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% C. Petersen, H. Werkle, Dynamik der Baukonstruktionen
% 2. Auflage, Springer Vieweg, Wiesbaden, 2018
%
% ML_13_1_Antwortspektrum: Ermittlung eines Antwortspektrums

% Version 1.0, April 2018
% Softwareentwicklung:
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% Aufbau Eingabedateien:
% Inputdatei_1: Beschleunigungszeitverlauf
%               Spalte 1 - Zeitvektor [s],
%               Spalte 2 - Beschleunigungsvektor [m/s^2])
% ANMERKUNG: Dezimaltrennzeichen '.'
%
% Ausgabedateien:
% Outputdatei_1: Eingaben- und Ergebnisübersicht
% Outputdatei_2_ Zeitverläufe der Bewegungsgrößen fü das Antwortsystem

%---------------------------- EINGABEBLOCK --------------------------------
% Einlesen von Eingabedateien und Generierung der entsprechenden Matrizen
% und Vektoren
Beschleunigung=dlmread('Inputdatei_1.txt');
t_acc=Beschleunigung(:,1);  % Zeitvektor [s]
acc=Beschleunigung(:,2);    % Beschleunigungsvektor [m/s^2]
%--------------------------------------------------------------------------
% Eingaben im Quellcode
xi=0.05;      % Dämpfungsmaß des Systems

T_0=1;        % Eigenschwingzeit des Antwortsystems [s] (für Darstellung)

Tmax=2.5;     % obere Grenze der Eigenschwingzeit [s]

n_unt=25;     % Anzahl der Teilungen auf der Ordinate (zwischen 0 und Tmax)
%--------------------------------------------------------------------------

%------------------------- BERECHNUNGSBLOCK -------------------------------
dT=Tmax/n_unt;         % Schrittweite auf der Ordinate des Antwortspektrums
T=0:dT:Tmax;           % Vektor der Eigenschwingzeiten
nr=length(T);          % Anzahl der Eigenschwingzeiten
omega=zeros(nr,1);     % Vektor der Eigenkreisfrequenzen
omega_d=zeros(nr,1);   % Vektor der gedämpften Eigenkreisfrequenzen
for i=1:1:nr
    omega(i)=2*pi/T(i);
    omega_d(i)=sqrt(1-xi^2)*omega(i);
end

% Berechnungszeitschritt
dt=T(2)/30;

% Interpolation des Beschleunigungsvektors mit Berücksichtigung des
% Berechnungszeitschrittes 'dt'
t_acc_int_0=t_acc(1):dt:t_acc(end);
acc_int_0 = interp1(t_acc,acc,t_acc_int_0,'linear');
acc_int=acc_int_0;
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```
% Anzahl der Berechnungszeitschritte
nt=ceil((t_acc_int_0(end)-t_acc_int_0(1))/dt)+1;

% Definition des Matrizen der Bewegungsgrößen
y_rel=zeros(nr,nt);           % Relativverschiebungen
v_rel=zeros(nr,nt);           % Relativgeschwindigkeiten
a_rel=zeros(nr,nt);           % Relativbeschleunigungen
a_abs=zeros(nr,nt);           % Absolutbeschleunigungen

% Berechnung der aller Bewegungsgrößen mittels Duhamel-Integral
for k=1:1:nr
    for i=1:1:nt
     g_y=zeros(1,nt);
     g_v=zeros(1,nt);
     g_a=zeros(1,nt);
     for j=1:1:i
          g_y(j)=-(acc_int(j)*dt/(omega_d(k))).*exp(-xi.*(dt*i-dt*j)*...
              omega(k)).*sin(omega_d(k)*(dt*i-dt*j));

          g_v(j)=-(acc_int(j)*dt).*exp(-xi.*(dt*i-dt*j)*...
              omega(k)).*(cos(omega_d(k)*(dt*i-dt*j))-...
              xi*sin(omega_d(k)*(dt*i-dt*j)));

          g_a(j)=(acc_int(j)*dt*(omega_d(k))).*exp(-xi.*(dt*i-dt*j)*...
              omega(k)).*((1-xi^2)*sin(omega_d(k)*(dt*i-dt*j))+...
              2*xi*cos(omega_d(k)*(dt*i-dt*j)));

          y_rel(k,i)=y_rel(k,i)+g_y(j);
          v_rel(k,i)=v_rel(k,i)+g_v(j);
          a_abs(k,i)=a_abs(k,i)+g_a(j);
     end
    a_rel(k,:)=a_abs(k,:)-acc_int(1,:);
    end
end
% Berücksichtigung der Bedingung für T=0 (sehr steifes System)
if T(1)==0
    a_abs(1,:)=acc_int;
    a_rel(1,:)=0;
    v_rel(1,:)=0;
    y_rel(1,:)=0;
end

% Berechnung des Antwortspektren
S_a_abs=zeros(nr,1);
S_a_rel=zeros(nr,1);
S_v_rel=zeros(nr,1);
S_y_rel=zeros(nr,1);
for j=1:1:nr
    % absolute Beschleunigung
    S_a_abs(j)=max(abs(max(a_abs(j,:))),abs(min(a_abs(j,:))));
    % relative Beschleunigung
    S_a_rel(j)=max(abs(max(a_rel(j,:))),abs(min(a_rel(j,:))));
    % relative Geschwindigkeit
    S_v_rel(j)=max(abs(max(v_rel(j,:))),abs(min(v_rel(j,:))));
    % relative Verschiebung
    S_y_rel(j)=max(abs(max(y_rel(j,:))),abs(min(y_rel(j,:))));
end
```

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%-------------------------------------------------------------------------
% Zusätzliche Rechnung für Plot der Ergebnisse für das Antwortsystem (T_0)
omega_T_0=2*pi/T_0;
omega_d_T_0=sqrt(1-xi^2)*omega_T_0;
y_rel_T_0=zeros(1,nt);
a_abs_T_0=zeros(1,nt);
v_rel_T_0=zeros(1,nt);
a_rel_T_0=zeros(1,nt);
    for i=1:1:nt
     g_y_T_0=zeros(nt,1);
     g_v_T_0=zeros(nt,1);
     g_a_T_0=zeros(nt,1);
     for j=1:1:i
          g_y_T_0(j)=-(acc_int(j)*dt/(omega_d_T_0))....
              *exp(-xi.*(dt*i-dt*j)*omega_T_0)...
              *sin(omega_d_T_0*(dt*i-dt*j));

          g_v_T_0(j)=-(acc_int(j)*dt).*exp(-xi.*(dt*i-dt*j)*omega_T_0).*...
              (cos(omega_d_T_0*(dt*i-dt*j))-...
              xi*sin(omega_d_T_0*(dt*i-dt*j)));

          g_a_T_0(j)=(acc_int(j)*dt*(omega_d_T_0))...
              .*exp(-xi.*(dt*i-dt*j)*omega_T_0).*...
              ((1-xi^2)*sin(omega_d_T_0*(dt*i-dt*j))+...
              2*xi*cos(omega_d_T_0*(dt*i-dt*j)));

          y_rel_T_0(i)=y_rel_T_0(i)+g_y_T_0(j);
          v_rel_T_0(i)=v_rel_T_0(i)+g_v_T_0(j);
          a_abs_T_0(i)=a_abs_T_0(i)+g_a_T_0(j);
     end
    a_rel_T_0(i)=a_abs_T_0(i)-acc_int(i);
    end
if T_0==0
    a_abs_T_0(1,:)=acc_int;
    a_rel_T_0(1,:)=0;
    v_rel_T_0(1,:)=0;
    y_rel_T_0(1,:)=0;
end
S_a_abs_T_0=max(abs(max(a_abs_T_0)),abs(min(a_abs_T_0)));
S_v_rel_T_0=max(abs(max(v_rel_T_0)),abs(min(v_rel_T_0)));
S_y_rel_T_0=max(abs(max(y_rel_T_0)),abs(min(y_rel_T_0)));
S_a_rel_T_0=max(abs(max(a_rel_T_0)),abs(min(a_rel_T_0)));
%-------------------------------------------------------------------------

%------------------------ DARSTELLUNGSBLOCK ------------------------------
% Grafische Darstellung der Ergebnisse
name_fig1 = 'Beschleunigungsantwortspektrum';
fig1=figure('Name',name_fig1,'NumberTitle','off');
set(fig1,'Position',[200 300 800 500]);

subplot(2,1,1)
plot(t_acc_int_0,acc_int);
title1 = 'Beschleunigungsverlauf am Fußpunkt';
title(title1);
xlabel('Zeit [s]');
ylabel('Beschleunigung [m/s^2]');
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```
grid on; zoom on;

subplot(2,1,2)
plot(T,S_a_abs,'-',T_0,S_a_abs_T_0,'o','MarkerSize',8);
title1 = ['Beschleunigungsantwortspektrum (absolut) für ',...
    num2str(xi*100),' % Dämpfung'];
title(title1);
xlabel('Eigenschwingzeit [s]');
ylabel('Maximale Antwortbeschleunigung [m/s^2]');
Legend_1 = ['Antwortspektrum für T=0 bis T=',num2str(Tmax),' s'];
Legend_2 = ['Ergebnis für T_0=',num2str(T_0),' s'];
legend(Legend_1,Legend_2);
grid on; zoom on;

name_fig2 = 'Zeitverläufe des Antwortsystems';
fig2=figure('Name',name_fig2,'NumberTitle','off');
set(fig2,'Position',[1000 300 700 500]);

subplot(2,2,1)
plot(t_acc_int_0,y_rel_T_0,'MarkerSize',3);
title1 = ['Verschiebungszeitverlauf für T_0= ',num2str(T_0),' s, bei ',...
    num2str(100*xi),' % Dämpfungsmaß'];
title(title1);
xlabel('Zeit [s]');
ylabel('Verschiebung [m]');
grid on; zoom on;

subplot(2,2,2)
plot(t_acc_int_0,v_rel_T_0,'MarkerSize',3);
title1 = ['Geschwindigkeitszeitverlauf für T_0= ',num2str(T_0),...
    ' s, bei ',num2str(100*xi),' % Dämpfungsmaß'];
title(title1);
xlabel('Zeit [s]');
ylabel('Geschwindigkeit [m/s]');
grid on; zoom on;

subplot(2,2,3)
plot(t_acc_int_0,a_rel_T_0,'MarkerSize',3);
title2 = ['Beschleunigungszeitverlauf (rel.) für T_0= ',num2str(T_0),...
    ' s, bei ',num2str(100*xi),' % Dämpfungsmaß'];
title(title2);
xlabel('Zeit [s]');
ylabel('Beschleunigung [m/s^2]');
grid on; zoom on;

subplot(2,2,4)
plot(t_acc_int_0,a_abs_T_0,'MarkerSize',3);
title2 = ['Beschleunigungszeitverlauf (abs.) für T_0= ',num2str(T_0),...
    ' s, bei ',num2str(100*xi),' % Dämpfungsmaß'];
title(title2);
xlabel('Zeit [s]');
ylabel('Beschleunigung [m/s^2]');
grid on; zoom on;
%-------------------------------------------------------------------------

%--------------------------- AUSGABEBLOCK ------------------------------
% Ausgabe der Ergebnisse in eine Datei
```

```
fid = fopen('Outputdatei_1_Allgemein.txt', 'w');
fprintf(fid,...
    '%s\n','C. Petersen, H. Werkle, Dynamik der Baukonstruktionen');
fprintf(fid,...
    '%s\n','2. Auflage, Springer Vieweg, Wiesbaden, 2018');
fprintf(fid,...
    '%s\n','Softwareentwicklung: Andrei Firus (andrei.firus@gmail.com)');
fprintf(fid,'%s\n','Programm ML_13_1: Eingaben- und Ergebnisuebersicht');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,...
    '%s\n','-------------------------------------------------------------');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,...
    '%s\n','EINGABEDATEN:');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Daempfungmaß des Systems [-]:');
fprintf(fid,'%d\n',xi);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s %s\n','Obere Grenze der Eigenschwingzeit für',...
    'die Berechnung (Tmax) [s]:');
fprintf(fid,'%d\n',Tmax);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s %s\n%s\n','Anzahl der Unterteilungen auf der Ordinate des',...
    'Antwortspektrums','(zwischen 0 und Tmax):');
fprintf(fid,'%d\n',n_unt);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Eigenschwingzeit des Antwortsystems [s]:');
fprintf(fid,'%d\n',T_0);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Fusspunktbeschleunigung: s. Dateiende');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,...
    '%s\n','-------------------------------------------------------------');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,...
    '%s\n','ERGEBNISSE:');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Berechnungszeitschritt [s]:');
fprintf(fid,'%d\n',dt);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s %s\n','Schrittweite auf der Ordinate des',...
    'Antwortspektrums [s]:');
fprintf(fid,'%d\n',dT);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Anzahl der Berechnungszeitschritte [-]:');
fprintf(fid,'%d\n',nt);
```

```
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Anzahl der Eigenschwingzeiten im Spektrum [-]:');
fprintf(fid,'%d\n',nr);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Spektralwerte des Antwortsystems:');
fprintf(fid,'%s \t %d\n','Abs. Beschl.:',S_a_abs_T_0);
fprintf(fid,'%s \t %d\n','Rel. Beschl.:',S_a_rel_T_0);
fprintf(fid,'%s \t %d\n','Rel. Geschw.:',S_v_rel_T_0);
fprintf(fid,'%s \t %d\n','Rel. Versch.:',S_y_rel_T_0);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Antwortspektren:');
fprintf(fid,'%s \t %s \t %s \t %s \t %s \t %s \t %s\n','Index',...
    'Eigenschwingzeit [s]','Eigenkreisfrequenz [1/s]',...
    'Spektrum a_abs [m/s^2]','Spektrum a_rel [m/s^2]',...
    'Spektrum v_rel [m/s]', 'Spektrum y_rel [m]');
for jj = 1:1:nr
     fprintf(fid, '%d \t %d \t %d \t %d \t %d \t %d \t %d\n',...
         jj,T(jj),omega(jj),S_a_abs(jj),S_a_rel(jj),S_v_rel(jj),...
         S_y_rel(jj));
end
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Fusspunktbeschleunigung:');
fprintf(fid,'%s \t %s\n','Zeit [s]','Beschleunigung [m/s^2]');
for jj=1:1:length(acc)
    fprintf(fid,'%d \t %d\n',t_acc(jj),acc(jj));
end
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fclose(fid);

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
Ergebnis_Verschiebungen=[t_acc_int_0' y_rel_T_0' v_rel_T_0' a_rel_T_0'...
    a_abs_T_0'];
fid = fopen('Outputdatei_2_Bewegungsgroessen.txt', 'w');
fprintf(fid,...
    '%s\n','C. Petersen, H. Werkle, Dynamik der Baukonstruktionen');
fprintf(fid,...
    '%s\n','2. Auflage, Springer Vieweg, Wiesbaden, 2018');
fprintf(fid,...
    '%s\n','Softwareentwicklung: Andrei Firus (andrei.firus@gmail.com)');
fprintf(fid,'%s %s\n','Programm ML_13_1: Zeitverlauefe der',...
    'Bewegungsgroessen');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,...
    '%s\n','------------------------------------------------------------');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s \t %s \t %s \t %s \t %s\n','Zeit [s]',...
    'Rel. Versch. [m]','Rel. Geschw. [m/s]',...
    'Rel. Beschl. [m/s^2]','Abs. Beschl. [m/s^2]');
for jj = 1:1:length(Ergebnis_Verschiebungen)
    fprintf(fid, '%d \t %d \t %d \t %d \t %d\n',...
        Ergebnis_Verschiebungen(jj,:));
```

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end
fclose(fid);
%--------------------------------------------------------------------------
```