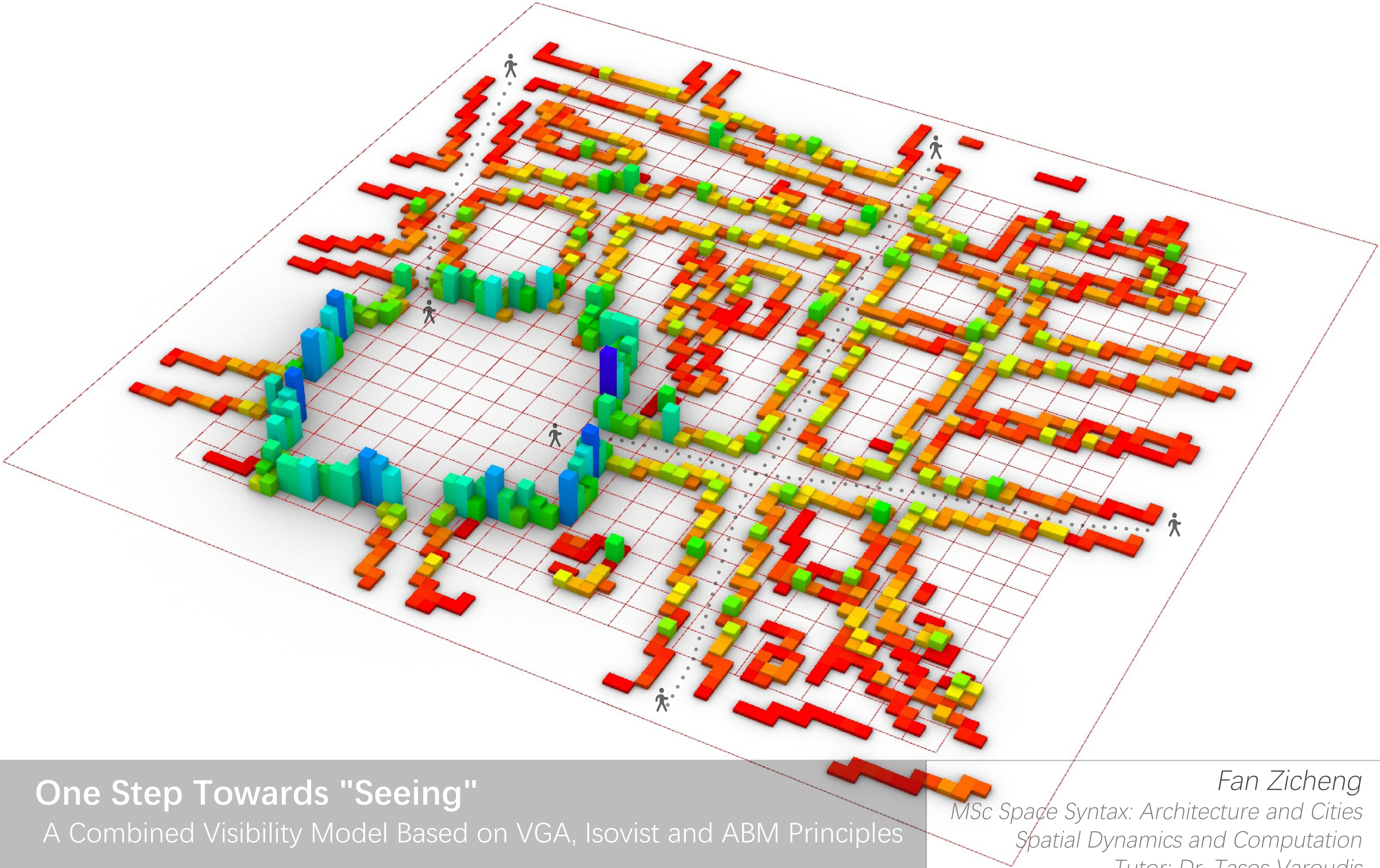

One Step Towards "Seeing"

A Combined Visibility Model Based on VGA, Isovist and ABM Principles

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MSc Space Syntax: Architecture and Cities

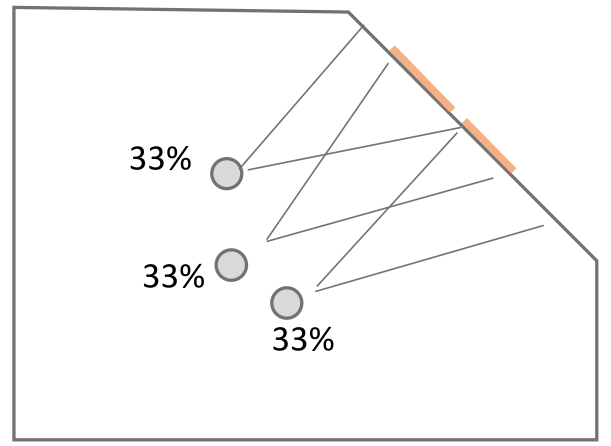
Spatial Dynamics and Computation

Tutor: Dr. Tasos Varoudis

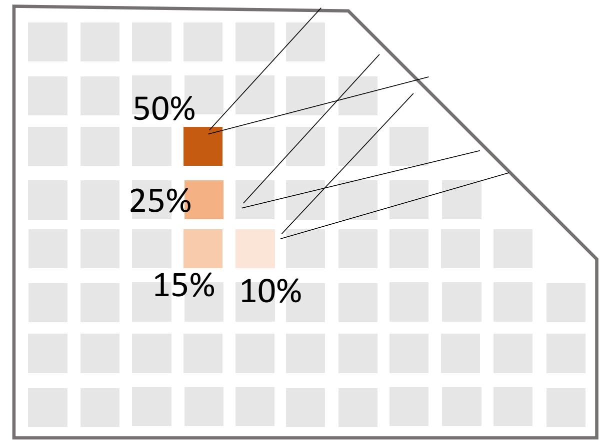
UCL

Part Ⅰ

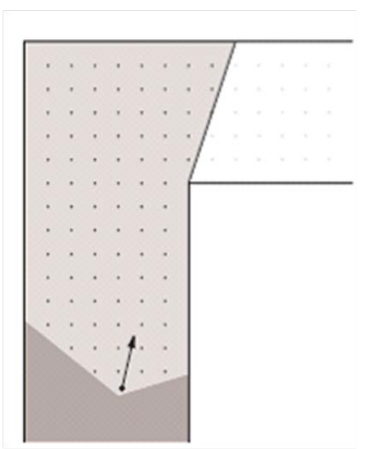
As a visibility analysis tool based on graph, can the VGA model be used to analyze the concrete spatial objects in the environment?



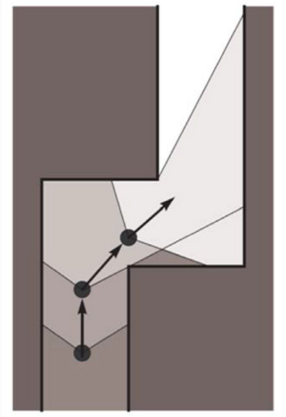
1.In traditional isovist analysis, the observers stay at fixed points and it is hard to simulate the view of moving pedestrians. While in VGA analysis, the pedestrian only see the "open space" and it is hard to see the real objects such as interface of buildings .



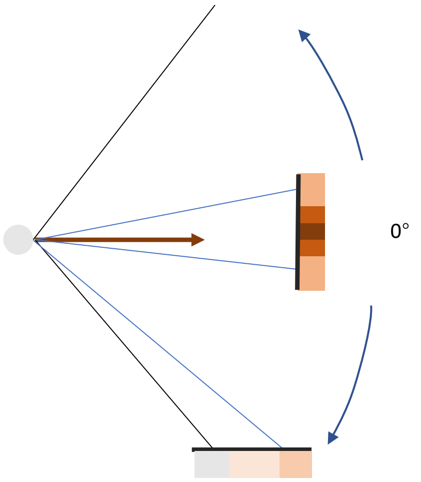
2. If combine the two analysis together, can we develop a model that simulate the view of pedestrians in natural movement, and learn the frequency or the effectiveness of all or part of the street objects can be seen.



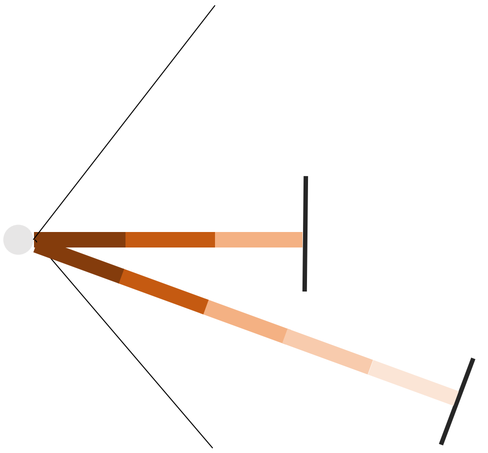
3.The agent based model provide a framework to combine these two analysis together. The EVA model in space syntax community use isovist analysis to search the available direction in agent's visible field and the integration from VGA is used as a weight to make choice(Penn & Turner, 2001).



4. For traditional EVA model, the isovist is only used for the directing searching and have a angle of 170 degree. However, in real visual environment, people's line of sight should also see the objects in the end. The use of isovist can be extended and developed.



5. The effectiveness of the observation can be measure by the angle of isovist line and objects' interface. The middle line of the 170 degree angle can be regarded as the sight line with most attention, while sight line at two edges of the angle have the least attention.



6. The distance from the agent to the objects may also work as an attribute. For most cases, the closer the better visibility. However, for theose building with much different proportion or height, a relatively larger ditance could have better visibility.

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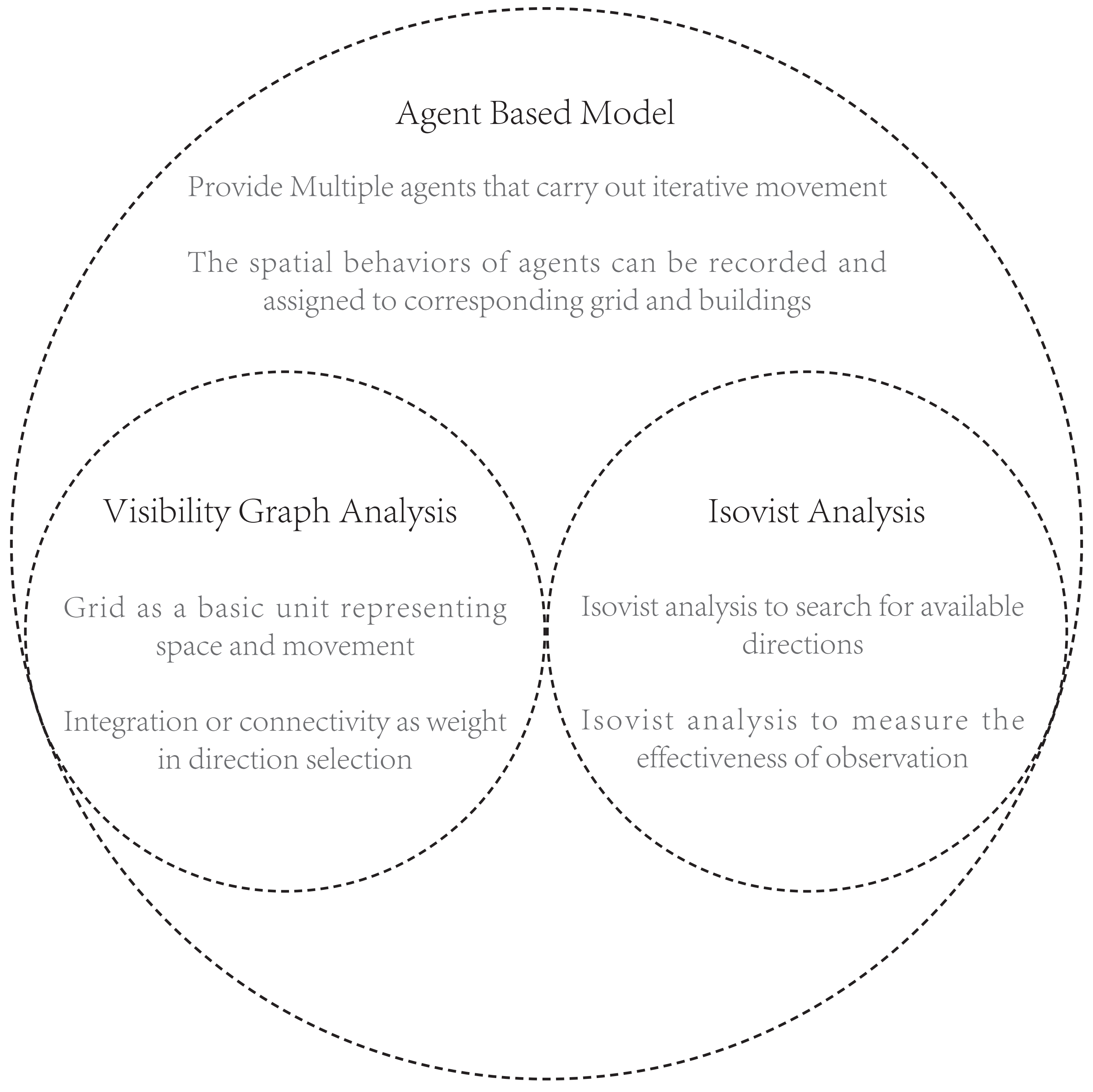
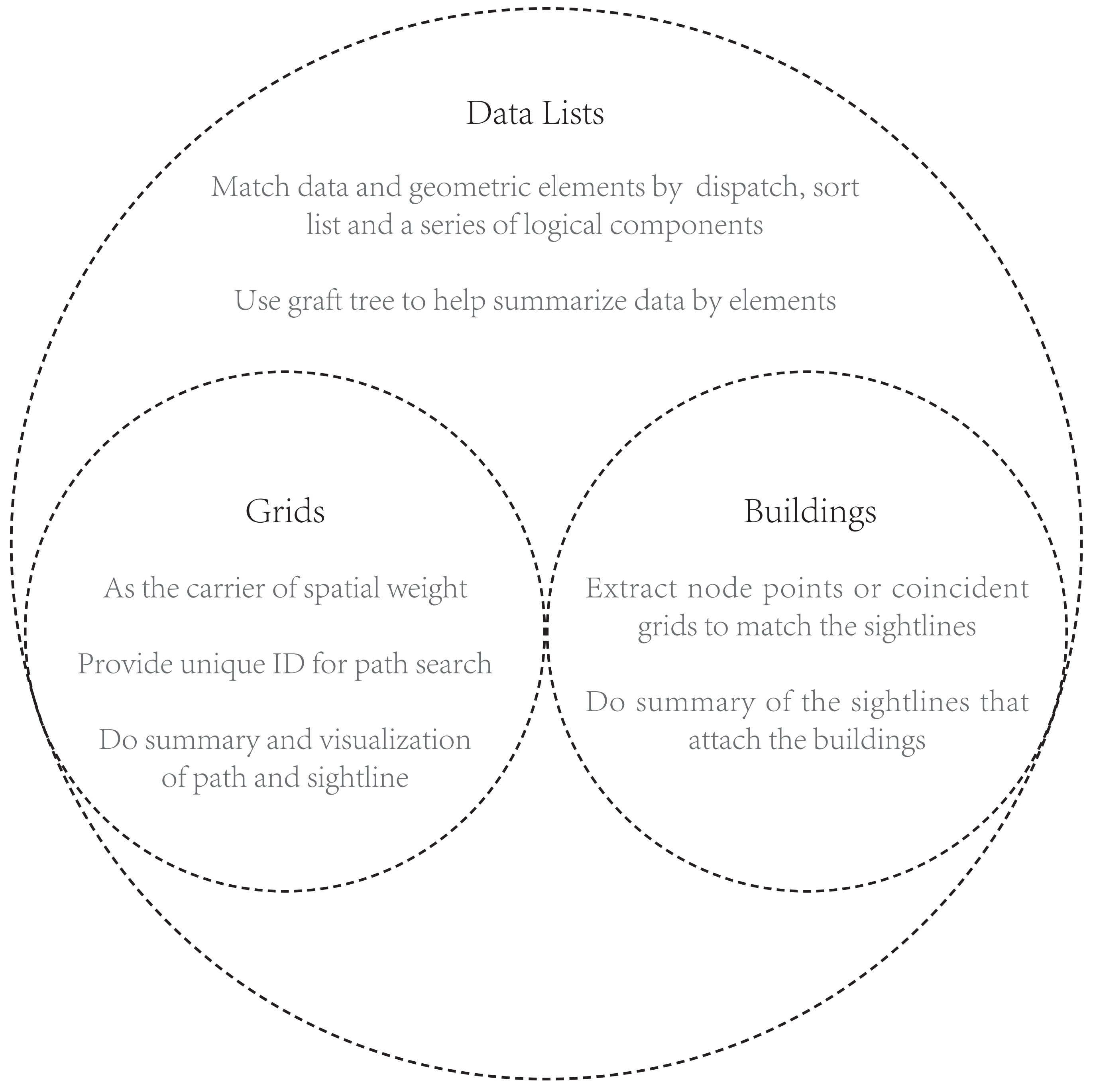
Spatial Dynamics and Computation

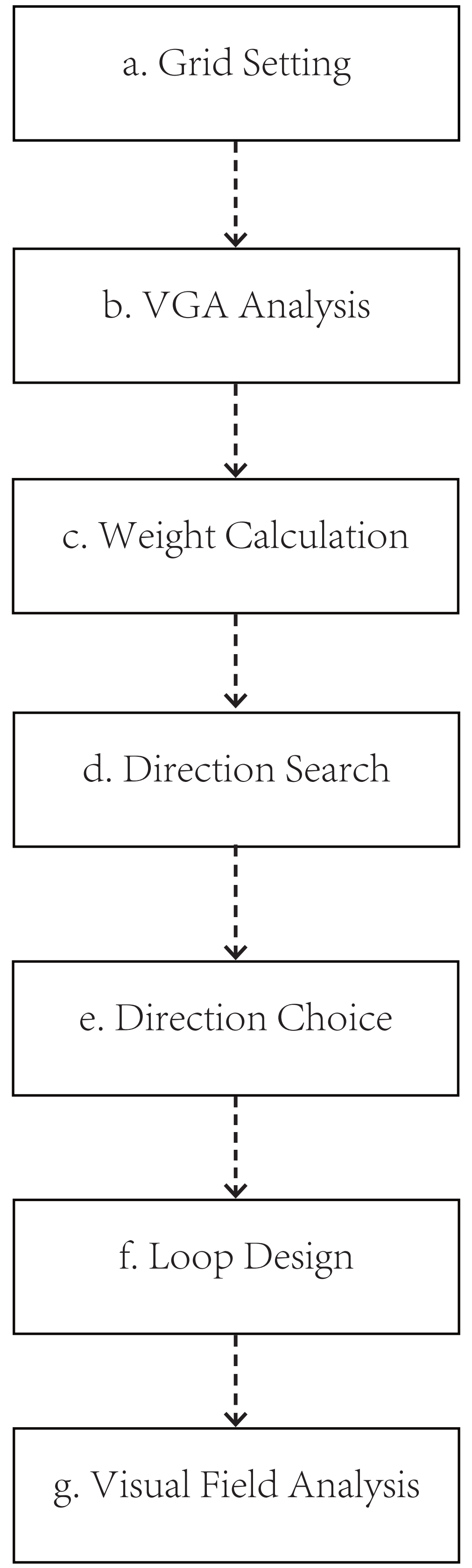


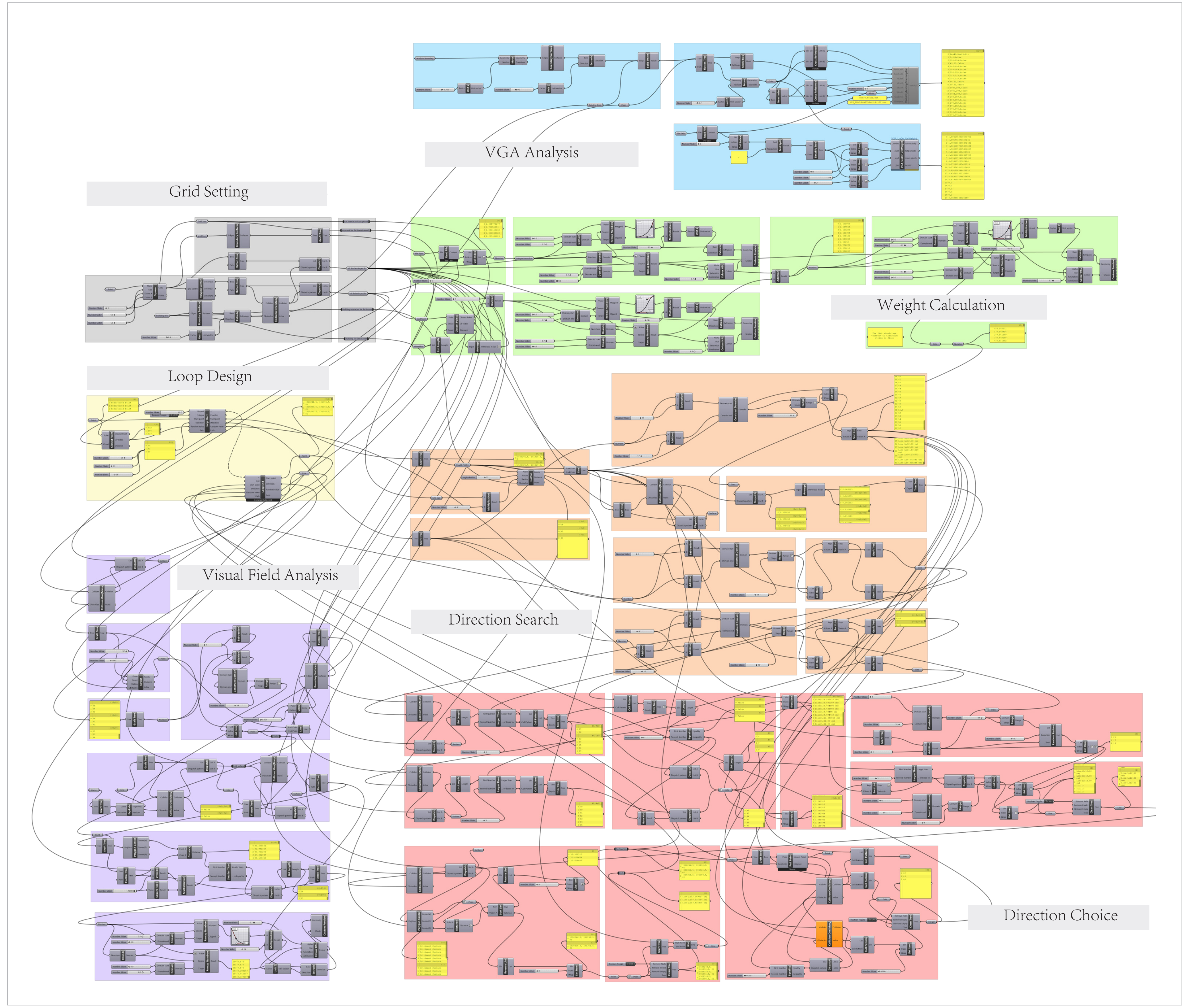
Model Structure



Data Structure

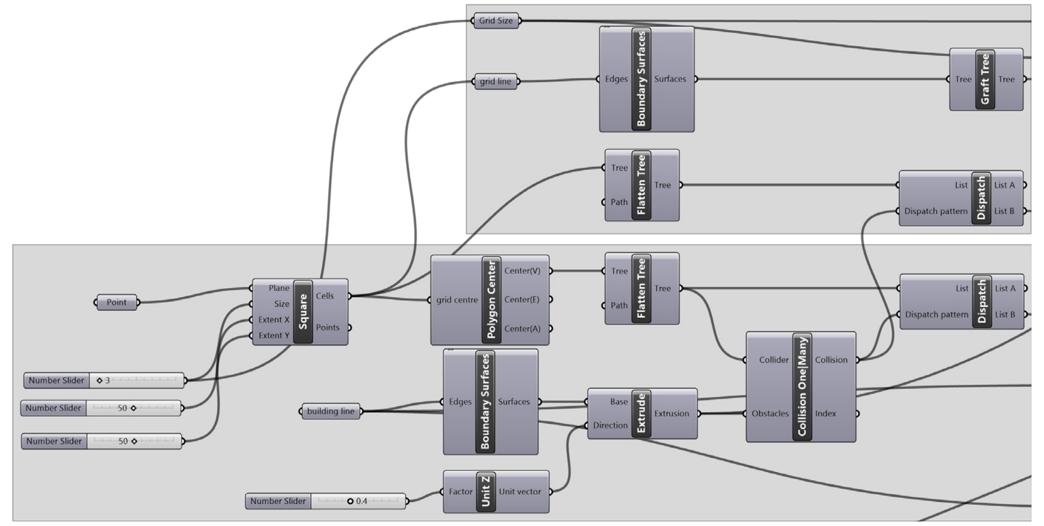
Based on the principle of original EVAS model, this project attempts to further integrate and expand the application of VGA and Isovist, and build an improved agent based model to analyse the pedestrians' visual interest in 3D built environment. The project can be divided into three stage: firstly, design and calculate weights that affect the agent's movement. Secondly, set rules for direction searching and selecting in ABM process. Thirdly, extend the Isovist analysis towards surrounding buildings and calculate the visual interest or the visibility.



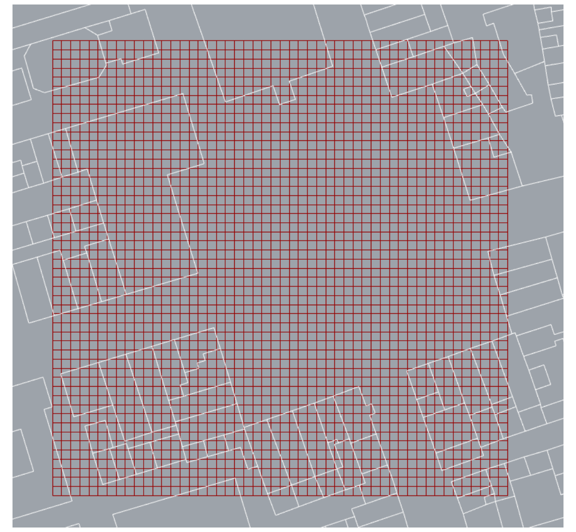


a. Grid Settings

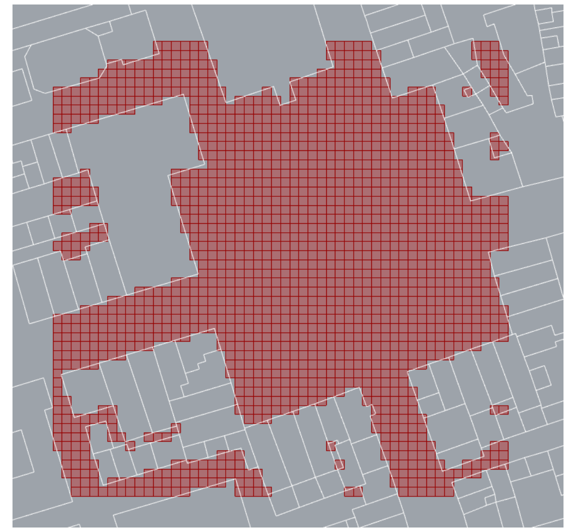
The grid network is applied in VGA to code and analysis open space, and it is also the main environment for ABM model to search the moving direction.Taking the Manchester Square in London as an object, a 3×50×50 grid network is built as the basis of the model and grids available in open space are selected. To simplify the model, other spatial elements such as green space and plants are not considered



Manchester Square



Grid Network



Available Grids in Open Space

b. VGA Analysis

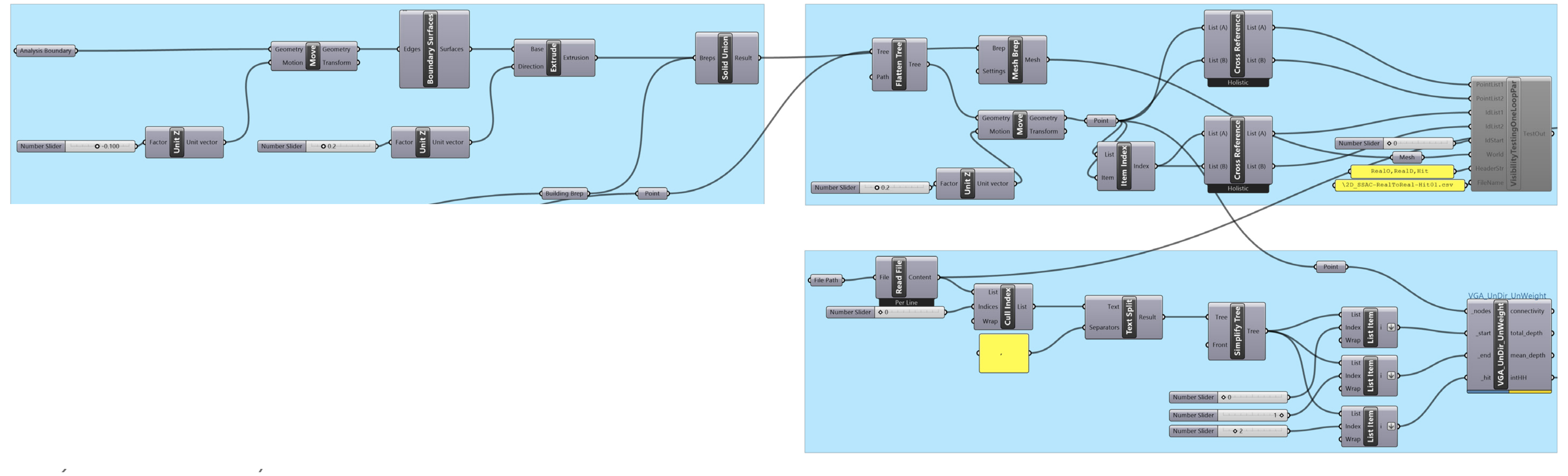
With he VGA analysis components(Varoudis, 2021) in Grasshopper, the global integration and other space syntax indices can be calculated for the grids in open space.

	RealO	RealD	Hit
0	0	0	FALSE
1	126	126	FALSE
2	63	63	FALSE
3	145	126	FALSE
4	189	189	FALSE
5	252	252	FALSE
6	315	315	FALSE
7	316	315	FALSE
8	88	63	FALSE
9	89	63	FALSE
10	1049	283	FALSE
11	1050	283	FALSE
12	1051	283	FALSE
13	203	189	FALSE
14	0	0	FALSE
...	...	...	...

Visibility Test Among Points

	Integration	Connectivity
0	1.894197	8
1	1.895773	10
2	1.790568	11
3	1.88417	9
4	1.900835	9
5	2.283441	10
6	2.428012	9
7	3.033237	8
8	4.753675	79
9	5.572312	183
10	5.775764	266
11	5.692057	298
12	5.426301	251
13	5.163103	198
14	4.6737	94
...	...	...

VGA Analysis



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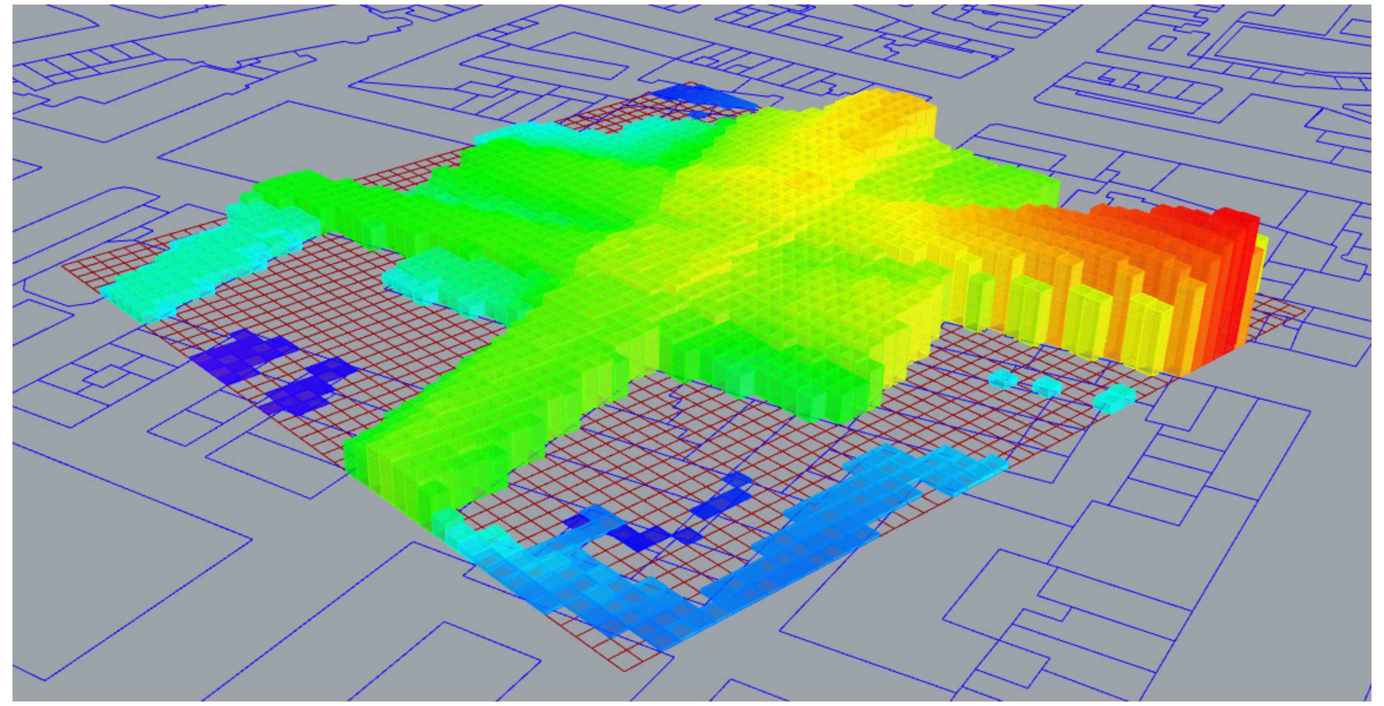
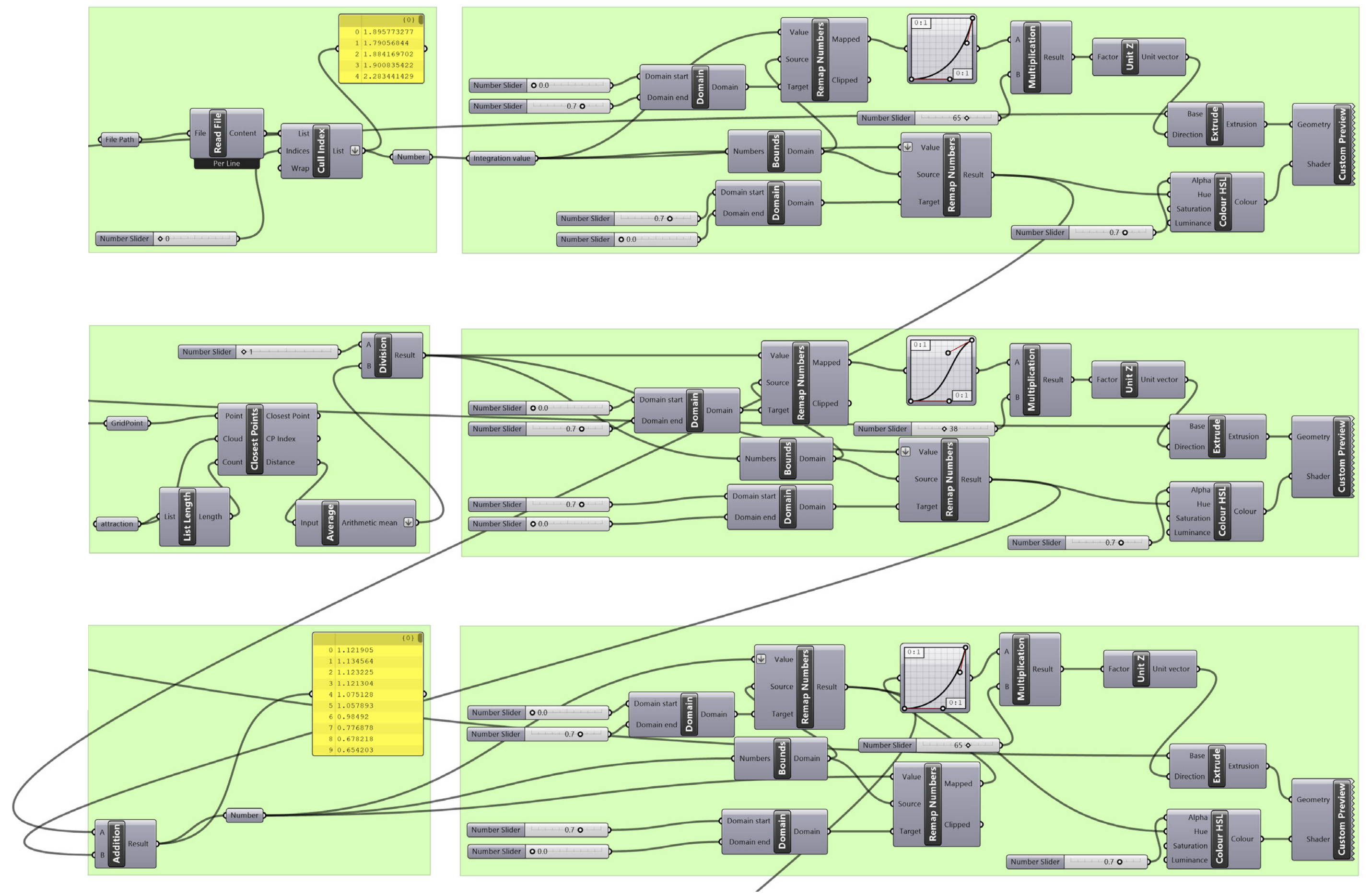
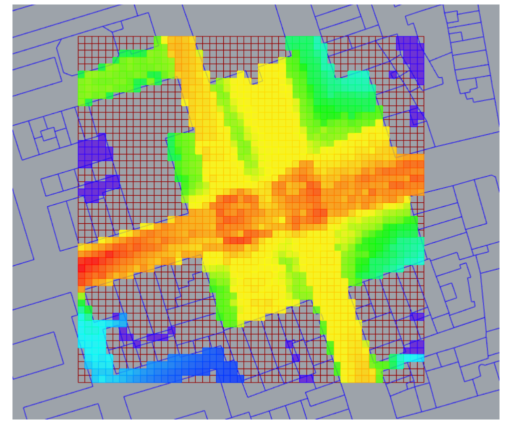
c. Weight Calculation

Based on the principle of EVAS model, global intrgration can be selected as the first weight to guide the natural movement of pedestrians(Penn & Turner, 2001; Hillier, 1996). Considering that in real urban environment, there are also other attractors influencing pedestrians, such as the street activities or the appearence of the building interface, an additional weight can be necessary. Ferguson, Friedrich and Karimi (2012)introduced OD matrix of gates or land use into the EVAS model. In a similar way ,grids' distance to the POI points nearby can be used us a second weight in this model. The sum of the two constitutes a comprehensive weight, which is used to guide the direction selection of agents.

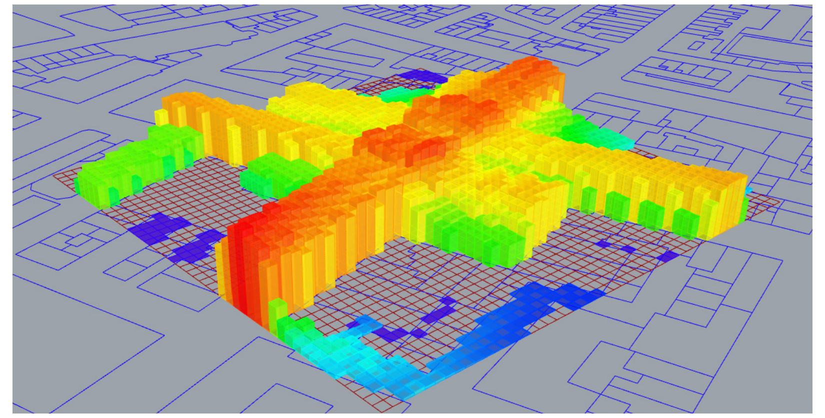


Comprehensive Weight for Direction Choice





Integration from VGA Analysis



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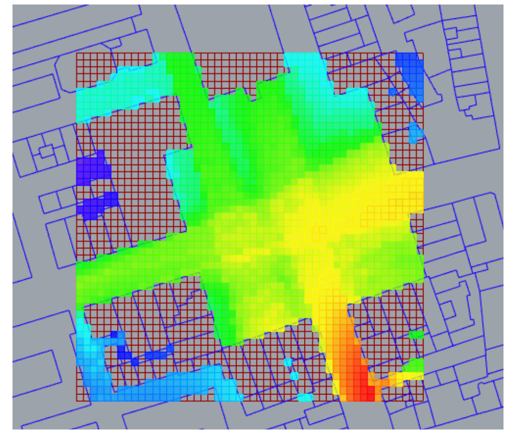
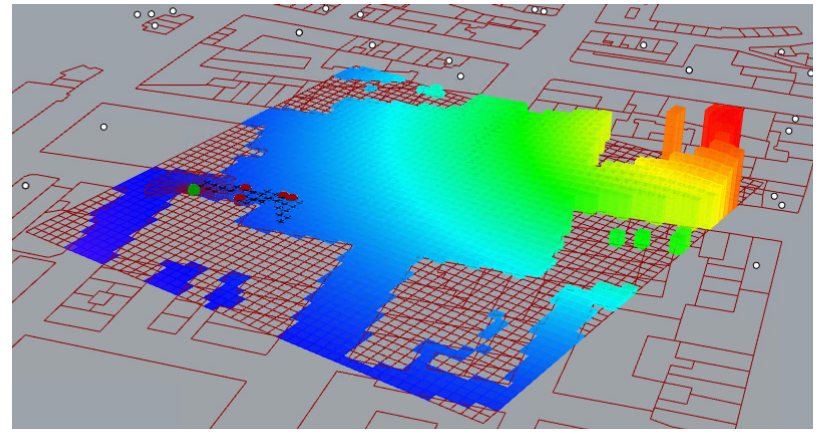
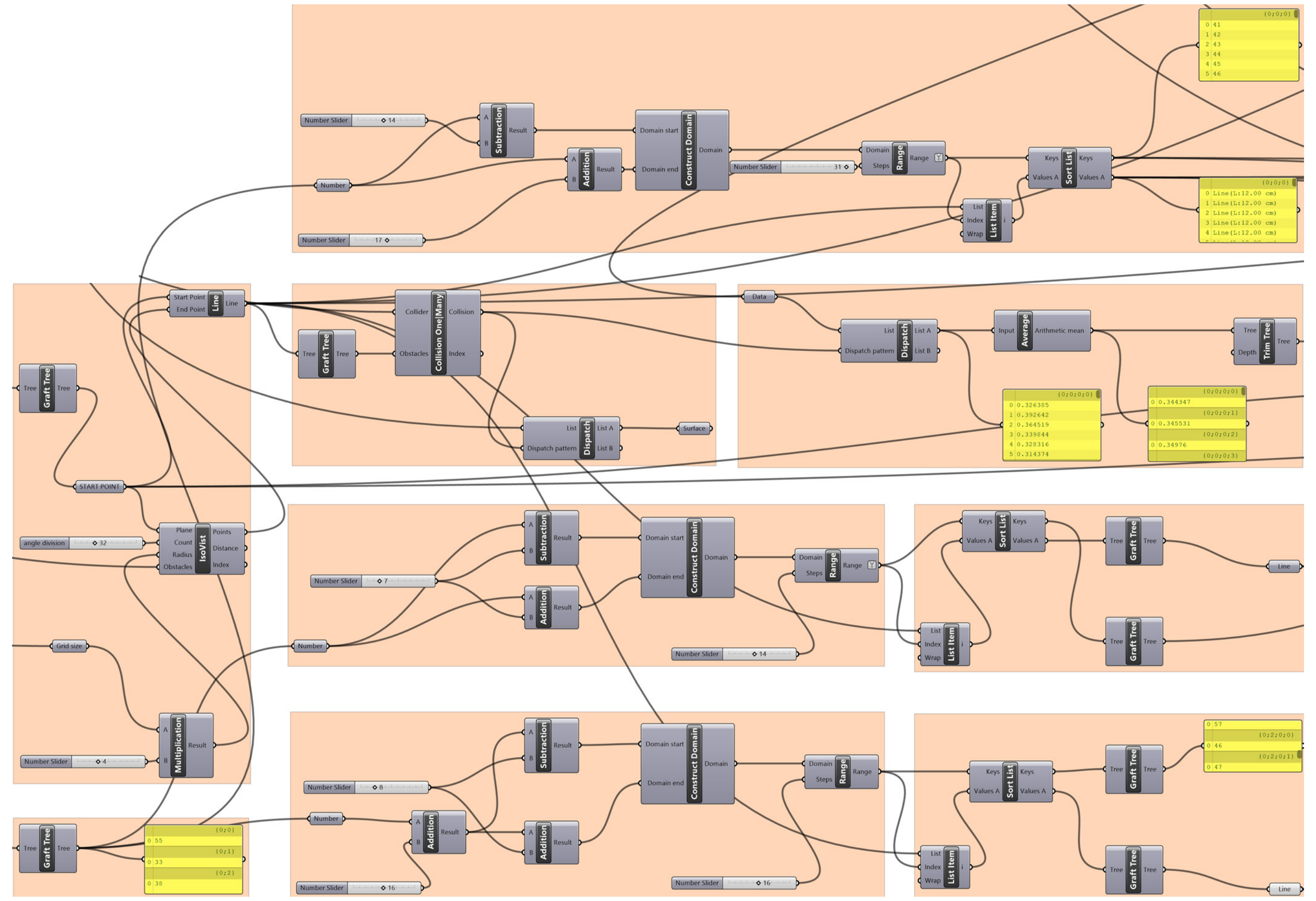


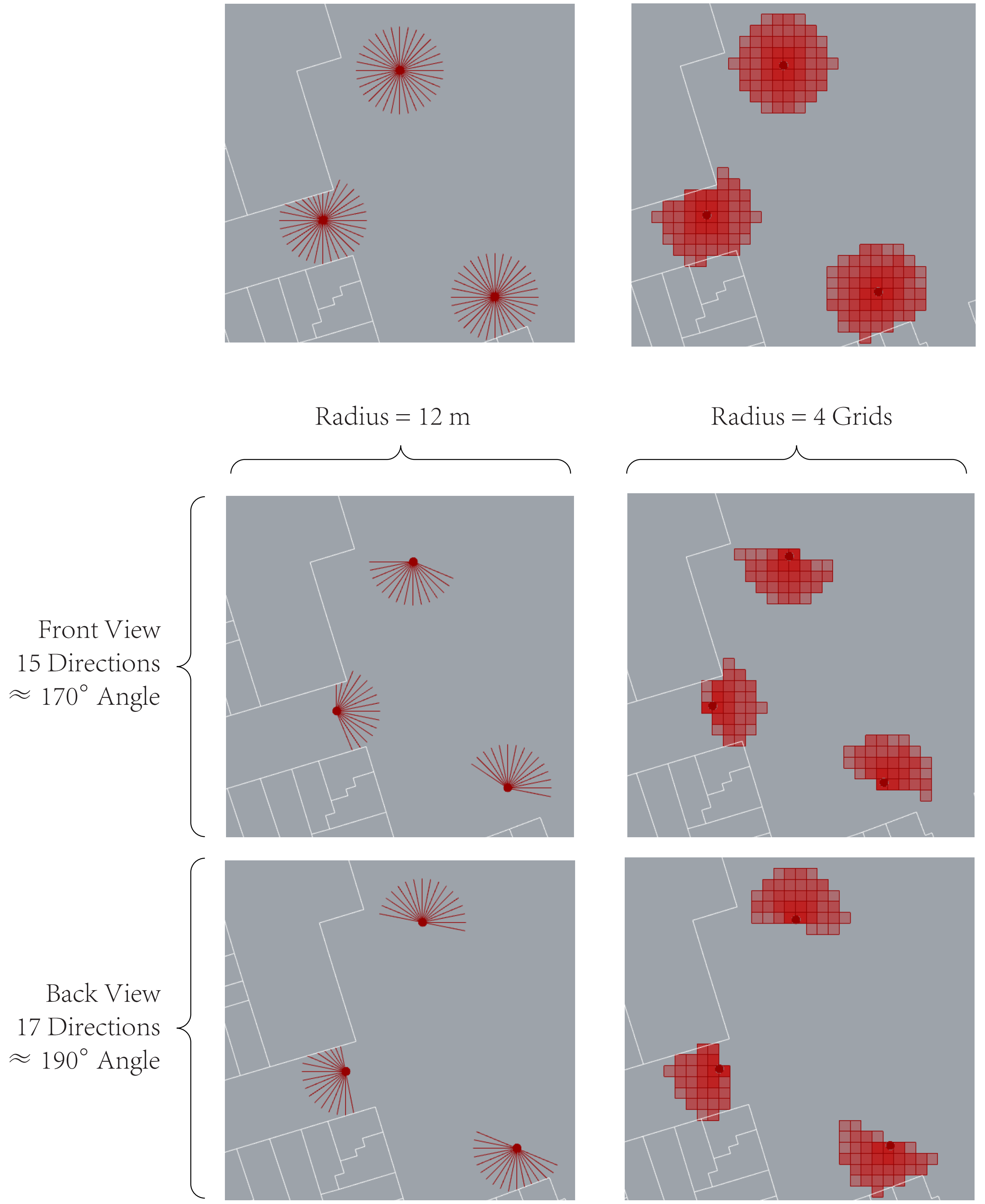


Attraction from POI

d. Direction Search

In original EVAS model, the isovist analysis is carried out for each agent to equally divide the 360° angle in 32 parts, as the visual field in different directions. To simplify the calculation, in this model 32 isovist lines are directely used as a represent of different visual field, and the default setting of the isovist radius is 4 grids. On this basis, one isovist line can be selected as the start direction that the agent is heading towards.Then, front view (170° angle and 15 lines) and back view((190° angle and 17 lines) can be further divided. For every isovist line in front view and back view, find the overlapping grids and the corresponding weight in the background.



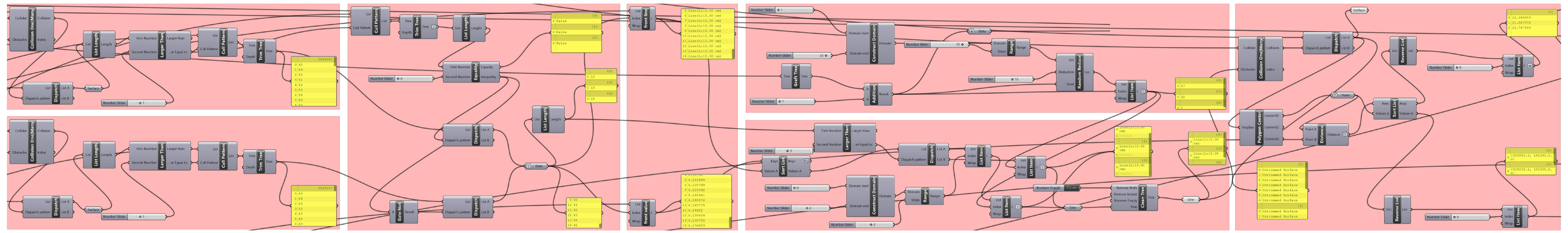


e. Direction Choice

There are three steps in the direction choice process. Firstly, based on the input starting direction, it is necessary to judge whether the direction is leading to a dead end. If there is not a dead end ahead, continue the selection to next step, otherwise, turn to the other 190°. This process gives the agent the ability to turn around before colliding with the environment. Secondly, summarize the mean weight of the grids by corresponding isovist lines and select 3 lines with highest value. This limits the global direction of the agents. Finally, random number is introduced to the model and help select one line for every agent. For every start point, there is a unique random seed assigned.

Go Straight or Turn Around (Collision Detection) | Global Direction | Local Direction

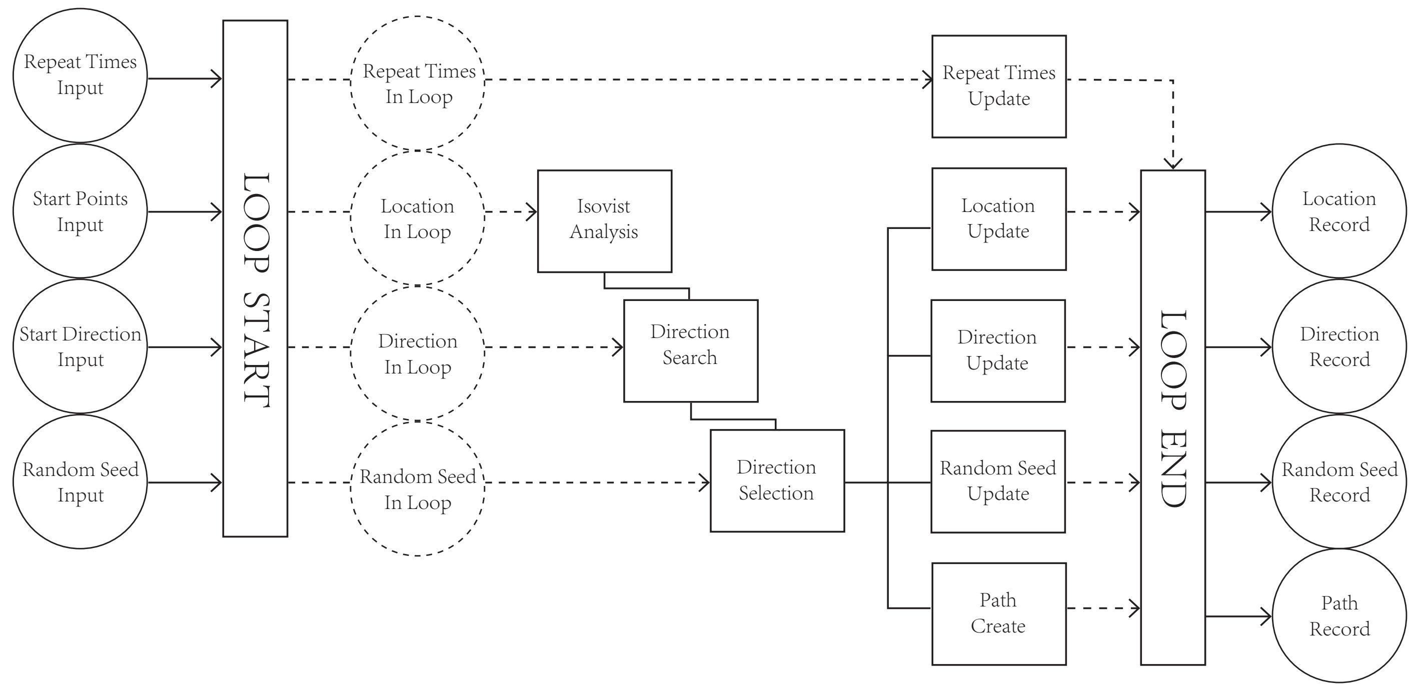
Front View — If -Directions With More Than 3 Grids Exist — Yes — Front View Directions With More Than 3 Grids; No — Back View Directions With More Than 3 Grids — Mean Weight Calculation For Each Direction — If -Directions With More Than 3 Grids > 3 — Yes — Select Top 3 Directions With Highest Weight; No — Select All Directions — Random Selection For 1 Direction

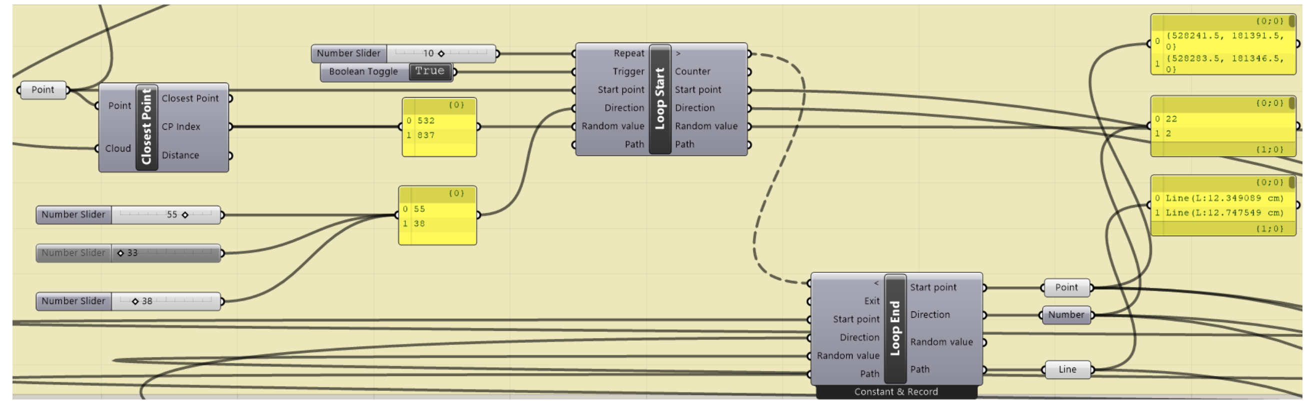


Visual Field of 360° | Collision Detection | Global Direction Select | Local Direction Select | Next Position Select

f. Loop Design

Based on the way-finding rules, the loop component "anemone"(Zwierzycki, 2015) is introduced to the model. This component make the direction and position of the agent iterate continuously, and keep the random seeds being updated.Through a series of debugging, the model realizes the multi-points input and multiple loops, and is enable to output the history position of the agents as well as the corresponding heading directions. On this basis, the path and the visual field of agents in every position can be visualized.





Agents' Path in Lines

Agents' Path in Grids

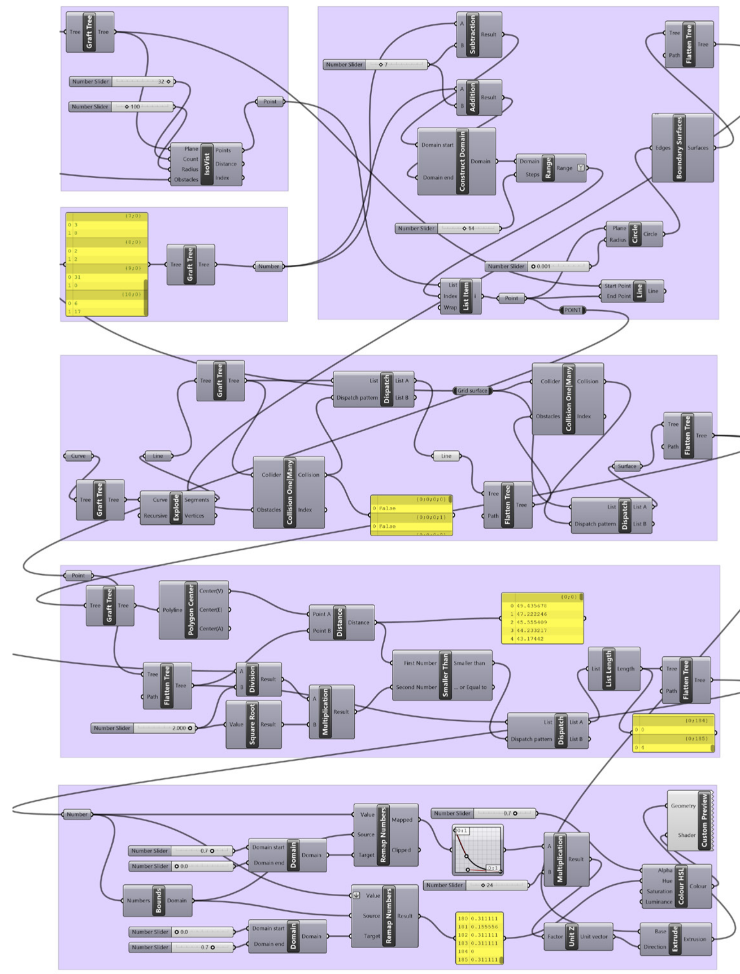
Visual Field of Agents at Every Step

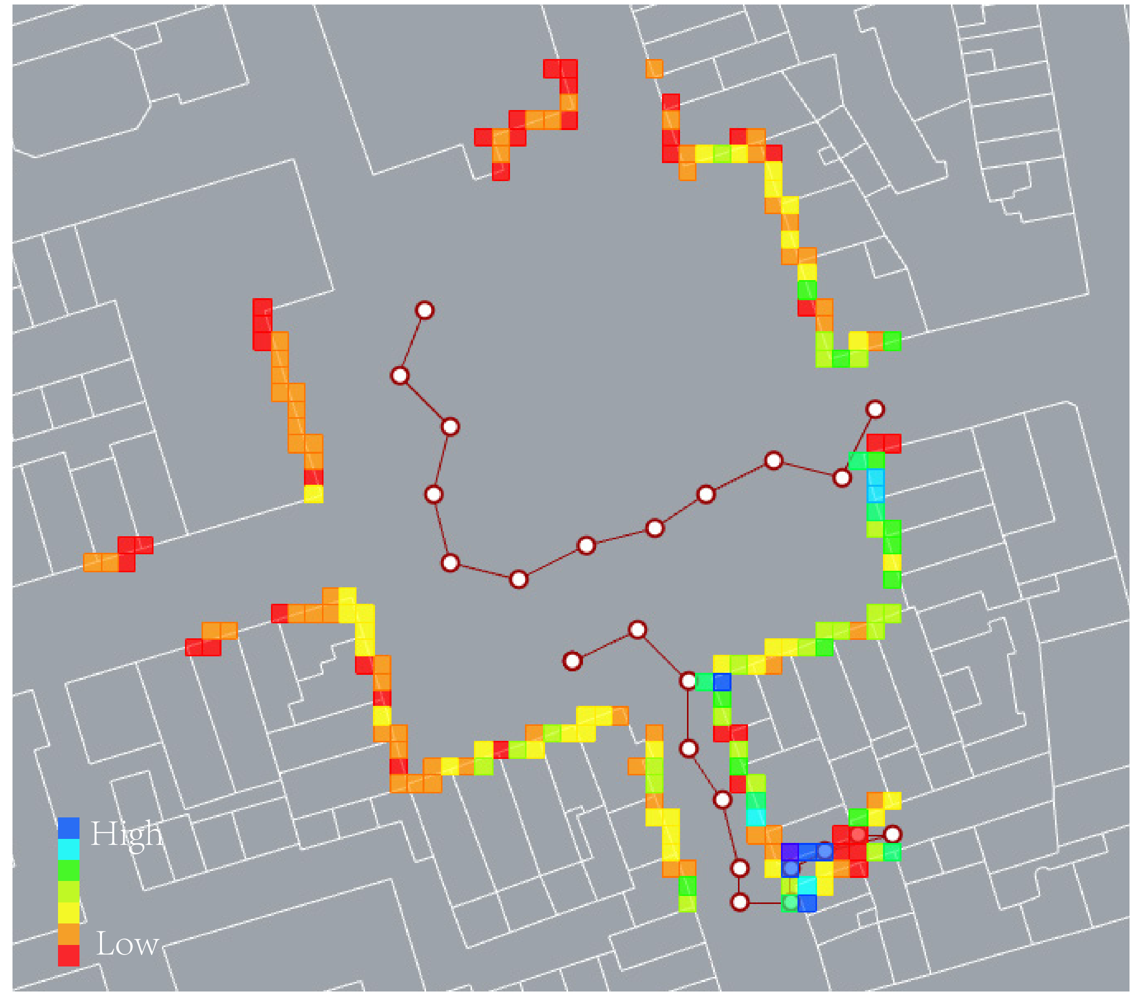
g. Visual Field Analysis

Based on the agent path, isovist analysis with a larger search radius can be redone for each step. This makes isovist lines intersect with the surrounding buildings. On this basis, select isovist lines within the visible angle and their intersection points with the building interface. Then Summarize the count of the points, by grids corresponding to the building interface. The count of points indicate the frequency of the agent's sightlines falling into the area, that is, the visibility. Weighted calculation can be further considered in the count summary, according to the length and angle of the Isovist lines. However, considering that the overall design of the current model is not perfect, more weight calculation may be left for future exploration.

Intersection Points Between Isovist and Building

Building Lines Exploded — Lines of Building Interface Intersected with Isovist points — Grids Intersected With Building Interface Lines — Intersection Points Within Each Grid





Count of Isovist Points on Building Interface - Summarized by Grid

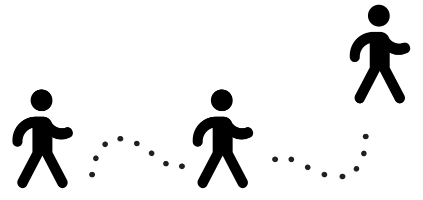
Isovist Lines in Selected Degree

Selected Isovist Points on Buildings

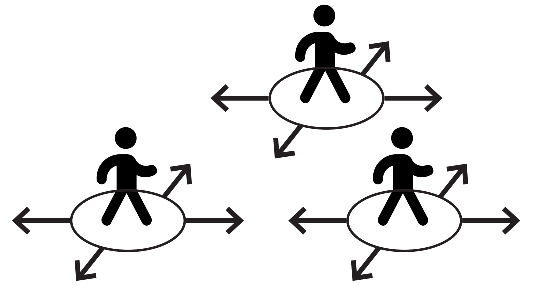
Grids Coincident with Building Interface

Extention
In Large Scale Space

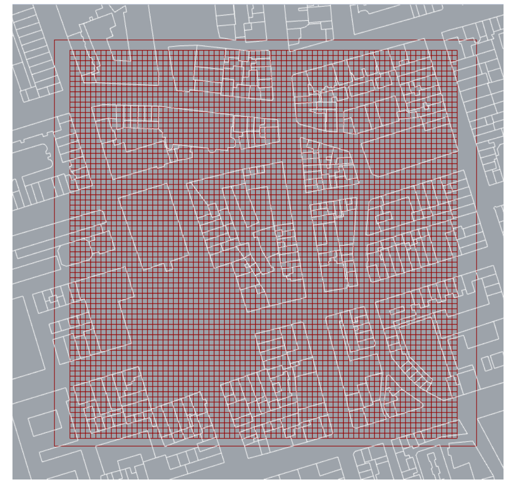
Through preliminary experiments, it is found that when there are multiple agents input, the computing time for the loop components can be greatly increased, resulting in frequent crashes. However, for analysis in a large scale space, multiple agents can be necessary. It's reasonable to input multiple directions for every agent in one step, and predict their next-step directions respectively. The location of agents can be widely distributed in the whole area, simulating the possible way-finding decision of pedestrians from different directions, in each potential location. Because this method only increases the amount of data to be processed in a single calculation, rather than loops of the whole process, it takes less time to return the result. It can be regard as an attempt to balance the effiency and accuracy of the model.



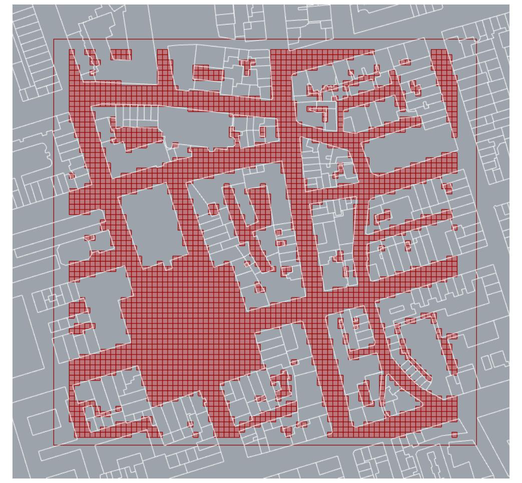
Single Person
Multiple Times' Loop
One Direction Input
One Path Output
↓
Small Scale Research



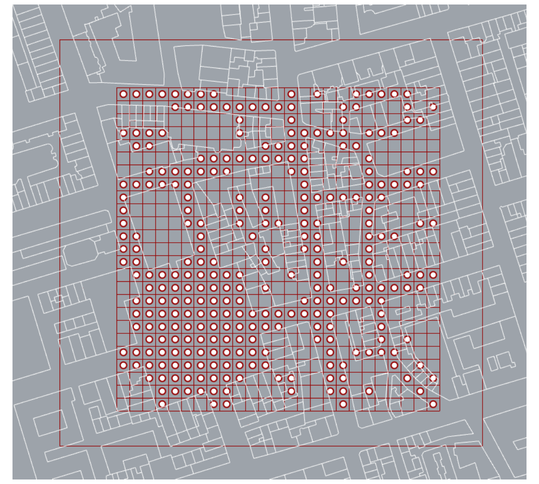
Multiple People
One Loop
Multiple Directions Input
Multiple Paths Output
↓
Large Scale Research



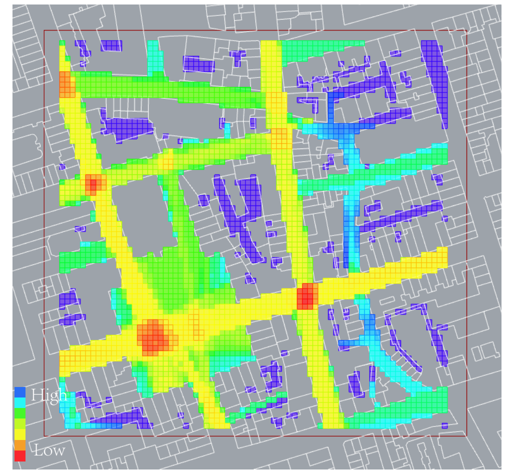
Enlarged Grid Network



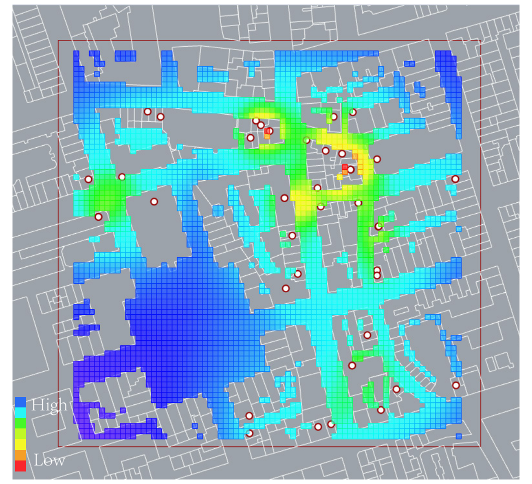
Available Grids Selected



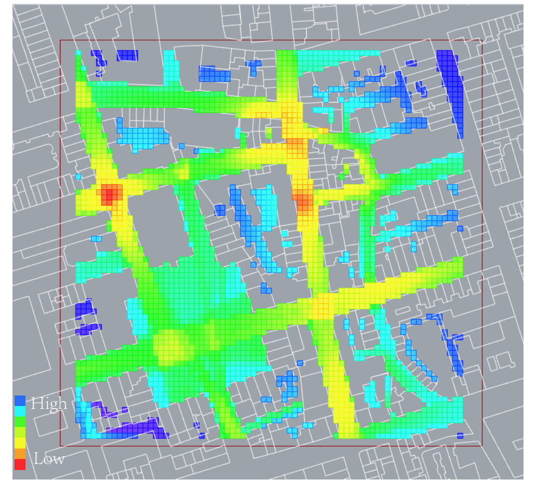
Agents Position Selected



Weight - Integration

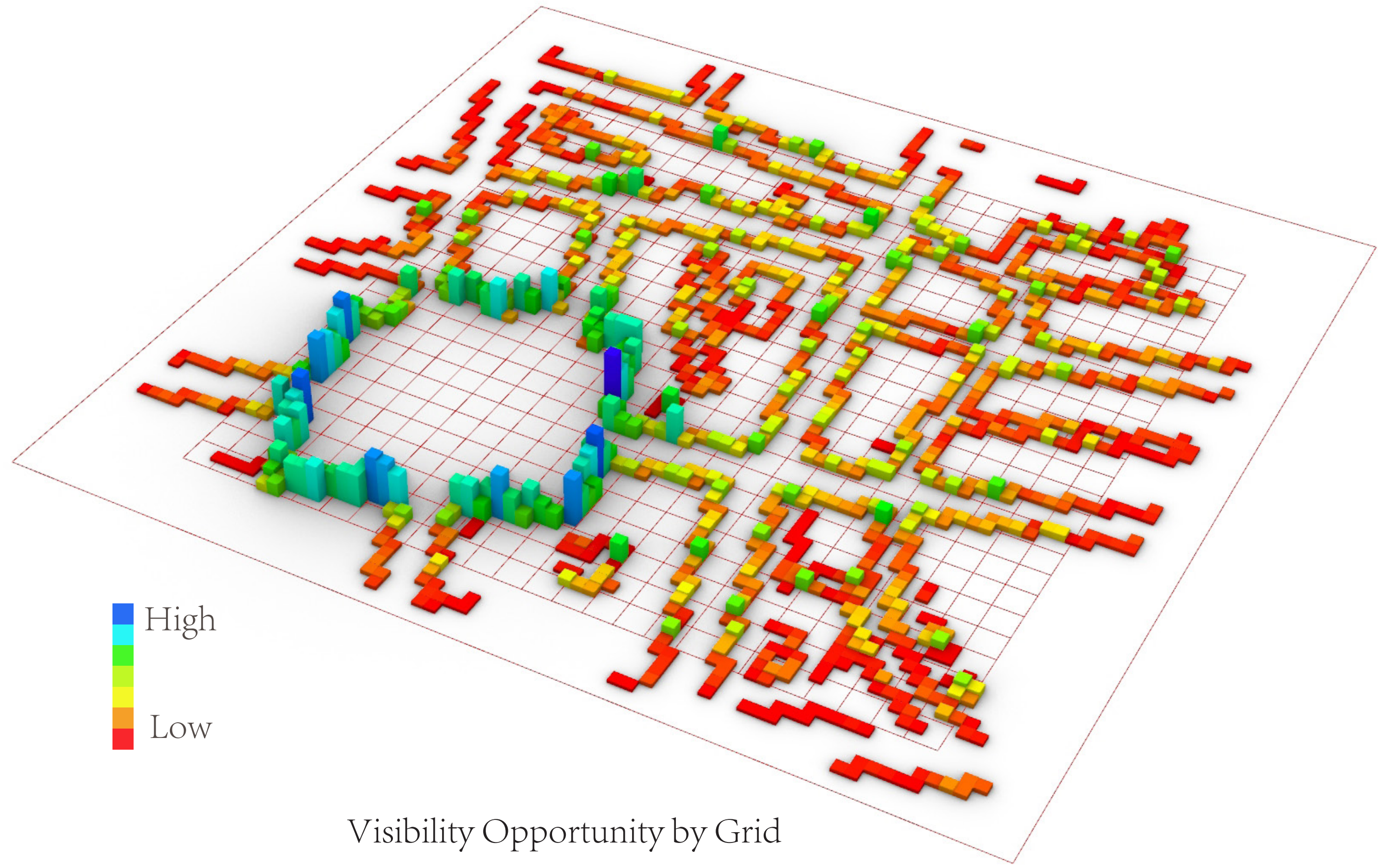


Weight - POI Distance

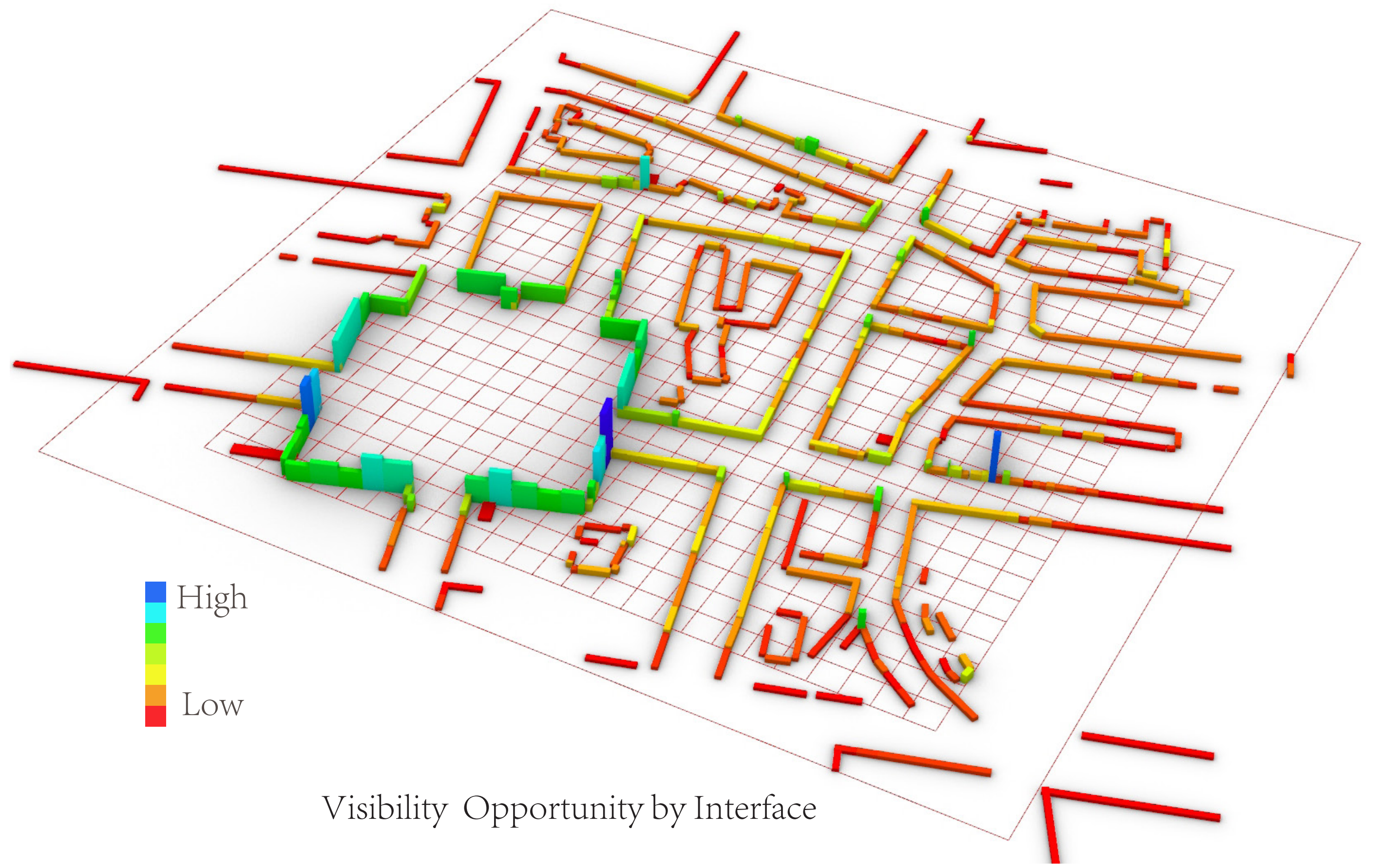


Weight - Comprehensive

The Visibility of the Grids in front of the Building Interface



Visibility Opportunity by Grid



Visibility Opportunity by Interface

Furthermore, the points falling into the grid can be summarized to the building interface corresponding to the grid and the whole building. As shown in the figures, the dark blue building interface and building blocks indicate that the space they represent may be more likely to be noticed by pedestrians. These spaces are usually adjacent to or oriented to the main flow of people, or there are more attractive activities in the adjacent areas.

To sum up, the model realizes the preliminary simulation of pedestrian visual interest based on the principles of VGA, Isovist and ABM models. The main difficulties of the model lie in the setting of agents' way finding rules, the iteration of agents movement and the expansion of its application in large-scale space. The innovation of the model is reflected in that the agent can observe the surrounding environment in the corresponding field of vision while searching his path in movement.This extends the application of original VGA in 2D space to a 3D world, and enhances its practicability in spatial analysis and urabn design.

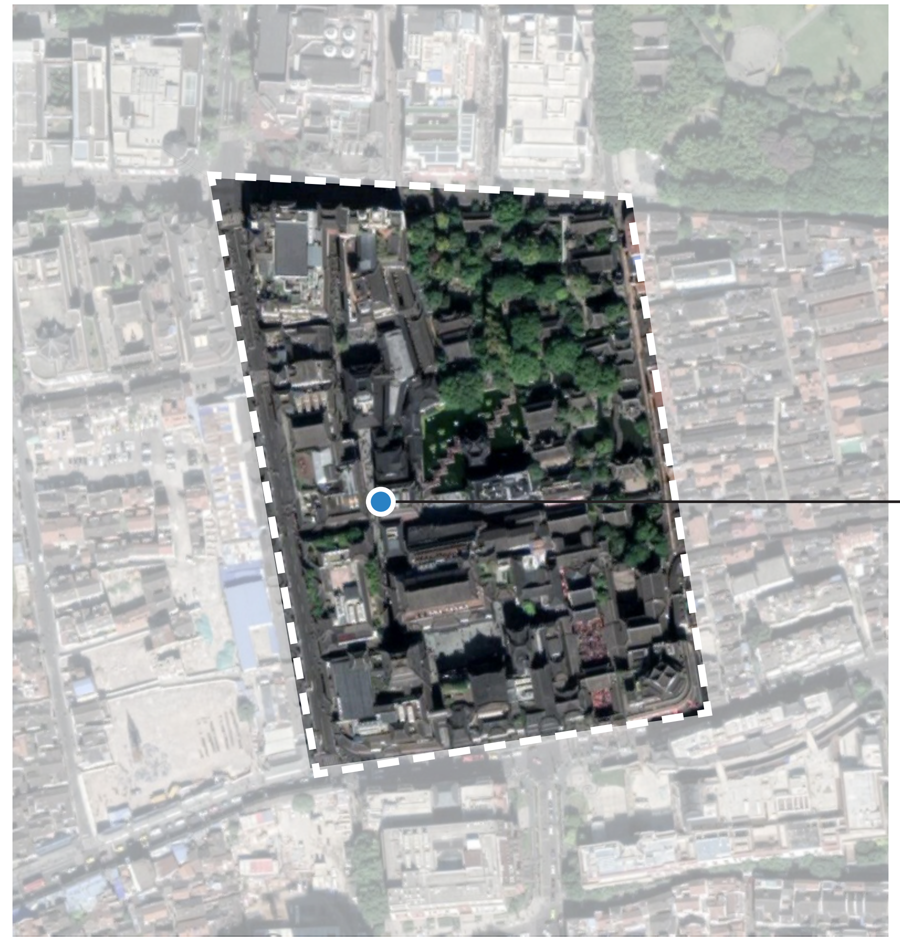
However, there are also limitations for the model. First of all, the model is relatively weak in weight design, only considering the global integration of VGA and the guiding effect of POI points on pedestrian movement. In the real street environment, a large number of street landscape and street furnitures, the color and form of building interface may all have an impact on the behavior of pedestrians. On the other hand, the model is mainly based on grasshopper components, and the process of analysis and judgment can be redundant and time consuming. The practicability of the model in the analysis of multi agents and large scale space can be improved.

Visibility Opportunity by Single Building

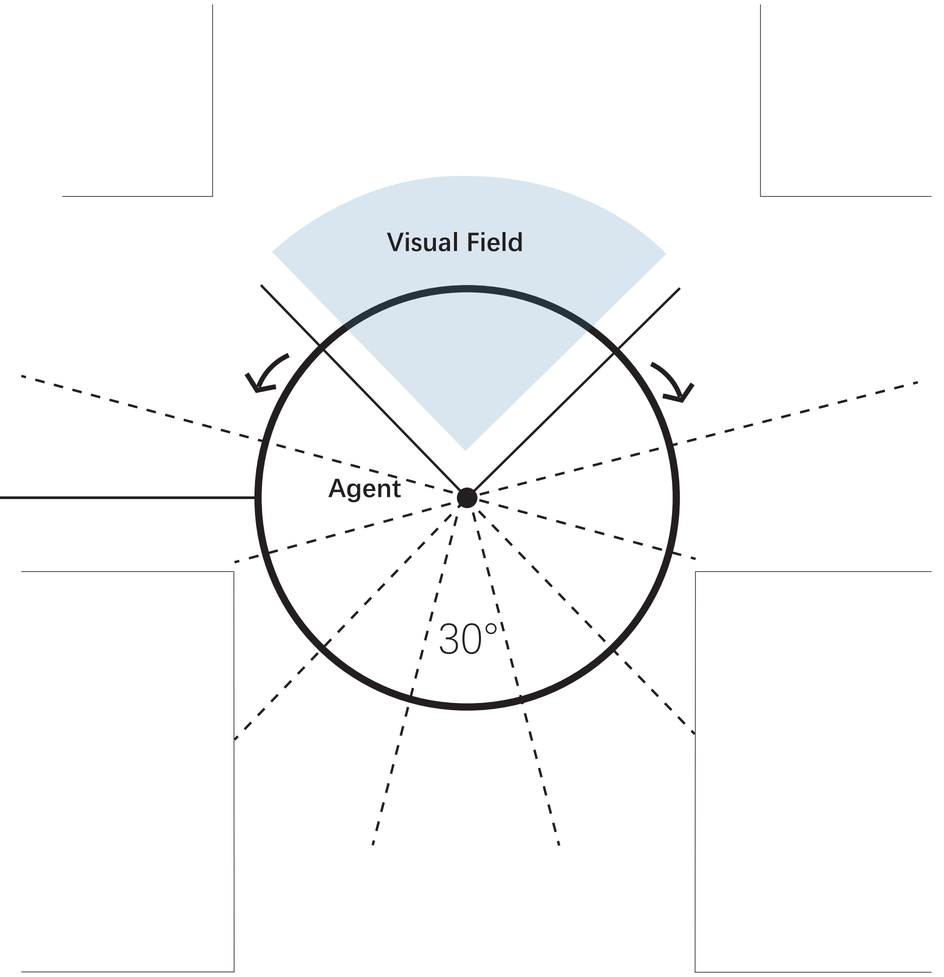
Part II

Based on the visual field direction calculated at potential locations, what may agents see in a real built environment?

Based on the model above, try further exploring the visual possibility of agents in a real street environment. The Chenghuang Temple Area in Shanghai, China is selected as an example.

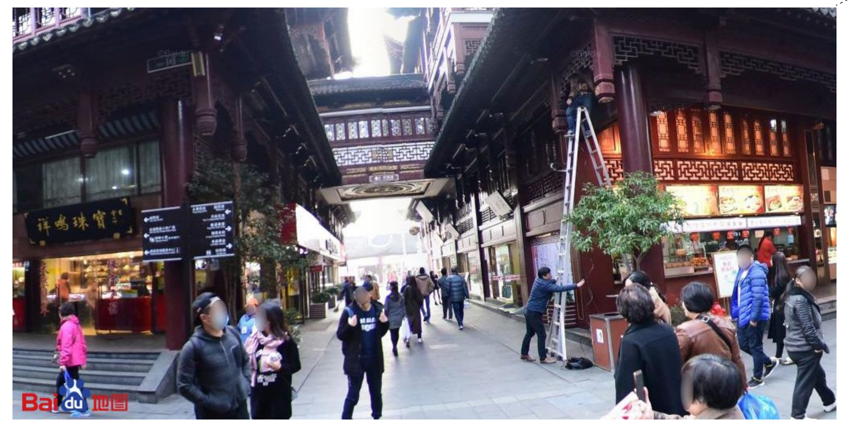


The research area is a famous as a crowded tourist attraction and has relatively complete street view image data. Based on the Baidu street view API, it is available to establish the corresponding relationship between the street view images and the agent's position and angle in the model.



On this basis, below is an attempt to explore the differences between the image features observed from the high-frequency direction of field of vision and the general features reflected from the environment, and learn how people's movement patterns affect their environmental perception.

α-30°



α

α+30°

The difference in the directions and the horizontal and vertical field of views(fov) of street view pictures reflect on the proportion difference of the features contained in the scenes.

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Supposing that for every potential location, pedestrians have equal opportunities to walk in from 12 evenly distributed directions. From these directions, agents first observe the surrounding environment and then turn to one direction with more probability of available roads, the next-step directions. Then there should be two assumptions valuable to test.

Firstly, street view pictures on the new directions may contain some unique visual features related with the choice based on the 2D accessibility. That is, we can test if there is a posivite or negative correlation between the **mean weight of the visual direction** in the model and the **propotion of typical visual features** in the street view pictures.

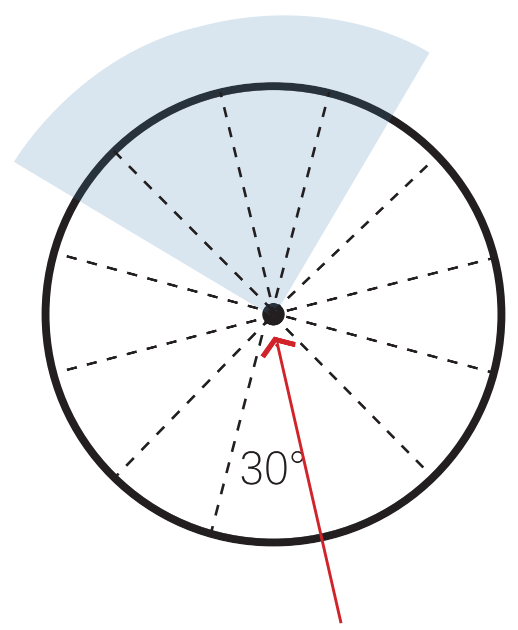
Secondly, if pictures of the original 12 directions can be regarded as the general image of the space, and the new pictures reflect the spatial perception of agents in movement. Then there should be some **difference in the spatial distribution of the visual feature in two groups** of street view pictures.

Calculate the new directions and the corresponding weight

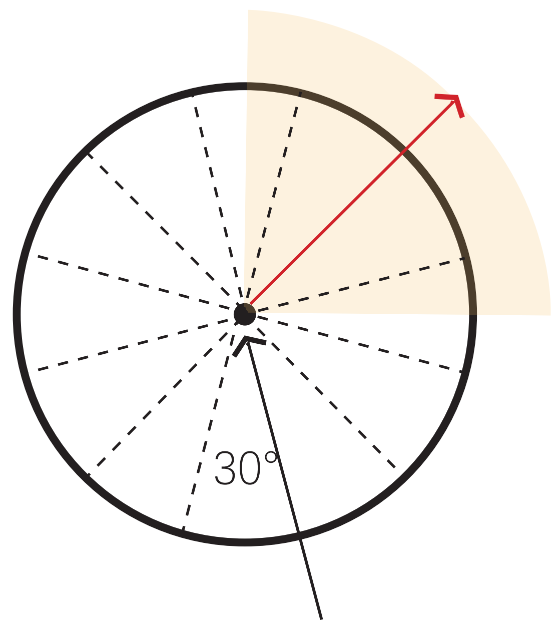
Analysis the street view pictures with machine learning methods

Compare spatial perception from the general pictures and agent-based pictures

Analysis the correlation between the visual features and weight for direction choice



Single Direction Input

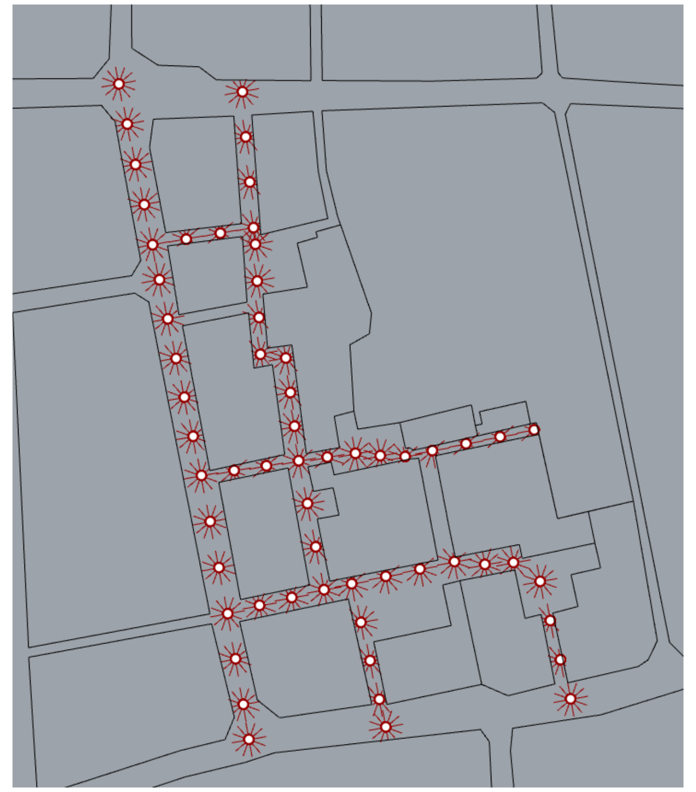


Single Direction Output

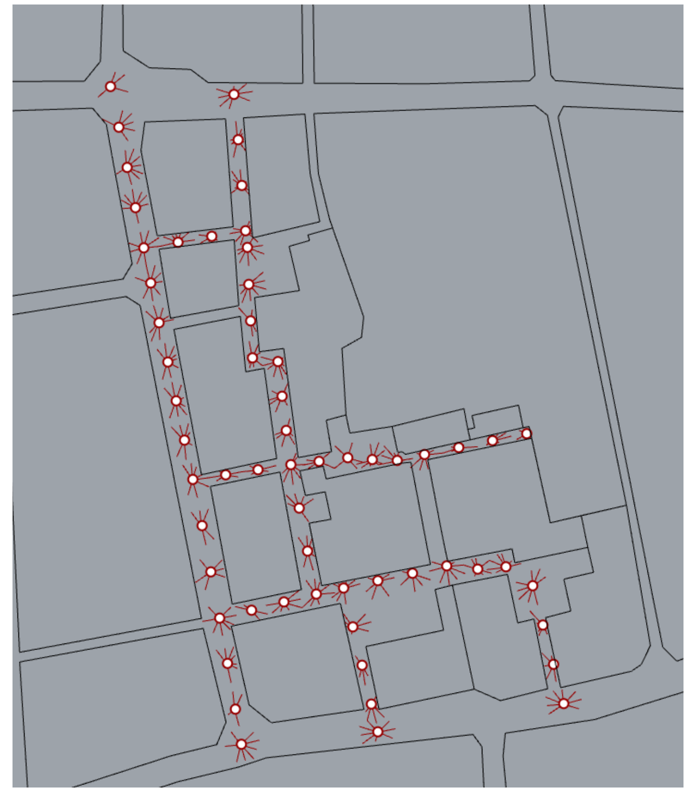
The street view pictures are collected from 60 positions in the Chenghaung Temple Area, with 30° angle interval ,90° horizontal field of view, -15° vertical field of view.

50% weight from the Intergation value

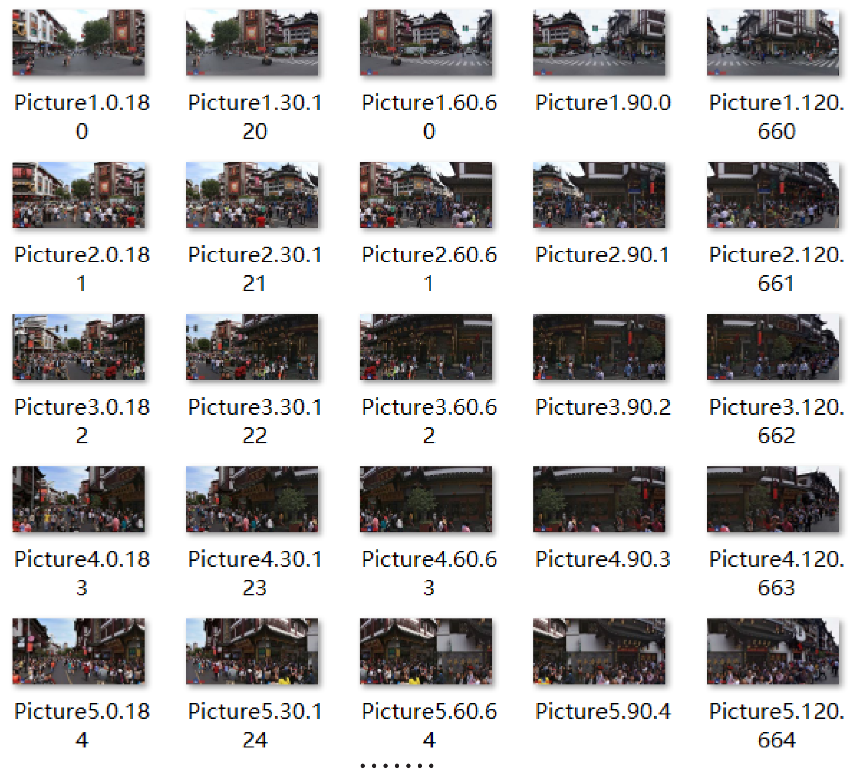
50% weight from the attraction of open space



720 Directions Input for 60 Potential Positions



720 Directions Output for 60 Potential Positions



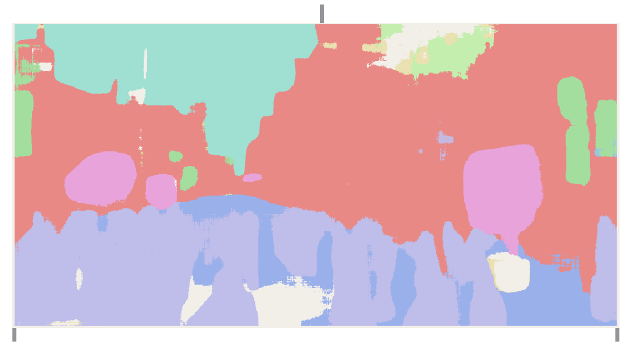
Original 705 Street view Pictures from Baidu Street View API

Semantic Segmentation

Semantic Segmentation App1.0

by CUG.HPSCIL

Based on FCN network



View Features Detected in the Picture

Feature Selection
based on ADE_20K dataset

Wall

Building

Sky

Tree

Road

Person

Signboard

Object Detection

ImageAI 2. 1.6

by Moses Olafenwa and John Olafenwa

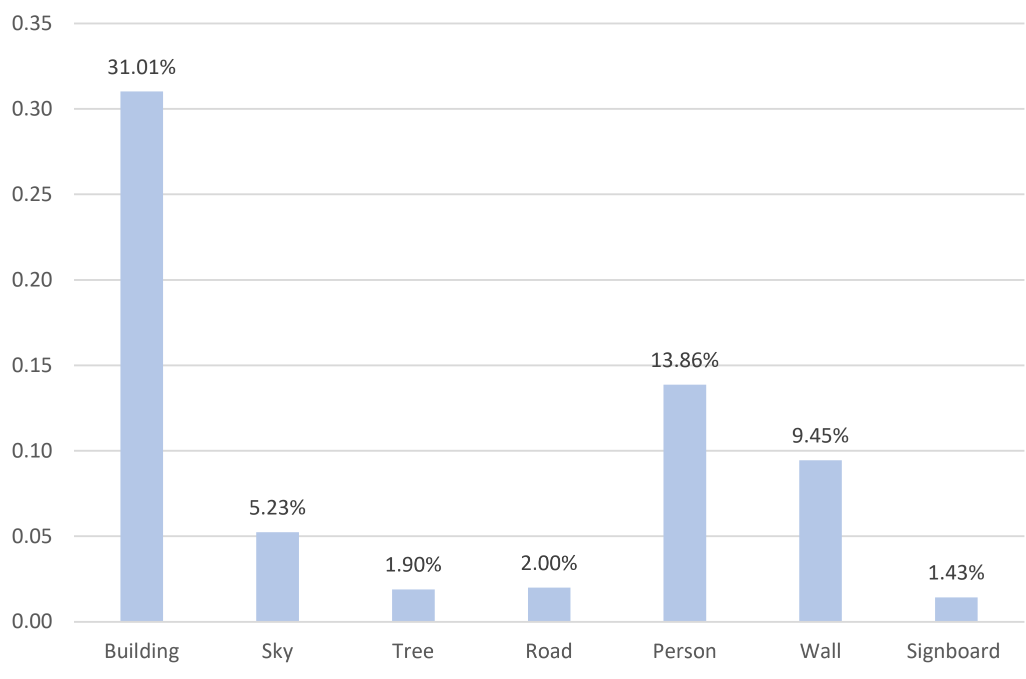
Based on ResNet50 network

People Detected in the Picture

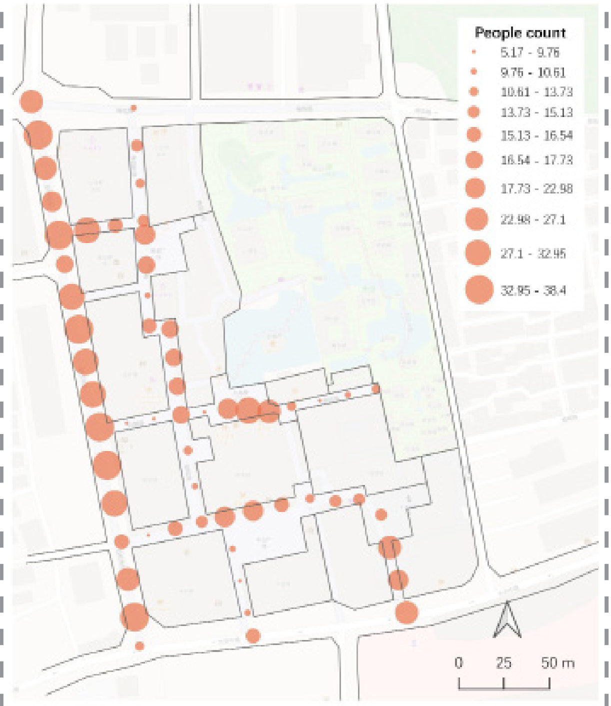
		Building	Sky	Tree	Road	Person	Wall	Signboard
Mean Weight of Heading Direction	Pearson Correlation	.283**	.165**	.163**	.312**	-.084*	-.216**	-.186**
	Sig.(Double)	.000	.000	.000	.000	.026	.000	.000
	N	705	705	705	705	705	705	705

Based on the 720 directions calculated from the 60 positions, 705 valid pictures are collected and renamed by position and direction. Then, the machine learning methods of semantic segmentation and object detection are used to do further analysis. Proportion of the typical view features and the count of people in the pictures are summarized by locations.

Besides, it is preliminarily found that builing, sky, tree and road maintain a weak positive correlation with the weight of the direction while the person, wall and sighboard maintain a weak negative correlation.

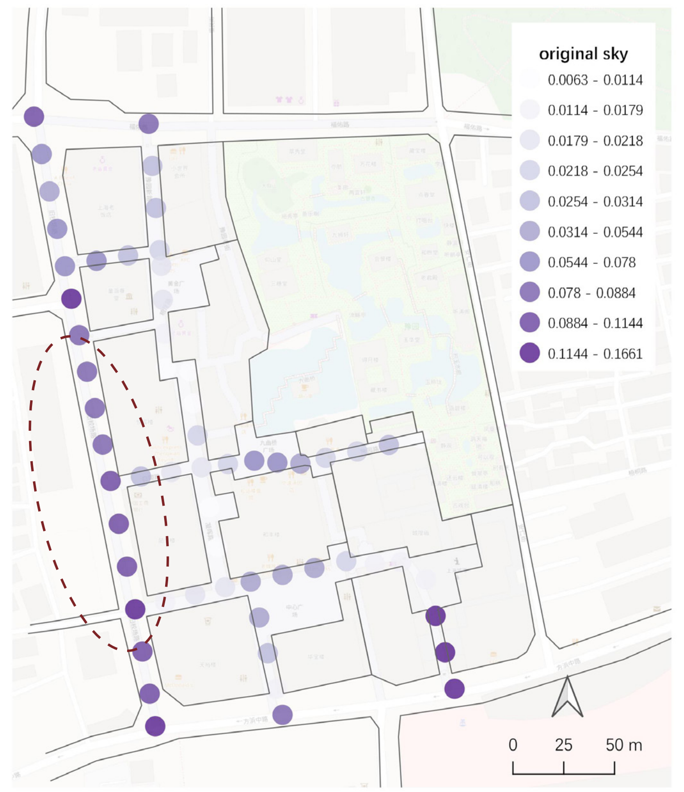


The Average Porpotion of Typical Visual Features in the Area

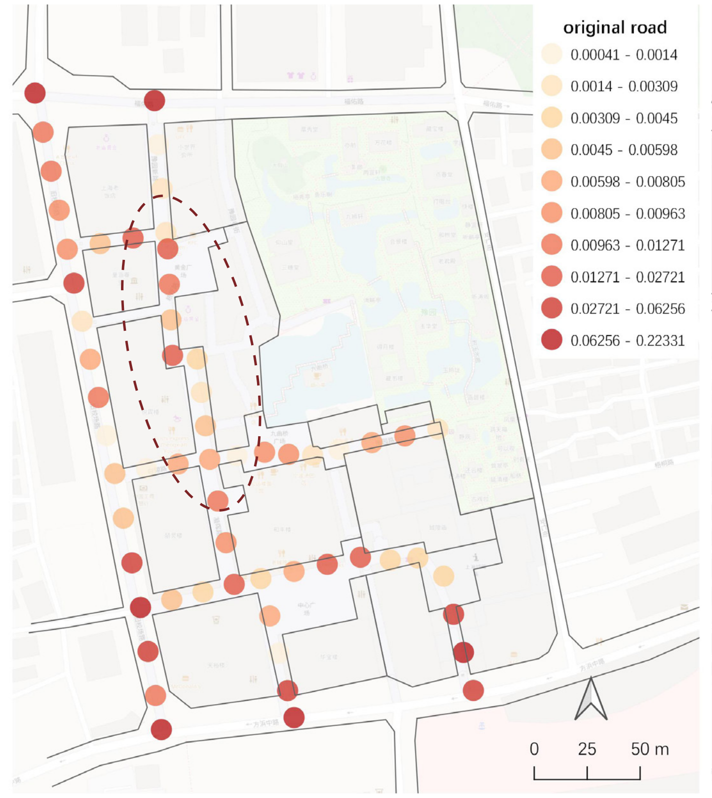


People Detectd from Each Positon in the Area

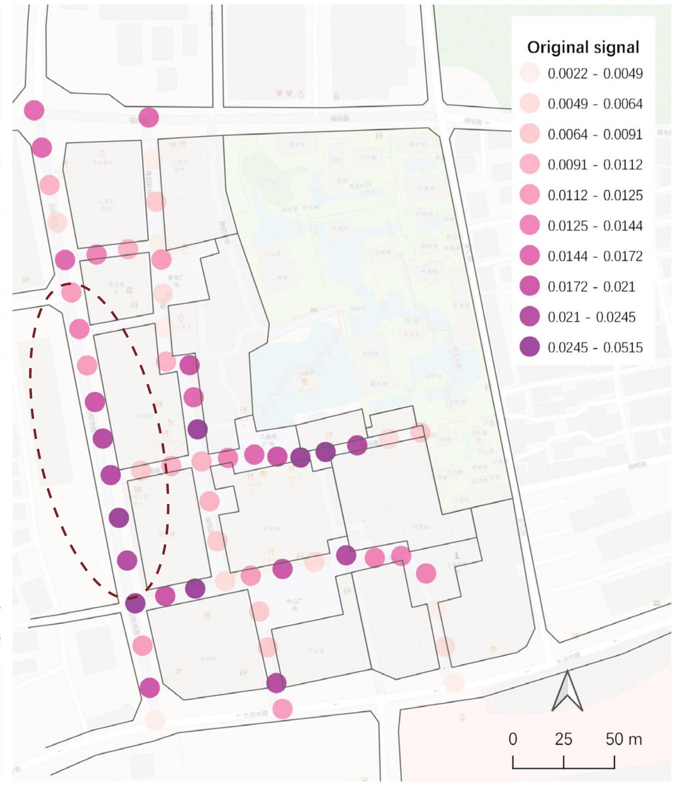
Under the general perception conditions, the visible proportion of the sky on the west is higher, together with the proportion of signboard. From the corresponding picture, we can see that the street on the west side is relatively wide, and there are a large number of shops on both sides, which gather a large number of tourists during the holidays.



Proportion of Sky in General Perception



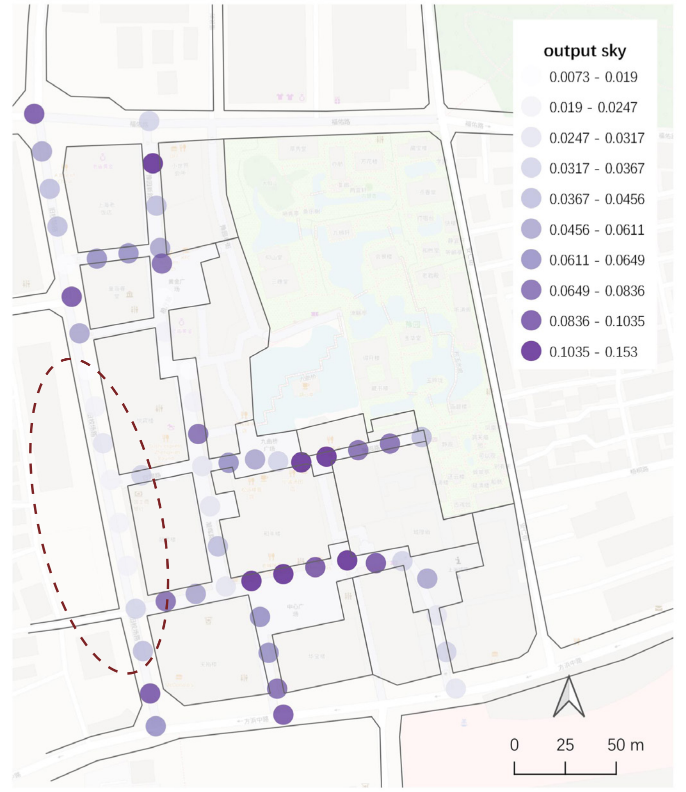
Proportion of Road in General Perception



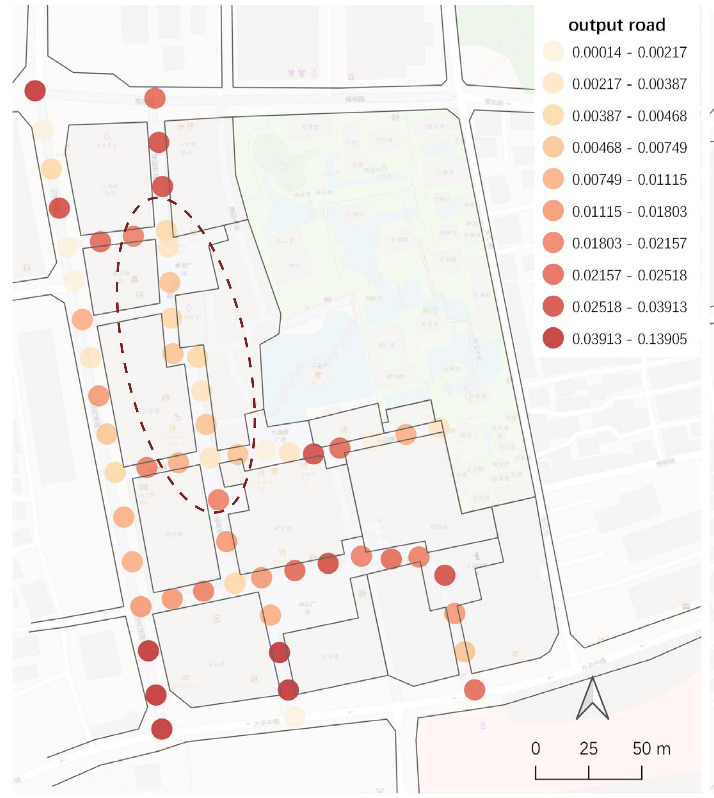
Proportion of Signboard in General Perception

From the perception of agents, the spatial distribution of skys and signboards decreases significantly on the west, but increases in the East and south. That means when agents flow with the restriction of surrounding environment, there may be some visual features ignored in their visual field, which may result in a difference in spatial perception.

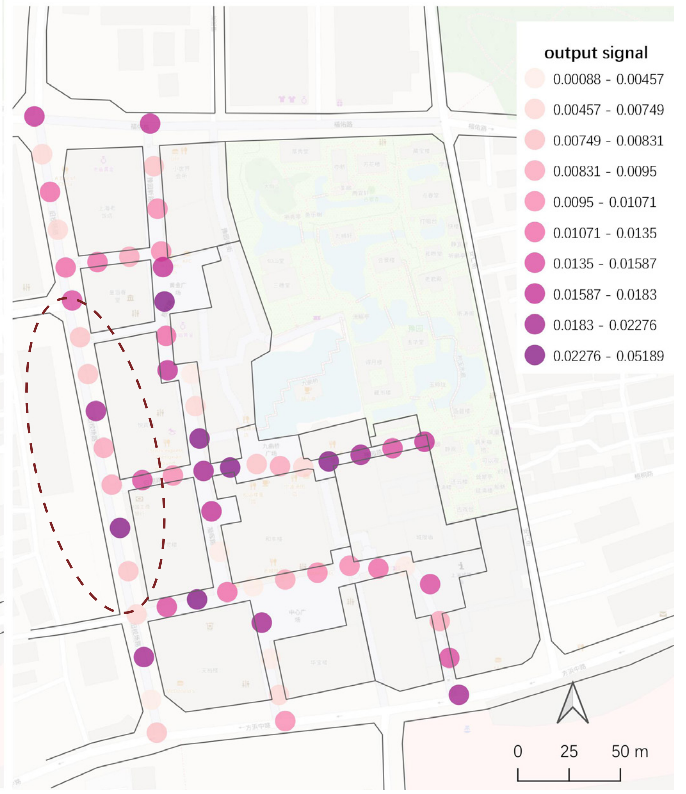
It is noteworthy that the street in the middle area maintain a lower proportion of visible sky and roads in both perception, but a even higer proportion of signboard in agents' view. Agents in this area may feel a loss of sense of direction(sky and road) and feel more distracted by the activites on the street.



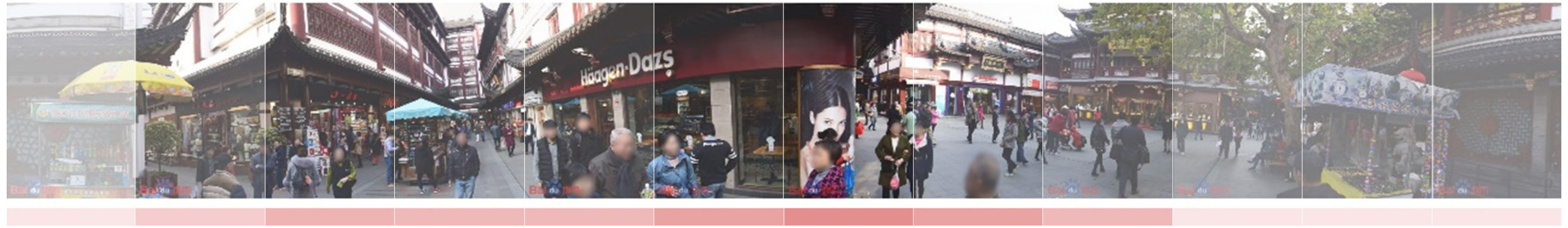
Proportion of Sky in Agents' Perception



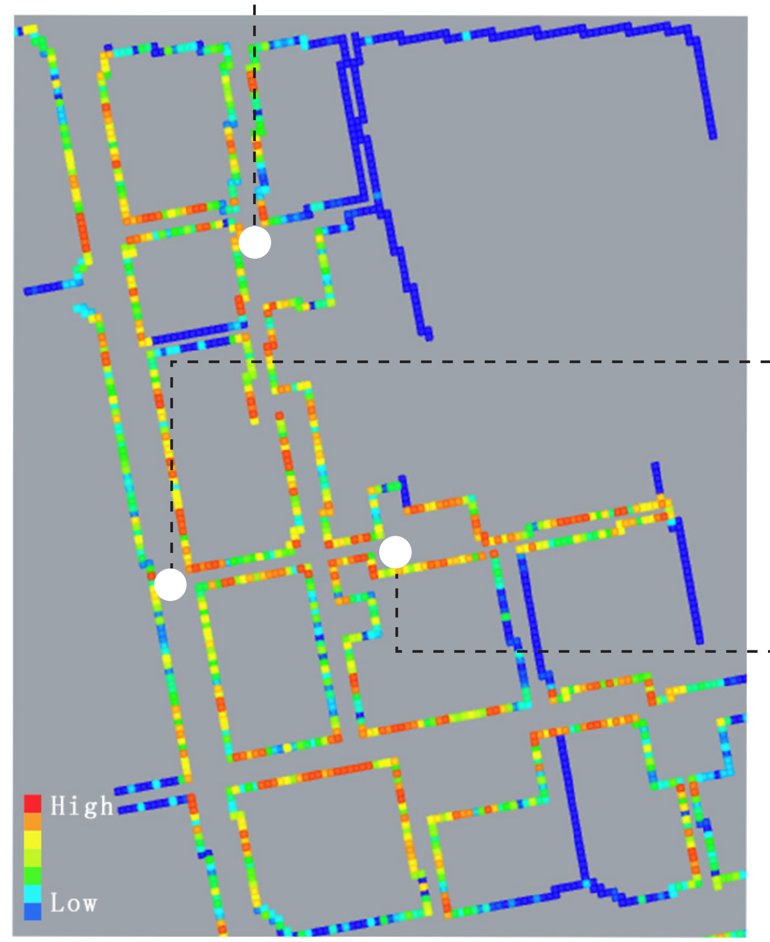
Proportion of Road inAgents' Perception



Proportion of Signboard in Agents' Perception



Superimposing the street view pictures with a certain transparency helps reveal the agents' frequent visual direction and the objects they may focus in a real environment. As shown in the figure above, the attention of agent located at the corner of the plaza, can be easily attracted by the Haagen Dazs ice cream store. The interface of this archor store gain a well display because of its spatial relationship with the surrounding open space. Similarly, two figures below indicate the possible focus of agents when they walk into the block.



Visibility Opportunity in Chenghuang Area

The agent mainly focus on the entrance of the block, following the design of spatial weigh

The agent has a higher probility to look towards the central landscape

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