6.300: Signal Processing

Speech

Quiz 2: November 10, 2-4pm, room 50-340 (Walker).

- Closed book except for two pages of notes (8.5"x11" four sides total).
- No electronic devices. (No headphones, cellphones, calculators, ...)
- Coverage up to and including classes on November 5 and HW 8.

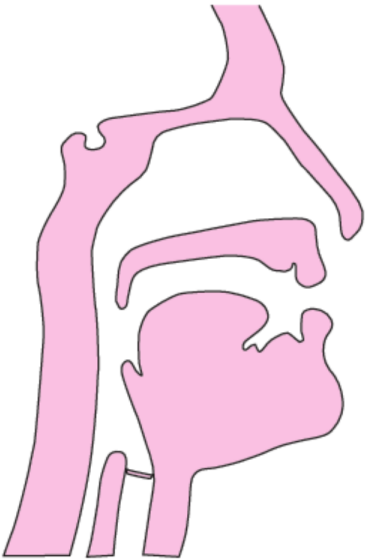
There is no HW 9.

If you have personal or medical difficulties, please contact S^3 and/or 6.300-instructors@mit.edu for accommodations.

November 05, 2026

Speech Production

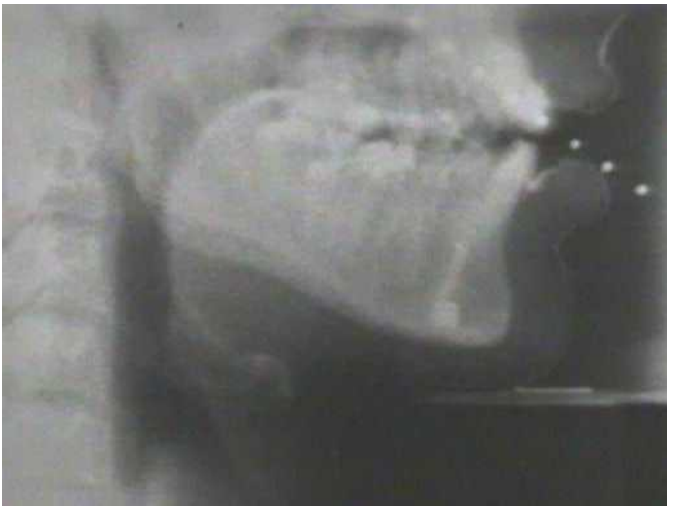
Motions of mouth, lips, and chin are essential to speech production.
Most of us have only a vague notion of how the system works.



Cross-section of human head showing air cavities and articulators.

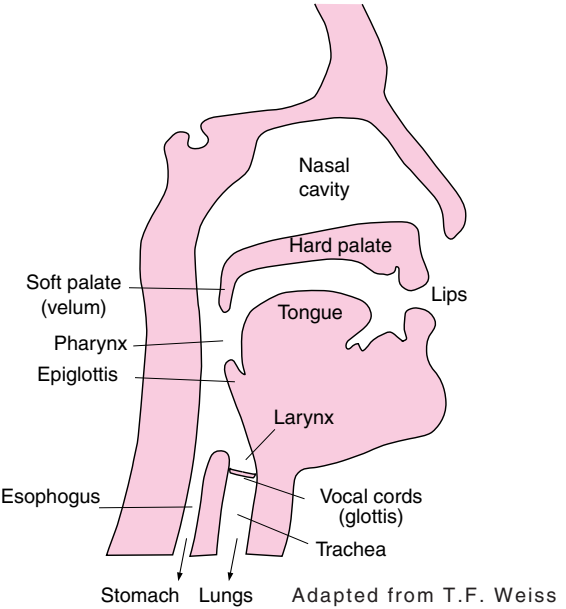
Speech Production

X-ray movie showing motions of speech articulators.



Source/Filter Model of Speech Production

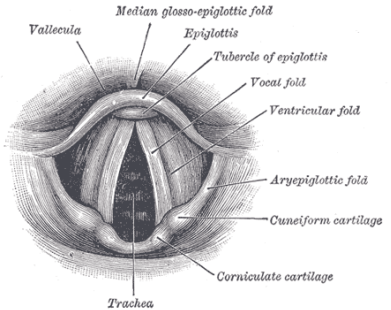
Two parts of speech production: the **source** and the **filter**.



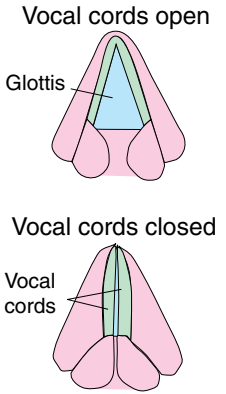
Source/Filter Model of Speech Production

Controlled by complicated muscles, vocal cords are set in vibration by the passage of air from the lungs.

Looking down the throat:



Gray's Anatomy

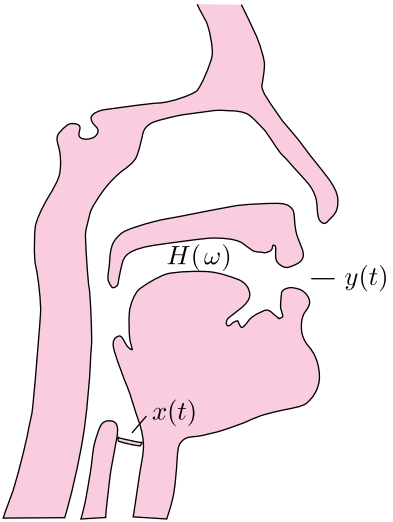


Adapted from T.F. Weiss

During voiced speech, the glottis generates puffs of air that are a few ms in duration. The frequency of puffs ranges from 100–300 Hz.

Source/Filter Model of Speech Production

Vibrations of the vocal cords are "filtered" by the mouth and nasal cavities to generate speech.



buzz from vocal cords → mouth, lips and nasal cavities → speech

Demonstration

Physical model of the vocal tract.



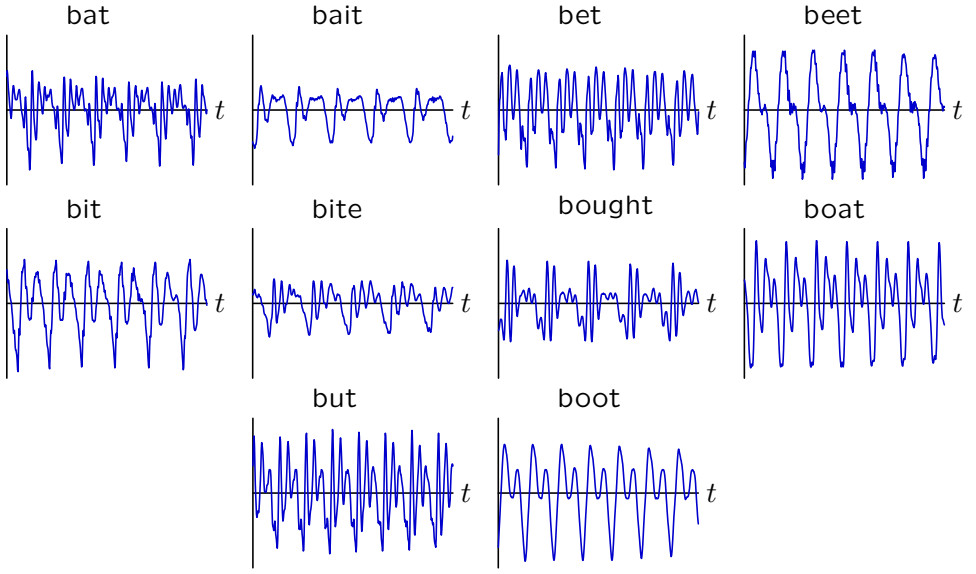
Buzzer represents sound from glottis.

Machined cavities represent vocal tract.

Chiba and Kajiyama Model replicated by Takayuki Arai.

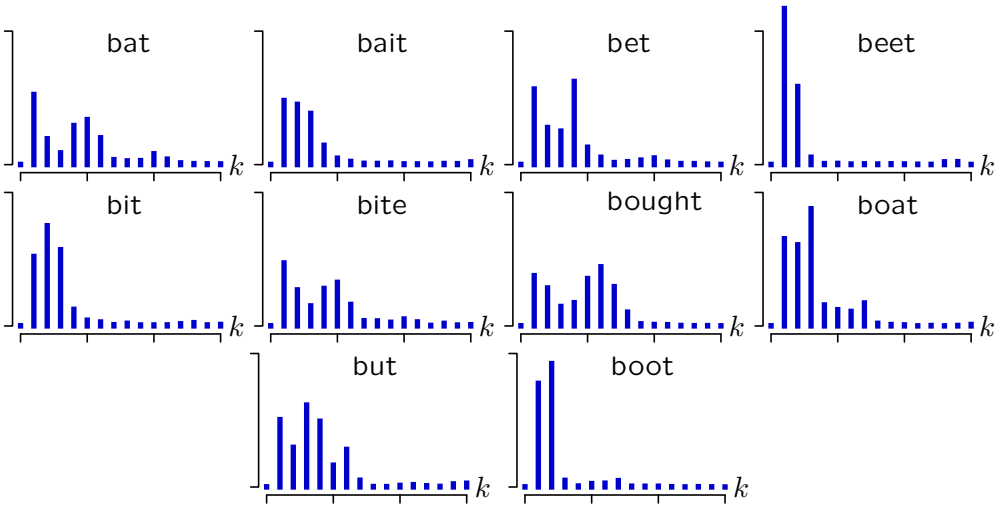
Source/Filter Model of Speech Production

Vowels sound different because mouth and lip positions are different.



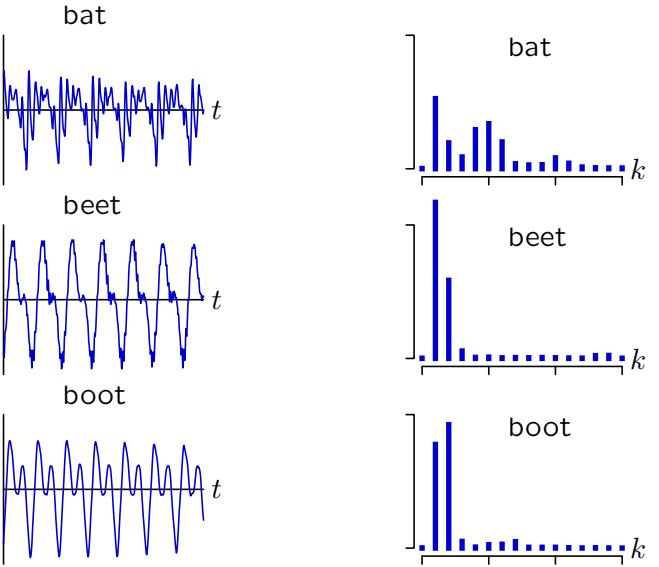
Source/Filter Model of Speech Production

Harmonic content is natural way to describe vowel sounds.



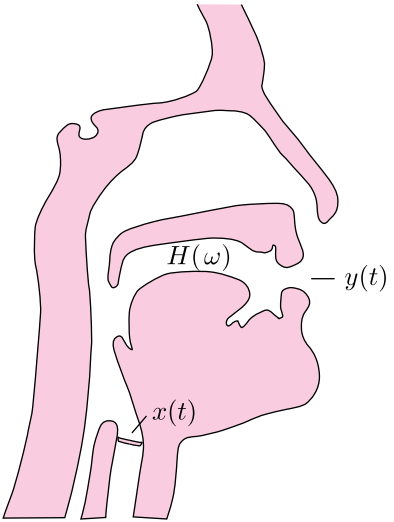
Source/Filter Model of Speech Production

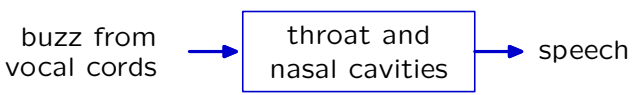
Harmonic content is natural way to describe vowel sounds.



Source/Filter Model of Speech Production

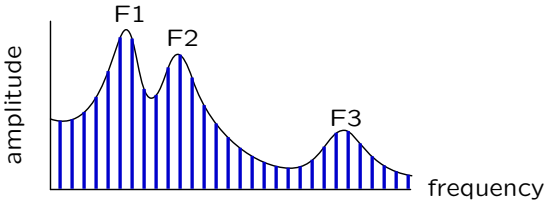
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Formants

Resonant frequencies of the vocal tract.*

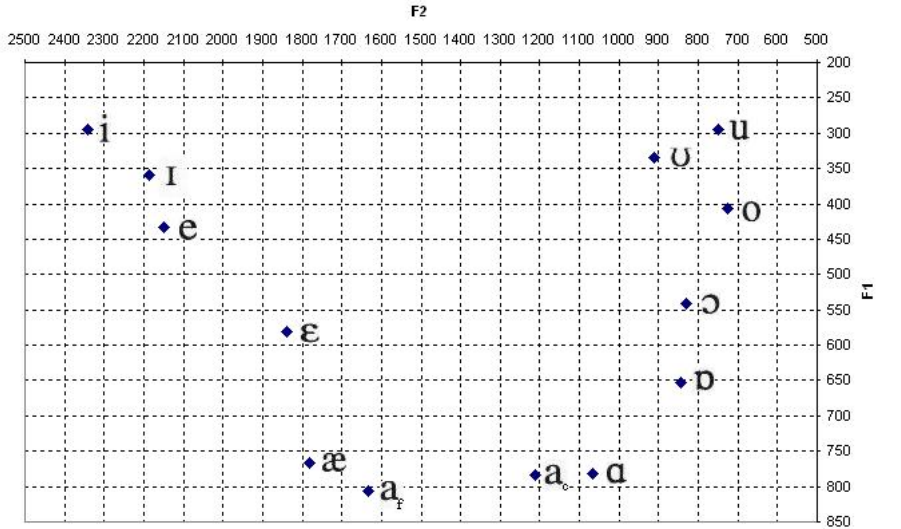


	Formant	heed	head	had	hod	haw'd	who'd
Men	F1	270	530	660	730	570	300
	F2	2290	1840	1720	1090	840	870
	F3	3010	2480	2410	2440	2410	2240
Women	F1	310	610	860	850	590	370
	F2	2790	2330	2050	1220	920	950
	F3	3310	2990	2850	2810	2710	2670
Children	F1	370	690	1010	1030	680	430
	F2	3200	2610	2320	1370	1060	1170
	F3	3730	3570	3320	3170	3180	3260

* http://www.sfu.ca/sonic-studio/handbook/Formant.html

Formants

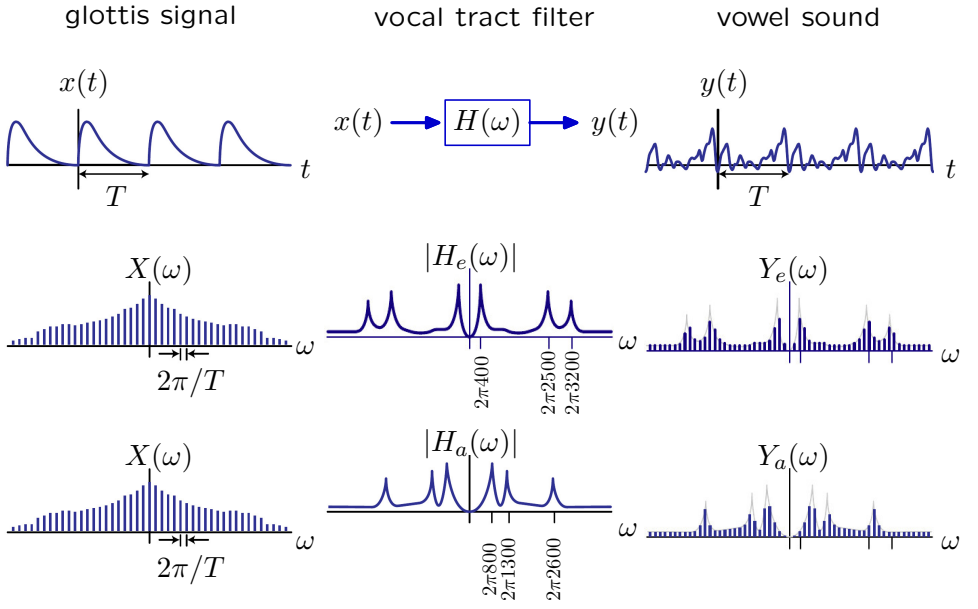
Formant frequencies for common vowels.*



* https://linguistics.ucla.edu/people/hayes/103/Charts/VChart

Speech Production

Same glottis signal + different formants → different vowels.



We detect changes in the filter function to recognize vowels.

Singing

We detect changes in the filter function to recognize vowels

... at least sometimes.

Demonstration.

"la" scale.

"lore" scale.

"loo" scale.

"ler" scale.

"lee" scale.

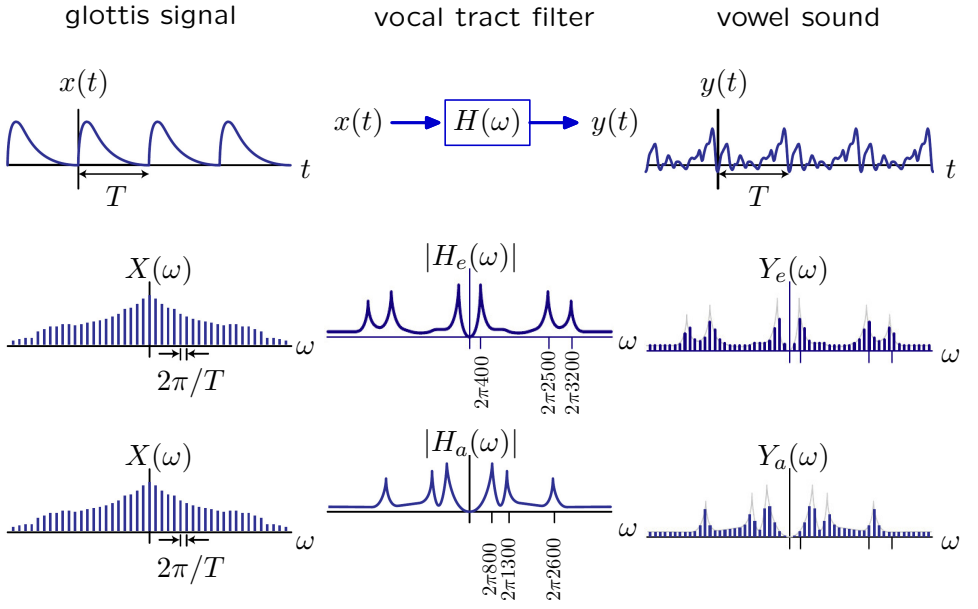
Low Frequency: "la" "lore" "loo" "ler" "lee".

High Frequency: "la" "lore" "loo" "ler" "lee".

http://www.phys.unsw.edu.au/jw/soprane.html

Speech Production

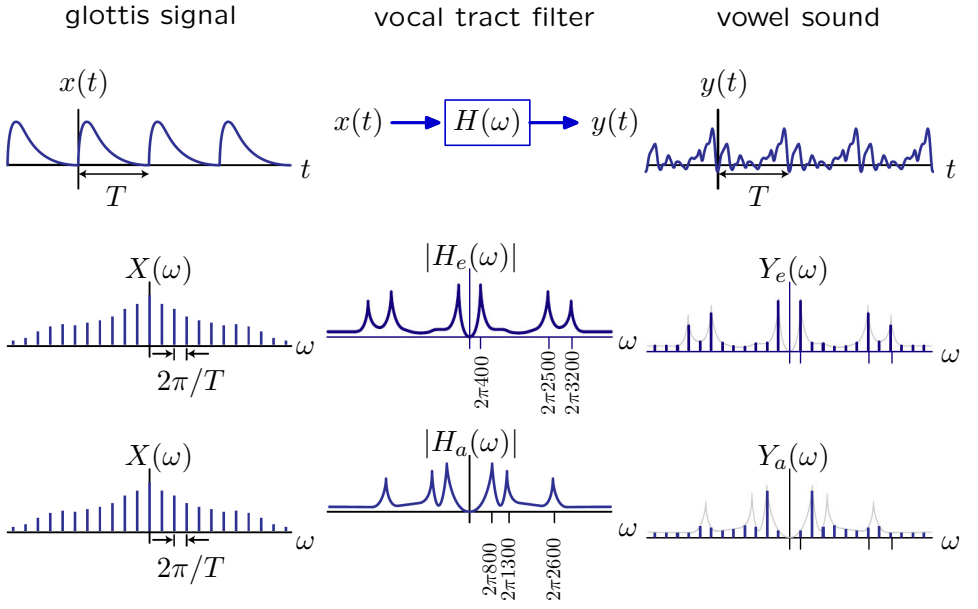
Same glottis signal + different formants → different vowels.



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Speech Production

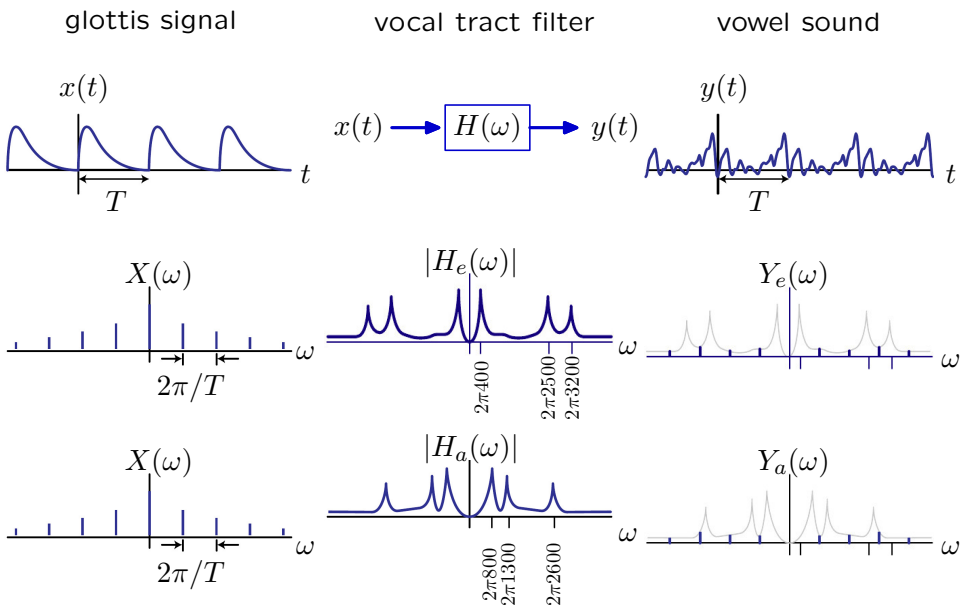
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Speech Production

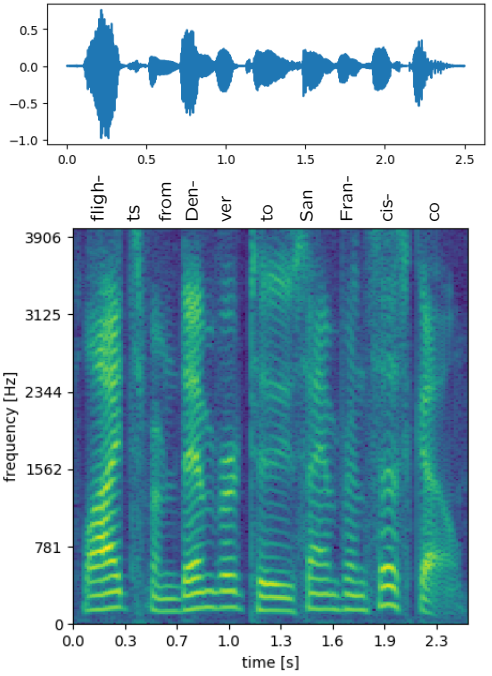
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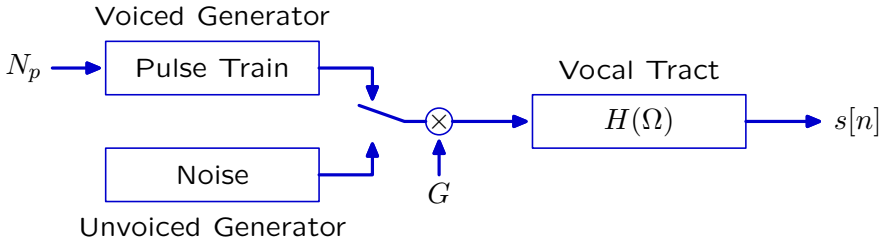
Time and Frequency Structure of Speech

Time plot & spectrogram of "flights from Denver to San Francisco."



Model of Running Speech

Model of speech production.



Acoustic sources:

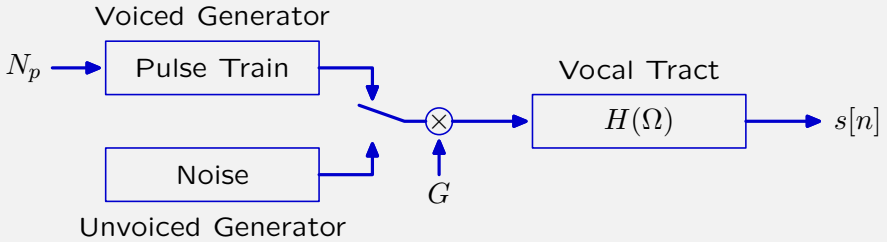
- pulse train with period N_p for voiced utterances
- gaussian noise for unvoiced utterances

Gain: G controls loudness

Vocal tract: filter represented shapes of mouth, tongue, and lips

Model of Running Speech

"Flights from Denver ..." was analyzed with the source/filter model and a new sound was produced using a modified model

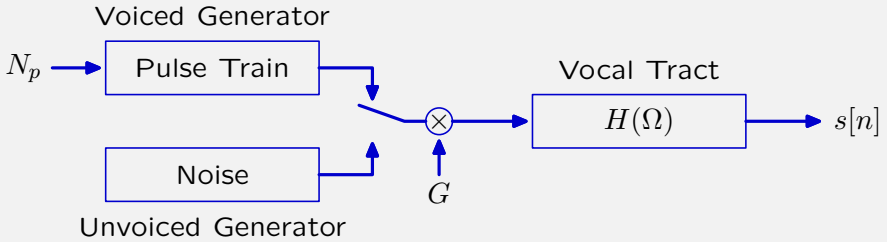


What part of the model was changed?

1. Original
2. Modification #1
3. Modification #2
4. Modification #3

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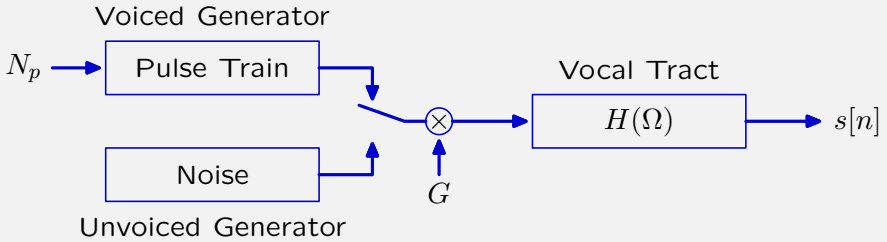


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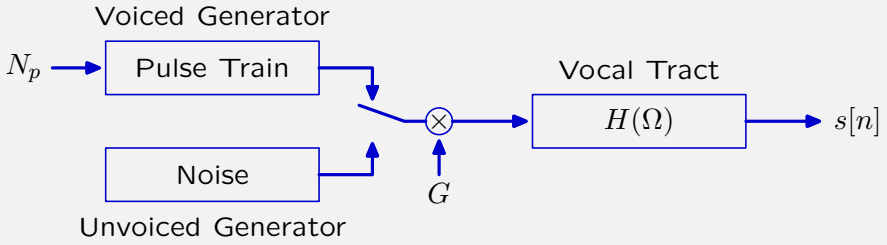


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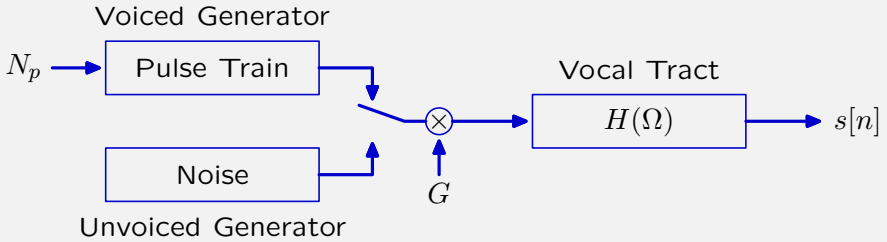


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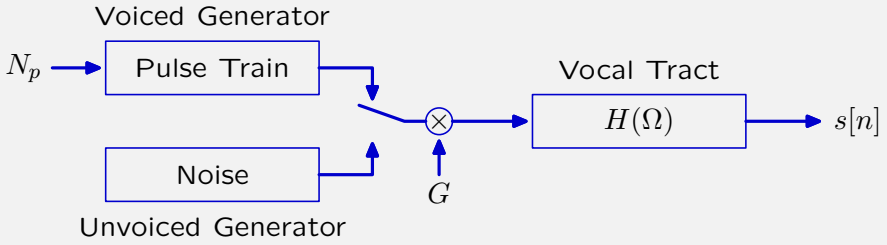


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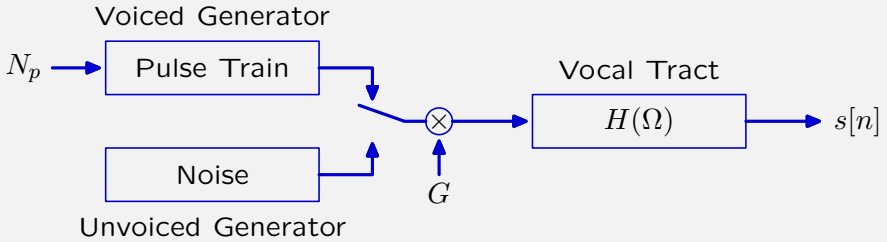


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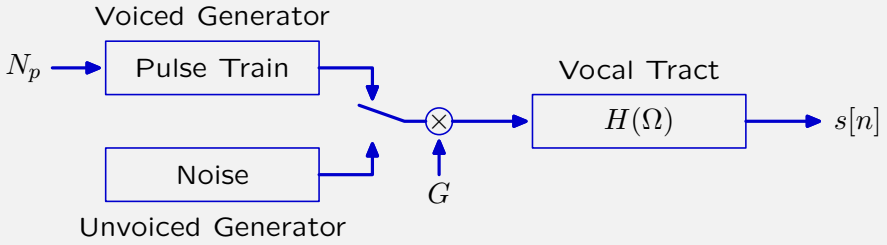


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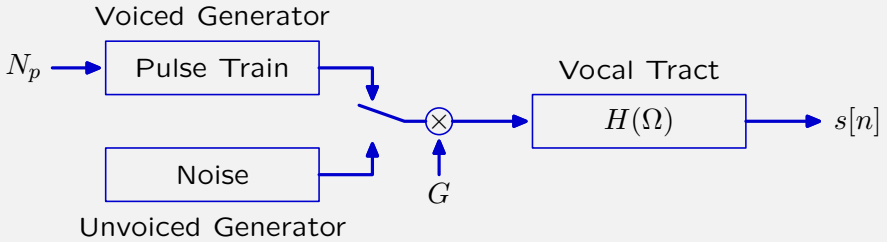


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Summary

Introduction to speech processing

- source/filter model of speech production
- speech analysis
- speech synthesis