Data Import

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

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

In[ ]:= datafull = Import["../data/csp_manipulated_205496.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 / 19, 1];
        {a, b, c, d, e, f, g, h, i, j, k, l, m, n, o, p, r, s, t} =
          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}, 2, 1]}], 1]];
        win2 = Length@data2;
```

Investigation of Constraints Impact in Time Windows

Fixed Step Size Networks

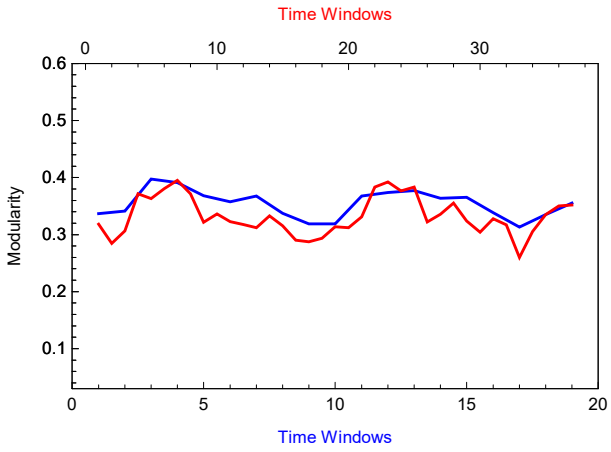
Width Feature

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

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

Out[ ]= {90.2845, 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}];
```

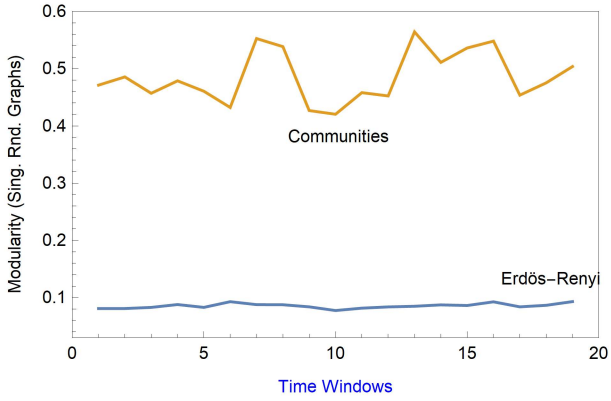
```
In[•]:= singlerandomgraphserdren1 = Table[
          RandomGraph[{VertexCount[i], EdgeCount[i]}], {i, graphsandnodenumbers1[[All, 1]]}];
        singlerandomerdrenmodularityvalues1 =
          Table[N@GraphAssortativity[singlerandomgraphserdren1[[i]],
            FindGraphCommunities[singlerandomgraphserdren1[[i]]], "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[•]= {565.607, Null}

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

Out[•]= 92

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

Out[•]= {77.4829, 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[•]= 89

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

In[•]:=
```
modularityplotrange = {0.03, 0.6};
(*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[{"Erdös-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[{"Erdös Renyi", "Communities"}, {Scaled[1], Above}]]}
```

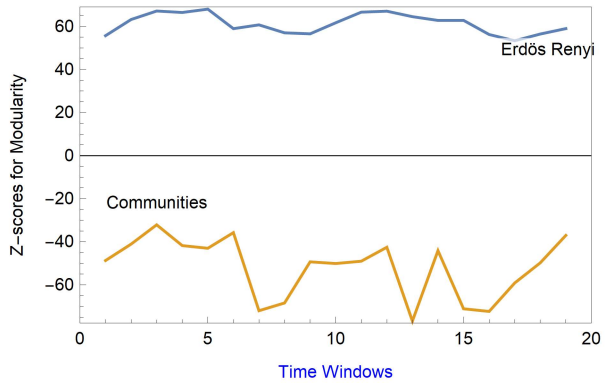
Out[ ]=



,



,



}

Thickness Feature

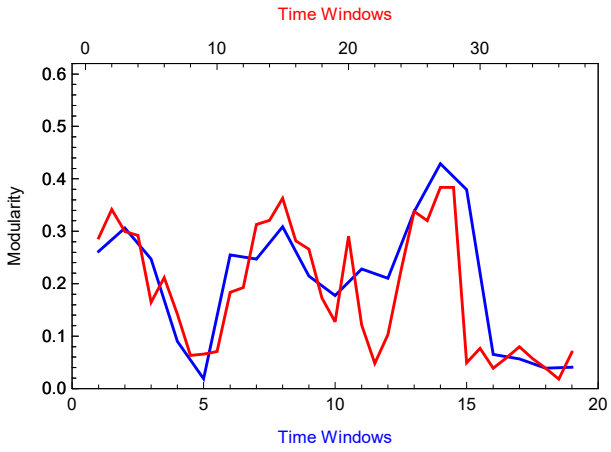
In[ ]:=

```
step1 = 0.05;
step2 = 0.05;
```

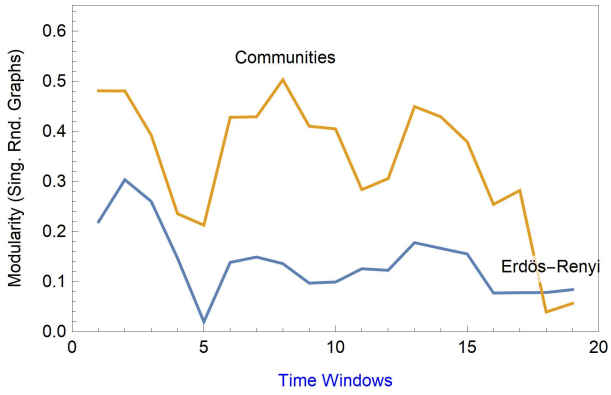
```
In[•]:= AbsoluteTiming[thicknessdataintimewindowsFixedstep1 =
          snetworkdatabinnedintimewindows[data1, 10, step1, win1];]
Out[•]= {347.463, Null}

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]]}];
      singlerandomerdrenmodularityvalues2 =
        Table[N@GraphAssortativity[singlerandomgraphserdren2[[i]],
            FindGraphCommunities[singlerandomgraphserdren2[[i]]], "Normalized" -> False],
          {i, Length@singlerandomgraphserdren2}];
      singlerandomgraphscomm2 = Table[randomizedgraphamongcommunities[i],
          {i, graphsandnodenumbers2[[All, 1]]}];
      singlerandomcommmodularityvalues2 = Table[N@GraphAssortativity[
            singlerandomgraphscomm2[[i]], FindGraphCommunities[singlerandomgraphscomm2[[i]]],
            "Normalized" -> False], {i, Length@singlerandomgraphscomm2}];

In[•]:= AbsoluteTiming[Zscoresmodularity2 = Table[randomnessfunctionformodularitytwonullmodel[i],
          {i, graphsandnodenumbers2[[All, 1]]}];]
Out[•]= {203.683, Null}

In[•]:= bucketnode21 = Round@N@Mean@graphsandnodenumbers2[[All, 2]]
Out[•]= 21

In[•]:= AbsoluteTiming[thicknessdataintimewindowsFixedstep2 =
          snetworkdatabinnedintimewindows[data2, 10, step1, win2];]
Out[•]= {309.342, 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[•]= 18
```

In[ ]:=
```
modularityplotrange = {0, 0.62};
(* 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[{"Erdös-Renyi", "Communities"}, {Scaled[1], Above}]],
 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 /. Indeterminate → 0], 1]},
  PlotLabels → Placed[{"Erdös Renyi", "Communities"}, {Scaled[1], Above}]]}
```

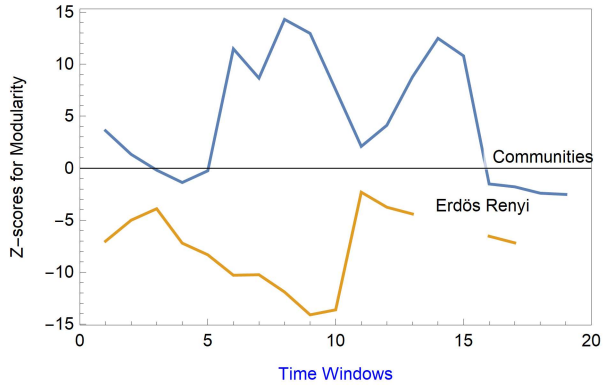
Out[•]=



,



,



}

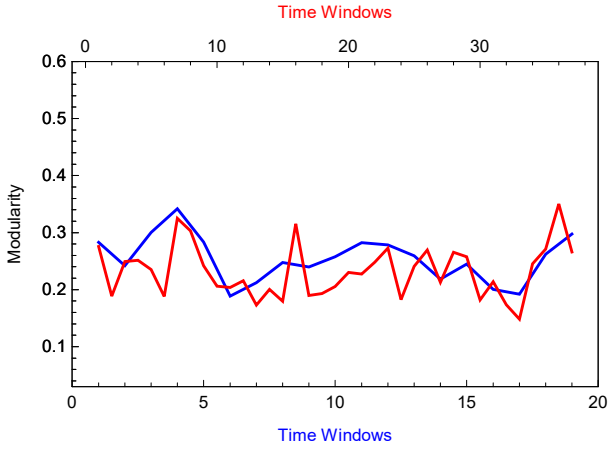
Fixed Bucket Size Networks

Width Feature

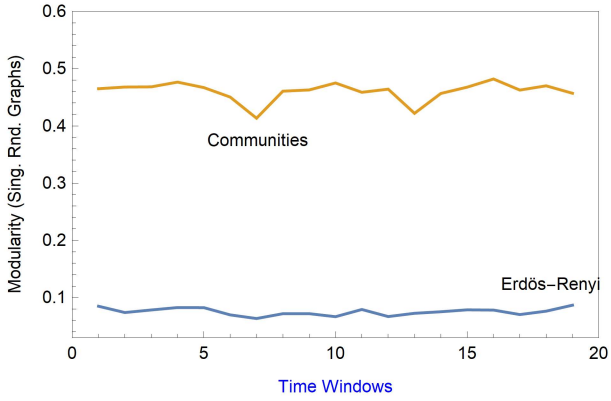
```
In[•]:= AbsoluteTiming[widthdataintimewindowsFixedbucket1 =
          snetworkdatafxdbucketintimewindows[data1, 9, bucketnode11, win1];]
Out[•]= {21.3469, Null}

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]]}];
        singlerandomerdrenmodularityvalues3 =
          Table[N@GraphAssortativity[singlerandomgraphserdren3[[i]],
            FindGraphCommunities[singlerandomgraphserdren3[[i]]], "Normalized" -> False],
          {i, Length@singlerandomgraphserdren3}];
        singlerandomgraphscomm3 = Table[randomizedgraphamongcommunities[i],
          {i, graphsandnodenumbers3[[All, 1]]}];
        singlerandomcommmodularityvalues3 = Table[N@GraphAssortativity[
            singlerandomgraphscomm3[[i]], FindGraphCommunities[singlerandomgraphscomm3[[i]]],
            "Normalized" -> False], {i, Length@singlerandomgraphscomm3}];

In[•]:= AbsoluteTiming[Zscoresmodularity3 = Table[randomnessfunctionformodularitytwonullmodel[i],
          {i, graphsandnodenumbers3[[All, 1]]}];]
Out[•]= {372.415, Null}

In[•]:= AbsoluteTiming[widthdataintimewindowsFixedbucket2 =
          snetworkdatafxdbucketintimewindows[data2, 9, bucketnode12, win2];]
Out[•]= {8.96818, 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, 0.6};
(* 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[{"Erdös-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[{"Erdös Renyi", "Communities"}, {Scaled[1], Above}]]}
```

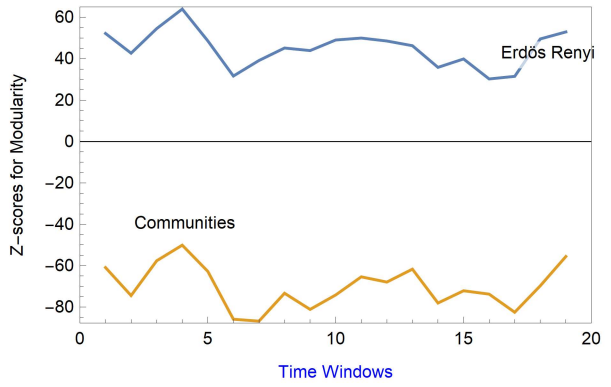
Out[ ]=



,



,



}

Thickness Feature

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

Out[•]= {9.70113, 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]]}];
singlerandomerdrenmodularityvalues4 =
  Table[N@GraphAssortativity[singlerandomgraphserdren4[[i]],
    FindGraphCommunities[singlerandomgraphserdren4[[i]]], "Normalized" -> False],
   {i, Length@singlerandomgraphserdren4}];
singlerandomgraphscomm4 = Table[randomizedgraphamongcommunities[i],
   {i, graphsandnodenumbers4[[All, 1]]}];
singlerandomcommmodularityvalues4 = Table[N@GraphAssortativity[
    singlerandomgraphscomm4[[i]], FindGraphCommunities[singlerandomgraphscomm4[[i]]],
    "Normalized" -> False], {i, Length@singlerandomgraphscomm4}];
```

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

Out[•]= {263.297, Null}

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

Out[•]= {5.44396, 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[•]:=
```
Table[Head@i, {i, singlerandomerdrenmodularityvalues4}]
```

Out[•]= {Real, Real, Real, Real, Real, Real, Real, Real,
 Real, Real, Real, Real, Real, Real, Real, Real, Real, Real}

In[•]:=
```
singlerandomcommmodularityvalues4 = ReplacePart[singlerandomcommmodularityvalues4,
  Position[singlerandomcommmodularityvalues4, _?(Head@# == GraphAssortativity &)] → ""]
```

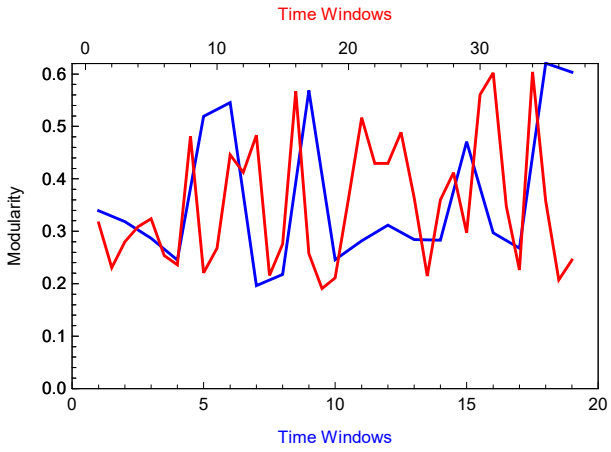
Out[•]= {0.36522, 0.416716, 0.408642, 0.42793, 0.561633, , 0.39366, 0.4458, 0.559829, 0.406207,
 0.46382, 0.423913, 0.46875, 0.462307, 0.479571, 0.421007, 0.435249, 0.5904, 0.582222}

In[•]:=
```
Zscoresmodularity4 = ReplacePart[Zscoresmodularity4, {6, 2} → ""]
```

Out[•]= {{0.26074, −0.800398}, {0.511572, −3.40402}, {0.922464, −3.57916},
{0.399148, −4.40267}, {4.13001, −0.744885}, {6.00632, }, {1.12843, −8.89142},
{1.62684, −7.85353}, {6.96477, 0.20735}, {2.21211, −6.17363}, {2.82186, −5.39276},
{2.62548, −4.40744}, {2.20704, −4.6617}, {2.3125, −4.9772}, {3.54693, −1.40984},
{2.54829, −5.01939}, {−0.591529, −5.81637}, {3.3973, 0.175844}, {4.80336, 0.375827}}

In[•]:=
```
modularityplotrange = {0, 0.62};
(* 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[{"Erdös-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 /. "" → 0], 1]},
  PlotLabels → Placed[{"Erdös Renyi", "Communities"}, {Scaled[1], Above}]]}
```

Out[•]=


Time Windows
Modularity
Time Windows

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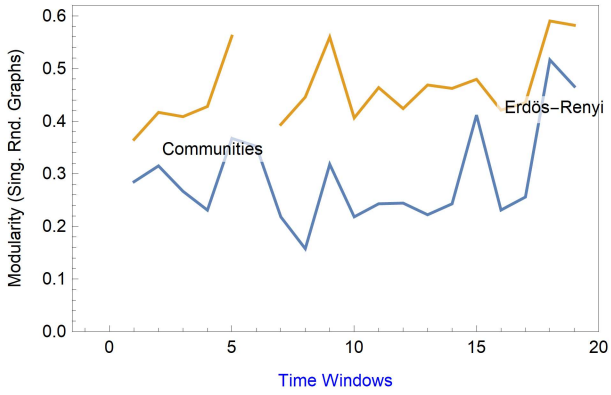
Modularity (Sing. Rnd. Graphs)
Erdös–Renyi
Communities
Time Windows

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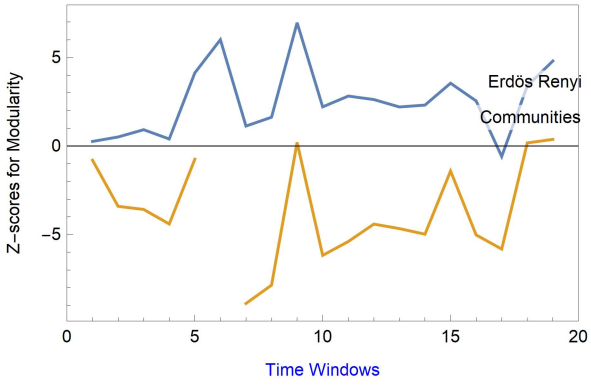
Z-scores for Modularity
Erdös Renyi
Communities
Time Windows

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