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LAMPIRAN

Lampiran 1. Pembuktian lengkap Teorema 4.2 untuk $P(t) > 0$, $E(t) > 0$, $D(t) > 0$, $C_T(t) > 0$, dan $C_S(t) > 0$.

Akan ditunjukkan bahwa $P(t)$ positif. Dari persamaan kedua pada sistem Persamaan (4.1) diperoleh

$$\begin{aligned} \frac{dP(t)}{dt} &= \theta_1 H(t) - (\beta_1 + \gamma_1 + \mu)P(t), \\ \frac{dP(t)}{dt} &\geq -(\beta_1 + \gamma_1 + \mu)P(t). \end{aligned}$$

Dengan menggunakan metode pemisahan variabel maka $dP(t)/dt$ dapat ditulis ulang sebagai

$$\frac{dP(t)}{(\beta_1 + \gamma_1 + \mu)P(t)} \geq -dt. \tag{0.1}$$

Jika kedua ruas dari Persamaan (0.1) diintegralkan dari 0 sampai t maka diperoleh

$$\begin{aligned} \int_0^t \frac{1}{(\beta_1 + \gamma_1 + \mu)P(s)} dP(s) &\geq -\int_0^t ds, \\ \frac{1}{(\beta_1 + \gamma_1 + \mu)} [\ln P(s)]_0^t &\geq -t, \\ \ln P(t) - \ln P(0) &\geq -(\beta_1 + \gamma_1 + \mu)t, \\ \ln\left(\frac{P(t)}{P(0)}\right) &\geq -(\beta_1 + \gamma_1 + \mu)t, \\ \frac{P(t)}{P(0)} &\geq exp\left(-(\beta_1 + \gamma_1 + \mu)\right) t, \\ P(t) &\geq P(0)\, exp\left(-(\beta_1 + \gamma_1 + \mu)\right) t. \end{aligned}$$

Diketahui nilai awal $P(0)$ adalah positif dan fungsi eksponensial juga selalu bernilai positif, sehingga

$$P(t) \geq P(0)\, exp\left(-(\beta_1 + \gamma_1 + \mu)\right) t > 0.$$

Jadi, terbukti bahwa solusi $P(t)$ dari sistem Persamaan (4.1) adalah positif. ■

Akan ditunjukkan bahwa $E(t)$ positif. Dari persamaan ketiga pada sistem Persamaan (4.1) diperoleh

$$\begin{aligned} \frac{dE(t)}{dt} &= \theta_2(1 - u_1)H(t) - (\beta_2(1 - u_2)(1 - u_3) + \mu)E(t), \\ \frac{dE(t)}{dt} &\geq -(\beta_2(1 - u_2)(1 - u_3) + \mu)E(t). \end{aligned}$$

Dengan menggunakan metode pemisahan variabel maka $dE(t)/dt$ dapat ditulis ulang sebagai

$$\frac{dE(t)}{\left(\beta_2(1-u_2)(1-u_3)+\mu\right)E(t)} \geq -dt. \tag{0.2}$$

Jika kedua ruas dari Persamaan (0.2) diintegralkan dari 0 sampai t maka diperoleh

$$\begin{aligned}
\int_0^t \frac{1}{\left(\beta_2(1-u_2)(1-u_3)+\mu\right)E(s)}dE(s) &\geq -\int_0^t ds, \\
\frac{1}{\left(\beta_2(1-u_2)(1-u_3)+\mu\right)}[\ln E(s)]_0^t &\geq -t, \\
\ln E(t) - \ln E(0) &\geq -\left(\beta_2(1-u_2)(1-u_3)+\mu\right)t, \\
\ln\left(\frac{E(t)}{E(0)}\right) &\geq -\left(\beta_2(1-u_2)(1-u_3)+\mu\right)t, \\
\frac{E(t)}{E(0)} &\geq exp\left(-\left(\beta_2(1-u_2)(1-u_3)+\mu\right)\right)t, \\
E(t) &\geq E(0)\, exp\left(-\left(\beta_2(1-u_2)(1-u_3)+\mu\right)\right)t.
\end{aligned}$$

Diketahui nilai awal $E(0)$ adalah positif dan fungsi eksponensial juga selalu bernilai positif, sehingga

$$E(t) \geq E(0)\, exp\left(-\left(\beta_2(1-u_2)(1-u_3)+\mu\right)\right)t > 0.$$

Jadi, terbukti bahwa solusi $E(t)$ dari sistem Persamaan (4.1) adalah positif. ■

Akan ditunjukkan bahwa $D(t)$ positif. Dari persamaan keempat pada sistem Persamaan (4.1) diperoleh

$$\begin{aligned}
\frac{dD(t)}{dt} &= \beta_1 P(t) + \beta_2(1-u_2)(1-u_3)E(t) - \alpha_1(1-u_2)\frac{E(t)D(t)}{N} - \\
&\quad \gamma_2(1-u_3)(1-u_4)D(t) - \eta_1(1-u_4)(1-u_5)D(t) - \mu D(t), \\
\frac{dD(t)}{dt} &\geq -\left(\alpha_1(1-u_2)\frac{E(t)}{N} + \gamma_2(1-u_3)(1-u_4) + \eta_1(1-u_4)(1-u_5) + \mu\right)D(t).
\end{aligned}$$

Dengan menggunakan metode pemisahan variabel maka $dD(t)/dt$ dapat ditulis ulang sebagai

$$\frac{dD(t)}{\left(\alpha_1(1-u_2)\frac{E(t)}{N} + \gamma_2(1-u_3)(1-u_4) + \eta_1(1-u_4)(1-u_5) + \mu\right)D(t)} \geq -dt. \tag{0.3}$$

Jika kedua ruas dari Persamaan (0.3) diintegralkan dari 0 sampai t maka diperoleh

$$\int_0^t \frac{1}{\left(\alpha_1(1-u_2)\frac{E(t)}{N} + \gamma_2(1-u_3)(1-u_4) + \eta_1(1-u_4)(1-u_5) + \mu\right)D(s)}dD(s) \geq -\int_0^t ds,$$

$$\frac{1}{\left(\alpha_1(1-u_2)\frac{E(t)}{N}+\gamma_2(1-u_3)(1-u_4)+\eta_1(1-u_4)(1-u_5)+\mu\right)}[\ln D(s)]_0^t \quad \geq -t,$$

$$\begin{aligned}
\ln D(t)-\ln D(0) &\geq -\left(\alpha_1(1-u_2)\frac{E(t)}{N}+\gamma_2(1-u_3)(1-u_4)+\eta_1(1-u_4)(1-u_5)+\mu\right)t,\\
\ln\left(\frac{D(t)}{D(0)}\right) &\geq -\left(\alpha_1(1-u_2)\frac{E(t)}{N}+\gamma_2(1-u_3)(1-u_4)+\eta_1(1-u_4)(1-u_5)+\mu\right)t,\\
\frac{D(t)}{D(0)} &\geq exp\left(-\left(\alpha_1(1-u_2)\frac{E(t)}{N}+\gamma_2(1-u_3)(1-u_4)+\eta_1(1-u_4)(1-u_5)+\mu\right)\right)t,\\
D(t) &\geq D(0)\,exp\left(-\left(\alpha_1(1-u_2)\frac{E(t)}{N}+\gamma_2(1-u_3)(1-u_4)+\eta_1(1-u_4)(1-u_5)+\mu\right)\right)t.
\end{aligned}$$

Diketahui nilai awal $E(0)$ adalah positif dan fungsi eksponensial juga selalu bernilai positif, sehingga

$$D(t)\geq D(0)\,exp\left(-\left(\alpha_1(1-u_2)\frac{E(t)}{N}+\gamma_2(1-u_3)(1-u_4)+\eta_1(1-u_4)(1-u_5)+\mu\right)\right)t>0.$$

Jadi, terbukti bahwa solusi $D(t)$ dari sistem Persamaan (4.1) adalah positif. ■

Akan ditunjukkan bahwa $C_T(t)$ positif. Dari persamaan kelima pada sistem Persamaan (4.1) diperoleh

$$\begin{aligned}
\frac{dC_T(t)}{dt} &= \gamma_1 P(t)+\gamma_2(1-u_3)(1-u_4)D(t)+\alpha_1(1-u_2)\frac{E(t)D(t)}{N}-\\
&\quad \alpha_2(1-u_3)\frac{E(t)C_T(t)}{N}-\eta_2(1-u_4)(1-u_5)C_T(t)-\mu C_T(t),\\
\frac{dC_T(t)}{dt} &\geq -\left(\alpha_2(1-u_3)\frac{E(t)}{N}+\eta_2(1-u_4)(1-u_5)+\mu\right)C_T(t).
\end{aligned}$$

Dengan menggunakan metode pemisahan variabel maka $dC_T(t)/dt$ dapat ditulis ulang sebagai

$$\frac{dC_T(t)}{\left(\alpha_2(1-u_3)\frac{E(t)}{N}+\eta_2(1-u_4)(1-u_5)+\mu\right)C_T(t)} \geq -\,dt. \qquad (0.4)$$

Jika kedua ruas dari Persamaan (0.4) diintegralkan dari 0 sampai t maka diperoleh

$$\int_0^t \frac{1}{\left(\alpha_2(1-u_3)\frac{E(t)}{N}+\eta_2(1-u_4)(1-u_5)+\mu\right)C_T(t)}dC_T(s) \quad \geq -\int_0^t ds,$$

$$\frac{1}{\left(\alpha_2(1-u_3)\frac{E(t)}{N}+\eta_2(1-u_4)(1-u_5)+\mu\right)}[\ln C_T(s)]_0^t \quad \geq -t,$$

$$
\begin{aligned}
\ln C_T(t) - \ln C_T(0) &\geq -\left(\alpha_2(1-u_3)\frac{E(t)}{N} + \eta_2(1-u_4)(1-u_5) + \mu\right)t,\\
\ln\left(\frac{C_T(t)}{C_T(0)}\right) &\geq -\left(\alpha_2(1-u_3)\frac{E(t)}{N} + \eta_2(1-u_4)(1-u_5) + \mu\right)t,\\
\frac{C_T(t)}{C_T(0)} &\geq exp\left(-\left(\alpha_2(1-u_3)\frac{E(t)}{N} + \eta_2(1-u_4)(1-u_5) + \mu\right)\right)t,\\
C_T(t) &\geq C_T(0)\, exp\left(-\left(\alpha_2(1-u_3)\frac{E(t)}{N} + \eta_2(1-u_4)(1-u_5) + \mu\right)\right)t.
\end{aligned}
$$

Diketahui nilai awal $C_T(0)$ adalah positif dan fungsi eksponensial juga selalu bernilai positif, sehingga

$$
C_T(t) \geq C_T(0)\, exp\left(-\left(\alpha_2(1-u_3)\frac{E(t)}{N} + \eta_2(1-u_4)(1-u_5) + \mu\right)\right)t > 0.
$$

Jadi, terbukti bahwa solusi $C_T(t)$ dari sistem Persamaan (4.1) adalah positif. ■

Akan ditunjukkan bahwa $C_S(t)$ positif. Dari persamaan kelima pada sistem Persamaan (4.1) diperoleh

$$
\begin{aligned}
\frac{dC_S(t)}{dt} &= \eta_1(1-u_4)(1-u_5)D(t) + \eta_2(1-u_4)(1-u_5)C_T(t) + \\
&\quad \alpha_2(1-u_3)\frac{E(t)C_T(t)}{N} - (\delta+\mu)C_S(t),\\
\frac{dC_S(t)}{dt} &\geq -(\delta+\mu)C_S(t).
\end{aligned}
$$

Dengan menggunakan metode pemisahan variabel maka $dC_S(t)/dt$ dapat ditulis ulang sebagai

$$
\frac{dC_S(t)}{(\delta+\mu)C_S(t)} \geq -\,dt. \qquad (0.5)
$$

Jika kedua ruas dari Persamaan (0.5) diintegralkan dari 0 sampai t maka diperoleh

$$
\begin{aligned}
\int_0^t \frac{1}{(\delta+\mu)C_S(t)}dC_S(t) &\geq -\int_0^t ds\,,\\
\frac{1}{(\delta+\mu)}[\ln C_S(s)]_0^t &\geq -t,\\
\ln C_S(t) - \ln C_S(0) &\geq -(\delta+\mu)t,\\
\ln\left(\frac{C_S(t)}{C_S(0)}\right) &\geq -(\delta+\mu)t,\\
\frac{C_S(t)}{C_S(0)} &\geq exp\big(-(\delta+\mu)\big)t,\\
C_S(t) &\geq C_S(0)\, exp\big(-(\delta+\mu)\big)t.
\end{aligned}
$$

Diketahui nilai awal $C_S(0)$ adalah positif dan fungsi eksponensial juga selalu bernilai positif, sehingga

$$C_S(t) \geq C_S(0)\, exp\big(-(\delta + \mu)\big)t > 0.$$

Jadi, terbukti bahwa solusi $C_S(t)$ dari sistem Persamaan (4.1) adalah positif. ■

Lampiran 2. Sintaksis untuk program utama.

```
clear all; close all; clc;

global I t1 t2 b1 b2 g1 g2 a1 a2 e1 e2 d mu B1 B2 B3 B4 B5

% initial populations (in million)
H0= 14.0;      D0 = 6.2;
P0= 6.66;      Ct0= 4.5;
E0= 13.0;      Cs0= 2.0;
x0= [H0;P0;E0;D0;Ct0;Cs0];

% bobot kontrol
disp('========= MASUKKAN BOBOT KONTROL YG DIINGANKAN =========')
B1= input('Masukkan B1(bobot kontrol edukasi)              : ');
B2= input('Masukkan B2(bobot kontrol pengaturan pola makan): ');
B3= input('Masukkan B3(bobot kontrol aktivitas fisik)      : ');
B4= input('Masukkan B4(bobot kontrol terapi farmakologi)   : ');
B5= input('Masukkan B5(bobot kontrol pengobatan komplikasi): ');

% b=beta,t=theta,a=alpha,g=gamma,d=delta,e=eta
I = 2;
t1= 0.1;        t2= 0.2;
b1= 0.2;        b2= 0.06;
a1= 0.4;        a2= 0.6;
g1= 0.01;       g2= 0.08;
e1= 0.3;        e2= 0.6;
mu= 0.02;       d = 0.001;

t0= 0;
tf= 120;
h = 0.1;
ti= t0:h:tf;
z = length(ti);

nx   = 6;  % the number of state variable
nlam= 6;   % the number of costate variable
nu   = 5;  % the number of control

% batas kontrol
M1= 0;
M2= 0.9;
Lb= M1.*ones(nu,z);   % lower bounds matrix
Ub= M2.*ones(nu,z);   % upper bounds matrix

% transversility cond
% lambda1(tf)=lambda2(tf)=lambda6(tf)=0
% lambda3(tf)=lambda4(tf)=lambda5(tf)=1
lambdatf = [0;0;1;1;1;0];

% parameter of steepest decent
eps = 10^-5;
kmax= 5;
ki   = 1;
it    = 0;
maxit= 49;
```

```
% ----------------------------------------------------------------
---
% without control
u0s     = zeros(nu,z);
options= odeset('RelTol',1e-4,'AbsTol',[1e-4 1e-4 1e-4 1e-4 1e-4
1e-4]);
x0s     = deval(ode23s(@(t,x) f_state_5523(t,x,u0s,ti),[0
tf],x0,options),ti);
% ----------------------------------------------------------------
---

% initial step for steepest decent method
u       = rand(nu,z);
x       = deval(ode23s(@(t,x) f_state_5523(t,x,u,ti),[0
tf],x0,options),ti);
lambda = deval(ode23s(@(t,lambda)
f_costate_5523(t,lambda,x,u,ti),[tf 0],lambdatf,options),ti);

dH      = f_stat_cond_5523(x,lambda,u);
J0s     = f_obj_5523(x,u,ti);
disp('========== WITHOUT CONTROL (u=0) ==========')
disp(['>>> norm(dH,2)= ',num2str(norm(dH,2))])
disp(['>>> J(u)       = ',num2str(J0s)])
% ----------------------------------------------------------------
---

if norm(dH,2)<eps
else
    alpha(ki)= 15000;
    grad   = dH/norm(dH,2);
    newu   = u-alpha(ki)*grad;
    newu   = f_simplebounds(newu,Lb,Ub);

    x      = deval(ode23s(@(t,x) f_state_5523(t,x,newu,ti),[0
tf],x0,options),ti);
    lambda= deval(ode23s(@(t,lambda)
f_costate_5523(t,lambda,x,newu,ti),[tf 0],lambdatf,options),ti);
    newJ   = f_obj_5523(x,newu,ti);
    error(ki)= abs(newJ-J0s);
    disp('========== 1th looping ==========')
    disp(['>>> error(1): ',num2str(error(ki))])
    disp(['>>> J(newu) : ',num2str(newJ)])

    disp('========== 2nd looping ==========')
    while error(ki)>eps
        it     = it+1;

        dH       = f_stat_cond_5523(x,lambda,newu);
        grad     = dH/norm(dH,2);
        alpha(ki)= alpha(ki)*0.5;
        newu     = newu-alpha(ki)*grad; %grad=dH/norm(dH,2)
        newu     = f_simplebounds(newu,Lb,Ub);

        x      = deval(ode23s(@(t,x) f_state_5523(t,x,newu,ti),[0
tf],x0,options),ti);
        lambda= deval(ode23s(@(t,lambda)
f_costate_5523(t,lambda,x,newu,ti),[tf 0],lambdatf,options),ti);
```

```
        newJ  = f_obj_5523(x,newu,ti);
        error(ki)= abs(newJ-J0s);
        disp(['>>> error(',num2str(it+1),')  :
',num2str(error(ki))])

        %newu = u;
        if it>maxit
            break
        end
    end
    disp(['>>> norm(dH,2) : ',num2str(norm(dH,2))])
    disp(['>>> J(newu)    : ',num2str(newJ)])

    u = newu;
    u = f_simplebounds(u,Lb,Ub);
end

lambda = deval(ode23s(@(t,lambda)
f_costate_5523(t,lambda,x,u,ti),[tf 0],lambdatf,options),ti);
x      = deval(ode23s(@(t,x) f_state_5523(t,x,u,ti),[0
tf],x0,options),ti);
u      = f_kontrol_5523(x,lambda);
u      = f_simplebounds(u,Lb,Ub);

clf
figure(1)
plot(ti,x0s(1,:),'r','LineWidth',1.5); hold on
plot(ti,x(1,:),'b','LineWidth',1.5)
xlabel('t')
ylabel('H(t)')
legend('Before control','After control')
title('Compartment of Healthy People (H)')
grid on
set(findall(gcf,'-property','FontSize'),'FontSize',12)

figure(2)
plot(ti,x0s(2,:),'r','LineWidth',1.5); hold on
plot(ti,x(2,:),'b','LineWidth',1.5)
xlabel('t')
ylabel('P(t)')
legend('Before control','After control')
title({'Compartment of People Who are Risky to Have',...
       'Diabetes Through Genetic Factor (P)'})
grid on
set(findall(gcf,'-property','FontSize'),'FontSize',12)

figure(3)
plot(ti,x0s(3,:),'r','LineWidth',1.5);
hold on
plot(ti,x(3,:),'b','LineWidth',1.5)
xlabel('t')
ylabel('E(t)')
legend('Before control','After control')
title({'Compartment of People Who are Risky to Have',...
       'Diabetes Through Unhealthy Lifestyle (E)'})
grid on
set(findall(gcf,'-property','FontSize'),'FontSize',12)
```

```
figure(4)
plot(ti,x0s(4,:),'r','LineWidth',1.5);
hold on
plot(ti,x(4,:),'b','LineWidth',1.5)
xlabel('t')
ylabel('D(t)')
legend('Before control','After control')
title('Compartment of Diabetics without Complications (D)')
grid on
set(findall(gcf,'-property','FontSize'),'FontSize',12)

figure(5)
plot(ti,x0s(5,:),'r','LineWidth',1.5);
hold on
plot(ti,x(5,:),'b','LineWidth',1.5)
xlabel('t')
ylabel('Ct(t)')
legend('Before control','After control')
title({'Compartment of Diabetics with',...
       'Moderate Complications (Ct)'})
grid on
set(findall(gcf,'-property','FontSize'),'FontSize',12)

figure(6)
plot(ti,x0s(6,:),'r','LineWidth',1.5);
hold on
plot(ti,x(6,:),'b','LineWidth',1.5)
xlabel('t')
ylabel('Cs(t)')
legend('Before control','After control')
title({'Compartment of Diabetics with',...
       'Serious Complications (Cs)'})
grid on
set(findall(gcf,'-property','FontSize'),'FontSize',12)

figure(7)
subplot(3,2,1)
    plot(ti,u(1,:),'r','LineWidth',2); hold on
    xlabel('t')
    ylabel('Education (u1)')
    grid on
subplot(3,2,2)
    plot(ti,u(2,:),'g','LineWidth',2); hold on
    xlabel('t')
    ylabel({'Physical','Activity (u2)'})
    grid on
subplot(3,2,3)
    plot(ti,u(3,:),'b','LineWidth',2); hold on
    xlabel('t')
    ylabel({'Dietary','Arrangements (u3)'})
    grid on
subplot(3,2,4)
    plot(ti,u(4,:),'c','LineWidth',2); hold on
    xlabel('t')
    ylabel({'Pharmacological','Therapy (u4)'})
    grid on
subplot(3,2,5)
    plot(ti,u(5,:),'y','LineWidth',2); hold on
```

```
    xlabel('t')
    ylabel({'Treatment of','Complications (u5)'})
    grid on
set(findall(gcf,'-property','FontSize'),'FontSize',12)
```

Lampiran 3. Sintaksis untuk persamaan *state*.

```
function xdot = f_state_5523(t,x,u,ti)

global I t1 t2 b1 b2 g1 g2 a1 a2 e1 e2 d mu

%I = 2; mu=0.02;
H  =x(1);
P  =x(2);
E  =x(3);
D  =x(4);
Ct =x(5);
Cs =x(6);
%N  =I/mu;
N  = H+P+E+D+Ct+Cs;

u1 =u(1,:);
u2 =u(2,:);
u3 =u(3,:);
u4 =u(4,:);
u5 =u(5,:);

u1 =interp1(ti,u1',t);
u2 =interp1(ti,u2',t);
u3 =interp1(ti,u3',t);
u4 =interp1(ti,u4',t);
u5 =interp1(ti,u5',t);

xdot    = zeros(6,1);
xdot(1)= I-(t1+mu)*H-t2*(1-u1)*H;
xdot(2)= t1*H-(b1+g1+mu)*P;
xdot(3)= t2*(1-u1)*H-b2*(1-u2)*(1-u3)*E-mu*E;
xdot(4)= b1*P+b2*(1-u2)*(1-u3)*E-a1*(1-u2)*E*D./N-...
         g2*(1-u3)*(1-u4)*D-e1*(1-u4)*(1-u5)*D-mu*D;
xdot(5)= g1*P+g2*(1-u3)*(1-u4)*D+a1*(1-u2)*E*D./N-...
         a2*(1-u3)*E*Ct./N-e2*(1-u4)*(1-u5)*Ct-mu*Ct;
xdot(6)= e1*(1-u4)*(1-u5)*D+e2*(1-u4)*(1-u5)*Ct+...
         a2*(1-u3)*E*Ct./N-(d+mu)*Cs;
end
```

Lampiran 4. Sintaksis untuk persamaan *co-state*.

```
function lambdadot = f_costate_5523(t,lambda,x,u,ti)

global t1 t2 b1 b2 g1 g2 a1 a2 e1 e2 d mu

lambdaH = lambda(1);
lambdaP = lambda(2);
lambdaE = lambda(3);
lambdaD = lambda(4);
lambdaCt= lambda(5);
lambdaCs= lambda(6);

x=interp1(ti,x',t);
%I = 2; mu=0.02;
H  =x(1);
P  =x(2);
E  =x(3);
D  =x(4);
Ct =x(5);
Cs =x(6);
%N =I/mu;
N  = H+P+E+D+Ct+Cs;

u1 =u(1,:);
u2 =u(2,:);
u3 =u(3,:);
u4 =u(4,:);
u5 =u(5,:);

u1 =interp1(ti,u1',t);
u2 =interp1(ti,u2',t);
u3 =interp1(ti,u3',t);
u4 =interp1(ti,u4',t);
u5 =interp1(ti,u5',t);

lambdadot=zeros(6,1);
lambdadot(1)= lambdaH*(t1+t2*(1-u1)+mu)-lambdaP*t1-lambdaE*t2*(1-
u1);
lambdadot(2)= lambdaP*(b1+g1+mu)-lambdaD*t1-lambdaCt*g1;
lambdadot(3)= -1+lambdaE*(b2*(1-u2)*(1-u3)+mu)-lambdaD*(b2*(1-
u2)*...
              (1-u3)-a1*D*(1-u2)./N)-lambdaCt*(a1*D*(1-u2)./N-
a2*Ct*...
              (1-u3)./N)-lambdaCs*(a2*Ct*(1-u3)./N);
lambdadot(4)= -1+lambdaD*(a1*E*(1-u2)./N+g2*(1-u3)*(1-
u4)+mu+e1*...
              (1-u4)*(1-u5))-lambdaCt*(g2*(1-u3)*(1-u4)+a1*E*(1-
u2)./N)...
              -lambdaCs*(e1*(1-u4)*(1-u5));
lambdadot(5)= -1+lambdaCt*(a2*E*(1-u3)./N+e2*(1-u4)*(1-u5)+mu)-...
              lambdaCs*(e2*(1-u4)*(1-u5)+a2*E*(1-u3)./N);
lambdadot(6)= lambdaCs*(d+mu);
end
```

Lampiran 5. Sintaksis untuk fungsi tujuan.

```
function J=f_obj_5523(x,u,ti)

global B1 B2 B3 B4 B5

x3 = x(3,:);
x4 = x(4,:);
x5 = x(5,:);

u1 =u(1,:);
u2 =u(2,:);
u3 =u(3,:);
u4 =u(4,:);
u5 =u(5,:);

int=x3+x4+x5+0.5*(B1*u1.^2+B2*u2.^2+B3*u3.^2+B4*u4.^2+B5*u5.^2);

%J=E(tf)+D(tf)+Ct(tf)+int
%E(tf) is E at tf (final time)
%we know that: ti= t0:h:tf=0:0.1:120
%              z = length(ti)
%because the time interval ti is divided by z points then
%the value of E at tf is at point z (final time), so
%E(tf)=E(z) in MATLAB
t0= 0; tf=120; %adjust like main program
ti= t0:0.1:tf;
z = length(ti);

J=x3(1,z)+x4(1,z)+x5(1,z)+trapz(ti, int);
end
```

Lampiran 6. Sintaksis untuk fungsi kontrol.

```
function u=f_kontrol_5523(x,lambda)

global t2 b2 g2 a1 a2 e1 e2 B1 B2 B3 B4 B5

lambdaH = lambda(1,:);
lambdaP = lambda(2,:);
lambdaE = lambda(3,:);
lambdaD = lambda(4,:);
lambdaCt= lambda(5,:);
lambdaCs= lambda(6,:);

H = x(1,:);
P = x(2,:);
E = x(3,:);
D = x(4,:);
Ct= x(5,:);
Cs= x(6,:);
N = H+P+E+D+Ct+Cs;

k1= b2*(lambdaD-lambdaE);
```

```
k2= g2*(lambdaCt-lambdaD);
k3= a1*(lambdaCt-lambdaD);
k4= a2*(lambdaCs-lambdaCt).*E.*D;
k5= e1*D.*(lambdaCs-lambdaD)+e2*Ct.*(lambdaCs-lambdaCt);
k6= k1.*(B2*N-E.*(k1.*N+k3)).*E+k4.*B2;
k7= N.*(B2*B3-(k1.*E).^2);
k8= B5*k2.*D+k5.*(B5-k5);


u1 = t2*(lambdaE-lambdaH).*H/B1;
u4 = (k2.*D.*(B5.*k6+B2.*N)-k7.*k8)./B5.*k2.*D;
u5 = ((1-u4).*k5)/B5;
u3 = (k8+u4.*(k5.^2-B4*B5))./B5.*k2.*D;
u2 = (E.*(k1.*(1-u3).*N)+k3)./N.*B2;

u=[u1;u2;u3;u4;u5];
end
```

Lampiran 7. Sintaksis untuk kondisi stasioner.

```
function dH=f_stat_cond_5523(x,lambda,u)

global t2 b2 g2 a1 a2 e1 e2 B1 B2 B3 B4 B5

u1 =u(1,:);
u2 =u(2,:);
u3 =u(3,:);
u4 =u(4,:);
u5 =u(5,:);

lambdaH =lambda(1,:);
lambdaP =lambda(2,:);
lambdaE =lambda(3,:);
lambdaD =lambda(4,:);
lambdaCt=lambda(5,:);
lambdaCs=lambda(6,:);

H  =x(1,:);
P  =x(2,:);
E  =x(3,:);
D  =x(4,:);
Ct =x(5,:);
Cs =x(6,:);
N  = H+P+E+D+Ct+Cs;

dH1 =t2*H.*(lambdaH-lambdaE)+B1*u1;
dH2 =b2*lambdaE.*E.*(1-u3)+lambdaD.*(-b2*E.*(1-u3)+a1*E.*D./N)-...
     a1*lambdaCt.*E.*D./N+B2*u2;
dH3 =b2*E.*lambdaE.*(1-u2)+lambdaD.*(-b2*E.*(1-u2)+g2*D.*(1-
u4))+...
     lambdaCt.*(-g2*D.*(1-u4)+a2*E.*D./N)-
a2*lambdaCs.*E.*D./N+B3*u3;
dH4 =lambdaD.*(g2*D.*(1-u3)+e1*D.*(1-u5))+lambdaCt.*(-g2*D.*(1-
u3)+e2*Ct.*(1-u5))-...
     lambdaCs.*(e1*D.*(1-u5)+e2*Ct.*(1-u5))+B4*u4;
dH5 =e1*lambdaD.*D.*(1-u4)+e2*lambdaCt.*Ct.*(1-u4)-...
```

```
     lambdaCs.*(e1*D.*(1-u4)+e2*Ct.*(1-u4))+B5*u5;

dH=[dH1;dH2;dH3;dH4;dH5];
end
```

Lampiran 8. Sintaksis untuk batas fungsi kontrol.

```
function s=f_simplebounds(s,Lb,Ub)
  % Apply the lower bound
  ns_tmp=s;
  I=ns_tmp<Lb;
  ns_tmp(I)=Lb(I);

  % Apply the upper bounds
  J=ns_tmp>Ub;
  ns_tmp(J)=Ub(J);

  % Update this new move
  s=ns_tmp;
end
```

Lampiran 9. Sintaksis untuk plot kurva masing-masing kasus pada suatu skenario dan luas daerah di bawah kurva.

```
clc;
clear all;
close all;

% SCENARIO 1 FOR EACH CASE
scene1  =readtable('skenario_1.xlsx');
toarray =table2array(scene1);
x       =toarray;

ti   = x(:,1);
xe0 = x(:,2); %before control for E
xd0 = x(:,8); %before control for D
xct0= x(:,14);%before control for Ct

%after control for E (each case)
xe1= x(:,3); %case 1
xe2= x(:,4); %case 2
xe3= x(:,5); %case 3
xe4= x(:,6); %case 4
xe5= x(:,7); %case 5

figure(1)
plot(ti,xe0,'--k','LineWidth',1.5); hold on
plot(ti,xe1,'r','LineWidth',1.5); hold on
plot(ti,xe2,'b','LineWidth',1.5); hold on
plot(ti,xe3,'c','LineWidth',1.5); hold on
plot(ti,xe4,'y','LineWidth',1.5); hold on
plot(ti,xe5,'m','LineWidth',1.5); hold on
grid on
```

```
xlabel('t')
ylabel('E(t)')
legend('Before control','Case 1: Focus on education','Case 2:
Focus on physical activity',...
       'Case 3: Focus on dietary arrangement','Case 4: Focus on
pharmacological therapy',...
       'Case 5: Focus on treatment of diabetes')
title({'Comparison of compartment of people who are risky',...
       'to have diabetes through unhealthy lifestyle (E)'})
set(findall(gcf,'-property','FontSize'),'FontSize',11.5

%-----------------------------------------------------------
disp('>>> FOR COMPARTMENT E -------------------------------')
areaxe0= trapz(ti,xe0);
    fprintf('Area of under red curve (before control) = %4.10f
\n',areaxe0)
areaxe1= trapz(ti,xe1);
    value1 = ((areaxe0-areaxe1)/areaxe0)*100;
    fprintf('Area of under case 1 curve = %4.6f, (decreased %2.6f
percent) \n',areaxe1,value1)
areaxe2= trapz(ti,xe2);
    value2 = ((areaxe0-areaxe2)/areaxe0)*100;
    fprintf('Area of under case 2 curve = %4.6f, (decreased %2.6f
percent) \n',areaxe2,value2)
areaxe3= trapz(ti,xe3);
    value3 = ((areaxe0-areaxe3)/areaxe0)*100;
    fprintf('Area of under case 3 curve = %4.6f, (decreased %2.6f
percent) \n',areaxe3,value3)
areaxe4= trapz(ti,xe4);
    value4 = ((areaxe0-areaxe4)/areaxe0)*100;
    fprintf('Area of under case 4 curve = %4.6f, (decreased %2.6f
percent) \n',areaxe4,value4)
areaxe5= trapz(ti,xe5);
    value5 = ((areaxe0-areaxe5)/areaxe0)*100;
    fprintf('Area of under case 5 curve = %4.6f, (decreased %2.6f
percent) \n',areaxe5,value5)
```

Lampiran 10. Hasil *run* program pada Lampiran 9 untuk luas daerah di bawah kurva pada masing-masing kasus.

- Skenario 1

```
Command Window
New to MATLAB? See resources for Getting Started.
>>> FOR COMPARTMENT E ------------------------------
Area of under red curve (before control) = 1902.7090195420
Area of under case 1 curve = 545.852198, (decreased 71.311841 percent)
Area of under case 2 curve = 545.852072, (decreased 71.311847 percent)
Area of under case 3 curve = 545.852188, (decreased 71.311841 percent)
Area of under case 4 curve = 545.852257, (decreased 71.311837 percent)
Area of under case 5 curve = 545.852154, (decreased 71.311843 percent)
```

- Skenairo 2

```
Command Window
New to MATLAB? See resources for Getting Started.
>>> FOR COMPARTMENT E ------------------------------
Area of under red curve (before control) = 1902.7090195420
Area of under case 1 curve = 545.852582, (decreased 71.311820 percent)
Area of under case 2 curve = 545.852072, (decreased 71.311847 percent)
Area of under case 3 curve = 545.852761, (decreased 71.311811 percent)
```

- Skenario 3

```
Command Window
New to MATLAB? See resources for Getting Started.
>>> FOR COMPARTMENT E ------------------------------
Area of under red curve (before control) = 1902.7090195420
Area of under case 1 curve = 545.852118, (decreased 71.311845 percent)
Area of under case 2 curve = 545.852072, (decreased 71.311847 percent)
Area of under case 3 curve = 545.852148, (decreased 71.311843 percent)
```