Artificial Neural Network and Cellular Automata As A Modeling Simulation for Night Market Spatial Development

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Abstract: Night-market is a special living culture of Taiwan. It is a natural process of spatial development, and presents popular night entertainment of Taiwanese people. The goal of this research is to establish the simulation model to analyze spatial development factors of Taiwanese Night-market. The method is integrated 「Cellular Automata」 (CA) and 「Artificial Neural Network」 (ANN) to experiment spatial simulation of Night-market. The simulation process is employed by Geographic Information System (GIS). The result of this research illustrates the 76.897% similarity between simulation result and existing condition. It provides the evidence that the implement simulation parameters have the apparent connections between Taiwanese Night-market spatial development and street structures.

Key words: Geographic Information System (GIS), Artificial Neural Network (ANN), Cellular Automata (CA), Taiwanese night market.

1. Introduction

Night-market is a unique culture in Taiwan. It combines traditional culture and consumption behavior. The following are some clarifications of Taiwanese night-market:

(1). Night-markets are kinds of street-market which operating mostly at night. (Tsai, 1995)
(2). Night-markets are consisted of stores and stalls along the street. The activity at night is longer than daytime. (Hou, 1988)
(3). Night-markets are the aggregation places of stalls, and people. It sells all kinds of goods and food. There are some features of night-market included casual, convenient, bustling, and family-suited. (Yu, 1992)
(4). Night-markets are the aggregation place of stores and stalls which are regularly operating at night with large scale. (Wang, 1996)

Many stalls of night-market don’t have legal business licenses and they run the business from local union agreement. Taiwanese government had regarded night-markets as the urban chaotic problem formerly. Yu mentioned night-markets reveal characters of ‘undeveloped’ situation under the ideology of modernization in Taiwan. The chaos of night-market contradicts the aim of being neat and in order emphasized by modern design (Yu, 1994). Data from Tourism Bureau at 2004 shows that Taiwanese night-market has drown great attention for foreign tourists. Therefore, the government has listed night market as the important development project in the ‘Tourists Double, 2008’ (Su, 2004). In recent years for solving the chaotic problems of night-market, government restricted many special-purpose zones for the night markets. Stalls could operate the business legally in these
zones. However, after being changed by modernized value as “sightseeing” areas, many night markets had lost their original characters. Being crowded is probably the reason that night market is regarded as the most popular night entertainment at public open space (Yu, 1994). Consequently, the policy of setting special-purpose zone for night market usually causes the decline of night-market development, and losing original characters and attractions of night-market. Therefore the development of night market is strongly connected with the local street structure and its context.

2. Research method
This research establishes the simulation model of night-market spatial development by applying methodology of CA and ANN on GIS platform.

2.1 The concept of Cellular Automata (CA)
The concept of CA was occurred around 1920~1930 (Almeida and Gleriani, 2005). Evolution of CA shows self-duplication in the form of unit cells. It also shows self-similarity and self-organization. (Wolfram, 1994). CA model is contained four components as followed: cells, states, neighborhood, and rule. (Batty et al., 1997).

1. Cells: the form of cells
CA is constituted by group of grids (or cells). These grids may be any geometric shapes, and also can be three dimensional objects. However, the regular square grid is most extensively used in CA relevant research. (Fig. 1)

Fig. 1 The cells setting of CA:

Left figure expresses check grid state, and right figure expresses hexagon grid state.

2. States: evolved state of cells
The state of each cell can be binary, for example alive or dead, vacuum or occupied. It could also be multiple, for example residential land-use, commercial land-use, leisure land-use, factory land-use…and etc. (Fig. 2)

Fig. 2 The states setting of CA:

0: white, dead, and undeveloped; 1: black, alive, and developed.

3. Neighborhood: relation with a single cell's neighbors
The state of each cell evolves according to the neighbors' states. The region of the neighbor size needs to be defined in a CA model to determine the scale of interaction. (Fig. 3)

Fig. 3 Neighborhood setting of CA:

B and A have the adjacency, but C and A don’t have. Assumption A is the developed cell, and then following development situation is that B cell has more developed opportunity than C cell.

4. Rule: evolution rule of cells
The state of each cell in the next step is determined by the interaction with neighbor region and their present states. CA's evolution is determined by certain defined rules. (Fig. 4)
Fig. 4 Rule setting of CA:
Diagram A explains the condition of constant evolved process. Diagram B explains the condition of cell dying of lonely or crowded in evolved process. Diagram C explains the condition of cell breeding in evolved process.

CA model is established according to the upper four basic settings. With GIS technology progressive, many applications in urban analyzing used method of integration of CA and GIS (Couclelis, 1994, 1997; Batty and Xie, 1994; White and Engelen, 1993; Wu and Webster, 1998). This research used CA evolution model which is based on GIS platform to simulate and analyze night-market spatial development. The settings of CA-Rule and CA-Neighborhood are decided in Artificial Neural Network (ANN) of the following introduction.

2.2 The concept of Artificial Neural Network (ANN)
Artificial Neural Network (ANN) is a very useful mathematical tool for perception and classification. It is through training and learning process to decide the classification of new samples. Fig. 5 is the diagram to explain concept of ANN implementing. ANN is consisted of three parts: input layer, hidden layer, and output layer. Any ANN must experience the training step, then to produce classified results.

Fig. 5 Diagram of ANN concept:

2.3 Integration of CA and ANN
Works associated ANN to CA models for spatial analysis are quite few. Li and Yeh (2001) conducted a simulation of land-use changed for a cluster of cities in southern China. ANN embedded in a CA model upon a binary state basis (urban/nonurban use) was tested in that experiment. They further refined this model dealing with multiple regional land-use (Yeh and Li, 2002), and simulation for alternative development scenarios (Yeh and Li, 2003).

This research is an application of ANN to decide the evolved rules of CA-model in simulation process of night-market. The investigated area is transformed into CA grids based on GIS platform. It is divided into training-area and simulation-area. The samples in training-area are used to train ANN, and the trained ANN is used to analyze samples in simulation-area in order to determine the evolution probabilities. These evolution probabilities structured the rules of CA model in this research.
3. Research area and materials

3.1 Research area

The simulation target of this research is Feng-Chia night-market in Taichung, Taiwan. Night-market is usually occurred from a public aggregation site such as schools and large temples. Examples like Shi-Lin night-market in Taipei arose from Tsz-Shian temple. Then after Mine-Chuan University relocated to this area in 1963, it stimulated the expansion of Shi-Lin night market (Yu, 1994). The other example Feng-Chia night-market thrived because of the neighborhood around Feng-Chia University. It becomes prosperous after years of development and is one of the biggest night-market in Taiwan. The following Fig. 6 defines the investigation domain:

![Fig. 6 Explanation on research domain](image)

Feng-Chia night-market is a typical night-market in Taiwan. The stalls aggregate along the streets in the night. In the earlier period, the night market only covered the area indicated in section-1 (Fig. 6). It gradually expanded to nowadays extent. This study model divided the streets of Feng-Chia night-market as ‘training-area’ and ‘simulation-area’ for the purpose of training process in ANN and simulation process in CA after training.

3.2 CA model set-up

The CA model settings are grid-setting, state-setting, and rule-setting:

A. Grid-setting: Like many other night markets, the commercial behavior of Feng-Chia night-market developed along the street. There are 2 types of stalls: one is immobile and the other is mobile. The immobile stalls are those stores inside the buildings on both sides of the street indicate in C section (Fig. 7). The mobile stalls are those occupy places in front of building arcade or sidewalk on both sides of the street. It is indicated in section B (Fig. 7). Mobile stalls usually rent the place from immobile stalls to obtain the trading permission. This permission doesn’t have any legitimate and is just a common consensus of the local stalls and local union.

![Fig. 7 The cell grid-setting for street](image)
The explanation of CA grid-setting above is:
1. Each cell is a grid form of 2m by 2m. It is the smallest size of operating stall in Feng-Chia night-market.
2. Grid-1 and grid-9 are the spaces inside the buildings. Grid-2 and grid-8 are the arcade or sidewalk spaces in front of the buildings. Grid-3 to grid-7 are the spaces of street.
3. The target of this research is to observe the development state on the streets of night-market. Therefore these grids are the simplified states from existing condition.

**B. State-setting:** There are two states in CA model evolution: developed and undeveloped (Fig. 8).

**C. Rule-setting:** The procedure of this research applied ANN to decide the development probability for each grid in the process of CA evolution. The results of CA evolution are demonstrated on GIS. The process exploited the training-area including section-1, section-2, and section-3 as ANN training-sample and training-target. The simulation-area is section-4, section-5, section-6, and section-7. It was set in the trained ANN to generate the development probability for each grid. These probabilities are the setting of CA-rule.

### 3.3 Establish parameters for ANN

The data of each grid is transferred to the following parameters for ANN operation. The values of parameters are through the continual process of try-and-error. The process is through the comparison and adjustment of present data and simulation data. This result represents parameters' significance and corresponding relationships.

**Table 1:** Parameter and definition

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$D$</th>
<th>$R_w$</th>
<th>$R_s$</th>
<th>$R_i$</th>
<th>$S$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definition</td>
<td>the index of core depth</td>
<td>the index of road width</td>
<td>the index of road position</td>
<td>the index of road intersection</td>
<td>the index of stall gathering</td>
</tr>
</tbody>
</table>

**$D$: The index of core depth.** The core located on section-1 is the beginning place of Feng-Chia night-market. The $D$ value decreases as grid farther away from the core. We found in the process of simulation that decreasing in $D$ value follows the pattern of streets instead of radial distance from the core.

9-a experimented the $D$ values based on the setting of radial decreasing from the core.

9-b experimented the $D$ values based on the setting of distance decreasing along the street structure from the core. The research process discovered that the setting of $D$ values by 9-b is more appropriate through the comparison of existing condition.

**Fig. 9** Parameter: $D$ setting
<table>
<thead>
<tr>
<th>District</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>D1</em></td>
<td>The streets of section-1 and section-3.</td>
</tr>
<tr>
<td><em>D2</em></td>
<td>The streets of section-4 and section-5.</td>
</tr>
<tr>
<td><em>D3</em></td>
<td>The streets of section-2, section-6, and section-7.</td>
</tr>
</tbody>
</table>

*Di is the primary core area. D3 is a sub-night-market with independent development due to the isolation by a 20M width road. Its development is depended on the aggregation effect of stalls rather than the affection by core area. D2 is a secondary area that adjacent to D1. Its development is strongly affected by D1. The joints of D1 and D2 are the road intersections. The commercial activities at the intersection show the tendency of increase.*

**Rw:** The index of road width. This index indicates the road width that has affected the aggregation of stalls in night-market: The aggregation of stalls is lower in wider road and the higher in narrower road.

<table>
<thead>
<tr>
<th>Road width</th>
<th>0m &lt; Rw &lt; 5m</th>
<th>5m &lt; Rw &lt; 10m</th>
<th>10m &lt; Rw &lt; 15m</th>
<th>10m &lt; Rw &lt; 20m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rw Value</td>
<td>Rw = 2.5</td>
<td>Rw = 2</td>
<td>Rw = 1</td>
<td>Rw = 0</td>
</tr>
</tbody>
</table>

*Rs:* The index of road position. This index indicates the locations on street. These locations may have positive or negative development factors. Grid-1 and grid-9 are the locations of immobile stalls with legitimacy. Therefore, these grids show the tendency of positive development. Although grid-2 and grid-8 may have higher development with mobile stalls, but these locations need to pay rental and still struggle with legality. Grid-3 to grid-7 are the locations of road, and have strong tendency of negative development.

![Fig. 10 Parameter: Rs setting](image)

<table>
<thead>
<tr>
<th>Location</th>
<th>Grid-1 and grid-9</th>
<th>Grid-2 and grid-8</th>
<th>Grid-3 to grid-7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rs Value</td>
<td>Rs = 1</td>
<td>Rs = -1</td>
<td>Rs = -5</td>
</tr>
</tbody>
</table>

**Ri:** The index of road intersection. The positive development tendency of stalls in road intersection.

**S:** The index of stalls gathering. The grid adjacent to the other stalls has higher development probability.

![Fig. 11 The different types of S-values](image)

With no adjacent stall grid-A indicates S = 0. With one adjacent stall grid-A indicates that S = 1. With two adjacent stalls grid-A indicates that S = 2. With three adjacent stalls grid-A indicates that S = 3. With four adjacent stalls grid-A indicates that S = 4.

### 4. Result of simulation experiment

This research used *Arcmap 9.0* to execute the CA simulation process. It allows obtaining the location attributes of GIS and analyze the process of night market simulation experiment. In ANN process, *Matlab2008* is applied to conduct training-stage and generated development probability in simulation stage.
4.1 Process of simulation experiment
A. Current development data transfer CA grid-setting in training-area section-1, section-2, and section-3. All grids with parameters are input to ANN training-stage. In the following, Fig. 13 displays the finished CA grid-setting in training-area.
B. Probability is generated by finished training-ANN through the inputted parameters of grids in simulation-area section-4, section-5, section-6, and section-7. In the reality, there will not have the same development probability at two different locations with same conditions. Therefore the additionally input of the random probability is between -2.5% ~ +2.5% owing to the final development probability.

![Fig. 14](image)

**Fig. 14** Current data of section-4 and section-5 in simulation-area.

C. Simulation result of stage one: There are 1,173 grid-data in simulation-area. The matched grids number is 902 from the comparison of simulation result and current data. The similarity average is 76.897%.

![Fig. 15](image)

**Fig. 15** Simulation result of stage one: 15-a is the simulation area 4 and 5, 15-b is the simulation area 6 and 7.

D. Simulation result of stage two: With the result from stage-one simulation continues to conduct second simulation experiment. The result from second simulation shows high capacity development. The primary factor for spatial development on second simulation result is determined by parameter $S$.

![Fig. 16](image)

**Fig. 16** Simulation result of stage two: 16-a is the simulation-area 4 and 5, 16-b is the simulation-area 6 and 7.

E. Simulation result of stage three: The purpose of third simulation experiment is to mend the situation of over-developed stalls on street. While rental will get higher with increasingly commercial activities and the legitimacy.
issues, the parameter \( Rs \) value of mobile stalls is manipulated to change from -1 to -3 and parameter \( Rs \) value of road is changed from -5 to -7.

![Fig. 17 Simulation result of stage three: 17-a is the simulation-area 4 and 5, 17-b is the simulation area 6 and 7.](image)

4.2 Discussion of simulation experiment

A. The first simulation experiment shows the 76.897% similarity between simulation data (Fig. 15) and reality data (Fig. 14). However Fig. 15 indicates some unexpected developed grids in the middle of the street which is contracted to the existing condition. The result reveals more simulation experiments need to be minor adjusted.

B. The second simulation (Fig. 16) discovers simulation-area section-4, section-5, and section-7 are over-developed in the middle of the road. At simulation-area section-6 remains the same condition. These results show different influences of parameter \( S \) on different widths of road.

C. Third simulation result (Fig. 17) can observe that the tendency of simulation-area section-4, section-5, and section-7 have obviously reduced its development on the street.

D. During the three stages experiment of this research, the development of simulation-area section-6 maintained constant balanced from right side of road to the left side. Since right side is adjacent to the road intersection and has more development grids, it shows the independent development no matter the changes of parameter \( S \) or \( Rs \). It’s approximately conform realistic situation.

E. The result of three simulation experiments can discover that the key factor of night market development is whether the pattern of street is suitable for congregation of retailers. And that is the significance of parameter \( S \) in this research. \( S \) is largely determined by the width of roads \( (Rw) \) and number of the road \( (Ri) \) intersections. This shows strong correlation between night-market development and street structure. Therefore in reality in order to effectively manage night market, the action of relocating the night markets to the special-purpose zone that Taiwanese government had adopted would cause the decline of night market.

5. Conclusion

Night market is an open and non-linear complex system as complicated as a city development. In the existing context where architecture design offers limited empirical models, this research borrows insights from urban planning under the conditions of land use planning simulation. It constructs a new framework simulation model for architecture spatial development. By applying ANN and CA in our research, the proposed model explores the primary factors of spatial development in night-market. Although the results from each simulation are not identical, they are highly related to the existing condition. The findings of this research are in the following:

A. The similarity between simulation and reality is 76.897%. Though the result is acceptable, we expect to gain
better findings through more experiments by adjusting those parameters.

B. Based on the research and simulation result, we find the key factors to determine the night market development is the pattern of the streets and whether it is suitable for congregation of stalls. We parameterized this factor as $S$ value. $S$ is largely determined by $Rw$ (the width of roads) and $Ri$ (the road intersection).

C. The model constructed in this research is based on the condition of developed or un-developed commercial activity. We found the adjacency of different retailers follows certain rules. It is possible to apply multi-layer ANN concept to study the component of different types of retailers for future study.

6. References


