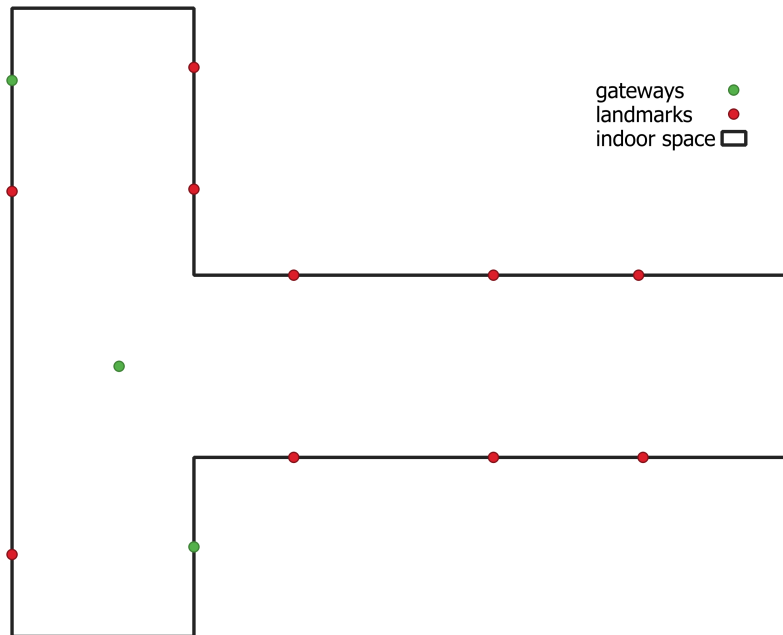


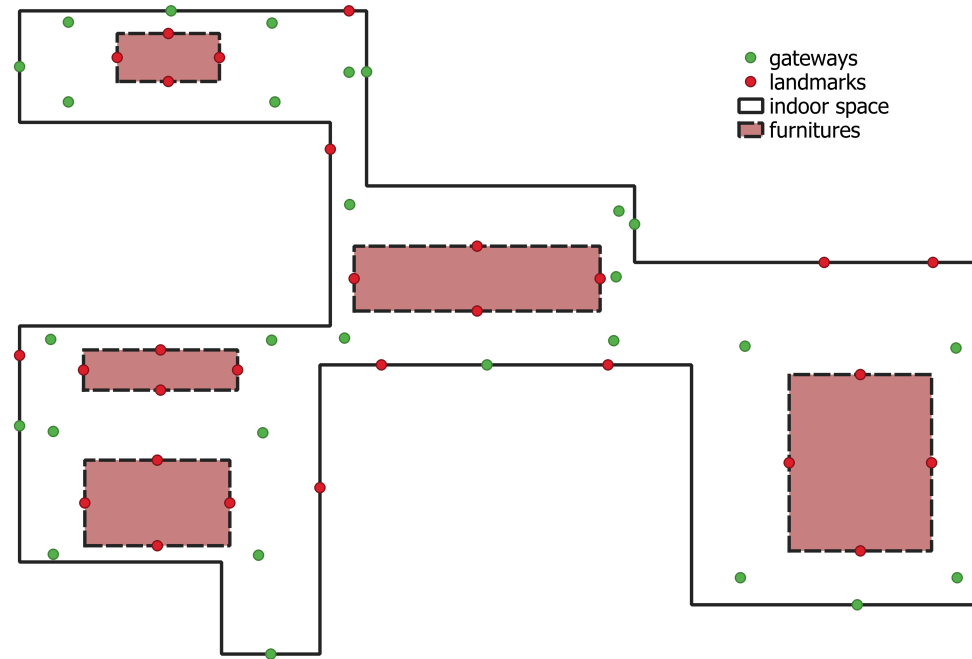
View Graph For Indoor Navigation

Test Environments

Hypothetical Floor Plan (Basic)



Hypothetical Floor Plan

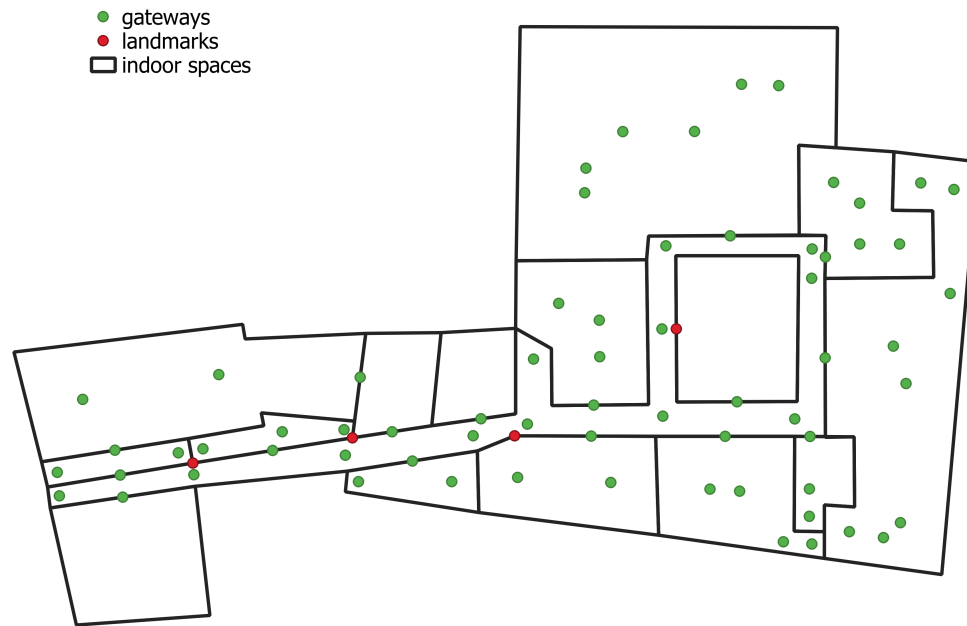


Real World Environment (University Layout)

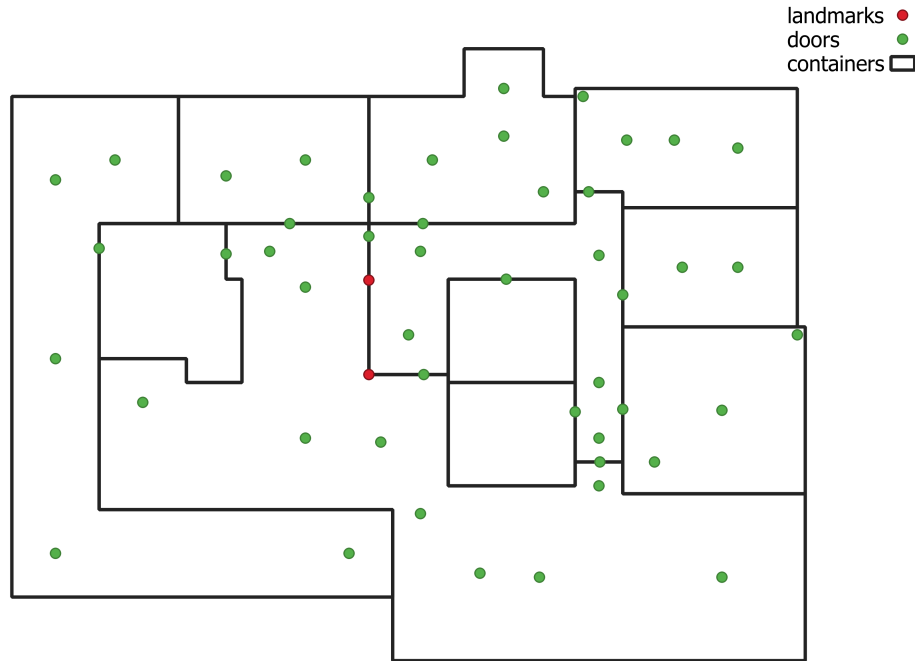


Real World Environment (Regent Place Shopping Mall)

Constructed from - with minor simplification: <https://www.regentplace.com.au/floor-plan>



Test Environment Constructed From Liu and Zlatanova (2011)



References

Configurational and Route Information

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- Zhou Z, Weibel R, Richter KF, Huang H. HiVG: A hierarchical indoor visibility-based graph for navigation guidance in multi-storey buildings. Computers, Environment and Urban Systems. 2022 Apr 1;93:101751.
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Setup

Loading classes

```
In [1]: # Parameters
from Parameters import Parameters

# Utilities for mathematical calculation, isovist and visualization
from Isovist import Isovist
from Plotter import Plotter
from Utility import Utility

# Container -> Environment -> View Graph
```

```

from Container import Container
from Environment import IndoorEnvironment
from ViewGraph import ViewGraph

from pyvis.network import Network

import matplotlib.pyplot as plt
plt.rcParams['figure.figsize'] = [10, 8]

```

Variables and parameters

```

In [2]: Parameters.set_env("real") # this can be set to "basic" environment, "hypo" environment as well
Parameters.print_info()

```

Real-world environment is active

Static Variables:

```

    epsilon: 0.01
    precision: 2
    alpha: 40
    fov: 160
    min_area: 0.005
    max_distance: 1000000
    door_weight: 50
    turn_weight: 0.05

```

Reading Datasets

```

In [3]: def read_env():
        # Basic environment
        if Parameters.basic:
            address = 'envs/basic/'
            pfiles = ['t_bound.geojson']
            hfiles = [None]
            dfiles = ['t_doors.geojson']
            dpfiles = [None]
            lfiles = ['t_landmarks.geojson']
            # create an indoor environment
            ie = IndoorEnvironment(address, pfiles, hfiles, dfiles, dpfiles, lfiles)

```

```

# Hypo environment
elif Parameters.hypo:
    address = 'envs/hypo/'
    pfiles = ['hypo_env.geojson']
    hfiles = ['hypo_holes.geojson']
    dfiles = ['hypo_doors.geojson']
    dpfiles = ['hypo_dpoints.geojson']
    lfiles = ['hypo_landmarks.geojson']
    # create an indoor environment
    ie = IndoorEnvironment(address, pfiles, hfiles, dfiles, dpfiles, lfiles)

# MC5 real world environment
else:
    if Parameters.mc:
        address = 'envs/mc-floor-5/'
    else:
        address = 'envs/RegentPlace'
    pfiles, hfiles, dfiles, dpfiles, lfiles = IndoorEnvironment.reformat(
        address, 'containers.geojson', 'doors.geojson', 'landmarks.geojson')
    # create an indoor environment
    ie = IndoorEnvironment('', pfiles, hfiles, dfiles, dpfiles, lfiles)

return ie

```

University Layout

In [4]: `ie = read_env()`

```

environment files -- count is valid
reading GeoJSON files (boundary, holes, doors and decision points)
reading GeoJSON files (boundary, holes, doors and decision points)
reading GeoJSON files (boundary, holes, doors and decision points)
reading GeoJSON files (boundary, holes, doors and decision points)
reading GeoJSON files (boundary, holes, doors and decision points)
reading GeoJSON files (boundary, holes, doors and decision points)
reading GeoJSON files (boundary, holes, doors and decision points)
reading GeoJSON files (boundary, holes, doors and decision points)
reading GeoJSON files (boundary, holes, doors and decision points)

```

Decomposing regions into isovists, and create view graph

Here, the following tasks are performed:

- calculate isovists
- decompose containers to regions
- calculate visibility signature for each region
- create adjacency matrix
- find initial views
- decompose views
- construct view graph
- calculate spatial relationships
- augment the actions in view graphs (to nodes and edges)

```
In [5]: # create view graph  
vgs, isovist_objects = ie.construct_view_graph()
```

Analyzing: Emergency Stairs
Container environment is valid: True
region initial : 1
regions : 1 -- 1
calculating the visibility signatures...
calculating adjacency matrix for regions
finding regions that contains doors/gateways and decision points
decompose views
len: 12
constructing view graph for regions
calculating all spatial relationships visible in each view
Adding actions to views (nodes)
Adding actions to view relations (edges)

Analyzing: Women Toilet
Container environment is valid: True
region initial : 3
regions : 4 -- 3
calculating the visibility signatures...
calculating adjacency matrix for regions
finding regions that contains doors/gateways and decision points
decompose views
len: 49
constructing view graph for regions
calculating all spatial relationships visible in each view
Adding actions to views (nodes)
Adding actions to view relations (edges)

Analyzing: Disabled Toilet
Container environment is valid: True
region initial : 1
regions : 1 -- 1
calculating the visibility signatures...
calculating adjacency matrix for regions
finding regions that contains doors/gateways and decision points
decompose views
len: 2
constructing view graph for regions
calculating all spatial relationships visible in each view
Adding actions to views (nodes)
Adding actions to view relations (edges)

```
*****
Analyzing: Men Toilet
Container environment is valid: True
region initial : 1
regions : 1 -- 1
calculating the visibility signatures...
calculating adjacency matrix for regions
finding regions that contains doors/gateways and decision points
decompose views
len: 2
constructing view graph for regions
calculating all spatial relationships visible in each view
Adding actions to views (nodes)
Adding actions to view relations (edges)
```

```
*****
Analyzing: Corridor
Container environment is valid: True
region initial : 21
regions : 10 -- 21
calculating the visibility signatures...
calculating adjacency matrix for regions
finding regions that contains doors/gateways and decision points
decompose views
len: 219
constructing view graph for regions
calculating all spatial relationships visible in each view
Adding actions to views (nodes)
Adding actions to view relations (edges)
```

```
*****
Analyzing: Active Hub
Container environment is valid: True
region initial : 43
regions : 12 -- 43
calculating the visibility signatures...
calculating adjacency matrix for regions
finding regions that contains doors/gateways and decision points
decompose views
len: 280
constructing view graph for regions
calculating all spatial relationships visible in each view
Adding actions to views (nodes)
```

Adding actions to view relations (edges)

Analyzing: Stairs to Lower Floors

Container environment is valid: True

region initial : 1

regions : 1 -- 1

calculating the visibility signatures...

calculating adjacency matrix for regions

finding regions that contains doors/gateways and decision points

decompose views

len: 2

constructing view graph for regions

calculating all spatial relationships visible in each view

Adding actions to views (nodes)

Adding actions to view relations (edges)

Analyzing: Ngi-a Djerring Gat-ith

Container environment is valid: True

region initial : 1

regions : 1 -- 1

calculating the visibility signatures...

calculating adjacency matrix for regions

finding regions that contains doors/gateways and decision points

decompose views

len: 72

constructing view graph for regions

calculating all spatial relationships visible in each view

Adding actions to views (nodes)

Adding actions to view relations (edges)

Analyzing: UX Lab

Container environment is valid: True

region initial : 16

regions : 12 -- 16

calculating the visibility signatures...

calculating adjacency matrix for regions

finding regions that contains doors/gateways and decision points

decompose views

len: 191

constructing view graph for regions

calculating all spatial relationships visible in each view

Adding actions to views (nodes)
 Adding actions to view relations (edges)

In [6]: `ie.containers_names`

Out[6]: ['Emergency Stairs',
 'Women Toilet',
 'Disabled Toilet',
 'Men Toilet',
 'Corridor',
 'Active Hub',
 'Stairs to Lower Floors',
 'Ngi-a Djerring Gat-ith',
 'UX Lab']

Shortest Path and Route Instruction

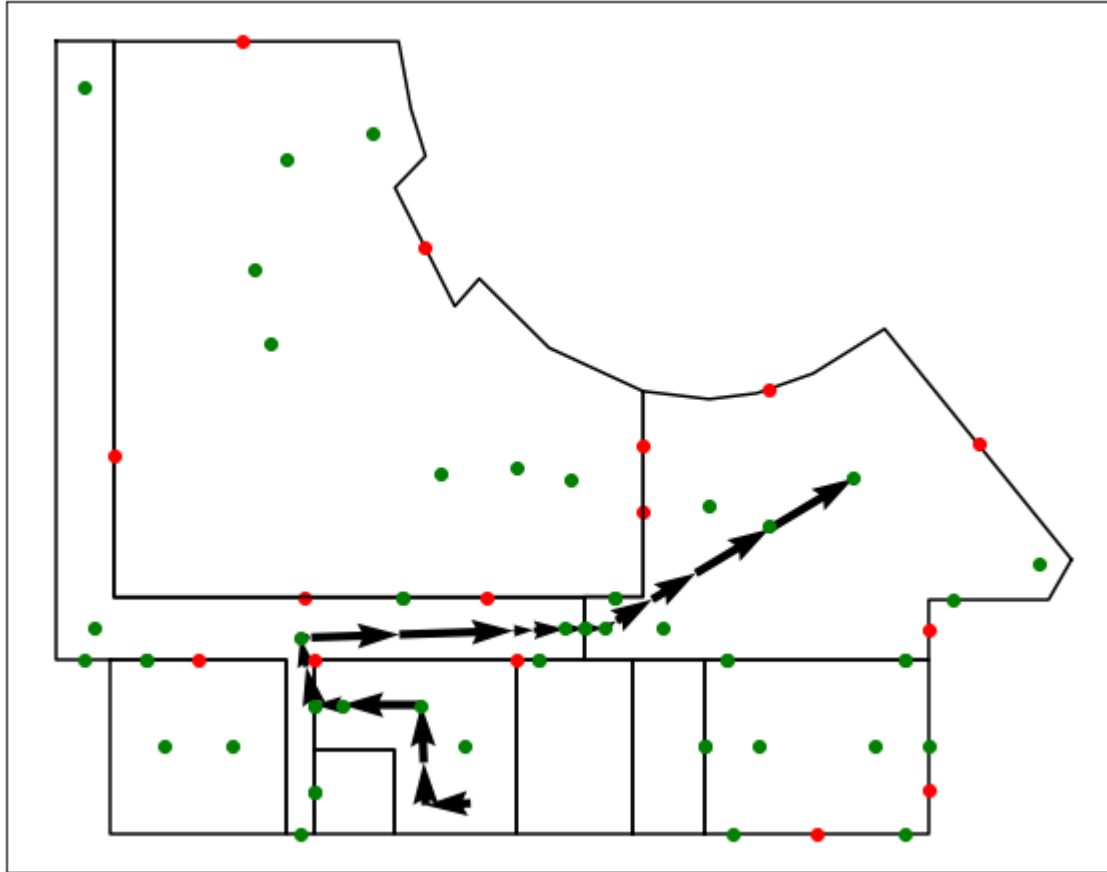
Here, we first generate a shortest path from a region to another. Then we use the augmented actions and relationships in view graph to generate route instructions from its results.

In [7]: `# set parameters to Parameters class
 start_container = 'Women Toilet'
 start_region = 3
 end_container = 'Active Hub'
 end_region = 3`

In [8]: `# calculate shortest path and generate verbal description
 vp, pv = ie.shortest_path(start_container, start_region, end_container, end_region)

 # plot shortest path
 plotter = Plotter()
 for isovist_object in ie.isovist_objects:
 plotter.add_isovist(isovist_object)
 plotter.add_views(pv)
 plotter.show(False)
 plotter.close()`

enter: Corridor
 enter: Active Hub



<Figure size 720x576 with 0 Axes>

```
In [9]: # generate route instructions
def generate_route_descriptions(vp):
    container = ''
    container_vids = {}
    finals = {}
    for v in vp[1:-1]:
        info = v.split('-V')
        if container != info[0]:
            container = info[0]
            container_vids[container] = []
        container_vids[container].append(int(info[1]))
    for container, vids in container_vids.items():
        cidx = ie.containers_names.index(container)
        vg = vgs[cidx]
```

```

        rds = vg.generate_route_description(vids)
        finals[container] = rds
    return finals

def print_route_descriptions(rd_dictionary):
    containers = list(rd_dictionary.keys())
    for container in containers:
        rd = rd_dictionary[container]
        if containers.index(container) < len(containers) - 1:
            rd[len(rd)-1] = rd[len(rd)-1].replace('until you reach the destination', 'to enter {}'.format(containers[containers.index(container)+1]))
        for r in rd:
            print(r)
# vg.generate_route_description(vp)
print_route_descriptions(generate_route_descriptions(vp))

```

Head towards decision point 1 and turn left
 Pass decision point 1 and move forward to enter Corridor
 Head towards the door to women toilet
 Pass the door to women toilet and veer right
 Pass the door to male toilet and move forward to enter Active Hub
 Head towards the door to corridor
 Pass the landmark 0 and move forward until you reach the destination

Derive Door-to-Door Visibility Graph

Generate door-to-door visibility graph (for doors and decision points)

```

In [10]: # selecting a space
        cidx = ie.containers_names.index('Active Hub')
        vg = vgs[cidx]
        isovist_object = isovist_objects[cidx]

In [11]: # derive door-to-door visibility graph (doors and decision points)
        connected, dtd_graph = vg.generate_door_to_door_graph(isovist_object)

        print('Press Enter: Door to door visibility (doors+gateways)')
        plotter = Plotter()
        plotter.add_isovist(isovist_object)
        plotter.add_points_lines(connected)
        plotter.show()

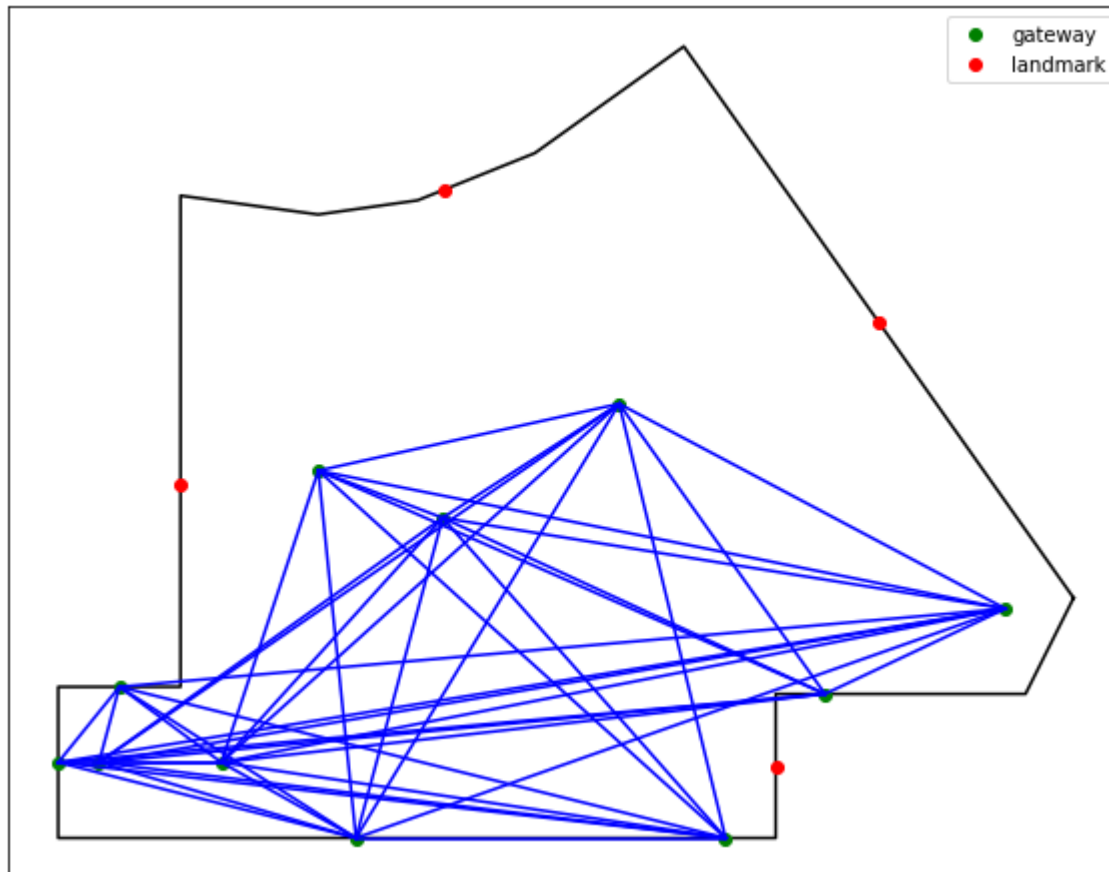
```

```

plotter.close()
plotter.write_graph('d-t-d-all.html', dtd_graph, is_directed=False)

```

generate door-to-door graph, only_doors False from view graph
 Press Enter: Door to door visibility (doors+gateways)



<Figure size 720x576 with 0 Axes>

Generate door-to-door visibility graph (only for doors)

```

In [12]: # derive door-to-door visibility graph (only doors)
connected2, dtd_graph2 = vg.generate_door_to_door_graph(isovist_object, only_doors=True)
plotter = Plotter()
plotter.add_poly(isovist_object.space_x, isovist_object.space_y)
plotter.add_holes(isovist_object.holes_x, isovist_object.holes_y)

```

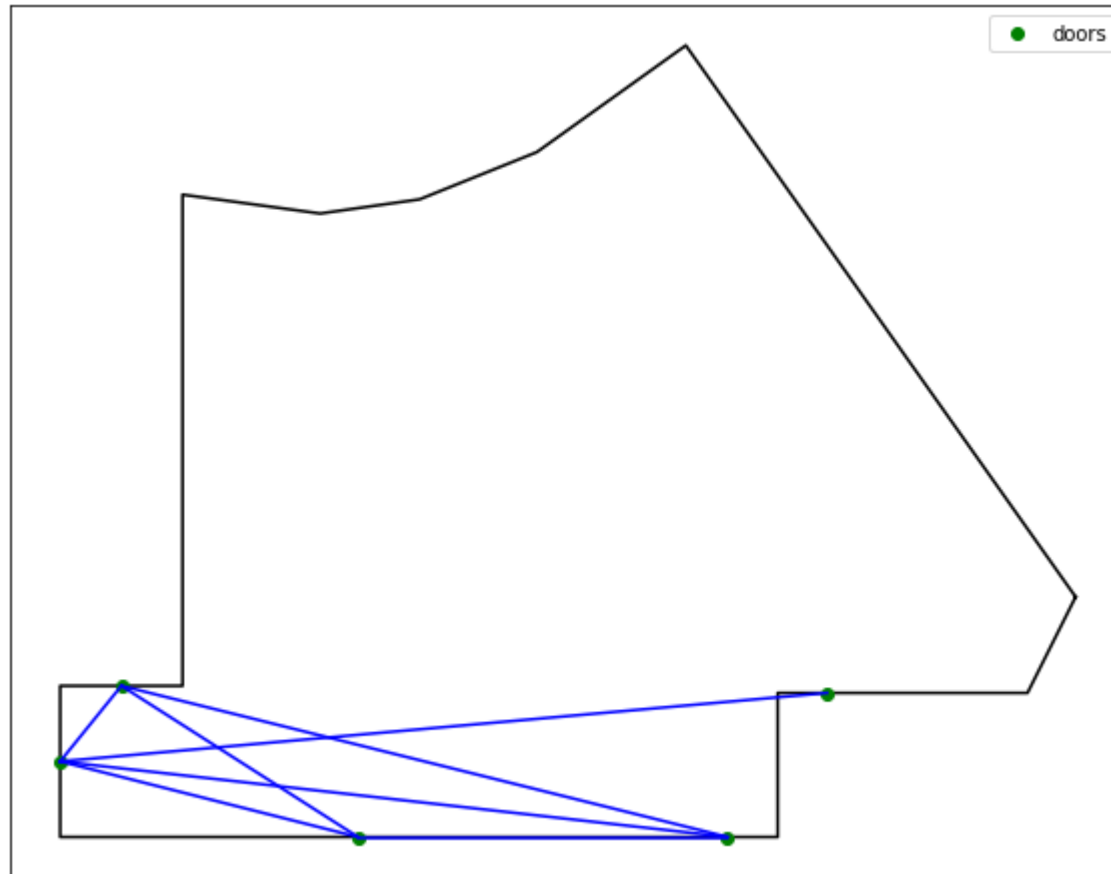


```

plotter.add_points(isovist_object.door_points[:isovist_object.door_idx], 'doors')
plotter.add_points_lines(connected2)
plotter.show()
plotter.close()
plotter.write_graph('d-t-d-doors.html', dtd_graph2, is_directed=False)

```

generate door-to-door graph, only_doors True from view graph



<Figure size 720x576 with 0 Axes>

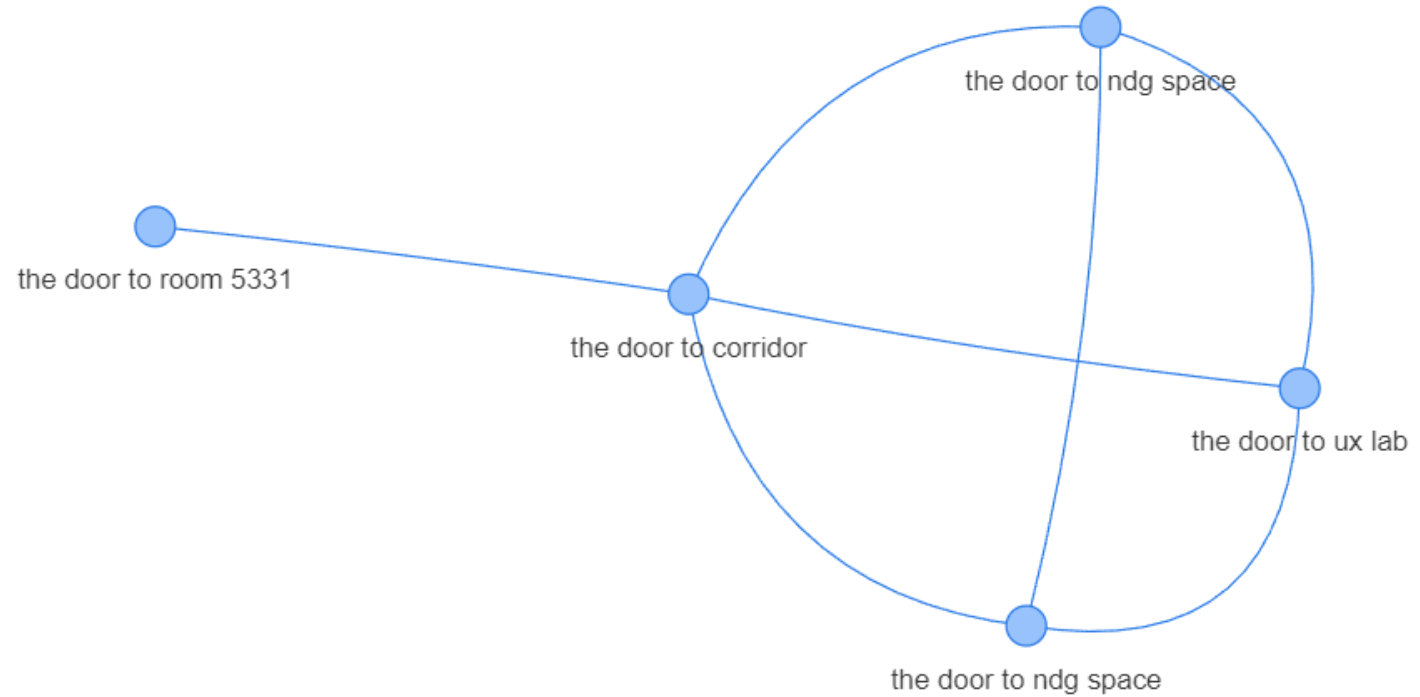
```

In [13]: nt2 = Network(width='1000px', height='600px', directed=False, notebook=True)
nt2.from_nx(dtd_graph2, show_edge_weights=False)
nt2.options.physics.use_repulsion({'node_distance': 185, 'central_gravity': 0.2, 'spring_length': 200,
                                   'spring_strength': 0.05, 'damping': 0.09})

nt2.show('d-t-d-doors.html')

```

Out[13]:



Derive navigation graph

Reference

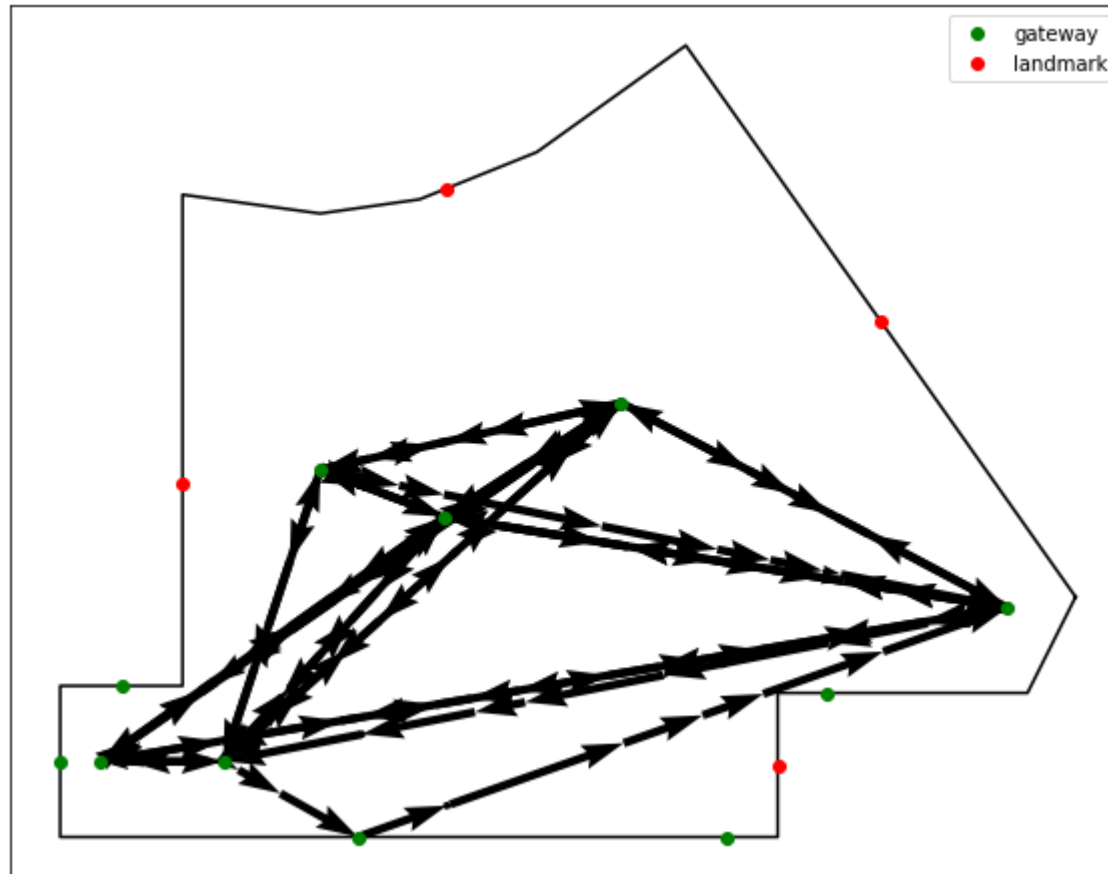
- Yang L, Worboys M. Generation of navigation graphs for indoor space. International Journal of Geographical Information Science. 2015 Oct 3;29(10):1737-56.
- Pang Y, Zhou L, Lin B, Lv G, Zhang C. Generation of navigation networks for corridor spaces based on indoor visibility map. International Journal of Geographical Information Science. 2020 Jan 2;34(1):177-201.

```
In [14]: # derive all shortest path visibility graph and spanning tree
vps, pvs, st_vps, st_pvs, nvgraph = \
    vg.generate_navigation_graph(isovist_object, indirect_access=False)

plotter = Plotter()
plotter.add_isovist(isovist_object)

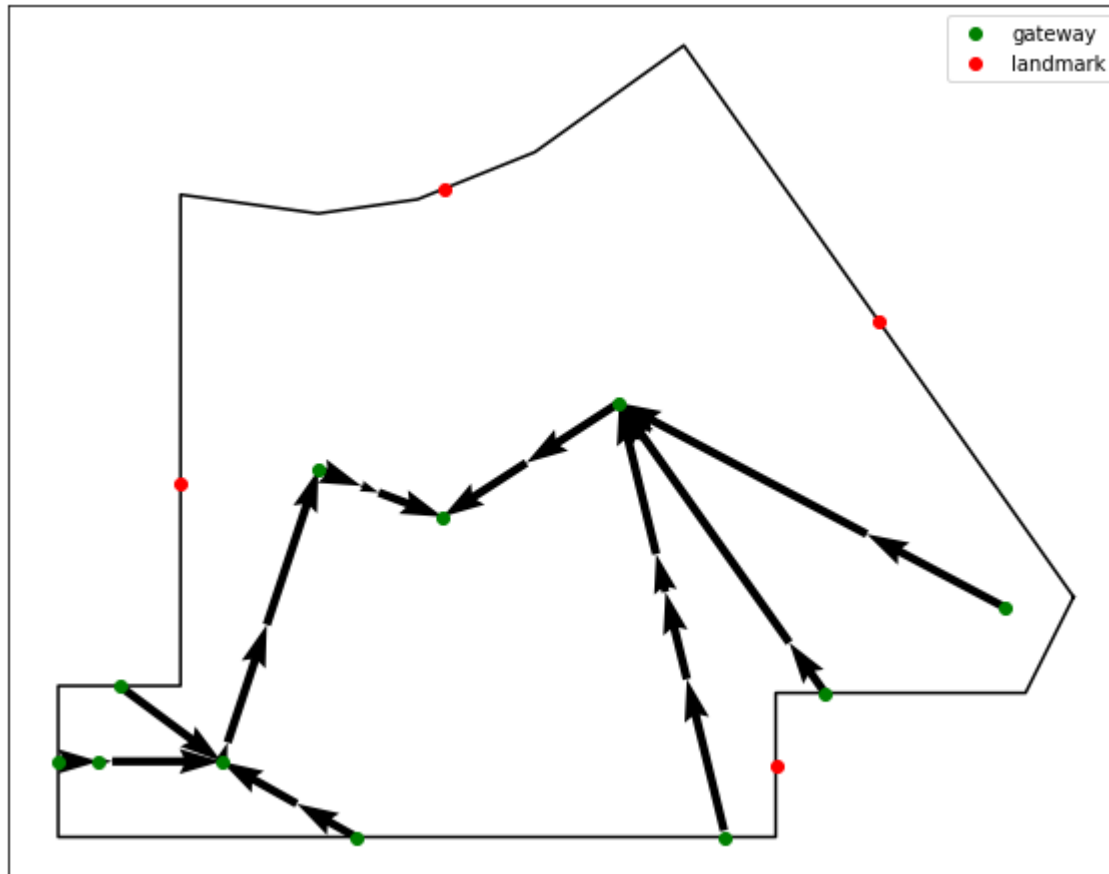
for pv in pvs:
    plotter.add_views(pv)
plotter.show()
```

derive navigation graph using spanning tree from viewgraph



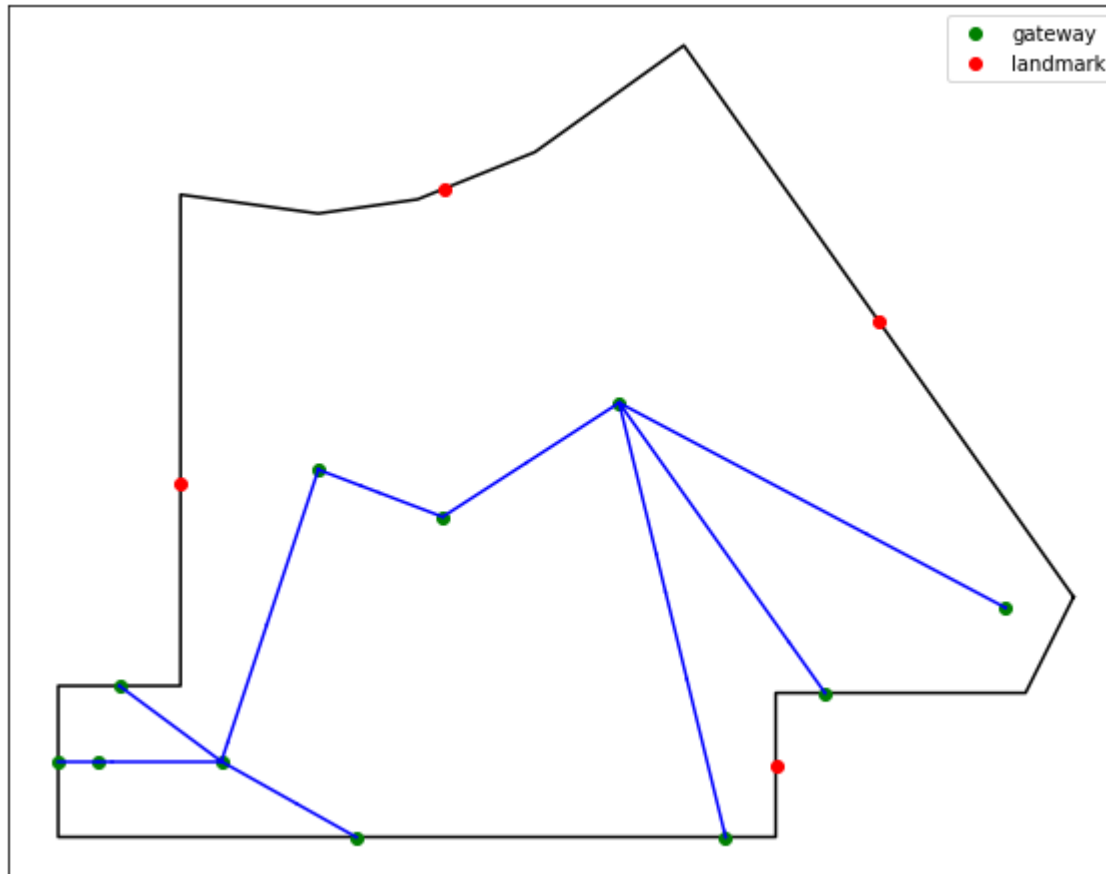
```
In [15]: plotter.refresh()
         for pv in st_pvs:
             plotter.add_views(pv)
         plotter.show()
```

<Figure size 720x576 with 0 Axes>



```
In [16]: plotter.refresh()
         for pv in st_pvs:
             plotter.add_points_lines(pv, is_vis=False)
         plotter.show()
```

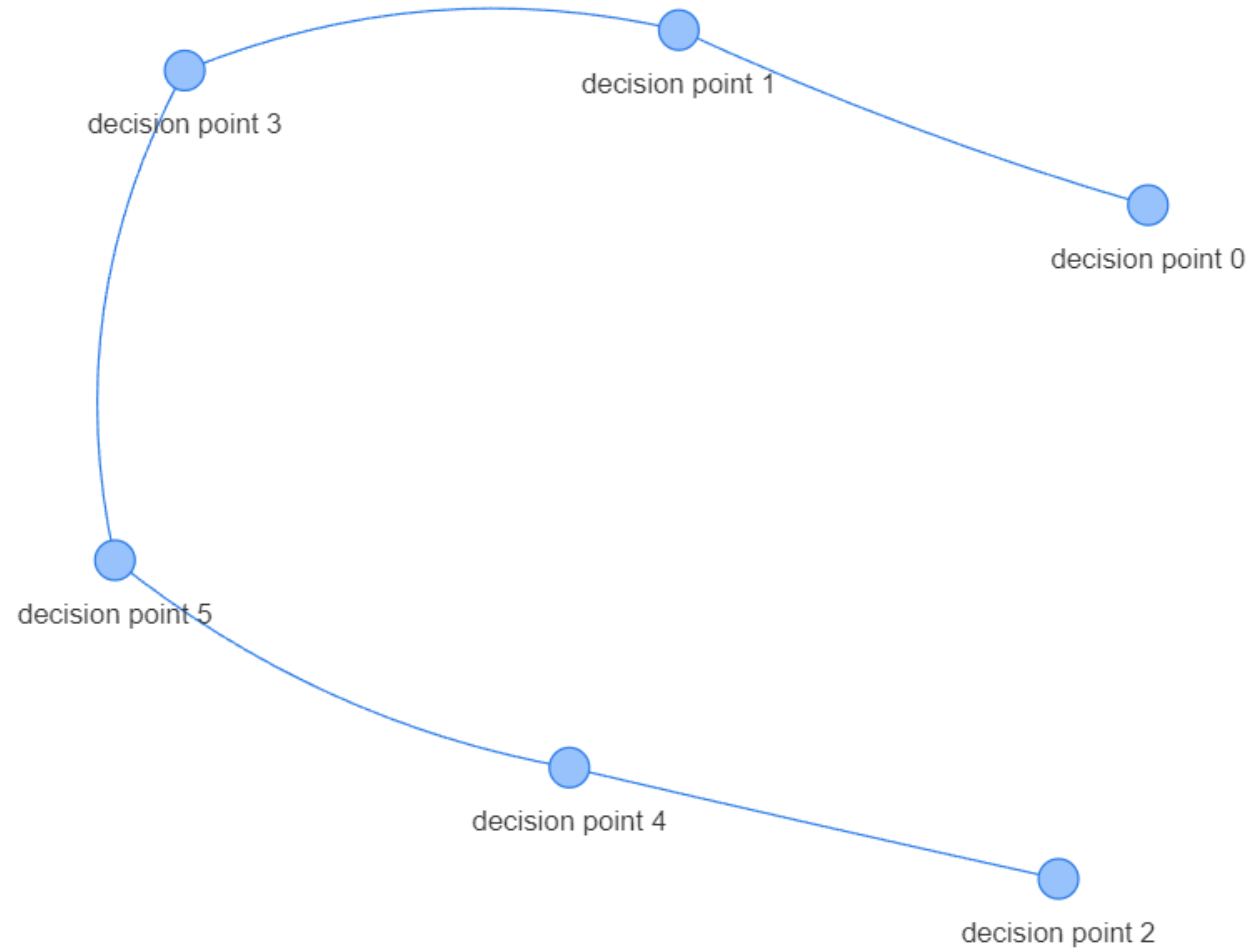
<Figure size 720x576 with 0 Axes>



```
In [17]: # generate navigation 'graph' for gateways + doors
nt2 = Network(width='1000px', height='600px', directed=False, notebook=True)
nt2.from_nx(nvgraph, show_edge_weights=False)
nt2.options.physics.use_repulsion({'node_distance': 185, 'central_gravity': 0.2, 'spring_length': 200,
                                   'spring_strength': 0.05, 'damping': 0.09})

nt2.show('nvgraph.html')
```

Out[17]:



Derive place graph from view graph

Nodes:

- place
- reference
- n-plet
- spatial relationship

Edges:

- locatum
- relatum
- map
- referred by
- has reference direction

Reference: Chen H, Vasardani M, Winter S, Tomko M. A graph database model for knowledge extracted from place descriptions. ISPRS International Journal of Geo-Information. 2018 Jun;7(6):221.

```
In [18]: # derive place graph
place_graph = vg.generate_place_graph(isovist_object)
```

derive place graph from view graph

```
In [19]: print('Place graph generation; visualize for all and only for landmark 2')
plotter.write_graph('placegraph.html', place_graph)
```

Place graph generation; visualize for all and only for landmark 2

```
In [20]: # selecting a space
cidx = ie.containers_names.index('Corridor')
vg = vgs[cidx]
isovist_object = isovist_objects[cidx]
```

```
In [21]: place_graph = vg.generate_place_graph(isovist_object)
```

derive place graph from view graph

Single Nplet

Select a single n-plet from different spatial relationships and visualize the graph and spatial configuration

1. between
2. near
3. left/right

```
In [22]: # selecting a space
cidx = ie.containers_names.index('Corridor')
vg = vgs[cidx]
isovist_object = isovist_objects[cidx]

def nplet_extraction(nplet_id):
    ## nplet_id = 'n830'
    place_graph[nplet_id] # Left
    # place_graph['n100'] # between

    # nodes = ['n830', 'Left', 'place12', 'gateway 12', 'Landmark 20', 'gateway 1']
    nodes = [nplet_id]
    nodes.extend(list(dict(place_graph[nplet_id]).keys()))

    additional = []
    for node in nodes:
        if node.startswith('place'):
            additional.extend(list(dict(place_graph[node]).keys()))
    nodes.extend(additional)

    for v in list(place_graph.edges):
        if v[1] == nplet_id:
            nodes.append(v[0])
            if v[0].startswith('place'):
                nodes.extend(list(dict(place_graph[v[0]]).keys()))

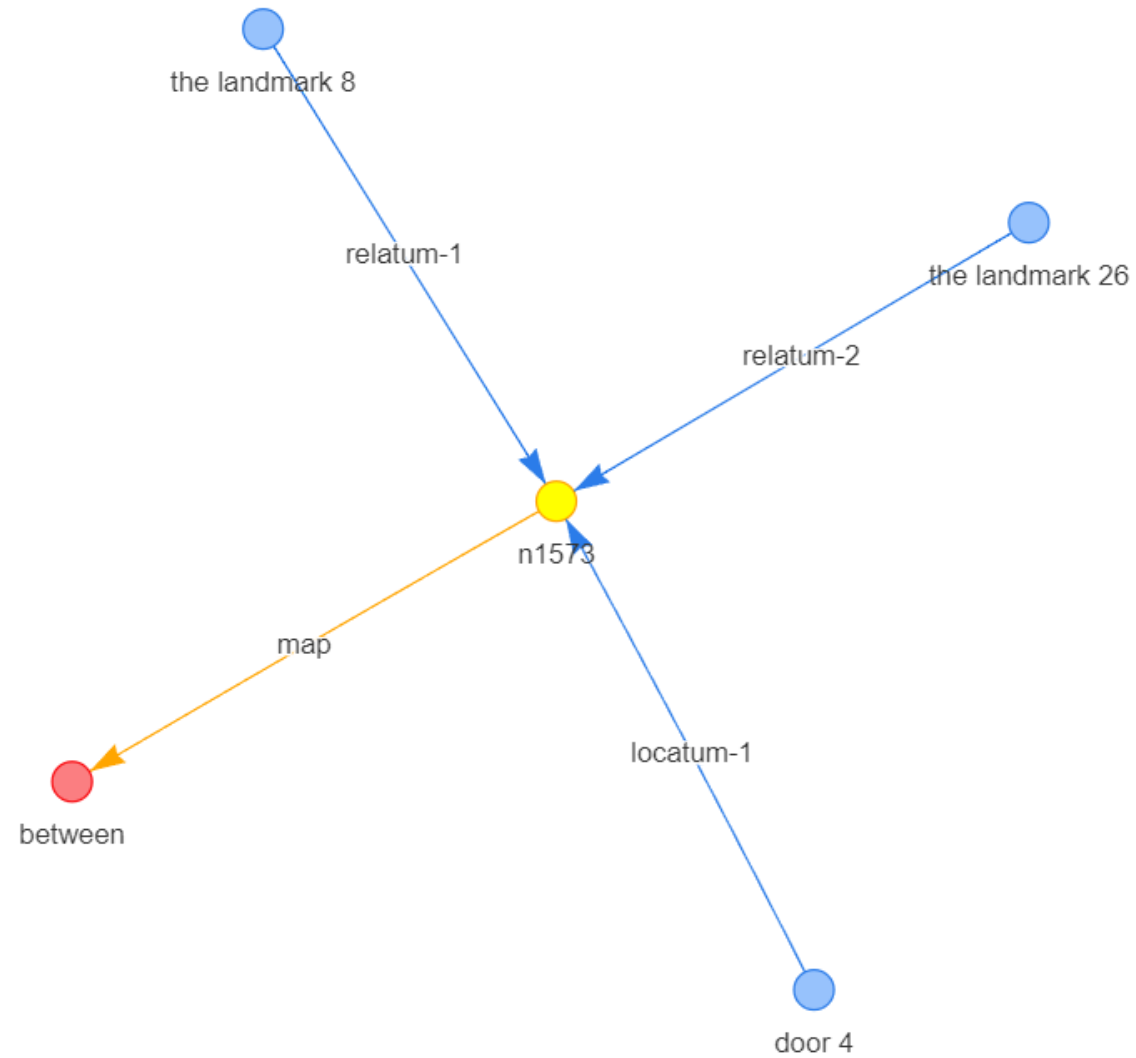
    nplets = place_graph.subgraph(nodes)
    nt2 = Network(width='1000px', height='600px', directed=True, notebook=True)
    nt2.from_nx(nplets, show_edge_weights=False)
    nt2.options.physics.use_repulsion({'node_distance': 185, 'central_gravity': 0.2, 'spring_length': 200,
                                      'spring_strength': 0.05, 'damping': 0.09})

    return nt2, nodes

spatial_expression = 'the door to women toilet between the landmark 2 and the door to disabled toilet'
for n in place_graph.nodes:
    if n.startswith('n') and 'exp' in place_graph.nodes[n].keys() and place_graph.nodes[n]['exp'] == spatial_expression:
```

```
nplet = n  
break  
nt2, nplet_nodes = nplet_extraction(nplet)  
nt2.show('nplet_1.html')
```

Out[22]:



Regent Place - Shopping Mall

Testing the view graph capabilities in computing shortest path, generating route descriptions, navigation graphs and place graphs in another test environment: Regenet Place Shopping Mall (<https://www.regentplace.com.au/floor-plan>)

Reading the Floorplan Files

```
In [23]: # reading the new floorplan dataset
Parameters.set_env(env="real", mc=False)
address = 'envs/RegentPlace/'
pfiles, hfiles, dfiles, dpfiles, lfiles = IndoorEnvironment.reformat(
    address, 'containers.geojson', 'doors.geojson', 'landmarks.geojson')
# create an indoor environment
ie = IndoorEnvironment('', pfiles, hfiles, dfiles, dpfiles, lfiles)
```

```
environment files -- count is valid
reading GeoJSON files (boundary, holes, doors and decision points)
reading GeoJSON files (boundary, holes, doors and decision points)
reading GeoJSON files (boundary, holes, doors and decision points)
reading GeoJSON files (boundary, holes, doors and decision points)
reading GeoJSON files (boundary, holes, doors and decision points)
reading GeoJSON files (boundary, holes, doors and decision points)
reading GeoJSON files (boundary, holes, doors and decision points)
reading GeoJSON files (boundary, holes, doors and decision points)
reading GeoJSON files (boundary, holes, doors and decision points)
reading GeoJSON files (boundary, holes, doors and decision points)
reading GeoJSON files (boundary, holes, doors and decision points)
reading GeoJSON files (boundary, holes, doors and decision points)
reading GeoJSON files (boundary, holes, doors and decision points)
reading GeoJSON files (boundary, holes, doors and decision points)
reading GeoJSON files (boundary, holes, doors and decision points)
reading GeoJSON files (boundary, holes, doors and decision points)
reading GeoJSON files (boundary, holes, doors and decision points)
```

Creating View Graph

```
In [24]: # creating view graph
vgs, isovist_objects = ie.construct_view_graph()
```

Analyzing: Ice Kirin Bar
Container environment is valid: True
region initial : 1
regions : 1 -- 1
calculating the visibility signatures...
calculating adjacency matrix for regions
finding regions that contains doors/gateways and decision points
decompose views
len: 20
constructing view graph for regions
calculating all spatial relationships visible in each view
Adding actions to views (nodes)
Adding actions to view relations (edges)

Analyzing: Shop
Container environment is valid: True
region initial : 3
regions : 2 -- 3
calculating the visibility signatures...
calculating adjacency matrix for regions
finding regions that contains doors/gateways and decision points
decompose views
len: 14
constructing view graph for regions
calculating all spatial relationships visible in each view
Adding actions to views (nodes)
Adding actions to view relations (edges)

Analyzing: Fireside By Yunn
Container environment is valid: True
region initial : 1
regions : 1 -- 1
calculating the visibility signatures...
calculating adjacency matrix for regions
finding regions that contains doors/gateways and decision points
decompose views
len: 2
constructing view graph for regions
calculating all spatial relationships visible in each view
Adding actions to views (nodes)
Adding actions to view relations (edges)

```
*****
Analyzing: Yakitori Yokochō
Container environment is valid: True
region initial : 2
regions : 3 -- 2
calculating the visibility signatures...
calculating adjacency matrix for regions
finding regions that contains doors/gateways and decision points
decompose views
len: 51
constructing view graph for regions
calculating all spatial relationships visible in each view
Adding actions to views (nodes)
Adding actions to view relations (edges)
```

```
*****
Analyzing: Loading Dock
Container environment is valid: True
region initial : 9
regions : 5 -- 9
calculating the visibility signatures...
calculating adjacency matrix for regions
finding regions that contains doors/gateways and decision points
decompose views
len: 69
constructing view graph for regions
calculating all spatial relationships visible in each view
Adding actions to views (nodes)
Adding actions to view relations (edges)
```

```
*****
Analyzing: Fujimi Bakehouse
Container environment is valid: True
region initial : 3
regions : 3 -- 3
calculating the visibility signatures...
calculating adjacency matrix for regions
finding regions that contains doors/gateways and decision points
decompose views
len: 43
constructing view graph for regions
calculating all spatial relationships visible in each view
Adding actions to views (nodes)
```

Adding actions to view relations (edges)

Analyzing: Daiso

Container environment is valid: True

region initial : 14

regions : 10 -- 14

calculating the visibility signatures...

calculating adjacency matrix for regions

finding regions that contains doors/gateways and decision points

decompose views

len: 165

constructing view graph for regions

calculating all spatial relationships visible in each view

Adding actions to views (nodes)

Adding actions to view relations (edges)

Analyzing: The Parks Sydney

Container environment is valid: True

region initial : 12

regions : 7 -- 12

calculating the visibility signatures...

calculating adjacency matrix for regions

finding regions that contains doors/gateways and decision points

decompose views

len: 90

constructing view graph for regions

calculating all spatial relationships visible in each view

Adding actions to views (nodes)

Adding actions to view relations (edges)

Analyzing: Mido Mart

Container environment is valid: True

region initial : 48

regions : 22 -- 48

calculating the visibility signatures...

calculating adjacency matrix for regions

finding regions that contains doors/gateways and decision points

decompose views

len: 238

constructing view graph for regions

calculating all spatial relationships visible in each view

Adding actions to views (nodes)
Adding actions to view relations (edges)

Analyzing: Toilet
Container environment is valid: True
region initial : 2
regions : 3 -- 2
calculating the visibility signatures...
calculating adjacency matrix for regions
finding regions that contains doors/gateways and decision points
decompose views
len: 34
constructing view graph for regions
calculating all spatial relationships visible in each view
Adding actions to views (nodes)
Adding actions to view relations (edges)

Analyzing: Yakinku Yokochō
Container environment is valid: True
region initial : 6
regions : 5 -- 6
calculating the visibility signatures...
calculating adjacency matrix for regions
finding regions that contains doors/gateways and decision points
decompose views
len: 71
constructing view graph for regions
calculating all spatial relationships visible in each view
Adding actions to views (nodes)
Adding actions to view relations (edges)

Analyzing: Diosa by Devon
Container environment is valid: True
region initial : 1
regions : 1 -- 1
calculating the visibility signatures...
calculating adjacency matrix for regions
finding regions that contains doors/gateways and decision points
decompose views
len: 12
constructing view graph for regions

```
calculating all spatial relationships visible in each view
Adding actions to views (nodes)
Adding actions to view relations (edges)
```

```
*****
```

```
Analyzing: Arctic White
Container environment is valid: True
region initial : 1
regions : 1 -- 1
calculating the visibility signatures...
calculating adjacency matrix for regions
finding regions that contains doors/gateways and decision points
decompose views
len: 12
constructing view graph for regions
calculating all spatial relationships visible in each view
Adding actions to views (nodes)
Adding actions to view relations (edges)
```

```
*****
```

```
Analyzing: Edomae Sushi
Container environment is valid: True
region initial : 1
regions : 1 -- 1
calculating the visibility signatures...
calculating adjacency matrix for regions
finding regions that contains doors/gateways and decision points
decompose views
len: 2
constructing view graph for regions
calculating all spatial relationships visible in each view
Adding actions to views (nodes)
Adding actions to view relations (edges)
```

```
*****
```

```
Analyzing: FraserSuites
Container environment is valid: True
region initial : 1
regions : 1 -- 1
calculating the visibility signatures...
calculating adjacency matrix for regions
finding regions that contains doors/gateways and decision points
decompose views
len: 2
```



```

constructing view graph for regions
calculating all spatial relationships visible in each view
Adding actions to views (nodes)
Adding actions to view relations (edges)

*****

Analyzing: Corridor
Container environment is valid: True
region initial : 577
regions : 51 -- 577
calculating the visibility signatures...
calculating adjacency matrix for regions
finding regions that contains doors/gateways and decision points
decompose views
len: 1068
constructing view graph for regions
calculating all spatial relationships visible in each view
Adding actions to views (nodes)
Adding actions to view relations (edges)

```

Shortest Path Computation

In [25]: `ie.containers_names`

Out[25]:

```

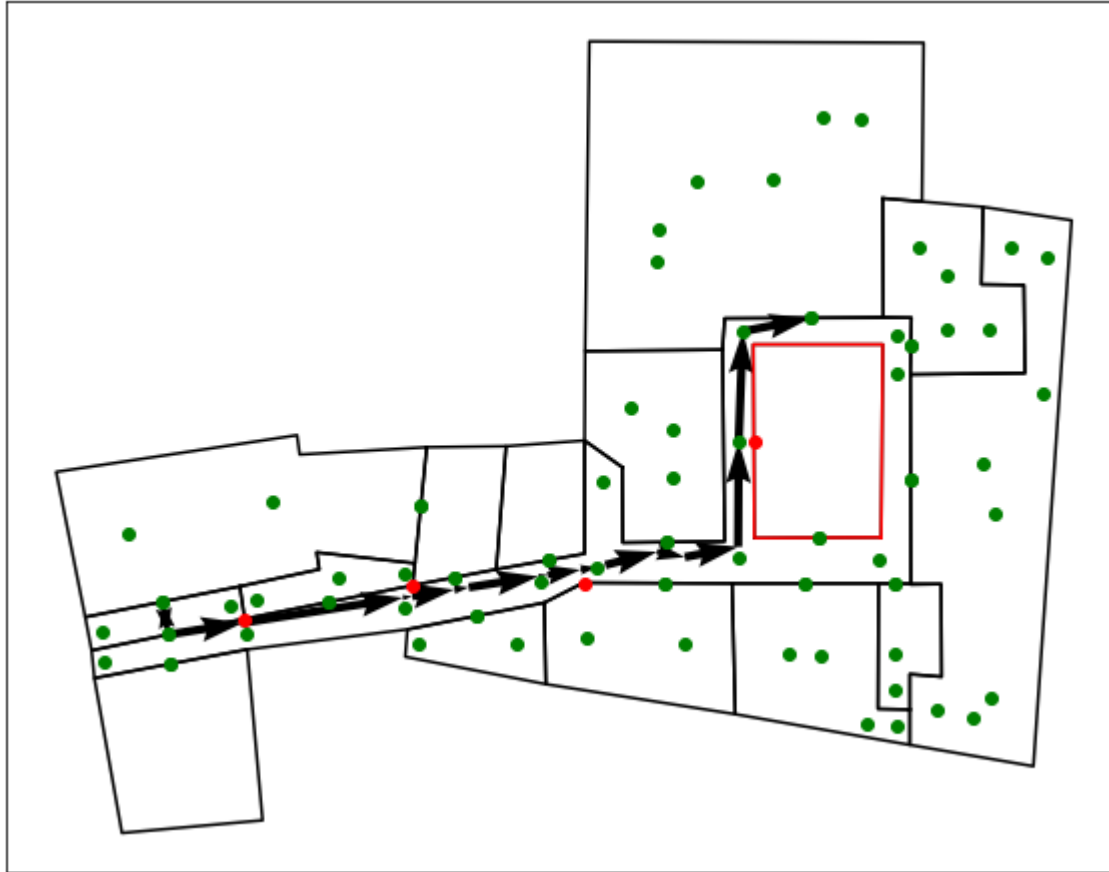
['Ice Kirin Bar',
 'Shop',
 'Fireside By Yunn',
 'Yakitori Yokochō',
 'Loading Dock',
 'Fujimi Bakehouse',
 'Daiso',
 'The Parks Sydney',
 'Mido Mart',
 'Toilet',
 'Yakinku Yokochō',
 'Dioa by Devon',
 'Arctic White',
 'Edomae Sushi',
 'FraserSuites',
 'Corridor']

```

In [26]: `# set parameters to Parameters class`
`start_container = 'Ice Kirin Bar'`

```
start_region = 0  
end_container = 'Daiso'  
end_region = 1
```

```
In [27]: # calculate shortest path and generate verbal description  
vp, pv = ie.shortest_path(start_container, start_region, end_container, end_region)  
  
# plot shortest path  
plotter = Plotter()  
for isovist_object in ie.isovist_objects:  
    plotter.add_isovist(isovist_object)  
plotter.add_views(pv)  
plotter.show(False)  
plotter.close()  
  
enter: Corridor  
enter: Daiso
```



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Generating Route Description

```
In [28]: # generate route instructions
def generate_route_descriptions(vp):
    container = ''
    container_vids = {}
    finals = {}
    for v in vp[1:-1]:
        info = v.split('-V')
        if container != info[0]:
            container = info[0]
            container_vids[container] = []
        container_vids[container].append(int(info[1]))
```

```

    for container, vids in container_vids.items():
        cidx = ie.containers_names.index(container)
        vg = vgs[cidx]
        rds = vg.generate_route_description(vids)
        finals[container] = rds
    return finals

def print_route_descriptions(rd_dictionary):
    containers = list(rd_dictionary.keys())
    for container in containers:
        rd = rd_dictionary[container]
        if containers.index(container) < len(containers) - 1:
            rd[len(rd)-1] = rd[len(rd)-1].replace('until you reach the destination', 'to enter {}'.format(containers[containers.index(container)+1]))
        for r in rd:
            print(r)
# vg.generate_route_description(vp)
print_route_descriptions(generate_route_descriptions(vp))

```

Head towards the door to Corridor and move forward to enter Corridor

Head towards the door to Ice Kirin Bar

Pass decision point 11 and turn left

Follow decision point 7 on the front and turn right and move forward until you reach the destination

Creating Navigation Graphs - Door-to-Door

```

In [29]: # selecting a space
        cidx = ie.containers_names.index('Corridor')
        vg = vgs[cidx]
        isovist_object = isovist_objects[cidx]

```

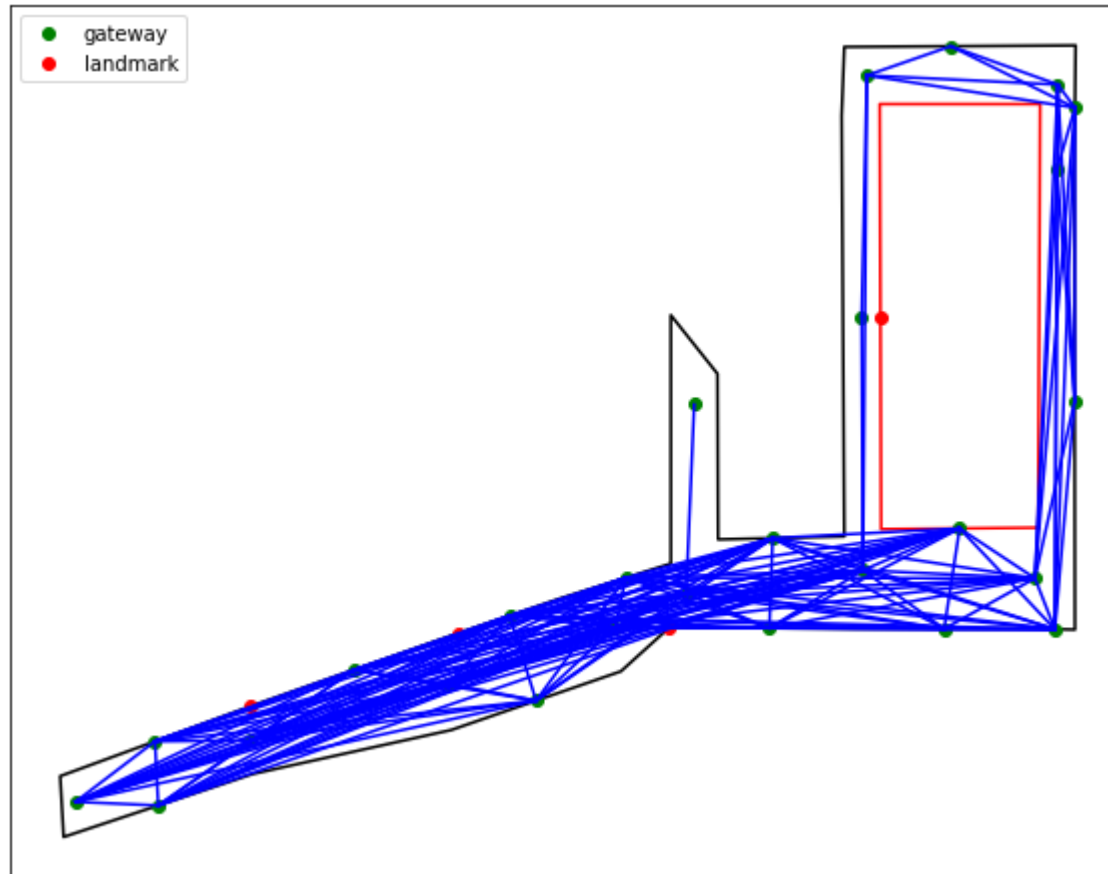
```

In [30]: # derive door-to-door visibility graph (doors and decision points)
        connected, dtd_graph = vg.generate_door_to_door_graph(isovist_object)

        plotter = Plotter()
        plotter.add_isovist(isovist_object)
        plotter.add_points_lines(connected)
        plotter.show()
        plotter.close()

```

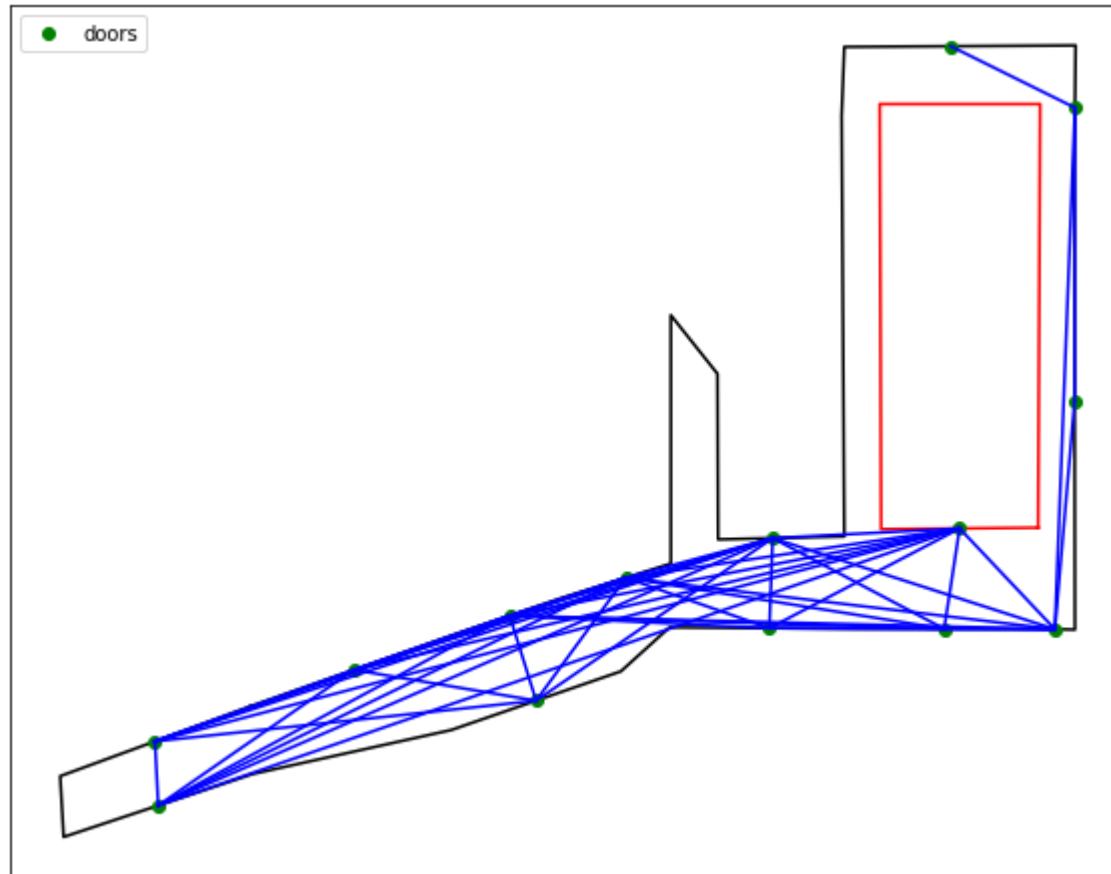
generate door-to-door graph, only_doors False from view graph



<Figure size 720x576 with 0 Axes>

```
In [31]: # derive door-to-door visibility graph (only doors)
connected2, dtd_graph2 = vg.generate_door_to_door_graph(isovist_object, only_doors=True)
plotter = Plotter()
plotter.add_poly(isovist_object.space_x, isovist_object.space_y)
plotter.add_holes(isovist_object.holes_x, isovist_object.holes_y)
plotter.add_points(isovist_object.door_points[:isovist_object.door_idx], 'doors')
plotter.add_points_lines(connected2)
plotter.show()
plotter.close()
```

generate door-to-door graph, only_doors True from view graph



<Figure size 720x576 with 0 Axes>

Creating Place Graph

```
In [32]: # derive place graph
place_graph = vg.generate_place_graph(isovist_object)
```

derive place graph from view graph

```
In [33]: # selecting a space
cidx = ie.containers_names.index('Corridor')
vg = vgs[cidx]
isovist_object = isovist_objects[cidx]

def nplet_extraction(nplet_id):
```

```

## nplet_id = 'n830'
place_graph[nplet_id] # left
# place_graph['n100'] # between

# nodes = ['n830', 'left', 'place12', 'gateway 12', 'landmark 20', 'gateway 1']
nodes = [nplet_id]
nodes.extend(list(dict(place_graph[nplet_id]).keys()))

additional = []
for node in nodes:
    if node.startswith('place'):
        additional.extend(list(dict(place_graph[node]).keys()))
nodes.extend(additional)

for v in list(place_graph.edges):
    if v[1] == nplet_id:
        nodes.append(v[0])
    if v[0].startswith('place'):
        nodes.extend(list(dict(place_graph[v[0]]).keys()))

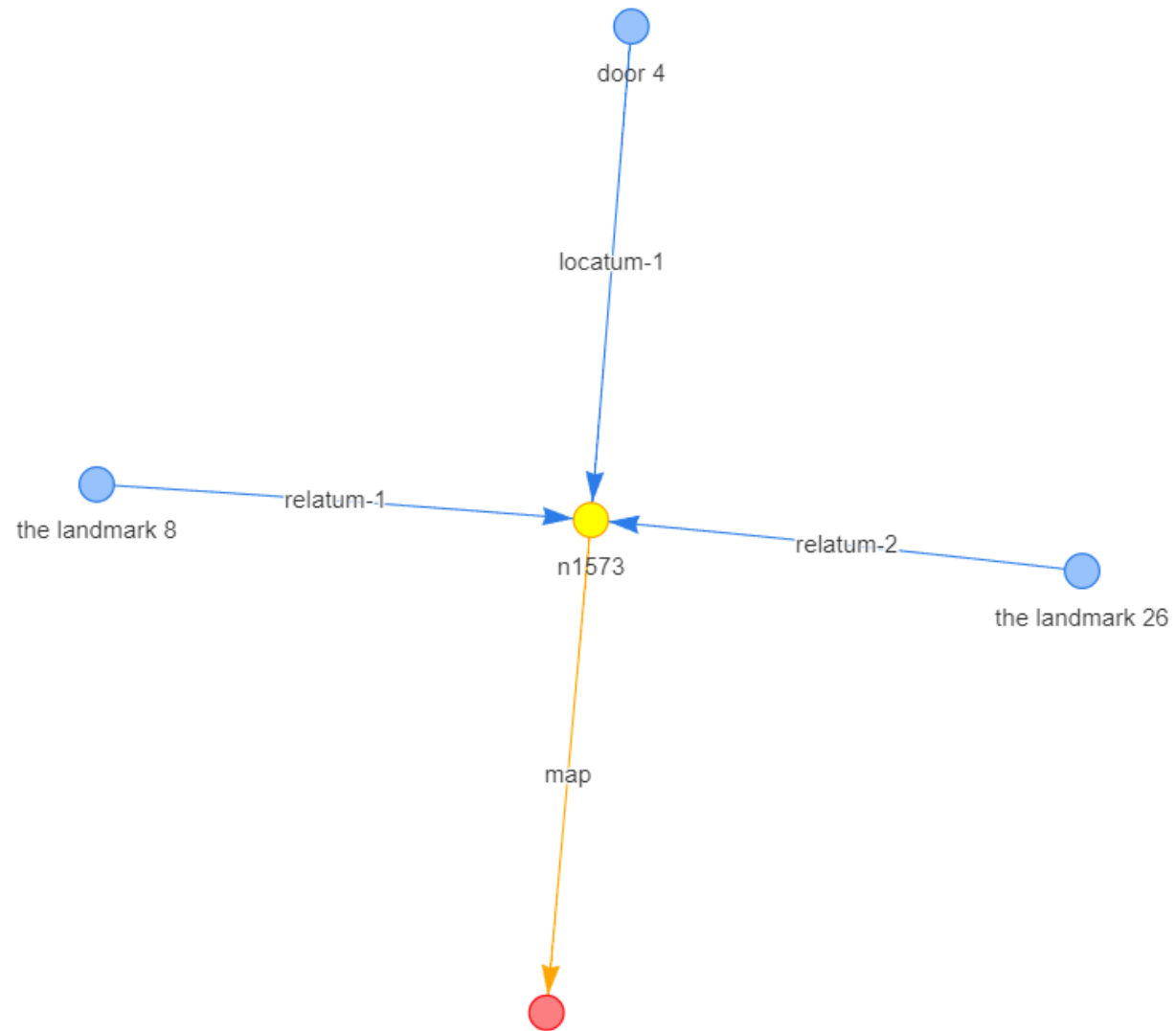
nplets = place_graph.subgraph(nodes)
nt2 = Network(width='1000px', height='600px', directed=True, notebook=True)
nt2.from_nx(nplets, show_edge_weights=False)
nt2.options.physics.use_repulsion({'node_distance': 185, 'central_gravity': 0.2, 'spring_length': 200,
                                   'spring_strength': 0.05, 'damping': 0.09})

return nt2, nodes

spatial_expression = 'the landmark 1 between the door to Fireside By Yunn and the door to Fujimi Bakehouse'
for n in place_graph.nodes:
    if n.startswith('n') and 'exp' in place_graph.nodes[n].keys() and place_graph.nodes[n]['exp'] == spatial_expression:
        nplet = n
        break
nt2, nplet_nodes = nplet_extraction(nplet)
nt2.show('nplet_1.html')

```

Out[33]:



Hypothetical Floorplan (with holes)


```
In [34]: Parameters.set_env(env="hypo", mc=False)
print(Parameters.min_area)
```

5e-07

```
In [35]: ie = read_env()
```

environment files -- count is valid
reading GeoJSON files (boundary, holes, doors and decision points)

Creating View Graph

```
In [36]: # creating view graph
vgs, isovist_objects = ie.construct_view_graph()
```

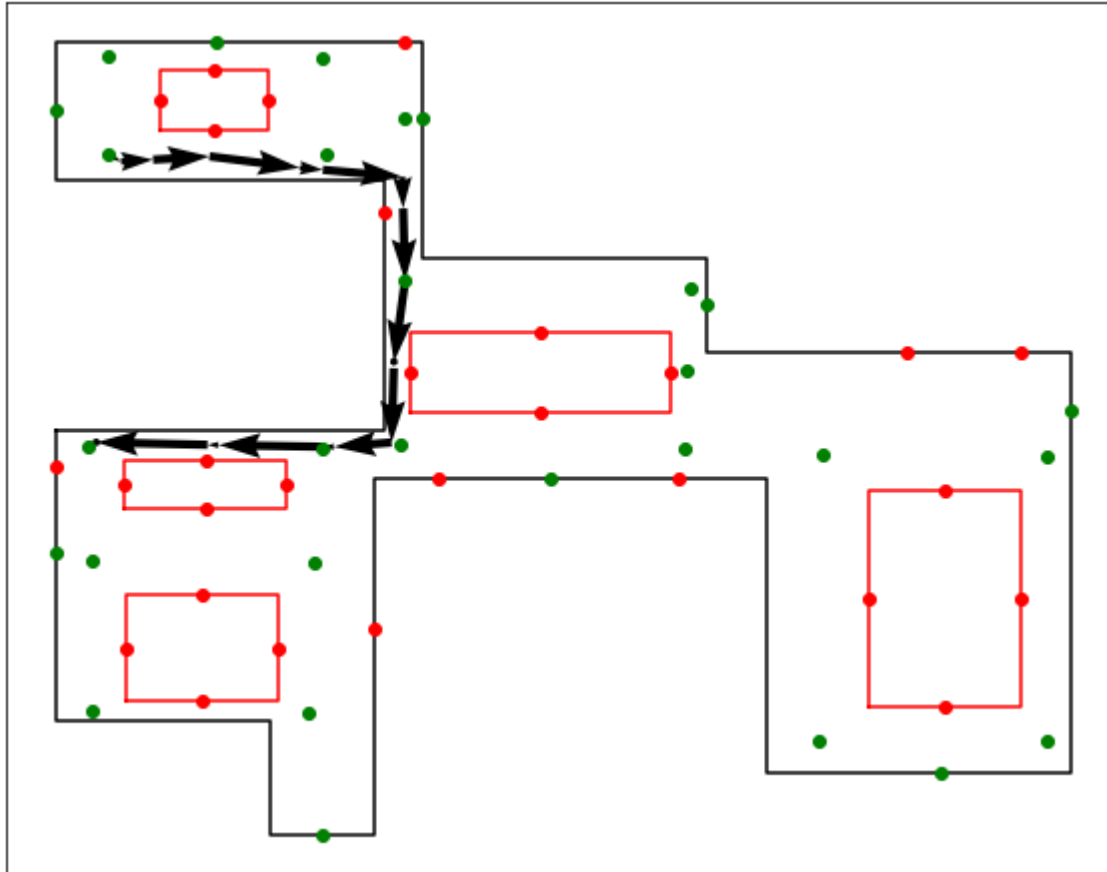
```
*****
Analyzing: Container
Container environment is valid: True
region initial : 272
regions : 115 -- 272
calculating the visibility signatures...
calculating adjacency matrix for regions
finding regions that contains doors/gateways and decision points
decompose views
len: 1458
constructing view graph for regions
calculating all spatial relationships visible in each view
Adding actions to views (nodes)
Adding actions to view relations (edges)
```

Shortest Path and Route Instruction

```
In [37]: # set parameters to Parameters class
start_container = 'Container'
start_region = 0
end_container = 'Container'
end_region = 60
```

```
In [38]: # calculate shortest path and generate verbal description
vp, pv = ie.shortest_path(start_container, start_region, end_container, end_region)
```

```
# plot shortest path
plotter = Plotter()
for isovist_object in ie.isovist_objects:
    plotter.add_isovist(isovist_object)
plotter.add_views(pv)
plotter.show(False)
plotter.close()
```



<Figure size 720x576 with 0 Axes>

Generating Route Descriptions

```
In [39]: # generate route instructions
def generate_route_descriptions(vp):
    container = ''
```

```

container_vids = {}
finals = {}
for v in vp[1:-1]:
    info = v.split('-V')
    if container != info[0]:
        container = info[0]
        container_vids[container] = []
    container_vids[container].append(int(info[1]))
for container, vids in container_vids.items():
    cidx = ie.containers_names.index(container)
    vg = vgs[cidx]
    rds = vg.generate_route_description(vids)
    finals[container] = rds
return finals

def print_route_descriptions(rd_dictionary):
    containers = list(rd_dictionary.keys())
    for container in containers:
        rd = rd_dictionary[container]
        if containers.index(container) < len(containers) - 1:
            rd[len(rd)-1] = rd[len(rd)-1].replace('until you reach the destination', 'to enter {}'.format(containers[containers.index(container)+1]))
        for r in rd:
            print(r)
# vg.generate_route_description(vp)
print_route_descriptions(generate_route_descriptions(vp))

```

Head towards the landmark 21
 Pass the landmark 21 and turn right
 Pass the landmark 18 and turn right
 Pass decision point 15 and move forward until you reach the destination

Creating Navigation Graphs

```

In [40]: # selecting a space
cidx = 0
vg = vgs[cidx]
isovist_object = isovist_objects[cidx]

```

```

In [41]: # derive door-to-door visibility graph (doors and decision points)
connected, dtd_graph = vg.generate_door_to_door_graph(isovist_object)

plotter = Plotter()
plotter.add_isovist(isovist_object)

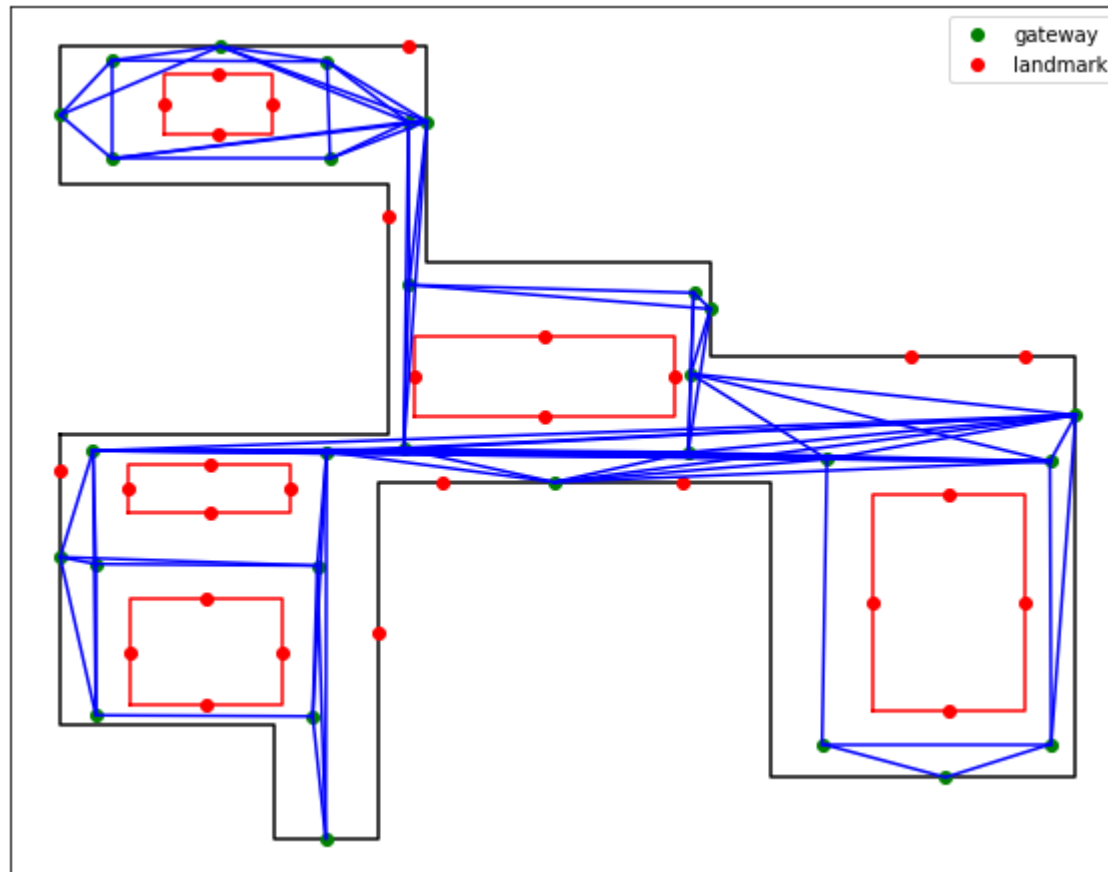
```

```

plotter.add_points_lines(connected)
plotter.show()
plotter.close()

```

generate door-to-door graph, only_doors False from view graph



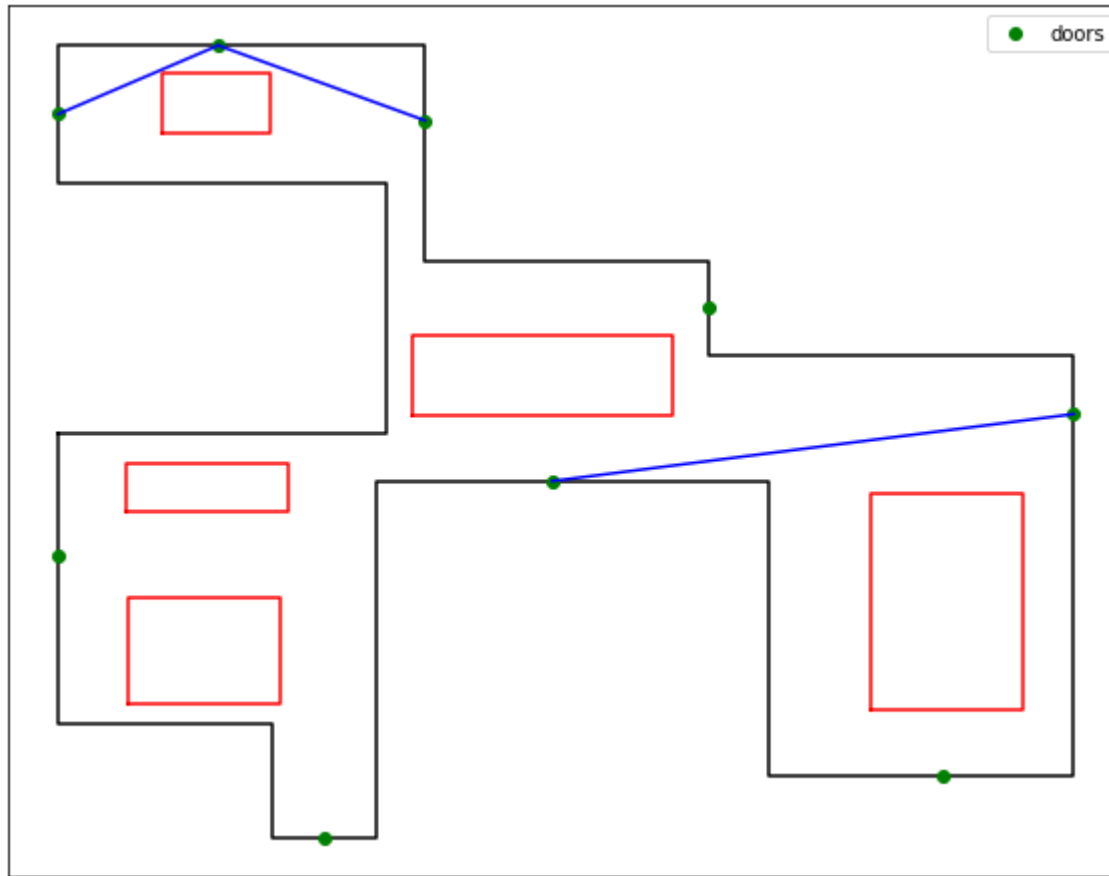
<Figure size 720x576 with 0 Axes>

```

In [42]: # derive door-to-door visibility graph (only doors)
connected2, dtd_graph2 = vg.generate_door_to_door_graph(isovist_object, only_doors=True)
plotter = Plotter()
plotter.add_poly(isovist_object.space_x, isovist_object.space_y)
plotter.add_holes(isovist_object.holes_x, isovist_object.holes_y)
plotter.add_points(isovist_object.door_points[:isovist_object.door_idx], 'doors')
plotter.add_points_lines(connected2)
plotter.show()
plotter.close()

```

generate door-to-door graph, only_doors True from view graph



<Figure size 720x576 with 0 Axes>

Creating Place Graphs

```
In [43]: # derive place graph
place_graph = vg.generate_place_graph(isovist_object)
```

derive place graph from view graph

```
In [44]: # selecting a space
cidx = 0
vg = vgs[cidx]
isovist_object = isovist_objects[cidx]
```

```

def nplet_extraction(nplet_id):
    ## nplet_id = 'n830'
    place_graph[nplet_id] # left
    # place_graph['n100'] # between

    # nodes = ['n830', 'left', 'place12', 'gateway 12', 'landmark 20', 'gateway 1']
    nodes = [nplet_id]
    nodes.extend(list(dict(place_graph[nplet_id]).keys()))

    additional = []
    for node in nodes:
        if node.startswith('place'):
            additional.extend(list(dict(place_graph[node]).keys()))
    nodes.extend(additional)

    for v in list(place_graph.edges):
        if v[1] == nplet_id:
            nodes.append(v[0])
            if v[0].startswith('place'):
                nodes.extend(list(dict(place_graph[v[0]]).keys()))

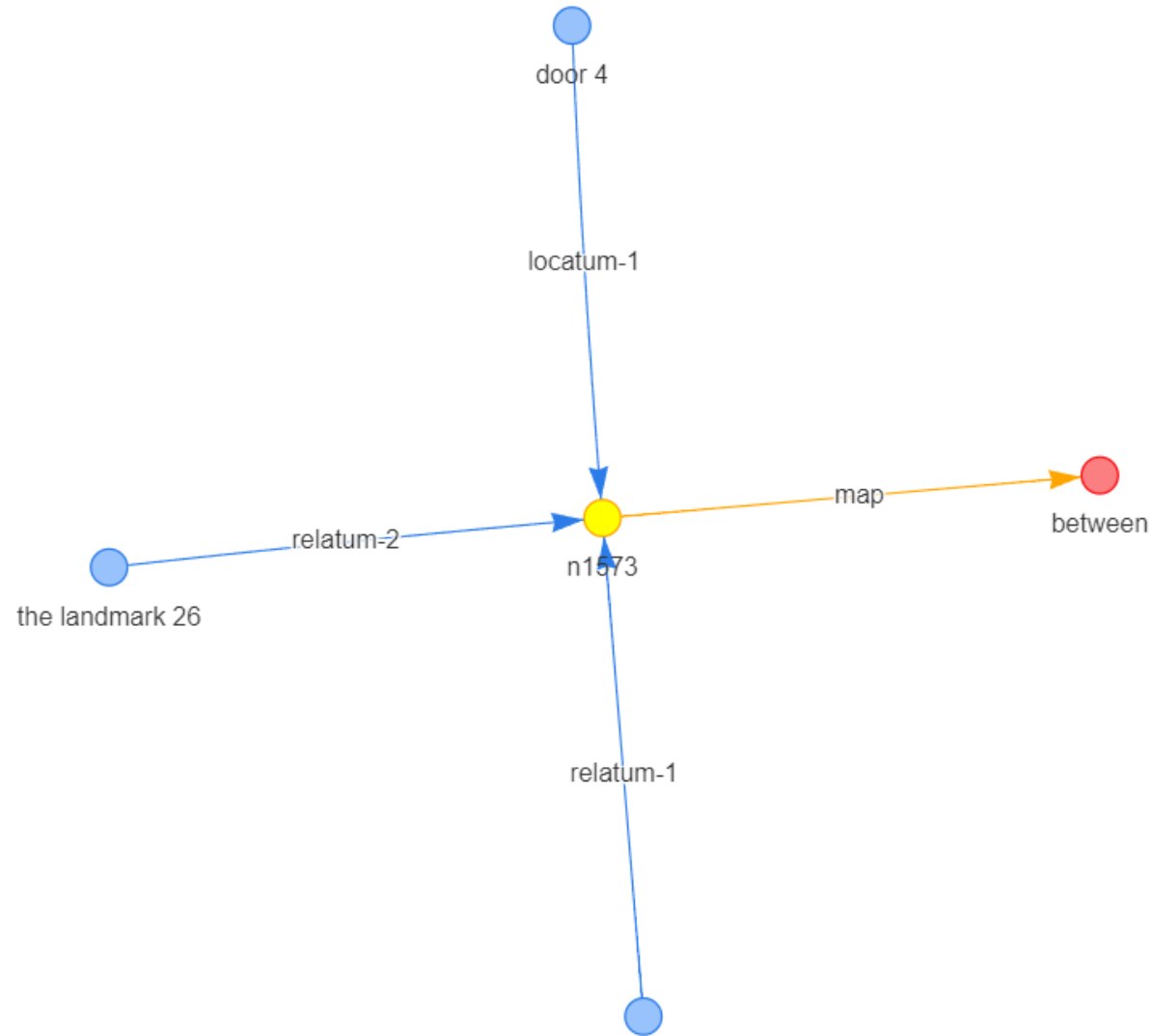
    nplets = place_graph.subgraph(nodes)
    nt2 = Network(width='1000px', height='600px', directed=True, notebook=True)
    nt2.from_nx(nplets, show_edge_weights=False)
    nt2.options.physics.use_repulsion({'node_distance': 185, 'central_gravity': 0.2, 'spring_length': 200,
                                      'spring_strength': 0.05, 'damping': 0.09})

    return nt2, nodes

spatial_expression = 'door 4 between the landmark 8 and the landmark 26'
for n in place_graph.nodes:
    if n.startswith('n') and 'exp' in place_graph.nodes[n].keys() and place_graph.nodes[n]['exp'] == spatial_expression:
        nplet = n
        break
nt2, nplet_nodes = nplet_extraction(nplet)
nt2.show('nplet_1.html')

```

Out[44]:



Hypothetical Environment

constructed from Liu and Zlatanova (2011)

```
In [45]: # reading the new floorplan dataset
Parameters.set_env(env="real", mc=True)
address = 'envs/paper/'
pfiles, hfiles, dfiles, dpfiles, lfiles = IndoorEnvironment.reformat(
    address, 'containers.geojson', 'doors.geojson', 'landmarks.geojson')
# create an indoor environment
ie = IndoorEnvironment('', pfiles, hfiles, dfiles, dpfiles, lfiles)

environment files -- count is valid
reading GeoJSON files (boundary, holes, doors and decision points)
reading GeoJSON files (boundary, holes, doors and decision points)
reading GeoJSON files (boundary, holes, doors and decision points)
reading GeoJSON files (boundary, holes, doors and decision points)
reading GeoJSON files (boundary, holes, doors and decision points)
reading GeoJSON files (boundary, holes, doors and decision points)
reading GeoJSON files (boundary, holes, doors and decision points)
reading GeoJSON files (boundary, holes, doors and decision points)
reading GeoJSON files (boundary, holes, doors and decision points)
reading GeoJSON files (boundary, holes, doors and decision points)
reading GeoJSON files (boundary, holes, doors and decision points)
```

```
In [46]: ie.containers_names
```

```
Out[46]: ['c1', 'c2', 'c3', 'c4', 'c5', 'c6', 'c7', 'c8', 'c9', 'c10', 'c11']
```

View Graph Construction

```
In [47]: # creating view graph
vgs, isovist_objects = ie.construct_view_graph()
```



```
*****
Analyzing: c1
Container environment is valid: True
region initial : 10
regions : 10 -- 10
calculating the visibility signatures...
calculating adjacency matrix for regions
finding regions that contains doors/gateways and decision points
decompose views
len: 116
constructing view graph for regions
calculating all spatial relationships visible in each view
Adding actions to views (nodes)
Adding actions to view relations (edges)
```

```
*****
Analyzing: c2
Container environment is valid: True
region initial : 1
regions : 1 -- 1
calculating the visibility signatures...
calculating adjacency matrix for regions
finding regions that contains doors/gateways and decision points
decompose views
len: 20
constructing view graph for regions
calculating all spatial relationships visible in each view
Adding actions to views (nodes)
Adding actions to view relations (edges)
```

```
*****
Analyzing: c3
Container environment is valid: True
region initial : 6
regions : 6 -- 6
calculating the visibility signatures...
calculating adjacency matrix for regions
finding regions that contains doors/gateways and decision points
decompose views
len: 109
constructing view graph for regions
calculating all spatial relationships visible in each view
Adding actions to views (nodes)
Adding actions to view relations (edges)
```

```
*****
Analyzing: c4
Container environment is valid: True
region initial : 3
regions : 2 -- 3
calculating the visibility signatures...
calculating adjacency matrix for regions
finding regions that contains doors/gateways and decision points
decompose views
len: 46
constructing view graph for regions
calculating all spatial relationships visible in each view
Adding actions to views (nodes)
Adding actions to view relations (edges)
```

```
*****
Analyzing: c5
Container environment is valid: True
region initial : 1
regions : 1 -- 1
calculating the visibility signatures...
calculating adjacency matrix for regions
finding regions that contains doors/gateways and decision points
decompose views
len: 12
constructing view graph for regions
calculating all spatial relationships visible in each view
Adding actions to views (nodes)
Adding actions to view relations (edges)
```

```
*****
Analyzing: c6
Container environment is valid: True
region initial : 1
regions : 1 -- 1
calculating the visibility signatures...
calculating adjacency matrix for regions
finding regions that contains doors/gateways and decision points
decompose views
len: 20
constructing view graph for regions
calculating all spatial relationships visible in each view
Adding actions to views (nodes)
```

Adding actions to view relations (edges)

Analyzing: c7

Container environment is valid: True

region initial : 146

regions : 95 -- 146

calculating the visibility signatures...

calculating adjacency matrix for regions

finding regions that contains doors/gateways and decision points

decompose views

len: 1261

constructing view graph for regions

calculating all spatial relationships visible in each view

Adding actions to views (nodes)

Adding actions to view relations (edges)

Analyzing: c8

Container environment is valid: True

region initial : 27

regions : 16 -- 27

calculating the visibility signatures...

calculating adjacency matrix for regions

finding regions that contains doors/gateways and decision points

decompose views

len: 325

constructing view graph for regions

calculating all spatial relationships visible in each view

Adding actions to views (nodes)

Adding actions to view relations (edges)

Analyzing: c9

Container environment is valid: True

region initial : 1

regions : 1 -- 1

calculating the visibility signatures...

calculating adjacency matrix for regions

finding regions that contains doors/gateways and decision points

decompose views

len: 2

constructing view graph for regions

calculating all spatial relationships visible in each view

```
Adding actions to views (nodes)
Adding actions to view relations (edges)
```

```
*****
```

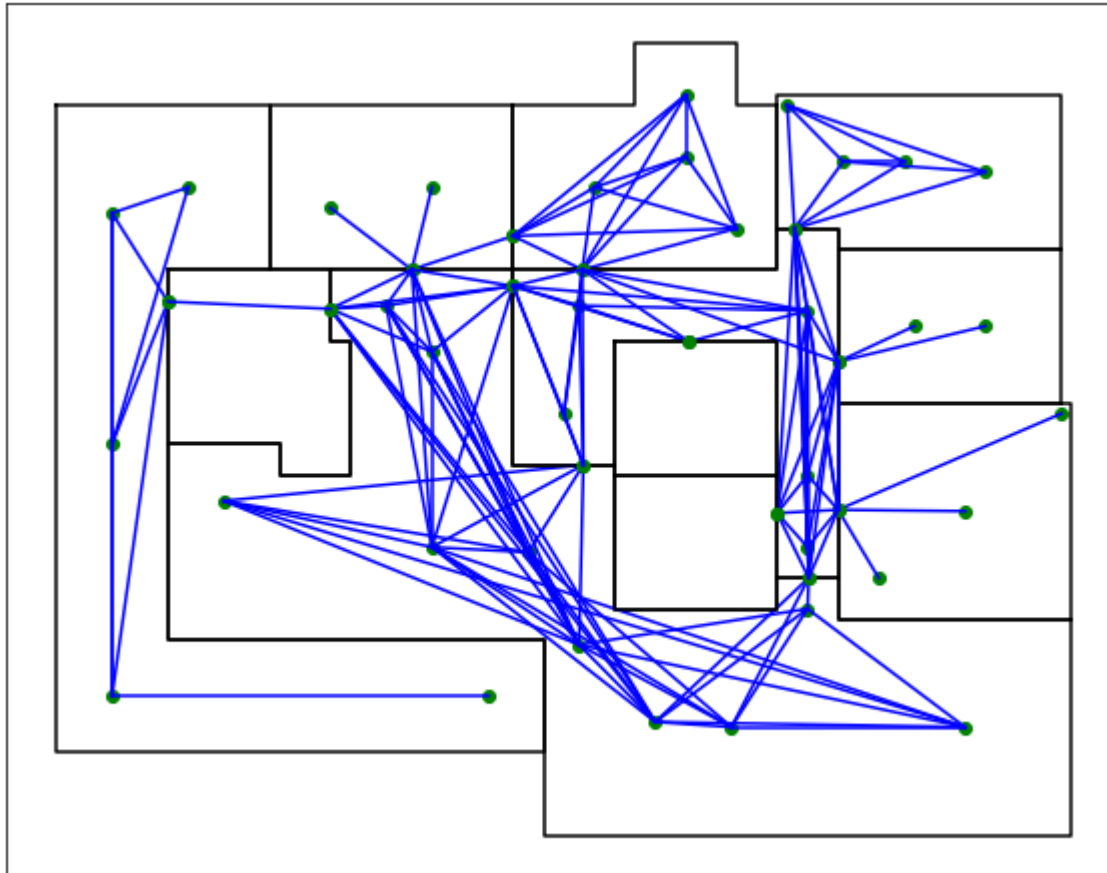
```
Analyzing: c10
Container environment is valid: True
region initial : 1
regions : 1 -- 1
calculating the visibility signatures...
calculating adjacency matrix for regions
finding regions that contains doors/gateways and decision points
decompose views
len: 2
constructing view graph for regions
calculating all spatial relationships visible in each view
Adding actions to views (nodes)
Adding actions to view relations (edges)
```

```
*****
```

```
Analyzing: c11
Container environment is valid: True
region initial : 3
regions : 4 -- 3
calculating the visibility signatures...
calculating adjacency matrix for regions
finding regions that contains doors/gateways and decision points
decompose views
len: 20
constructing view graph for regions
calculating all spatial relationships visible in each view
Adding actions to views (nodes)
Adding actions to view relations (edges)
```

```
In [48]: # derive door-to-door visibility graph (doors+gateways)
plotter = Plotter()
for idx,vg in enumerate(vgs):
    isovist_object = isovist_objects[idx]
    connected2, dtd_graph2 = vg.generate_door_to_door_graph(isovist_object, only_doors=False)
    plotter.add_poly(isovist_object.space_x, isovist_object.space_y)
    plotter.add_holes(isovist_object.holes_x, isovist_object.holes_y)
    plotter.add_points(isovist_object.door_points, 'gateways')
    plotter.add_points_lines(connected2)
plotter.show(False)
plotter.close()
```

```
generate door-to-door graph, only_doors False from view graph
generate door-to-door graph, only_doors False from view graph
generate door-to-door graph, only_doors False from view graph
generate door-to-door graph, only_doors False from view graph
generate door-to-door graph, only_doors False from view graph
generate door-to-door graph, only_doors False from view graph
generate door-to-door graph, only_doors False from view graph
generate door-to-door graph, only_doors False from view graph
generate door-to-door graph, only_doors False from view graph
generate door-to-door graph, only_doors False from view graph
```



<Figure size 720x576 with 0 Axes>

Computing Shortest Path Using Door-to-Door Graph

```
In [49]: gids = Utility.global_gateway_ids(ie)
gids
gids_rev = {}
for cname, vals in gids.items():
    for did, gid in vals.items():
        if gid not in gids_rev:
            gids_rev[gid] = []
        gids_rev[gid].append({'container': cname, 'did': did})
```

```
In [50]: door_to_door_graph = Utility.generate_door_to_door_graph(ie)
```

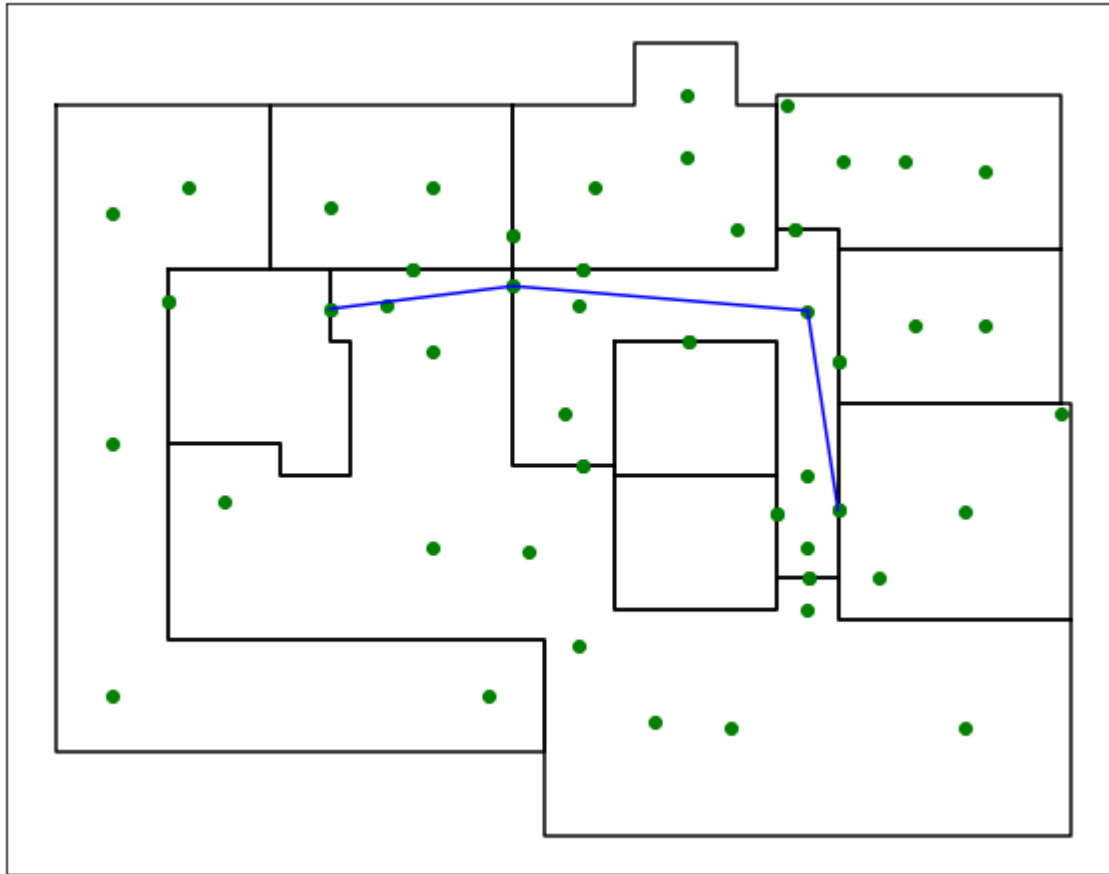
```
generate door-to-door graph, only_doors False from view graph
generate door-to-door graph, only_doors False from view graph
generate door-to-door graph, only_doors False from view graph
generate door-to-door graph, only_doors False from view graph
generate door-to-door graph, only_doors False from view graph
generate door-to-door graph, only_doors False from view graph
generate door-to-door graph, only_doors False from view graph
generate door-to-door graph, only_doors False from view graph
generate door-to-door graph, only_doors False from view graph
generate door-to-door graph, only_doors False from view graph
```

```
In [51]: container = 'c11'
door_id = 1
container2 = 'c6'
door_id2 = 0

import networkx as nx
path = nx.shortest_path(door_to_door_graph, gids[container][door_id], gids[container2][door_id2])
```

```
In [52]: plotter = Plotter()
for idx, vg in enumerate(vgs):
    isovist_object = isovist_objects[idx]
    plotter.add_poly(isovist_object.space_x, isovist_object.space_y)
    plotter.add_holes(isovist_object.holes_x, isovist_object.holes_y)
    plotter.add_points(isovist_object.door_points, 'gateways')
for idx, gid in enumerate(path[:-1]):
    gid2 = path[idx+1]
    c1 = ie.isovist_objects[ie.containers_names.index(gids_rev[gid][0]['container'])].door_points[gids_rev[gid][0]['did']]
    c2 = ie.isovist_objects[ie.containers_names.index(gids_rev[gid2][0]['container'])].door_points[gids_rev[gid2][0]['did']]
    plotter.add_points_lines([[c1, c2]])
```

```
plotter.show(False)  
plotter.close()
```



<Figure size 720x576 with 0 Axes>