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A Study on the Space Usage Pattern in Metaverse

Targeting ZEPETO on the Metaverse Platform

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ABSTRACT

As metaverse attracts interests of more people following the growth of online platforms, research on virtual space of metaverse is needed. Using space syntax theory, this study examined space configuration of virtual space within metaverse to understand and explain spatial behaviours of the users. Analyses using traffic count survey, VGA (visibility graph analysis), and agent-based model revealed that starting points of the virtual space that have been designated without consideration for spatial hierarchy led to some discrepancy between movement patterns predicted by space configuration and actual movement patterns of the users. However, additional testing of models that reflects location of starting points show that users display movement patterns that depend on visibility and accessibility of space configuration. The study concludes that users' spatial behaviors in the metaverse are impacted by space configuration, just as in the real world.

KEYWORDS

Metaverse, Virtual World, Space Syntax, Spatial Behavior

1 INTRODUCTION

The use of virtual space increased dramatically during the COVID-19 (coronavirus) global pandemic, and various contents emerged across a range of virtual platforms. The technological advancement made in virtual space technology is blurring the boundary between the real world and the virtual world, and the recent growth of relevant online platforms made metaverse a hot topic. Metaverse is a term coined by combining 'meta' (meaning 'beyond') and 'universe' (meaning 'real world'). In a metaverse, people create their own avatars to participate in activities and interact with each other. The users of metaverse platforms interact with each other in activities such as shopping, entertainment, and other experiences within virtual space – experiencing social interactions similar to ones in reality. It can be predicted that while metaverse exists within virtual space, it provides an environment similar to reality and will lead to similar behaviors found in the real world. In online games, for example, the structure of the game map (virtual space) is one of the dominant factors that determine the success of a game along with the characters (Kim, 2007). In the same context, the design of virtual space in metaverse is one of the most important factors that determines overall level of entertainment and completeness and requires careful planning. Designing intuitively without understanding of the characteristics of virtual space can lead to either an unbalanced spatial structure or one that is overly simple. However, there have not been many studies in the past on methodologies capable of analyzing virtual space quantitatively and objectively. This is changing as more researchers are becoming interested in metaverse. For example, Cho et al(2010) reported that in virtual space, spatial behaviors of the users are more diverse than the ones in the real world. But more research on user behaviors in metaverse environment is needed. By examining how users perceive virtual space and behave in a metaverse platform that is designed in a similar manner to the real world, this study aims to examine how spatial configuration influences avatar's behaviour in metaverse space.

2 CHARACTERISTICS OF THE GAME SPACE AND SPACE SYNTAX STUDIES

It is emphasized that game space must be planned with consideration for elements of placeness. For player's experience of exploration and place in particular, the planning process should not be confined to production of functional spaces (Jung et al. 2019). The space in online games influences players through three dimensions – spatial configuration, spatial layout, and spatial experience. Multiple spatial meanings can be derived from same space by mental operations of the players (Park 2010).

Several studies have utilized space syntax theory to analyze game space.

Kim (2008) studied a game map's level of integration, intelligibility, and homogeneity using space syntax theory. He studied the game map of *Unreal Tournament 2004*, a FPS (first-person shooter) game, and argued that the seemingly simple structure of the game map was made more interesting by varying the locations of integration. The study also showed that the level of intelligibility was very low compared to real-world space, making it very difficult to decipher the overall spatial layout. Cho and Kim (2010) studied the game map of *WoW (World of Warcraft)*, a MMORPG (massive multiplayer online role playing game). They showed that when moving from one location to the next, users tend to move in a way that minimizes the number of direction changes rather than shortest distance. It indicates that when designing virtual reality, planning to increase the level of global integration helps the users' perception of space. In Moon (2014)'s study, the game map of *Counter-Strike*, one of the most popular FPS game, was examined to determine the factors for evaluating a game's spatial design. Connectivity, control, global integration, and local integration values were calculated. A comparison of the four factors and the extent of space usage by real users show that there is a high level of correlation. The study showed the potential of space syntax methodology application for design and evaluation of game maps.

3 METHODS

This study utilizes the space syntax theory to analyze the relationship between space usage patterns and the space configuration characteristics displayed by the spatial structures. First, a traffic survey was conducted to analyze usage patterns of the users in the map. Next, spatial structures of the ZEPETO maps were examined using VGA (visibility graph analysis) volume of avatars. To better understand the relationship between the results of traffic survey and the results of VGA, an agent-based model was additionally applied. The starting points of the avatars in ZEPETO virtual space are taken into consideration in the agent-based model, which then can explain the usage patterns of few users that cannot be fully understood from the results of only traffic survey and VGA.

3.1 Subject of the study: ZEPETO of Naver Z

This study will analyze Naver Z Corporation's ZEPETO, a virtual reality metaverse service. ZEPETO is an avatar app based on AR (augmented reality) that enables 3D simulation of virtual world. The service currently has 200 million users worldwide, and more than 80% of the users are teenagers and more than 90% of the users connect from outside of Korea.

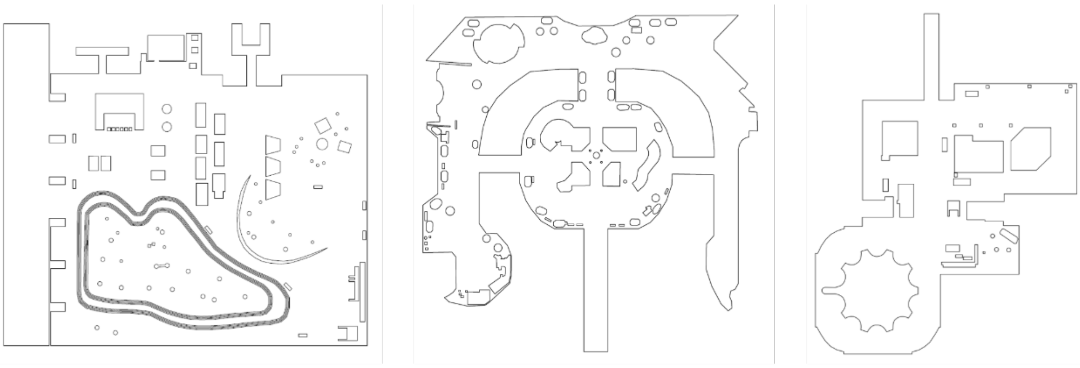
The ZEPETO platform provides many themes from real life and focuses on supporting communication among avatars in virtual space. In ZEPETO's virtual space, everyday activities that take place in the real world are replicated. You can have a conversation with another person's avatar in a café, join a party, go to a photo spot to take a picture, or attend a concert. Users can create their own avatars and move around in the virtual world, buy luxury goods, and also phone or text other users. The platform is mobile app-based, and provides content service through either local or global server depending on cellular phone location. In the local server, the users can meet new friends in the same country, while in the global server, there are friends from all over the world. This study observed spatial behaviors of the users using ZEPETO platform through the local server.

The official world map was created by Naver Z, but Naver Z also provides a 'build-it system' which enables users to create their own 'creator world maps.' This study selected and analyzed several official maps used by the most number of users. As of December 2021, there are more than 70 official maps, and can be categorized into 'Theme Space', 'Entertainment Space', and

'Commercial Space'. For selection of maps for analysis, a total of 63 official maps were reviewed which include 29 theme maps, 27 entertainment maps, and 7 commercial maps. The three maps for analysis were selected based on the number of visits – two maps (Lotte World, Downtown) were selected from entertainment space, and 1 map (Han-river Park) was selected from theme space (see Figure 1). Using 'top view' of each map, the layouts (see Figure 2) of the maps were extracted.

(a) Han-river Park image (b) Lotte World image (c) Downtown image

Figure 1. Three official maps of ZEPETO that are the subject of analysis



(a) Han-river Park plan (b) Lotte World plan (c) Downtown plan

Figure 2. Analysis model created through top view of each map

3.2 Observation of avatar movements

First, a traffic survey was conducted to analyze usage patterns of the users in the map. There are users who connect to a map and move around, while some who stay immobile as they talk to friends who are also online for other reasons. The maximum number of users in a single map at one time is limited to 16. While the number of users in a map connected simultaneously is limited, various users enter and leave during the period of observation. After reviewing ZEPETO's user environment, 20 locations (gates) were selected as major traffic nodes to be observed during weekend afternoon when there would be large number of users. A virtual line was drawn at each of the 20 locations, and the number of avatars passing through the lines over a 2-hour period was recorded (see Figure 3).

3.3 Visibility graph analysis

Next, VGA was conducted to examine the spatial configuration properties of the maps based on the accessibility and visibility. Since the size of user avatars varies, the grid size for analysis was set at 500 (0.5m x 0.5m). Considering the actual space accessible to avatars, ZEPETO maps cover relatively small space. Global integration values in VGA were calculated (see Figure 4).

3.4 Agent-based model

Finally, 'predicted movement pattern' was observed using an agent-based model in order to compare the movement pattern based on space configuration and the movement of actual users. This approach measures the frequency of agent's movement from one cell to another, which is then compared to traffic volume of avatars at the selected locations. In the depthmapX software, agent-based model is applied by first dividing the study area into unit spaces. 'Timesteps' refers to the time unit of analysis, which is the time it takes to move from unit space to another. As such, the size of the unit space is related to time unit of the analysis and clear criteria for grid definition are required. Sutherland et al. (1994) suggested a 0.75m x 0.75m cell size based on average step length (0.77m) of an average adult. They also assumed 2 timesteps to represent 1 second, given that average walking speed on flat surface is approximately 1.5m per second. Meanwhile, Turner et al. (2001) argued that for VGA to serve as basis for an agent-based model, the grid resolution only needs to satisfy the conditions that all spaces in the study area are connected and accessible. They presented these conditions as criteria for defining grids for analysis. As such, the grid size was also set at 500, and timesteps for the simulation was set at 2,000 based on the speed of the avatars and length of observation period. In ZEPETO service, a user has a starting point when joining a map. This must be reflected when conducting an agent-based model. The starting point is designated within a certain radius, and therefore instead of identifying a single cell as the starting point, a total of nine cells (one cell and its surrounding eight cells) are set as the starting points in the agent-based model. The results of the simulations are shown below (see Figure 5).

4 RESULTS

To compare the space configuration characteristics of ZEPETO's metaverse and its spatial hierarchy to the virtual space usage patterns of the actual users, the results from VGA, agent-based model, and avatar movement volume were reviewed based on the space syntax theory. First, the integration values from the VGA and the count values from agent-based model analysis were examined. Next, the relationship between different data was analyzed by studying avatar movement volume, average integration values, and average count values at each observation location.

4.1 Results of the analysis

For the three maps, the basic statistics are shown in Table 1 while Table 2 shows values for all observation locations (gates). The average integration value was highest in the Downtown map (Figure 2-(c)), as is the min-max difference value. This indicates that compared to Han-river Park (Figure 2-(a)) or Lotte World (Figure 2-(b)) maps, spatial hierarchy is higher in the Downtown map. In contrast, Han-river Park map showed lowest spatial hierarchy. But it had the highest average gate count while the min-max difference was largest in the Lotte World map. In the Lotte World map, there is only one route leading from the starting point to other locations, while in the other maps, there are multiple routes from the starting point to other locations. Hence, the movement count of the avatars (users) in the Lotte World map is higher in spaces adjacent to the starting point compared to other two maps.

Table 1. Visibility Graph Analysis and Agent-based Model Analysis

Value	Map	Average	Minimum	Maximum	Min-max difference
Integration in visibility graph analysis	Han-river Park	8.5613	3.2928	12.6606	9.3678
	Lotte World	8.5129	3.1461	14.3779	11.2318
	Downtown	11.7929	5.7362	20.1801	14.4439
Gate Counts in agent-based analysis	Han-river Park	12.2437	1	67	66
	Lotte World	10.1516	1	142	141
	Downtown	9.9334	1	63	62

Table 2. Values derived from passing points on each map

Gate number	Han-river Park				Lotte World				Downtown			
	Number of cell in the gate	Avatar movement counts	Average of integration	Average of gate counts	Number of cell in the gate	Avatar movement counts	Average of integration	Average of gate counts	Number of cell in the gate	Avatar movement counts	Average of integration	Average of gate counts
1	3	8	7.57	2	11	24	10.83	3	14	10	14.31	1
2	27	80	10.84	1	16	33	10.22	3	33	20	10.61	11
3	8	81	10.25	5	15	63	9.74	4	39	29	10.76	8
4	14	19	8.93	15	13	35	8.65	8	22	38	7.50	8
5	14	16	8.52	23	5	32	6.67	1	20	62	10.97	13
6	14	7	7.98	10	8	70	9.57	4	7	36	7.67	4
7	11	57	9.27	30	7	51	8.22	6	25	87	10.62	11
8	8	49	8.84	16	7	42	7.40	4	6	31	10.63	2
9	7	68	9.55	31	7	29	6.79	7	20	18	10.39	1
10	13	73	8.58	7	8	27	6.63	1	14	7	8.61	1
11	7	94	10.54	22	15	43	8.92	3	5	4	7.96	1
12	4	11	8.28	1	14	13	7.32	4	19	60	16.05	3
13	22	59	10.58	18	11	53	6.77	3	10	43	8.23	2
14	7	41	7.81	3	6	70	6.82	8	5	37	7.23	1
15	8	47	7.96	10	8	32	6.83	11	21	51	10.71	4
16	3	36	9.68	2	8	88	9.58	8	3	24	9.40	1
17	4	23	8.25	7	10	67	7.33	16	30	72	17.47	20
18	17	38	9.29	7	12	46	8.04	10	24	39	11.61	2
19	5	6	8.00	6	18	20	8.18	6	17	17	7.61	1
20	6	20	6.88	8	17	121	9.75	43	33	48	15.93	11

Observation of avatar movements (see Figure 3) show that traffic count is highest near the starting point in all maps. The avatars were moving most actively at the starting point and adjacent spaces and moved across wide spaces that were visually accessible. Traffic declined rapidly with distance from the starting point, and at the map’s peripheries. Traffic also declined even near the starting point if the space was narrow or in areas where many traffic barriers were present, or if the space was closed.

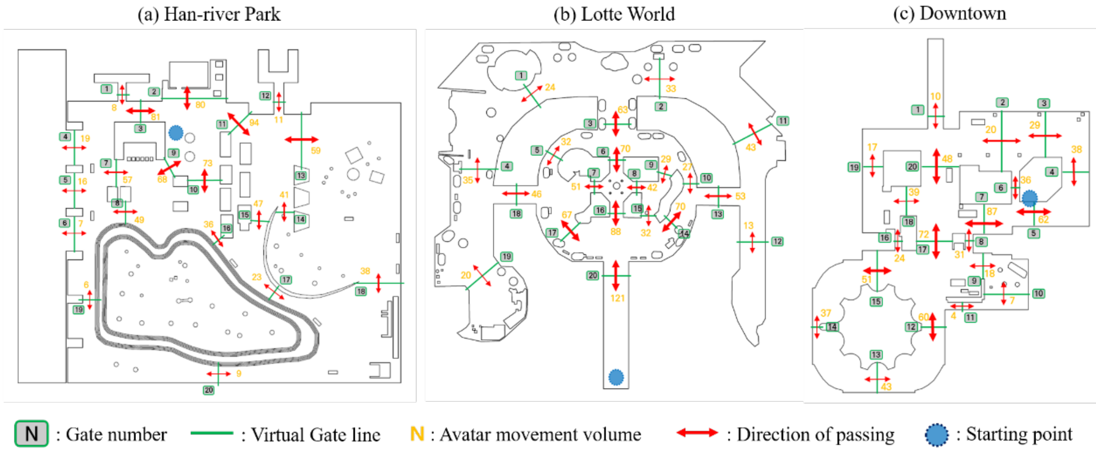


Figure 3. Passing Volume through passing observation at 20 virtual gate lines on each map

The results of VGA (see Figure 4) show that in Han-river Park and Lotte World maps, the space with highest integration values was the horizontal axis at the top of the map while in the Downtown map, it followed a vertical axis in the center. An overlay of the VGA and avatar movement volumes show that the starting point of the Han-river Park map (Figure 4-(a)) has relatively high integration value, while spaces with high avatar movement volume are often located in spaces near the starting point with high integration values. The starting point of Lotte World map (Figure 4-(b)) and Downtown (Figure 4-(c)) have relatively low integration values. In both maps, the avatar movement volumes were higher in spaces adjacent to the starting point and near landmark buildings rather than in spaces with high integration values.

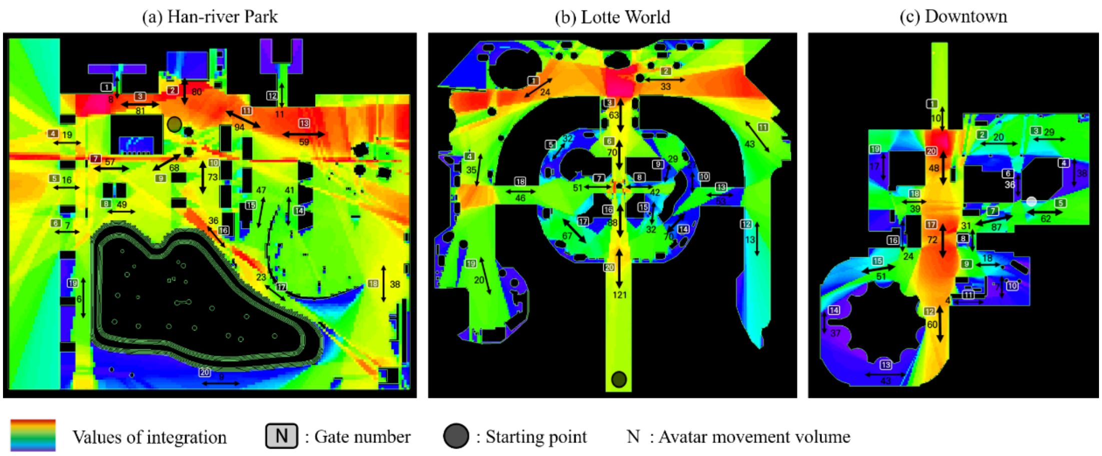


Figure 4. Visibility graph analysis of each map and avatar movement volume overlaps on the VGA(red color indicates a higher degree of integration, and a blue color indicates a lower level of integration).

Analysis of agent-based model (see Figure 5) shows that in Han-river Park map, areas with large number of agent movements are widely distributed, from the starting point to large spaces to both left and right in spaces with relatively high integration values. In contrast, in Lotte World and Downtown maps, the number of agent movements are concentrated at the starting point and its immediate neighborhood. In the Lotte World map, there are with highest integration value in the upper part of the map was far away from the starting point, and therefore showed very low agent movement volume. A corridor linked to the starting point and some parts of the areas at the map's center showed higher agent movement volume. In Downtown map, agent movement volume was higher in areas near the starting point (which had lower integration value) and in area at the map's center (which had higher integration value).

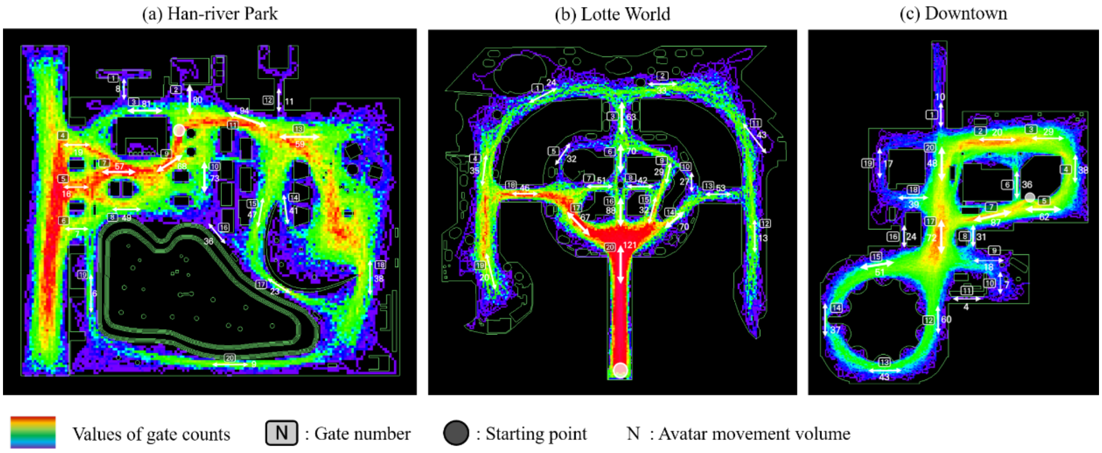
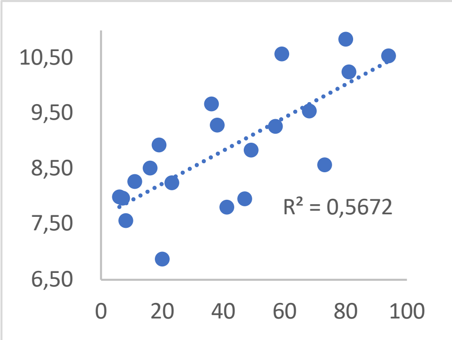
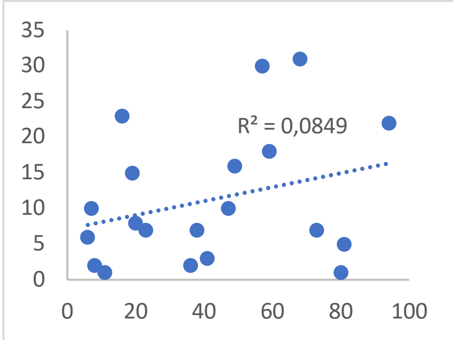


Figure 5. Individual movement behavior in which agents of each map and avatar movement volume overlaps on the agent-based analysis. Colors signify the frequency of cells occupied by the agent in the graph. Red represents presence of a large number of agents, while blue represents sparsely populated areas.

Correlational analyses of avatar movement in virtual space and space configuration analysis using space syntax theory show that in Han-river Park map, about 57% of avatar movement volume is explained by VGA integration value; in Lotte World and Downtown maps, about 50% and 42% avatar movement volume is explained by agent gate counts of agent-based model, respectively. In other words, avatar movement volume which represent movements of actual users is related to different analysis factors(VGA, agent-based model) depdending on the map type.

Table 3. The table on the left shows the correlation between visibility graph analysis and observed avatar movement in the ZEPETO map, and the right table shows the correlation between agent movement and observed avatar movement in the ZEPETO map.

<table>
<tr><th>Map</th><th>Relation between observation of avatar movement and visibility graph analysis (x-axis is avatar movement counts, y-axis is integration of VGA)</th><th>Relation between observation of avatar movement and agent-based model(x-axis is avatar movement counts, y-axis is agent gate counts of agent-based model)</th></tr>
<tr><td>Han-river Park</td><td>
</td><td>
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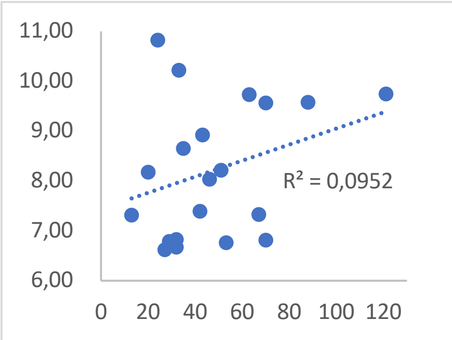
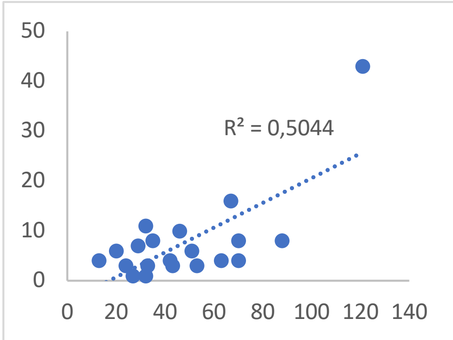
<tr><td>Lotte World</td><td>
</td><td>
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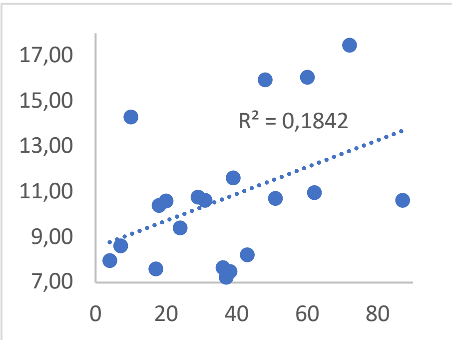
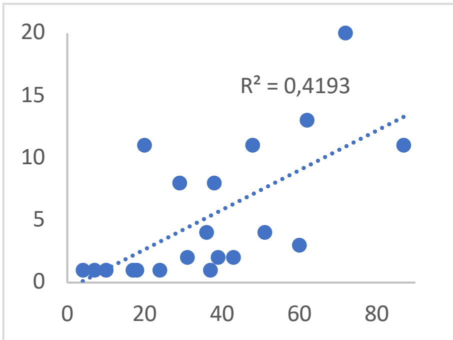
<tr><td>Downtown</td><td>
</td><td>
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4.2 Discussion

In this section, the relationship between user movements and space configuration analysis of virtual space was examined to confirm that space configuration characteristics of the virtual space is a factor that affects user movements. While the integration values calculated in space configuration analysis was able to explain some cases (Han-river Park), there were others which could not be explained (Lotte World, Downtown). The reason behind this result may be that the starting point where a user first enters the map is different for each map. In a map where the starting point was located in a space with very low integration value, a high traffic volume was observed; while in a space with very high integration value, traffic volume was low if it was located far away from the starting point. Also, users often connect to the map, look around areas near the starting point of avatars, then quickly leaves the map. All these phenomena contribute to potentially higher traffic volume around the starting point compared to other places. To account for cases where integration values cannot explain traffic volume, an agent-based model was created and analyzed additionally to reflect the location of the starting point. In agent-based models with starting points based on the spatial structure of the study areas, agents tended to move from the starting point with low integration value to areas with high integration values. This in fact did correspond to actual users' movements. Due to environmental factors of the platform that affects the users of metaverse space, the movement volumes observed in the virtual space show different patterns from the integration values calculated in space configuration analysis and the predicted movement patterns observed in the agent-based model. But in the end, all users' (avatars) spatial behaviors were impacted by space configuration.

5 CONCLUSIONS

This study showed that in ZEPETO's virtual space for which no key map is provided (unlike most online games), users display movement patterns that depend on visibility and accessibility. In the virtual space of the metaverse, a user can enter at any location and begin to move around, unlike in the real world. Just as map and navigation system can help a person travel to the destination faster and easier in the real world, key maps, when provided, can help a user travel to destination faster and easier in the virtual world. Just as a person walks while depending on visual cues and spatial structure, in ZEPETO platform, a user depends on screen of the mobile device to experience a virtual space. In such environment, it can be predicted that people's space usage behaviors in the ZEPETO world and the real world can be similar.

The results of this study demonstrate that the users of the metaverse space are impacted by factors of space configuration. In ZEPETO platform environment in particular, the location of starting point where a user enters the virtual space has significant impact on how the user experiences and uses space. To control or guide users' movement patterns, virtual space designers can designate the starting point of virtual space appropriately by considering spatial hierarchy and other environmental factors. With accelerating technological progress and increasing popularity of online communities, the virtual world will increasingly become similar to the real world. Therefore, designing and creating virtual space requires more careful approach, including analyzing space configuration factors that have impact on users. This study contributes to the body of research by quantitatively and objectively analyzing spatial behaviors of the users - not simply in an online virtual reality but in a metaverse's virtual space that is replica of the real world. There are many types of spaces in the metaverse, and spatial behaviors can change depending on contents type and user's objectives. Users who entered the virtual space for general conversations and social relationships show behaviors that are influenced by space configuration characteristics.

The findings of this study have to be seen in light of its limitations, including the smaller number of case studies. For better understanding of user behaviors in even more diverse virtual space, spatial behaviors and space configuration analysis of other cases are needed.

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