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Codes in MATLAB for Training Artificial Neural Network using Particle Swarm Optimization

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Abstract

In this paper, codes in MATLAB for training artificial neural network (ANN) using particle swarm optimization (PSO) have been given. These codes are generalized in training ANNs of any input features and single target feature. The proposed training approach has been tested on chemical_dataset available in MATLAB.

Keywords: artificial neural network, particle swarm optimization, optimum training.

1. Introduction

Artificial neural network (ANN) serves the objective providing a model which has the ability to relate very complex input and output datasets. This ANN model works extremely well for very complex data sets which are normally very difficult to predict using mathematical modelling (equations).

2. Artificial Neural Network (ANN)

The ANN is a network of neuron connected among themselves through weights and biases. A typical ANN model is shown in Figure 1. Once the structure of the ANN is formed then the next task is to train the network.

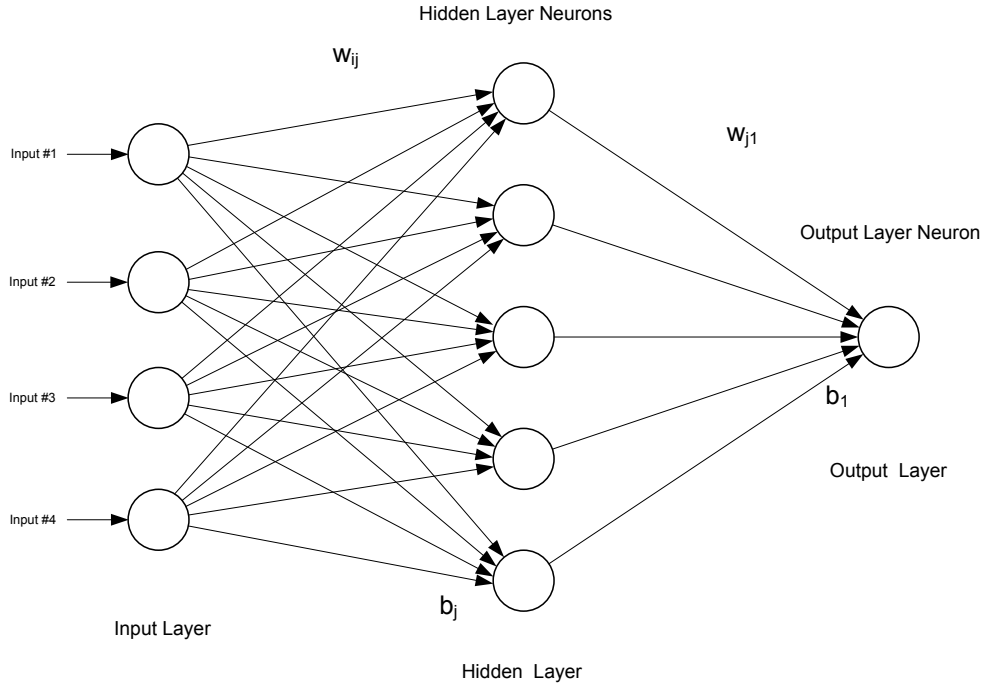

Figure 1: A typical artificial neural network (ANN)

Training of the networks means finding the optimum values of various weights and biases of the network. Normally, various types of techniques are used to find the suitable values of weights and biases of the ANN. I this work, optimum training of the network have been obtained through particle swarm optimization (PSO). The details about the PSO can be found in [1], [2], [3], [4], [5]. The PSO algorithm used in this work is well explained in [6]. Further, codes in MATLAB environment are available in [7], [8].

3. Proposed Artificial Neural Networks Training approach using Particle Swarm Optimization

The following seven steps have been used to train ANN using PSO.

Step 1) Collect data

Step 2) Create the network

Step 3) Configure the network

Step 4) Initialize the weights and biases

Step 5) Train the network using PSO

Step 6) Validate the network

Step 7) Use the network

4. Objective Function of Training Artificial Neural Networks

The objective function of the optimum training of ANN using PSO can be defined as given in the rectangular box below. The codes given in the box must be saved as 'myfunc.m' and need to be placed in the same directory of the MATLAB where the main PSO codes program is available which is given in the next section.

```
%These codes are part of research work done by Mahamad Nabab Alam
%Research Scholar, Indian Institute of Technology, Roorkee, India

function [f] = myfunc(x,n,m,o,net,inputs,targets)

k=0;
for i=1:n
    for j=1:m
        k=k+1;
        xi(i,j)=x(k);
    end
end
for i=1:n
    k=k+1;
    xl(i)=x(k);
    xb1(i,1)=x(k+n);
end
for i=1:o
    k=k+1;
    xb2(i,1)=x(k);
end
net.iw{1,1}=xi;
net.lw{2,1}=xl;
net.b{1,1}=xb1;
net.b{2,1}=xb2;
f=sum((net(inputs)-targets).^2)/length(inputs);
```

5. Main Program of Particle Swarm Optimization for Training Artificial Neural Networks

The main program file for training ANN using PSO is given in the rectangular box below. Save these codes as 'nn_pso.m' (any suitable name can be used to save this program). Before, running this program, the datasets (input datasets) must be made in Microsoft Excel (.xlsx) which will be used to train the network. The details about the making of the datasets are discussed in the next section.

```
%This codes are part of research work done by Mahamad Nabab Alam
%Research Scholar, Indian Institute of Technology, Roorkee, India

clc
tic
close all
clear all
rng default

filename = 'datafile.xlsx';
sheetname1 = 'Sheet1';
sheetname2 = 'Sheet2';

input = xlsread(filename,sheetname1,'A1:Z10000');
target = xlsread(filename,sheetname2,'A1:Z10000');

inputs=input';
targets=target';

m=length(inputs(:,1));
o=length(targets(:,1));

n=5;
net=feedforwardnet(n);
net=configure(net,inputs,targets);
kk=m*n+n+n+o;

for j=1:kk
    LB(1,j)=-1.5;
    UB(1,j)=1.5;
end
pop=10;
for i=1:pop
    for j=1:kk
        xx(i,j)=LB(1,j)+rand*(UB(1,j)-LB(1,j));
    end
end

maxrun=1;
for run=1:maxrun
    fun=@(x) myfunc(x,n,m,o,net,inputs,targets);
    x0=xx;

    % pso initialization----------------------------------------------start
    x=x0;       % initial population
    v=0.1*x0;   % initial velocity
    for i=1:pop
        f0(i,1)=fun(x0(i,:));
    end
    [fmin0,index0]=min(f0);
```

```
pbest=x0;                % initial pbest
gbest=x0(index0,:);      % initial gbest
% pso initialization-----------------------------------------------------end

% pso algorithm---------------------------------------------------------start
c1=1.5; c2=2.5;
ite=1; maxite=1000; tolerance=1;
while ite<=maxite && tolerance>10^-8

    w=0.1+rand*0.4;
    % pso velocity updates
    for i=1:pop
        for j=1:kk
            v(i,j)=w*v(i,j)+c1*rand*(pbest(i,j)-x(i,j))...
                    +c2*rand*(gbest(1,j)-x(i,j));
        end
    end

    % pso position update
    for i=1:pop
        for j=1:kk
            x(i,j)=x(i,j)+v(i,j);
        end
    end

    % handling boundary violations
    for i=1:pop
        for j=1:kk
            if x(i,j)<LB(j)
                x(i,j)=LB(j);
            elseif x(i,j)>UB(j)
                x(i,j)=UB(j);
            end
        end
    end

    % evaluating fitness
    for i=1:pop
        f(i,1)=fun(x(i,:));
    end

    % updating pbest and fitness
    for i=1:pop
        if f(i,1)<f0(i,1)
            pbest(i,:)=x(i,:);
            f0(i,1)=f(i,1);
        end
    end

    [fmin,index]=min(f0);    % finding out the best particle
    ffmin(ite,run)=fmin;     % storing best fitness
    ffite(run)=ite;          % storing iteration count

    % updating gbest and best fitness
    if fmin<fmin0
        gbest=pbest(index,:);
        fmin0=fmin;
    end
```

```
        % calculating tolerance
        if ite>100;
            tolerance=abs(ffmin(ite-100,run)-fmin0);
        end

        % displaying iterative results
        if ite==1
            disp(sprintf('Iteration    Best particle    Objective fun'));
        end
        disp(sprintf('%8g  %8g          %8.4f',ite,index,fmin0));
        ite=ite+1;
    end
    % pso algorithm---------------------------------------------------------end

    xo=gbest;
    fval=fun(xo);
    xbest(run,:)=xo;
    ybest(run,1)=fun(xo);
    disp(sprintf('****************************************'));
    disp(sprintf('    RUN   fval       ObFuVa'));
    disp(sprintf('%6g %6g %8.4f %8.4f',run,fval,ybest(run,1)));
end
toc

% Final neural network model
disp('Final nn model is net_f')
net_f = feedforwardnet(n);
net_f=configure(net_f,inputs,targets);
[a b]=min(ybest);
xo=xbest(b,:);
k=0;
for i=1:n
    for j=1:m
        k=k+1;
        xi(i,j)=xo(k);
    end
end
for i=1:n
    k=k+1;
    xl(i)=xo(k);
    xb1(i,1)=xo(k+n);
end
for i=1:o
    k=k+1;
    xb2(i,1)=xo(k);
end
net_f.iw{1,1}=xi;
net_f.lw{2,1}=xl;
net_f.b{1,1}=xb1;
net_f.b{2,1}=xb2;

%Calculation of MSE
err=sum((net_f(inputs)-targets).^2)/length(net_f(inputs))

%Regression plot
plotregression(targets,net_f(inputs))

disp('Trained ANN net_f is ready for the use');
%Trained ANN net_f is ready for the use
%Kindly, write your feedback and cite the paper in your work using its DOI
```

6. Making of Datasets for Training ANN using PSO

For running the proposed program, raw data must be given in Microsoft Excel file (.xlsx). The first sheet (Sheet1) must have the input data where all features of an input and output data set must be placed in one row of Sheet1 whereas, the corresponding output data (target data) of the input feature data must be placed in the first column of the first row of the second sheet (Sheet2). This complete file must be saved as 'datafile.xlsx' and placed in the same directory. Kindly, see Figure 2 and Figure 3 for details of raw data entries. Here, input features are 8 to produce a single output data.

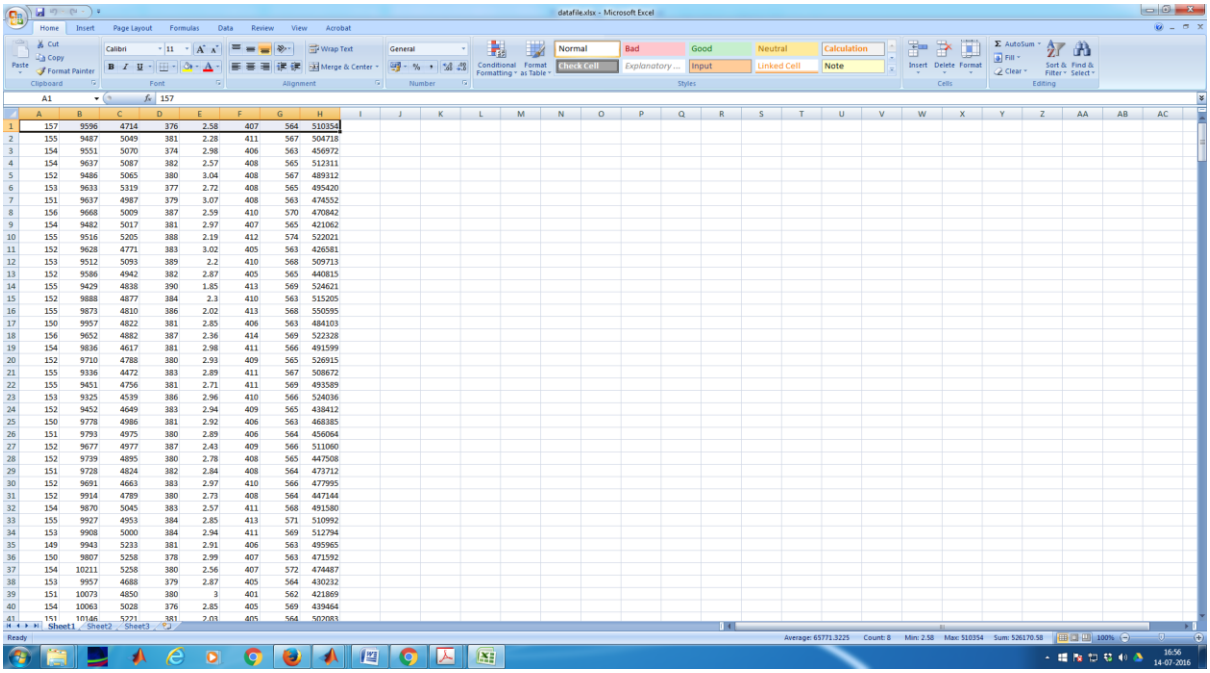

Figure 2: Input data entries

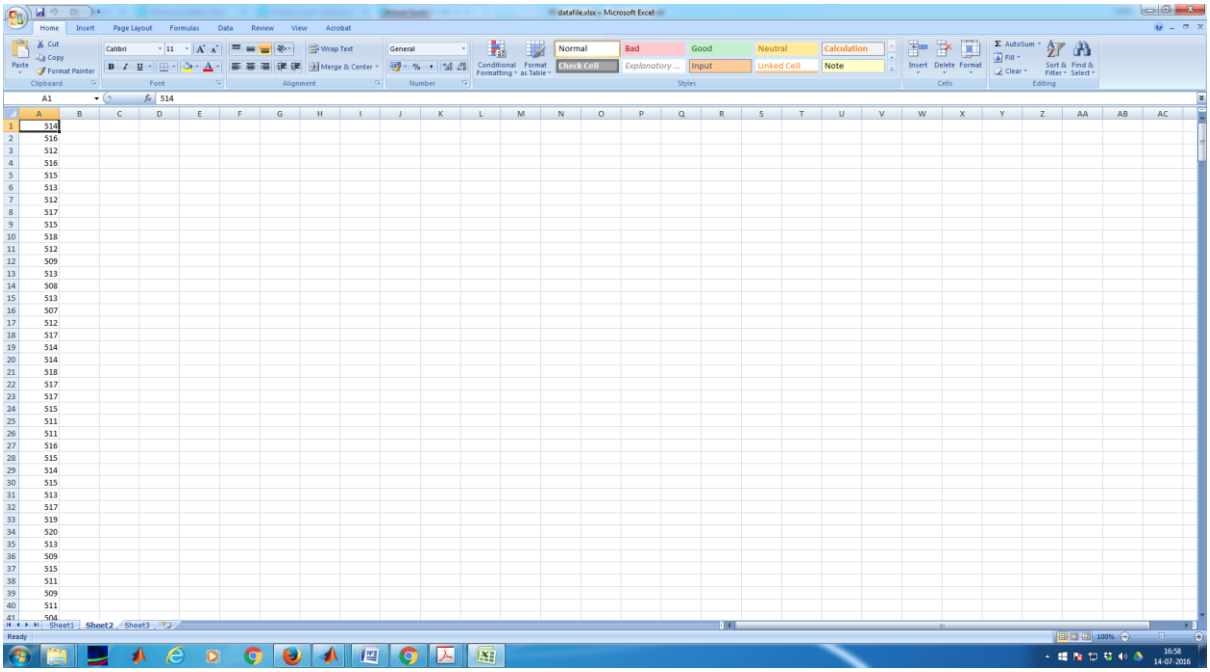

Figure 3: Target (output) data entries

The complete datasets of chemical_dataset available in MATLAB are given the Table I. Kindly, save this data in the excel file as mentioned above. Copy and paste this data in Shee1 and Sheet2 of the excel file saved as datafile.xlsx.

TABLE I: Raw Datasets for chemical_dataset available in MATLAB

Input data (Sheet1)								Output data (Sheet2)
157	9596	4714	376	2.58	407	564	510354	514
155	9487	5049	381	2.28	411	567	504718	516
154	9551	5070	374	2.98	406	563	456972	512
154	9637	5087	382	2.57	408	565	512311	516
152	9486	5065	380	3.04	408	567	489312	515
153	9633	5319	377	2.72	408	565	495420	513
151	9637	4987	379	3.07	408	563	474552	512
156	9668	5009	387	2.59	410	570	470842	517
154	9482	5017	381	2.97	407	565	421062	515
155	9516	5205	388	2.19	412	574	522021	518
152	9628	4771	383	3.02	405	563	426581	512
153	9512	5093	389	2.2	410	568	509713	509
152	9586	4942	382	2.87	405	565	440815	513
155	9429	4838	390	1.85	413	569	524621	508
152	9888	4877	384	2.3	410	563	515205	513
155	9873	4810	386	2.02	413	568	550595	507
150	9957	4822	381	2.85	406	563	484103	512
156	9652	4882	387	2.36	414	569	522328	517
154	9836	4617	381	2.98	411	566	491599	514
152	9710	4788	380	2.93	409	565	526915	514
155	9336	4472	383	2.89	411	567	508672	518
155	9451	4756	381	2.71	411	569	493589	517
153	9325	4539	386	2.96	410	566	524036	517
152	9452	4649	383	2.94	409	565	438412	515
150	9778	4986	381	2.92	406	563	468385	511
151	9793	4975	380	2.89	406	564	456064	511
152	9677	4977	387	2.43	409	566	511060	516
152	9739	4895	380	2.78	408	565	447508	515
151	9728	4824	382	2.84	408	564	473712	514
152	9691	4663	383	2.97	410	566	477995	515
152	9914	4789	380	2.73	408	564	447144	513
154	9870	5045	383	2.57	411	568	491580	517
155	9927	4953	384	2.85	413	571	510992	519
153	9908	5000	384	2.94	411	569	512794	520
149	9943	5233	381	2.91	406	563	495965	513
150	9807	5258	378	2.99	407	563	471592	509
154	10211	5258	380	2.56	407	572	474487	515
153	9957	4688	379	2.87	405	564	430232	511
151	10073	4850	380	3	401	562	421869	509
154	10063	5028	376	2.85	405	569	439464	511
151	10146	5221	381	2.03	405	564	502083	504
154	9910	4961	381	2.64	404	563	476764	512
148	9966	5600	373	3.06	392	558	443955	505
155	9549	5385	377	2.47	400	565	505913	507
149	9978	7809	370	1.86	395	563	649442	501
145	9746	6868	376	1.9	396	562	557851	500
142	9620	6984	376	2.15	396	564	572242	505
143	9628	7125	380	2.12	395	560	654240	502
145	9659	7078	377	2.23	400	565	634647	508
144	9805	7202	378	1.97	396	563	663116	502
147	9557	7008	378	1.94	404	564	619637	504
147	9647	6994	379	1.85	404	564	644845	503

147	9415	6700	379	1.83	404	565	611236	504
148	9388	7387	376	1.69	405	564	683235	501
148	9545	7082	374	1.86	405	562	598951	500
146	9606	7013	376	1.8	403	563	662400	499
149	9547	6697	376	1.83	407	563	626245	500
144	9504	6126	381	1.87	401	559	621051	498
149	9625	6324	379	1.91	407	563	617893	501
147	9616	6165	380	1.83	405	563	599292	499
150	9576	6196	380	1.85	408	565	599371	503
137	9677	6364	377	1.78	393	554	641902	489
141	9858	7597	373	1.73	394	561	666013	494
147	9766	6536	376	1.69	401	562	579424	500
146	9768	6595	379	1.76	400	563	589871	498
146	9518	6623	375	1.74	401	563	569214	499
145	9769	6857	376	1.77	399	565	606231	499
147	9583	6692	373	1.77	402	563	587871	498
144	9616	6763	375	1.67	397	563	616520	497
142	9560	6762	372	1.76	398	562	573663	497
142	9710	6945	374	1.79	396	562	596343	495
141	9561	6793	374	1.84	396	560	566924	496
142	9666	6828	374	1.76	395	561	596178	495
144	9590	6682	374	1.81	398	562	589518	498
145	9542	6670	374	1.68	398	562	631865	498
144	9577	6683	373	1.74	400	563	564024	498
145	9494	6927	373	1.75	401	561	634826	498
147	9375	6594	374	1.7	403	565	592892	498
147	9538	6509	374	1.71	402	564	597395	497
145	9485	6400	374	1.77	400	561	574966	496
144	9543	6663	374	1.68	400	562	610112	496
142	9410	6596	375	1.76	398	560	590367	499
144	9541	6721	374	1.77	400	562	587762	498
137	9415	6667	373	1.84	392	551	551945	490
142	9244	6892	373	1.67	395	561	602791	495
145	9162	6773	373	1.8	399	560	559580	497
143	9079	6811	374	1.78	398	561	569416	500
146	9101	6745	375	1.82	399	560	592637	501
146	9278	6875	375	1.87	399	563	618905	504
146	9344	6933	375	1.84	398	562	634371	503
152	9250	6763	377	1.89	403	566	614605	508
144	9228	6818	376	1.8	395	561	628316	501
144	9396	6682	375	1.91	397	562	609158	502
144	9535	6863	373	1.85	394	560	635744	497
145	9510	6895	374	1.94	395	561	624588	500
143	9619	6836	376	2.26	396	560	605164	507
141	9463	7104	374	1.92	394	560	634747	497
147	9575	6955	376	2.02	401	565	650400	507
147	9596	6790	372	2.03	397	564	583574	504
149	9626	6989	375	2.05	397	564	630825	506
144	9633	6671	377	1.87	395	565	596329	503
142	9408	6783	376	1.9	393	563	581677	503
147	9883	6737	376	1.87	396	567	565803	504
154	10009	6769	375	1.96	404	573	556875	507
156	9753	6535	376	1.9	408	576	581021	509
145	9924	6703	373	1.96	395	563	538269	499
145	10018	6647	376	1.8	398	569	566942	502
147	9962	6409	376	1.85	402	570	546577	506
145	9936	6581	379	1.76	400	570	626417	506
147	9960	6545	376	1.76	401	571	573635	505
148	9971	6603	379	1.77	401	572	608496	506
149	10081	6506	377	1.87	403	574	571357	508
147	9751	6833	378	1.68	403	575	620174	508
144	9904	6632	375	1.79	397	568	550677	503
148	10008	6622	376	1.92	402	573	554418	510
145	10070	6762	377	1.82	399	575	574874	505

150	10020	6638	378	1.89	404	577	532037	511
147	10029	6655	377	1.88	400	574	543685	508
149	10003	6571	375	1.94	401	573	522276	509
150	9993	6502	376	1.87	404	577	536575	510
147	10092	6503	375	1.9	400	569	527752	507
149	10038	6068	379	1.85	403	573	532899	507
152	10255	5889	379	1.95	404	570	513691	507
153	10248	6018	381	1.94	406	574	530751	510
152	10314	6257	379	1.95	404	572	536424	508
150	10317	6280	381	1.89	404	582	555191	507
149	10305	6279	379	1.96	403	573	504650	509
150	10287	6278	380	1.89	405	588	532391	508
156	10113	6296	381	1.83	409	575	547064	512
150	10456	5896	378	2.21	406	572	520278	507
149	10802	5902	377	2.3	398	567	472533	504
146	9502	6080	372	1.46	399	570	523875	500
149	10583	5415	380	2	405	567	516101	500
149	10584	5316	382	1.86	405	568	526927	502
151	10665	5117	381	2.01	407	570	518985	504
154	10638	5137	385	2.32	409	571	521784	512
155	10730	5105	381	3	409	572	482819	515
150	10821	5191	379	2.96	403	566	442823	510
160	10448	5381	385	2.47	415	579	466446	523
152	10657	5782	385	2.38	407	573	514692	517
151	10705	5515	380	2.69	404	571	457048	513
157	10793	5958	384	1.92	412	577	545965	513
158	10804	5782	382	2.52	413	576	483714	523
162	10886	6088	381	2.29	410	577	489375	516
156	10884	7096	371	2.65	405	570	511422	517
136	11232	7755	375	1.97	385	556	662340	488
147	10837	6814	379	1.93	401	573	581926	506
149	10946	6609	378	1.86	395	571	514168	501
146	10750	6754	378	1.9	398	572	551373	507
147	10726	7007	377	1.91	397	571	586225	506
148	10831	6484	378	1.97	398	571	515336	504
147	10782	6521	386	1.82	405	579	603074	508
146	11097	6368	382	2.1	403	572	578394	506
148	11046	6662	385	1.89	405	573	661374	508
148	10956	6276	384	2.24	407	573	632118	510
144	11255	6286	385	2.04	403	568	650223	503
145	11122	6202	385	1.9	404	571	650123	504
149	11094	5604	384	2.04	408	571	549458	506
144	11226	6014	378	2.62	402	567	519950	510
147	11253	5875	385	2.01	404	573	523827	505
144	10981	6460	372	1.98	385	558	445077	487
149	11234	6394	376	2.17	392	566	492896	500
159	10902	6072	380	2.04	404	576	483281	510
160	10862	6062	379	2.04	405	580	482487	511
153	10835	6141	378	1.92	400	571	531234	507
152	10792	6109	379	1.92	398	569	527355	504
150	10952	6438	378	1.86	397	572	552486	506
156	10687	6237	378	1.9	402	576	534539	507
151	10829	6229	379	1.89	397	572	550519	504
149	10734	6556	378	1.82	395	567	565477	501
149	10901	6841	376	2	396	571	551289	503
152	10436	6209	383	1.96	398	566	521898	503
153	10724	6298	378	2	400	570	501760	507
152	10301	5979	380	1.93	400	573	488747	506
148	10554	6076	379	2.01	394	565	523490	498
149	10641	6692	377	1.96	397	565	556228	507
152	10531	6536	378	1.9	397	567	542835	503
151	10566	6572	377	1.99	397	567	539402	502
152	10706	6871	377	1.92	396	567	548937	501
148	10515	6329	378	2.01	397	568	522763	503

151	10853	6873	377	1.99	394	566	537231	500
153	10620	6455	378	2.18	397	565	513004	505
156	10539	6572	380	2.04	398	567	518591	506
151	10568	6510	379	2.16	396	567	521437	505
155	10767	6661	380	2.11	397	568	524507	505
153	10862	6449	381	2.35	397	566	521783	506
155	10554	6462	382	2.06	398	568	525915	506
153	10583	6511	382	2.12	400	568	553069	508
154	10535	6554	385	2.11	401	566	566039	509
153	10460	6479	383	2.32	400	570	534597	510
156	10571	5897	386	2.35	408	575	524557	517
154	10370	6519	386	2.05	404	571	569023	511
151	10697	6583	383	2.38	397	564	546361	506
152	10687	6663	384	2.12	399	564	560831	505
151	10653	6438	383	2.33	397	565	536339	505
154	10681	6407	382	2.08	399	565	524172	504
152	10674	6463	382	2.42	397	565	537954	508
151	10916	6624	382	2.36	396	562	559481	503
154	10519	6419	383	2.17	399	564	527590	505
157	10780	6344	385	2.14	405	572	576033	511
158	10780	6359	383	2.32	405	570	556457	513
163	10405	6084	389	1.96	412	576	601237	517
156	10538	6198	384	2.07	406	574	580112	513
158	10503	6164	387	2.04	405	572	587034	511
159	10537	6181	386	2.09	406	573	575080	512
160	10513	6051	388	2.06	407	575	590538	513
156	10744	6294	385	2.22	403	570	573665	509
154	10794	6226	387	2.1	404	572	600707	510
149	10843	6395	380	2.82	392	561	523410	509
155	10895	6448	386	2.1	402	572	589483	508
155	10567	5884	384	3.09	401	570	496916	515
154	10739	6040	384	3.22	399	565	505860	513
150	11032	6130	381	3.23	393	563	486380	509
157	10819	6351	379	1.94	390	570	497947	504
154	10639	6784	378	1.94	392	573	544239	507
157	10712	6964	377	1.89	392	571	569690	506
149	10684	6915	377	1.93	389	568	561221	503
151	10786	6742	378	1.89	389	572	566505	502
147	10850	6686	382	2.11	394	571	604602	502
147	10903	6501	384	2.06	395	572	602956	503
150	10966	6164	384	2.65	397	566	550305	509
151	10816	6043	388	2.53	396	572	569707	511
159	10928	6231	383	2.57	405	574	556604	517
153	10973	6688	379	1.98	394	572	561665	504
151	11009	6346	381	2.12	397	573	561724	506
153	10971	6416	383	2.06	402	575	586253	508
151	10915	6406	382	2.12	398	572	579546	506
154	10552	6274	383	2.06	404	574	563207	510
148	10388	6883	378	2.27	399	572	609709	506
148	10844	6440	382	2.15	397	571	571010	505
152	10265	6342	389	2.07	409	573	650170	514
149	10550	6396	385	2.25	406	574	622437	511
147	10545	6404	388	2.14	404	572	665333	509
149	10433	6232	385	2.6	406	572	608629	515
147	10619	6578	386	2.11	403	571	664231	507
148	10635	6499	384	2.29	404	572	629363	509
145	10418	6581	384	2	401	572	658139	506
143	10449	6703	383	2.08	400	571	657804	504
139	10901	6751	378	2.03	395	565	630754	494
136	10944	6508	380	2.09	392	563	673099	490
139	10837	6371	378	1.98	396	564	611200	494
140	10772	6725	380	2.13	396	567	629734	499
137	10841	6982	378	2.23	393	566	648482	499
143	10665	7147	380	2.08	400	571	676616	502

137	10830	6755	378	2.19	393	565	644713	495
139	10787	6674	381	2.08	396	566	664041	497
138	10838	6562	379	2.13	395	564	655974	496
139	10725	6680	381	2.01	397	565	690864	496
140	10952	6884	381	2.09	397	567	704458	496
133	10212	7029	376	2.01	390	557	671453	491
138	10311	5899	381	2.11	395	567	613494	493
139	10430	6438	379	2.12	396	564	654029	494
144	10340	6623	381	2.14	401	571	676351	504
145	10482	6642	379	2.07	401	570	695000	501
141	10835	6657	378	2.06	398	569	666254	499
145	10346	6605	378	1.89	402	573	684433	503
143	10574	6857	378	1.96	400	571	693429	499
143	10657	7226	379	1.97	401	576	738507	503
139	10721	7691	377	1.98	397	571	767592	498
141	10643	7430	380	1.97	398	571	784814	500
137	10735	7634	377	1.99	395	570	769061	497
142	10712	6695	380	2.07	399	569	700747	499
143	10701	6723	379	2.01	400	573	671642	499
143	10742	6675	381	2.02	400	572	699929	500
147	10109	6381	381	1.92	405	574	654909	505
141	10319	6423	374	1.77	397	567	592629	496
141	10676	6487	376	1.84	398	573	635448	496
141	10376	6423	378	1.8	399	569	660347	497
143	10431	6371	379	1.82	401	571	679799	499
144	10273	6226	379	1.83	402	569	667428	499
143	10286	6386	380	1.89	401	567	697258	497
142	10251	6425	379	1.9	400	564	667329	496
146	10293	6495	381	1.88	404	572	704454	503
144	10488	6683	380	1.87	402	571	694948	501
143	10385	6583	381	1.87	401	569	707227	500
142	10481	6332	381	1.85	400	568	705534	497
142	10416	6433	379	1.86	400	565	673037	496
142	10323	6342	381	1.9	400	566	712974	497
142	10063	6067	380	1.99	400	562	685957	497
138	10322	6891	381	1.99	396	561	729430	494
140	10360	7094	380	2.1	398	566	751902	496
136	10405	7721	380	1.97	394	564	816958	494
137	10414	7087	379	2.09	395	562	746543	493
134	10391	6950	381	2.06	391	562	731479	490
139	10393	6615	382	2.39	397	563	680434	500
137	10421	6805	381	2.13	393	563	678534	495
140	10446	6552	380	2.1	395	565	640524	498
143	10364	6700	379	2.03	400	568	642204	502
145	10409	6671	382	2.03	402	575	673271	505
146	10425	6563	382	2.17	404	570	640351	508
144	10251	6893	380	1.92	401	575	686920	506
146	10121	6862	379	1.89	404	576	697381	506
148	10299	6532	383	2	406	575	678106	507
147	10478	6661	383	2.07	405	576	676806	507
146	10484	6672	382	2.01	403	574	682653	504
146	10501	6706	383	2.06	404	573	686008	505
146	10451	6808	384	1.93	403	575	686761	506
147	10312	6616	384	1.96	404	576	672014	508
150	10261	6564	383	2	406	577	641357	509
149	10281	6590	382	2.03	405	574	641483	512
145	10371	6687	382	2.08	402	575	643324	506
146	10408	6691	382	2.01	402	575	655242	507
149	10315	6553	382	2.02	405	575	644898	510
152	10242	6854	384	2.04	409	581	665446	514
148	10119	6851	382	1.95	405	576	667581	509
151	10009	6856	384	1.95	408	576	705218	513
148	10022	7069	383	1.9	405	576	732525	510
149	10085	6594	384	1.93	407	577	694182	509

146	10595	6663	383	2.04	404	573	712857	505
146	10576	6664	383	2	404	573	710643	505
146	10272	6542	378	2.07	404	574	682581	503
143	10569	6931	380	1.93	400	572	694937	501
143	10609	7068	382	2.22	400	573	672173	505
146	10571	6618	383	1.96	403	576	710099	503
146	10354	6389	385	1.96	405	571	710204	506
144	10520	6666	383	1.91	402	572	720046	501
146	9699	6209	376	1.72	404	574	639499	505
133	10745	6478	372	1.72	392	558	727421	485
145	10764	6222	381	2.08	402	573	644462	502
138	10691	6553	378	1.79	395	565	690828	490
141	10658	6467	379	1.9	398	566	686095	493
148	10555	6151	383	2.01	404	575	658686	503
146	10565	5823	382	1.99	403	571	633938	505
145	10450	6352	383	2	401	571	671344	500
144	10457	6244	385	2.02	400	571	651344	503
142	10007	6709	379	1.79	399	572	713224	501
140	10485	6666	381	1.92	396	568	686282	497
138	10420	6545	381	1.92	395	566	661232	493
143	10557	6758	380	1.96	399	565	689200	498
137	10704	6396	381	2.12	393	561	644867	494
138	10701	6530	381	2.06	394	563	656015	496
143	9475	6405	379	1.9	402	563	638496	497
140	10043	6796	380	1.93	397	567	701678	498
140	10264	6489	381	2.09	397	566	665299	499
141	10107	6752	381	1.91	398	568	699757	499
137	10576	6576	379	2.05	394	559	666091	492
138	10562	6408	380	2.13	396	563	656019	495
142	10525	6569	380	2	399	567	674585	497
143	9733	5736	379	1.82	402	562	606729	493
142	9958	6186	381	2.03	400	565	668203	498
143	10447	6356	381	2.1	399	568	673161	500
145	10455	6137	381	2.27	402	570	653325	503
143	10326	6371	382	2.15	399	566	679053	500
150	10041	6373	381	2.13	407	573	676766	506
148	10108	6427	382	2.09	404	571	686769	504
155	9868	6409	380	2.02	412	577	714041	510
143	10089	6494	380	2	399	568	713743	498
142	10111	5948	382	2.12	398	564	656045	499
143	10188	6332	381	2.03	399	567	678033	499
143	10096	5991	381	2.09	400	564	655965	499
142	10330	6216	381	2.11	398	567	664612	499
141	10218	6316	380	2.15	398	564	636470	499
141	10150	6404	380	2.06	398	568	661806	498
143	10103	6317	379	2.12	400	567	636127	499
146	9633	5867	383	1.97	405	564	688733	499
144	9913	5928	380	2.07	402	563	659269	496
145	9949	5735	383	2.11	404	564	696455	498
147	9988	5620	384	2.2	406	564	671229	500
146	9917	5695	384	2.15	405	564	700459	499
147	9953	5492	386	2.58	406	563	687509	508
149	9923	5720	387	2.17	408	567	744333	503
144	9921	5404	384	2.26	403	563	666208	499
146	9954	5635	385	2.22	405	564	670818	500
142	9740	5337	384	2.57	401	561	625694	504
147	9865	5654	385	2.57	406	564	637704	506
147	9837	5365	384	2.58	406	564	608056	507
145	9995	5623	385	2.63	405	562	678213	505
147	9850	5441	384	2.57	406	564	618718	506
146	9848	5422	384	2.18	405	564	671709	499
150	9825	5026	388	2.49	415	562	674943	510
147	9668	5601	387	2.19	407	562	745809	503
147	9735	5507	384	2.29	406	563	680467	502

146	9709	5613	386	2.18	405	563	740615	498
144	9860	5500	385	2.47	403	561	695846	505
147	9756	5650	386	2.16	406	566	732681	501
150	9528	5377	387	2.59	409	564	689818	509
146	9581	5597	388	2.15	405	562	719739	501
146	9634	5423	386	2.05	405	562	697119	497
148	9588	5237	387	2.59	409	561	692788	507
148	9656	5296	387	2.08	408	563	701720	500
149	9720	5236	385	2.17	408	562	674615	502
146	9817	5457	387	2.08	405	563	706595	497
145	9771	5263	385	2.08	404	560	637784	497
146	9634	5480	385	2.3	405	557	619143	497
145	9747	5595	385	2.24	405	562	693278	500
145	9695	5619	386	2.14	404	561	698401	496
155	9683	5383	386	2.55	405	560	652196	504
144	9726	5542	387	2.21	403	557	697085	496
148	9657	5478	384	2.54	407	562	689532	505
145	9665	5625	386	2.46	404	560	691960	506
144	9764	5519	385	2.57	403	558	659386	504
145	9813	5423	386	2.49	404	562	657026	505
148	10001	5398	388	2.62	410	563	687089	506
147	9880	5662	388	2.58	407	562	696518	507
145	9853	5480	387	2.56	404	560	655516	505
148	9905	5552	387	2.1	407	563	689660	499
146	9766	5430	386	2.59	405	561	658516	506
145	9860	5494	388	2.17	404	562	692012	498
142	9844	5532	387	2.58	401	558	671519	503
145	9866	5602	387	2.21	404	562	662285	497
144	9737	5503	386	2.58	403	558	634700	504
145	10082	5576	389	2.23	404	562	686384	497
147	10148	5531	390	2.58	407	565	659701	507
148	10299	5440	391	2.62	408	566	681147	507
142	10175	5503	388	2.57	402	565	660468	504
153	10215	5983	391	2.45	412	571	709938	507
143	10260	6041	393	2.61	403	567	695099	508
152	9789	5804	395	2.14	412	568	729781	509
149	9754	5238	395	2.72	409	568	651968	512
146	9734	5427	396	2.2	406	568	678401	505
154	9427	5398	397	2.58	416	572	673127	516
147	9575	5444	396	2.2	407	566	671793	505
147	9909	5422	395	2.1	406	567	680577	503
149	10016	5418	393	2.21	409	574	666403	506
143	10104	5398	393	2.12	403	563	677164	497
147	10055	5263	394	2.57	407	565	659816	507
142	10164	5459	394	2.41	401	562	657402	498
144	10164	5441	395	2.58	404	566	668653	506
143	10264	5468	395	2.19	402	567	670152	502
148	9907	5247	398	2.55	408	570	628369	513
137	10273	5464	391	3.25	396	558	602003	501
137	10098	5645	389	3.27	395	562	600731	500
143	10110	5543	394	2.67	402	566	631159	507
143	9787	5684	393	2.12	401	565	639241	499
142	10195	5534	393	2.13	401	565	636914	497
139	10189	5491	392	2.58	398	558	649914	501
144	10098	5363	395	2.51	403	562	673814	506
145	9828	5435	391	2.4	403	566	618181	505
141	10033	5959	393	2.6	400	563	626330	506
139	10031	5574	391	2.43	397	563	570846	502
139	9963	5471	390	2.53	398	558	548267	502
155	10060	5350	392	2.05	413	578	582090	508
149	9974	5514	392	2.48	408	566	579934	509
145	10001	5491	394	2.42	403	567	585133	507
147	9365	5572	390	2.55	404	570	569381	511
152	9690	5450	395	1.87	411	566	564961	501

144	9793	5681	386	2.53	403	563	576749	507
148	8995	5651	388	2.55	406	560	625439	508
145	9014	5611	388	2.54	404	563	582622	509
145	8946	5712	388	2.59	403	557	607854	508
149	9019	5925	387	2.59	407	568	559445	514
155	8978	6025	392	2.59	414	575	664085	519
147	8990	5815	391	2.61	402	565	599161	515
147	9349	5977	388	2.57	402	570	577016	517
148	8916	6082	387	2.61	404	572	542630	518
148	9124	5861	388	2.59	404	568	619350	515
152	8926	6103	390	2.59	408	575	630756	521
152	8749	5552	391	2.81	408	573	618408	520
146	8809	5689	388	3.04	402	564	626545	517
150	8820	5637	390	2.74	406	571	628673	519
151	8931	5574	386	2.76	402	567	589620	517
148	8830	5679	386	3.12	402	566	587219	517
152	9089	5748	386	2.57	402	570	574045	516
153	9050	5494	388	2.17	404	572	619339	511
154	9064	5638	386	2.34	404	571	603585	513
153	9167	5755	385	2.26	399	567	576941	508
149	9146	5591	389	3.17	403	570	622328	517
148	9006	5431	387	3.12	399	565	590049	513
159	8949	5533	390	2.34	404	569	592044	512
161	8998	5140	389	2.96	406	572	519306	521
155	9109	5133	390	2.64	400	568	558757	516
159	8676	5188	390	3.34	409	576	562491	520
153	8818	5071	381	3.3	396	564	507944	513
147	8701	5035	382	3.08	404	566	557286	516
157	8145	5115	389	2.35	413	576	580131	520
158	8139	5248	388	2.3	414	576	575053	520
150	9339	6320	376	2.28	404	571	598304	508
149	8961	6191	377	2.27	404	566	562126	509
151	9051	6235	376	2.35	405	572	553503	510
152	9000	6296	376	2.31	406	574	561737	514
153	9004	6237	376	2.33	407	574	552218	515
153	9313	6048	378	3.04	406	575	506776	518
159	9239	5876	382	3.33	417	578	542984	526
154	8380	6623	378	2.22	409	573	534676	516
151	9271	7650	374	2.49	406	577	534451	516
157	8555	5711	380	2.29	411	577	532251	518
149	9678	7407	377	3.01	404	575	512733	516
150	10008	8236	377	2.24	406	579	584828	515
153	9360	7563	378	2.29	408	578	532908	516
153	9436	6640	384	3.3	410	573	535237	517
152	9828	6944	380	3.34	405	575	482004	518
156	10184	6878	377	2.89	401	574	471643	515
155	10161	6781	378	2.34	399	575	485891	509
171	9431	6080	383	2.03	417	592	464236	527
160	9200	6271	384	2.04	415	587	493526	517
159	9207	6302	384	2.09	415	581	490972	515
156	9296	6540	382	2.11	412	578	503316	515
140	10141	6470	376	2.68	396	561	452661	499
140	10318	6749	378	2.76	394	565	511390	501
146	10575	6665	380	3.08	400	572	468670	509
146	10603	6907	385	2.27	400	573	534159	506
145	10307	6868	383	2.52	400	576	520671	508
146	10745	7138	380	2.98	399	574	465033	510
148	11036	7099	384	3.23	403	580	502424	513
154	11092	6945	388	3.27	410	587	491275	522
159	10081	7038	386	2.48	414	584	512259	521
153	10102	7201	384	2.79	406	579	503718	520
164	9827	7252	386	2.08	420	589	537719	520
157	9596	4714	376	2.58	407	564	510354	514

Note: These data sets can easily be loaded in MATLAB workspace by writing the following codes in command window:

```
[x,t] = chemical_dataset;
inputs = x';
outputs = t';
```

7. Training ANN using PSO and Application of the Trained ANN (Result and discussion)

All the three files ('myfunc.m', 'nn_pso.m', and 'datafile.xlsx') must be placed in the same directory of MATLAB to train the ANN using PSO. Now, run 'nn_pso.m' file to train ANN using PSO. The trained ANN is **'net_f'**. Once the training is completed the regression plot will be displayed. Figure 4 shows the regression plot of the trained ANN (net_f). From this figure, it is observed that regression coefficient R is 0.96394.

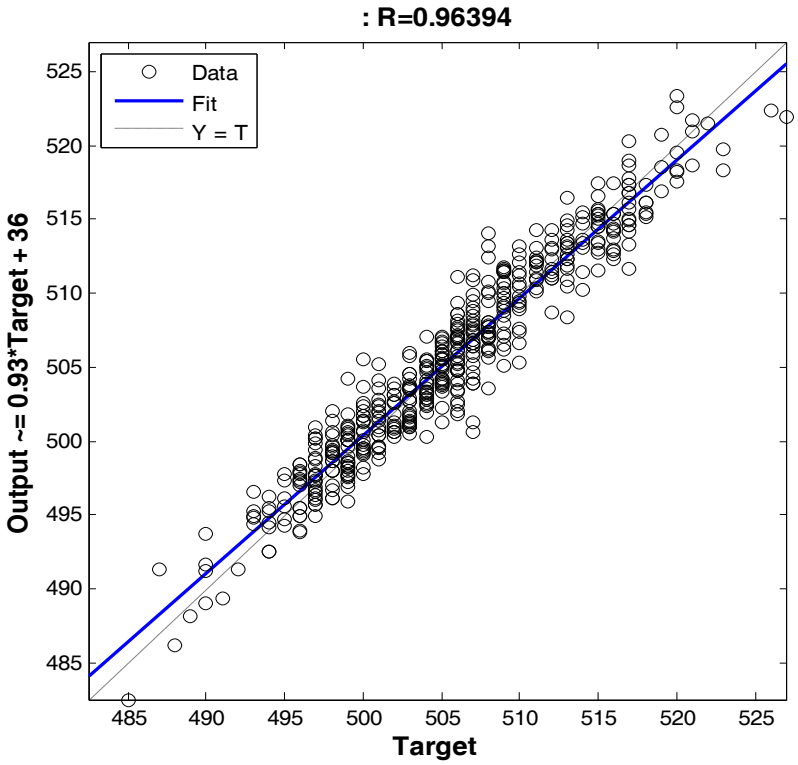

Figure 4: Regression plot of the trained ANN (net_f)

Now, the trained network can be applied to know the output of unknown input features. Let input feature for the trained ANN of the mentioned dataset is test_input which is given below.

```
test_input = [155, 9516, 5205, 388, 2.19, 412, 574, 522021];
```

Now, to know the output corresponding to this input, the following need to be written in the MATLAB's command window;

```
test_output = net_f(test_input')
```

This is giving the output as 515.1436.

Actually, the test_input is the 10th dataset taken from Table I whose target is 518. Thus, the trained network is given the output (test_output) with 0.55% error.

8. Conclusion

This paper presents codes in MATLAB for training artificial neural network (ANN) using particle swarm optimization (PSO). The presented codes have been tested for training ANN using cheminal_dataset available in MATLAB.

References

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