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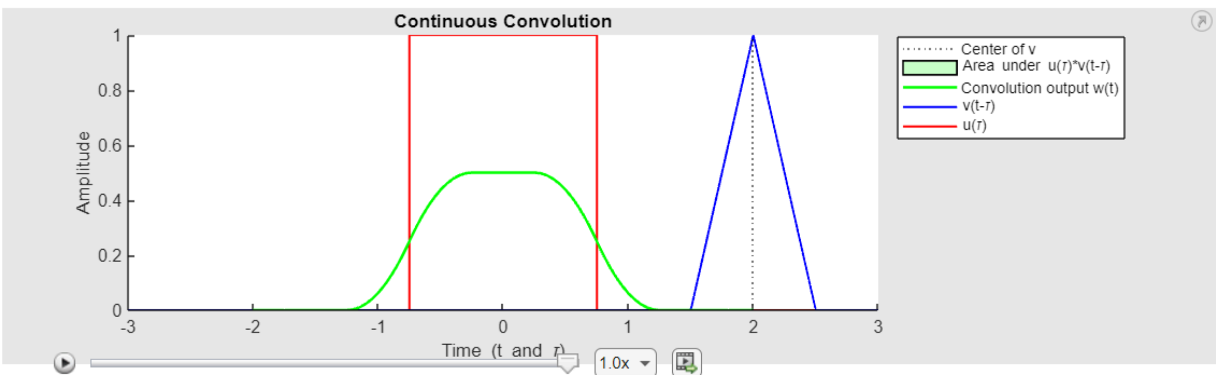
SNS lab 05

Try 1:

1. *Change u to a rectangular pulse of width 1.5 and amplitude 1.*

```
u = rectpuls (t, 1.5 ) * 1 ; % The first slider sets the width,
v = tripuls  (t, 1   ) * 1 ; % The first slider sets the width,
Run

animateConvolution(u,v,ts,t,-2);
```



2.Change v to a triangular pulse of width 1.5 and amplitude 1.

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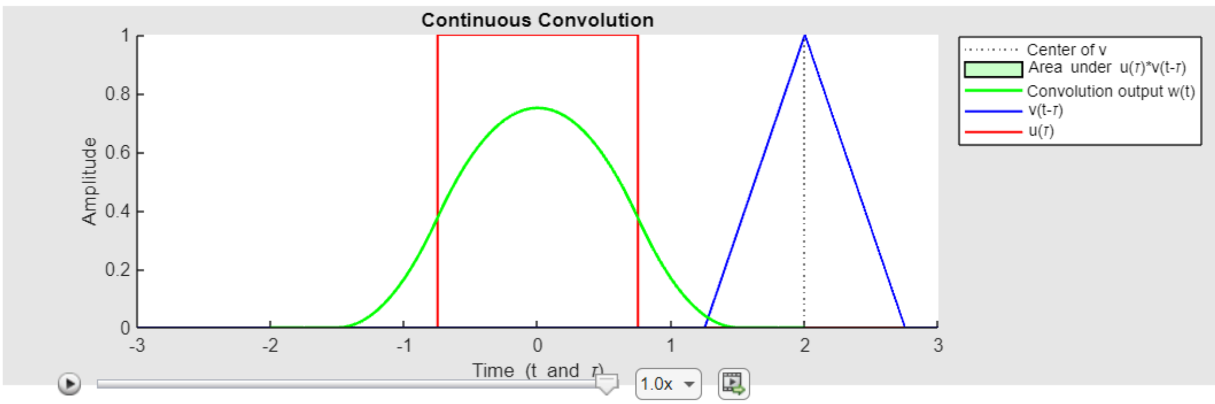
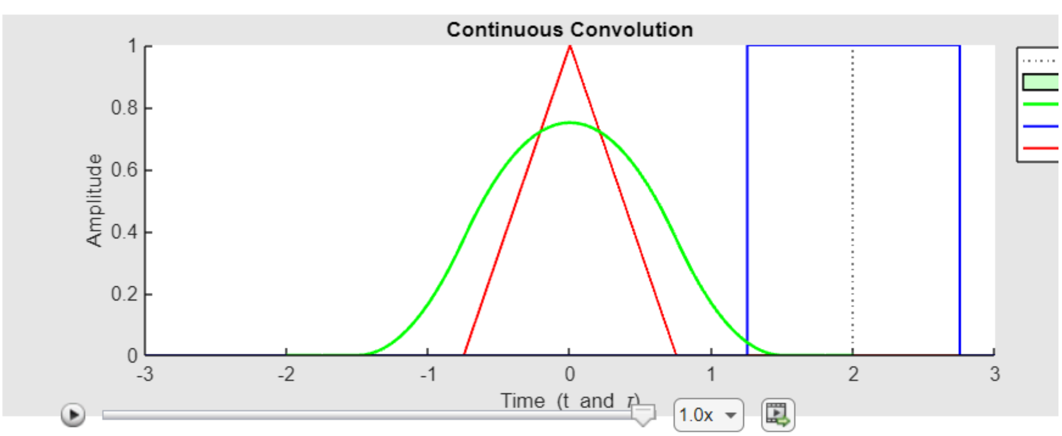
```
u = rectpuls (t, 1.5 ) * 1 ; % The first slider sets the
v = tripuls (t, 1.5 ) * 1 ; % The first slider sets the
Run

animateConvolution(u,v,ts,t,-2);
```



1. *Swap the u and v signal settings.*

```
v = rectpuls (t, 1.5 ) * 1 ; % The t
u = tripuls (t, 1.5 ) * 1 ; % The t
Run

animateConvolution(u,v,ts,t,-2);
```



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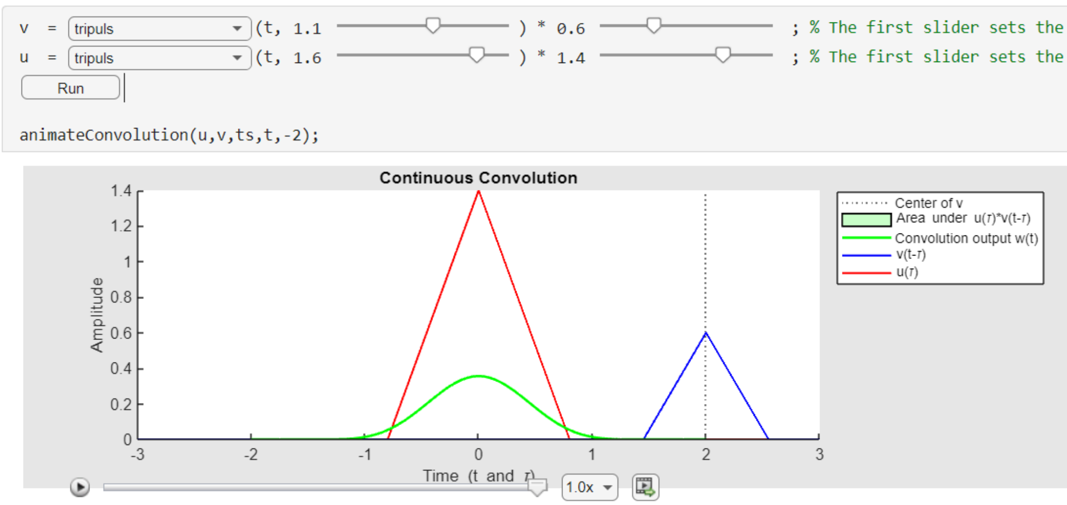
1. *Set* u *and* v *both to triangular pulse with different widths and amplitudes.*



- *Does the order of inputs matter? Is convolution commutative?*

The order of inputs doesnt matters, we see that by interchanging two signals u and v. first we did in uv order and then in vu order but in end the output of convolution was same in both cases. Hence convolution is commutative.

- *Describe your general observations about the convolution output* w *compared to the inputs* u *and* v*?*

The convolution output shows that how much area are we getting when both the graphs are overlapping. Simply, the area under the intersection of the graphs as one of the graphs is shifting horizontally is determined by the convolution operation.

task 2:

How is the length of convolution output related to the length L of the two input signals?

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```
figure("Position",[0 0 1200 350], "Color", [0.9 0.9 0.9]);

L = 150;                 % length of input sequences u and v. Keep it odd for simplicity
n = -(L-1)/2:(L-1)/2;    % X axis data for the signals

u  =  rectpuls (n, 80 );
stem(n,u,"r.")
```

We use the conv function to convolve two vectors i

```
w  =  conv(u, v) ;
disp("Output length = " + length(w))
```

```
Output length = 299
```

The output length of the convolution sum is almost equal to the sum of individual inputs, the individual inputs in this case have equal lengths so the output signal has almost the double of the lengths of the individual inputs. The length of individual inputs is 151 (150+ 1) and the length of the output is about 299(300-1).

What do you think will happen if the input sequences had different lengths? say, M and N, instead of L

```
figure("Position",[0 0 1200 350], "Color", [0.9 0.9 0.9]);

L = 150;                 % length of input sequences u and v. Keep it odd for simplicity
n = -(L-1)/2:(L-1)/2;    % X axis data for the signals

u  =  rectpuls (n, 80 );
stem(n,u,"r.")
```

```
L=120;
n = -(L-1)/2:(L-1)/2;
v  =  tripuls (n, 90 );
stem(n,v,"b.")
```

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We use the conv function to convolve two vectors in MATLAB.

```
w = conv(u, v);
disp("Output length = " + length(w))
```

```
Output length = 269
```

In the case when the inputs are of different lengths, the length of the convolution is the sum of the lengths of the inputs-1, in the case when the length of one input is 150 and other is 120 then the length of the convolution output is 269 (150+120-1) or m+n-1.

Task 3:

```
% Defining time index
clear all;
n = -20:0.1:20
% Generating the signal x[n] = z[n] + noise[n]
z = sin(0.3142 * n);
noise = rand(size(z));
xn = z + noise;
```

```
% (a) Moving average filter on x[n]
y1 = movmean(xn, 5);
```

```
% (b) Impulse response
h = (n==0) % Unit impulse at n=0
hn=movmean(h,5);
% (c) Convolution
y2 = conv(xn, hn, "same");
```

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```
%y2 = y2(1:length(xn));

% Plotting

figure;

subplot(2, 2, 1);

plot(n, xn);

title("Plot of x[n]");

xlabel("time");

ylabel("Amplitude");
```

```
subplot(2, 2, 2);

plot(n, y1);

title("Plot of y1[n]");

xlabel("time");

ylabel("Amplitude");
```

```
subplot(2, 2, 3);

plot(n,hn);

title("Plot of h[n]");

xlabel("time");

ylabel("Amplitude");
```

```
subplot(2, 2, 4);

plot(n,y2);

title("Plot of y2[n]");

xlabel("time");

ylabel("Amplitude");
```

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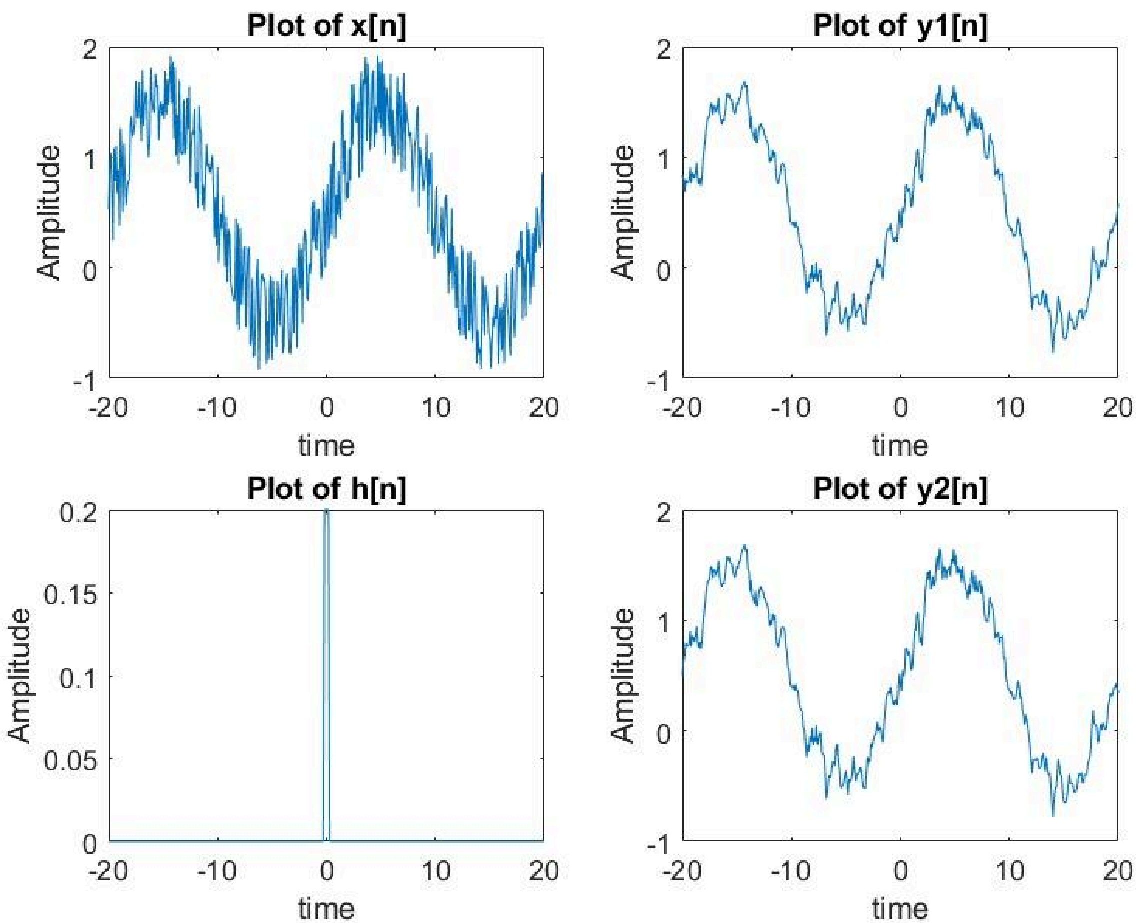
Output:



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Task 4:

$\Rightarrow$ Moving Average filter is linear

$$y[n] = \frac{1}{N} \sum_{k=0}^{n} \left(a x_1[k] + b x_2[k] \right) h[n-k]$$

$$= \frac{1}{N} \sum_{k=0}^{n} a x_1[k] h[n-k] + \frac{1}{N} \sum_{k=0}^{n} b x_2[k] h[n-k]$$

$$= \frac{a}{N} \sum_{k=0}^{n} x_1[k] h[n-k] + \frac{b}{N} \sum_{k=0}^{n} x_2[k] h[n-k]$$

$$= a y_1[n] + b y_2[n] \rightarrow \text{hence Proved}$$

$\Rightarrow$ Moving average filter is time invariant:

$$x[n-m] \rightarrow y_0[n] = \frac{1}{N} \sum_{k=l-N+1}^{l} x[k-m]$$

By Substitution

$$l = k, \quad P = k-m$$

$$y_0[k] = \frac{1}{N} \sum_{p=k-m-N+1}^{k-m} x[p]$$

$$x(n-m) \rightarrow y_0[n] = y[n-m]$$

↳ hence Proved

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Task 5:

```
% Load the impulse response and ringtone

[h, Fh] = audioread("1st_baptist_nashville_balcony.wav");

[x, Fx] = audioread('ringtone.wav');

% Display sizes of impulse response and ringtone

disp(size(h));

disp(size(x));

% Play the impulse response

sound(h, Fh);

pause(length(h) / Fh);

% Play the ringtone

sound(x, Fx);

pause(length(x) / Fx);

% Extract channels from the impulse response

h1 = h(:, 1);

h2 = h(:, 2);

% Convolve each channel with the ringtone

z1 = conv(h1, x, 'same');

z2 = conv(h2, x, 'same');

% Concatenate the outputs

y3 = [z1, z2];

% Play the resulting sound

sound(y3, Fx);

% Plot the audio signals
```

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```
figure;
subplot(3,1,1); plot(h);
subplot(3,1,2); plot(x);
subplot(3,1,3); plot(y3);
% Play the ringtone again
[s, Fh] = audioread("ringtone.wav");
sound(s, Fh);
% Extract the first channel from the ringtone
s1 = s(:, 1);
% Convolve the first channel with itself
z3 = conv(s1, s, 'same');
% Concatenate the output (as only one channel is available)
y4 = [z3];
% Play the resulting sound
sound(y4, Fx);
% Display sizes of ringtone and convolved output
disp(size(s));
disp(size(y4));
% Pause for the duration of the ringtone
pause(length(s) / Fh);
% Pause for the duration of the convolved output
pause(length(y4) / Fx);
```

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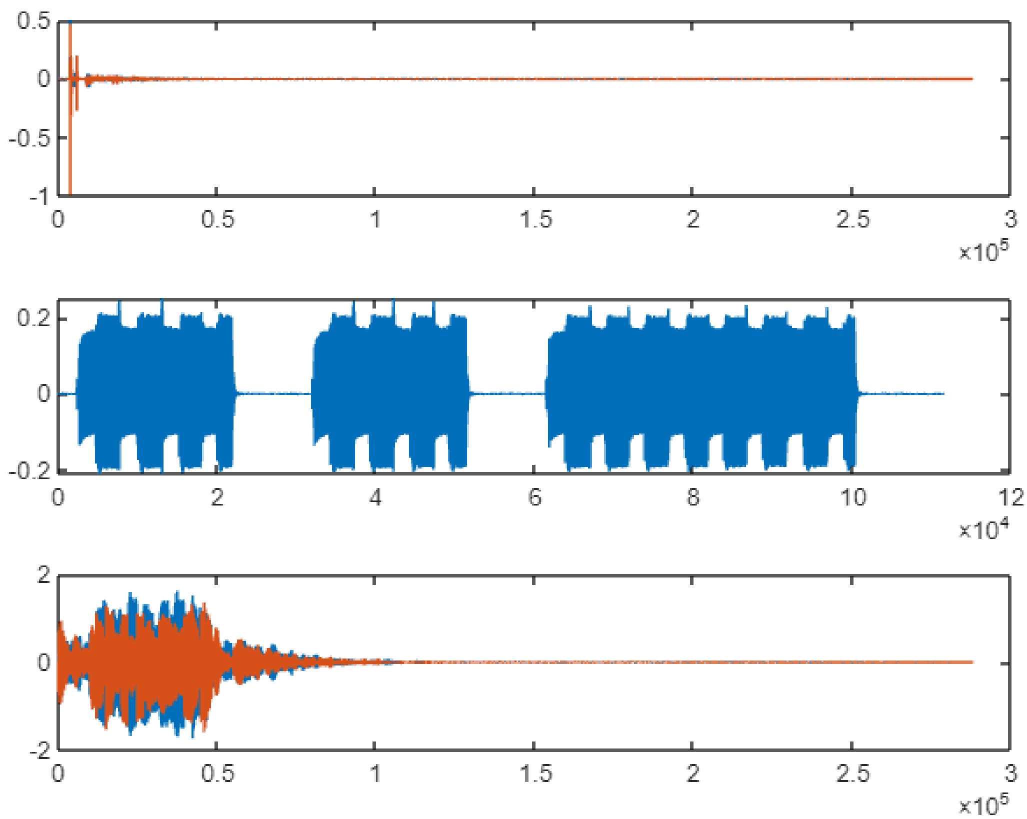
Output:

```
288000    2
111616    1
```



Last plot shows us reverberated sound signal.

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Task 6:

```
function w = discrete_convolution(u, v)

  %lengths and total length of convolution

  len1 = length(u);

  len2 = length(v);

  total = len1 + len2 - 1;


  % Reversing the signal v here

  reversed_v = zeros(1, len2);

  for a = 1:len2

      reversed_v(a) = v(len2 - a + 1);

  end


  % changing the new signal hnew to match the length for convolution

  hnew = [zeros(1, len2 - 1), reversed_v, zeros(1, len2 - 1)];

  newL = length(hnew);


  % Initializing output vector for convolution result

  w = zeros(1, total);

  % Sliding the reversed signal over the u signal and calculating convolution

  for b = 1:total
```

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```
    % this is Convolution sum
    convolution_sum = 0;
    for c = 1:len1
        convolution_sum = convolution_sum + (u(c) * hnew(b + len1 - c));
    end
    % output vector which will contain the convolution result
    w(b) = convolution_sum;
  end
end
```