Automatic Optimization of Wayfinding Design Supplementary Material

1 Additional Examples

We use our approach to generate wayfinding designs for two more examples: *City* and *Canyon*. Figure 1 shows the 3D virtual worlds from which the layouts are extracted. Figure 2 shows the generated wayfinding designs.

City. We run our approach on a virtual city, which is similar to a city in common video games. The player starts navigating from a bus stop, which is taken as the entrance of the layout. The POIs represent different interesting places in the city, including a school, a hotel, a restaurant and a post office. The source-destination pairs include walking from the entrance to each of the POIs, and walking between every pair of POIs. We set the weights of the global path length cost and the global path node cost to a relatively large value of 10 in this example. As a result, as Figure 2 depicts, the generated paths tend to overlap with shared intersections. We also use this layout for visualization showcases and user study (Section 7.3 and Section 8 in main paper). Please also refer to the supplementary video which shows some interactive navigation sessions using the generated road signs in this layout.

Canyon. This example takes a canyon as the input layout. The POIs refer to the landmarks which the visitors may want to visit. The source-destination pairs include walking from the entrance to each of the POIs, and walking between every pair of POIs. For this example, the robustness of the wayfinding design is an important consideration to ensure that nobody gets lost in the canyon. In the agent-based sign placement step, the weight $w^{\text{F}}_{\text{sign}}$ of the wayfinding failure cost term is set to a high value of 10 and the failure tolerance level μ to be zero, to prompt the generated wayfinding design to be more robust. We also set the agents' visibility to a relatively low level of 10 meters to account for low-visibility situations due to bad weather such as fog or rain. Figure 2 shows the generated road signs, which are densely placed along the paths. Additionally, road signs are placed on some roads which do not belong to any path, for guiding the visitors back to the right paths in case they get lost.

2 Details of Results in Main Paper

We include the details of some of the generated wayfinding designs discussed in our main paper:

- Figure 3 and 4 correspond to our illustrative example, *City*. The path generated for each source-destination input pair is shown. It corresponds to Figure 4 in our main paper.
- Figure 5 and Table 2 show the information of each generated sign in the *Penn Station* example. They correspond to Figure 10 in our main paper.
- Figure 6 and Table 3 show the information of each generated sign in the *City* example. They correspond to Figure 4 in our main paper.
- Table 4 and Table 5 show the 9 parameters of our approach and the suggested ranges of the parameter values.

3 Comparison

We compare our optimization approach by simulated annealing with other optimization strategies, namely, exhaustive search, greedy search and genetic algorithm on our running example, *Downtown*. We compare the result quality in terms of the total cost values of the solutions found, and the time needed to compute the solutions.

Table 1 shows the results. The exhaustive search finds the global optimal solution by evaluating all the possible solutions. Due to the stochastic nature of the greedy search, simulated annealing and genetic algorithm, we run each of these algorithms 100 times and report the average costs of the solutions and computation times. For the genetic algorithm, we used $1,000$ samples for each iteration. It can be seen that from the results that the greedy search runs fastest, while the genetic algorithm returns results of the best quality (with average total cost closest to the total cost of the global optimal solution found by the exhaustive search. Simulated annealing attains a good trade-off between results quality and time. It is noted that, by lowering the temperature of the simulated annealing search, one can increase the greediness of the simulated annealing search and makes it converge faster, but with a possible sacrifice in result quality.

TABLE 1
Results of different algorithms. For greedy search, simulated annealing and genetic algorithm, the average cost values and the average computation times from 100 runs of the algorithms are shown.

	#Evaluations	Time (sec)	Cost
Exhaustive	29,214,432	11,664	0.0927
Greedy	1,639	0.62	0.0961
Simulated Annealing	34,038	12.70	0.0935
Genetic Algorithm	47,540	17.08	0.0928

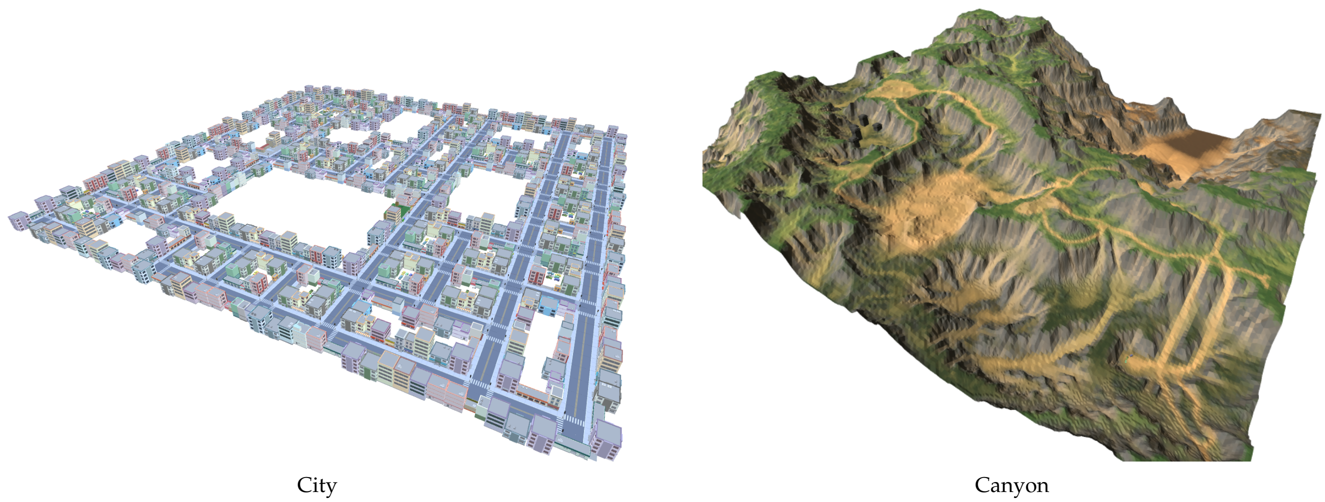


Fig. 1. 3D models from which the layouts are extracted.

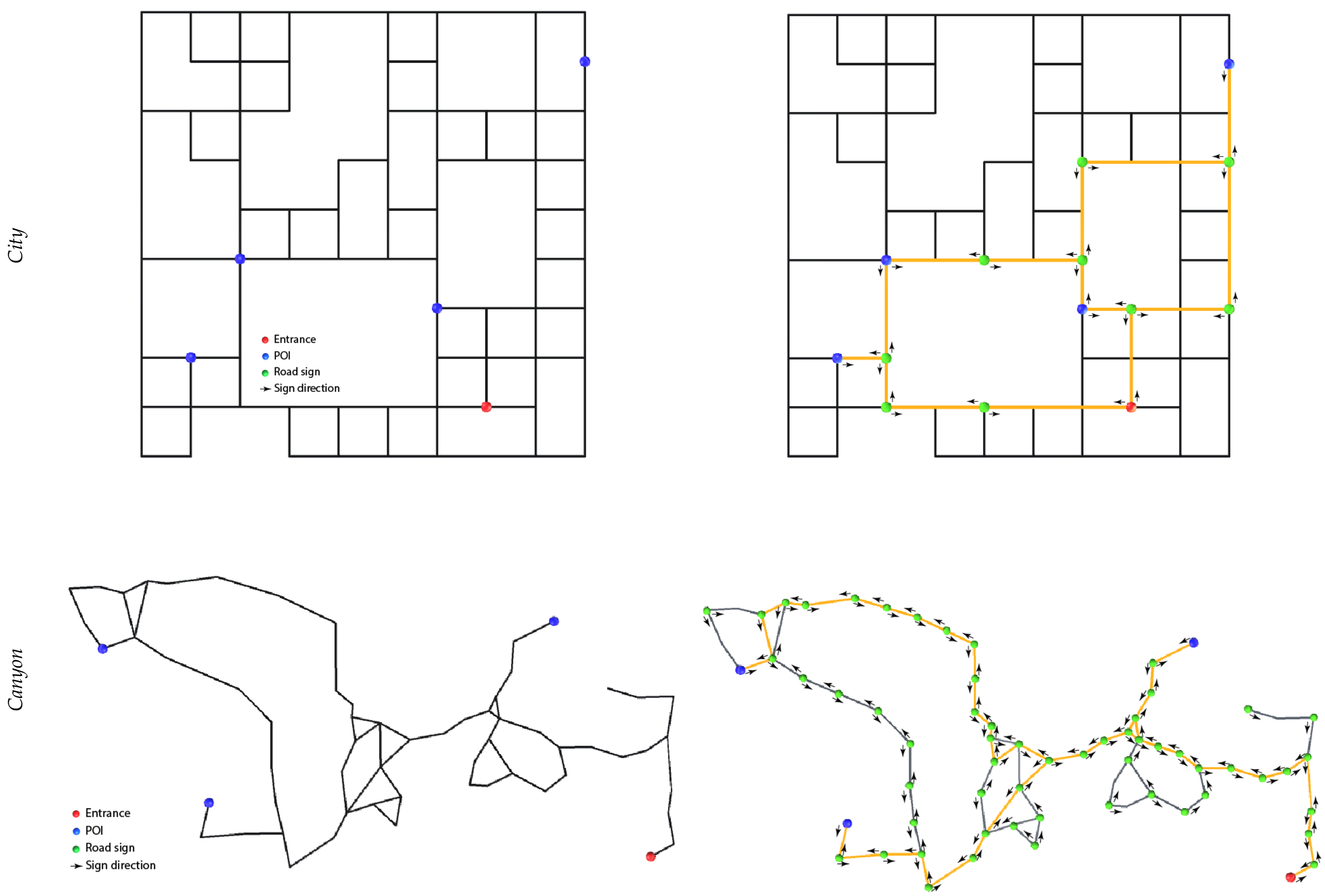


Fig. 2. Wayfinding designs generated for *City* and *Canyon*.

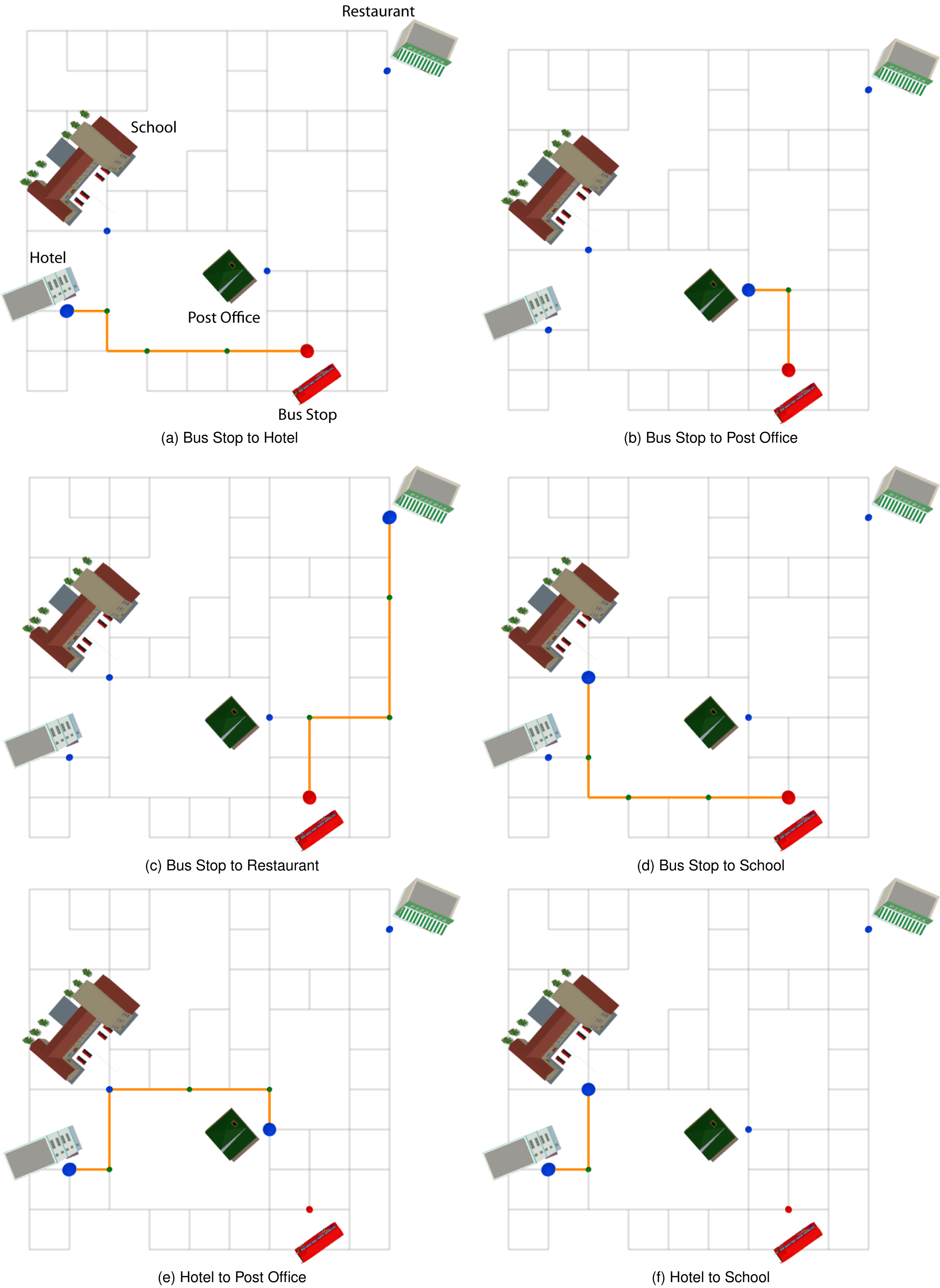
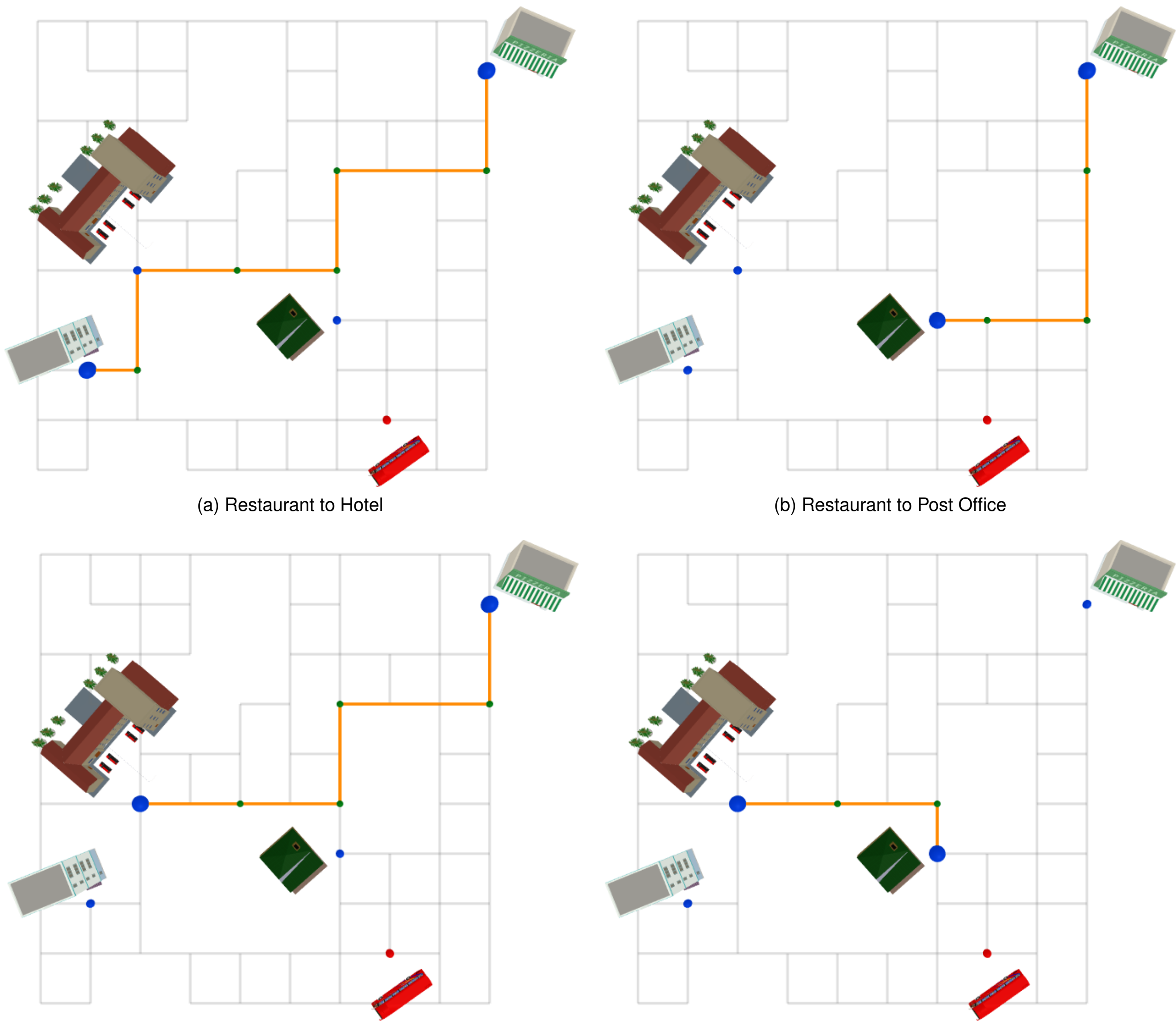


Fig. 3. Generated paths of different input pairs. The blue points, red point and green points respectively denote the points of interests, the Bus Stop (starting point) and road sign locations.



(a) Restaurant to Hotel

(b) Restaurant to Post Office

(c) Restaurant to School

(d) School to Post Office

Fig. 4. Generated paths of different input pairs. The blue points, red point and green points respectively denote the points of interests, the Bus Stop (starting point) and road sign locations.

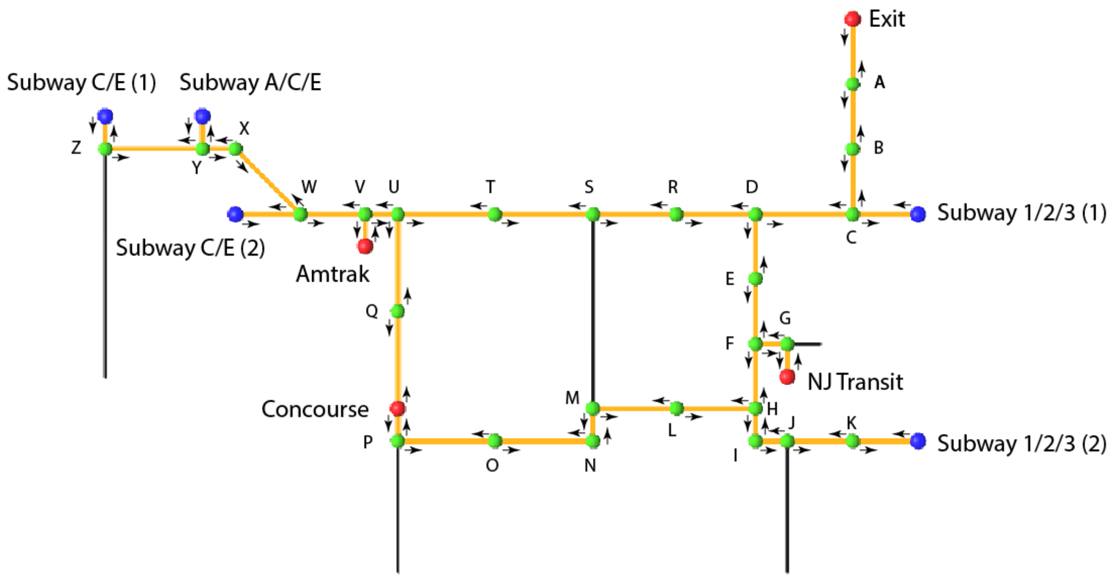


Fig. 5. Wayfinding design generated for the *Penn Station* layout.

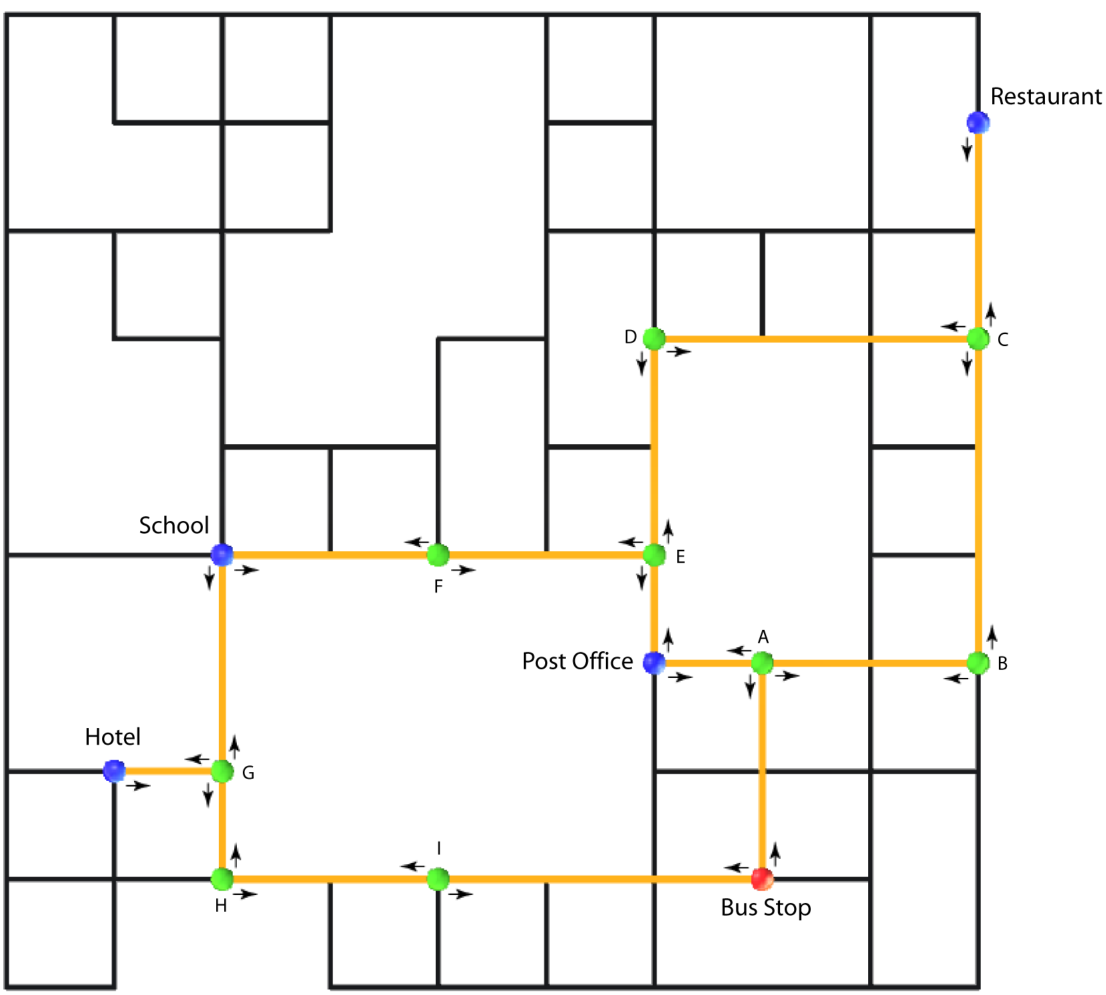


Fig. 6. Wayfinding design generated for the *City* layout.

TABLE 2
Information of each sign in the *Penn Station* example

Sign	Up	Left	Down	Right
(S 1/2/3) Subway 1/2/3 (1)	-	(S A/B/C) (A), (C), (NJ), Exit	-	-
(S 1/2/3) Subway 1/2/3 (2)	-	(S A/B/C) (A), (C), (NJ), Exit	-	-
(S A/C/E) Subway A/C/E	-	-	(S 1/2/3) (A), (C), (NJ), Exit	-
(S C/E) Subway C/E (1)	-	-	(S 1/2/3/A/C/E) (A), (C), (NJ), Exit	-
(S C/E) Subway C/E (2)	-	-	-	(S 1/2/3/A/C/E) (A), (C), (NJ), Exit
(A) Amtrak	(S 1/2/3/A/C/E) (C), (NJ), Exit	-	-	-
(C) Concourse	(S 1/2/3/A/C/E) (A), Exit	-	(S 1/2/3), (NJ)	-
(NJ) NJ Transit	(S 1/2/3/A/C/E) (A),(C), Exit	-	-	-
Exit	-	-	(S 1/2/3/A/C/E) (A),(C), (NJ)	-
A	Exit	-	(S 1/2/3/A/C/E)	-
B	Exit	-	(S 1/2/3/A/C/E)	-
C	Exit	(S A/B/C),(A),(C),(NJ)	-	(S 1/2/3)
D	-	(S A/C/E),(A),(C)	(S 1/2/3) (NJ)	S(1/2/3)
E	(S 1/2/3/A/C/E) (A), Exit	-	(S 1/2/3),(C),(NJ)	-
F	(S 1/2/3/A/C/E) (A), Exit	-	(S 1/2/3),(C)	(NJ)
G	-	(S 1/2/3/A/C/E) (A),(C), Exit	(NJ)	-
H	(S 1/2/3/A/C/E) (A),(NJ),Exit	(C)	(S 1/2/3)	-
I	(S 1/2/3/A/C/E) (A),(C),(NJ),Exit	-	-	(S 1/2/3)
J	-	(S 1/2/3/A/C/E) (A),(C),(NJ),Exit	-	(S 1/2/3)
K	-	(S 1/2/3/A/C/E) (A),(C),(NJ),Exit	-	(S 1/2/3)
L	- -	(S A/C/E) (A),(C)	-	(S 1/2/3),(NJ), Exit
M	-	-	(S A/C/E) (A),(C)	(S 1/2/3),(NJ), Exit
N	(S 1/2/3) (NJ), Exit	(S A/C/E),(A),(C)	-	-
O	-	(S A/C/E) (A),(C)	-	(S 1/2/3),(NJ), Exit
P	(S A/C/E) (A),(C), Exit	-	-	(S 1/2/3),(NJ)
Q	(S 1/2/3/A/C/E) (A),,(NJ)Exit	-	(S 1/2/3),(C)	-
R	-	(S A/C/E) (A),(C)	-	(S 1/2/3),(NJ),Exit
S	-	(S A/C/E) (A),(C)	-	(S 1/2/3),(NJ),Exit
T	-	(S A/C/E) (A),(C)	-	(S 1/2/3),(NJ),Exit
U	-	(S A/C/E),(A)	(C)	(S 1/2/3) (NJ),Exit
V	-	(S A/C/E)	(A)	(S 1/2/3) (C),(NJ),Exit
W	(S A/C/E)	(S C/E)	-	(S 1/2/3)
X	-	(S A/C/E)	(S 1/2/3/C/E) (A),(C),(NJ),Exit	-
Y	(S A/C/E)	(S C/E)	-	(S 1/2/3/C/E) (A),(C),(NJ),Exit
Z	(S C/E)	-	-	(S 1/2/3/C/E) (A),(C),(NJ),Exit

TABLE 3
Information of each sign in the *City* example

Sign	Up	Left	Down	Right
A	-	Post Office, School	Bus Stop	Restaurant
B	Restaurant	School, Post Office	-	-
C	Restaurant	School, Hotel	Bus Stop, Post Office	-
D	-	-	Post Office, School, Hotel	Restaurant
E	Restaurant	School, Hotel	Post Office	-
F	-	School, Hotel	-	Post Office, Restaurant
G	Post Office, School, Restaurant	Hotel	Bus Stop	-
H	Hotel	-	-	Bus Stop
I	-	Hotel	-	Bus Stop
Bus Stop	Post Office, School, Restaurant	Hotel	-	-
Post Office	School, Hotel	-	-	Bus Stop, Restaurant
School	-	-	Bus Stop, Hotel	Post Office, Restaurant
Hotel	-	-	-	Bus Stop, Post Office, School, Restaurant
Restaurant	-	-	Bus Stop, Post Office, School, Hotel	-

TABLE 4
Wayfinding scheme parameter settings and suggested ranges.

Parameter	Meaning	Suggested Range
$w^{\mathrm{L}}_{\mathrm{local}}$	Weight of local length	0.5 - 1.0
$w^{\mathrm{N}}_{\mathrm{local}}$	Weight of local intersection	0.1 - 0.5
$w^{\mathrm{A}}_{\mathrm{local}}$	Weight of local turning angle	0.0 - 0.5
$w^{\mathrm{L}}_{\mathrm{global}}$	Weight of global length	0.0 - 0.5
$w^{\mathrm{N}}_{\mathrm{global}}$	Weight of global turning angle	0.0 - 0.5
$\kappa_p L(p)$	Importance value of each source-destination pair	0.0 - 1.0

TABLE 5
Agent-based sign refinement parameter settings and suggested ranges.

Parameter	Meaning	Suggested Range
$w^{\mathrm{N}}_{\mathrm{sign}}$	Weight of number of signs	0.1 - 1.0
$w^{\mathrm{D}}_{\mathrm{sign}}$	Weight of SD	0.0 - 0.1
$w^{\mathrm{F}}_{\mathrm{sign}}$	Weight of failure	0.1 - 1.0