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%
%The files contain code and data associated with the paper titled
%"A Deep Learning Approach to Estimate Stress Distribution: A Fast and
%Accurate Surrogate of Finite Element Analysis".
%
%The paper is authored by Liang Liang, Minliang Liu, Caitlin Martin,
%and Wei Sun, and published at Journal of The Royal Society Interface, 2018.
%
%The file list: ShapeData.mat, StressData.mat, DLStress.py, im2patch.m,
%UnsupervisedLearning.m, ReadMeshFromVTKFile.m, ReadPolygonMeshFromVTKFile.m,
%WritePolygonMeshAsVTKFile.m, Visualization.m, TemplateMesh3D.vtk, TemplateMesh2D.vtk.
%Note: *.m and *.py files were converted to pdf files for documentation purpose.
%
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%FOR A PARTICULAR PURPOSE.
%=====
%%
function Result=UnsupervisedLearning (OutputDataFile, ShapeDataFile, StressDataFile,
IdxList_train, IdxList_test)
%%
Result=0;
load(ShapeDataFile)
load(StressDataFile)
IdxList_train=IdxList_train(:)';
IdxList_test=IdxList_test(:)';
%%
ShapeData_train=ShapeData(:,IdxList_train);
ShapeData_test=ShapeData(:,IdxList_test);
MeanShape=mean(ShapeData_train,2);
X=zeros(size(ShapeData_train));
for k=1:length(IdxList_train)
    X(:,k)=ShapeData_train(:,k)-MeanShape;
end
X=X/sqrt(length(IdxList_train));
[U, S, V]=svd(X);
Lambda=diag(S);
V123=sum(Lambda(1:3).^2)/sum(Lambda.^2);
PC={};
PC_count=3;
for k=1:PC_count
    PC{k}=U(:,k);
end
Proj=[];
for k=1:PC_count
    Proj(:,k)=U(:,k)/Lambda(k);
end
ShapeCode_train=zeros(PC_count,length(IdxList_train));
ShapeError_train=zeros(1,length(IdxList_train));
for k=1:length(IdxList_train)

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temp=ShapeData_train(:,k)-MeanShape;
c=zeros(1,PC_count);
for n=1:PC_count
    c(n)=sum(PC{n}(:).*temp(:))/Lambda(n);
end
ShapeCode_train(:,k)=c;
end
ShapeCode_test=zeros(PC_count,length(IdxList_test));
ShapeError_test=zeros(1,length(IdxList_test));
for k=1:length(IdxList_test)
    temp=ShapeData_test(:,k)-MeanShape;
    c=zeros(1,PC_count);
    for n=1:PC_count
        c(n)=sum(PC{n}(:).*temp(:))/Lambda(n);
    end
    ShapeCode_test(:,k)=c;
end
%%
StressData_train=StressData(:,: ,IdxList_train);
StressData_test=StressData(:,: ,IdxList_test);
S11_train=reshape(StressData_train(1,:,:),[5000,length(IdxList_train)]);
S22_train=reshape(StressData_train(2,:,:),[5000,length(IdxList_train)]);
S12_train=reshape(StressData_train(4,:,:),[5000,length(IdxList_train)]);
Sdata_train=zeros(50,100,3,length(IdxList_train));
for k=1:length(IdxList_train)
    Sdata_train(:,: ,1,k)=reshape(S11_train(:,k),[50,100]);
    Sdata_train(:,: ,2,k)=reshape(S22_train(:,k),[50,100]);
    Sdata_train(:,: ,3,k)=reshape(S12_train(:,k),[50,100]);
end
S11_test=reshape(StressData_test(1,:,:),[5000,length(IdxList_test)]);
S22_test=reshape(StressData_test(2,:,:),[5000,length(IdxList_test)]);
S12_test=reshape(StressData_test(4,:,:),[5000,length(IdxList_test)]);
Sdata_test=zeros(50,100,3,length(IdxList_test));
for k=1:length(IdxList_test)
    Sdata_test(:,: ,1,k)=reshape(S11_test(:,k),[50,100]);
    Sdata_test(:,: ,2,k)=reshape(S22_test(:,k),[50,100]);
    Sdata_test(:,: ,3,k)=reshape(S12_test(:,k),[50,100]);
end
%%
Data1=[];
for k=1:length(IdxList_train)
    tempPatch=im2patch(Sdata_train(:,: ,k),[10,20],[10,20]);
    for n=1:size(tempPatch,4)
        temp=tempPatch(:,: ,n);
        Data1(:,end+1)=temp(:);
    end
end
Data1=single(Data1);
C1=Data1*Data1'/size(Data1,1);
[P1,L1,V1]=svd(C1);
L1=sqrt(diag(L1));
%% setup MatConvnet
run('Z:\matconvnet-1.0-beta24\matlab\vl_setupnn.m')

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%%
W1=[];
Ps1=P1(:,1:256);
for k=1:size(Ps1,2)
    W1(:,:,:,k)=reshape(Ps1(:,k),[10,20,3]);
end
Y1=vl_nnconv(Sdata_train,W1,zeros(1,size(W1,4)), 'stride',[10,20]);
Data2=[];
for k=1:size(Y1,4)
    temp=Y1(:,:,:,k);
    Data2(:,end+1)=temp(:);
end
Data2=single(Data2);
C2=Data2*Data2'/size(Data2,1);
[P2,L2,V2]=svd(C2);
L2=sqrt(diag(L2));
W2=[];
Ps2=P2(:,1:64);
for k=1:size(Ps2,2)
    W2(:,:,:,k)=reshape(Ps2(:,k),[size(Y1,1),size(Y1,2),size(Y1,3)]);
end
Y2=vl_nnconv(Y1,W2,zeros(1,size(W2,4)), 'stride',1);
Y1_t=vl_nnconv(Sdata_test,W1,zeros(1,size(W1,4)), 'stride',[10,20]);
Y2_t=vl_nnconv(Y1_t,W2,zeros(1,size(W2,4)), 'stride',1);
Y2n_train=zeros(size(Y2));
for k=1:64
    Y2n_train(:,:,:,k)=Y2(:,:,:,k)/L2(k);
end
Y2n_test=zeros(size(Y2_t));
for k=1:64
    Y2n_test(:,:,:,k)=Y2_t(:,:,:,k)/L2(k);
end
%%
Stress_train=[S11_train;S22_train;S12_train];
Stress_test=[S11_test;S22_test;S12_test];
try
delete(OutputDataFile)
catch
end
save(OutputDataFile,'MeanShape','Proj','ShapeCode_train','ShapeCode_test','Stress_train','Stress_test',...
'Y2n_train','Y2n_test','L2','W1','W2',...
'OutputDataFile','ShapeDataFile','StressDataFile','IdxList_train','IdxList_test');
Result=1;

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