SIMULATION OF SPATIAL DIFFUSION OF MEMES ON SOCIAL MEDIA AND OTHER NETWORKS

INTRODUCTION

Funded by the Interdisciplinary Behavioral and Social Science Research (IBSS) of National Science Foundation from 2015 to 2019, a desktop simulator and a web-based were developed for users to simulate how memes spread spatially over social media networks.

The simulator has two modules.

1. The **First Module** allows users to generate different types of networks by specifying different values for network parameters. In this module, a suite of tools is available for users to calculate several indices and measurements that describe different aspects of the generated networks or real-world networks that users upload to the simulator.
2. The **Second Module** allows users to simulate how memes spread over a network. The network used by the simulator can be one that is generated by using the tools in the first part, or a network uploaded by the user.

Specifically, the simulations work at two levels: (a) **User Level**, in which each node is a social media user, and (b) **City Level**, in which each node is a city.

The URL for the simulator is http://sdpmsmn.geog.kent.edu. Please address any problem or concerns to Jay Lee (jlee@kent.edu).

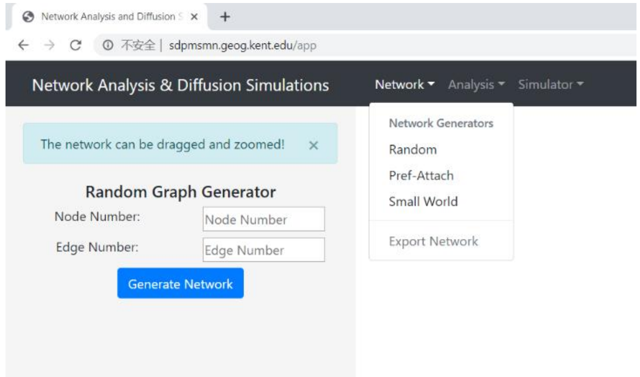
SIMULATOR

Part I: First Module

1. Network generation

Three network generators are provided:

- **Random network generator**
  The generation of new nodes and links in the network is random. Networks created by this generator may or may not have detached subnetworks.
- **Preferential attachment network generator**
  Each new node generated and added to the network is more likely linked to the node of higher network degree, *i.e.*, the node already linked to other nodes.
- **Small world network generator**
  The network is generated so that most nodes can be reached from every other node by a small number of hops/steps.



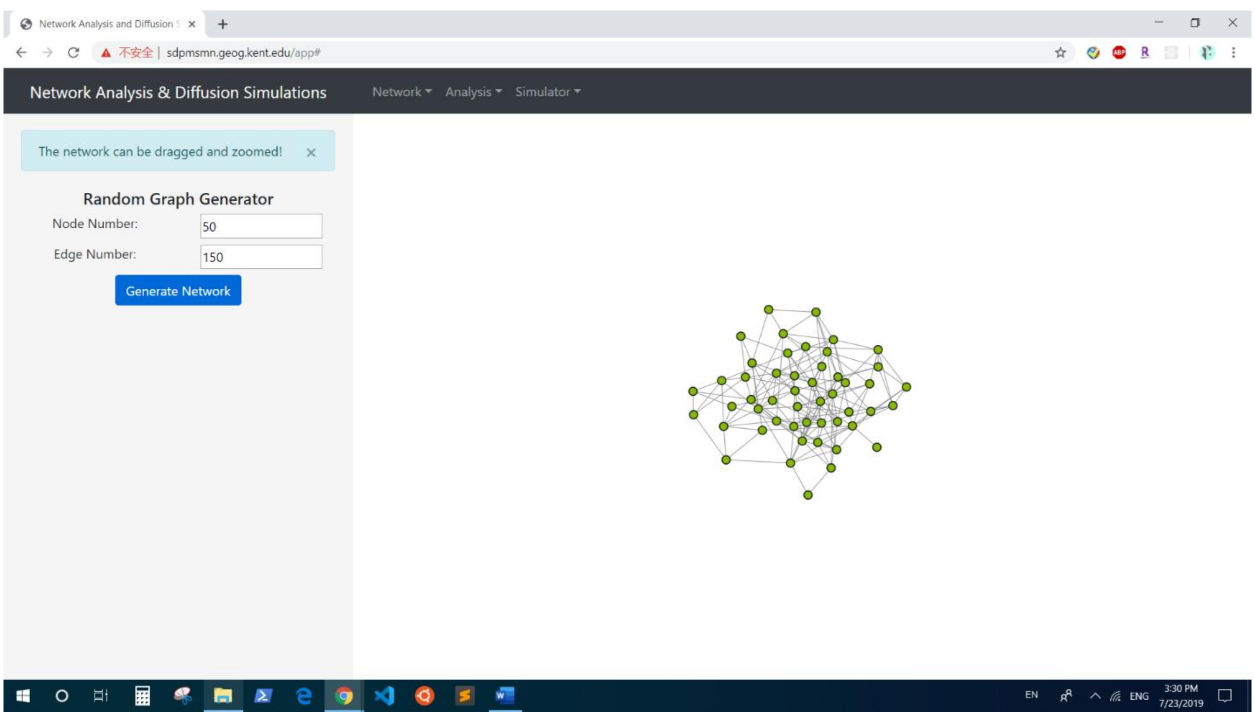
1.1. Random network generator

There are two parameters that users can control while generating such networks. Users specify the number of nodes and the number of edges in the network.

Parameters: (1) Node Number, (2) Edge Number

Usage:

a. Select Random in the Network menu
b. Input two positive integers for two parameters above, respectively
c. Click Generate network to generate and present a network



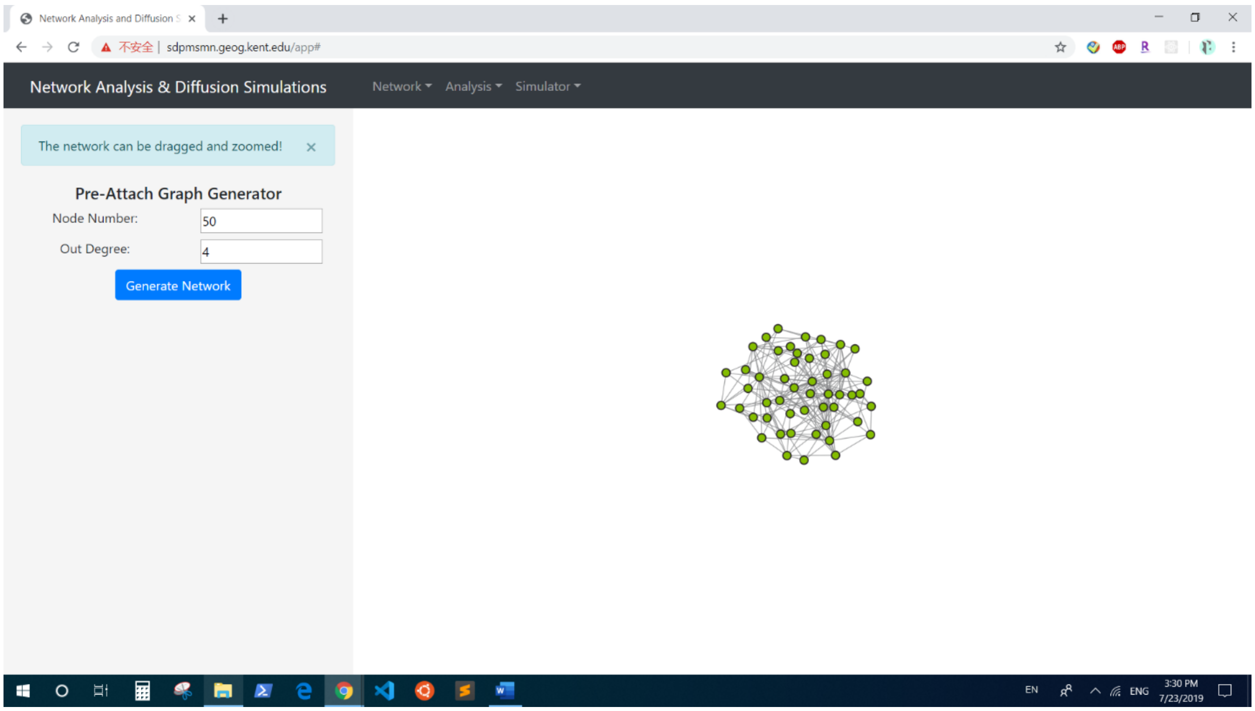
1.2. Preferential attachment network generator

There are two parameters that users can control while generating such networks: Users specify the number of nodes and the average out degree of each node.

Parameters: (1) Node Number, (2) Out Degree

Usage:

a. Select Pref-Attach in the Network menu
b. Input two positive integers for two parameters above respectively. Please noted that value of Out Degree should not exceed the value of Node Number, otherwise the network becomes a fully connected network or a complete graph in graph theory.
c. Click Generate network to generate and present a network



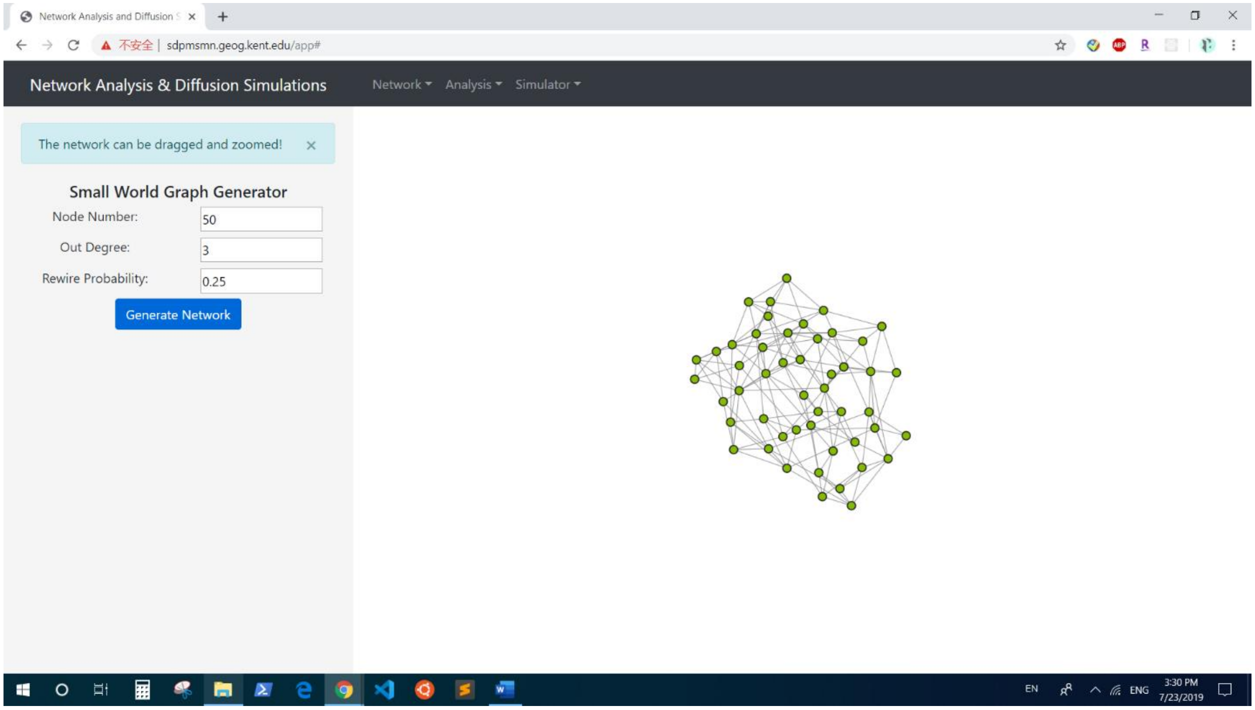
1.3. Small world network generator

There are three parameters that users can control while generating such networks. Users specify the number of nodes, the average out degree of each node and the probability that an edge will be rewired so that to achieve the characteristics of small world network.

Parameter: (1) Node Number, (2) Out Degree, and (3) Rewired Probability

Usage:

a. Select Small World in the Network menu
d. Input two positive integers for node number and out degree and one decimal between 0 and 1 for rewired probability respectively. Please noted that value of Out Degree should not exceed the value of Node Number, otherwise the network becomes a fully connected network or a complete graph in graph theory.
b. Click Generate network to generate and present a network



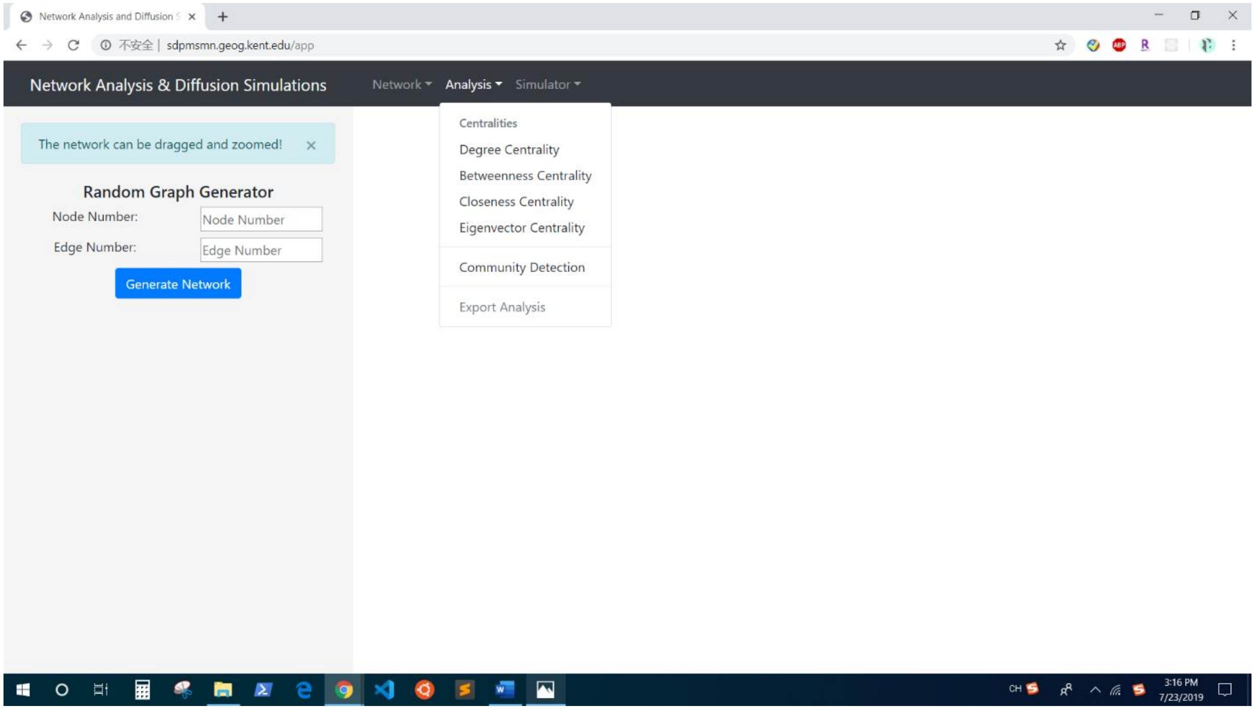
2. Centrality computations

Tools for four centrality indicators are provided for inspect the generated network:

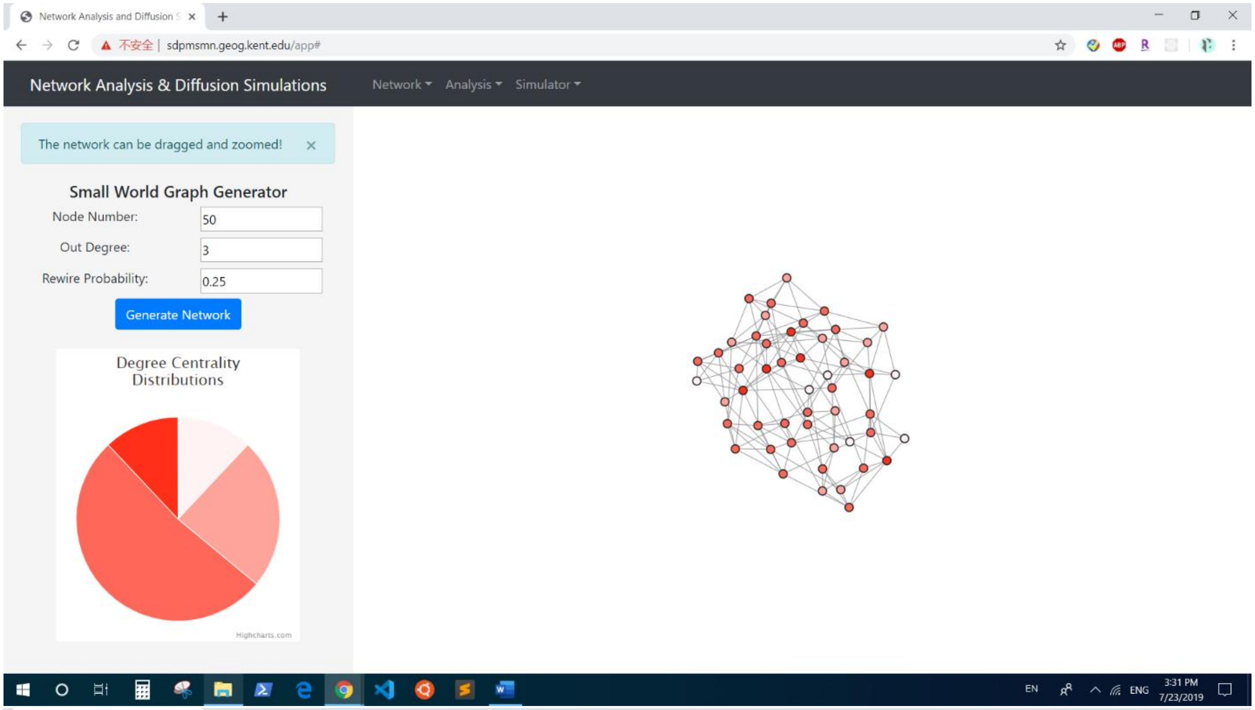
- Degree centrality
  Degree centrality is calculated by computing the number of links/edges incidents upon a node.
- Betweenness centrality
  Each node's betweenness centrality in a network is derived by calculating the proportional fraction of a node being on the shortest paths between any two paired nodes in the network that pass through that node.
- Closeness centrality
  Closeness centrality of a node is the average length of the shortest path between the node and all other nodes in the network.
- Eigenvector centrality
  Eigenvector centrality assigns relative scores to all nodes in the network based on the concept that connections to high-scoring nodes contribute more to the score of the node in question than equal connections to low-scoring nodes.

Prerequisites: Please use the Centrality tools only after generating a network with one of the three network generators.

Usage: Select the desired centrality from the four centralities in the Analysis menu to check the results on the page. Colors are assigned to each range of centrality distribution shown at the left side of the page and these colors also correspond to the colors of nodes in the network.



Examples of using the four centralities:


Network Analysis and Diffusion S
sdpmsmn.geog.kent.edu/app#
Network Analysis & Diffusion Simulations
Network
Analysis
Simulator
The network can be dragged and zoomed!
Small World Graph Generator
Node Number:
50
Out Degree:
3
Rewire Probability:
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Generate Network
Degree Centrality Distributions
3:31 PM
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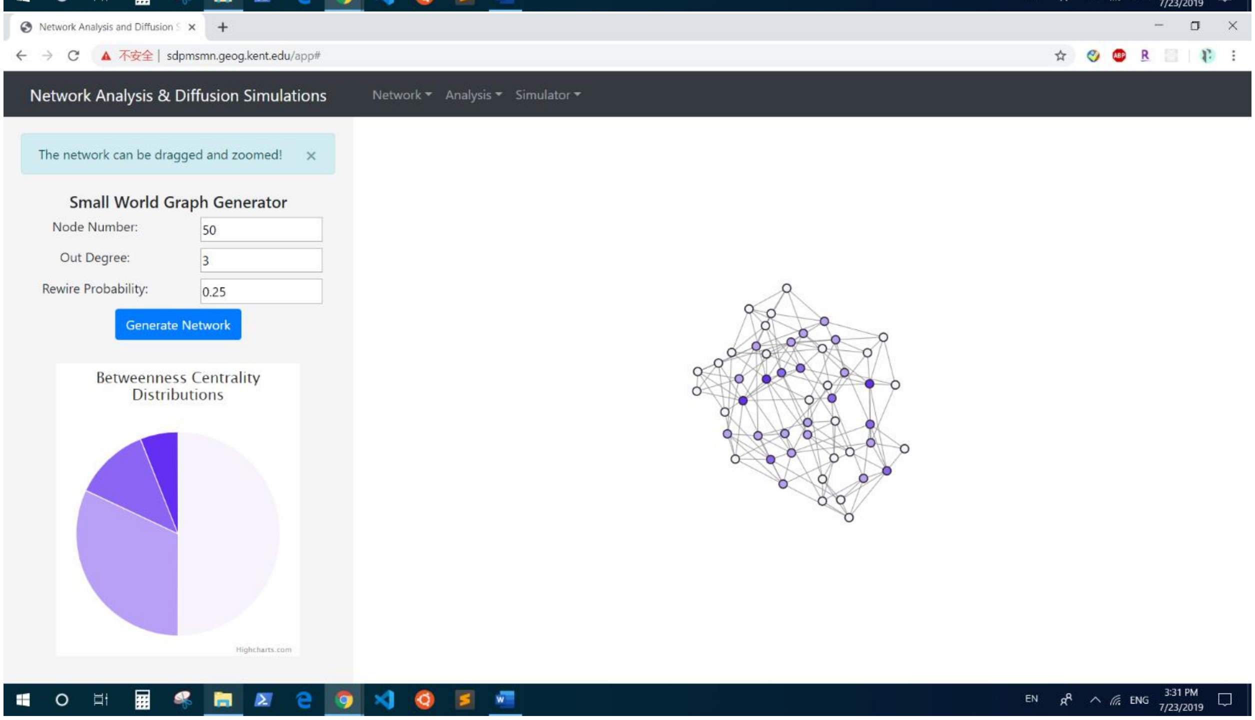
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The network can be dragged and zoomed!
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Betweenness Centrality Distributions
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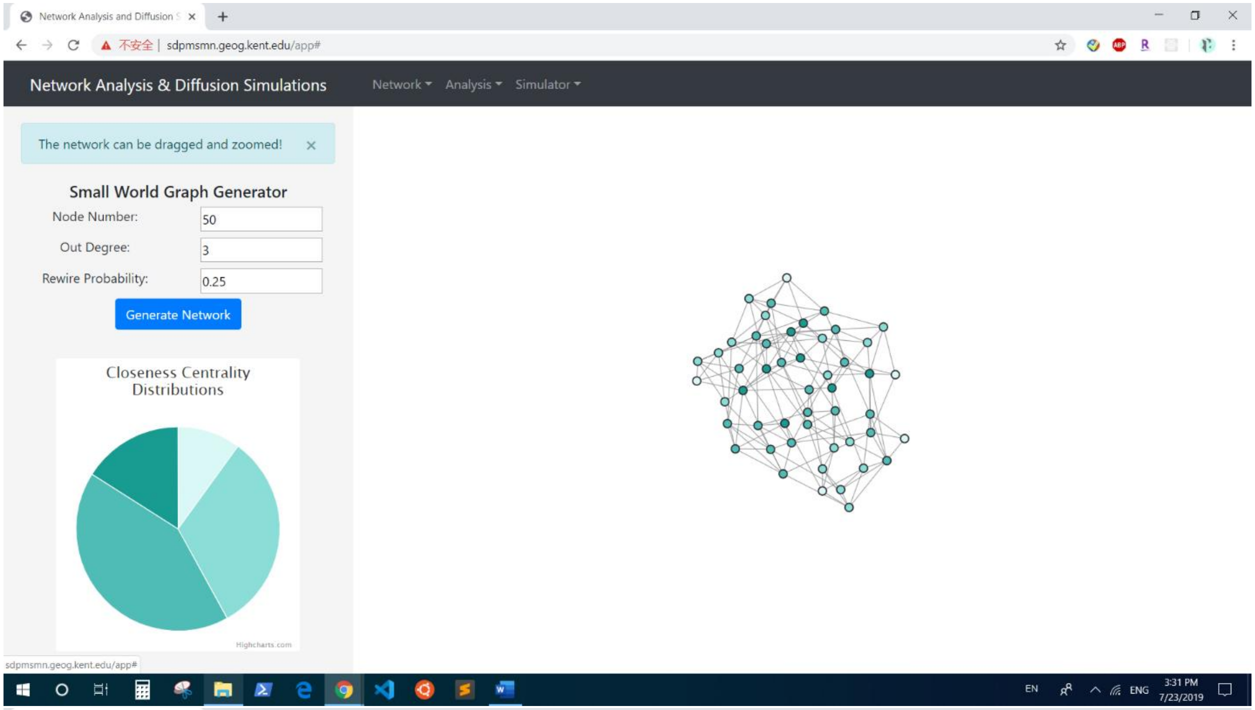
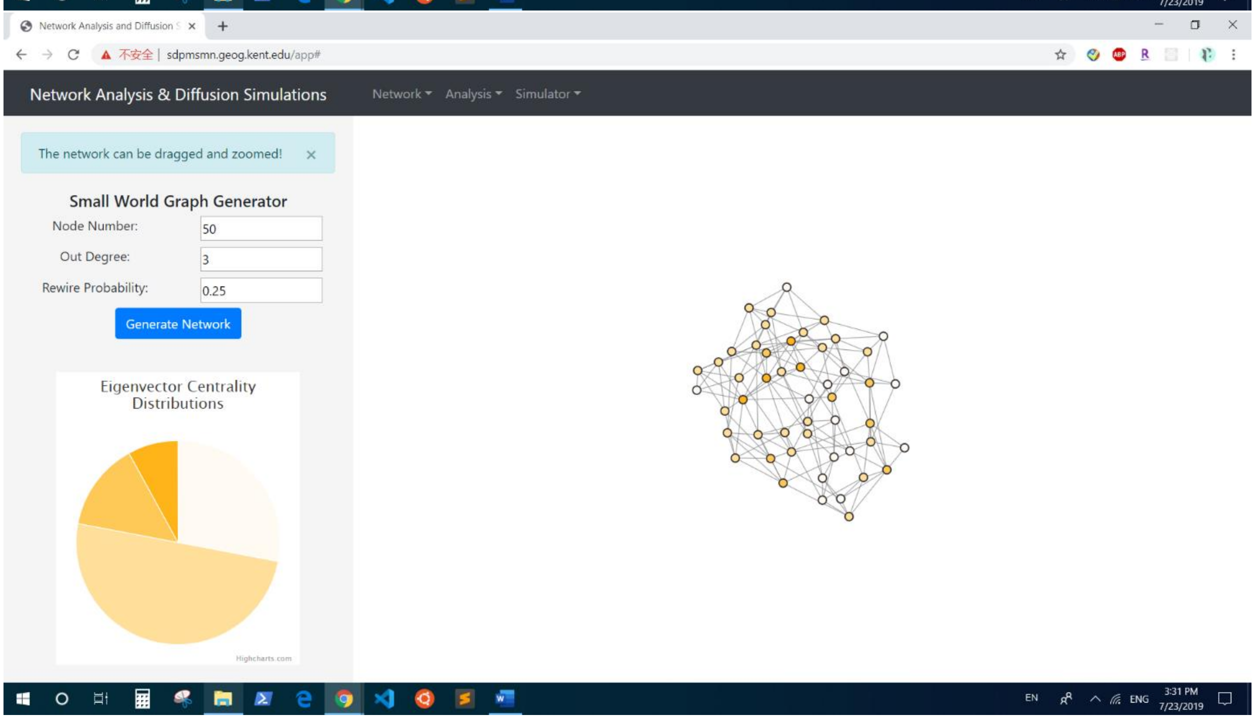


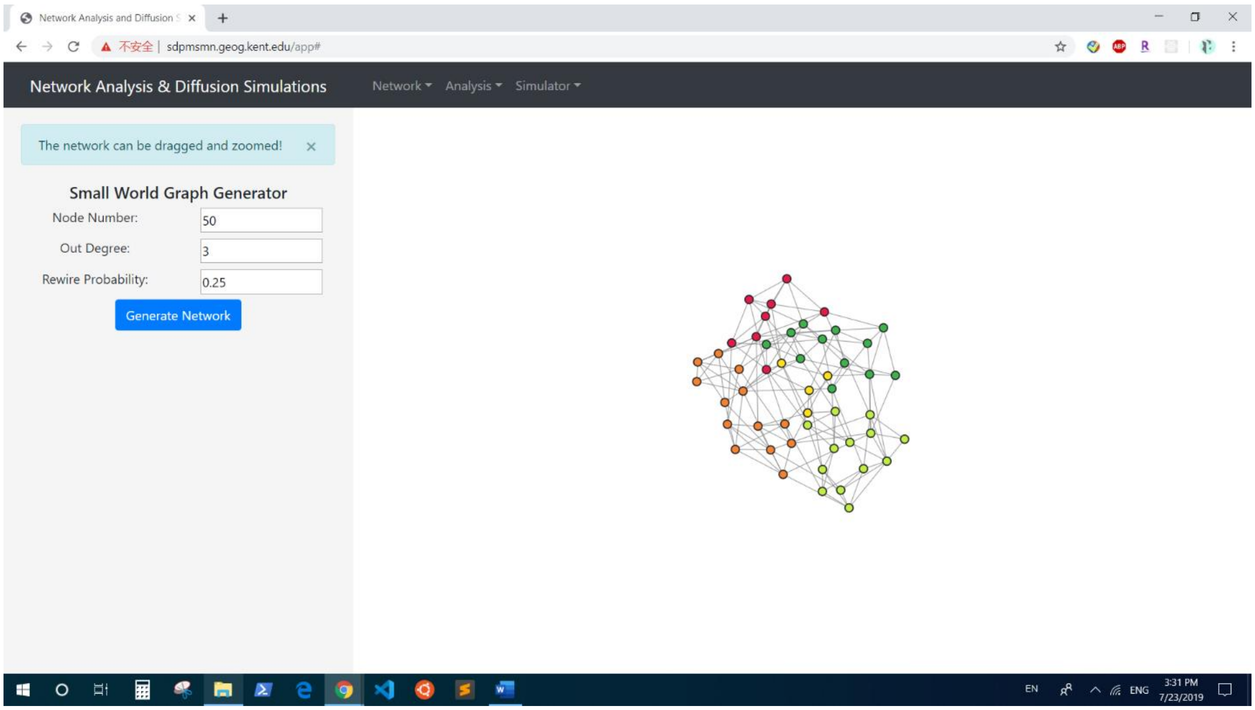


3. Community detection

Community detection is to find and present all communities in a generated network. A subset of nodes is considered as a community when these nodes is densely connected internally. Like centralities, please use community detection after generating a network with one of the three network generators. The nodes with the same color are in the same community. Up to twenty colors are available for visualizations, but the information of all communities are accessible in the exported files.

Prerequisites: A network should be generated using one of the three generators.

Usage: Select Community Detection in the Analysis menu to check the results on the page.



4. General network diffusion (User Level)

General network diffusion can be simulated with one of two models: linear threshold model (LTM) and independent cascade model (ICM). In LTM, each inactive node has a uniform random threshold [0, 1] as the probability of being influenced. Each neighbor of that node can be given a weight to represent how influential it is. At each time step, the probability of successful activation depends on the total weight of its active neighbors. In ICM, if one node sends a message, all nodes connected to it has equal probability to receive the message. That is to say, an independent cascade model is sender-centric while a linear threshold model is receiver-centric.

Prerequisites: A network should be generated before using this function.

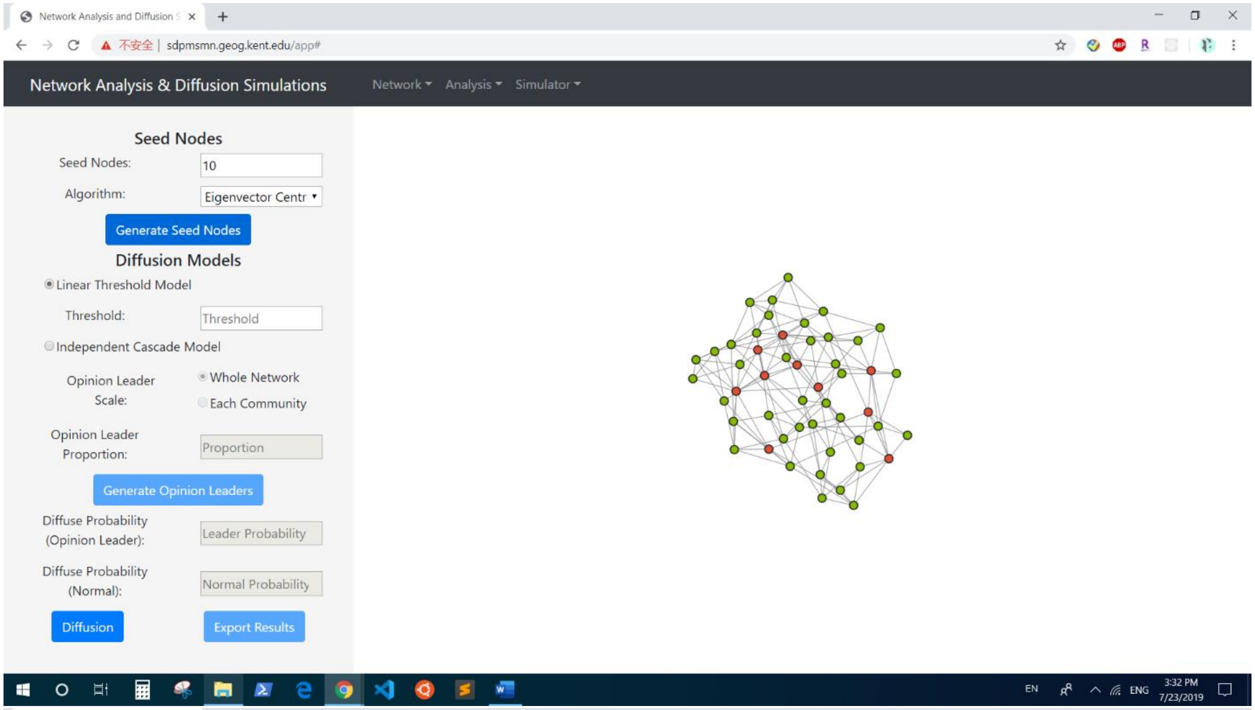
Common Parameters: (1) Seed Node Number, (2) Seed Node Selection Algorithm

LTM-specified parameters: Threshold

ICM-specified parameters: (1) Opinion Leader Selection Scale, (2) Opinion Leader Proportion, (3) Opinion Leader Diffusion Probability, (4) Normal Diffusion Probability

Usage:

a. Select User Level in the Simulator menu
b. Input a positive integer for the seed node number and select the seed node selection indicator
c. Click Generate Seed Nodes to generate and present specific seed nodes
d. Select the desired model (i.e., LTM or ICM) for simulation
e. For LTM, input a decimal between 0 and 1 for the threshold; for ICM, (I) choose opinion leader selection scale and input a decimal between 0 and 1 for the opinion leader proportion, (II) click Generate Opinion Leaders to generate and present specific opinion leaders, (III) Input two decimals between 0 and 1 for opinion leader and normal diffusion probabilities respectively
f. Click Diffusion to generate and present the diffusion visualization on the generated network of the page


Network Analysis and Diffusion S
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Network Analysis & Diffusion Simulations
Network
Analysis
Simulator
Seed Nodes
Seed Nodes:
10
Algorithm:
Eigenvector Centr
Generate Seed Nodes
Diffusion Models
Linear Threshold Model
Threshold:
Threshold
Independent Cascade Model
Opinion Leader Scale:
Whole Network
Each Community
Opinion Leader Proportion:
Proportion
Generate Opinion Leaders
Diffuse Probability (Opinion Leader):
Leader Probability
Diffuse Probability (Normal):
Normal Probability
Diffusion
Export Results
EN
ENG
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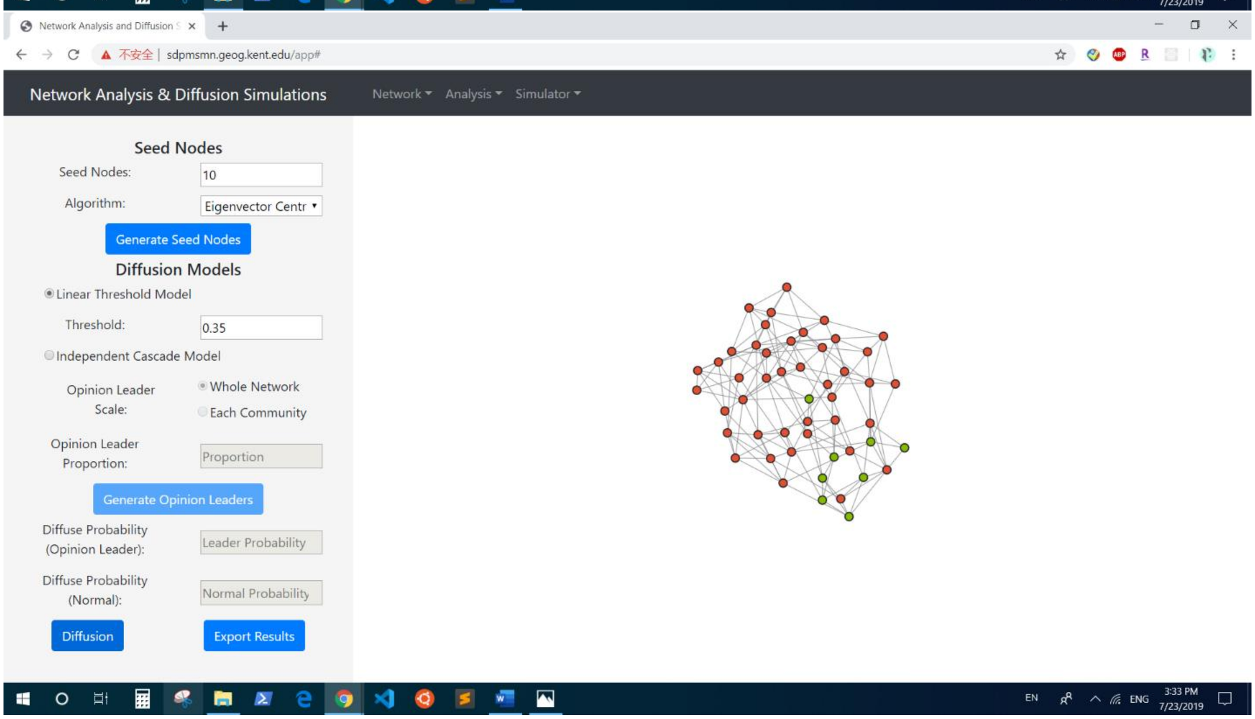
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Algorithm:
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Generate Seed Nodes
Diffusion Models
Linear Threshold Model
Threshold:
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Independent Cascade Model
Opinion Leader Scale:
Whole Network
Each Community
Opinion Leader Proportion:
Proportion
Generate Opinion Leaders
Diffuse Probability (Opinion Leader):
Leader Probability
Diffuse Probability (Normal):
Normal Probability
Diffusion
Export Results
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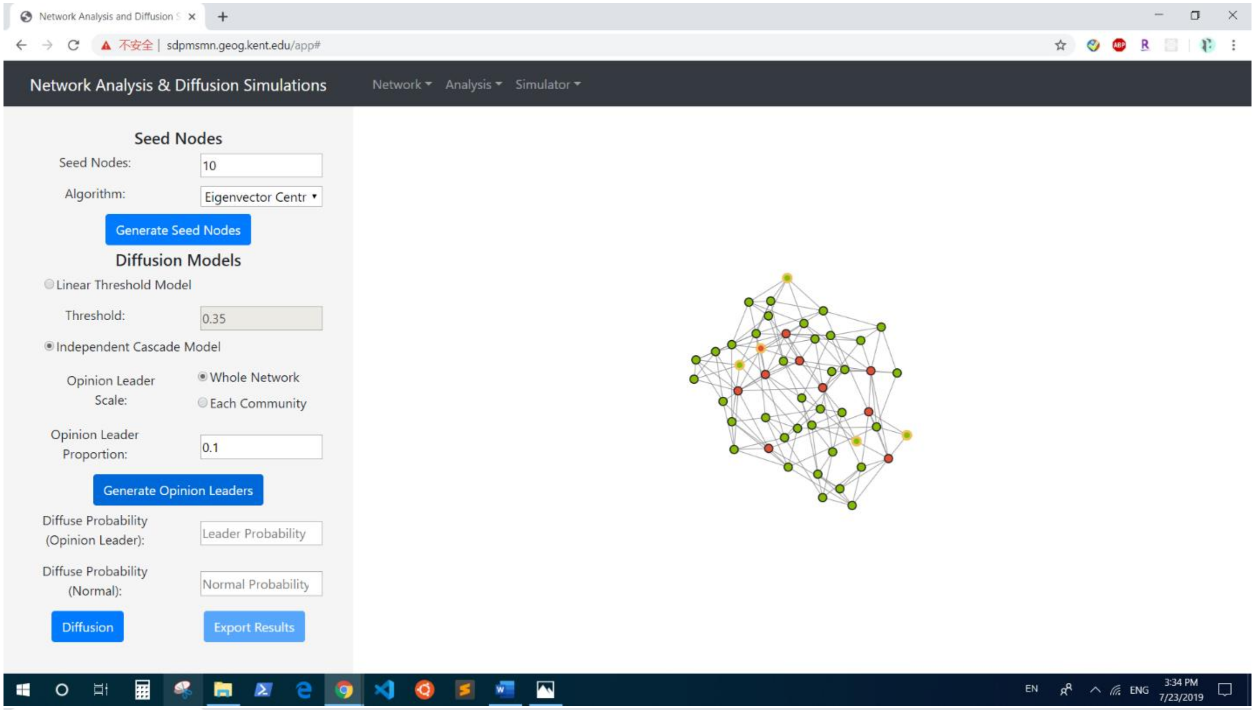
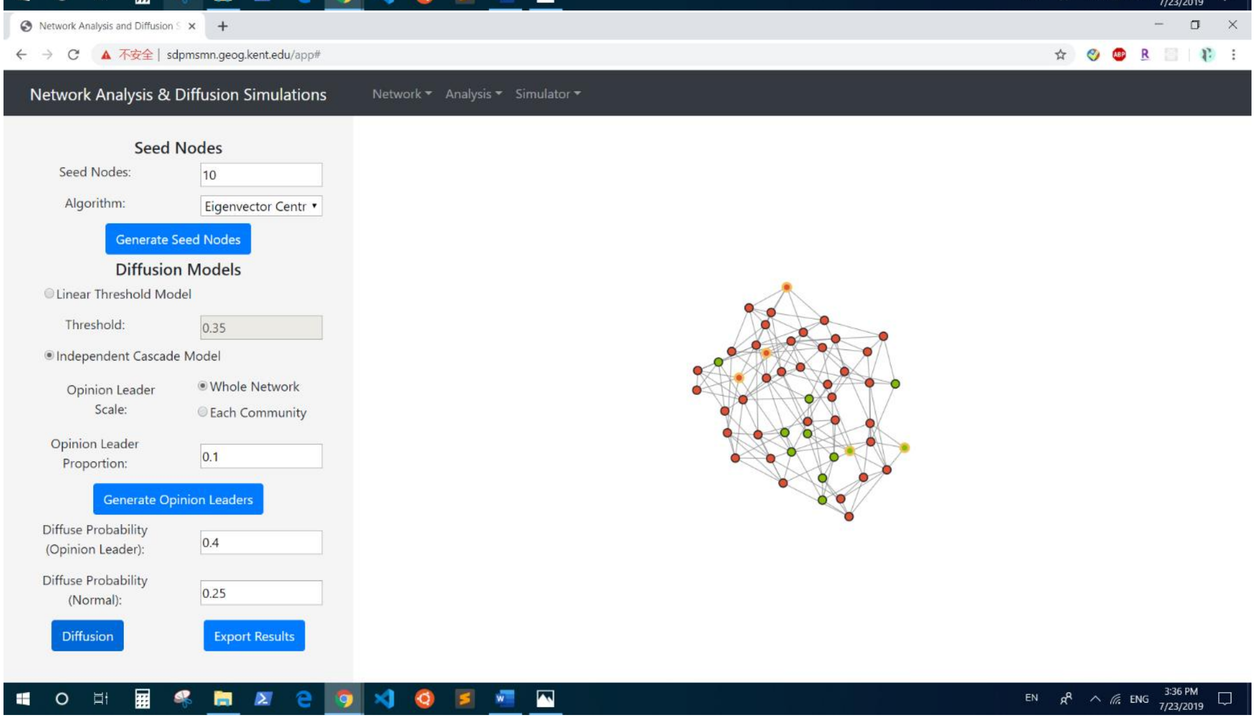


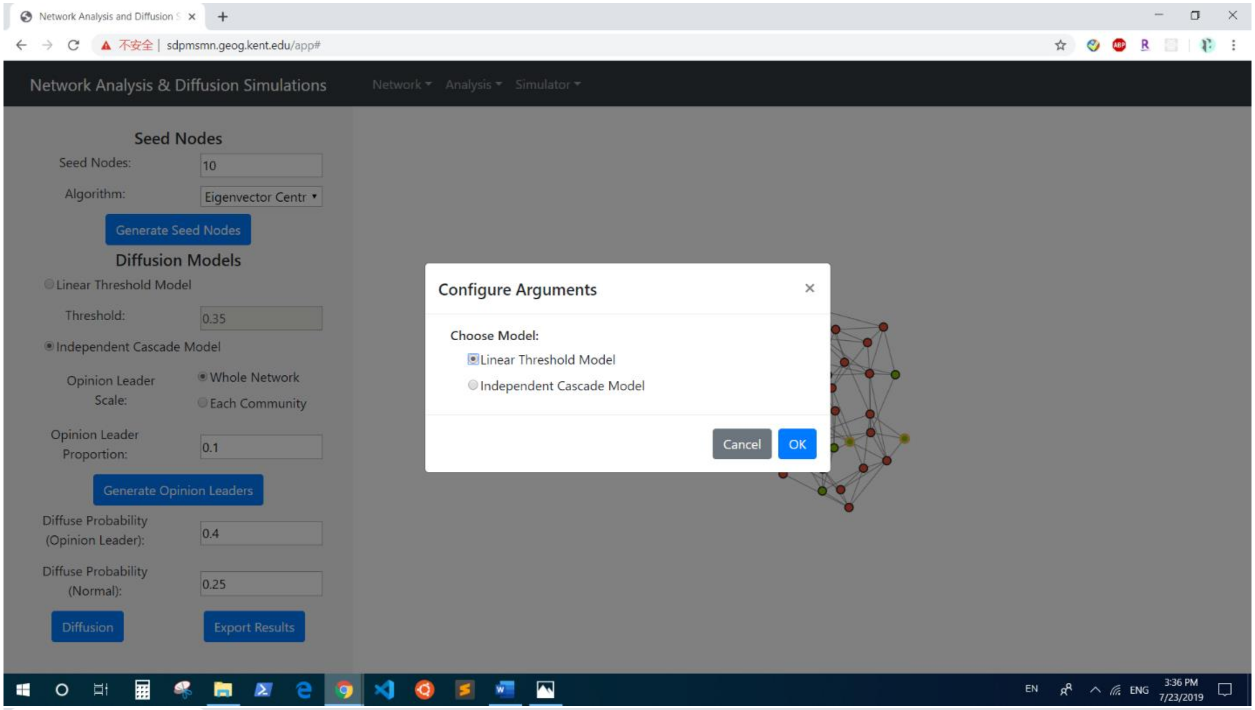


5. General network diffusion with ranges (User Level)

General network diffusion with ranges is to compute results based on sequences of parameters in specific ranges. The purpose of this function is to examine how different sets of parameters will affect the diffusion. It has the same types of parameters as general network diffusion, but all numeric parameters can be set with ranges respectively. Some integer-related parameters will use flooring to avoid decimals during computations. Additionally, two ranges will be configured for one-time execution so that the user needs to select two parameters to set up ranges in ICM.

Usage:

a. Select User Level with Ranges in the Simulator menu
b. Select one of two models (i.e., LTM or ICM) for diffusions. For ICM, select two parameters as the parameters with ranges.
c. Input values into the form. Value-based parameters are set like general network diffusion. However, ranges are set with minimum, maximum and the number of ranges.
d. Click Diffusion to generate and present the diffusion statistical chart.


Network Analysis and Diffusion S
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Network Analysis & Diffusion Simulations
Network
Analysis
Simulator
Seed Nodes
Seed Nodes:
10
Algorithm:
Eigenvector Centr
Generate Seed Nodes
Diffusion Models
Linear Threshold Model
Threshold:
0.35
Independent Cascade Model
Opinion Leader Scale:
Whole Network
Each Community
Opinion Leader Proportion:
0.1
Generate Opinion Leaders
Diffuse Probability (Opinion Leader):
0.4
Diffuse Probability (Normal):
0.25
Diffusion
Export Results
Configure Arguments
Choose Model:
Linear Threshold Model
Independent Cascade Model
Cancel
OK
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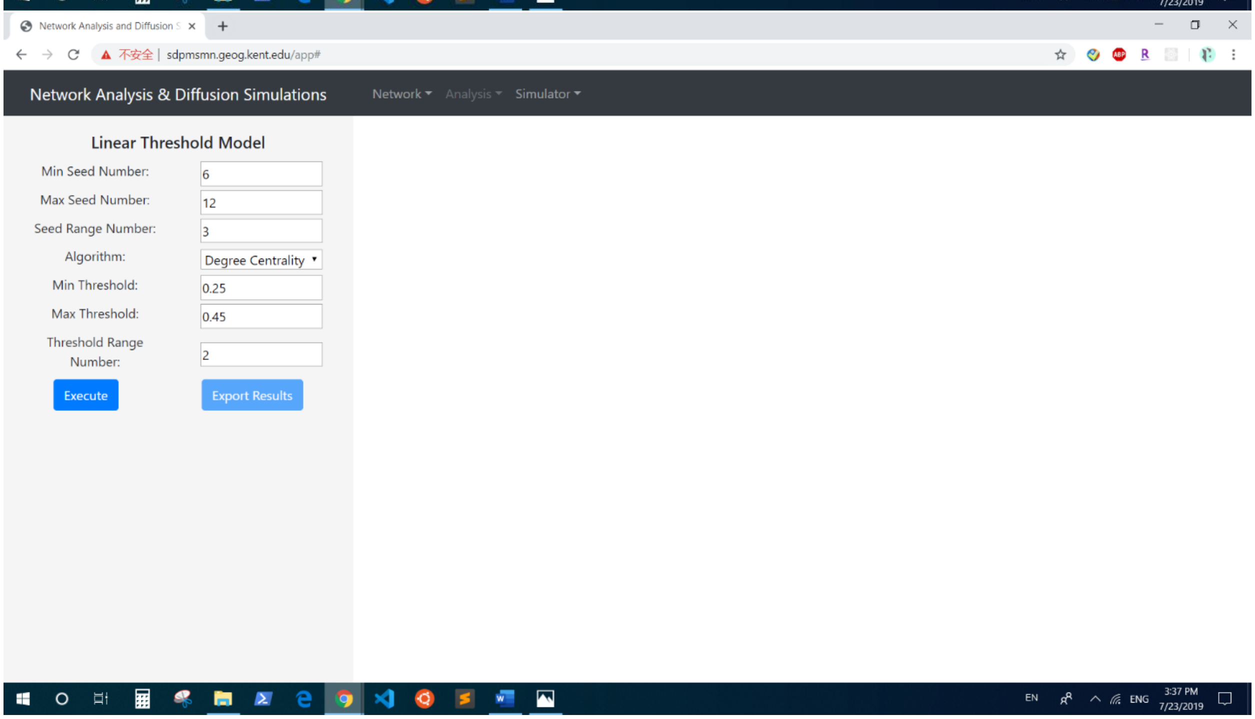
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Network Analysis & Diffusion Simulations
Network
Analysis
Simulator
Linear Threshold Model
Min Seed Number:
6
Max Seed Number:
12
Seed Range Number:
3
Algorithm:
Degree Centrality
Min Threshold:
0.25
Max Threshold:
0.45
Threshold Range Number:
2
Execute
Export Results
3:37 PM
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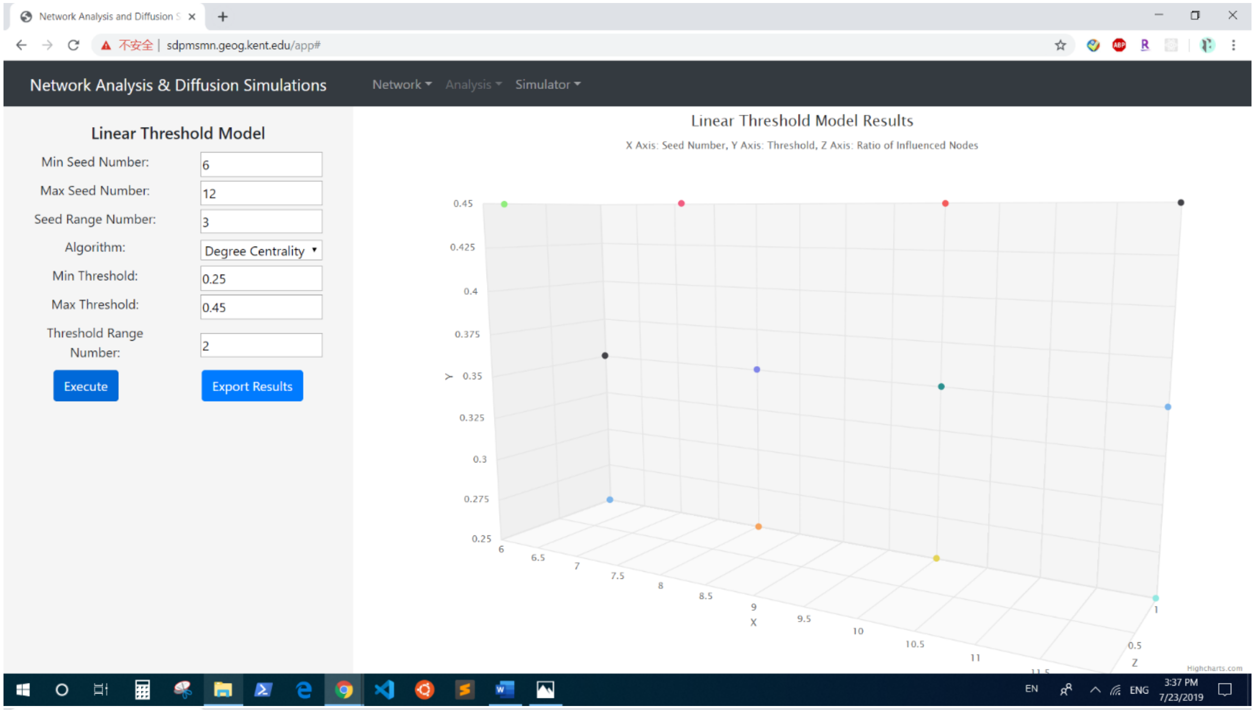
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Network Analysis & Diffusion Simulations
Network
Analysis
Simulator
Linear Threshold Model
Min Seed Number: 6
Max Seed Number: 12
Seed Range Number: 3
Algorithm: Degree Centrality
Min Threshold: 0.25
Max Threshold: 0.45
Threshold Range Number: 2
Execute
Export Results
Linear Threshold Model Results
X Axis: Seed Number, Y Axis: Threshold, Z Axis: Ratio of Influenced Nodes
0.45
0.425
0.4
0.375
0.35
0.325
0.3
0.275
0.25
Y
6
6.5
7
7.5
8
8.5
9
9.5
10
10.5
11
X
1
0.5
Z
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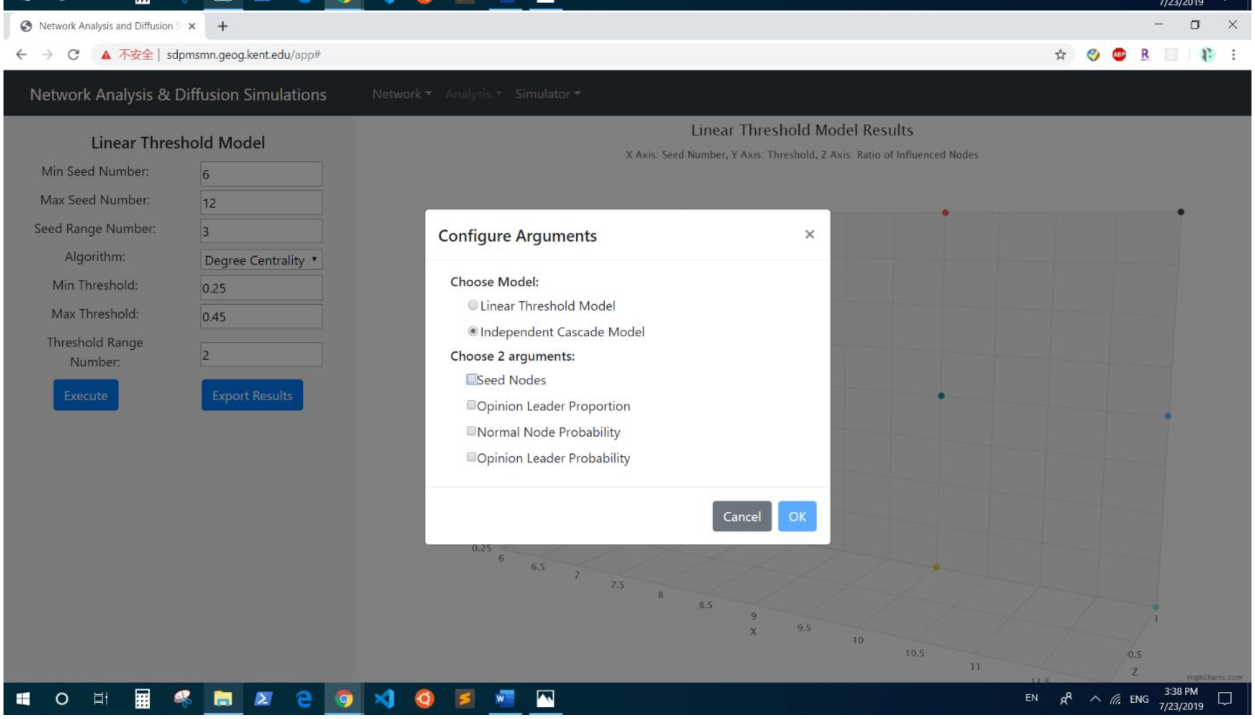
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Network Analysis & Diffusion Simulations
Linear Threshold Model
Linear Threshold Model Results
X Axis: Seed Number, Y Axis: Threshold, Z Axis: Ratio of Influenced Nodes
Configure Arguments
Choose Model:
Linear Threshold Model
Independent Cascade Model
Choose 2 arguments:
Seed Nodes
Opinion Leader Proportion
Normal Node Probability
Opinion Leader Probability
Cancel
OK
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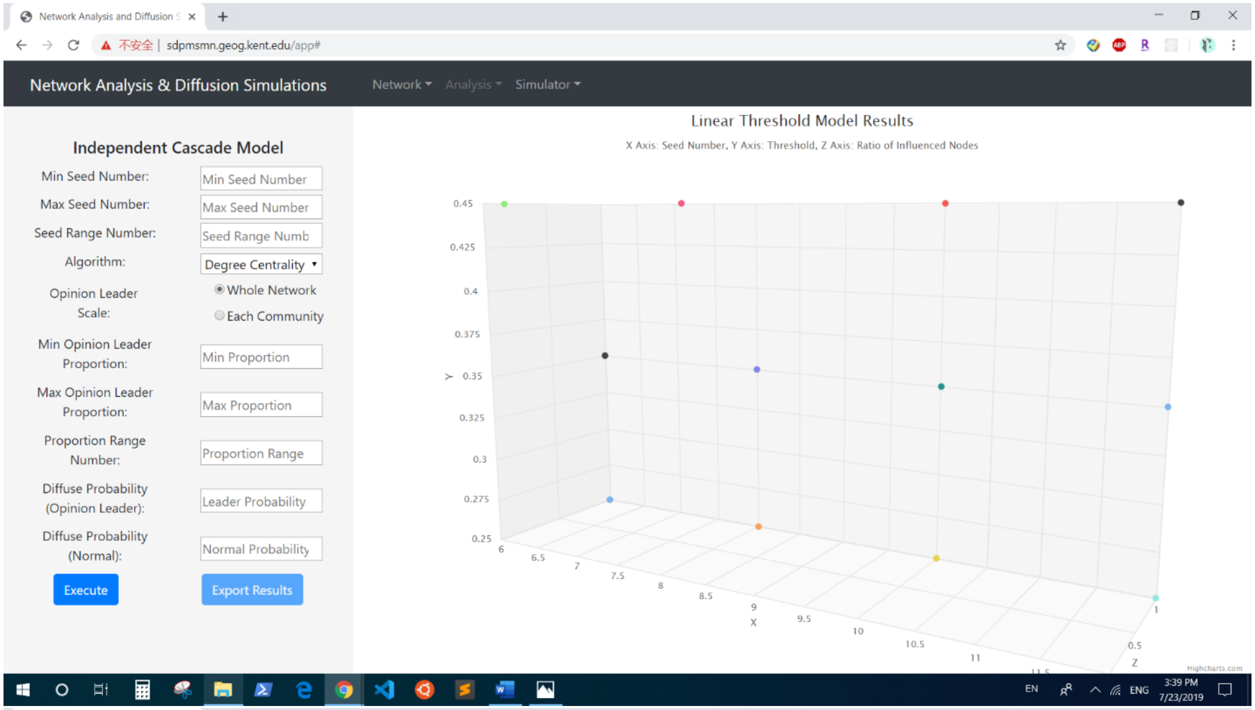
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Independent Cascade Model
Min Seed Number:
Min Seed Number
Max Seed Number:
Max Seed Number
Seed Range Number:
Seed Range Numb
Algorithm:
Degree Centrality
Opinion Leader Scale:
Whole Network
Each Community
Min Opinion Leader Proportion:
Min Proportion
Max Opinion Leader Proportion:
Max Proportion
Proportion Range Number:
Proportion Range
Diffuse Probability (Opinion Leader):
Leader Probability
Diffuse Probability (Normal):
Normal Probability
Execute
Export Results
Linear Threshold Model Results
X Axis: Seed Number, Y Axis: Threshold, Z Axis: Ratio of Influenced Nodes
Highcharts.com
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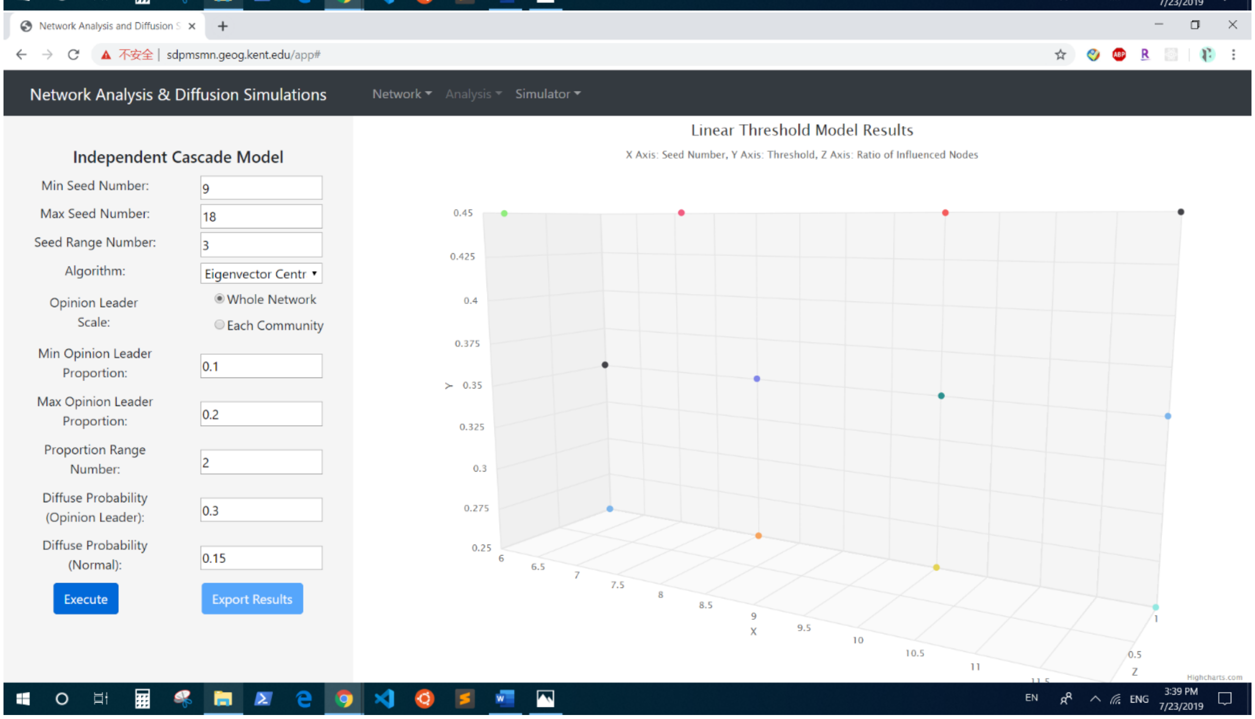
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Network Analysis & Diffusion Simulations
Network
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Simulator
Independent Cascade Model
Min Seed Number:
9
Max Seed Number:
18
Seed Range Number:
3
Algorithm:
Eigenvector Centr
Opinion Leader Scale:
Whole Network
Each Community
Min Opinion Leader Proportion:
0.1
Max Opinion Leader Proportion:
0.2
Proportion Range Number:
2
Diffuse Probability (Opinion Leader):
0.3
Diffuse Probability (Normal):
0.15
Execute
Export Results
Linear Threshold Model Results
X Axis: Seed Number, Y Axis: Threshold, Z Axis: Ratio of Influenced Nodes
Highcharts.com
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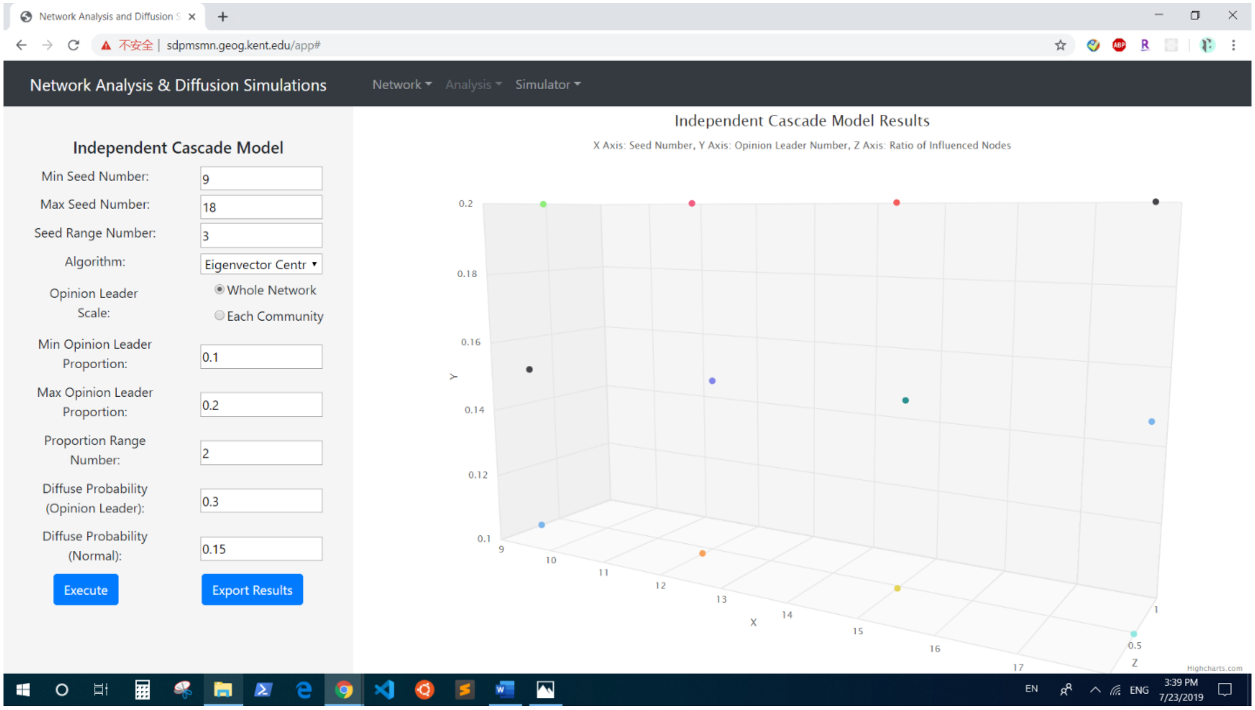


6. Geographic network diffusion (City Level)

General network diffusion requires users to upload their own data files: base map (i.e. ESRI shapefile), network file and weight file.

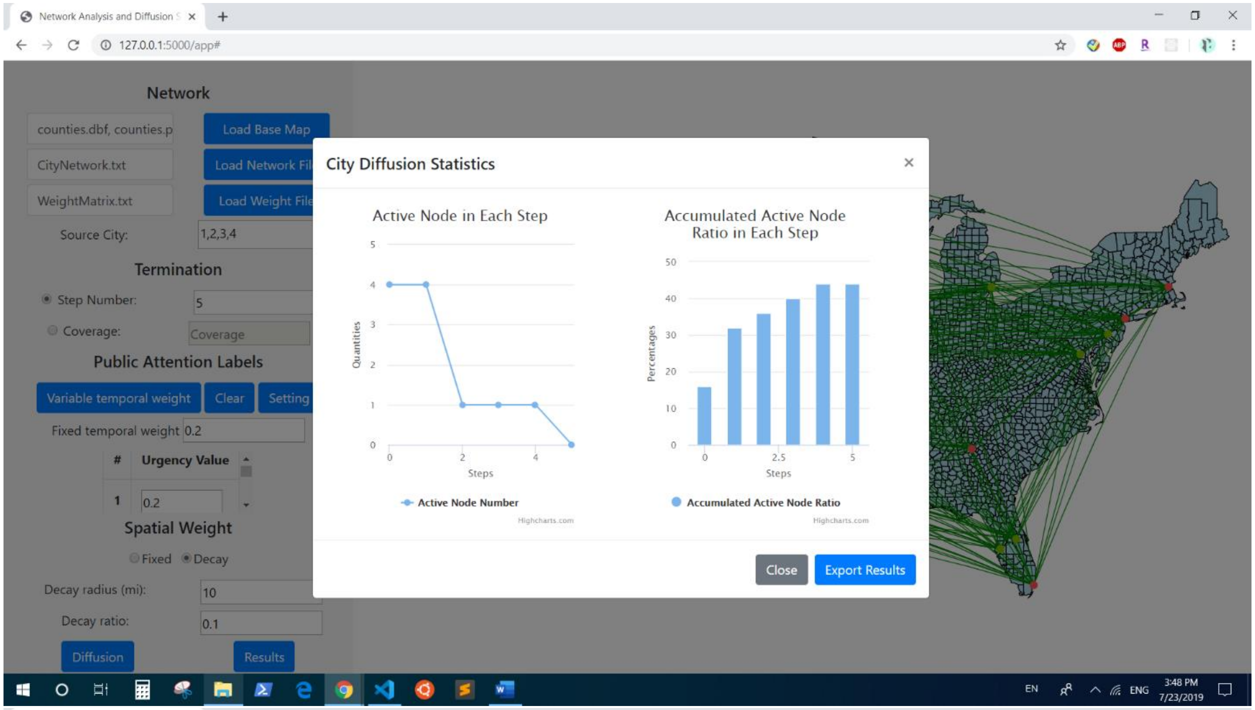
Parameters: (1) Base Map, (2) Network File, (3) Weight File, (4) Source City IDs, (5) Termination Option, (6) Termination Parameter, (7) Temporal Weight According to the Termination Part, (8) Spatial Weight Type, (9) Spatial Weight Decaying Parameters (Radius And Ratio)

Usage:

a. Click Choose Base Map, Choose Network File and Choose Weight File to select corresponding data files from your local computer respectively. (Base map is in the form of shapefile, network file and weight file are text files with required forms.)
b. Click Load Base Map, Load Network File and Load Weight File to upload data files respectively, and the base map and the network are generated and presented on the page
c. Choose the termination type to end the simulation as wanted and then input a parameter for the selected type: for Step Number, a positive integer is required for total execution steps; for Coverage, a decimal between 0 and 1 is required for total proportion of diffused nodes
d. After determining the termination type and parameter, input temporal weight for the diffusion process.
   (I) Fixed temporal weight works for either of the two termination types. Input a decimal between 0 and 1, and then click Setting to set up temporal weight in a table.

(II) Variable temporal weights only work for termination steps. Click Variable temporal weight to generate a table to input a series of different decimals for each step. Click Clear to clear the table.

e. Finally, choose one of two spatial weight types: Fixed or Decay. User can choose Fixed to set a fixed weight to all the cities no matter the distance among them. If user hope that the distance affects the information diffusion. User can choose Decay and input two decimals between 0 and 1 for extra parameters: Decaying radius and Decaying ratio.
f. Click Diffusion to generate and present diffusion visualizations.


Network Analysis and Diffusion S
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Load Base Map
CityNetwork.txt
Load Network Fil
WeightMatrix.txt
Load Weight File
Source City:
1,2,3,4
Termination
Step Number:
5
Coverage:
Coverage
Public Attention Labels
Variable temporal weight
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Fixed temporal weight 0.2
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Spatial Weight
Fixed Decay
Decay radius (mi):
10
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0.1
Diffusion
Results
City Diffusion Statistics
Active Node in Each Step
Quantities
Steps
Active Node Number
Highcharts.com
Accumulated Active Node Ratio in Each Step
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Accumulated Active Node Ratio
Highcharts.com
Close
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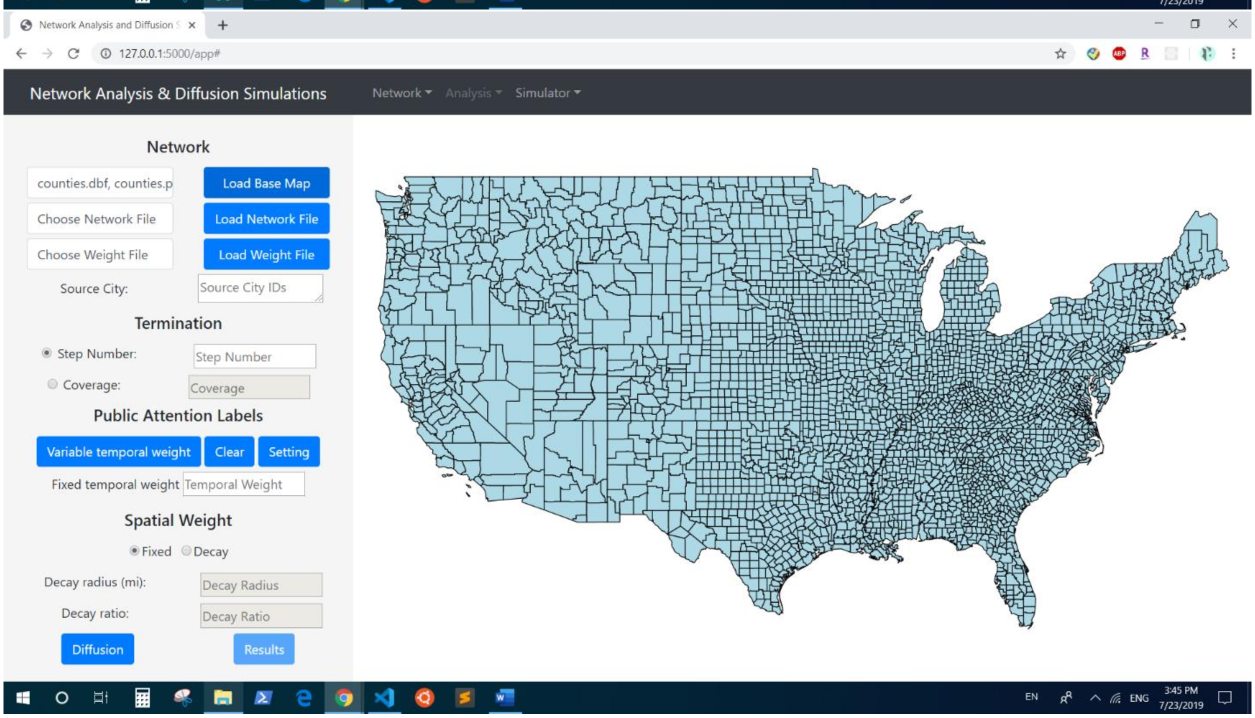
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Network Analysis & Diffusion Simulations
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counties.dbf, counties.p
Load Base Map
Choose Network File
Load Network File
Choose Weight File
Load Weight File
Source City:
Source City IDs
Termination
Step Number:
Step Number
Coverage:
Coverage
Public Attention Labels
Variable temporal weight
Clear
Setting
Fixed temporal weight
Temporal Weight
Spatial Weight
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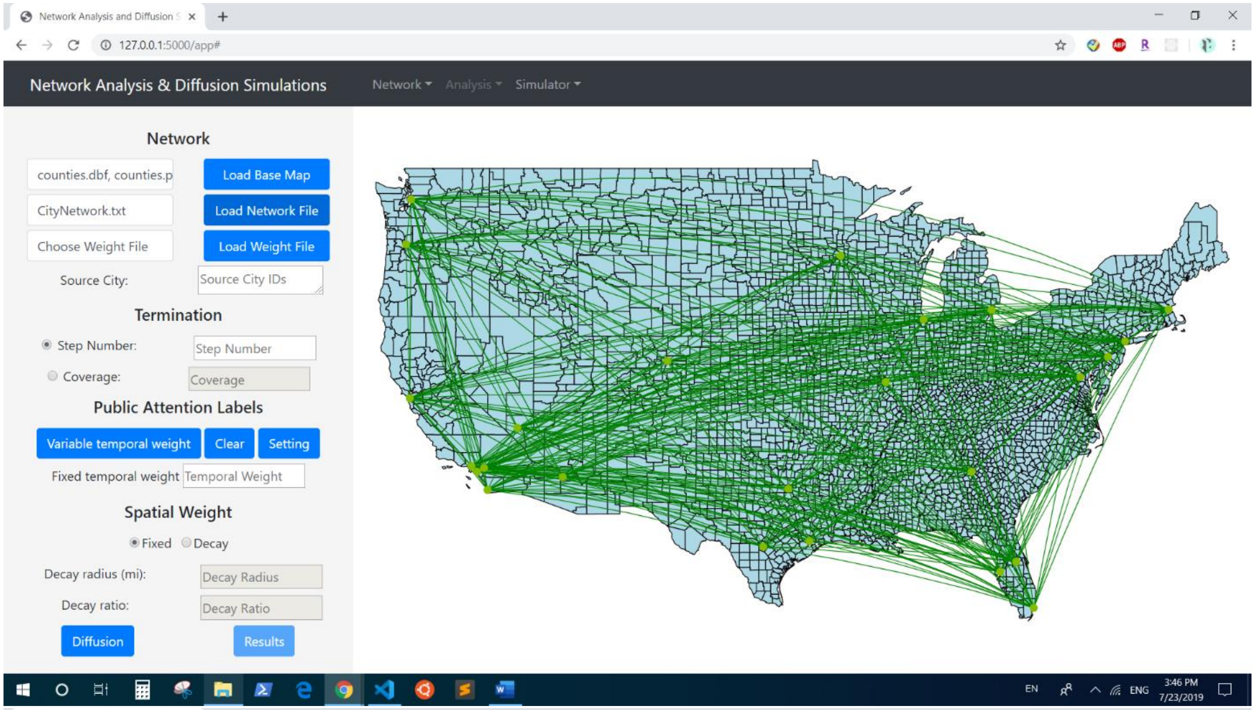
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CityNetwork.txt
Load Network File
Choose Weight File
Load Weight File
Source City:
Source City IDs
Termination
Step Number:
Step Number
Coverage:
Coverage
Public Attention Labels
Variable temporal weight
Clear
Setting
Fixed temporal weight
Temporal Weight
Spatial Weight
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Decay Radius
Decay ratio:
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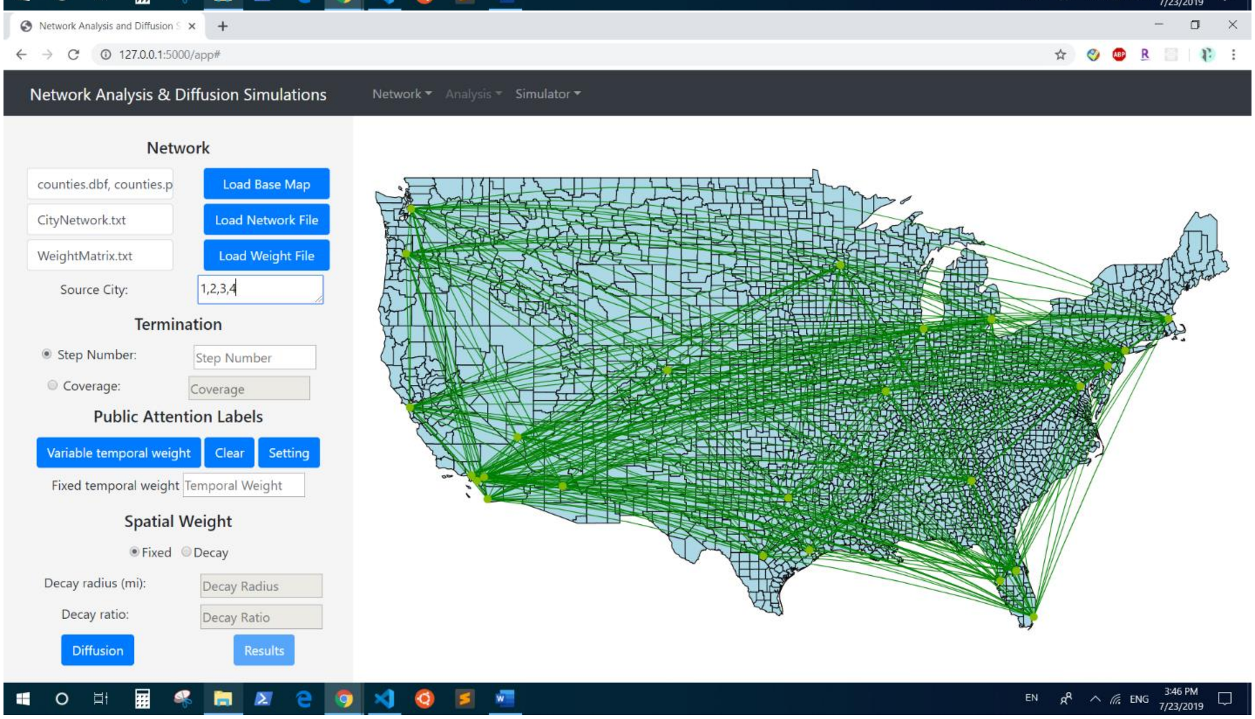
Network Analysis and Diffusion S
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counties.dbf, counties.p
Load Base Map
CityNetwork.txt
Load Network File
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Source City:
1,2,3,4
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Step Number:
Step Number
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Public Attention Labels
Variable temporal weight
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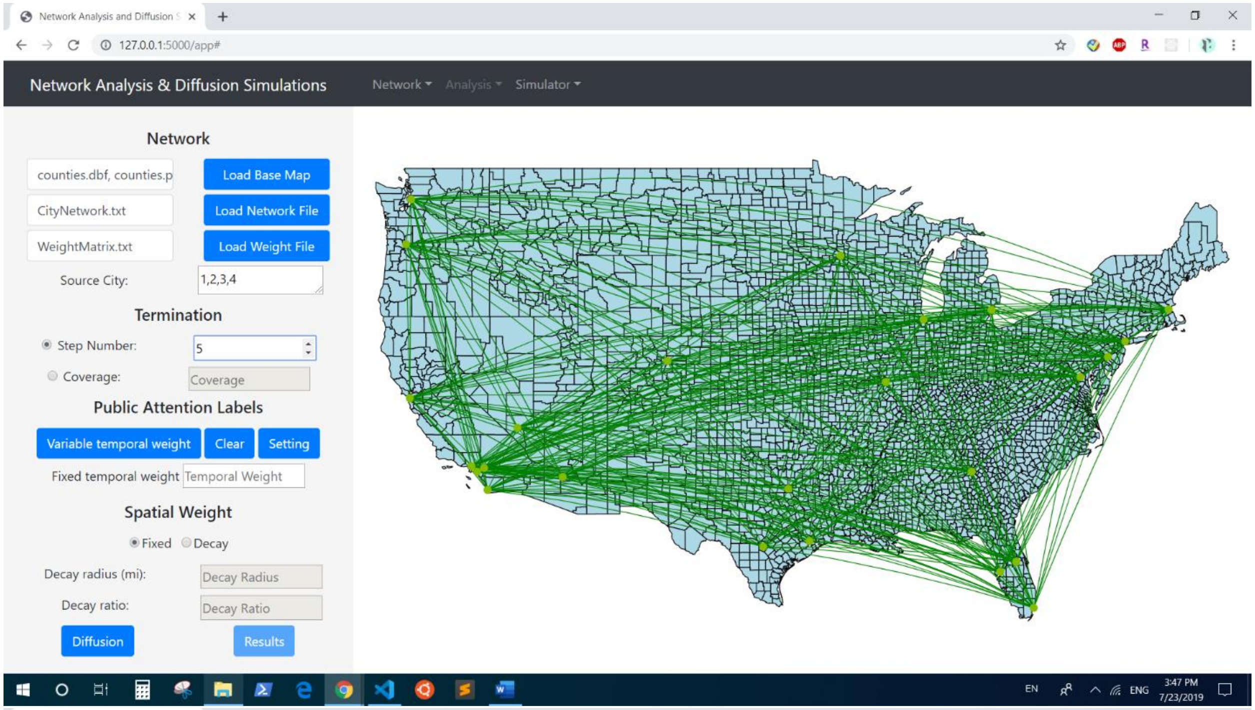
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Step Number:
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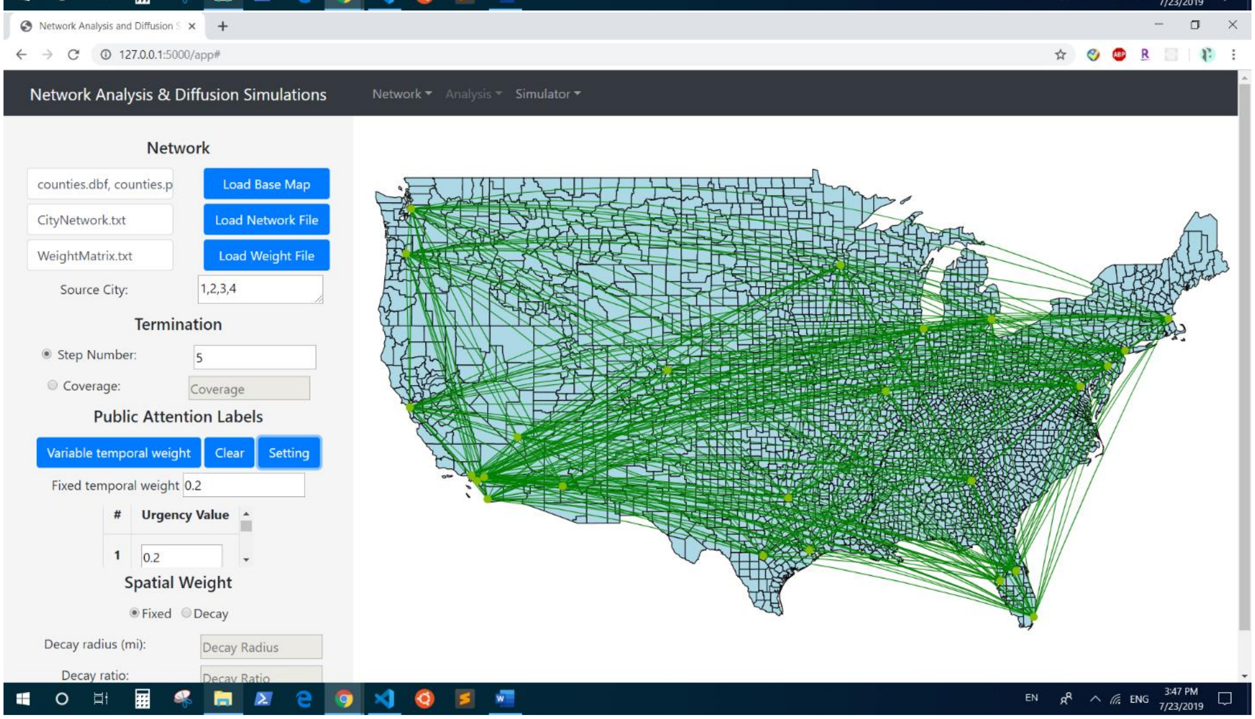
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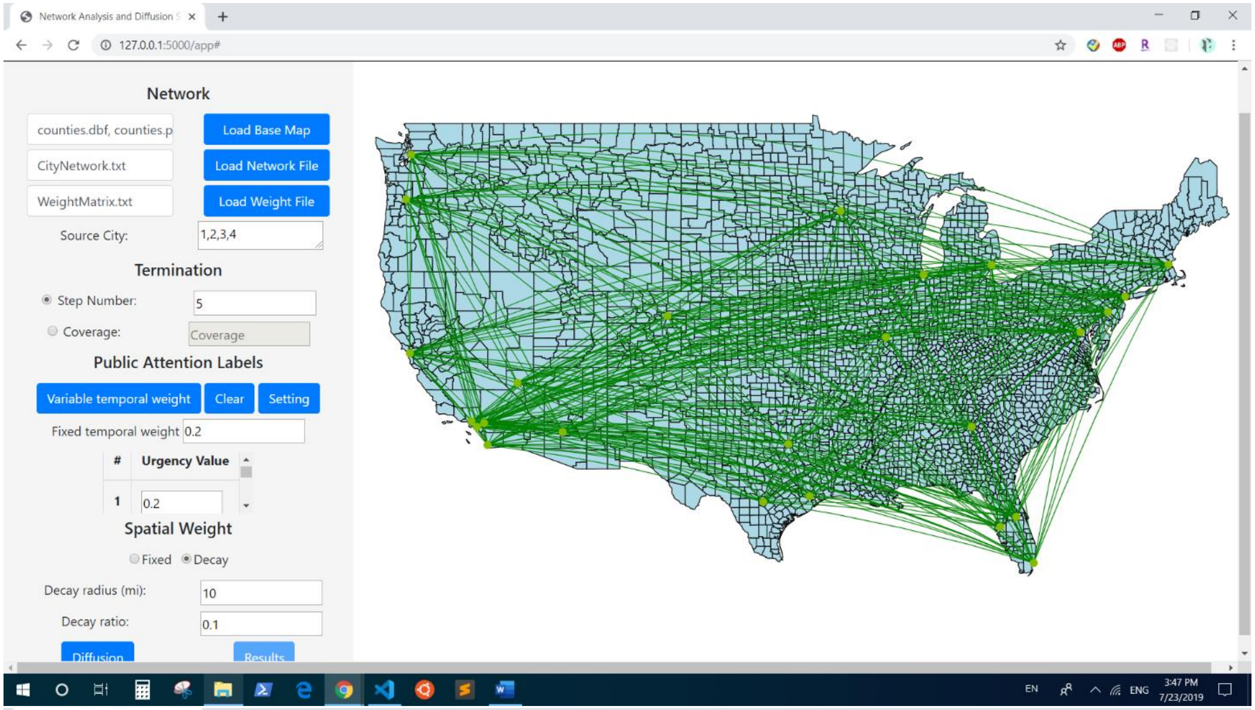
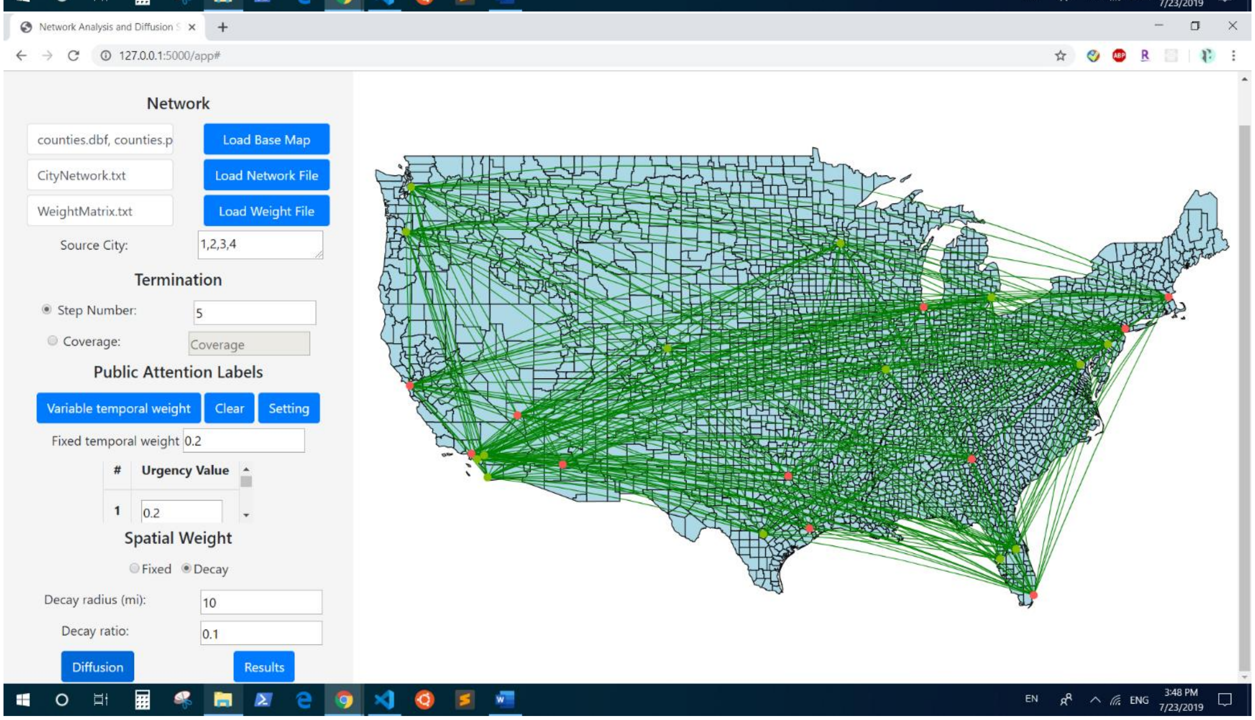
Network
counties.dbf, counties.p
Load Base Map
CityNetwork.txt
Load Network File
WeightMatrix.txt
Load Weight File
Source City:
1,2,3,4
Termination
Step Number:
5
Coverage:
Coverage
Public Attention Labels
Variable temporal weight
Clear
Setting
Fixed temporal weight
0.2
#
Urgency Value
1
0.2
Spatial Weight
Fixed
Decay
Decay radius (mi):
Decay Radius
Decay ratio:
Decay Ratio
EN
ENG
3:47 PM
7/23/2019





7. Export Results

All the results of network generations, analysis and simulations can be exported and downloaded as a zip package to your local computer.

Prerequisite: Corresponding results are generated successfully.

Usage: For network generations and analysis, select Export Network in the Network menu or Export Analysis in the Analysis menu to download the results; for network simulations, there is also an Export Results button available for downloading.