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% C. Petersen, H. Werkle, Dynamik der Baukonstruktionen
% 2. Auflage, Springer Vieweg, Wiesbaden, 2017
%
% ML_05_4_Einfreiheitsgradschwinger_DFT_IDFT:
% Diskrete FOURIER-Transformation (DFT/IDFT)
%
% Version 1.0, April 2018
%
% Softwareentwicklung:
% Andrei Firus, M.Eng (andrei.firus@gmail.com)

% Aufbau Eingabedatei:
%   - Spalte 1: Indexvektor des Kraftverlaufs [-]
%   - Spalte 2: Kraftvektor [N]
% ANMERKUNG: Dezimaltrennzeichen '.'

% Ausgabedateien:
% Outputdatei_1: Eingaben- und Ergebnisübersicht
% Outputdatei_2: Verschiebungszeitverläufe

%---------------------------- EINGABEBLOCK ---------------------------------
% Eingaben im Quellcode
m=1000;                          % Masse [kg]
k=25000;                         % Federkonstante [N/m]
xi=0.02;                         % Dämpfungsmaß

dt=0.1;                          % Abtastintervall [s]

l=400;                           % Gesamtzahl der diskreten Daten:
                                 % geradzahlig, durch 4 teilbar

dt_y=0.001;                      % Zeitschritt für Darstellung des
                                 % Verschiebungszeitverlaufs im Zeitbereich

%---------------------------------------------------------------------------

% Einlesen der diskreten Lastwerte von der Eingabedatei und Generierung der
% entsprechenden Vektoren
Kraftverlauf=dlmread('Inputdatei_1.txt');
Index_Kraft=Kraftverlauf(:,1);
Kraft=Kraftverlauf(:,2);

%---------------------------------------------------------------------------

%-------------------------- BERECHNUNGSBLOCK -------------------------------

% Berechnung weiterer System- und Berechnungsparameter
lf=length(Index_Kraft);          % Anzahl der diskreten Daten der
                                 % Lastfunktion innerhalb der
                                 % Einwirkungsdauer
omega=sqrt(k/m);                 % Eigenkreisfrequenz
f=omega/(2*pi);                  % Eigenfrequenz
T_1=1/f;                         % Eigenschwingzeit
d=xi*(2*omega*m);                % Dämpfungskoeffizient
omega_d=sqrt(1-xi^2)*omega;      % gedämpfte Eigenkreisfrequenz
fc=1/(2*dt);                     % Nyquist-Frequenz
```

```
T=dt*l;                          % Grundperiode der Entwicklung

%--------------------------------------------------------------------------

% Definition des Kraftvektors für die ganze Wiederkehrperiode. Der Kraft
% Vektor wird bis zum Ende der Entwicklungperiode mit Nulleinträgen
% ergänzt.
F=zeros(l,1);
for i=1:1:l
    if i<=lf
        F(i)=Kraft(i);
    else
        F(i)=0;
    end
end

%--------------------------------------------------------------------------

% DFT für die Lastfunktion: Ermittlung FOURIER-Glieder

% Komplexes FOURIER-Glied der Lastfunktion
cf_k=zeros(l,1);
for n=1:1:l
    e_term=zeros(l,1);
    e_term(1)=F(1)*exp(-1i*2*pi*(n-1)*0/l);
    e_fkt=e_term(1);
    for mm=2:1:l
        e_term(mm)=F(mm)*exp(-1i*2*pi*(n-1)*(mm-1)/l);
        e_fkt=e_fkt+e_term(mm);
    end
    cf_k(n)=(1/l)*e_fkt;
end

% Koeffizienten a_n und b_n
a=zeros(l/2+1,1);
b=zeros(l/2+1,1);
for n=1:1:l/2+1
    if n<l/2+1
        a(n)=2*real(cf_k(n));
        b(n)=-2*imag(cf_k(n));
    else
        sum=0;
        for mm=1:1:l
            sum=sum+(-1)^(mm-1)*F(mm);
        end
        a(n)=(1/l)*sum;
        b(n)=0;
    end
end

% Amplitude und Phase der n-ten Harmonischen
c=sqrt(a.^2+b.^2);
phi=a./b;

% Kontrolle: Rücktransformation der Lastfunktion in Zeitbereich (IDFT)
t_t=0:dt:T;
F_IDFT=zeros(length(t_t),1)+a(1)/2;
```

```
for i=1:1:length(F_IDFT)
    x_x=zeros(l/2+1,1);
    for n=2:1:length(x_x)
        x_x(n)=a(n)*cos((n-1)*(2*pi/T)*t_t(i))+...
               b(n)*sin((n-1)*(2*pi/T)*t_t(i));
        F_IDFT(i)=F_IDFT(i)+x_x(n);
    end
end

%--------------------------------------------------------------------------

% Ermittlung der Verschiebung im Frequenzbereich (FOURIER-Glieder)

gr=zeros(l,1);  % Realteil der Übertragungsfunktion
gi=zeros(l,1);  % Imaginärteil der Übertragungsfunktion
ita=zeros(l,1); % Auf omega bezogene Erregerkreisfrequenz
cfr=zeros(l,1); % Ergänzter Koeffizientenvektor (cfr entspricht a)
cfi=zeros(l,1); % Ergänzter Koeffizientenvektor (cfi entspricht b)

% FOURIER-Koeffizienten der gesuchten Schwingungsfunktion
cyr=zeros(l,1); % Realteil des komplexen Glieds des Weges
cyi=zeros(l,1); % Imaginärteil des komplexen Glieds des Weges

for n=1:1:l
    if n<=l/2+1
        cfr(n)=a(n);
        cfi(n)=-b(n);
    else
        cfr(n)=a((l/2+1)-(n-(l/2+1))); % (symmetrische Fortsetzung)
        cfi(n)=+b((l/2+1)-(n-(l/2+1)));% (schiefsymmetrische Fortsetzung)
    end
end

f_dft=1/T;
for n=1:1:l
    ita(n)=(2*pi*(n-1)*f_dft)/omega;
    gr(n)=(1-ita(n)^2)/(k*((1-ita(n)^2)^2+(2*xi*ita(n))^2));
    gi(n)=-(2*xi*ita(n))/(k*((1-ita(n)^2)^2+(2*xi*ita(n))^2));
    cyr(n)=(gr(n)*cfr(n)-gi(n)*cfi(n));
    cyi(n)=(gr(n)*cfi(n)+gi(n)*cfr(n));
end

% Inverse FOURIER-Transformation (IDFT) der Verschiebung
t_t_v=0:dt_y:T;
yr_k=zeros(length(t_t_v),1); % Realteil der komplexen Verschiebung
yi_k=zeros(length(t_t_v),1); % Imaginärteil der komplexen Verschiebung
for i=1:1:length(yr_k)
        x_u_re=zeros(l,1);
        x_u_im=zeros(l,1);
    for n=1:1:length(x_u_re)
        x_u_re(n)=cyr(n)*cos((n-1)*(2*pi/T)*t_t_v(i))-...
                  cyi(n)*sin((n-1)*(2*pi/T)*t_t_v(i));
        x_u_im(n)=cyr(n)*sin((n-1)*(2*pi/T)*t_t_v(i))+...
                  cyi(n)*cos((n-1)*(2*pi/T)*t_t_v(i));
        yr_k(i)=yr_k(i)+x_u_re(n);
        yi_k(i)=yi_k(i)+x_u_im(n);
    end
```

```
end

% Extremwerte des Verschiebungsverlaufs (Realteil):
ymax=max(yr_k);
ymin=min(yr_k);
%--------------------------------------------------------------------------

%------------------------ DARSTELLUNGSBLOCK -----------------------------
%Grafische Darstellung der Ergebnisse
name_fig1 = 'Ergebnisse DFT/IDFT Kraftverlauf';
fig1=figure('Name',name_fig1,'NumberTitle','off');
set(fig1,'Position',[1000 50 700 900]);
Index_Koeffizienten=0:1:length(a)-1;
Index_Koeffizienten_e=0:1:length(cfr)-1;

subplot(4,1,1)
t_kraft=0:dt:T-dt;
plot(t_kraft,F,'bo',t_t,F_IDFT,'-.r','MarkerSize',3);
legend('Eingabekraft','IDFT-Kraft')
title('Kraftverlauf');
xlabel('Zeit [s]');
ylabel('Kraft [N]');
grid on; zoom on;

subplot(4,1,2)
stem(Index_Koeffizienten,a,'MarkerSize',3);
title('Koeffizienten a_n');
xlabel('Index [-]');
ylabel('a [-]');
grid on; zoom on;

subplot(4,1,3)
stem(Index_Koeffizienten,b,'MarkerSize',3);
title('Koeffizienten b_n');
xlabel('Index [-]');
ylabel('b [-]');
grid on; zoom on;

subplot(4,1,4)
stem(Index_Koeffizienten,c,'MarkerSize',3);
title('Koeffizienten c_n');
xlabel('Index [-]');
ylabel('c [-]');
grid on; zoom on;
%--------------------------------------------------------------------------

name_fig2 = 'Ergebnisse Systemverschiebung';
fig2=figure('Name',name_fig2,'NumberTitle','off');
set(fig1,'Position',[200 300 800 500]);

subplot(4,1,1)
stem(Index_Koeffizienten_e,k*gr,'MarkerSize',3);
title('k*g_r');
xlabel('Index [-]');
ylabel('k*g_r_n [-]');
grid on; zoom on;
```

```
subplot(4,1,2)
stem(Index_Koeffizienten_e,k*gi,'MarkerSize',3);
title('k*g_i');
xlabel('Index [-]');
ylabel('k*g_i_n [-]');
grid on; zoom on;

subplot(4,1,3)
stem(Index_Koeffizienten_e,cyr,'MarkerSize',3);
title('FOURIER - Koeffizienten der Verschiebung c_y_r');
xlabel('Index [-]');
ylabel('c_y_r [-]');
grid on; zoom on;

subplot(4,1,4)
stem(Index_Koeffizienten_e,cyi,'MarkerSize',3);
title('FOURIER - Koeffizienten der Verschiebung c_y_i');
xlabel('Index[-]');
ylabel('c_y_i [-]');
grid on; zoom on;
%--------------------------------------------------------------------------

name_fig3 = 'Kraft- und Verschiebungszeitverlauf';
fig3=figure('Name',name_fig2,'NumberTitle','off');
set(fig1,'Position',[200 300 800 500]);

subplot(2,1,1)
plot(t_kraft,F,'b','MarkerSize',3);
legend('Eingabekraft')
title('Kraftverlauf');
xlabel('Zeit [s]');
ylabel('Kraft [N]');
grid on; zoom on;

subplot(2,1,2)
plot(t_t_v,yr_k,'-r');
legend('IDFT-Verschiebung')
title('Verschiebungszeitverlauf');
xlabel('Zeit [s]');
ylabel('Verschiebung [m]');
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_05_4: Eingaben- und Ergebnisuebersicht');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,...
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```
    '%s\n','-------------------------------------------------------------');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,...
    '%s\n','EINGABEDATEN:');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Masse des Einfreiheitsgradschwingers [kg]:');
fprintf(fid,'%d\n',m);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Federkonstante [N/m]:');
fprintf(fid,'%d\n',k);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Daempfungsmass [-]:');
fprintf(fid,'%.3f\n',xi);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Abtastintervall der eingelesenen Lastwerte [-]:');
fprintf(fid,'%d\n',dt);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Gesamtzahl der diskretisierten Daten [-]:');
fprintf(fid,'%d\n',l);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Zeitschritt für Darstellung der Verschiebung [s]:');
fprintf(fid,'%d\n',dt_y);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Kraftzeitverlauf:');
fprintf(fid,'%s \t %s\n','Zeit [s]','Kraft [N]');
for ii=1:1:length(Index_Kraft)
fprintf(fid, '%d \t %d\n', dt*(Index_Kraft(ii)-1),Kraft(ii));
end
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,...
    '%s\n','-------------------------------------------------------------');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,...
    '%s\n','ERGEBNISSE:');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s%s\n',...
    'Anzahl der diskreten Daten der Lastfunktion innerhalb',...
    ' der Einwirkungsdauer:');
fprintf(fid,'%d\n',lf);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Eigenkreisfrequenz [1/s]:');
fprintf(fid,'%d\n',omega);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Gedaempfte Eigenkreisfrequenz [1/s]:');
fprintf(fid,'%d\n',omega_d);
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fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Eigenfrequenz [Hz]:');
fprintf(fid,'%d\n',f);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Eigenschwingzeit [s]:');
fprintf(fid,'%d\n',T_1);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Daempfungskoeffizient [Ns/m]:');
fprintf(fid,'%d\n',d);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Nyquist-Frequenz [Hz]:');
fprintf(fid,'%d\n',fc);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Grundperiode der Entwicklung [s]:');
fprintf(fid,'%d\n',T);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Maximale Verschiebung [m]:');
fprintf(fid,'%d\n',ymax);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Minimale Verschiebung [m]:');
fprintf(fid,'%d\n',ymin);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Fourier-Koeffizienten der Kraft:');
fprintf(fid,'%s \t %s \t %s \t %s\n','n','a_n', 'b_n', 'c_n');
for ii=1:1:length(a)
    fprintf(fid,'%d \t %d \t %d \t %d\n',ii, a(ii), b(ii), c(ii));
end
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s %s\n','Kontrolle: Rücktransformation der Lastfunktion',...
    'in Zeitbereich (IDFT)');
fprintf(fid,'%s \t %s\n','Zeit [s]','Kraft [N]');
for ii=1:1:length(F_IDFT)
    fprintf(fid, '%d \t %d\n',t_t(ii),F_IDFT(ii));
end
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Ergebnisse Systemverschiebung im Frequenzbereich:');
fprintf(fid, '%s\n', ' ');
fprintf(fid,'%s\n','Real- und Imaginärteil der Übertragungsfunktion:');
fprintf(fid,'%s \t %s \t %s\n','n','g_r * k', 'g_i * k');
for ii=1:1:length(a)
    fprintf(fid,'%d \t  %d \t %d\n',Index_Koeffizienten(ii),...
        gr(ii)*k, gi(ii)*k);
end
fprintf(fid, '%s\n', ' ');
fprintf(fid,'%s\n','Fourier-Koeffizienten des Verschiebungsverlaufs:');
fprintf(fid,'%s \t %s \t %s\n','n','cyr', 'cyi');
for ii=1:1:length(a)
    fprintf(fid,'%d \t %d \t %d\n',Index_Koeffizienten(ii),...
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        cyr(ii), cyi(ii));
end
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,...
    '%s\n','-------------------------------------------------------------');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fclose(fid);

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
Ergebnis_Verschiebungen=[t_t_v' yr_k yi_k];
fid = fopen('Outputdatei_2_Verschiebungen.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_05_4: Verschiebungszeitverläufe');
fprintf(fid, '%s\n', ' ');
fprintf(fid,...
    '%s\n','-------------------------------------------------------------');
fprintf(fid, '%s\n', ' ');
fprintf(fid,'%s\n','Verschiebungszeitverläufe:');
fprintf(fid,'%s \t %s \t %s\n','Zeit [s]', 'Verschiebung Realteil [m]',...
    'Verschiebung Imaginärteil ');
for ii=1:1:length(Ergebnis_Verschiebungen)
    fprintf(fid,'%d \t %d \t %d\n',Ergebnis_Verschiebungen(ii,:));
end
fclose(fid);

%-------------------------------------------------------------------------
```