Data Import

```
In[ ]:= SetDirectory[
          "C:/Users/serha/OneDrive/Masaüstü/MyRepo/master_thesis_MMT003/210407_sliding_time
            _windows_and_OR_model"];

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

In[ ]:= datafull = Import["../data/cgl_data_csp_sequences_only.csv", HeaderLines → 1];
        datafull = Join[Join[datafull[[All, {1, 118}]], ConstantArray[{0, 0, 0, 0, 0, 0}, 32138], 2],
           datafull[[All, {113, 111}]], 2];
```

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

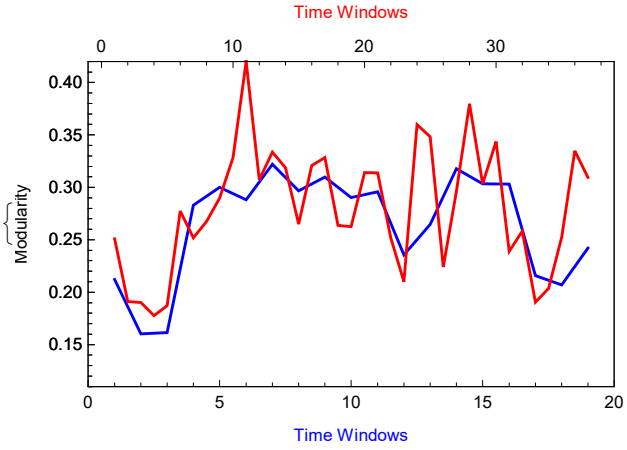
Width Feature

```
In[ ]:= AbsoluteTiming[
         widthdataintimewindowsFixedstep1 = snetworkdatabinnedintimewindows[data1, 9, 11, win1];]
Out[ ]= {8.4993, Null}
```

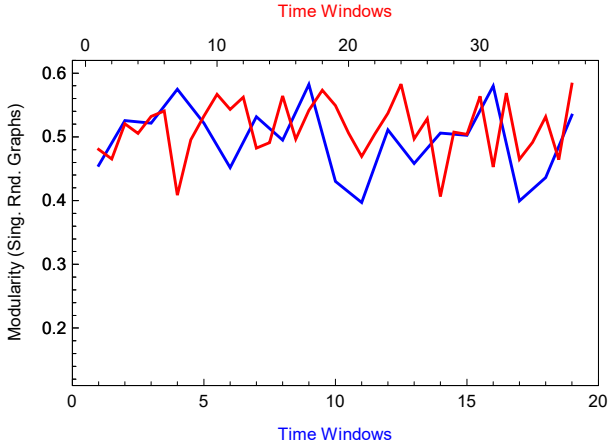
```
In[ ]:= graphsandnodenumbers = Table[snetworkgraph[widthdataintimewindowsFixedstep1[[1]][[i]],
          widthdataintimewindowsFixedstep1[[2]][[i]], 2, 7, 400, Green], {i, Range@win1}];
        modularityvalues1 = Table[N@GraphAssortativity[graphsandnodenumbers[[i]][[1]],
            FindGraphCommunities[graphsandnodenumbers[[i]][[1]]],
            "Normalized" → False], {i, Length@graphsandnodenumbers}];
        singlerandomgraphscomm = Table[randomizedgraphamongcommunities[i],
           {i, graphsandnodenumbers[[All, 1]]}];
        singlerandomcommmodularityvalues1 = Table[N@GraphAssortativity[
            singlerandomgraphscomm[[i]], FindGraphCommunities[singlerandomgraphscomm[[i]]],
            "Normalized" -> False], {i, Length@singlerandomgraphscomm}];
        AbsoluteTiming[Zscoresmodularity1 = Table[randomnessfunctionformodularityonenullmodel[i],
          {i, graphsandnodenumbers[[All, 1]]}];]
Out[ ]= {452.923, Null}

In[ ]:= AbsoluteTiming[
         widthdataintimewindowsFixedstep2 = snetworkdatabinnedintimewindows[data2, 9, 11, win2];]
Out[ ]= {13.2335, Null}

In[ ]:= graphsandnodenumbers = Table[snetworkgraph[widthdataintimewindowsFixedstep2[[1]][[i]],
          widthdataintimewindowsFixedstep2[[2]][[i]], 2, 7, 400, Green], {i, Range@win2}];
        modularityvalues2 = Table[N@GraphAssortativity[graphsandnodenumbers[[i]][[1]],
            FindGraphCommunities[graphsandnodenumbers[[i]][[1]]],
            "Normalized" → False], {i, Length@graphsandnodenumbers}];
        singlerandomgraphscomm = Table[randomizedgraphamongcommunities[i],
           {i, graphsandnodenumbers[[All, 1]]}];
        singlerandomcommmodularityvalues2 = Table[N@GraphAssortativity[
            singlerandomgraphscomm[[i]], FindGraphCommunities[singlerandomgraphscomm[[i]]],
            "Normalized" -> False], {i, Length@singlerandomgraphscomm}];
        AbsoluteTiming[Zscoresmodularity2 = Table[randomnessfunctionformodularityonenullmodel[i],
          {i, graphsandnodenumbers[[All, 1]]}];]
Out[ ]= {657.988, Null}
```

In[ ]:=
```
{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}, {0.11, 0.42}}],
   ListLinePlot[Thread[{Range@win2, modularityvalues2}], 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}, {0.11, 0.42}}]}],
  Overlay[{ListLinePlot[Thread[{Range@win1, singlerandomcommmodularityvalues1}],
    Frame → True, ImagePadding → 38, FrameTicks → {{All, None}, {All, None}}, FrameLabel →
     {{"Modularity (Sing. Rnd. Graphs)", None}, {Style["Time Windows", Blue], None}},
    PlotStyle → Blue, ImageSize → 350, PlotRange → {{0, win1 + 1}, {0.11, 0.62}}],
   ListLinePlot[Thread[{Range@win2, singlerandomcommmodularityvalues2}],
    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}, {0.11, 0.62}}]}],
  Overlay[{ListLinePlot[Thread[{Range@win1, Zscoresmodularity1}],
    Frame → True, ImagePadding → 38, FrameTicks → {{All, None}, {All, None}},
    FrameLabel → {{"Z-score for Modularity", None}, {Style["Time Windows", Blue], None}},
    PlotStyle → Blue, ImageSize → 350, PlotRange → {{0, win1 + 1}, {-7.5, -50}}],
   ListLinePlot[Thread[{Range@win2, Zscoresmodularity2}], 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}, {-7.5, -50}}]}]}
```

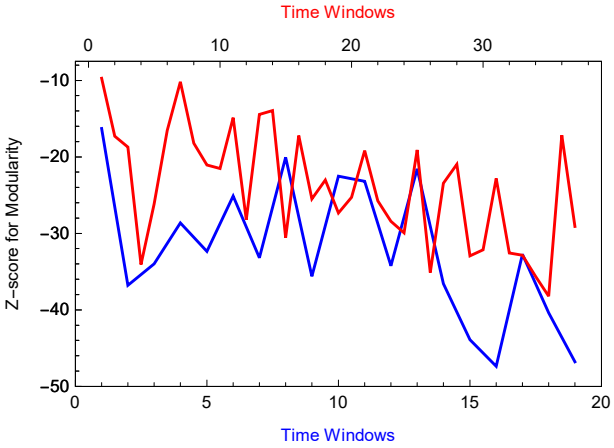
Out[ ]=



,



,



}

Thickness Feature

In[ ]:=
```
AbsoluteTiming[thicknessdataintimewindowsFixedstep1 =
  snetworkdatabinnedintimewindows[data1, 10, 0.05, win1];]
```

Out[ ]= {4.07611, Null}

In[ ]:=
```
graphsandnodenumbers =
  Table[snetworkgraph[thicknessdataintimewindowsFixedstep1[[1]][[i]],
    thicknessdataintimewindowsFixedstep1[[2]][[i]], 2,
    7, 400, RGBColor[0.1, 0.5, 1.]], {i, Range@win1}];
modularityvalues1 = Table[N@GraphAssortativity[graphsandnodenumbers[[i]][[1]],
     FindGraphCommunities[graphsandnodenumbers[[i]][[1]]],
     "Normalized" → False], {i, Length@graphsandnodenumbers}];
singlerandomgraphscomm = Table[randomizedgraphamongcommunities[i],
   {i, graphsandnodenumbers[[All, 1]]}];
singlerandomcommmodularityvalues1 = Table[N@GraphAssortativity[
     singlerandomgraphscomm[[i]], FindGraphCommunities[singlerandomgraphscomm[[i]]],
     "Normalized" -> False], {i, Length@singlerandomgraphscomm}];
AbsoluteTiming[Zscoresmodularity1 = Table[randomnessfunctionformodularityonenullmodel[i],
    {i, graphsandnodenumbers[[All, 1]]}];]
```

Out[ ]= {229.857, Null}

In[ ]:=
```
AbsoluteTiming[thicknessdataintimewindowsFixedstep2 =
   snetworkdatabinnedintimewindows[data2, 10, 0.05, win2];]
```

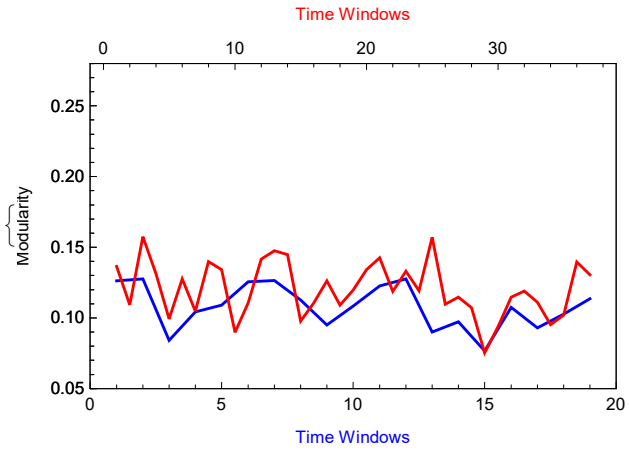
Out[ ]= {4.84092, Null}

In[ ]:=
```
graphsandnodenumbers =
  Table[snetworkgraph[thicknessdataintimewindowsFixedstep2[[1]][[i]],
    thicknessdataintimewindowsFixedstep2[[2]][[i]], 2,
    7, 400, RGBColor[0.1, 0.5, 1.]], {i, Range@win2}];
modularityvalues2 = Table[N@GraphAssortativity[graphsandnodenumbers[[i]][[1]],
     FindGraphCommunities[graphsandnodenumbers[[i]][[1]]],
     "Normalized" → False], {i, Length@graphsandnodenumbers}];
singlerandomgraphscomm = Table[randomizedgraphamongcommunities[i],
   {i, graphsandnodenumbers[[All, 1]]}];
singlerandomcommmodularityvalues2 = Table[N@GraphAssortativity[
     singlerandomgraphscomm[[i]], FindGraphCommunities[singlerandomgraphscomm[[i]]],
     "Normalized" -> False], {i, Length@singlerandomgraphscomm}];
AbsoluteTiming[Zscoresmodularity2 = Table[randomnessfunctionformodularityonenullmodel[i],
    {i, graphsandnodenumbers[[All, 1]]}];]
```

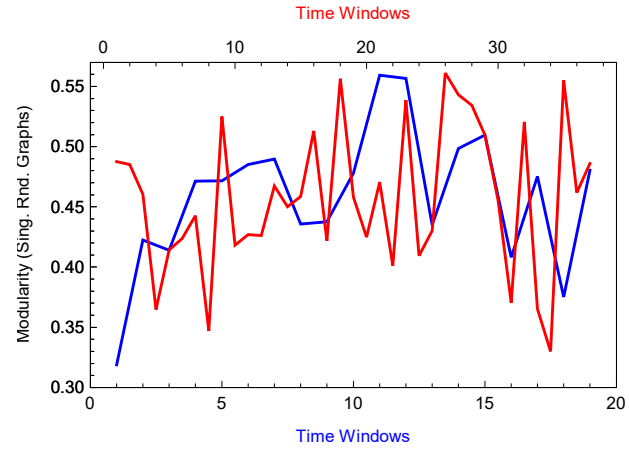
Out[ ]= {347.306, Null}

In[ ]:=
```
{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}, {0.05, 0.28}}],
   ListLinePlot[Thread[{Range@win2, modularityvalues2}], 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}, {0.05, 0.28}}]}],
  Overlay[{ListLinePlot[Thread[{Range@win1, singlerandomcommmodularityvalues1}],
    Frame → True, ImagePadding → 38, FrameTicks → {{All, None}, {All, None}}, FrameLabel →
     {{"Modularity (Sing. Rnd. Graphs)", None}, {Style["Time Windows", Blue], None}},
    PlotStyle → Blue, ImageSize → 350, PlotRange → {{0, win1 + 1}, {0.3, 0.57}}],
   ListLinePlot[Thread[{Range@win2, singlerandomcommmodularityvalues2}],
    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}, {0.3, 0.57}}]}],
  Overlay[{ListLinePlot[Thread[{Range@win1, Zscoresmodularity1}],
    Frame → True, ImagePadding → 38, FrameTicks → {{All, None}, {All, None}},
    FrameLabel → {{"Z-score for Modularity", None}, {Style["Time Windows", Blue], None}},
    PlotStyle → Blue, ImageSize → 350, PlotRange → {{0, win1 + 1}, {-15, -52}}],
   ListLinePlot[Thread[{Range@win2, Zscoresmodularity2}], 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}, {-15, -52}}]}]}
```

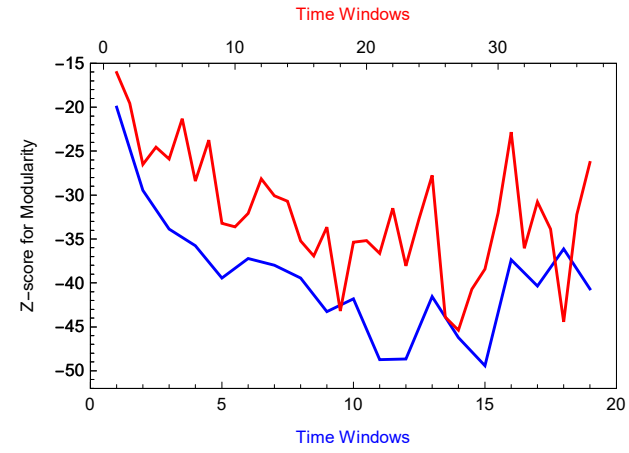
Out[•]=



,



,



}

Fixed Bucket Size Networks

Width Feature

In[•]:=
```
AbsoluteTiming[widthdataintimewindowsFixedbucket1 =
   snetworkdatafxdbucketintimewindows[data1, 9, 65, win1];]
```

Out[•]= {1.29116, Null}

In[•]:=
```
graphsandnodenumbers = Table[snetworkgraph[widthdataintimewindowsFixedbucket1[[1]][[i]],
    widthdataintimewindowsFixedbucket1[[2]][[i]], 1.5, 7, 400, Green], {i, Range@win1}];
modularityvalues1 = Table[N@GraphAssortativity[graphsandnodenumbers[[i]][[1]],
     FindGraphCommunities[graphsandnodenumbers[[i]][[1]]],
     "Normalized" → False], {i, Length@graphsandnodenumbers}];
singlerandomgraphscomm = Table[randomizedgraphamongcommunities[i],
   {i, graphsandnodenumbers[[All, 1]]}];
singlerandomcommmodularityvalues1 = Table[N@GraphAssortativity[
     singlerandomgraphscomm[[i]], FindGraphCommunities[singlerandomgraphscomm[[i]]],
     "Normalized" -> False], {i, Length@singlerandomgraphscomm}];
AbsoluteTiming[Zscoresmodularity1 = Table[randomnessfunctionformodularityonenullmodel[i],
    {i, graphsandnodenumbers[[All, 1]]}];]
```

Out[•]= {326.961, Null}

In[•]:=
```
AbsoluteTiming[widthdataintimewindowsFixedbucket2 =
   snetworkdatafxdbucketintimewindows[data2, 9, 65, win2];]
```

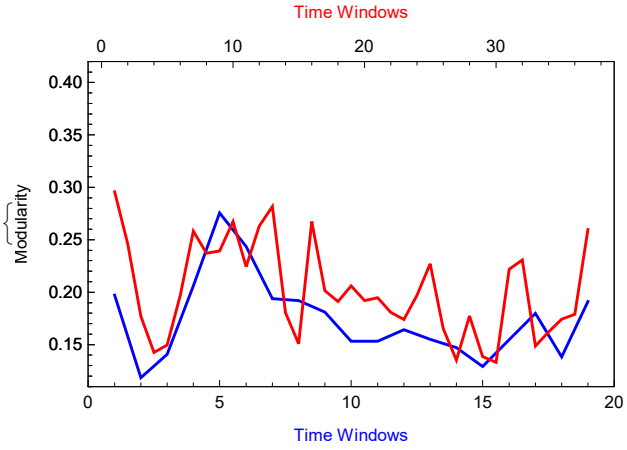
Out[•]= {1.73439, Null}

In[•]:=
```
graphsandnodenumbers = Table[snetworkgraph[widthdataintimewindowsFixedbucket2[[1]][[i]],
    widthdataintimewindowsFixedbucket2[[2]][[i]], 1.5, 7, 400, Green], {i, Range@win2}];
modularityvalues2 = Table[N@GraphAssortativity[graphsandnodenumbers[[i]][[1]],
     FindGraphCommunities[graphsandnodenumbers[[i]][[1]]],
     "Normalized" → False], {i, Length@graphsandnodenumbers}];
singlerandomgraphscomm = Table[randomizedgraphamongcommunities[i],
   {i, graphsandnodenumbers[[All, 1]]}];
singlerandomcommmodularityvalues2 = Table[N@GraphAssortativity[
     singlerandomgraphscomm[[i]], FindGraphCommunities[singlerandomgraphscomm[[i]]],
     "Normalized" -> False], {i, Length@singlerandomgraphscomm}];
AbsoluteTiming[Zscoresmodularity2 = Table[randomnessfunctionformodularityonenullmodel[i],
    {i, graphsandnodenumbers[[All, 1]]}];]
```

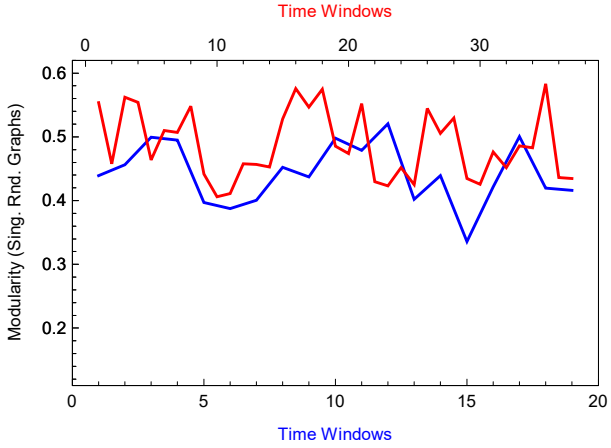
Out[•]= {723.769, Null}

In[ ]:=
```
{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}, {0.11, 0.42}}],
   ListLinePlot[Thread[{Range@win2, modularityvalues2}], 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}, {0.11, 0.42}}]}],
  Overlay[{ListLinePlot[Thread[{Range@win1, singlerandomcommmodularityvalues1}],
    Frame → True, ImagePadding → 38, FrameTicks → {{All, None}, {All, None}}, FrameLabel →
     {{"Modularity (Sing. Rnd. Graphs)", None}, {Style["Time Windows", Blue], None}},
    PlotStyle → Blue, ImageSize → 350, PlotRange → {{0, win1 + 1}, {0.11, 0.62}}],
   ListLinePlot[Thread[{Range@win2, singlerandomcommmodularityvalues2}],
    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}, {0.11, 0.62}}]}],
  Overlay[{ListLinePlot[Thread[{Range@win1, Zscoresmodularity1}],
    Frame → True, ImagePadding → 38, FrameTicks → {{All, None}, {All, None}},
    FrameLabel → {{"Z-score for Modularity", None}, {Style["Time Windows", Blue], None}},
    PlotStyle → Blue, ImageSize → 350, PlotRange → {{0, win1 + 1}, {-7.5, -60}}],
   ListLinePlot[Thread[{Range@win2, Zscoresmodularity2}], 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}, {-7.5, -60}}]}]}
```

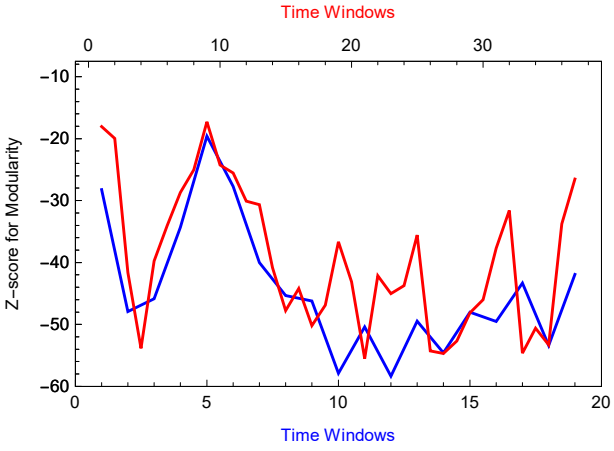
Out[ ]=



,



,



}

Thickness Feature

In[ ]:=
```
AbsoluteTiming[thicknessdataintimewindowsFixedbucket1 =
  snetworkdatafxdbucketintimewindows[data1, 10, 47, win1];]
```

Out[•]= {1.19404, Null}

In[•]:=
```
graphsandnodenumbers =
  Table[snetworkgraph[thicknessdataintimewindowsFixedbucket1[[1]][[i]],
    thicknessdataintimewindowsFixedbucket1[[2]][[i]],
    1.5, 7, 400, RGBColor[0.1, 0.5, 1.]], {i, Range@win1}];
modularityvalues1 = Table[N@GraphAssortativity[graphsandnodenumbers[[i]][[1]],
     FindGraphCommunities[graphsandnodenumbers[[i]][[1]]],
     "Normalized" → False], {i, Length@graphsandnodenumbers}];
singlerandomgraphscomm = Table[randomizedgraphamongcommunities[i],
   {i, graphsandnodenumbers[[All, 1]]}];
singlerandomcommmodularityvalues1 = Table[N@GraphAssortativity[
     singlerandomgraphscomm[[i]], FindGraphCommunities[singlerandomgraphscomm[[i]]],
     "Normalized" -> False], {i, Length@singlerandomgraphscomm}];
AbsoluteTiming[Zscoresmodularity1 = Table[randomnessfunctionformodularityonenullmodel[i],
    {i, graphsandnodenumbers[[All, 1]]}];]
```

Out[•]= {202.184, Null}

In[•]:=
```
AbsoluteTiming[thicknessdataintimewindowsFixedbucket2 =
   snetworkdatafxdbucketintimewindows[data2, 10, 47, win2];]
```

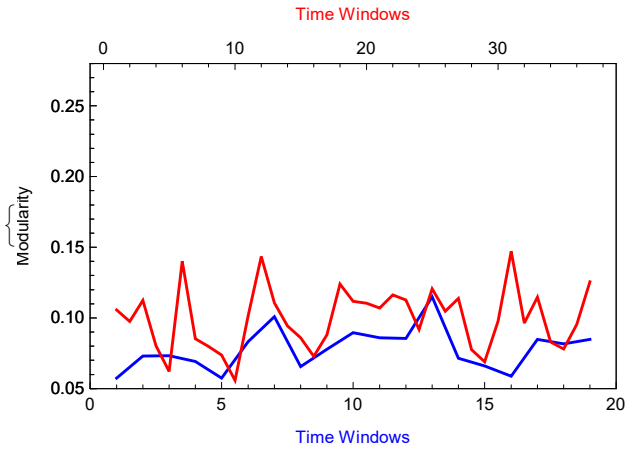
Out[•]= {1.28762, Null}

In[•]:=
```
graphsandnodenumbers =
  Table[snetworkgraph[thicknessdataintimewindowsFixedbucket2[[1]][[i]],
    thicknessdataintimewindowsFixedbucket2[[2]][[i]],
    1.5, 7, 400, RGBColor[0.1, 0.5, 1.]], {i, Range@win2}];
modularityvalues2 = Table[N@GraphAssortativity[graphsandnodenumbers[[i]][[1]],
     FindGraphCommunities[graphsandnodenumbers[[i]][[1]]],
     "Normalized" → False], {i, Length@graphsandnodenumbers}];
singlerandomgraphscomm = Table[randomizedgraphamongcommunities[i],
   {i, graphsandnodenumbers[[All, 1]]}];
singlerandomcommmodularityvalues2 = Table[N@GraphAssortativity[
     singlerandomgraphscomm[[i]], FindGraphCommunities[singlerandomgraphscomm[[i]]],
     "Normalized" -> False], {i, Length@singlerandomgraphscomm}];
AbsoluteTiming[Zscoresmodularity2 = Table[randomnessfunctionformodularityonenullmodel[i],
    {i, graphsandnodenumbers[[All, 1]]}];]
```

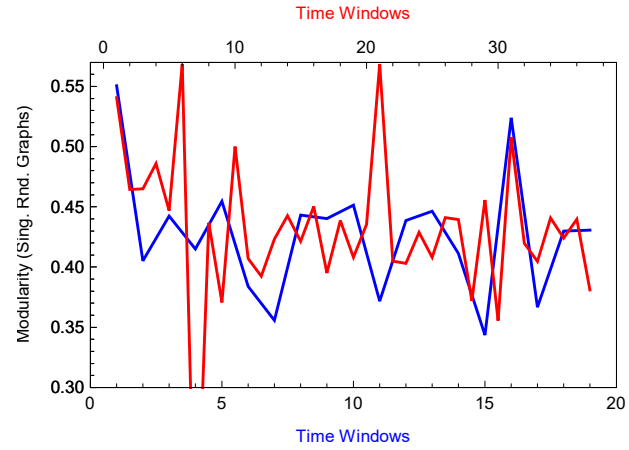
Out[•]= {451.74, Null}

In[ ]:=
```
{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}, {0.05, 0.28}}],
   ListLinePlot[Thread[{Range@win2, modularityvalues2}], 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}, {0.05, 0.28}}]}],
  Overlay[{ListLinePlot[Thread[{Range@win1, singlerandomcommmodularityvalues1}],
    Frame → True, ImagePadding → 38, FrameTicks → {{All, None}, {All, None}}, FrameLabel →
     {{"Modularity (Sing. Rnd. Graphs)", None}, {Style["Time Windows", Blue], None}},
    PlotStyle → Blue, ImageSize → 350, PlotRange → {{0, win1 + 1}, {0.3, 0.57}}],
   ListLinePlot[Thread[{Range@win2, singlerandomcommmodularityvalues2}],
    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}, {0.3, 0.57}}]}],
  Overlay[{ListLinePlot[Thread[{Range@win1, Zscoresmodularity1}],
    Frame → True, ImagePadding → 38, FrameTicks → {{All, None}, {All, None}},
    FrameLabel → {{"Z-score for Modularity", None}, {Style["Time Windows", Blue], None}},
    PlotStyle → Blue, ImageSize → 350, PlotRange → {{0, win1 + 1}, {-10, -60}}],
   ListLinePlot[Thread[{Range@win2, Zscoresmodularity2}], 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}, {-10, -60}}]}]}
```

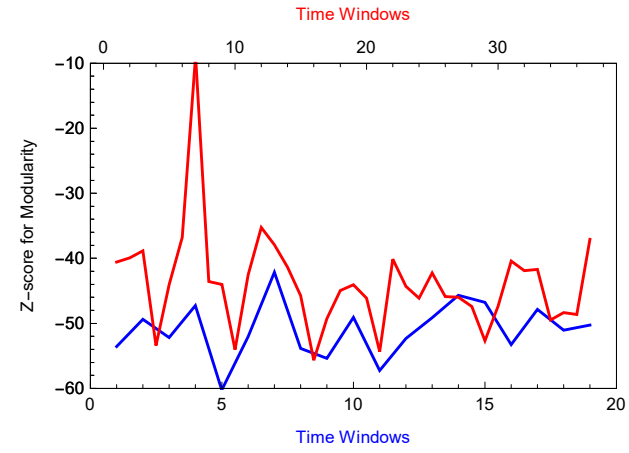
Out[•]=



,



,



}

Plots for Network Metrics and Z-scores