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%Objective: read in an input signal and identify the positions and
types
%of vowels in the signal.

%First, read in a voice signal at very high sampling frequency, here
set to
%44.1kHz. That way, you can have a lot of information to process
between
%any times t1 and t2, as opposed to if you had a small sampling
frequency.

%The parameter y is a very long voice signal of length 44100*n , where
n is
%the number of seconds of speech.

%Because of inevitable noise infiltrating our data, it is very
%difficult to establish the points in the signal where a sound
definitively
%starts and where it stops. So, we adopt a different approach and look
at
%the problem from a spectrogram-analysis point of view.

%Assumptions:
%1) The user will speak at a relatively constant amplitude. Note that
this
% is a little easier said than done, because words like "see" are
% naturally much quieter than "hat."
%2) The user will speak slowly and clearly so that we can look for
% consistency in determining the vowels said.

%"Recipe" for success:
%1) Establish a set of variables that store theoretical vowel
formants.
%2) Record an audio signal of n seconds from the user.
%3) Preprocess the data by detrending with a low-order polynomial.
%4) Split the data into non-overlapping chunks of 4000 samples.
%5) Determine the transfer function of the vocal tract associated with
% the current chunk using an ar model.
%6) Determine the peaks of the transfer function (the formants) and
match
% with the closest formant, filtering by a least means-squared
matched
% filter.
%7) If amplitude of signal exceeds 0.1 max amplitude of overall
signal, we
% assume it's potentially a vowel. Put its formants onto the "stack"
of
% recent_formant_pairs.
%8) If the last four formant pairs have been consistent (the same
value),
% then we will assume the vowel estimation has worked. Add the
formant

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% pair to the "stack" of vowels identified in
track_times_and_formants.
%9) Now we have processed our guesses for what vowels were said when.
We
% are going to have repeats, so run through a for-loop to clean up
the
% track_times_and_formants vector into a new, workable vector called
% track_begin_end_formants.
%10) Output data and guesses.

%Limitations:
%1) Requires very clear enunciation. Difficult to establish because we
% naturally change the pitch of our words as we start and end them.
Example:
% the end of the vowel in "rug" sounds remarkably similar to "hat"
% because of the way you shape your vocal tract as you close your
mouth.
%2) User has to say each vowel for a moderate duration of time. Too
long,
% and a wavering voice would affect success of the program. Too
short,
% and not enough data to assign formants.

% Establishes initial values and constants.

[giant_matrix, output_matrix, recent_formant_pairs,
track_times_and_formants, track_counter] = initialize_all_data();

disp('Now the program will analyze your speech signal, section by
section')
disp('It will split the signal into *non*overlapping chunks to
determine whether')
disp('a vowel is present at the corresponding locations in time.')

for t = 1:4000:length(y)-8001

    [h,w, isNoise] = determine_frequency_response(y, t, Fs);

    % time to determine formants
    % first determine indices of local maxima of transfer function
    [pks, locs] = findpeaks(abs(h));
    [~, locs_ordered] = sort(pks, 'descend');

    formants = 1:length(pks);
    %this loop assigns formants to the locations in w corresponding to
"peaks"
    % using relation discrete_freq = analog_freq * Sample_rate
    for i = 1:length(pks)
        analog_freq = w(locs(locs_ordered(i)))*Fs/(2*pi);
        if (analog_freq > 140) % tries to filter out any ultra-low
frequency sound messups
            formants(i) = w(locs(locs_ordered(i)))*Fs/(2*pi);
        end
    end
end

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    recent_formant_pairs = [recent_formant_pairs(2,:);
recent_formant_pairs(3,:) ; -1 0];

    if isNoise~=1
        %disp('THIS CONDITION WAS SATISFIED');
        formants_identified = (sort(formants(1:2)));
        %disp(['At time t = ' num2str(t/Fs) ', the signal chunk
has'])
        %disp(['formants at ' num2str(formants_identified)])
        vector_dist = 1:6;
        for k = 1:6
            weights = [1 1]; %weight the first formant three times as
much as the second formant
            vector_dist(k) = norm(weights.*(giant_matrix(k,:) -
formants_identified));
        end

        %min_index identifies the vowel location in giant_matrix by
using a matched
        %filter dependent on the least-squares difference of the
experimental and
        %theoretical vowel spectra.
        if (max(formants_identified) < 4200)
            [~, min_index] = min(vector_dist);
        else
            min_index = 0;
            % disp('The program rejects this set of formants because
the value of the ')
            % disp('second formant is too high!')
        end

        %print t/Fs.0;
        %print ' ';
        %print output_matrix(min_index,:)
        if (min_index ~= 0)
            recent_formant_pairs = [recent_formant_pairs(1,:);
recent_formant_pairs(2,:) ; giant_matrix(min_index, :)];
            if (rank(recent_formant_pairs) == 1) % i.e. all the rows
are linearly dependent, implying they're the same in this case
                % disp('The program has determined that the last four
measurements have been')
                % disp('consistent. That means we shall consider this
set of measurements')
                % disp('as a vowel that appears in your signal!')
                track_times_and_formants(track_counter, :) = [t/Fs
giant_matrix(min_index, :)];
                track_counter = track_counter + 1;
                % If we see that the program identifies the same vowel
                % for at least 4 loops, then we can be confident that
some
                % vowel is being said.

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        %disp(['According to the frequency spectrum of your
input signal, the vowel you said at time t = ' t/44100.0 'seconds is
the central vowel of the word ' output_matrix(min_index,:)]);
    end
end
end
end

%Now we have a matrix track_times_and_formants which has done its job.
%However, we have to do some post-processing, because we anticipate
many
%repetitions in the matrix. Aka if you say the word "see" for a long
time,
%there will be multiple rows in track_times_and_formants corresponding
to
%your voice signal.

%Create a track_begin_end_formants matrix that stores the beginning
and
%ending time of a vowel as well as the appropriate formants.

%first column of track_begin_end_formants is t1, the start time of the
%vowel
%second column is t2, the end time of the vowel
%3rd and 4th columns store the corresponding formants at those times

[track_begin_end_formants, row_track] =
cleanup_formant_data(track_times_and_formants);

display_matches(track_begin_end_formants, row_track, giant_matrix,
output_matrix, y)

Now the program will analyze your speech signal, section by section
It will split the signal into *non*overlapping chunks to determine
whether
a vowel is present at the corresponding locations in time.
Warning: Polynomial is badly conditioned. Add points with distinct X
values,
reduce the degree of the polynomial, or try centering and scaling as
described
in HELP POLYFIT.
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values,

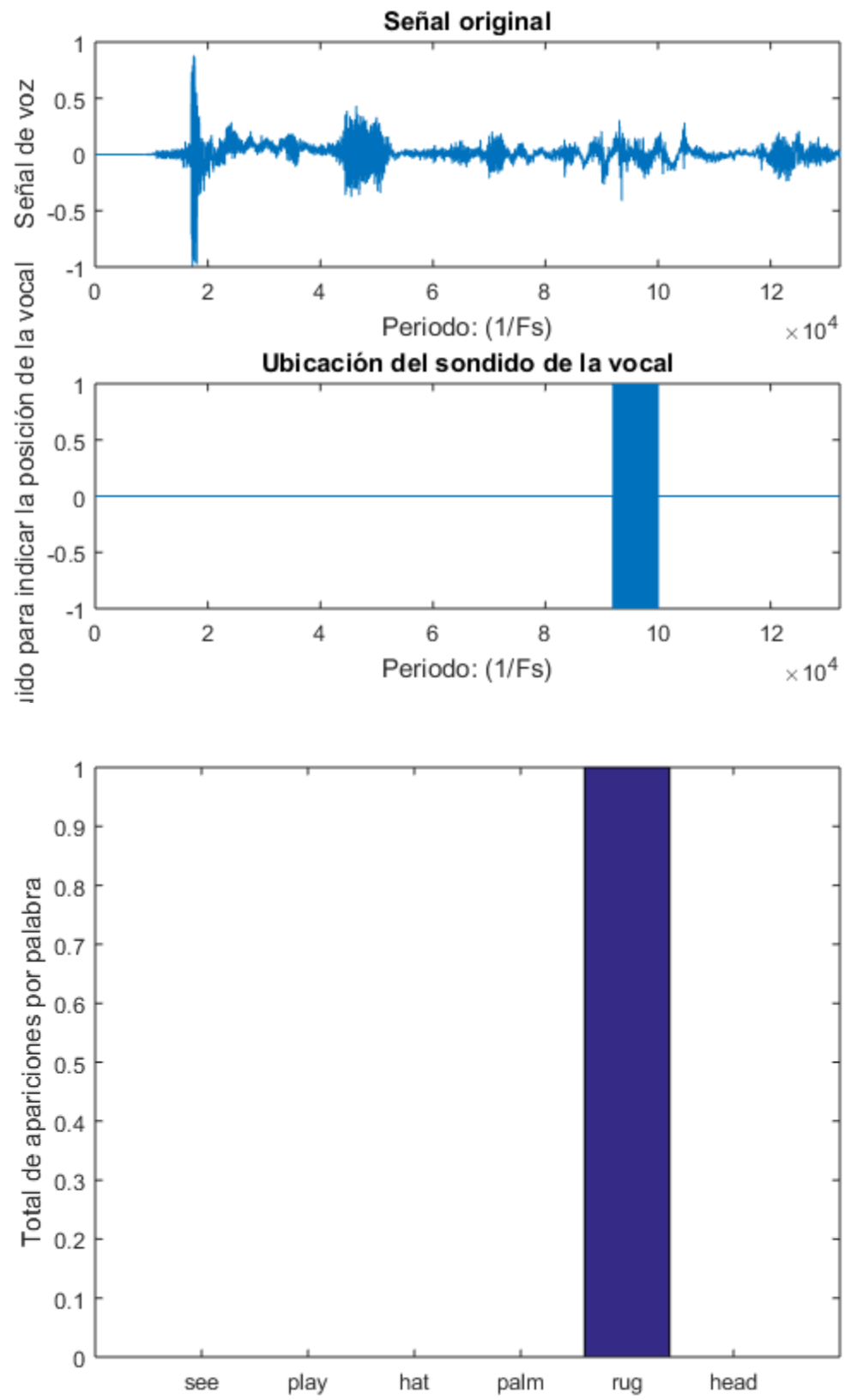
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