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% Problem (OCP)_1 from Pset 6

clear all; clf; clc; format long;

% Parameters and scenario
global N; N = 10;
global T; T = 1.;
global uMax; uMax = 1.0;
global x0; x0 = 1.;
global y0; y0 = 0.;

% Random initialization
uInit = 0.5*uMax*ones(N+1,1);
xInit = ones(N+1,1); yInit = zeros(N+1,1);
varInit = [xInit; yInit; uInit];

% Lower and upper bounds.
lb = zeros(3*N+3,1); ub = uMax*ones(3*N+3,1); % For the control:  $0 \leq u \leq u_{\max}$ 
ub(1:N+1) = 1.; % For the state  $x$ :  $0 \leq x \leq 1$ 
ub(N+2:2*N+2) = 1.; % For the state  $y$ :  $0 \leq y \leq 1$ 

% Solving the problem via fmincon
options=optimoptions('fmincon','Display','iter','Algorithm','sqp','MaxFunEvals',10000,'MaxIter',10000);
% options=optimoptions('fmincon','Display','iter','Algorithm','sqp','MaxFunctionEvaluations',100000,'MaxIterations',10000);
[var,Fval,convergence] = fmincon(@cost,varInit,[],[],[],[],lb,ub,@constraint,options); % Solving the problem
convergence % = 1, good

% Collecting the solution. Note that var = [x;y;u]
x = var(1:N+1); y = var(N+2:2*N+2); u = var(2*N+3:3*N+3);
tState = zeros(N+1,1);
t = zeros(N+1,1);
for i = 1:N
    t(i+1) = t(i) + (1.0*T/(1.0*N));
end

% Plotting
fprintf('Optimal Final Quantity for the Second Substance = %f\n\n',Fval);
% subplot(131); plot(t,x,'linewidth',3);
% title('\textbf{a} First Substance','interpreter','latex','FontSize',22,'FontWeight','bold');
% xlabel('\boldmath{\$t\$} \ \ \textbf{(s)}','interpreter','latex','FontSize',20,'FontWeight','bold');
% ylabel('\boldmath{\$x\$} \ \ \textbf{(\%)}'','interpreter','latex','FontSize',20,'FontWeight','bold');
% xlim([-inf inf]);
% ylim([-inf inf]);
% grid on;
% subplot(132); plot(t,y,'linewidth',3);
% title('\textbf{b} Second Substance','interpreter','latex','FontSize',22,'FontWeight','bold');
% xlabel('\boldmath{\$t\$} \ \ \textbf{(s)}','interpreter','latex','FontSize',20,'FontWeight','bold');
% ylabel('\boldmath{\$y\$} \ \ \textbf{(\%)}'','interpreter','latex','FontSize',20,'FontWeight','bold');
% xlim([-inf inf]);
% ylim([-inf inf]);
% grid on;
% subplot(133); plot(t,u,'linewidth',3);
% title('\textbf{c} Optimal Control','interpreter','latex','FontSize',22,'FontWeight','bold');
% xlabel('\boldmath{\$t\$} \ \ \textbf{(s)}','interpreter','latex','FontSize',20,'FontWeight','bold');
% ylabel('\boldmath{\$u\$}'','interpreter','latex','FontSize',20,'FontWeight','bold');
% xlim([-inf inf]);
% ylim([-inf inf]);
% grid on;

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Iter	F-count	f(x)	Feasibility	Steplength	Norm of First-order step	optimality
0	34	-0.000000e+00	5.000e-02			1.000e+00
1	68	-2.355430e-01	6.015e-03	1.000e+00	8.404e-01	2.996e-01
2	102	-2.595025e-01	1.487e-04	1.000e+00	9.635e-02	2.447e-02
3	136	-2.691728e-01	4.202e-04	1.000e+00	1.658e-01	2.300e-02
4	171	-2.802969e-01	2.296e-04	1.000e+00	4.903e-01	1.343e-02

5	205	-2.814745e-01	9.095e-05	1.000e+00	7.340e-02	1.337e-02
6	239	-2.848175e-01	6.548e-04	1.000e+00	1.986e-01	1.322e-02
7	273	-2.865277e-01	2.701e-04	1.000e+00	1.551e-01	1.946e-02
8	307	-2.875543e-01	2.145e-04	1.000e+00	1.164e-01	9.424e-03
9	341	-2.873440e-01	5.010e-05	1.000e+00	5.320e-02	7.636e-03
10	375	-2.877465e-01	4.403e-05	1.000e+00	5.583e-02	7.914e-03
11	409	-2.887661e-01	9.233e-05	1.000e+00	1.204e-01	1.138e-02
12	443	-2.893493e-01	1.236e-04	1.000e+00	1.105e-01	1.082e-02
13	477	-2.894912e-01	2.966e-05	1.000e+00	3.790e-02	7.160e-03
14	511	-2.896184e-01	2.723e-05	1.000e+00	3.681e-02	3.220e-03
15	545	-2.896203e-01	5.757e-06	1.000e+00	1.866e-02	2.536e-03
16	579	-2.896686e-01	7.119e-06	1.000e+00	1.912e-02	2.495e-03
17	613	-2.896967e-01	9.225e-06	1.000e+00	2.050e-02	1.997e-03
18	647	-2.896969e-01	4.026e-06	1.000e+00	1.278e-02	1.219e-03
19	681	-2.896988e-01	9.327e-07	1.000e+00	7.252e-03	1.153e-03
20	715	-2.897080e-01	1.363e-06	1.000e+00	1.031e-02	1.593e-03
21	749	-2.897188e-01	2.664e-06	1.000e+00	1.341e-02	1.973e-03
22	783	-2.897193e-01	4.064e-07	1.000e+00	4.369e-03	1.452e-03
23	817	-2.897202e-01	3.408e-07	1.000e+00	4.207e-03	2.091e-04
24	851	-2.897196e-01	1.149e-08	1.000e+00	7.273e-04	1.729e-04
25	885	-2.897203e-01	1.137e-07	1.000e+00	2.768e-03	3.421e-04
26	919	-2.897203e-01	4.886e-08	1.000e+00	1.673e-03	2.749e-04
27	953	-2.897203e-01	2.363e-08	1.000e+00	1.112e-03	1.060e-04
28	987	-2.897203e-01	1.187e-09	1.000e+00	2.958e-04	3.901e-05
29	1021	-2.897203e-01	9.043e-10	1.000e+00	2.835e-04	4.250e-05
30	1055	-2.897203e-01	1.477e-09	1.000e+00	3.157e-04	4.239e-05

Iter	F-count	f(x)	Feasibility	Steplength	Norm of First-order	
					step	optimality
31	1089	-2.897203e-01	1.560e-09	1.000e+00	2.744e-04	3.140e-05
32	1123	-2.897203e-01	4.151e-10	1.000e+00	1.342e-04	1.208e-05
33	1157	-2.897203e-01	3.489e-11	1.000e+00	4.701e-05	6.886e-06
34	1191	-2.897203e-01	3.684e-11	1.000e+00	4.258e-05	5.896e-06
35	1225	-2.897203e-01	3.106e-11	1.000e+00	4.442e-05	5.937e-06
36	1259	-2.897203e-01	1.542e-11	1.000e+00	3.203e-05	2.789e-06
37	1293	-2.897203e-01	2.077e-12	1.000e+00	1.215e-05	9.103e-07

Local minimum found that satisfies the constraints.

Optimization completed because the objective function is non-decreasing in feasible directions, to within the default value of the function tolerance, and constraints are satisfied to within the default value of the constraint tolerance.

convergence =

1

Optimal Final Quantity for the Second Substance = -0.289720