6.003: Signal Processing

Speech

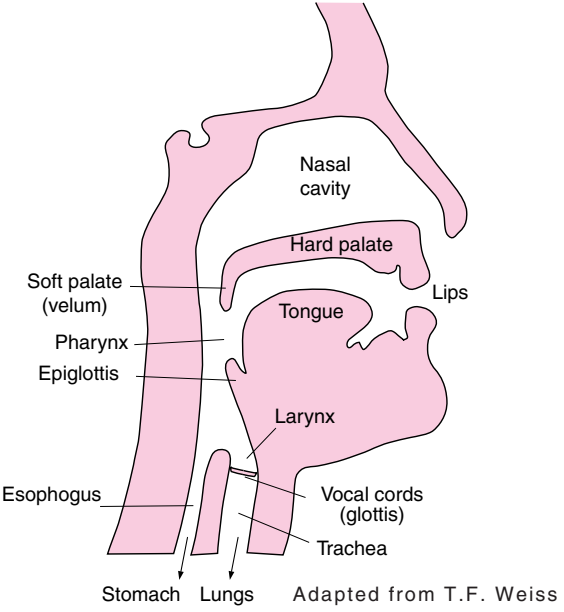
- source/filter model of speech production
- speech analysis
- speech synthesis

- Quiz 2: November 2, 2-4pm, 50-340 (Walker)
  - Coverage up to and including all of week 7, including HW7.
  - Closed book except for two page of notes (four sides total)
  - No electronic devices. (No headphones, cellphones, calculators, ...)
- No HW8 – a practice quiz is posted.

October 28, 2021

Source/Filter Model of Speech Production

Speech is generated by the passage of air from the lungs, through the vocal cords, mouth, and nasal cavity.

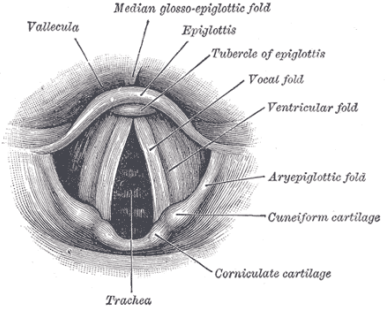


Adapted from T.F. Weiss

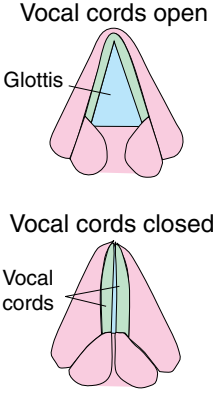
Source/Filter Model of Speech Production

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



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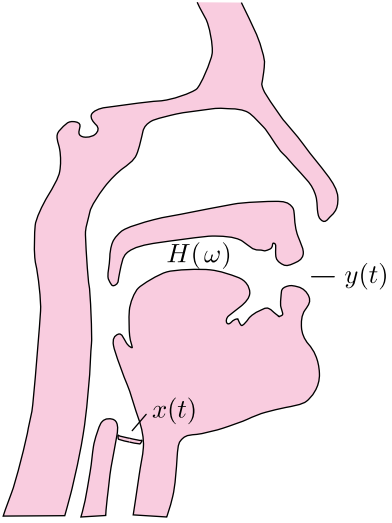
During voiced speech, the glottis generates puffs of air that are a few ms in duration. The frequency of puffs ranges from 100–300 Hz.

Source/Filter Model of Speech Production

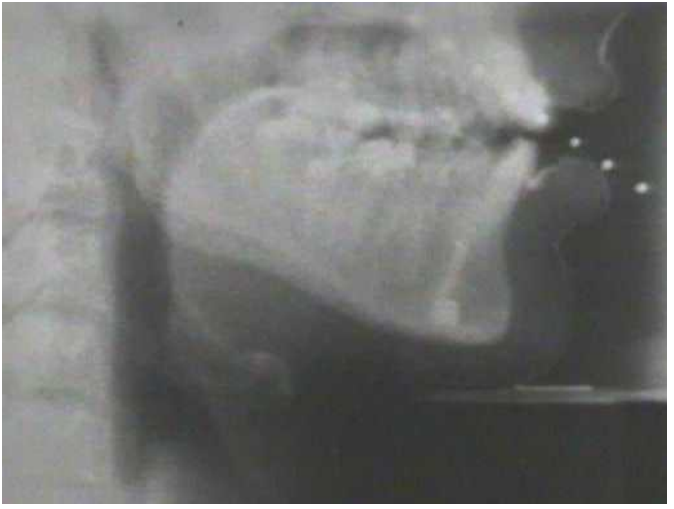
Vibrations of the vocal cords are "filtered" by the mouth and nasal cavities to generate speech.



buzz from vocal cords → throat and nasal cavities → speech

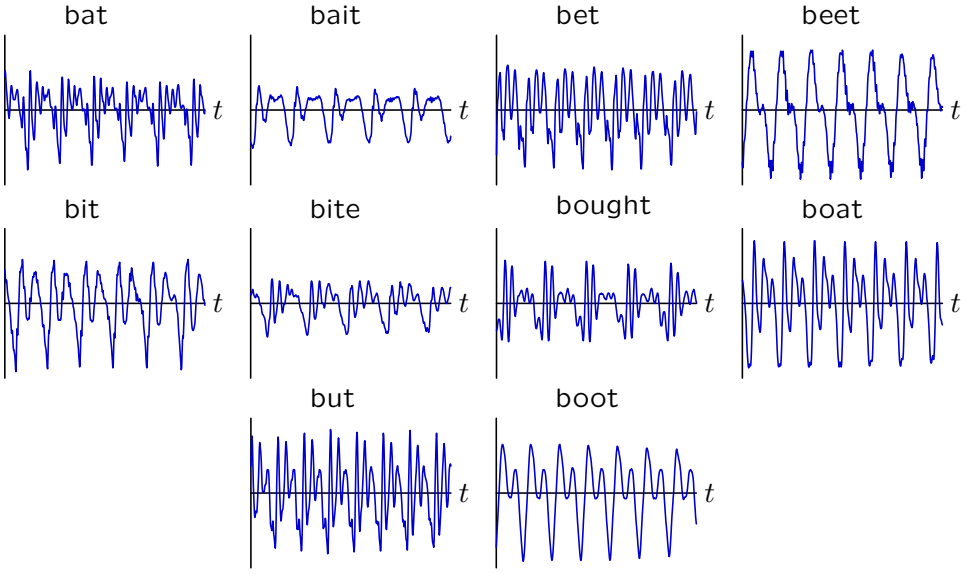
Speech Production

X-ray movie showing speech in production.



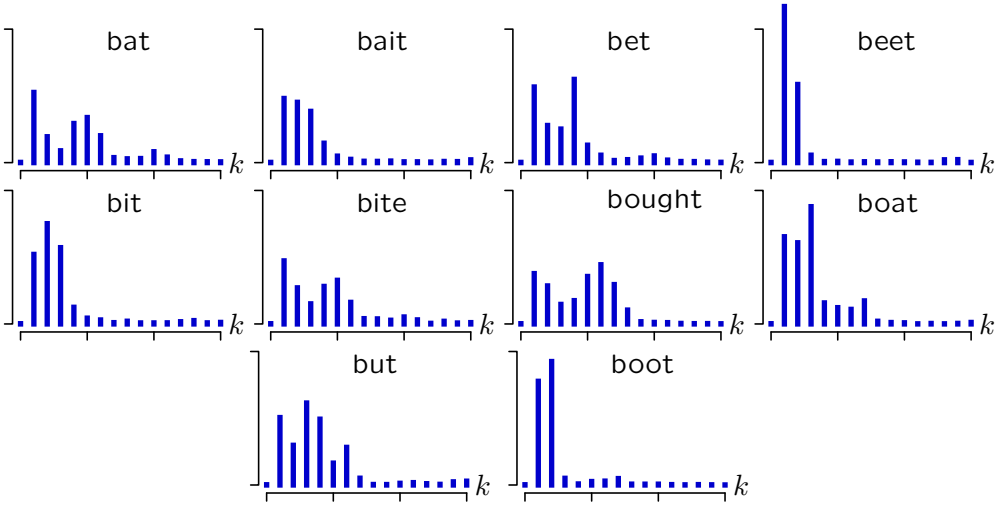
Source/Filter Model of Speech Production

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.



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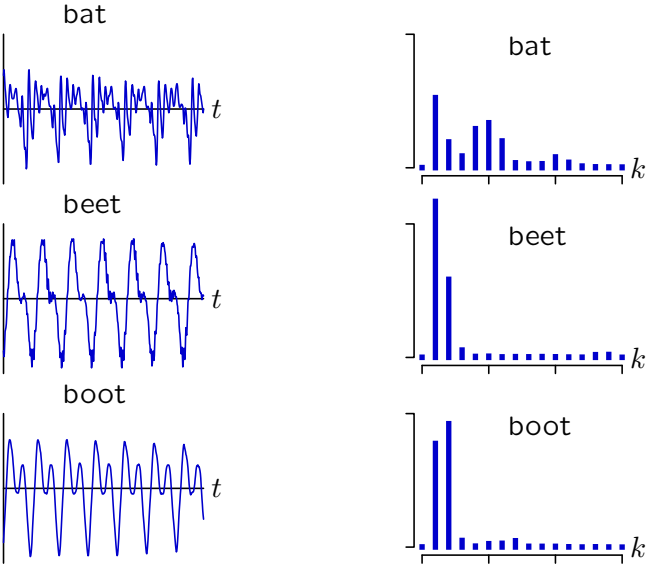

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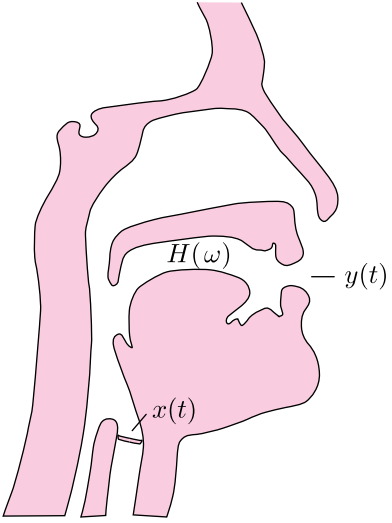


buzz from vocal cords → throat and nasal cavities → speech

Demonstration

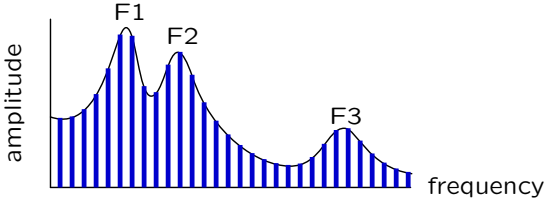
Physical model of the vocal tract.

Buzzer represents sound from glottis.

Machined cavities represent vocal tract.

Formants

Resonant frequencies of the vocal tract.

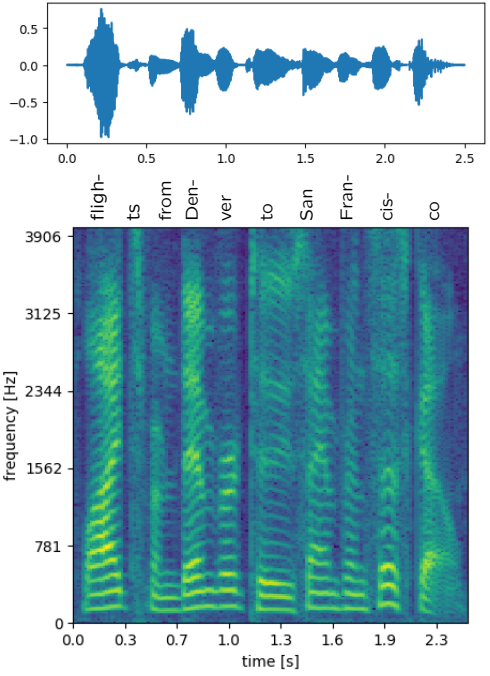


	Formant	heed	head	had	hod	haw'd	who'd
Men	F1	270	530	660	730	570	300
	F2	2290	1840	1720	1090	840	870
	F3	3010	2480	2410	2440	2410	2240
Women	F1	310	610	860	850	590	370
	F2	2790	2330	2050	1220	920	950
	F3	3310	2990	2850	2810	2710	2670
Children	F1	370	690	1010	1030	680	430
	F2	3200	2610	2320	1370	1060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

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

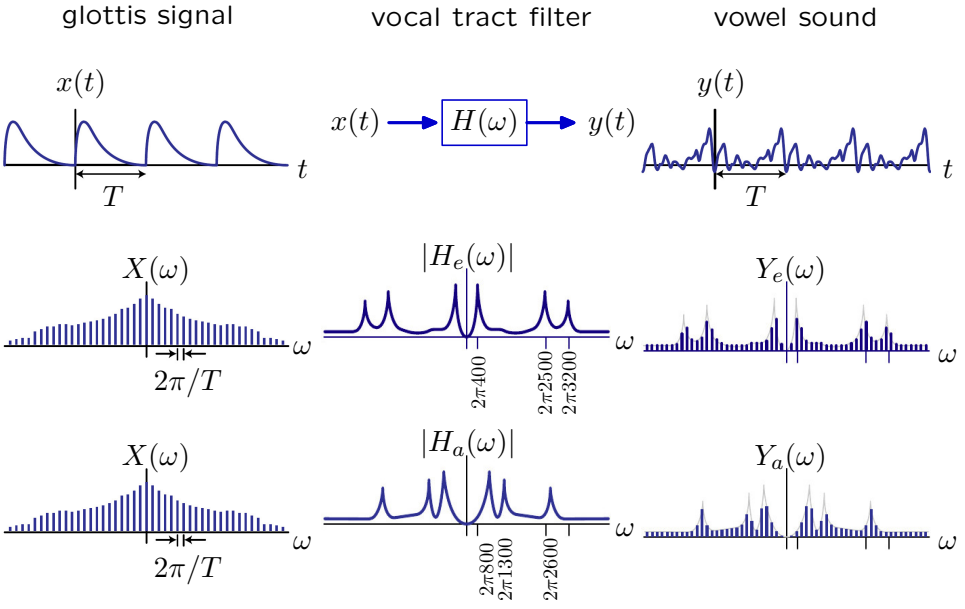
Time and Frequency Structure of Speech

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



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.

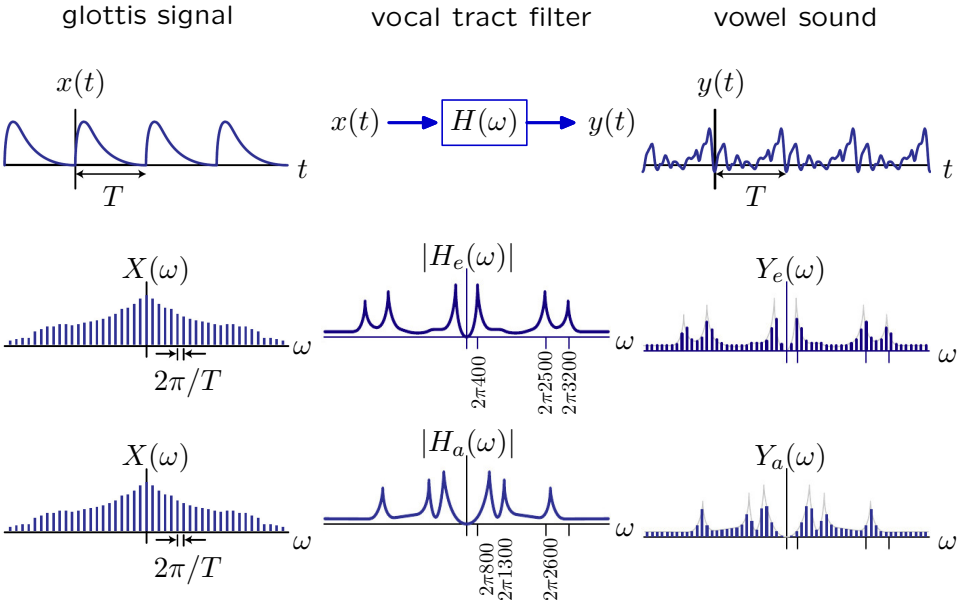
Low Frequency: "la" "lore" "loo" "ler" "lee".

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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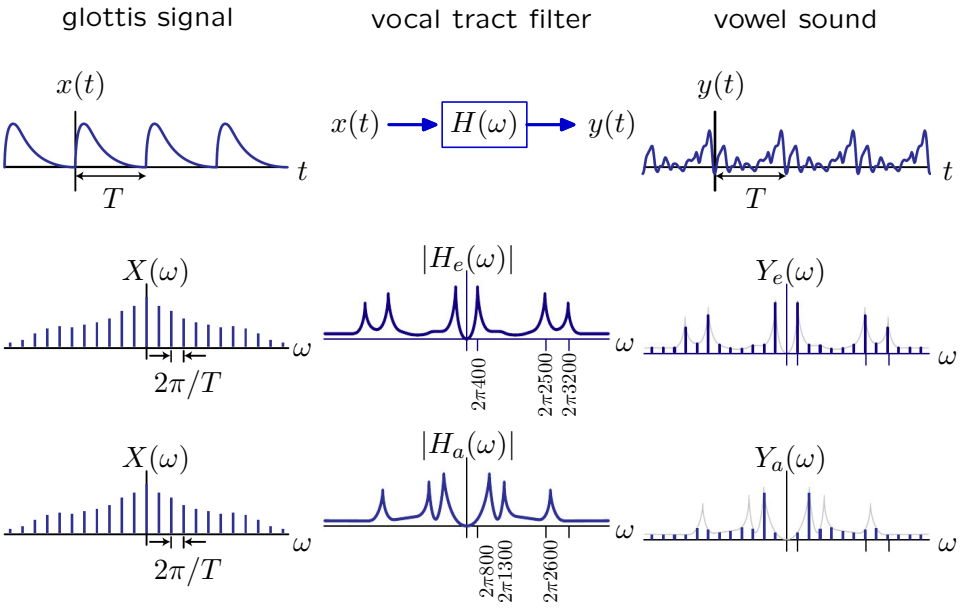

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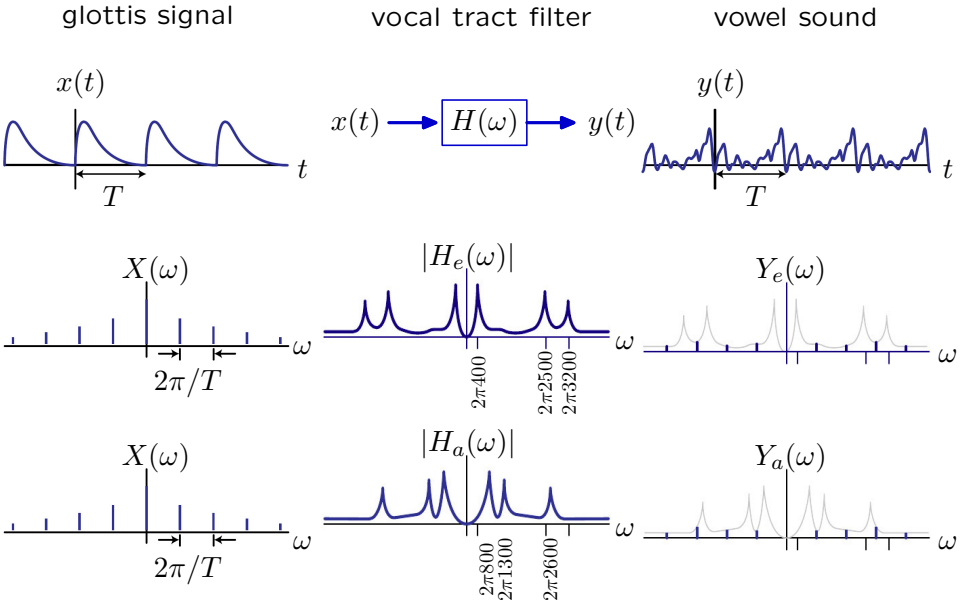

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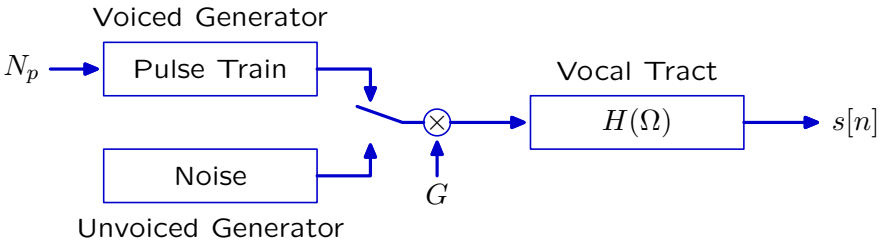
Source/Filter Model

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

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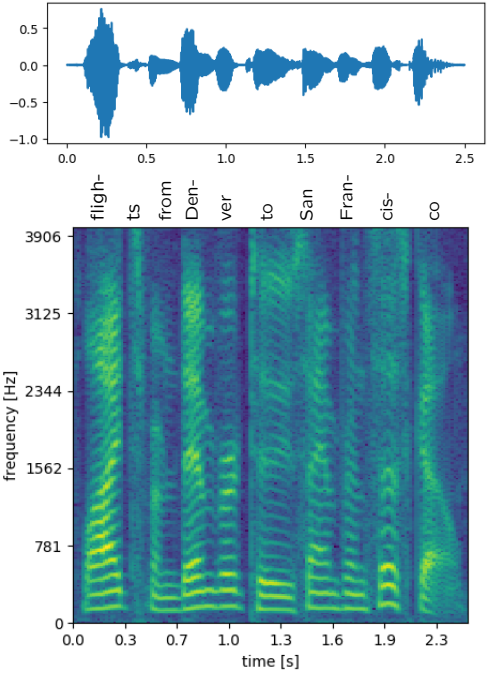

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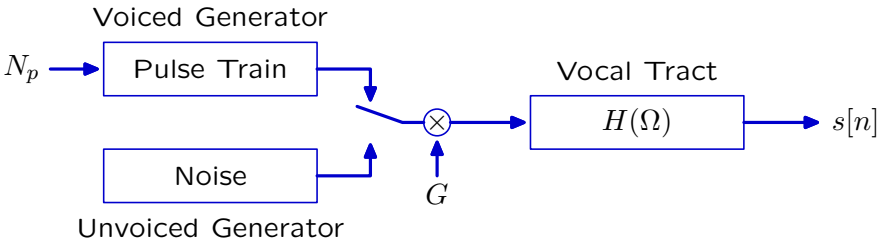

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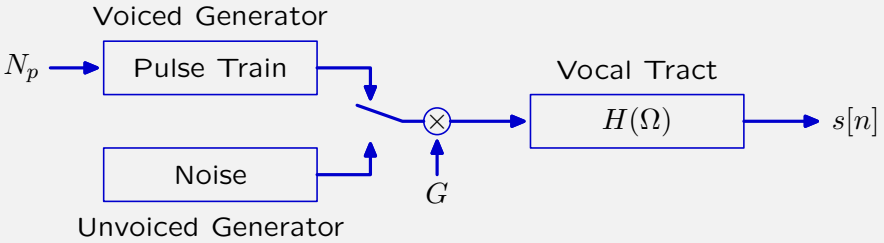
"Flights from Denver ..." was analyzed with the source/filter model and a new sound was produced using a modified model



What part of the model was changed?

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

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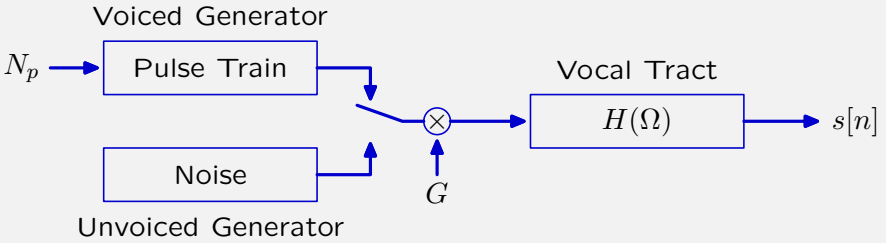

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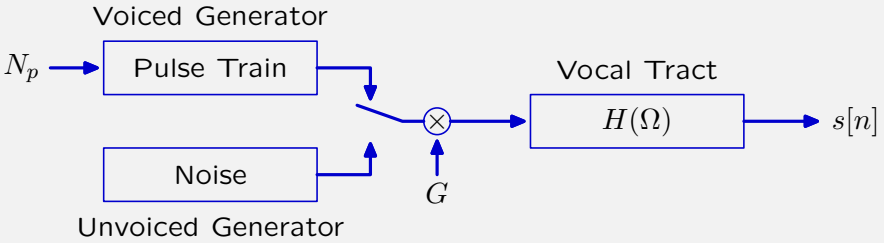

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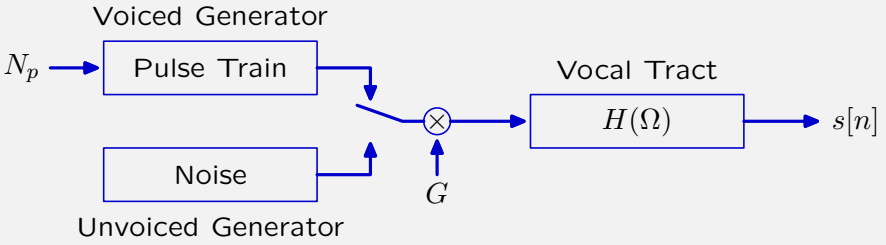

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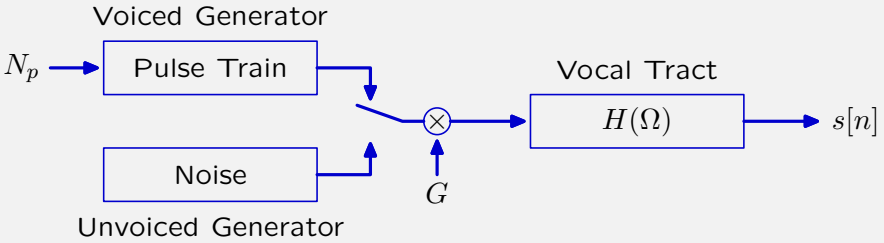

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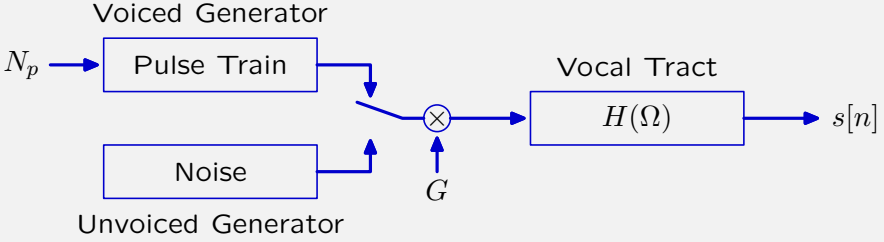

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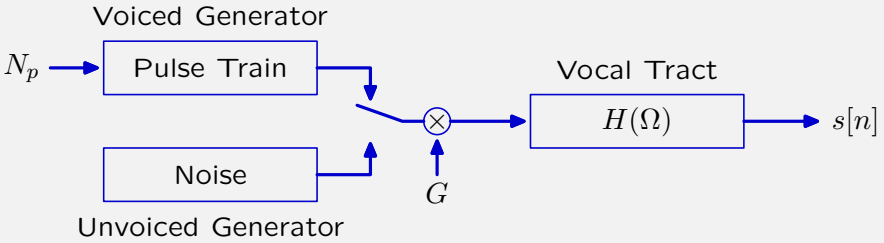

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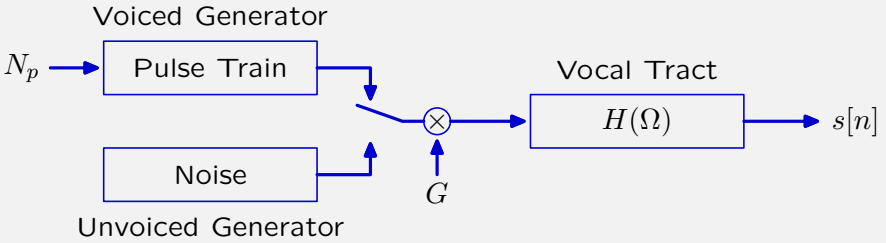

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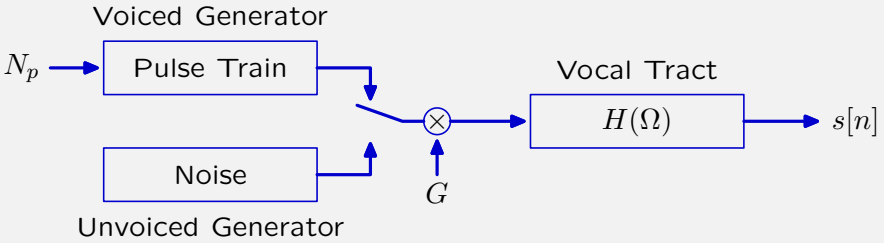

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Summary

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- speech analysis
- speech synthesis