The influence of atrium types on the consciousness of shared space in amalgamated traditional dwellings – a case study on traditional dwellings in Quanzhou City, Fujian Province, China

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ABSTRACT
The influence of the types of architectural space on the residents’ consciousness of shared space, targeting mixed-status-family traditional residential buildings in the West Street area of Quanzhou City, Fujian Province, China was studied. The research was conducted through surveying, mapping, and an investigation of the current state of the buildings’ atria by using data statistics and function-fitting analysis. The study included the following four stages:

1. Because of modernization and urbanization, traditional buildings have been transforming from single-family to multi-family, leading to amalgamation.
2. With the emergence of amalgamated buildings, the shared space between households has changed from a street space to an atrium space, which is the most influential and includes three types: porch enclosure, hallway connection, and direct pathway.
3. The shared space consciousness of occupants was simulated by investigating how the overflow (two- and three-dimensional) of the atrium has been used.
4. The influence of space types on the consciousness of shared space is elucidated using data statistics and function-fitting analysis.

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KEYWORDS
Amalgamated traditional dwellings; atrium space; overlap; shared space; space consciousness

1. Introduction

1.1. Research background and objectives

With rapid urbanization, traditional dwellings in cities cannot adapt to the needs of development. Consequently, they are confronted with the problems of demolition, destruction, or reconstruction into tourist areas or commercial streets, as well as residential congestion and deterioration of living conditions caused by the influx of large migrant populations. Therefore, it is important and urgent to study the protection and renewal of these traditional dwellings.

Taking the traditional dwellings in southern Fujian as an example, the atrium space represented by “Tianjing” and “Cheng” often occupies the geometric center on the plane, where most of the public activities of residents take place.

In the traditional community, the atrium space is an important place for family activities. Accompanied by the phenomenon of “amalgamation”...
caused by high-speed urbanization, the single-family dwelling has become the multi-family dwelling, and the atrium space has also changed from an inward private space to an outward shared space. Meanwhile, the most obvious manifestation of amalgamation is that a large number of residents’ daily necessities are stored in the atrium space, which is referred to as “overflow” annotation 2 in this paper.

This paper studies the atrium space in the traditional dwellings of the West Street in Quanzhou, Fujian. With the research method of simulating residents’ space consciousness by overflow, the purpose of this study is to analyze the relationship between the spatial elements of the atrium space and its effects on residents’ space consciousness as the shared space. This paper explores the possibility of protection, renovation, renewal, and regeneration of traditional dwellings, not limited to the study of traditional architectural styles from a historical perspective.

1.2. Previous studies

1.2.1. Previous research on the spatial composition of traditional dwellings in Quanzhou

Zhihong (2012) clarified the particularities (climate, geography, technologies, etc.) and research values of traditional dwellings in southern Fujian. In addition, Jingcong (2014) summarized the spatial characteristics of traditional dwellings in Quanzhou. Furthermore, Chong et al. (2011, 2012) classified the plane composition of residential dwellings in Quanzhou based on the span, depth, and number of atria, thus establishing the basic models of the plane composition of traditional dwellings in Quanzhou. At the same time, it was clarified that "Dacuo" is the basic type of traditional dwellings in southern Fujian, "Shoujinliao" is the transformed version of "Dacuo," and "Qilou" was introduced into Quanzhou as a new type of dwelling. Wang and Wang (2008) made a typological arrangement of the plane layouts of traditional dwellings in Taiwan and southern Fujian. This paper draws lessons from the classification of residential plane, depth, etc.

The aforementioned research carried out the detailed combing of plane layouts of traditional dwellings and clarified the importance of atrium space in the plane composition. However, it did not fully reflect how spatial elements affect daily life.

1.2.2. Previous research on space consciousness

Kobayashi and Suzuki (1981, 1982) pointed out that the range of household living areas, orientation of households, and entry and exit forms of the main entrance will affect each other. Inoue and Takada (2017) found that the location of intermediary space affects people’s communication in the shared space.

Aoki, Yuasa, and Osaragi (1994) optimized the analytical methods in KOBAYASHI’s research and set up a meticulous research and evaluation system with “overflow” as the research object. This paper also takes “overflow” as the object of investigation and evaluation. Onoda et al. (2009) used the method of action investigation to analyze the private space consciousness of residents in congregated dwellings. In addition, Hosoya, Tsumita, and Tsurusaki (2009) obtained the relationship between indoor space and user communication through statistical correlation analysis. Similar statistical methods are used and optimized in this paper.

The aforementioned studies mainly used questionnaires and action evaluation to establish the research system of space consciousness. The object of a study can also reflect the behaviours and phenomena in daily life. Meanwhile, scientific statistical analysis was also used. However, most of the research focused on user evaluation, and not much attention was paid to the study of traditional dwellings.

To summarize, based on previous research on spatial styles and elements of traditional dwellings, this study focuses on the spatial elements of the atrium space in traditional dwellings, simulates residents’ space consciousness with “overflow” as the main object of investigation, and then obtains the correlation between spatial elements and space consciousness.

The paper did not study the style and preservation of traditional architecture from a historical perspective. This study is based on studies of traditional buildings and living areas in Quanzhou, considering the possibility that the traditional space of Quanzhou can be preserved in the course of urbanization. Field research was conducted on the types of traditional dwelling in Quanzhou and the current situation of household overflow, in order to reveal the influence of the spatial forms of traditional dwellings in Quanzhou on the consciousness of shared spaces in amalgamating dwellings, and then identify the major factors and characteristics of traditional dwellings in Quanzhou.
2018 by the Quanzhou Bureau of Statistics. As the target site for the survey, the West Street area is located in the center of Quanzhou City. The area and its streets were first developed long ago. Dating back to the Song Dynasty, it marked the prosperity of Quanzhou. It is an area with profound historical heritage. It is also an important part of the layout of Quanzhou city. The layout of the streets has been well preserved in general, and a large number of original traditional dwellings remain. In the course of urbanization, Quanzhou has seen the density of the urban population increase. The original single-family dwellings have been changed into multi-family dwellings, revealing a clear amalgamation pattern. A traditional atrium is used as a common space among households, which is an important embodiment of the shared life space. The West Street area mainly consists of 32 lanes and alleys, including Xiangfeng Lane, Jingting Lane, Tongzheng Lane, Jinluo Lane, Jiuguan Lane, Gurong Lane, and Fei Lane. Each building is named after the street or lane on which it is located plus a door number (Figure 1).

### 2.1.2. Types and spatial features of traditional dwellings in Quanzhou

Many traditional dwellings and historic streets can be found in the West Street area. This area is full of life. The basic types of traditional dwelling in the area are **Dacuo** and **Shoujinliao**.

A **Dacuo** is a traditional large house with an inner courtyard; it is a typical type of traditional dwelling in Quanzhou. The floor plan of a **Dacuo** is symmetrical and the middle courtyard (patio) is surrounded by houses. The layout of the house is clear and neat. Its width is usually three-open and five-open (commonly known as three-bay and five-bay), and the depth can be two, three, or five halls. A **Shoujinliao** is a type of house that is narrow and long with only one bay. It is the main type of residential house built along the streets of Quanzhou. Its patio can be used for ventilation, lighting, and drainage, while the hallway (alley) can help organize the traffic in front of and behind the house. Its narrow and long architectural features fully reflect the characteristics of Quanzhou as a commercial city. In Quanzhou there are two types of traditional **Shoujinliao** dwelling: one is purely residential and the other is partially residential, where the front of the house is a shop and the back is for living. Sometimes, houses by the street can be used as shops or handicraft workshops, while ones by the river are more convenient for water transport. The houses that emerged had more street stores in the time of small business, small workshops, and the handicrafts industry.

![Figure 1. Street plan of protected area of West Street and the location of the target site.](image-url)
Given the features of Dacuo and Shoujinliao, the architectural features of traditional dwellings in Quanzhou can be summarized as below:

(1) Progressive: The depth of the space is usually large and is progressively increased through the combination of halls and patios or rooms and patios.
(2) Symmetric: The floor plan of the building is quite neat and has a clear central axis with one, three, or five bays on each side.
(3) Parallel: During the development of the architecture, traditional dwellings in Quanzhou showed a parallel relationship between houses along the streets, which are close to each other or are separated by lanes.
(4) Interleaved architecture: Considering the climatic conditions of Quanzhou, long houses often use the patio for lighting and ventilation. Therefore, a patio is placed between every two rooms, as seen in the floor plan (Figure 2).

2.2. Research methods

2.2.1. Survey
The research site for this study was the protection area of West Street in Licheng District of Quanzhou City. Survey research was conducted based on the map of Quanzhou City drawn by the Quanzhou Urban and Rural Planning Bureau from 20 August 2018 to 4 September 2018. A total of 16 traditional buildings (9 Dacuos and 7 Shoujinliaos) were studied, including 11 buildings on 3 streets and alleys on the southern side of the eastern part of West Street, 4 buildings on the northern side of the eastern part of the West Street, and 1 traditional building on the western side of West Street (see Figures 1, 3, and 4).

The main steps of the survey are as follows: (1) measuring the architectural site and stretching drawings; (2) recording the number of households in each building and the age of the buildings; (3) recording the status of household overflow and the appearance of the building for statistical purposes; and (4) taking photos of the four sides of the atrium using an 8 mm fisheye lens and the rest of the building using ordinary lenses.

2.2.2. Research process steps
(1) Summarize the common features of Dacuo and Shoujinliao and establish a basic model based on the mapping of traditional dwellings in Quanzhou.
(2) In the model, classify the atrium space (patio or courtyard) into three architectural styles: porch enclosure, hallway connection, and direct pathway.
(3) Organize the site mapping data (spatial elements, types of household overflow, etc.) and multi-dimensional data (fisheye photos and ordinary photos).
(4) Following data collation, use the function fitting method to simulate the influence of the three spatial forms on the overflow of the shared space (Figure 5).

3. Plane analysis

3.1. Envelope design
Overflowed items was categorized by type and marked them with symbols; the area and position on

![Figure 2. Space planning of traditional dwellings in Quanzhou.](image)
the plane were determined using the data obtained from site mapping. The envelope was converted into a straight line and made a minimum range map of the central area. The size of the data was compared between research subjects through envelope design and symbolization. A single unit of the shared space could not be used for the minimum range of the central area as its error could not be determined (Figure 6).

The area ratio of overflowed items in the atrium space was extracted to simulate the residents’ space consciousness of the shared space.

3.2. Classification of surveying plans

3.2.1. The vertical axis (Figure 7)

Surveying plans were categorized by the number of main halls. The main hall is another important shared

Figure 4. Site mapping of traditional dwellings in the West Street.

Figure 3. Site photos.

Figure 5. Site mapping of traditional dwellings in the West Street.
space in a traditional dwelling in Quanzhou in addition to patios and courtyards. The main hall was originally used to worship ancestors or to serve as a lobby or a leisure space for the family. Nowadays, due to the amalgamation of traditional dwellings, the worship space is still preserved but it is easy to see household overflow of many families.

The space of the main hall has very good ventilation at the front and back. However, affected by the corridors outside, the hall does not have good natural lighting, so it is pretty dim. As it is indoors, overflowing living items will not get wet on rainy days. Therefore, the existence of the main hall will affect the type, quantity, and distribution of living items in the patio and courtyard. In addition, whether there is a main hall before and after the outdoor shared space can help determine the location of a target space in the building. The results are summarized below:

1. If there is a main hall both in front and back of the outdoor space, then the space is in the middle of the whole building and it is usually a patio.
2. If the hall is only in front of or in the back of the outdoor space, then the space is at the front or back of the building, and it is usually a patio.
3. If a main hall is in neither front nor back of the outdoor space, then it is usually a courtyard.

3.2.2. The horizontal axis

1. Porch enclosure: Semi-outdoor spaces including porches can help occupants to cope with various outdoor environments such as direct sunlight and rain in summer, and they will have a certain impact on the type and distribution of overflow items.
2. Direct pathway: the width and nature of a road affect the number and type of overflow in the shared space that is connected to the road.
3. Hallway connection: the shared and public spaces are connected by hallways. The distance between a shared space and public roads will affect the number and type of household overflow.

The area ratio of space under the eaves to that of the atrium, the distance of the hallway under the atrium space, and the width of the public path connected to the atrium were extracted to simulate the three spatial elements of the atrium space.
### 3.3. Surveying plan analysis

#### 3.3.1. Function fitting analysis

In *A Correlation Analysis of Different Age Exchange and Indoor Composition by Indoor Play of a Nursery School*, Hosoya, Tsumita, and Tsurusaki (2009) used the function fitting method to analyze the influence of spatial elements in architecture on users’ psychological perception. The study found an approximate relationship and tendency. The paper also attempted to simulate the relationship between the area ratio of the overflow to the atrium and three key elements in an architectural space – ie, the area ratio of the space under the eaves to that of the atrium, the distance of the hallway under the atrium space, and the width of the public path connected to the atrium – by using cubic splines.

The reasons for using cubic splines are that cubic splines’ curve can be applied to continuous changes rather than sudden dramatic changes, they are used to observe the overall tendency more than specific numerical values, and they can estimate real data of the whole pattern based on collected data.

Here, in order to simulate the influential factors of the forms in architecture, the following elements was selected as independent variables: (1) the area ratio of the space under the eaves to that of the atrium, (2) the distance of the hallway under the atrium space, and (3) the width of the public path connected to the atrium. To simulate users’ consciousness of shared spaces and their daily use of the spaces, the area ratio of overflow items was extracted in the atrium as a dependent variable.

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**Figure 6.** Example of envelope design.
3.3.2. Results of the fitting analysis (Figure 8)

(1) The competitive relationship between the spaces under the eaves and atrium can be described as follows:

When the space under the eaves is smaller than that of the atrium (space under eaves/atrium space < 0.9), it is considered necessary to establish one’s own area for private items, and there is a tendency to place more living items under the eaves; when the space under the eaves is approximately the same or three times larger than the atrium space (space under eaves/atrium space = 1–2.8), it is considered necessary to extend the atrium space, and there is a tendency to place more living items in the atrium; and when the space under the eaves is further increased (space under eaves/atrium space > 2.8), then there is a tendency to place more living items under the eaves.

(2) The influence of the distance of the hallway under the atrium space on the ratio of overflow in the atrium is summarized below:

In real life, when the length of the entrance is short (approximately 0–20 m), issues regarding convenience will be considered such as being close to the entrance and exit, and the number of items in the atrium tends to increase; when the hallway is 20–35 meters long, participants consider the number of surrounding households, management difficulties, and safety issues, and they tend to put less items in the atrium; when the hallway is quite long (>35 m), the house provides good privacy because it is far away from the entrance. The shared space appears to be mostly private space, so people tend to put more things in the atrium.

(3) The influence of the width of public paths connected to the atrium on the ratio of overflow in the atrium is as follows:

The level of public roads may also affect the number of households living in the house, which might further affect the number of items placed in the atrium, but it does not have a significant impact as only the ratio of the area occupied by the items to the overall area will be considered.

(Note: Considering the errors in site mapping, recording data, and the graphical planning of the central area, the function fitting analysis could not fully reflect the influence, but it could reveal the basic relationship and tendency.)

4. Solid angle analysis (Jeong and Furuya 2003)

The degree of wall opening and the proportion of open space, such as the patio and courtyard, can...
Figure 8. Statistics and results from function fitting analysis.
reflect the degree of integration of occupants’ private spaces and outer spaces or natural environments. In order to explore this relationship, photos of the four faces (a, b, c, and d) of the patio and the courtyard was taken by using an 8 mm fisheye lens. The visual experience was set to be within the viewing angle, and the solid angles of the four faces were analyzed (Figure 9).

The analysis of solid angles was based on the spatial elements mentioned in Chapters 2 and 3. The classification and definitions of the factors and the results are listed below (Figure 10).

1. The degree of opening was calculated with the sky area ratio in the fisheye photograph. The degree of opening was equivalent to the sky area ratio in the fisheye photograph, which equalled the area of sky or the field of view.
2. The degree of wall opening was equal to the ratio of the door and windows in the fisheye photograph; it equalled the area of the door and windows divided by the field of view.
3. The degree of integration of the exterior or the natural environment was equivalent to the degree of opening plus the degree of wall opening of the household.

Much household overflow had occurred in terms of potted plants. This is probably because Quanzhou has a warm climate in all four seasons. It is also believed that the degree of integration of private spaces in the dwelling and the natural environment is related to the number, distribution, and type of overflow items. Household overflow in general reflected the degree that household private spaces have expanded.

In Figure 11, the X-axis is the total household overflow and the Y-axis is the total ratio of sky and open area. The quadratic function curve in the figure is a fitting curve. Looking at the curve, it can be observed that the higher the degree of integration between the space of the household and the external environment, the higher the likelihood that the occupants will extend the space to the area outside within a certain range. However, if it exceeds this range, there is a tendency for residents to stop expanding the used space to the outside area. Based on the data obtained from selected objects, if the ratio of sky to open area is smaller than 24%, the proportion of household overflow also increases. If the ratio of sky to open area is close to 24%, residents in Quanzhou are likely to extend their space to the outside area with an overflow ratio of around 18%. If the ratio continues to increase, the likelihood of residents extending the space will decrease.

5. Conclusion

This paper opened with the spatial features of traditional dwellings in Quanzhou – namely, parallel, progressive, symmetrical, and interleaved, followed by the extraction of elements (the space under the eaves, the length of the hallway, the width of public paths, and the open area ratio), which were later described using the envelope method and fisheye photos. Cubic splines were used to fit the relationship between the elements of traditional dwellings in Quanzhou and household overflow in the shared spaces. The main results of this study are listed below.

1. The relationship between the space under the eaves and the atrium space tends to be a counter-balance competition. The relationship will affect the location of private items in a shared space.

![Figure 9. Solid angle analysis.](image-url)
(2) The length of the hallway has an impact on the household overflow in the atrium space. This involves the accessibility of the property, item security, and privacy.

(3) The level of the external public path has a minor influence on the ratio of atrium overflow. Only the accessibility of the household affects the amount of atrium overflow.

(4) The degree of open design and the open area ratio: the higher the degree of integration between the space of the household and the external environment, the higher the likelihood that the occupants will extend the space to the area outside. However, if it exceeds a certain range, it will have an inhibitory effect.

In summary, in the study of traditional dwellings in Quanzhou, especially reconstructed traditional dwellings and traditional residential living spaces, the space under the eaves in the atrium, the hallway, and the opening of the building are important influencing factors and research objects. They have varying degrees of influence on the occupants’ consciousness of the shared space. This paper established a basic research model of the surveyed area, which was validated using statistical methods. Based on the previous studies of the classification of traditional dwelling plans in Quanzhou, this study has further discovered the influence of spatial elements on the occupants’ living status.

![Figure 10. Classified results of solid angle analysis.](image)
6. Discussion

6.1. Summary of purpose and conclusion

(1) This paper finds that the atrium space in traditional dwellings is often used as a shared space in the social backdrop of the “amalgamation” caused by high-speed urbanization;

(2) The phenomenon of “overflow” derived from “amalgamation” can reflect residents’ space consciousness regarding the shared space to a certain extent;

(3) In terms of the architectural styles of traditional dwellings, the inward spatial elements of the atrium space (such as the space under the eaves, and hallway space, etc.) have a greater impact on space consciousness;

(4) The function fitting analysis method can not only establish correlation, but can also provide a more intuitive representation of the relationship between spatial elements and space consciousness, which has interval features instead of being unidirectional.

6.2. Inheritance and development of previous research

(1) To investigate architectural styles of traditional dwellings, this paper further focuses on the inward shared space (the atrium space in particular), based on the plane layout classification and plane composition, and also how reflects the phenomena in daily life;

(2) Taking “overflow” (Onoda et al. 2009) as the main object of investigation, this paper attempts to use a more specific “envelope” method for investigation and sampling;

(3) Regarding the analytical method of space consciousness (Kobayashi and Suzuki 1981, 1982; Aoki, Yuasa, and Osaragi 1994; Inoue and Takada 2017), this paper tries to expand the correlation analysis and use the function fitting method to more intuitively simulate the relationship between spatial elements and space consciousness.

6.3. Problems and solutions in the research process

(1) The “overflow” phenomenon itself has category complexity (such as movable and immovable) and variability over time and uncertainties; thus, the data acquisition is also unstable. The analysis in this study is based on the types and number of overflows. Figure 12 shows the reference material for the main research above. In
addition, it is also conceived to investigate the
distribution of overflow by time interval in
future research;
(2) This paper establishes the research model and
method of the function fitting analysis. The
amount of data collected at this stage is quite
limited. It is still necessary to collect a large
quantity of data for support and revision so
that the research model and method can be
more persuasive and generalizable.

6.4. Research significance and future research
directions
(1) With rapid urbanization, traditional dwellings
have been demolished in large numbers due to
social contradictions such as economic develop-
ment and land use. Some of the demolitions
were mandatory, while some were voluntary
actions by residents. The same problem has
also arisen in city villages. In addition, many
superficial imitations of traditional dwellings
have been rebuilt in tourist areas or commercial
streets. Despite the imitation of traditional
dwellings in architectural styles, the original spa-
tial characteristics are basically lost;
(2) This paper places emphasis on the spatial char-
acteristics of traditional dwellings. It attempts to
call attention to the value of traditional dwell-
ings and suggests that the protection of tradition-
dwellings or development of commercial
tourism should not be confined to or blindly
follow the low-quality imitation of the architec-
tural style.
(3) For example, the newly emerging “community
building” (though not yet perfected in operation),
pays more attention to the opinions of existing
residents, improvement of the existing living
environment, and resolution of the conflicts
between local residents and migrant populations.
This study can provide basic insight on the spatial
characteristics for community buildings;
(4) Thus, this study extends the scope for future
research. First, future research could expand to
study traditional dwellings with similarities in
other areas, on the basis of this study’s discus-
sion of traditional dwellings in southern Fujian
with Quanzhou as the center. This study supple-
ments the proposed research model and
method with a large quantity of survey data
and also gathers basic first-hand information
for the protection and renewal of traditional
dwellings;
(5) Traditional dwellings can be analyzed from two
aspects: architectural style and the characteris-
tics of the living area. In the long river of history,
architectural forms have been changing along
with the evolution of society. More and more
traditional dwellings may disappear in the future
in a bid to improve people’s quality of life. While
traditional architectural styles may no longer
exist in the future due to the extinction of tradi-
tional dwellings, the geographical relationship
among traditional dwellings and the characteris-
tics of their living spaces can be preserved.
Compared to architectural styles, the spatial
characteristics of historical buildings tend to be
a more important topic in research.

7. Annotation
(1) Amalgamation:
In the course of urbanization, the growing urban
population cannot be accommodated using the
Model Summary

| Model | R     | R Square | Adjusted R Square | Std. Error of the Estimate |
|-------|-------|----------|-------------------|---------------------------|
| 1     | .673* | .453     | .404              | 0.063704852               |

a. Predictors: (Constant), corridor/courtyard(area)
b. Dependent Variable: courtyard effluence/courtyard area

ANOVA

| Model      | Sum of Squares | df  | Mean Square | F     | Sig. |
|------------|----------------|-----|-------------|-------|------|
| Regression | .037           | 1   | .037        | 9.118 | .012b|
| Residual   | .045           | 11  | .004        |       |      |
| Total      | .082           | 12  |             |       |      |

a. Dependent Variable: corridor/courtyard(area)
b. Predictors: (Constant), courtyard effluence/courtyard area

Coefficients

| Model                  | Unstandardized Coefficients | Standardized Coefficients | t     | Sig. |
|------------------------|----------------------------|---------------------------|-------|------|
| (Constant)             | .171                       | .038                      | 4.551 | .001 |
| corridor/courtyard(area)| .066                       | .022                      | 3.020 | .012 |

a. Dependent Variable: courtyard effluence/courtyard area

Figure 13. Statistics of overflow's type and quantity.
traditional household living style. Therefore, many traditional dwellings have transformed from single-family to multi-family dwellings. Such a transformation is called amalgamation.

(2) Overflow:

Due to the large influx of population in a short span of time, inadequate living space leads to the daily necessities being placed in a shared space on the premise of mutual permission among households. In this study, placing the daily necessities outside is collectively referred to as “overflow”. Similar concepts are also mentioned in the study of Aoki et al. reference 9

(3) envelope:

In plane geometry, an envelope of a curve family is a tangent line that shares at least one point with each one of a family of curves. (A curve family is an infinite set of curves where the curves have certain relationships with each other.) In three dimensions, a surface that is a tangent to each one of a family of surfaces is called an envelope surface.

(4) Function Fitting Analysis Method:

The function fitting analysis is based on the correlation analysis of Hosoya, Tsumita, and Tsurusaki (2009) and is further optimized by using statistical methods.

Firstly, the independent variables (spatial elements in Section 3.2 of this paper) and dependent variables (“overflow” in the simulation of space consciousness in Section 3.1 of this paper) are determined.

Secondly, SPSS software is used to analyze the correlation between these two variables (3 groups and 26 datasets were analyzed herein). Significance (P value), and the fitting degree ($R^2$) were used to determine the existence of correlation between these two variables according to the study criteria (see Figure 13).

On the basis that some data is known to conform to the correlation criteria (linear function), this study also attempts to determine the fitting degree of qualified data fitting into the cubic function. It was still within the allowable range, and the overall trend could be observed more clearly (see Figure 13).

**Disclosure statement**

No potential conflict of interest was reported by the authors.

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