

PROJECT REPORT

VIRTUAL COORDINATE GENERATOR AND ROUTING SIMULATION TOOL FOR WIRELESS
SENSOR NETWORKS IN 2 AND 3-DIMENSIONAL NETWORK SPACE

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ABSTRACT

VIRTUAL COORDINATE GENERATOR AND ROUTING SIMULATION TOOL FOR WIRELESS SENSOR NETWORKS IN 2 AND 3-DIMENSIONAL NETWORK SPACE

This project focuses on building Virtual Coordinate based simulator for wireless sensor networks (WSN) in 2-Dimensional and 3-Dimensional network space. It is the work done as an extension to the work presented in (Shah, 2013) and (Reddy, 2015) under the guidance of Dr. Anura P. Jayasumana. Wireless Sensor Networks (WSNs) consist of a large number of sensor nodes, deployed over an area to collaboratively monitor or sample data from physical or environmental phenomenon such as humidity in soil, temperature of water, density of chemicals in air, suspicious event or target in battlefield, etc. Sensors periodically communicate with each other and report sampled data to a base station so that large area sensing process can be managed intelligently.

Earlier work presented in (Shah, 2013) and (Reddy, 2015) focuses on virtual coordinate based techniques in wireless sensor networks in 2- Dimensional network space and 3-Dimensional network space respectively. The aim of this project is to create a one-stop tool for both 2-D and 3-D network space and to implement various routing techniques for both the network spaces.

(Shah, 2013) presents an interface or a tool called VCSIM (Virtual Coordinate based simulation) that runs the virtual coordinate based simulations for 2-Dimensional wireless sensor networks, which purely focuses on the Virtual Coordinate Space in 2D wireless sensor networks. This simulator has enabled the interaction with the user through a Graphical User Interface, with the help of which user can create uniform or random networks, networks of different shape and size and networks with voids embedded in them. The tool also enables the placement of anchors and generation of Virtual Coordinates. Localization and Planarization techniques were also facilitated in the VCSIM tool. (Reddy, 2015) extended the tool for a 3-D environment with the same features.

The importance of VCSIM tool's novel approach has inspired to extend the tool with new features such as to incorporate different existing routing algorithms with the tool and to analyze the results for different networks that can be created with the VCSIM tool. The Graphical User Interface, designed for the project in MatLab enables the user to provide inputs for routing analysis and to view the results.

Chapter 1

INTRODUCTION

1.1 Wireless Sensor Networks

Wireless sensor networks are self-governing spatially distributed sensors, these sensors are used to monitor physical and environmental conditions. Each network can comprise of dozens, hundreds or even thousands of sensors. These sensors are interconnected with wireless communication channel which creates a network of them. Each sensor that is a part of the Wireless Sensor Network is referred to as a node, typically comprises of transceiver, microcomputer, transducer and power source. These sensors cooperatively communicate with each other based on the range of communication or communicate with the base station. Sensor nodes have become tiny in size, affordable in cost, robust in performance, imbedded with powerful processor and have satisfactory computation capability and memory.

Wireless sensor networks are vulnerable to problems like power loss, packet loss and also privacy issues, unlike the wired connections wireless networks are accessible to all legitimate and illegitimate users. The wide spread usage of wireless sensor networks compels the need to look into more efficient methods of designing and maintenance of sensor networks. Unlike the wired connected sensor networks, Wireless Sensor Networks have very limited power source. The sensors are usually battery powered because of their relative small sizes. This puts limitations on the life span of the sensors and would require energy efficiency on all aspects, hence would need efficient routing techniques which enables effective communication among the sensors without having the power outage. Routing mechanism in the wireless sensor network plays a vital role in defining the efficiency of the network.

Wireless sensor networks have slowly started to become the integral part of many industries due to their high volume applications and lowered prices. Multiple wireless communication standards that are available today has made it more easy to have WSN's deployed for various purposes.

1.2 Motivation

The previous version of the simulator has features to form own network and obtain the set of Virtual Coordinates (VCs) of all the nodes from a set of anchor nodes. This feature was available separately for the 2D and 3D versions of the tool. Also the different routing mechanisms that can be followed by calculating VCs in a WSN were not available. A detailed analysis of routing in WSN either by selecting a random set of source and destination nodes or on the entire network will be helpful in designing the network and facilitates the proper placement of anchor nodes.

Recognizing the significance of the simulator, motivation towards building a one-stop simulator for 2- and 3-Dimensional network space has been drawn. As routing mechanism in the wireless sensor network plays a vital role in defining the efficiency of the network, it paved way for the motivation to add the feature of analyzing different routing mechanisms available.

1.3 Project Outline

The project goal is to integrate the simulator for 3D network space with the 2D space, which facilitates the user to design a sensor network of desired size, shape and density of nodes in them. It should enable the user to create desired voids in the networks. It also facilitates the user to input the simulator with desired set of anchors with the help of which virtual coordinates would be calculated and saved in a file. The simulator would return the virtual coordinates of the network defined by the user. Different routing mechanisms for both 2D and 3D network space is implemented and a way to calculate the efficiency of the routing mechanism for the user-defined network is provided.

ROUTING IN A WIRELESS SENSOR NETWORK

2.1 2D Routing mechanisms

2.1.1. GPSR: Greedy Perimeter Stateless Routing

Greedy Perimeter Stateless Routing (GPSR), is a responsive and efficient routing protocol for mobile, wireless networks which was proposed by Karp et al. GPSR exploits the correspondence between geographic position and connectivity in a wireless network, by using the positions of nodes to make packet forwarding decisions. GPSR uses greedy forwarding to forward packets to nodes that are always progressively closer to the destination. In regions of the network where such a greedy path does not exist, GPSR recovers by forwarding in perimeter mode, in which a packet traverses successively closer faces of a planar subgraph of the full radio network connectivity graph, until reaching a node closer to the destination, where greedy forwarding resumes.

2.1.2. GLR: Geo-logical Routing

Geo-Logical Routing (GLR) is a technique that brings the advantages of geographic routing to logical domain, without inheriting the disadvantages of physical domain, to achieve higher routability at a lower cost. It uses topology domain coordinates, derived solely from virtual coordinates (VCs), a better alternative for location information. In logical domain, a node is characterized by a VC vector, consisting of minimum number of hops to a set of anchor nodes. VCs contain information derived from connectivity of the network, but lack physical layout information such as directionality and geographic voids. GLR starts with Topographical Mode and then switches to Anchor Mode when it reaches a local minima. GLR then forwards packet using Anchor Mode until it reaches a local minima and then switches to Virtual Coordinate Mode. This happens till either the destination is reached or the packet is dropped.

2.2. 3D Routing Mechanisms

2.2.1. Greedy Distributed Spanning Tree Routing (GDSTR-3D)

GDSTR-3D attempts to forward packets greedily, i.e. to the neighbor whose coordinates are strictly closer to the destination node in Euclidean distance than the current minimum. Tree forwarding is guided by the convex hull information in the nodes and is guaranteed to find the destination if it is reachable. GDSTR-3D switches back to greedy when it finds a neighbor that is strictly closer to the destination than the current minimum. The key insight in GDSTR (and GDSTR-3D) is that the convex hulls of the nodes uniquely define a routing subtree that must contain the destination node, if the packet is deliverable. The routing subtree is defined as the subtree comprising of all the nodes in the network whose hulls contain the coordinates of the destination node. If a packet is not deliverable, the routing subtree will be a null tree.

2.2.2. 3D Geo-logical Routing

3D Geo-logical Routing (GLR) is the same as 2D GLR but this operates fairly on a 3D Wireless Sensor Network. It switches between virtual and topology coordinate domains to overcome the local minima of each other. This mechanism is demonstrated to be highly effective for complex 3D networks.

VCSIM TOOL

3.1 Switching between Network Spaces

Figure (1) and (2) shows the option given in the File menu to switch between network spaces.

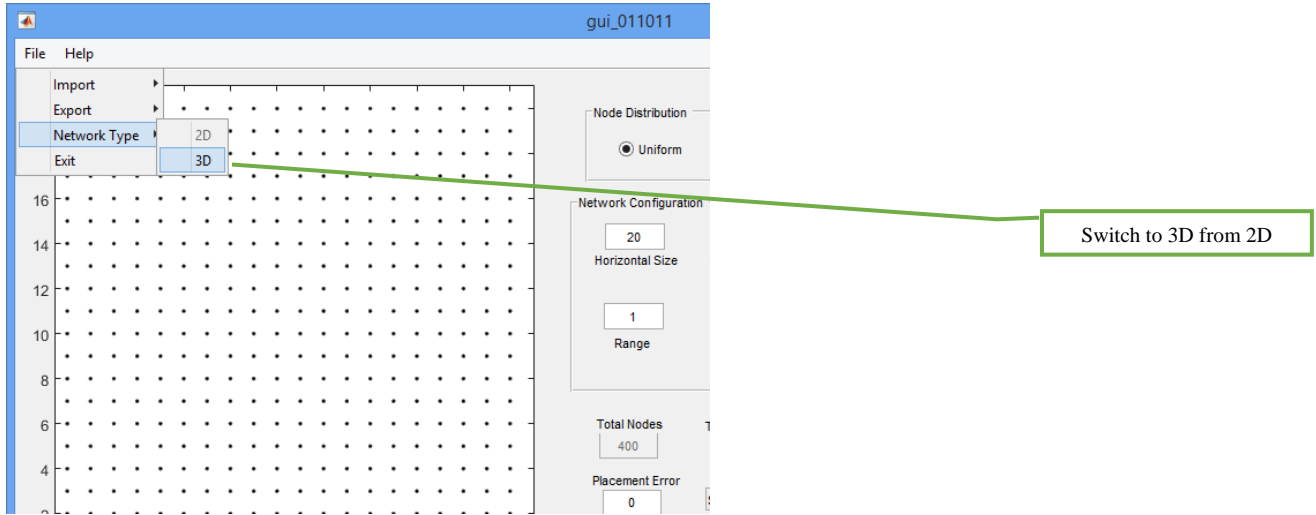


Figure 1: Switching option from 2D to 3D

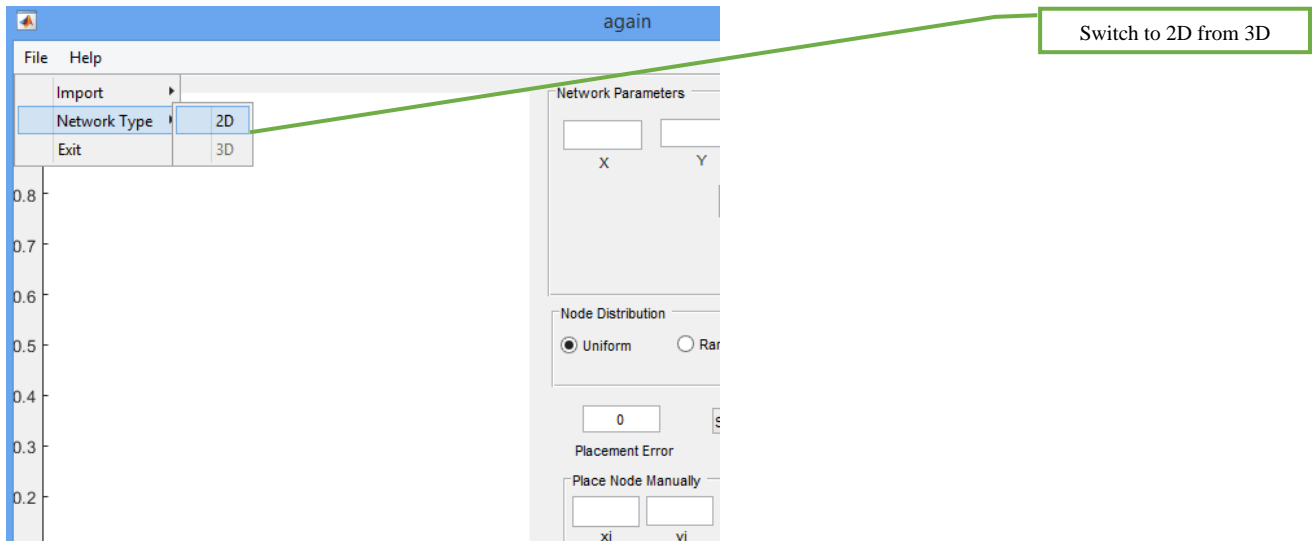


Figure 2 : Switching option from 3D to 2D

3.2 GUI for Analysis

3.2.1 2D Routing

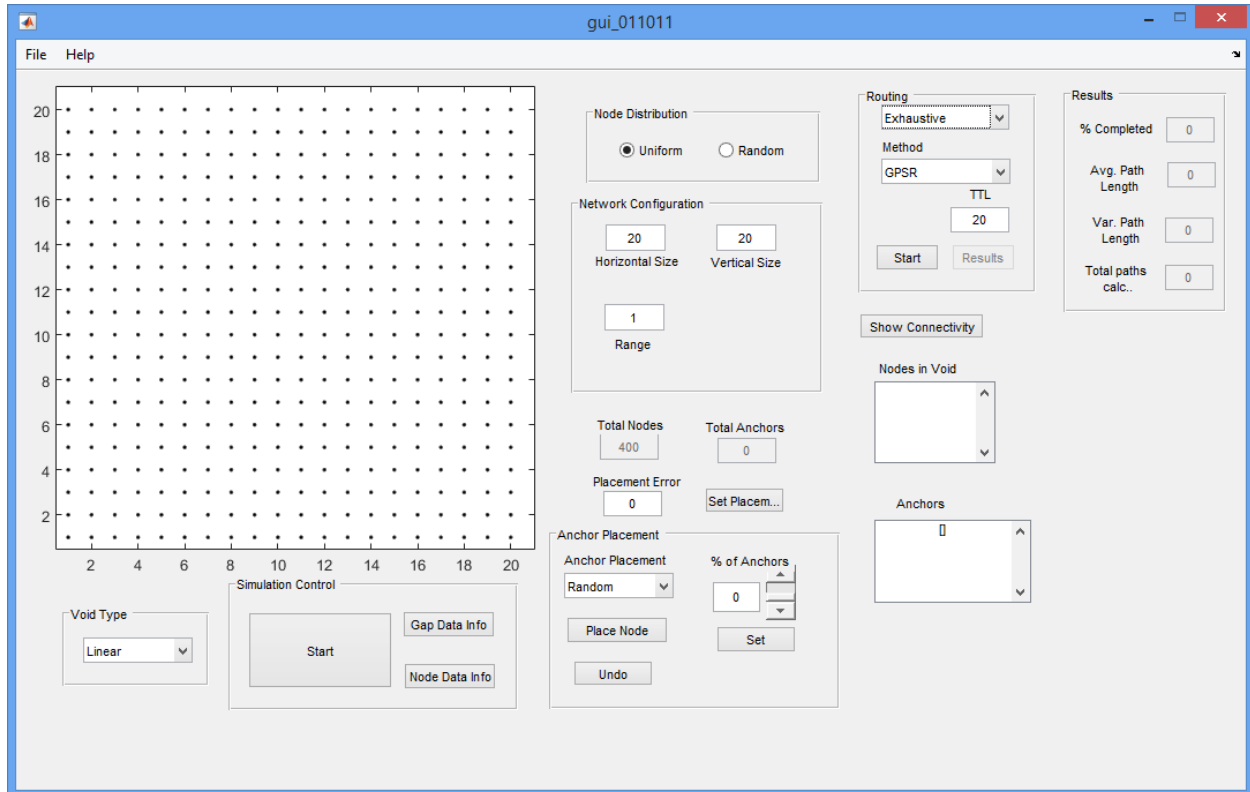


Figure 3 : GUI for 2D network space

Figure (3) shows the GUI for routing analysis and results for a 2D wireless sensor network. The routing analysis method can be either exhaustive or random. The routing mechanisms are included under the Method dropdown. Time to Live (TTL) is given in terms of route hops and the default value is 20. Routing will be done until the route hops exceeds the TTL value and then the packet is dropped. A TTL value of 0 indicates that the routing should be done until the destination is reached without dropping the packet. Once all the paths are simulated, the 'Results' button is enabled. A simulation can also be stopped before completion by using the 'Cancel' option in the progress bar that will be displayed while the simulation is underway.

3.2.2. 3D Routing

Figure (4) shows the GUI for routing analysis and results for a 3D wireless sensor network. The options for analysis are similar to that of 2D but the routing mechanisms differ.

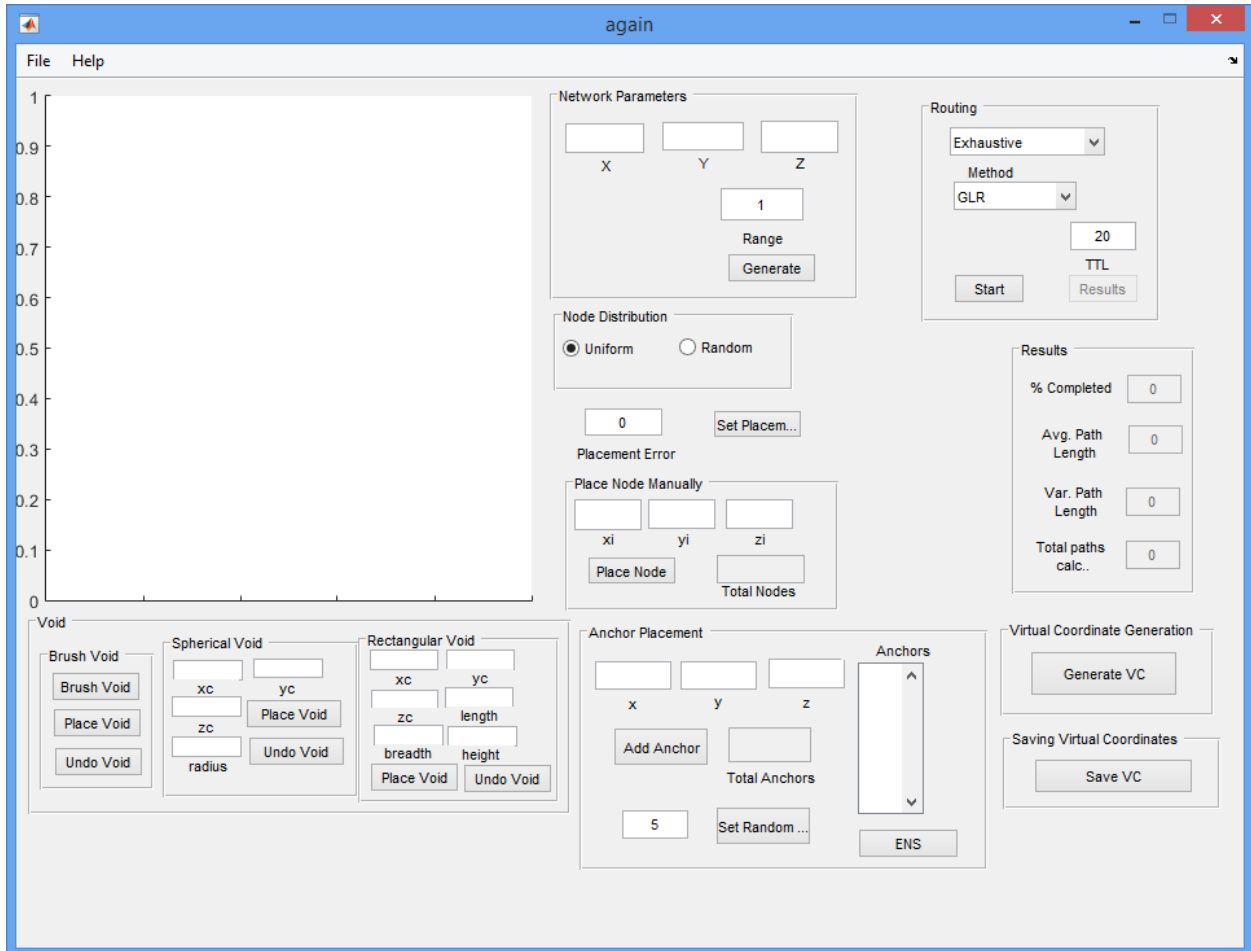


Figure 4 : GUI for 3D network space

3.2.3. Exhaustive Routing Analysis

Exhaustive Routing analysis calculates the path from each node to every other node. So in case of a network with 150 nodes, 22350 routing simulations will be done. This is used to determine if all nodes are approachable from every nodes in the network with a specified number of hops.

3.2.3. Random Routing Analysis

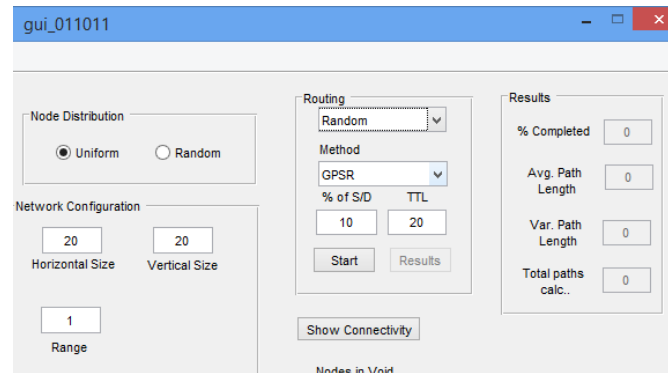


Figure 5 : Random routing analysis

Figure (5) shows the option of Random routing analysis. Random routing analysis allows the user to specify a percentage of Source/Destination (S/D) pairs in which the nodes are selected randomly. Routing is then performed on the selected nodes.

3.2.4. Results

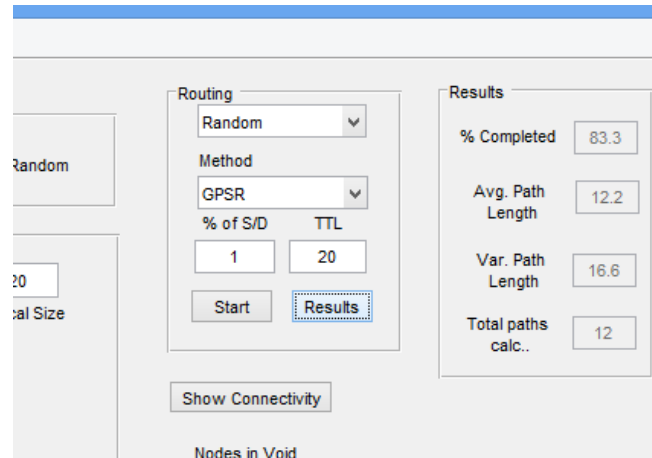


Figure 6 : Results after simulation

The following results are displayed at the end of simulation by using the 'Results' button (Figure 6).

- % Completed - Percentage of paths completed to the total paths calculated
- Avg. Path Length - Average path length (in hops)
- Var. Path Length - Variance path length (in hops)

- Total paths calc. - Total number of paths calculated
- Histogram of hops against the number of nodes (shown in Figure (7))

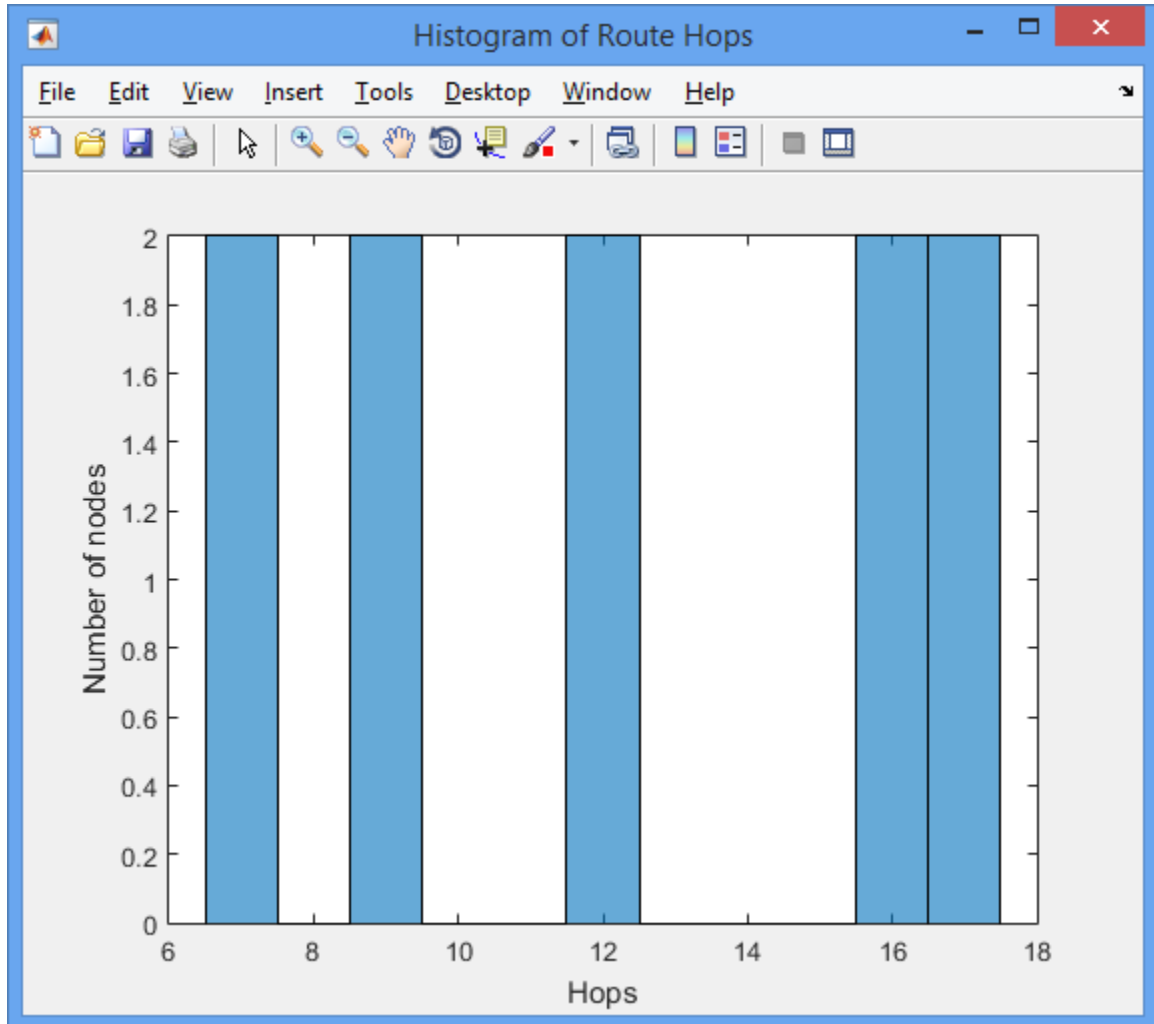


Figure 7 : Histogram of hops

3.2.5. Generation of Topologies

The size of the network to be simulated must be specified by the user. Node placement could either be 'Uniform' or 'Random'. In 'Random' placement user must specify the node density in a given area assuming each node is placed unit distance apart. Voids stand for the obstacles or absence of nodes in real environment. User can also import the topologies by providing nodes [x, y] coordinates or whole network

as matrix. Place Node allows user to individually place each node. Void creation could be accomplished in the following ways:

- 2D Network
 1. Linear - Vertices of polygon shaped obstacles must be given by user. The vertices are joined by a straight line to form a closed shape void.
 2. Interpolation - Approximate vertices are given to form the interpolated closed shape.
 3. Rectangle - Rectangular shaped polygons could be easily created.
 4. Circle - It is easy to create elliptical shape voids with this option.

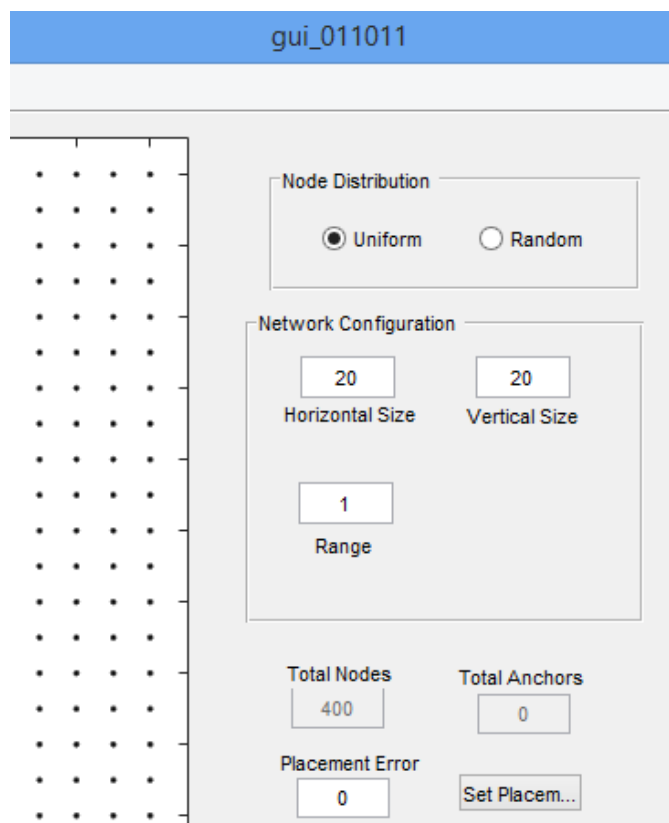


Figure 8 : Network generation – 2D

- 3D Network

1. Brush - Draw a void in the network of your own
2. Spherical - Create a spherical void by specifying the center and radius
3. Rectangular - Create a rectangular void by specifying one vertex and dimensions of the rectangle

'Placement Tolerance' specifies the placement tolerance allowed for each node. 10% placement tolerance mean nodes are placed within circle of 0.1 unit distance radius.

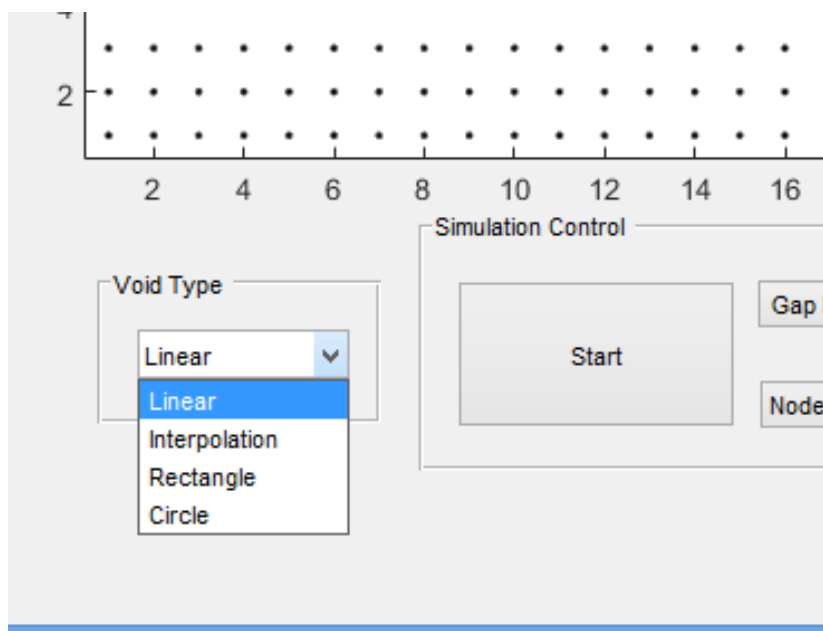


Figure 9 : Void creation – 2D

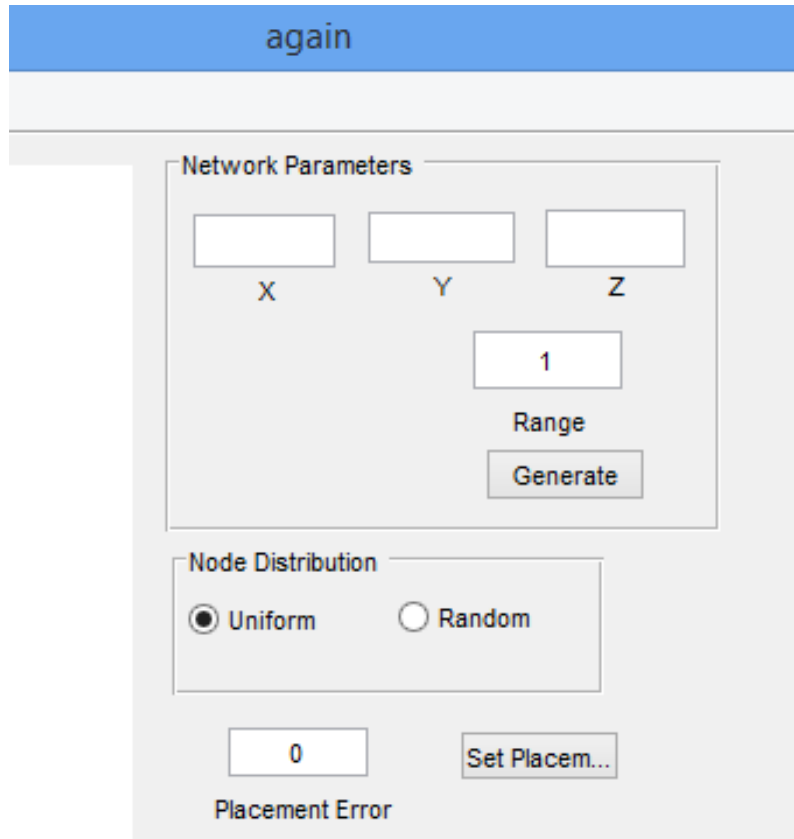


Figure 10 : Network Generation – 3D

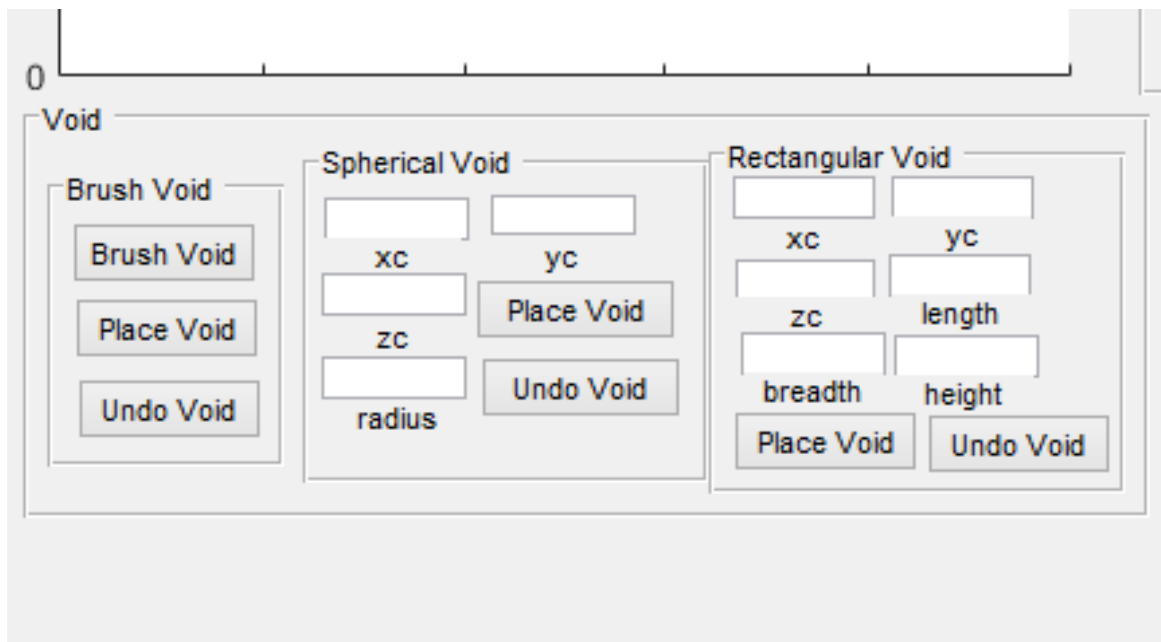


Figure 11 : Void creation – 3D

3.2.6. Anchor Placement

Anchors are specific nodes from which hop distances are counted to form virtual coordinates. Anchors are shown in 'Red' color (only in 2D). Three types of anchor selection methods are provided:

1. Random - User must specify percentage of anchors within given network. Random nodes are then selected as anchors.
2. Manual - User can either select particular nodes as anchors via mouse or by specifying approximate coordinates. The nearest node will be selected as anchor.
3. ENS - Extreme node search is an anchor selection scheme based on VCS. It requires selection of two anchors manually in case of a 2D network. The initial selection could again be done via mouse or specifying approximate coordinates. In case of a 3D network, Double ENS algorithm is used to select the appropriate anchors. It uses four randomly selected nodes as anchors and uses Directional Virtual Coordinates (DVC) to determine if a particular node can be selected as an anchor.

The 'Anchors' box shows the positions of selected anchors.

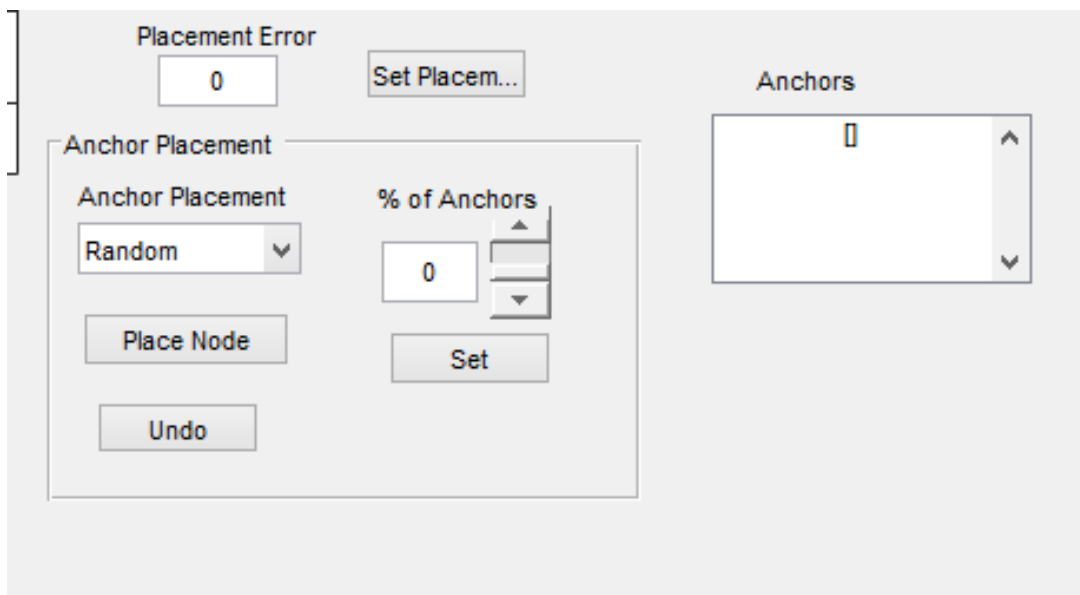


Figure 12 : Anchor Selection – 2D

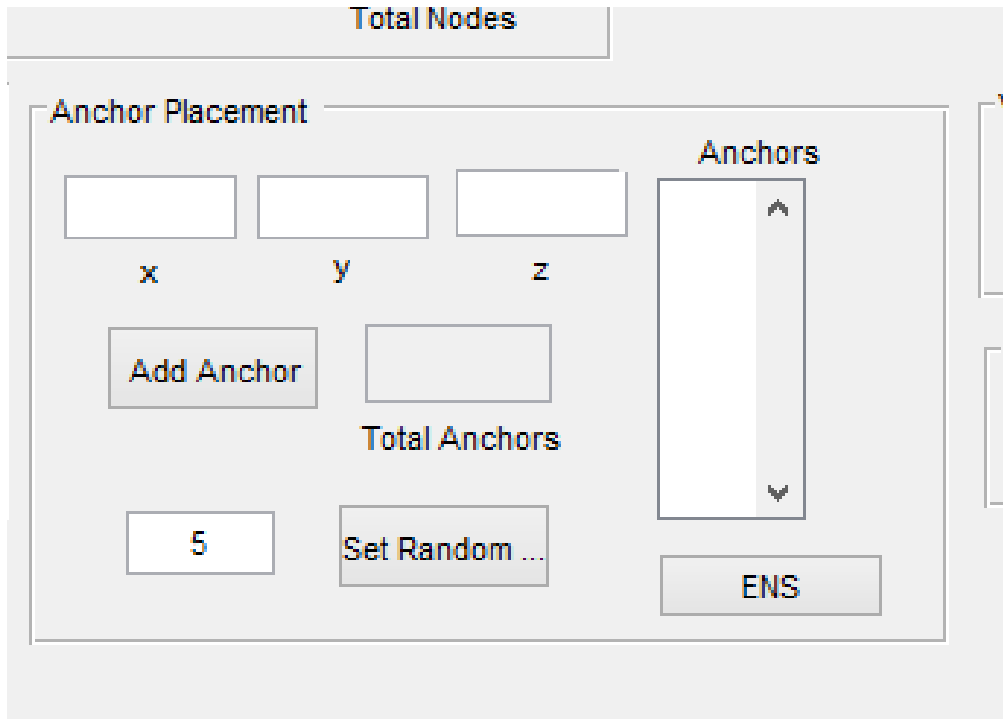


Figure 13 : Anchor Selection – 3D

3.2.7. Import Network

'Import' option under File menu enables user to import different network shapes and sizes. The 'Location' option requires the physical coordinates [(x,y) for 2D and (x,y,z) for 3D] of the sensors to be given as an input in a .mat file. The 'Network' option requires .mat file with a multi-dimensional array of 0s' and 1s' where 1s' represent the node being present in the network and 0s' represent the absence of nodes at the particular position.

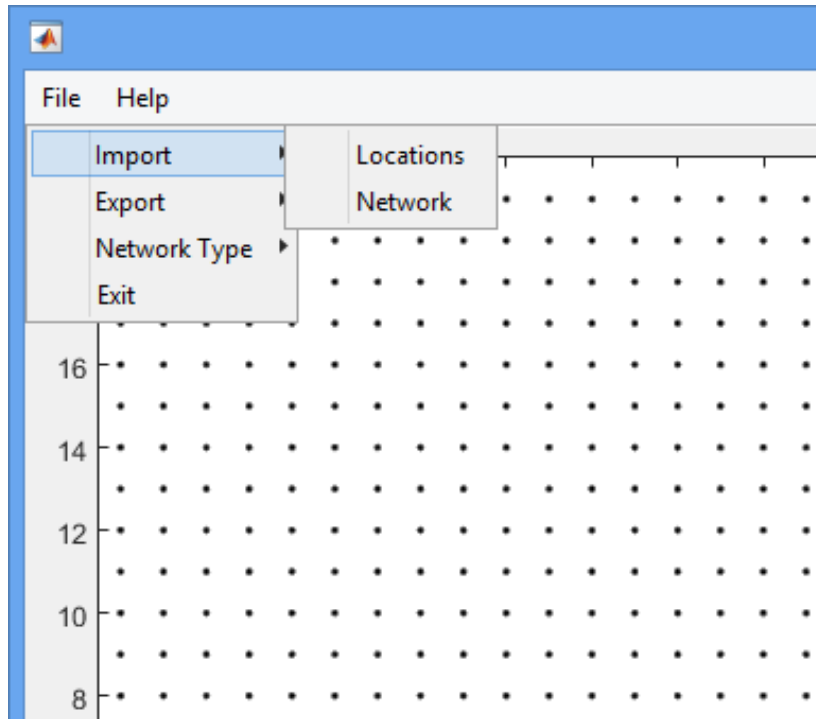


Figure 14 : Import Network

3.2.8. Prospective Work

The current tool can be used to create network of desired size, shape and density in 2 and 3-D network space, the tool also facilitates in choosing the anchors and calculating the Virtual Coordinates. Also it enables to perform simulations using various routing mechanisms that are available. Furthermore, routing algorithms can be added to the tool and the efficiency of those techniques can be calculated with ease.

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