Performance Evaluation of The Speaker-Independent HMM-based Speech Synthesis System "HTS-2007" for the Blizzard Challenge 2007

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Introduction

HMM-based speech synthesis system [Yoshimura et al. '00]

- Generate speech parameters from statistics

  Spectral, excitation, and duration parameters

- Vocoded (but smooth and stable)

- Easy to change speaker characteristics

  Spectral, excitation, and duration parameters

  can easily be adapted to new speakers (or emotions)

Blizzard Challenge: open evaluation of speech synthesis systems using common database

Entry from HTS (HMM-based Triple S) working group

2005: Basic system + STRAIGHT, GV, & HSMM
2006: 2005 + full-covariance modeling
2007: 2006 + speaker-adaptive approach

History & The New HTS-2007 System

Strategy:

Speaker-dependent approach

2005

Hidden semi-Markov model (HSMM)

STRAIGHT with mixed excitation

Parameter generation algorithm considering global variance (GV) :
Diagonal covariance GV pdf

2006

Full covariance modeling:
MLLT/ Semi-tied covariance

Parameter generation algorithm considering GV :
Full covariance GV pdf

Speaker-adaptive approach

2007

Hidden semi-Markov model (HSMM)
Adaptive training & adaptation

STRAIGHT with mixed excitation

Average voice model

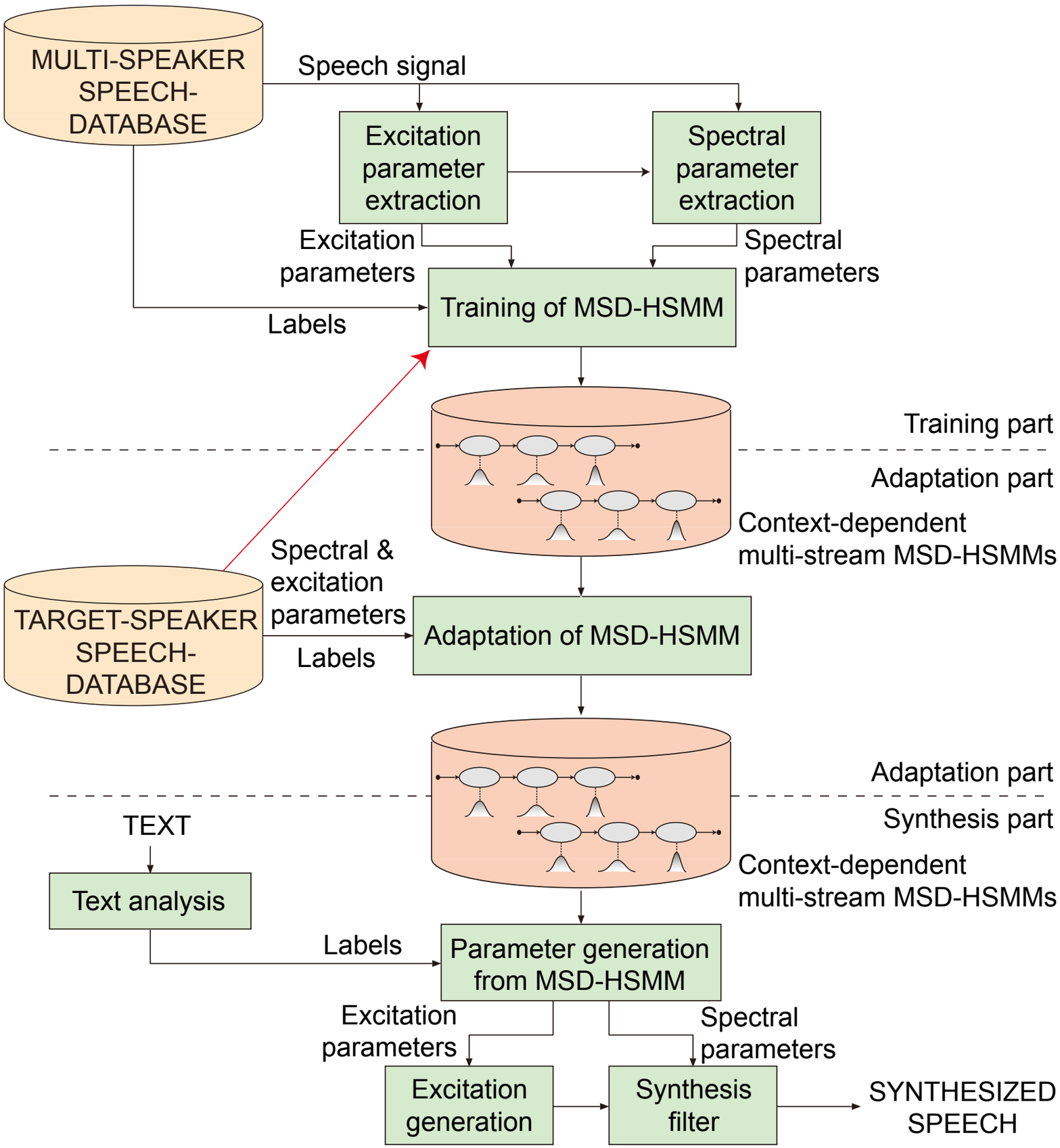
Mixed-gender acoustic modeling

CSMAPLR+MAP speaker adaptation

Full covariance modeling:
CSMAPLR transforms

Parameter generation algorithm considering GV :
Full covariance GV pdf

Overview: HTS-2007



STRAIGHT mel-cepstrum, F0, Aperiodicity measures

HSMM-based speaker adaptive training

Mixed-gender modeling

HSMM-based CSMAPLR+MAP adaptation

Full covariance modeling using CSMAPLR transforms

Parameter generation considering GV using full covariance GV pdf

STRAIGHT mel-cepstral vocoder with mixed excitation

Comparison points in this talk

Reports in previous talks

- HSMM-based adaptation and adaptive training
  [J. Yamagishi et al. IEICE Trans. 2007]
- CSMAPLR+MAP speaker adaptation
  [J. Yamagishi et al. ICASSP 2007]
- Mixed-gender modeling [J. Yamagishi et al. SSW6]
- Analysis/comparison of speaker-dependent and speaker-adaptive approaches using 3 to 30 min. of data
  [J. Yamagishi et al. ICASSP 2006]

Report in this talk

- Full-covariance modeling using CSMAPLR transforms
- Analysis/comparison of speaker-dependent and speaker-adaptive approaches using 1 to 8 hours of speech data

Full-Covariance Modeling

Diagonal covariance:

Ignore within-frame correlations

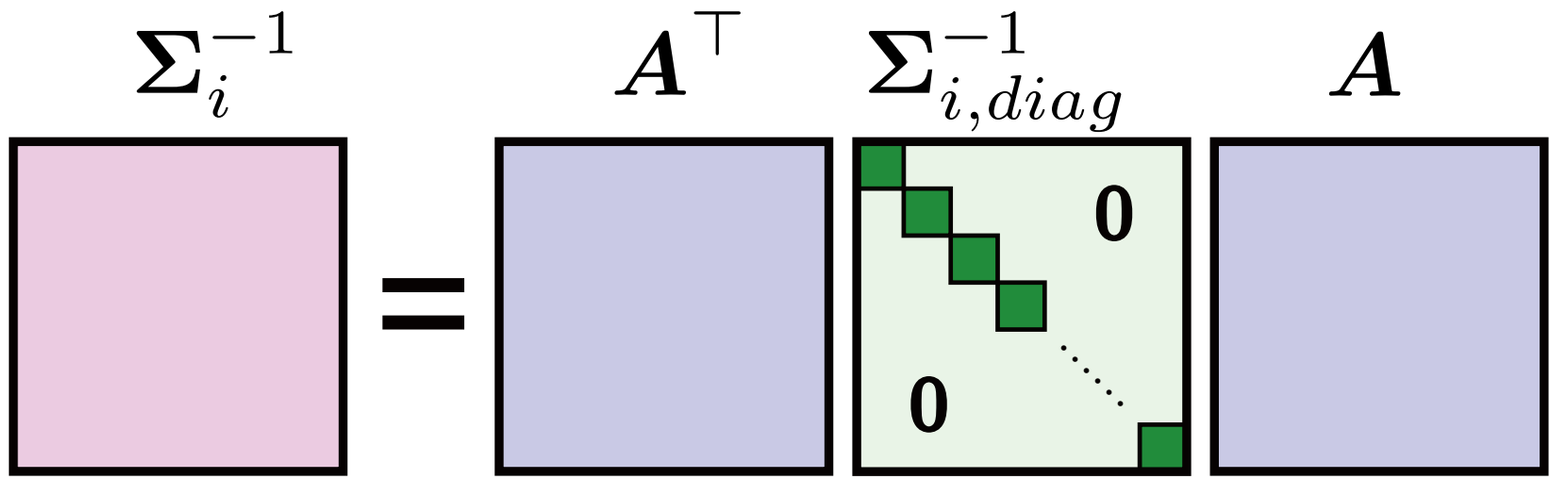
Full-covariance:

Direct modeling:

Number of model parameters drastically increases

Estimation accuracy becomes worse

An approximation method to full-covariance matrix



$\Sigma_{i,diag}^{-1}$ Diagonal precision (inverse cov.) matrix of state i

Σ_i^{-1} Approximated full precision matrix of state i

A Square transform matrix

CSMAPLR Full Covariance Modeling

CSMAPLR Transform

transform for mean

$$\widehat{\boldsymbol{\mu}}_i = \boldsymbol{A}_i^{-1}\boldsymbol{\mu}_i - \boldsymbol{A}_i^{-1}\boldsymbol{b}_i$$

transform for covariance

$$\boldsymbol{\Sigma}_i^{-1} = \boldsymbol{A}_i^{\top}\boldsymbol{\Sigma}_{i,diag}^{-1}\boldsymbol{A}_i$$

$\boldsymbol{\mu}_i$ mean vector of state i $\quad$ $\boldsymbol{b}_i$ bias vector of state i

Speaker adaptation:

Mean: (Piecewise) linear regression

Covariance: **From diagonal to full**

Advantages w.r.t. full-covariance modeling

Multiple transforms can be estimated

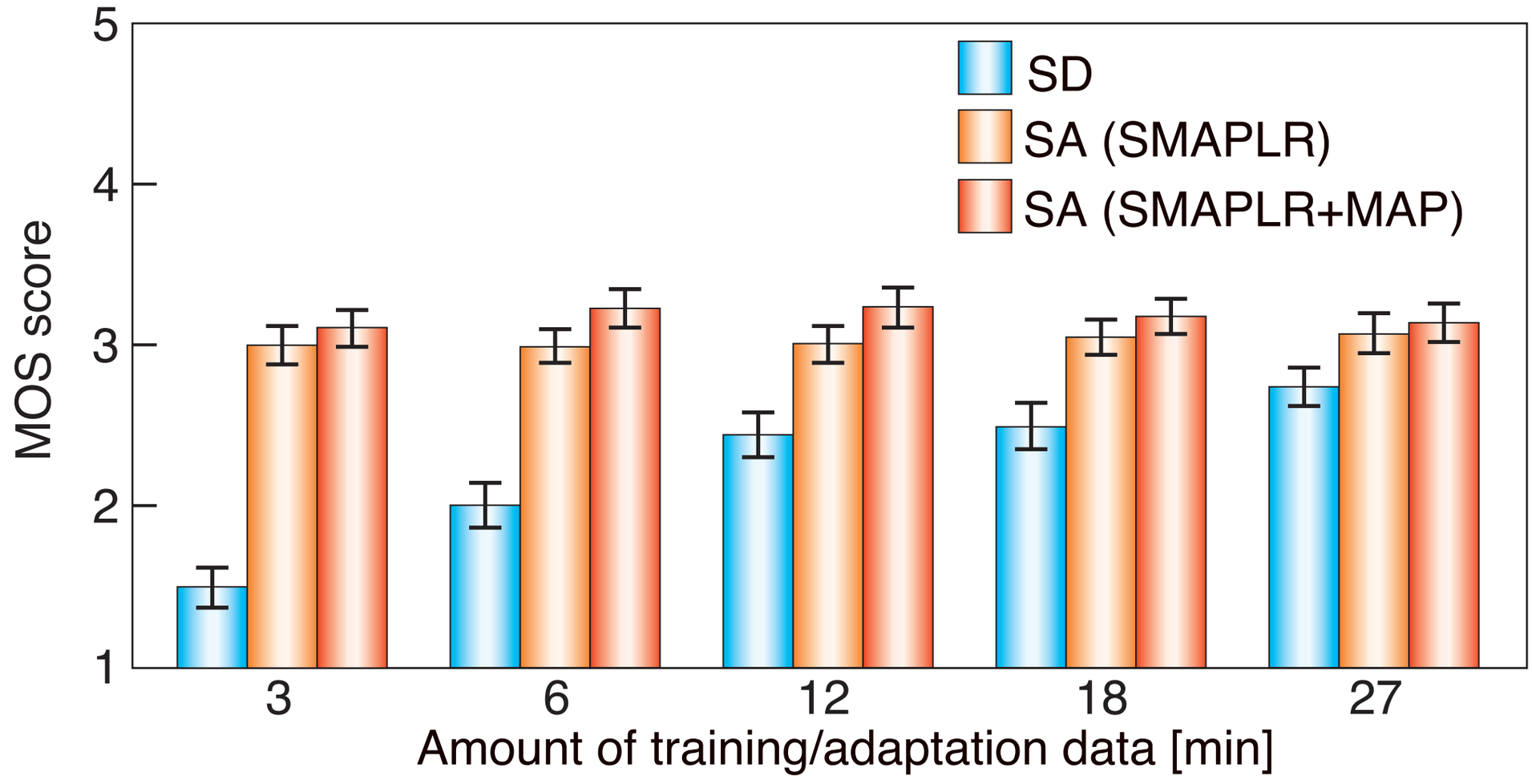
Precise approximation

Structural MAP (SMAP) criterion [K. Shinoda et al. ‘01] can be used to estimate the multiple transforms

Robust estimation even from limited amount of data

Speaker-dependent vs adaptive approach

Comparison of speaker-dependent and adaptive approaches
[J. Yamagishi et al. ICASSP 2006]



Speaker-adaptive (SA) approaches outperform speaker-dependent (SD) approach using 5 to 30 minutes of speech data.

How about more than 30 minutes of speech data?

6 minutes, 1 hour, and 8 hours

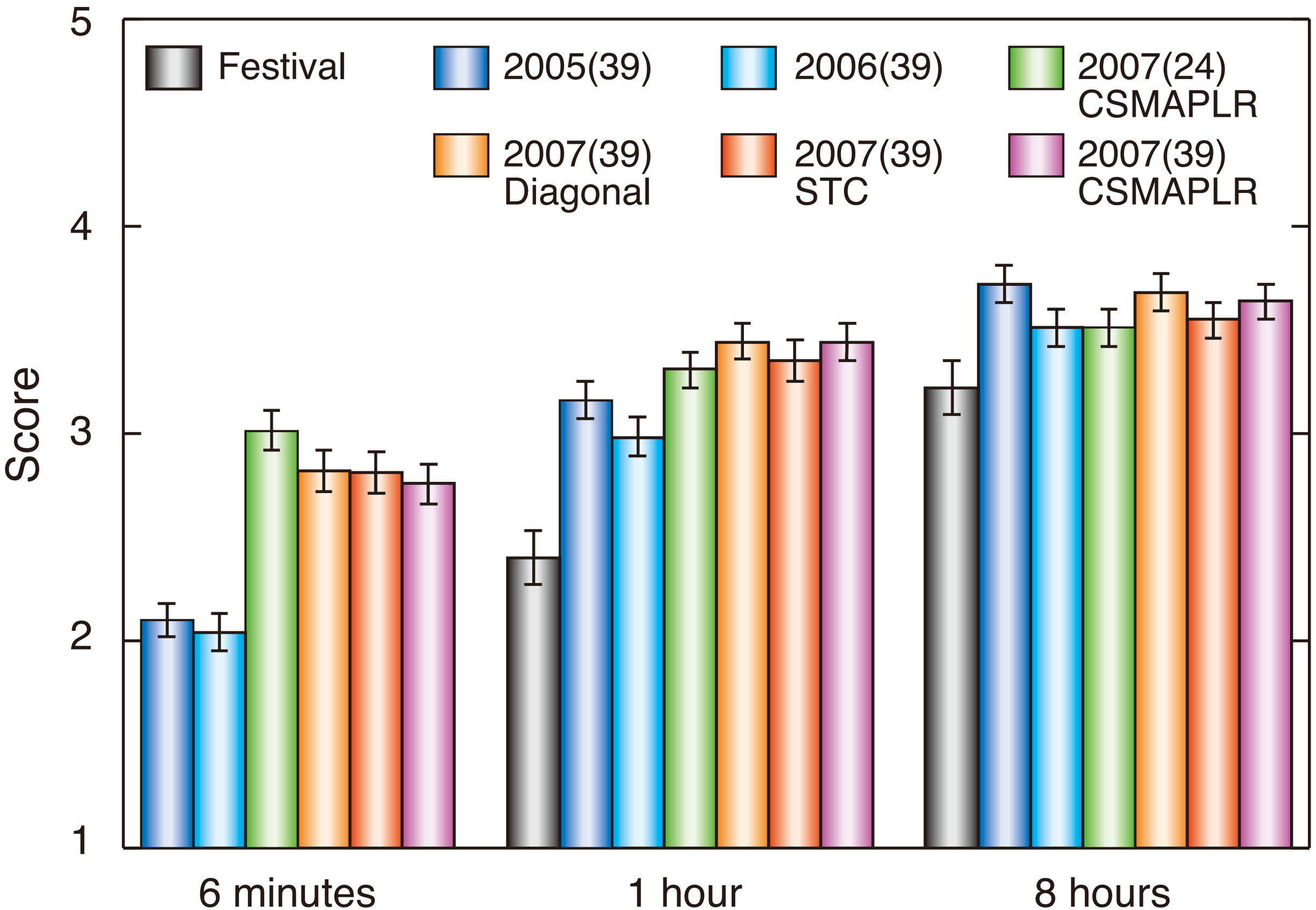
Experimental Conditions: English

Database	CMU-ARCTIC database 4 male speakers & 2 female speakers 6,780 utterances ATRECSS (Blizzard Challenge 2007) corpus 1 male speaker 6,579 utterances
Sampling rate	16 kHz
Spectral Analysis	512-order STRAIGHT analysis
Feature Vector	**0–24** or **0–40** STRAIGHT mel-cepstrum, logarithmic F0, 5 aperiodicity measures, and their delta, delta-delta parameters
Model	Context-dependent state-tied multi-stream 5-state left-to-right MSD-HSMM Gaussian pdf: Single mixture, Diagonal covariance

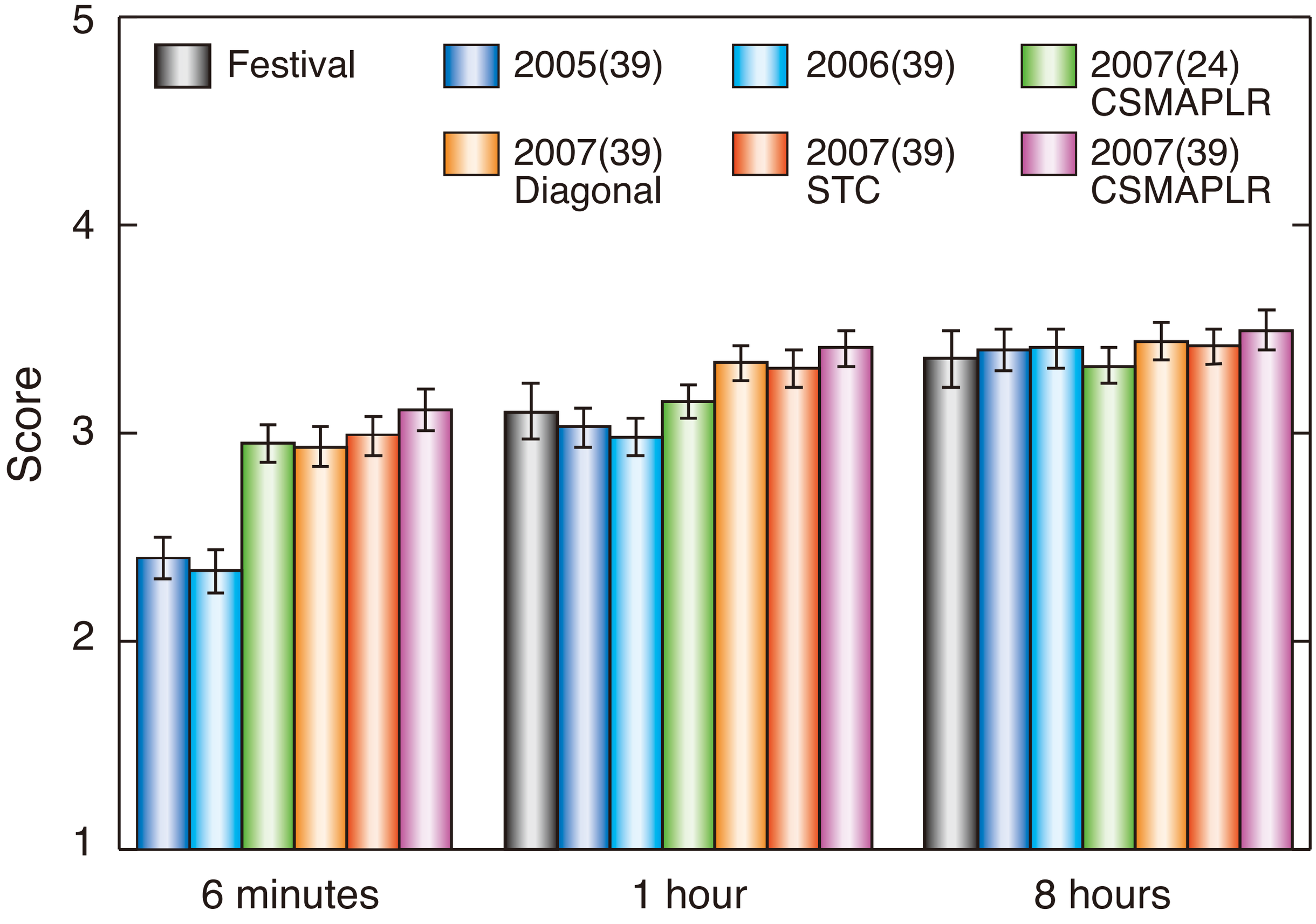
Experimental Conditions

Evaluation Methods	MOS test (naturalness) 1: poor — 5: natural CCR test (similarity) 1: very dissimilar — 5: very similar to reference
# of subjects	33 persons
# of test sentences	14 sentences randomly chosen from 50 sentences
Calibration system	Festival speech synthesis system (unit-selection)

Experimental results: MOS scores



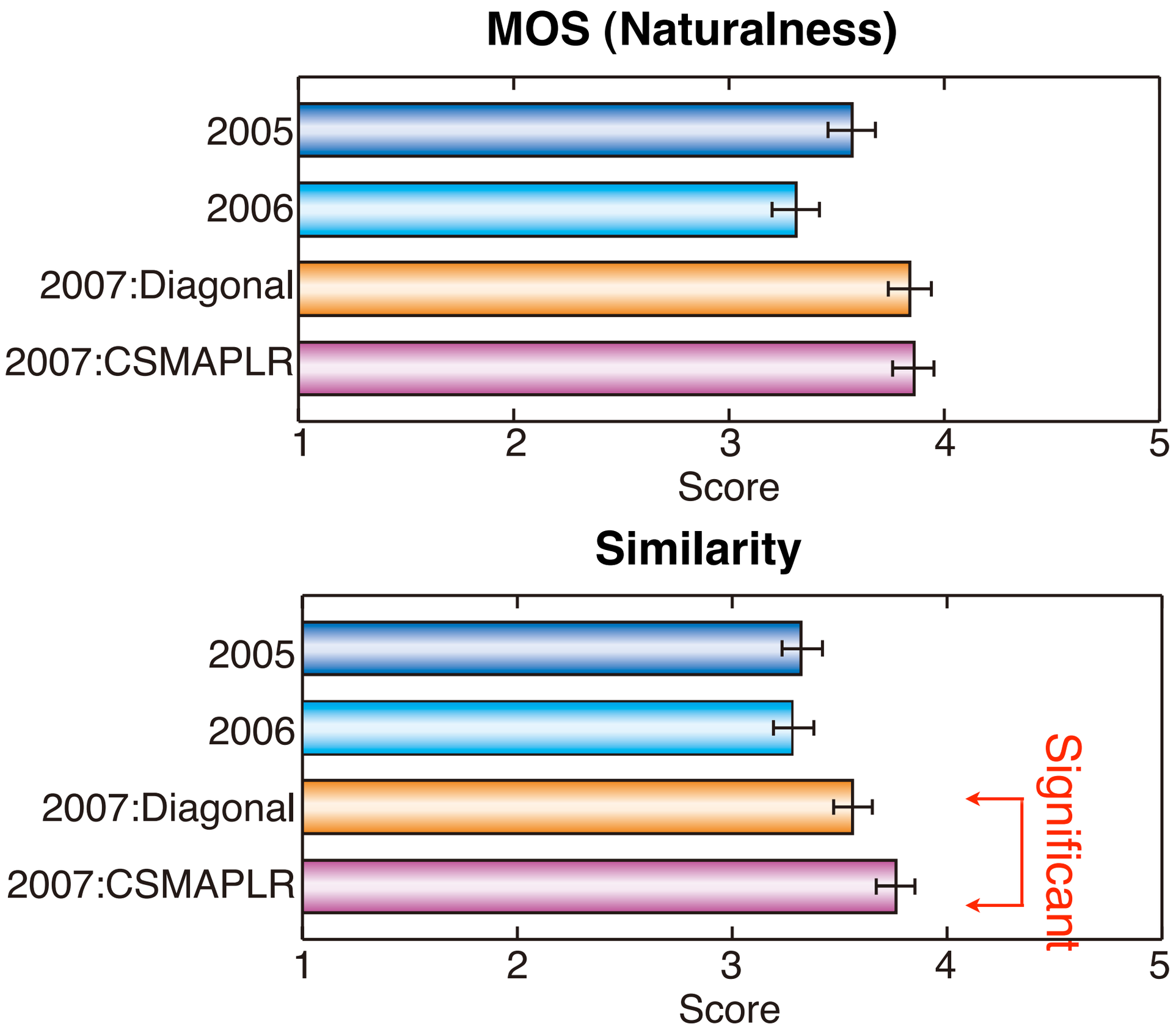
Experimental results: Similarity



Experimental Conditions: Japanese

Database	ATR Japanese speech database (B-set, C-set) 7 male speakers & 5 female speakers 5,230 utterances Japanese speech database of NIT and TIT 3 male speakers & 1 female speakers 2,012 utterances
Sampling rate	16 kHz
Spectral Analysis	512-order STRAIGHT analysis
Feature Vector	0–40 STRAIGHT mel-cepstrum, logarithmic F0, 5 aperiodicity measures, and their delta, delta-delta parameters
Model	Context-dependent state-tied multi-stream 5-state left-to-right MSD-HSMM Gaussian pdf: Single mixture, Diagonal covariance

Experimental results: Japanese



Demonstration: Various Voices

The HTS-2007 system can adapt the average voice model into ...

US English

Male

Female

Indian English

Male

Celebrity

Male

Can you guess the celebrity?
A: George W. Bush (GWB)
(another sample)

Conclusions

HTS-2007 System: High-quality speaker-adaptive speech synthesis

- significantly better than the speaker-dependent approaches in the case of realistic amount of speech data (<< 8 hours)
- comparable to the speaker-dependent approaches eve in the case of 8 hours of speech data
- significantly better than the Festival unit-selection system
  - HTS-2007 (6 min.) was comparable to Festival (1 hour)
  - HTS-2007 (1 hour) was comparable to Festival (8 hours)

Other Findings

Full-covariance modeling:

- Improves similarity of synthetic speech

High-order mel-cepstral analysis:

- Improves similarity when large amount of data is available
- Degrades naturalness when amount of speech data is limited

Online demonstration of HTS-2007

HTS-2007(39, diagonal), HTS-2005, & Festival Systems

http://www.cstr.ed.ac.uk/projects/festival/morevoices.html

Currently 5 unit-selection and 23 HTS voices are available

- 2 Scottish males
- 1 Scottish female
- 3 English males
- 1 English female
- 4 American males
- 2 American females

Please compare these systems yourselves

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