attorney, Agent, or Firm*—Howell & Haferkamp, L.C.

(57) **ABSTRACT**

A method and apparatus for speech analysis and synthesis, including speaker recognition, includes a programmable lattice-ladder notch filter which may be programmed to exhibit both filter poles and filter zeros and thereby exhibit a power spectral density with a better fit to that of a speech frame such that, when energized by a selected signal sample, a more accurate regeneration of speech is achieved. The filter parameters may be reliably and systematically determined as a single solution to a mathematical analysis given a set of gain parameters matching the observed covariance data and having a prescribed set of transmission zeros. These transmission zeros may either be preselected as a design specification, or recovered from analysis of the speech data. A speech frame may be analyzed and provide a set of parameters which may be transmitted to a remote location where a synthesizer may accurately reproduce the speech frame. A method and apparatus for speaker identification, and speaker verification with a smart card are disclosed implementing the lattice-ladder notch (LLN) filter methodology.

27 Claims, 5 Drawing Sheets