

Data Import

```
In[ ]:= SetDirectory[
  "C:/Users/serha/OneDrive/Masaüstü/MyRepo/master_thesis_MMT003/210421_OR_model_and
    _other_lines_sliding"];
```

```
In[ ]:= Get["../algorithm_packages/SingleNetworks-algorithm-package.wl"]
  (* ?SingleNetworks` * *)
```

```
In[ ]:= datafull = Import["../data/ccm_manipulated_347418.csv"];
```

Data with Sliding Time Windows

```
In[ ]:= x1 = Round@Ceiling[Length@datafull / 10, 1];
  {a, b, c, d, e, f, g, h, i, j} = Join[Range[x1, Length@datafull, x1], {Length@datafull}];
  data1 = Join[{Take[datafull, {1, a}]}],
    Flatten[Table[{Take[datafull, {z[[1]] - x1 / 2, z[[2]] - x1 / 2}],
      Take[datafull, {z[[1]], z[[2]]}]}], {z,
      Partition[{a, b, c, d, e, f, g, h, i, j}, 2, 1]}], 1]];
  win1 = Length@data1;
```

```
In[ ]:= x2 = Round@Ceiling[Length@datafull / 21, 1];
  {a, b, c, d, e, f, g, h, i, j, k, l, m, n, o, p, r, s, t, u, v} =
    Join[Range[x2, Length@datafull, x2], {Length@datafull}];
  data2 = Join[{Take[datafull, {1, a}]}],
    Flatten[Table[{Take[datafull, {z[[1]] - x2 / 2, z[[2]] - x2 / 2}],
      Take[datafull, {z[[1]], z[[2]]}]}], {z,
      Partition[{a, b, c, d, e, f, g, h, i, j, k, l, m, n, o, p, r, s, t, u, v}, 2, 1]}], 1]];
  win2 = Length@data2;
```

Investigation of Constraints Impact in Time Windows

Fixed Step Size Networks

Width Feature

```
In[ ]:= step1 = 11;
  step2 = 11;
```

```
In[ ]:= AbsoluteTiming[widthdataintimewindowsFixedstep1 =
  snetworkdatabinnedintimewindows[data1, 9, step1, win1];]
```

```
Out[ ]:= {147.71, Null}
```

```
In[ ]:= graphsandnodenumbers1 = Table[snetworkgraph[widthdataintimewindowsFixedstep1[[1]][[i]],
  widthdataintimewindowsFixedstep1[[2]][[i]], 2, 7, 400, Green], {i, Range@win1}];
  modularityvalues1 = Table[N@GraphAssortativity[graphsandnodenumbers1[[i]][[1]],
    FindGraphCommunities[graphsandnodenumbers1[[i]][[1]],
    "Normalized" → False], {i, Length@graphsandnodenumbers1}];
```

```

In[ ]:= singlerandomgraphserdren1 = Table[
  RandomGraph[{VertexCount[i], EdgeCount[i]}], {i, graphsandnodenumbers1[[All, 1]]}];
singlerandomerdrenmodularityvalues1 =
  Table[N@GraphAssortativity[singlerandomgraphserdren1[[i]],
    FindGraphCommunities[singlerandomgraphserdren1[[i]], "Normalized" -> False],
    {i, Length@singlerandomgraphserdren1}];
singlerandomgraphscomm1 = Table[randomizedgraphamongcommunities[i],
  {i, graphsandnodenumbers1[[All, 1]]}];
singlerandomcommmodularityvalues1 = Table[N@GraphAssortativity[
  singlerandomgraphscomm1[[i]], FindGraphCommunities[singlerandomgraphscomm1[[i]],
    "Normalized" -> False], {i, Length@singlerandomgraphscomm1}];

In[ ]:= AbsoluteTiming[Zscoresmodularity1 = Table[randomnessfunctionformodularitytwonullmodel[i],
  {i, graphsandnodenumbers1[[All, 1]]}];]

Out[ ]:= {349.748, Null}

In[ ]:= bucketnode11 = Round@N@Mean@graphsandnodenumbers1[[All, 2]]

Out[ ]:= 82

In[ ]:= AbsoluteTiming[widthdataintimewindowsFixedstep2 =
  snetworkdatabinintimewindows[data2, 9, step2, win2];]

Out[ ]:= {104.634, Null}

In[ ]:= graphsandnodenumbers12 = Table[snetworkgraph[widthdataintimewindowsFixedstep2[[1]][[i]],
  widthdataintimewindowsFixedstep2[[2]][[i]], 2, 7, 400, Green], {i, Range@win2}];
modularityvalues12 = Table[N@GraphAssortativity[graphsandnodenumbers12[[i]][[1]],
  FindGraphCommunities[graphsandnodenumbers12[[i]][[1]], "Normalized" -> False],
  {i, Length@graphsandnodenumbers12}];

In[ ]:= bucketnode12 = Round@N@Mean@graphsandnodenumbers12[[All, 2]]

Out[ ]:= 71

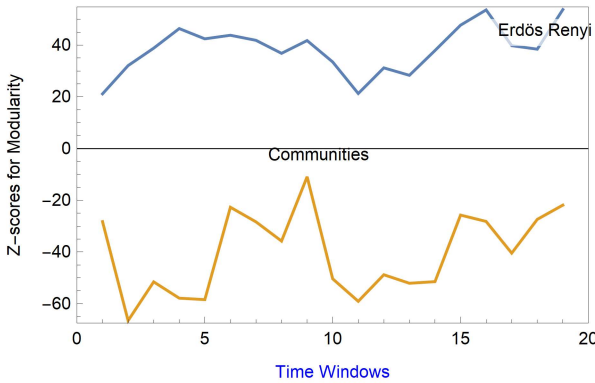
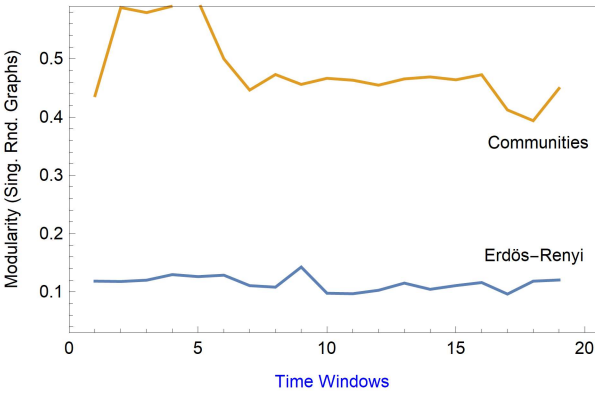
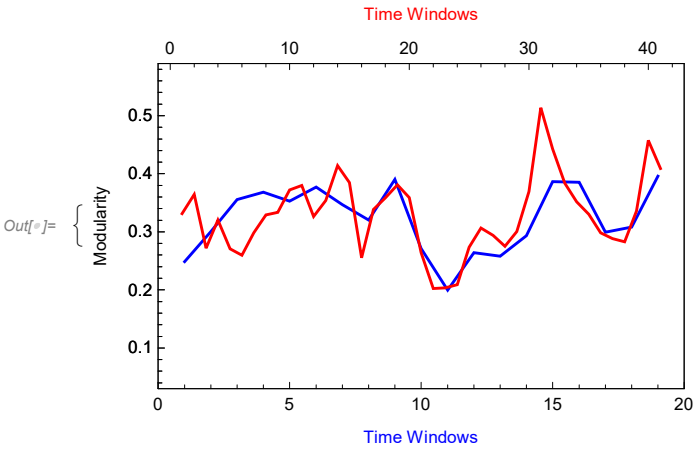
In[ ]:= (* AbsoluteTiming[widthdatafullFixedstep1=snetworkdatabinintimewindows[9,step1,datafull];
  graphsandnodenumbersdatafull1=snetworkgraph[
    widthdatafullFixedstep1[[1]],widthdatafullFixedstep1[[2]],2,7,400,Green];]
  randomnessvalues1=randomnessvaluesformodularitytwonullmodel[
    graphsandnodenumbersdatafull1[[1]]];*)

```

```

In[6]:= modularityplotrange = {0.03, 0.59};
(*MinMax[{modularityvalues1,singlerandomcommmodularityvalues1,
singlerandomerdrenmodularityvalues1,modularityvalues12}]*
{Overlay[{ListLinePlot[Thread[{Range@win1, modularityvalues1}],
Frame → True, ImagePadding → 38, FrameTicks → {{All, None}, {All, None}},
FrameLabel → {"Modularity", None}, {Style["Time Windows", Blue], None}},
PlotStyle → Blue, ImageSize → 350, PlotRange → {{0, win1 + 1}, modularityplotrange}],
ListLinePlot[Thread[{Range@win2, modularityvalues12}], Frame → True,
ImagePadding → 38, FrameTicks → {{All, None}, {None, All}},
FrameLabel → {{None, None}, {None, Style["Time Windows", Red]}}, PlotStyle → Red,
ImageSize → 350, PlotRange → {{0 - 1, win2 + 2}, modularityplotrange}}]],
ListLinePlot[{Thread[{Range@win1, singlerandomerdrenmodularityvalues1}],
Thread[{Range@win1, singlerandomcommmodularityvalues1}], Frame → True,
ImagePadding → 38, FrameTicks → {{All, None}, {All, None}}, FrameLabel →
{"Modularity (Sing. Rnd. Graphs)", None}, {Style["Time Windows", Blue], None}},
ImageSize → 350, PlotRange → {{0, win1 + 1}, modularityplotrange},
PlotLabels → Placed[{"Erdős-Renyi", "Communities"}, {Scaled[1], Below}]],
ListLinePlot[{Thread[{Range@win1, Zscoresmodularity1[[All, 1]]}],
Thread[{Range@win1, Zscoresmodularity1[[All, 2]]}],
Frame → True, ImagePadding → 42, FrameTicks → {{All, None}, {All, None}},
FrameLabel → {"Z-scores for Modularity", None}, {Style["Time Windows", Blue], None}},
ImageSize → 350, PlotRange → {{0, win1 + 1}, MinMax[Flatten[Zscoresmodularity1], 1]},
PlotLabels → Placed[{"Erdős Renyi", "Communities"}, {Scaled[1], Above}]]}

```



Thickness Feature

$ln[\epsilon] :=$ **step1 = 1;**
step2 = 1;

```

In[ ]:= AbsoluteTiming[thicknessdataintimewindowsFixedstep1 =
      snetworkdatabinnedintimewindows[data1, 10, step1, win1];]

Out[ ]:= {28.507, Null}

In[ ]:= graphsandnodenumbers2 =
      Table[snetworkgraph[thicknessdataintimewindowsFixedstep1[[1]][[i]],
      thicknessdataintimewindowsFixedstep1[[2]][[i]], 2,
      7, 400, RGBColor[0.1, 0.5, 1.]], {i, Range@win1}];
modularityvalues2 = Table[N@GraphAssortativity[graphsandnodenumbers2[[i]][[1]],
      FindGraphCommunities[graphsandnodenumbers2[[i]][[1]]],
      "Normalized" → False], {i, Length@graphsandnodenumbers2}];

In[ ]:= singlerandomgraphserdren2 = Table[
      RandomGraph[{VertexCount[i], EdgeCount[i]}], {i, graphsandnodenumbers2[[All, 1]]}];
singerandomerdrenmodularityvalues2 =
      Table[N@GraphAssortativity[singlerandomgraphserdren2[[i]],
      FindGraphCommunities[singlerandomgraphserdren2[[i]]], "Normalized" → False],
      {i, Length@singlerandomgraphserdren2}];
singerandomgraphscomm2 = Table[randomizedgraphamongcommunities[i],
      {i, graphsandnodenumbers2[[All, 1]]}];
singerandomcommmodularityvalues2 = Table[N@GraphAssortativity[
      singerandomgraphscomm2[[i]], FindGraphCommunities[singerandomgraphscomm2[[i]]],
      "Normalized" → False], {i, Length@singerandomgraphscomm2}];

In[ ]:= AbsoluteTiming[Zscoresmodularity2 = Table[randomnessfunctionformodularitytwonullmodel[i],
      {i, graphsandnodenumbers2[[All, 1]]}];]

Out[ ]:= {189.531, Null}

In[ ]:= bucketnode21 = Round@N@Mean@graphsandnodenumbers2[[All, 2]]

Out[ ]:= 19

In[ ]:= AbsoluteTiming[thicknessdataintimewindowsFixedstep2 =
      snetworkdatabinnedintimewindows[data2, 10, step1, win2];]

Out[ ]:= {24.2109, Null}

In[ ]:= graphsandnodenumbers22 =
      Table[snetworkgraph[thicknessdataintimewindowsFixedstep2[[1]][[i]],
      thicknessdataintimewindowsFixedstep2[[2]][[i]], 2,
      7, 400, RGBColor[0.1, 0.5, 1.]], {i, Range@win2}];
modularityvalues22 = Table[N@GraphAssortativity[graphsandnodenumbers22[[i]][[1]],
      FindGraphCommunities[graphsandnodenumbers22[[i]][[1]]], "Normalized" → False],
      {i, Length@graphsandnodenumbers22}];

In[ ]:= bucketnode22 = Round@N@Mean@graphsandnodenumbers22[[All, 2]]

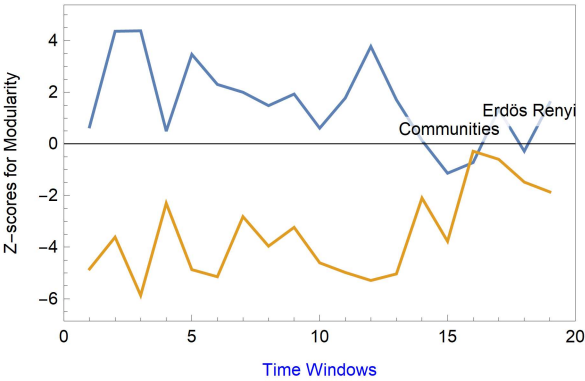
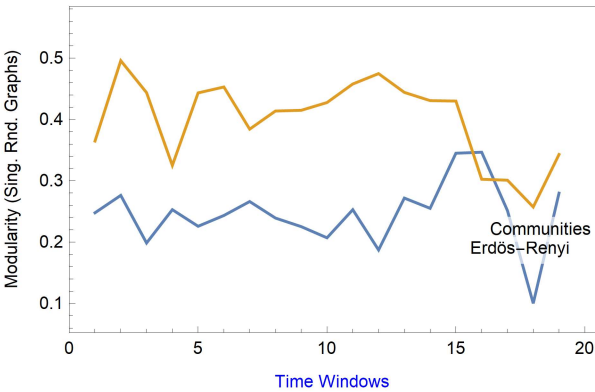
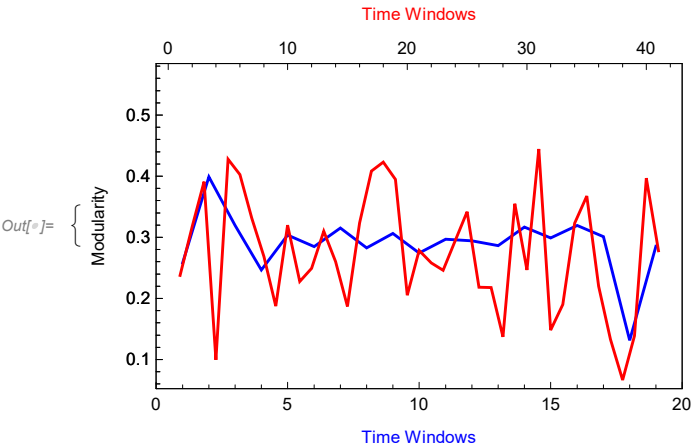
Out[ ]:= 14

```

```

In[ ]:= modularityplotrange = {0.05246, 0.584368};
(* MinMax[{modularityvalues2,singlerandomcommmodularityvalues2,
singlerandomerdrenmodularityvalues2,modularityvalues22}];*)
{Overlay[{ListLinePlot[Thread[{Range@win1, modularityvalues2}],
Frame → True, ImagePadding → 38, FrameTicks → {{All, None}, {All, None}},
FrameLabel → {"Modularity", None}, {Style["Time Windows", Blue], None}},
PlotStyle → Blue, ImageSize → 350, PlotRange → {{0, win1 + 1}, modularityplotrange}],
ListLinePlot[Thread[{Range@win2, modularityvalues22}], Frame → True,
ImagePadding → 38, FrameTicks → {{All, None}, {None, All}},
FrameLabel → {{None, None}, {None, Style["Time Windows", Red]}}, PlotStyle → Red,
ImageSize → 350, PlotRange → {{0 - 1, win2 + 2}, modularityplotrange}]]],
ListLinePlot[{Thread[{Range@win1, singlerandomerdrenmodularityvalues2}],
Thread[{Range@win1, singlerandomcommmodularityvalues2}], Frame → True,
ImagePadding → 38, FrameTicks → {{All, None}, {All, None}}, FrameLabel →
{"Modularity (Sing. Rnd. Graphs)", None}, {Style["Time Windows", Blue], None}},
ImageSize → 350, PlotRange → {{0, win1 + 1}, modularityplotrange},
PlotLabels → Placed[{"Erdős-Renyi", "Communities"}, {Scaled[1], Below}]],
ListLinePlot[{Thread[{Range@win1, Zscoresmodularity2[[All, 1]]}],
Thread[{Range@win1, Zscoresmodularity2[[All, 2]]}],
Frame → True, ImagePadding → 42, FrameTicks → {{All, None}, {All, None}},
FrameLabel → {"Z-scores for Modularity", None}, {Style["Time Windows", Blue], None}},
ImageSize → 350, PlotRange → {{0, win1 + 1}, MinMax[Flatten[Zscoresmodularity2], 1]},
PlotLabels → Placed[{"Erdős Renyi", "Communities"}, {Scaled[1], Above}]]}

```



Fixed Bucket Size Networks

Width Feature

```

In[ ]:= AbsoluteTiming[widthdataintimewindowsFixedbucket1 =
      snetworkdatafxdbucketintimewindows[data1, 9, bucketnode11, win1];]

Out[ ]:= {12.2497, Null}

In[ ]:= graphsandnodenumbers3 = Table[snetworkgraph[widthdataintimewindowsFixedbucket1[[1]][[i]],
      widthdataintimewindowsFixedbucket1[[2]][[i]], 1.5, 7, 400, Green], {i, Range@win1}];
modularityvalues3 = Table[N@GraphAssortativity[graphsandnodenumbers3[[i]][[1]],
      FindGraphCommunities[graphsandnodenumbers3[[i]][[1]]],
      "Normalized" → False], {i, Length@graphsandnodenumbers3}];

In[ ]:= singlerandomgraphserdren3 = Table[
      RandomGraph[{VertexCount[i], EdgeCount[i]}], {i, graphsandnodenumbers3[[All, 1]]}];
singerandomerdrenmodularityvalues3 =
      Table[N@GraphAssortativity[singlerandomgraphserdren3[[i]],
      FindGraphCommunities[singlerandomgraphserdren3[[i]]], "Normalized" → False],
      {i, Length@singlerandomgraphserdren3}];
singerandomgraphscomm3 = Table[randomizedgraphamongcommunities[i],
      {i, graphsandnodenumbers3[[All, 1]]}];
singerandomcommmodularityvalues3 = Table[N@GraphAssortativity[
      singlerandomgraphscomm3[[i]], FindGraphCommunities[singlerandomgraphscomm3[[i]]],
      "Normalized" → False], {i, Length@singlerandomgraphscomm3}];

In[ ]:= AbsoluteTiming[Zscoresmodularity3 = Table[randomnessfunctionformodularitytwonullmodel[i],
      {i, graphsandnodenumbers3[[All, 1]]}];]

Out[ ]:= {332.141, Null}

In[ ]:= AbsoluteTiming[widthdataintimewindowsFixedbucket2 =
      snetworkdatafxdbucketintimewindows[data2, 9, bucketnode12, win2];]

Out[ ]:= {10.1225, Null}

In[ ]:= graphsandnodenumbers32 =
      Table[snetworkgraph[widthdataintimewindowsFixedbucket2[[1]][[i]],
      widthdataintimewindowsFixedbucket2[[2]][[i]], 1.5, 7, 400, Green], {i, Range@win2}];
modularityvalues32 = Table[N@GraphAssortativity[graphsandnodenumbers32[[i]][[1]],
      FindGraphCommunities[graphsandnodenumbers32[[i]][[1]]], "Normalized" → False],
      {i, Length@graphsandnodenumbers32}];

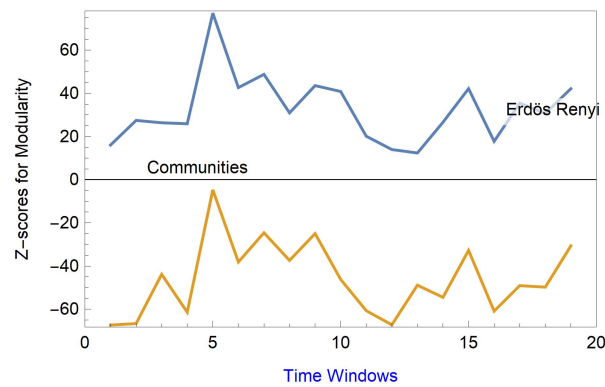
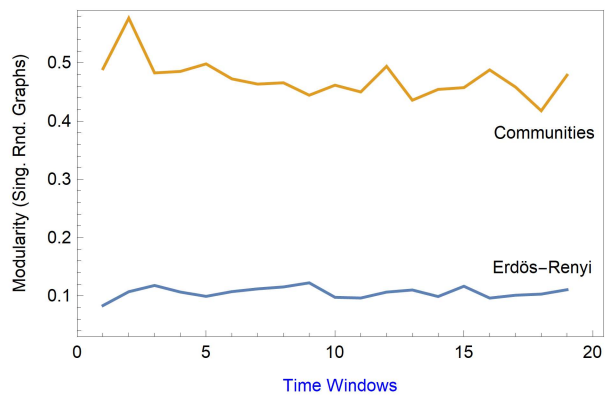
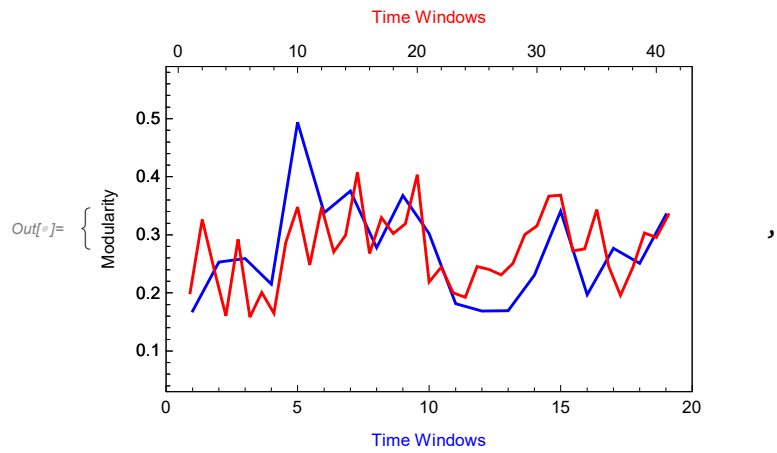
```



```

In[ ]:= modularityplotrange = {0.03, 0.59};
(* MinMax[{modularityvalues3,singlerandomcommmodularityvalues3,
singlerandomerdrenmodularityvalues3,modularityvalues32}];*)
{Overlay[{ListLinePlot[Thread[{Range@win1, modularityvalues3}],
Frame → True, ImagePadding → 38, FrameTicks → {{All, None}, {All, None}},
FrameLabel → {"Modularity", None}, {Style["Time Windows", Blue], None}},
PlotStyle → Blue, ImageSize → 350, PlotRange → {{0, win1 + 1}, modularityplotrange}],
ListLinePlot[Thread[{Range@win2, modularityvalues32}], Frame → True,
ImagePadding → 38, FrameTicks → {{All, None}, {None, All}},
FrameLabel → {{None, None}, {None, Style["Time Windows", Red]}}, PlotStyle → Red,
ImageSize → 350, PlotRange → {{0 - 1, win2 + 2}, modularityplotrange}]]],
ListLinePlot[{Thread[{Range@win1, singlerandomerdrenmodularityvalues3}],
Thread[{Range@win1, singlerandomcommmodularityvalues3}], Frame → True,
ImagePadding → 38, FrameTicks → {{All, None}, {All, None}}, FrameLabel →
{"Modularity (Sing. Rnd. Graphs)", None}, {Style["Time Windows", Blue], None}},
ImageSize → 350, PlotRange → {{0, win1 + 1}, modularityplotrange},
PlotLabels → Placed[{"Erdős-Renyi", "Communities"}, {Scaled[1], Below}]],
ListLinePlot[{Thread[{Range@win1, Zscoresmodularity3[All, 1]}],
Thread[{Range@win1, Zscoresmodularity3[All, 2]}]],
Frame → True, ImagePadding → 42, FrameTicks → {{All, None}, {All, None}},
FrameLabel → {"Z-scores for Modularity", None}, {Style["Time Windows", Blue], None}},
ImageSize → 350, PlotRange → {{0, win1 + 1}, MinMax[Flatten[Zscoresmodularity3], 1]},
PlotLabels → Placed[{"Erdős Renyi", "Communities"}, {Scaled[1], Above}]]}

```



Thickness Feature

```

In[ ]:= AbsoluteTiming[thicknessdataintimewindowsFixedbucket1 =
      snetworkdatafxdbucketintimewindows[data1, 10, bucketnode21, win1];]

```

```
Out[ ]:= {10.5703, Null}
```

```
In[ ]:= graphsandnodenumbers4 =
  Table[snetworkgraph[thicknessdataintimewindowsFixedbucket1[[1]][[i]],
    thicknessdataintimewindowsFixedbucket1[[2]][[i]],
    1.5, 7, 400, RGBColor[0.1, 0.5, 1.]], {i, Range@win1}];
modularityvalues4 = Table[N@GraphAssortativity[graphsandnodenumbers4[[i]][[1]],
  FindGraphCommunities[graphsandnodenumbers4[[i]][[1]]],
  "Normalized" -> False], {i, Length@graphsandnodenumbers4}];

In[ ]:= singlerandomgraphserdren4 = Table[
  RandomGraph[{VertexCount[i], EdgeCount[i]}], {i, graphsandnodenumbers4[[All, 1]]}];
singerandomerdrenmodularityvalues4 =
  Table[N@GraphAssortativity[singlerandomgraphserdren4[[i]],
    FindGraphCommunities[singlerandomgraphserdren4[[i]]], "Normalized" -> False],
  {i, Length@singlerandomgraphserdren4}];
singerandomgraphscomm4 = Table[randomizedgraphamongcommunities[i],
  {i, graphsandnodenumbers4[[All, 1]]}];
singerandomcommmodularityvalues4 = Table[N@GraphAssortativity[
  singerandomgraphscomm4[[i]], FindGraphCommunities[singerandomgraphscomm4[[i]]],
  "Normalized" -> False], {i, Length@singerandomgraphscomm4}];

In[ ]:= AbsoluteTiming[Zscoresmodularity4 = Table[randomnessfunctionformodularitytwonullmodel[i],
  {i, graphsandnodenumbers4[[All, 1]]}];]
```

```
Out[ ]:= {137.204, Null}
```

```
In[ ]:= AbsoluteTiming[thicknessdataintimewindowsFixedbucket2 =
  snetworkdatafxdbucketintimewindows[data2, 10, bucketnode22, win2];]
```

```
Out[ ]:= {9.35406, Null}
```

```
In[ ]:= graphsandnodenumbers42 =
  Table[snetworkgraph[thicknessdataintimewindowsFixedbucket2[[1]][[i]],
    thicknessdataintimewindowsFixedbucket2[[2]][[i]],
    1.5, 7, 400, RGBColor[0.1, 0.5, 1.]], {i, Range@win2}];
modularityvalues42 = Table[N@GraphAssortativity[graphsandnodenumbers42[[i]][[1]],
  FindGraphCommunities[graphsandnodenumbers42[[i]][[1]]], "Normalized" -> False],
  {i, Length@graphsandnodenumbers42}];
```

```

In[ ]:= modularityplotrange = {0.05246, 0.584368};
(* MinMax[{modularityvalues4,singlerandomcommmodularityvalues4,
singlerandomerdrenmodularityvalues4,modularityvalues42}];*)
{Overlay[{ListLinePlot[Thread[{Range@win1, modularityvalues4}],
Frame → True, ImagePadding → 38, FrameTicks → {{All, None}, {All, None}},
FrameLabel → {"Modularity", None}, {Style["Time Windows", Blue], None}},
PlotStyle → Blue, ImageSize → 350, PlotRange → {{0, win1 + 1}, modularityplotrange}],
ListLinePlot[Thread[{Range@win2, modularityvalues42}], Frame → True,
ImagePadding → 38, FrameTicks → {{All, None}, {None, All}},
FrameLabel → {{None, None}, {None, Style["Time Windows", Red]}}, PlotStyle → Red,
ImageSize → 350, PlotRange → {{0 - 1, win2 + 2}, modularityplotrange}]]],
ListLinePlot[{Thread[{Range@win1, singlerandomerdrenmodularityvalues4}],
Thread[{Range@win1, singlerandomcommmodularityvalues4}], Frame → True,
ImagePadding → 38, FrameTicks → {{All, None}, {All, None}}, FrameLabel →
{"Modularity (Sing. Rnd. Graphs)", None}, {Style["Time Windows", Blue], None}},
ImageSize → 350, PlotRange → {{0, win1 + 1}, modularityplotrange},
PlotLabels → Placed[{"Erdős-Renyi", "Communities"}, {Scaled[1], Below}]],
ListLinePlot[{Thread[{Range@win1, Zscoresmodularity4[[All, 1]]}],
Thread[{Range@win1, Zscoresmodularity4[[All, 2]]}],
Frame → True, ImagePadding → 42, FrameTicks → {{All, None}, {All, None}},
FrameLabel → {"Z-scores for Modularity", None}, {Style["Time Windows", Blue], None}},
ImageSize → 350, PlotRange → {{0, win1 + 1}, MinMax[Flatten[Zscoresmodularity4], 1]},
PlotLabels → Placed[{"Erdős Renyi", "Communities"}, {Scaled[1], Above}]]}

```

