From AUDREY to Siri.

Is speech recognition a solved problem?

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What is ICSI?

- The International Computer Science Institute
- Started in 1988, located in downtown Berkeley
- An **independent** research organization affiliated with (but not part of) the University of California at Berkeley
- 80-100 people, including staff, principal investigators, postdoctoral fellows, researchers, international visitors, and students
- Pursuing advanced research in many areas of computer science
  - Networking, Security, Speech, Vision, Artificial Intelligence, Algorithms, Computational Biology, Computer architectures
- Funded through federal grants, industry contracts, and collaborations with foreign countries

1952 AUDREY

- First known and documented speech recognizer
- Built in 1952 by Davis, Biddulph, and Balashek at Bell Laboratories
- Fully analogic
- Recognized strings of digits with pauses in the between
- 97-99% accuracy if “adapted” to speaker

HAPPY 60-TH BIRTHDAY
SPEECH RECO

…why was it not exploited?

Given these early successes, why were they not exploited? They were not economically attractive. […] AUDREY occupied a six-foot high relay rack, was expensive, consumed substantial power and exhibited the myriad maintenance problems associated with complex vacuum-tube circuitry. More important, its reliable operation was limited to accurate recognition of digits spoken by designated talkers. It could therefore be used for voice dialing by, say, toll operators, or especially affluent telephone customers, but this accomplishment was poorly competitive with manual dialing of numbers. In most cases, digit recognition is faster and cheaper by push-button dialing, rather than by speaking the successive digits

Jim Flanagan et al., in “Trends in Speech Recognition,” Wayne E. Lea editor, 1980

What happened after AUDREY?

- Early 1960s – exploration, hybrid systems, phonetic segmentation
- Late 1960s – brute force approach, templates: IT WORKS! Hard to scale…
- Early 1970s – first big ARPA project, Speech Understanding Research (SUR). The AI hype… not a great success, except template based brute force (HARPY)
- Late 1970s – first appearance of Hidden Markov Models (HMMs): IBM (Jelinek), Baker (Dragon)
- Early 1980s – More templates, HMMs are still a secret cult
- Late 1980s – New DARPA projects, HMMs become popular (Rabiner @Bell Labs)
- Early 1990s – More DARPA projects, better HMMs. AT&T's first large scale deployment (VRCP), the birth of VUI art (Wildfire)
- Mid 1990s – Better HMMs. The industry starts (Nuance, SpeechWorks)
- Late 1990s – Better HMMs. IVRs
- Early 2000s – Better HMMs. IVRs
- Early 2010s – Better HMMS. Mobile voice

IMPROVEMENTS MOSTLY DUE TO MOORE's LAW

2011 Siri

- Practically infinite vocabulary
- Contextual language understanding
  - – ANSWERS … NOT LINKS
- Voice access to calendar and contacts, help make reservations, gives answer on lots of things, including the meaning of life
- Integrated within iPhone, freely available to everyone (who buys an iPhone)

…why is Siri successful?

- Perception of intelligence
- Fun to use it, witty, catchy personality
- iPhone design and Apple marketing
- Works relatively well for a certain number of tasks
- Improves with time

So … is speech recognition a solved problems?

…is speech recognition a solved problem?

- NO…and language understanding is even *less solved.*
  - Fails where humans don't
  - Little basic science
  - More data, more improvements … but the rate of improvement is diminishing
  - Looks like we are hitting the intrinsic limitations of the underlying models
  - Each new task requires almost the same new level of effort

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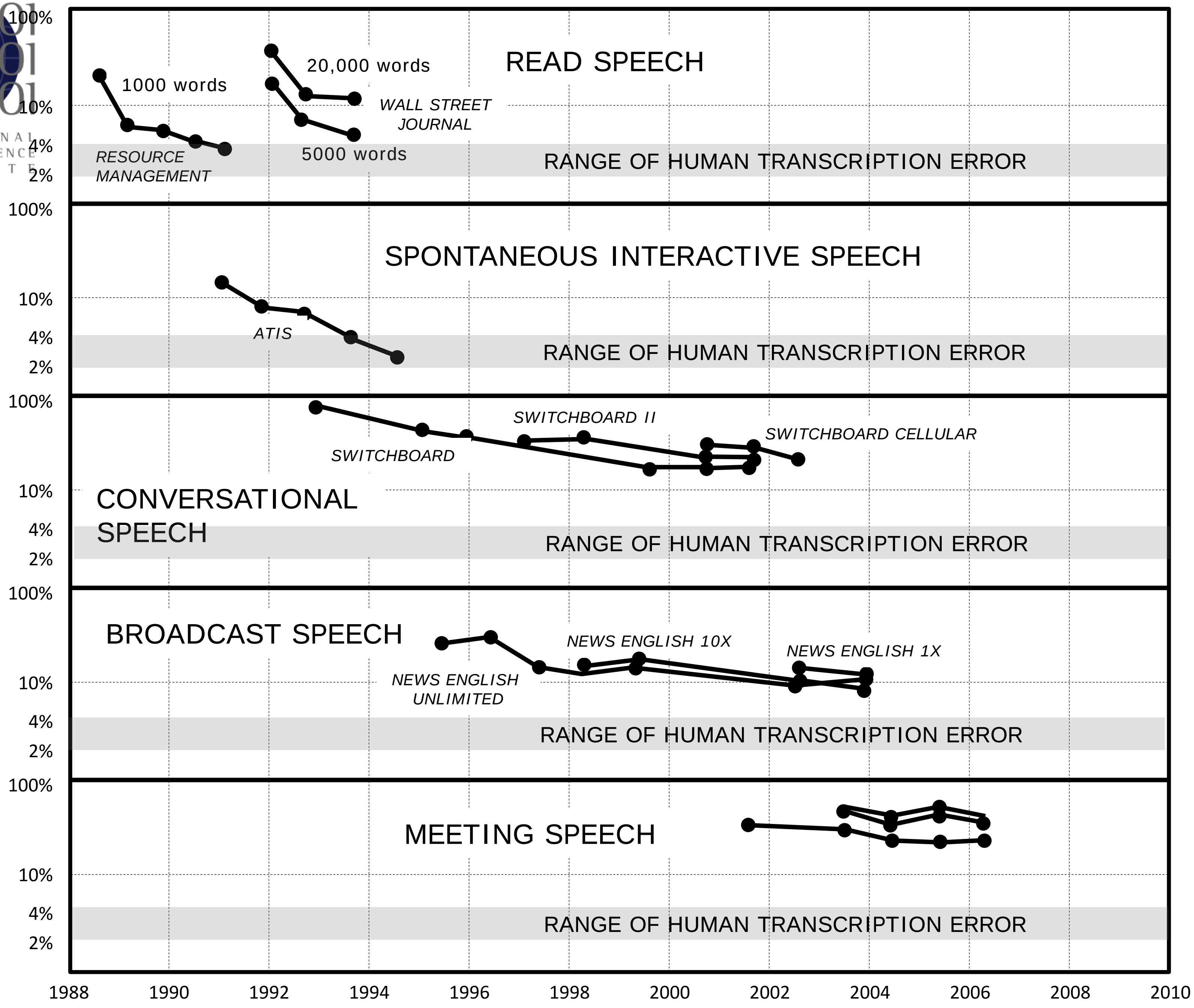

The evolution of speech recognition

- 1992
  - Feature extraction: frame-based measures
    - Mel frequency cepstral coefficients (MFCC)
    - Perceptual linear prediction (PLP)
    - Delta cepstra (and delta delta, etc)
  - Acoustic modeling: Hidden Markov Models (HMMs)
    - representing context-dependent phoneme-like units
  - Language modeling: Statistical language models
    - representing context-dependent words

MORE DATA, FASTER CPUs

Normalization, Adaptation,

Combination of different systems, …

- 2012
  - Feature extraction: frame-based measures
    - Mel frequency cepstral coefficients (MFCC)
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  - Acoustic modeling: Hidden Markov Models (HMMs)
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The evolution of language understanding

- 1992
  - Data-driven statistical models of semantic attributes
    - Concepts
    - Semantic classification
  - Handcrafted grammar based semantic parsing
    - Context-free grammar tagging
    - Robust parsing

- 2012
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MORE DATA, FASTER CPUs

Standards (SRGS), Tools, …

Where do we go from here?

- Data is not a problem today, models are
- Better features and models
  - Models of hearing/production -> better features
  - Models of these features -> better acoustic models
  - Models of understanding -> better language models, dialog models, pragmatics, etc.

Cortical models
Deep learning

Deep semantic analysis

- Understanding the errors
  - Examine statistical assumptions
  - Experiments to determine relative importance
  - Look for the cause, rather than for the cure

Wegmann/Gillick: Test model assumptions

Recognize some speech data using an HMM

- ✗ output fits HMM distribution
- ✗ satisfies independence assumptions

Test	WER
Original data	13.0

Wegmann/Gillick: Test model assumptions

Simulate pseudo speech data from the HMM

- ✓ output fits HMM distribution
- ✓ satisfies independence assumptions

Test	WER
Original data	13.0
Simulated data	**0.2**

Wegmann/Gillick: Test model assumptions

Resample real speech frames, respecting the model

✗ output fits HMM distribution

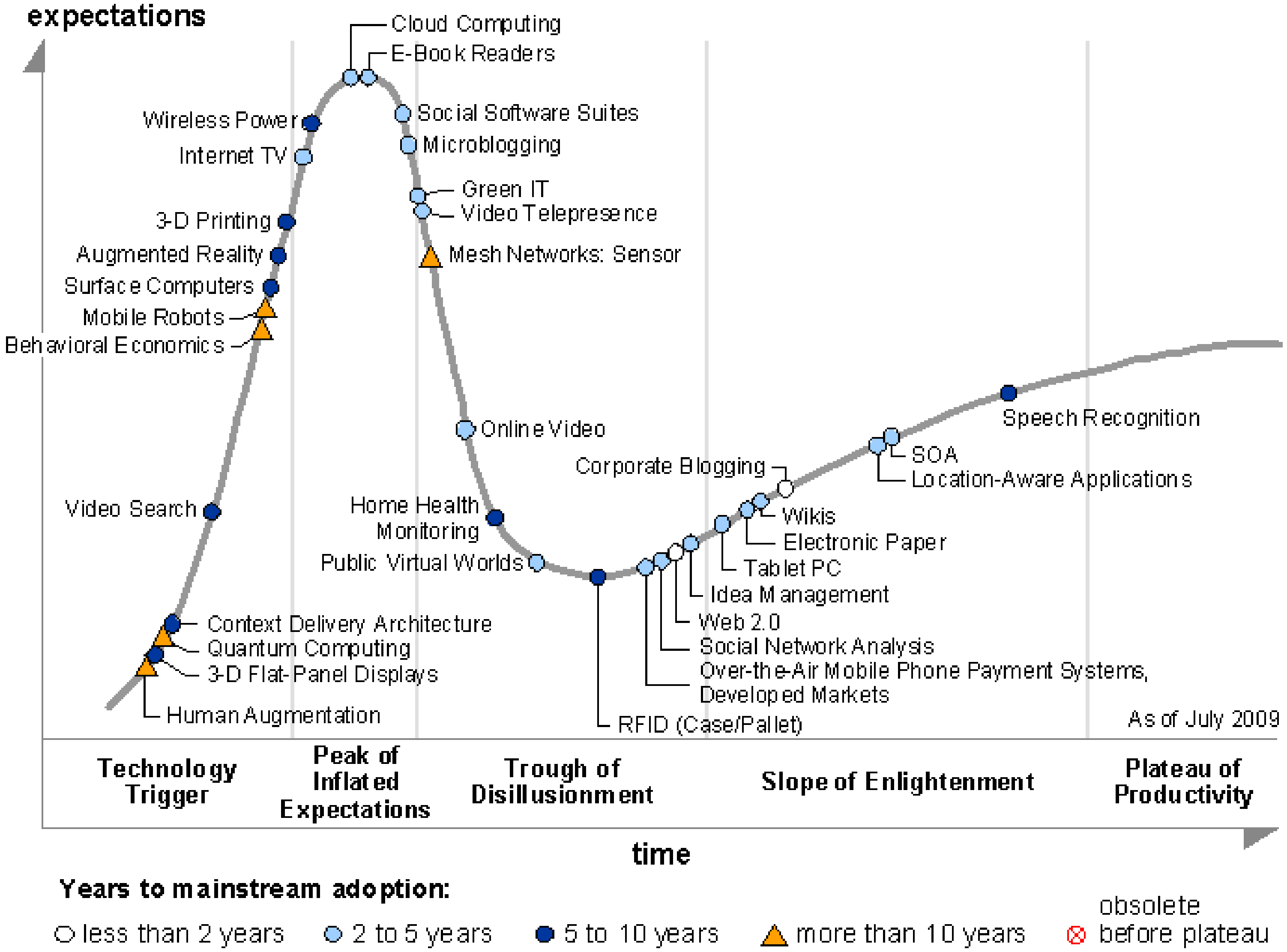
✓ satisfies independence assumptions

Test	WER
Original data	13.0
Simulated data	0.2
Resampled data	**0.4**

OUCH: Outing Unfortunate Characteristics of HMMs

- An ICSI project sponsored by AFRL (Air Force Research Lab) and IARPA (Intelligent Advanced Research Projects Activity)
- **Nelson Morgan**, Jordan Cohen, Steven Wegman, et al.
- In-depth study of acoustic modeling and effects of assumptions in current statistical models
  - Resampling, mismatch, advanced frond-ends
- Broad survey of field
  - Literature, expert survey

Gartner’s 2009 Hype Cycle



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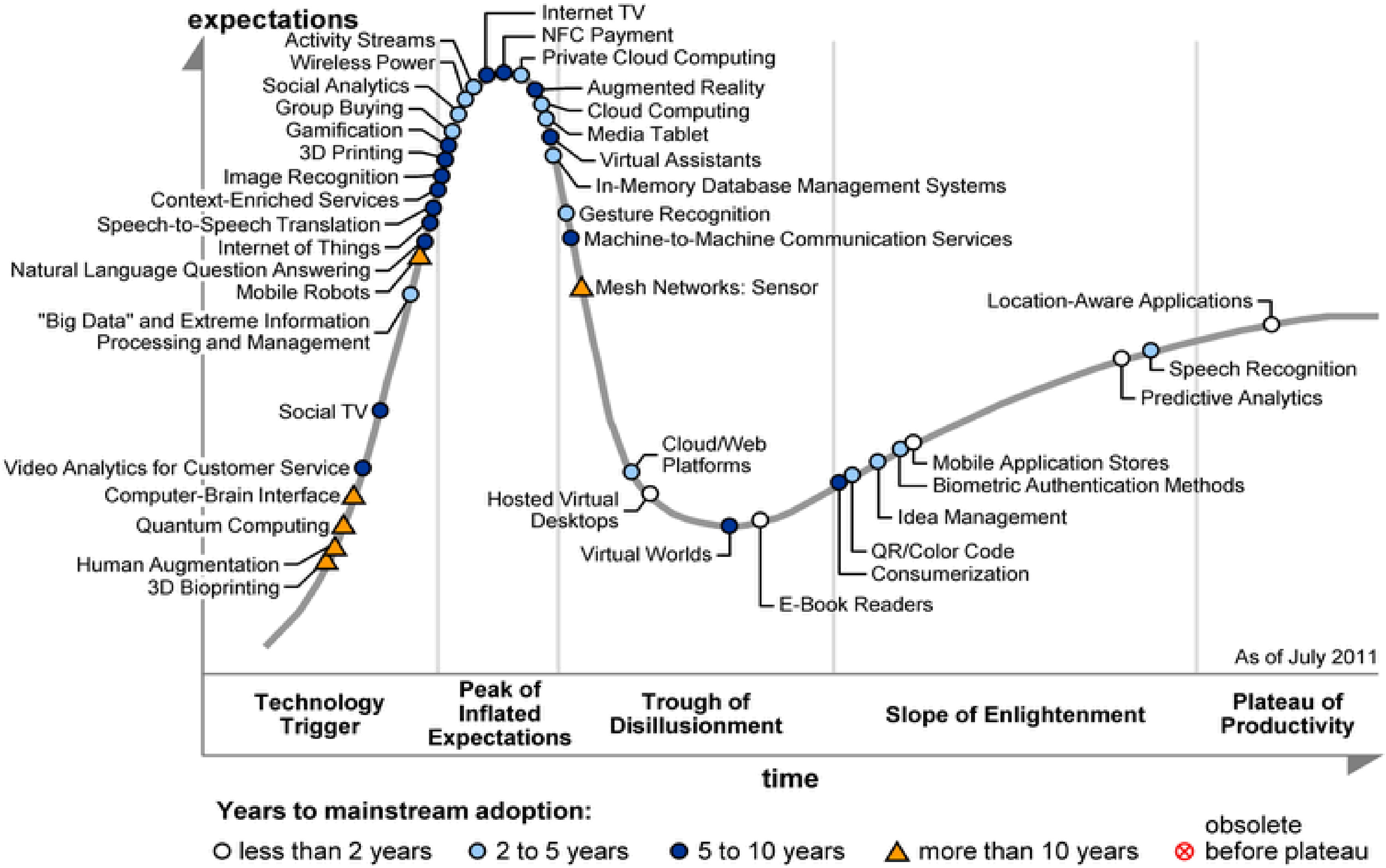
Gartner's 2011 Hype Cycle



Conclusions

- Speech recognition has a long history (60 years) of research, failures, and successes
- It feels like we are at a tipping point for the technology
- But the most general speech recognition problem is far from solved
- We do not want to see user expectations outgrow the actual capabilities.
- Continuing on the slope of enlightenment … or back to the trough of disillusionment?

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voice

Pieraccini