Adding noise to mesh

```
In[∘]:= NotebookDirectory[]
Out[∘]= D:\LocalData\hashmial\3D vertex model - github\curved monolayer\create monolayer - noisy\
```

Import Mesh

```
In[∘]:= DumpGet["D:\\LocalData\\hashmial\\3D vertex model -
            github\\curved monolayer\\create monolayer - smooth\\smoothgeometry.mx"];

In[∘]:= edges = SetPrecision[edges, 8];
        indToPtsAssoc = SetPrecision[indToPtsAssoc, 8];
        ptsToIndAssoc = KeyMap[SetPrecision[#, 8] &, ptsToIndAssoc];
        xLim = SetPrecision[xLim, 8];
        yLim = SetPrecision[yLim, 8];
        yLim -= yLim⟦1⟧;
        faceListCoords = Map[Lookup[indToPtsAssoc, #] &, cellVertexGrouping, {2}];
```

Initialization/F[x]’s

In[ ]:=

```
periodicRules::Information =
  "shift the points outside the simulation domain to inside the domain";
transformRules::Information =
  "vector that shifts the point outside the simulation domain back inside";
Clear@periodicRules;
With[{xlim1 = xLim⟦1⟧, xlim2 = xLim⟦2⟧, ylim1 = yLim⟦1⟧, ylim2 = yLim⟦2⟧},
  periodicRules = Dispatch[{
      {x_ /; x ≥ xlim2, y_ /; y ≤ ylim1, z_} ⧴ SetPrecision[{x - xlim2, y + ylim2, z}, 8],
      {x_ /; x ≥ xlim2, y_ /; ylim1 < y < ylim2, z_} ⧴ SetPrecision[{x - xlim2, y, z}, 8],
      {x_ /; xlim1 < x < xlim2, y_ /; y ≤ ylim1, z_} ⧴ SetPrecision[{x, y + ylim2, z}, 8],
      {x_ /; x ≤ xlim1, y_ /; y ≤ ylim1, z_} ⧴ SetPrecision[{x + xlim2, y + ylim2, z}, 8],
      {x_ /; x ≤ xlim1, y_ /; ylim1 < y < ylim2, z_} ⧴ SetPrecision[{x + xlim2, y, z}, 8],
      {x_ /; x ≤ xlim1, y_ /; y ≥ ylim2, z_} ⧴ SetPrecision[{x + xlim2, y - ylim2, z}, 8],
      {x_ /; xlim1 < x < xlim2, y_ /; y ≥ ylim2, z_} ⧴ SetPrecision[{x, y - ylim2, z}, 8],
      {x_ /; x ≥ xlim2, y_ /; y ≥ ylim2, z_} ⧴ SetPrecision[{x - xlim2, y - ylim2, z}, 8]
    }];

  transformRules = Dispatch[{
      {x_ /; x ≥ xlim2, y_ /; y ≤ ylim1, _} ⧴ SetPrecision[{-xlim2, ylim2, 0}, 8],
      {x_ /; x ≥ xlim2, y_ /; ylim1 < y < ylim2, _} ⧴ SetPrecision[{-xlim2, 0, 0}, 8],
      {x_ /; xlim1 < x < xlim2, y_ /; y ≤ ylim1, _} ⧴ SetPrecision[{0, ylim2, 0}, 8],
      {x_ /; x ≤ xlim1, y_ /; y ≤ ylim1, _} ⧴ SetPrecision[{xlim2, ylim2, 0}, 8],
      {x_ /; x ≤ xlim1, y_ /; ylim1 < y < ylim2, _} ⧴ SetPrecision[{xlim2, 0, 0}, 8],
      {x_ /; x ≤ xlim1, y_ /; y ≥ ylim2, _} ⧴ SetPrecision[{xlim2, -ylim2, 0}, 8],
      {x_ /; xlim1 < x < xlim2, y_ /; y ≥ ylim2, _} ⧴ SetPrecision[{0, -ylim2, 0}, 8],
      {x_ /; x ≥ xlim2, y_ /; y ≥ ylim2, _} ⧴ SetPrecision[{-xlim2, -ylim2, 0}, 8],
      {___Real} ⧴ SetPrecision[{0, 0, 0}, 8]
    }];
 ];
```

In[ ]:=

```
wrappedMat = AssociationThread[
   Keys[cellVertexGrouping] → Map[Lookup[indToPtsAssoc, #] /. periodicRules &,
     Values[cellVertexGrouping], {2}]];
```

In[ ]:=

```
triangulateFaces[faces_] := Block[{edgelen, ls, mean},
   (ls = Partition[#, 2, 1, 1];
     edgelen = Norm[SetPrecision[First[#] - Last[#], 8]] & /@ ls;
     mean = Total[edgelen * (Midpoint /@ ls)] / Total[edgelen];
     mean  = mean~SetPrecision~8;
     Map[Append[#, mean] &, ls]) & /@ faces
  ];
```

```
In[ ]:= With[{xlim1 = xLim⟦1⟧, xlim2 = xLim⟦-1⟧, ylim1 = yLim⟦1⟧, ylim2 = yLim⟦-1⟧},
          wrappedBoundaryPts[indptsassoc_, ptstoindassoc_] :=
           Block[{pts, ptsxy, ptsx, ptsy, zmin, zmax, posx,
             negx, posy, negy, outsidePts, outsidePtscoords, shiftedpts},
            pts = Values[indptsassoc];
            ptsxy = pts⟦All, 1 ;; 2⟧;
            ptsx = ptsxy⟦All, 1⟧;
            ptsy = ptsxy⟦All, 2⟧;
            {zmin, zmax} = MinMax@pts⟦All, -1⟧;
            posx = Position[UnitStep[ptsx - xlim2], 1];
            negx = Position[ptsx, x_ /; x ≤ xlim1];
            posy = Position[UnitStep[ptsy - ylim2], 1];
            negy = Position[ptsy, y_ /; y ≤ ylim1];
            outsidePts = Union@Flatten[posx~Append~negx~Append~posy~Append~negy];
            outsidePtscoords = Lookup[indptsassoc, outsidePts];
            shiftedpts = Map[
              Block[{tempvec = #},
                tempvec = Which[tempvec⟦1⟧ ≥  xlim2,
                  {tempvec⟦1⟧ - xlim2, tempvec⟦2⟧, tempvec⟦-1⟧}~SetPrecision~8,
                  tempvec⟦1⟧ ≤ xlim1,
                  {tempvec⟦1⟧ + xlim2, tempvec⟦2⟧, tempvec⟦-1⟧}~SetPrecision~8,
                  True, tempvec
                 ];
                tempvec = Which[tempvec⟦2⟧ ≥ ylim2,
                  {tempvec⟦1⟧, tempvec⟦2⟧ - ylim2, tempvec⟦-1⟧}~SetPrecision~8,
                  tempvec⟦2⟧ ≤  ylim1,
                  {tempvec⟦1⟧, tempvec⟦2⟧ + ylim2, tempvec⟦-1⟧}~
                   SetPrecision~8, True, tempvec]
               ] &, outsidePtscoords];
            Thread[
             {outsidePtscoords, Lookup[indptsassoc, Lookup[ptstoindassoc, shiftedpts]]}]
           ]
         ];
```

In[•]:=

```
displaceVertices[indToPtsAssoc_, stitchedPtsInds_, cellVertexGrouping_,
   stdDev_ : 0.05] := Block[{noiseFunc, lenstitchedPtsInds, unstitchedptsInds,
    newunstitchedpts, newunstitchedindtopts, newstitchedindtopts,
    $indToPtsAssoc, $ptsToIndAssoc, $edges, $faceListCoords, $wrappedMat},
   noiseFunc[μ_, σ_, n_] := RandomVariate[NormalDistribution[μ, σ], {n, 3}];
   lenstitchedPtsInds = Length@stitchedPtsInds;
   unstitchedptsInds = Complement[Keys@indToPtsAssoc, Flatten@stitchedPtsInds];
   newunstitchedpts = SetPrecision[Lookup[indToPtsAssoc, unstitchedptsInds] +
      noiseFunc[0., stdDev, Length@unstitchedptsInds], 8];
   newunstitchedindtopts = Thread[unstitchedptsInds → newunstitchedpts];
   newstitchedindtopts =
    MapThread[(x ↦ x → SetPrecision[Lookup[indToPtsAssoc, x] + #2, 8]) /@ #1 &,
     {stitchedPtsInds, noiseFunc[0., stdDev, lenstitchedPtsInds]}];
   $indToPtsAssoc = KeySort@<|newunstitchedindtopts ~ Join ~ newstitchedindtopts|>;
   $ptsToIndAssoc = AssociationMap[Reverse, $indToPtsAssoc];
   $faceListCoords = Map[Lookup[$indToPtsAssoc, #] &, cellVertexGrouping, {2}];
   $wrappedMat = AssociationThread[
     Keys[cellVertexGrouping] → Map[Lookup[$indToPtsAssoc, #] /. periodicRules &,
       Lookup[cellVertexGrouping, Keys[cellVertexGrouping]], {2}]];
   $edges = Flatten[Map[Partition[#, 2, 1, 1] &, Map[Lookup[$indToPtsAssoc, #] &,
        Values[cellVertexGrouping], {2}], {2}], 2] // DeleteDuplicatesBy[Sort];
   {$indToPtsAssoc, $ptsToIndAssoc, $faceListCoords, $wrappedMat, $edges}
  ];
```

In[•]:=

```
𝒟 = Rectangle[{First@xLim, First@yLim}, {Last@xLim, Last@yLim}];
```

In[•]:=

```
getLocalTopology[ptsToIndAssoc_, indToPtsAssoc_, vertexToCell_,
    cellVertexGrouping_, wrappedMat_, faceListCoords_][vertices_] :=
  Module[{localtopology = <||>, wrappedcellList = {}, vertcellconns,
    localcellunion, vertInBounds, v, wrappedcellpos, vertcs = vertices,
    transVector, wrappedcellCoords, wrappedcells, vertOutofBounds,
    shiftedPt, transvecList = {}, $faceListCoords = Values@faceListCoords,
    vertexQ},
   vertexQ = MatchQ[vertices, {__?NumberQ}];
   If[vertexQ,
    vertcellconns =
     AssociationThread[{#}, {vertexToCell[ptsToIndAssoc[#]]}] &@vertices;
    vertcs = {vertices};
    localcellunion = Flatten[Values@vertcellconns],
    (* this will yield vertex → cell indices connected in the local mesh *)
    vertcellconns =
     AssociationThread[#, Lookup[vertexToCell, Lookup[ptsToIndAssoc, #]]] &@vertices;
    localcellunion = Union@Flatten[Values@vertcellconns];
   ];
   (* condition to be an internal
 edge: both vertices should have 3 or more neighbours *)
(*Print["All topology known"];*)
(* the cells in the local mesh define the entire network topology →
 no wrapping required *)
(* else cells need to be wrapped because other cells are
  connected to the vertices → periodic boundary conditions *)
With[{vert = #},
   If[((𝒟~RegionMember~Most[vert]) && ! (vert⟦1⟧ == xLim⟦2⟧ || vert⟦2⟧ == yLim⟦2⟧)),
     (* the vertex has less than
      3 neighbouring cells but the vertex is within bounds *)
     (*Print["vertex inside bounds with fewer than 3 cells"];*)
     v = vertInBounds = vert;
     (* find cell indices that are attached to the vertex in wrappedMat *)
     wrappedcellpos = DeleteDuplicatesBy[
       Cases[Position[wrappedMat, x_ /; SameQ[x, v], {3}],
        {Key[p : Except[Alternatives @@
              Join[localcellunion, Flatten@wrappedcellList]]], y__} :→ {p, y}],
       First];
     (*wrappedcellpos = wrappedcellpos/.
        {Alternatives@@Flatten[wrappedcellList],__} :→ Sequence[];*)
     (* if a wrapped cell has not been considered earlier (i.e. is new)
      then we translate it to the position of the vertex *)
     If[wrappedcellpos ≠ {},
      If[vertexQ,
       transVector = SetPrecision[(v - Extract[$faceListCoords,
              Replace[#, {p_, q__} :→ {Key[p], q}, {1}]]) & /@ wrappedcellpos, 8],
       (*the main function is enquiring an edge and not a vertex*)
       transVector =
        SetPrecision[(v - Extract[$faceListCoords, #]) & /@ wrappedcellpos, 8]
      ];
      wrappedcellCoords = MapThread[
        #1 → Map[Function[x, SetPrecision[x + #2, 8]], $faceListCoords⟦#1⟧, {2}] &,
        {First /@ wrappedcellpos, transVector}];
      wrappedcells = Keys@wrappedcellCoords;
      AppendTo[wrappedcellList, Flatten@wrappedcells];
      AppendTo[transvecList, transVector];
      AppendTo[localtopology, wrappedcellCoords];
      (*local topology here only has wrapped cell *)
     ],
     (*Print["vertex out of bounds"];*)
     (* else vertex is out of bounds *)
     vertOutofBounds = vert;
     (* translate the vertex back into mesh *)
     transVector = vertOutofBounds /. transformRules;
     shiftedPt = SetPrecision[vertOutofBounds + transVector, 8];
     (* find which cells the vertex is a part of in the wrapped matrix *)
     wrappedcells = Complement[
        Union@Cases[Position[wrappedMat, x_ /; SameQ[x, shiftedPt], {3}],
           x_Key ⧴ Sequence @@ x, {2}] /. Alternatives @@ localcellunion → Sequence[],
        Flatten@wrappedcellList];
      (*forming local topology now that we know the wrapped cells *)
      If[wrappedcells ≠ {},
       AppendTo[wrappedcellList, Flatten@wrappedcells];
       wrappedcellCoords = AssociationThread[wrappedcells,
         Map[Lookup[indToPtsAssoc, #] &, cellVertexGrouping[#] & /@ wrappedcells, {2}]
        ];
       With[{opt = (vertOutofBounds /. periodicRules)},
        Block[{pos, vertref, transvec},
          Do[
           With[{cellcoords = wrappedcellCoords[cell]},
            pos = FirstPosition[cellcoords /. periodicRules, opt];
            vertref = Extract[cellcoords, pos];
            transvec = SetPrecision[vertOutofBounds - vertref, 8];
            AppendTo[transvecList, transvec];
            AppendTo[localtopology, cell →
              Map[SetPrecision[# + transvec, 8] &, cellcoords, {2}]];
           ], {cell, wrappedcells}]
         ];
       ];
      ];
     ];
   ] & /@ vertcs;
 If[localcellunion ≠ {},
  AppendTo[localtopology,
   Thread[localcellunion →
     Map[Lookup[indToPtsAssoc, #] &, cellVertexGrouping /@ localcellunion, {2}]]
  ]
 ];
 (*Print[Values@localtopology//Min/@Map[Precision,#,{3}]&];*)
 transvecList = Which[
   MatchQ[transvecList, {{{__?NumberQ}}}], First[transvecList],
   MatchQ[transvecList, {{__?NumberQ} ..}], transvecList,
   True, transvecList //. {x___, {p : {__?NumberQ} ..}, y___} ⧴ {x, p, y}
  ];
 {localtopology, Flatten@wrappedcellList, transvecList}
];
```

Addition of noise

In[∘]:=
```
outsideptspairs = wrappedBoundaryPts[indToPtsAssoc, ptsToIndAssoc];
mappedpts = GroupBy[#~Join~Reverse[#, 2] &@
    (Rule @@ Lookup[ptsToIndAssoc, #] & /@ outsideptspairs), First → Last];
```

In[∘]:=
```
stitchedPtsInds = Block[{wrapI, bpconn, val, temp, keys = Keys@mappedpts},
    ParallelTable[
     wrapI = {i};
     bpconn = First@FixedPoint[
        (val = #⟦-1⟧;
          temp = Flatten[Lookup[mappedpts, #] &@val];
          wrapI = If[Complement[temp, #1⟦1⟧] ≠ {},
            Union@Flatten@Append[wrapI, temp], wrapI];
          {wrapI, temp}) &, {wrapI, wrapI}, SameTest → (#⟦1⟧ === #2⟦1⟧ &)], {i, keys}]
   ] // DeleteDuplicatesBy[Sort];
```

In[∘]:=
```
bpts = Union@Flatten@stitchedPtsInds;
innerptsInds = Complement[Keys@indToPtsAssoc, bpts];
```

In[∘]:=
```
SeedRandom[3];
{$indToPtsAssoc, $ptsToIndAssoc, $faceListCoords, $wrappedMat, $edges} =
  displaceVertices[indToPtsAssoc, stitchedPtsInds, cellVertexGrouping, 0.05];
```

In[∘]:=
```
$wrappedMatTrim = KeyTake[$wrappedMat, Union@Flatten[vertexToCell /@ bpts, 1]];
```

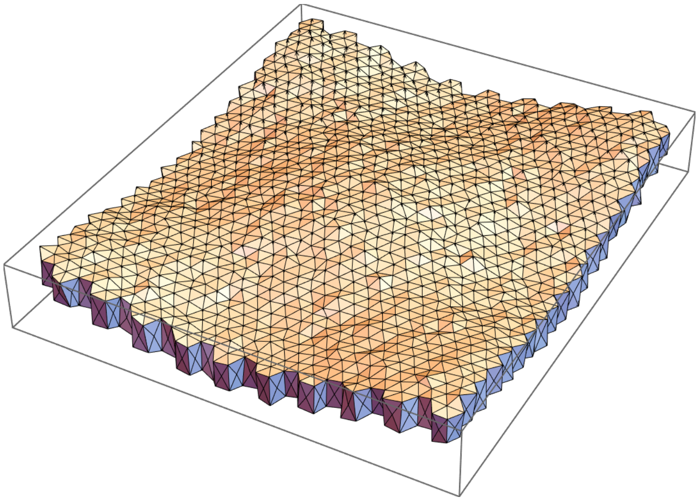
In[∘]:=
```
(problematicidx =
   Flatten@Position[Keys[getLocalTopology[$ptsToIndAssoc, $indToPtsAssoc, vertexToCell,
            cellVertexGrouping, $wrappedMatTrim, $faceListCoords][$indToPtsAssoc[#]] //
          First] & /@ bpts // Map[Length], _?(# < 3 &)]) == {}
```

Out[∘]=
```
True
```

In[∘]:=
```
mesh = Map[Lookup[$indToPtsAssoc, #] &, cellVertexGrouping, {2}];
```

```
In[•]:= Graphics3D[Polyhedron@Flatten[triangulateFaces@#, 1] & /@ Values[mesh]]
```

Out[•]=



```
In[•]:= (*Manipulate[Graphics3D[{Polyhedron@Flatten[triangulateFaces@#,1]&/@Values[mesh],
           PointSize[0.02],Red,Point@$indToPtsAssoc[#]&/@bpts⟦problemidx⟧,
           PointSize[0.01],Green,Point@$indToPtsAssoc[#]&/@Complement[bpts,bpts⟦problemidx⟧],
           PointSize[0.02],Black,Dynamic[Point@$indToPtsAssoc[i]]},
         ImageSize→Large],{i,1,Length[Keys@$indToPtsAssoc],1}]*)
```

all boundary vertices should have 3

```
In[•]:= Keys[getLocalTopology[$ptsToIndAssoc, $indToPtsAssoc,
               vertexToCell, cellVertexGrouping, $wrappedMatTrim, $faceListCoords][
             $indToPtsAssoc[#]] // First] & /@ bpts // Counts@*Map[Length]

Out[•]= <|3 → 316|>
```

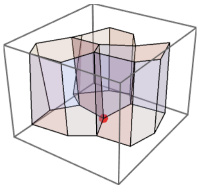
all vertices should have 3

```
In[•]:= Keys[getLocalTopology[$ptsToIndAssoc, $indToPtsAssoc, vertexToCell, cellVertexGrouping,
               $wrappedMatTrim, $faceListCoords][$indToPtsAssoc[#]] // First] & /@
           Range[Max@$ptsToIndAssoc] // Counts@*Map[Length]

Out[•]= <|3 → 1760|>
```

```
In[]:= Graphics3D[{{Opacity[0.2], Polyhedron /@ Values[
            getLocalTopology[$ptsToIndAssoc, $indToPtsAssoc, vertexToCell, cellVertexGrouping,
               $wrappedMatTrim, $faceListCoords][$indToPtsAssoc[#]] // First]},
         {Red, PointSize[0.05], Point@$indToPtsAssoc[#]}}, ImageSize → Tiny] &[
      RandomChoice@*Range@*Max@$ptsToIndAssoc]
```

Out[]=



```
In[]:=
      (*Manipulate[Graphics3D[{{Opacity[0.2],
           Polyhedron/@Values[getLocalTopology[$ptsToIndAssoc,$indToPtsAssoc,vertexToCell,
                 cellVertexGrouping,$wrappedMat,$faceListCoords][$indToPtsAssoc[i]]//First]},
          {Red,PointSize[0.03],Point@$indToPtsAssoc[i]}}],{i,1,Length@indToPtsAssoc,1}]*)
```

Exporting Mesh

Export the new mesh and all of the associated data-structures

```
(*{edges,indToPtsAssoc,ptsToIndAssoc,wrappedMat,faceListCoords}=
 {$edges,$indToPtsAssoc,$ptsToIndAssoc,$wrappedMat,$faceListCoords};
DumpSave["D:\\LocalData\\hashmial\\VERTX\\curved
   monolayer\\create monolayer - okuda noisy\\noisymesh.mx",
 {edges,indToPtsAssoc,ptsToIndAssoc,vertexToCell,cellVertexGrouping,
  wrappedMat,faceListCoords,xLim,yLim}];*)
```